Agricultural Medicine

Rural Occupational and Environmental Health, Safety, and Prevention

SECOND EDITION

KELLEY J. DONHAM AND ANDERS THELIN

WILEY Blackwell

AGRICULTURAL MEDICINE

AGRICULTURAL MEDICINE

Rural Occupational and Environmental Health, Safety, and Prevention

Second Edition

KELLEY J. DONHAM AND ANDERS THELIN

WILEY Blackwell

Published by John Wiley & Sons, Inc., Hoboken, New Jersey

Published simultaneously in Canada

Library of Congress Cataloging-in-Publication data applied for

ISBN: 9781118647202 (Hardback)
9781118647219 (EPDF)
9781118647400 (epub)
9781118647356 (oBook)

Cover image:

- Images in the center circle.
  - The farmer with one arm - Stephanie Leonard
  - The farm workers - LaMar Grafft
- Image of the woman (nurse) fitting the respirator on a farmer - Carolyn Sheridan, AgriSafe Network
- Image of the safety specialist checking the tractor with the farmer nearby - LaMar Grafft
- Image of the physician looking at an x-ray with a farmer - Alexander Raths from Shutterstock
- Image of the veterinarian and the woman pointing to a lesion on a cow - Goodluz from Shutterstock

Set in 10.5/12.5pt Adobe Garamond Pro by SPi Global, Pondicherry, India

1 2016

We dedicate the book to the millions of farmers, ranchers, their families, and workers who have either died or suffered disabling injuries or illnesses from their work producing food, fiber, and fuel for the people of this planet. We also dedicate this book to those who have lost a family member or loved one from a farm-related injury or illness. This author (KJD) dedicates this book to his eight first-level relatives who have suffered fatal or disabling farm injuries. Furthermore, we dedicate this book to the healthcare and safety professionals, veterinarians, governmental and non-governmental agencies, and the many volunteers who care for and work to prevent injuries and illnesses within farming communities.

This author (KJD) thanks his mentors (especially Pete Knapp and Clyde Berry) who in 1973 gave him the opportunity to engage in an educational and research program in agricultural medicine at the University of Iowa.

We thank the International Commission in Occupational Health for advocating this text and the more than 30 agricultural health and safety professionals who participated in the two consensus processes that set out the core topics and learning objectives that guided the contents of this book.

We thank the six added authors of Chapters 11 and 15, and the 14 reviewers who volunteered their time and talents for their expert review of the various chapters of this book. I thank my wife Jean Donham for her dedicated and detailed reading of every chapter.

Finally, we thank our families for their support and understanding through this effort, which like farming in so many ways is a labor of love.

Kelley J. Donham
Anders Thelin

Contents

About the Authors

Primary Author and Editor

Kelley J. Donham MS, DVM, DACVPM

Professor Emeritus, Department of Occupational and Environmental Health, College of Public Health, University of Iowa, Iowa City, Iowa, USA

Kelley was born and raised on a swine and beef cow farm in Johnson County, Iowa, where he was actively involved in the family farm operation for many years. He still is actively involved in agriculture, and owns and manages, with a colleague, a 440-acre farm in Mahaska County, Iowa. Kelley obtained a BS in Premedical Sciences, and an MS in Preventive Medicine and Environmental Health from the University of Iowa, and a Doctorate of Veterinary Medicine degree from Iowa State University. He was in a rural veterinary practice before returning to the Institute of Agricultural Medicine at the University of Iowa in 1973, achieving the rank of Professor in the College of Public Health in 1984.

In 1974 Dr. Donham founded the first – and one of the few – didactic teaching programs today in agricultural medicine, which provides specialty training for healthcare professionals, occupational and public health professionals, and veterinarians in occupational and environmental health to serve agricultural communities. Dr. Donham is also the founder of the occupational health service for farmers (now the AgriSafe Network), and founding Director of Iowa's Center for Agricultural Safety and Health (ICASH) and the Agricultural Health and Safety Training program at the University of Iowa, which includes MS and PhD programs, a continuing education program, and the Building Capacity program, which has initiated training in nine states in the United States and facilitated similar training in Australia, Turkey, and Sweden.

Dr. Donham's research has focused on diseases of agricultural workers, particularly respiratory diseases, zoonotic infectious diseases, and interventions for prevention. He conducted the original studies in regard to air quality and respiratory illnesses in workers and swine in intensive livestock housing. He has published over 150 peer-reviewed articles, three books, and 25 book chapters in the field of agricultural medicine.

Dr. Donham is a Diplomate and past President of the American College of Veterinary Preventive Medicine, and in 2002 received the Helwig–Jennings Award for sustained and lasting contributions to the field of veterinary preventive medicine. In 2003, he received the outstanding faculty award for service and in 2009 the Outstanding Teacher Award, both from the University of Iowa College of Public Health. Also in 2003, he received the Stange outstanding alumni award from the Iowa State University College of Veterinary Medicine.

Currently as Professor Emeritus, Dr. Donham remains active in the field, writing, speaking and leading a national consensus group to form a national Certified Safe Farm Program. He also co-founded the Rural Health and Safety Clinic of Eastern Iowa.

Co-primary Author

Anders Thelin

Former Head of Research and Development, The Swedish Farmers' Safety and Health Association (Lantbrukshalsan), Stockholm, Sweden

Dr. Thelin obtained his medical doctorate degree at the University of Lund, Sweden in 1970. He was active in medical practice, connected to the hospital of Växjö, Sweden, where he served for several years and worked as a practitioner in the rural service area of the hospital. He then transitioned into the occupational health service for that region. A rising interest in farmers' lives and working conditions brought him back to the University of Lund for further studies, resulting in a PhD, with his thesis focused on the panorama of farmers' occupational health and risks.

In the 1970s, Dr. Thelin was a principal in establishing the first occupational health service in the world specifically for farmers (the Swedish Farmers Health and Safety Association, or Lantbrukshälsan). Later he was head of research and development of Lantbrukshälsan and was active in designing innovative service programs to promote health and safety in dangerous agricultural working conditions.

Dr. Thelin lives in the countryside in Southern Sweden and, together with his family, operates a farm. The Thelin family is active in horse breeding, sheep production, and development of a novel fodder for horses.

Dr. Thelin's research has focused on diseases of agricultural workers, especially rheumatic disorders and injuries of the musculoskeletal system. He conducted several original studies and is currently responsible for a large prospective research program established in 1990 involving more than 1000 farmers. Dr. Thelin noticed early on the significant risk of osteoarthritis among farmers and has authored a number of publications over the years focusing on hip and knee joint osteoarthritis. Dr. Thelin's daughter is also a physician, and practices general medicine focusing on the rural population. She collaborates with her father, having published several joint research papers on musculoskeletal conditions in the cohort of farmers they have established in the rural region where they live.

Dr. Thelin's special knowledge and connection to the farm community provide him with a unique background for writing about farmers' health.

Single Chapter Authors

Chapter 11: Acute Injuries in Agriculture
Aaron Yoder PhD

Assistant Professor at the University of Nebraska Medical Center, Faculty of the Central States Center for Agricultural Safety and Health

Dr. Yoder began his professional career in agricultural safety and health at Pennsylvania State University as an instructor and Extension safety associate. There he provided leadership for the National Safe Tractor and Machinery Operation Program by coordinating online instructor training and educational programs. In addition, he taught in Penn State's Department of Agricultural and Biological Engineering and participated in other research and outreach programs for the Penn State Agricultural Safety and Health Program.

He graduated from Penn State University with a BS and MS in Agricultural Systems Management and Environmental Pollution Control, respectively. He earned his PhD degree in Agricultural and Biological Engineering from Purdue University. He serves on the Board of Directors for the International Society for Agricultural Safety and Health (ISASH) and the Agricultural Safety and Health Council of America (ASHCA). Dr. Yoder also maintains leadership roles in the eXtension.org/AgSafety Community of Practice, American Society of Agricultural and Biological Engineers, and the USDA NCERA197 Committee for Establishing Priorities in Land Grant University Research and Education Programs.

Kelley J. Donham (see above)
LaMar Grafft MS

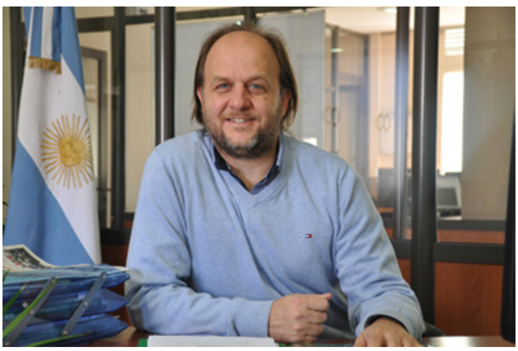
Associate Director, North Carolina Agromedicine Institute, University of East Carolina, Greenville, North Carolina, USA

Mr. Grafft was born and raised on a crop and livestock farm in Eastern Iowa. He received his BS and MS degrees from Iowa State University, and was an Extension Livestock Specialist for several years after moving off the farm. He worked part-time as a paramedic and flight paramedic for 25 years.

From 1993 to 2013 Mr. Grafft served as a Rural Health and Safety Specialist at the University of Iowa. During that time, he taught both occupational safety and agricultural safety classes. He was a member of the team that developed, researched, and coordinated the Certified Safe Farm audit tool, and taught implementation of the program. As part of that effort, he conducted safety audits on dozens of farms, including a 26,000-acre Iowa farm and the Navaho Nation's 63,000-acre farm in New Mexico.

In his current position, he develops, implements, and presents safety information in local programs, as well as presenting at national and international conferences. He has the additional responsibility of helping to determine priorities of research, intervention/prevention, and outreach/education. He is currently the co-chair of the Research and Development Committee of the International Society of Agricultural Safety and Health.

Authors of the International Chapter 15
South America (Mercosur 4), Section A
Marcos Grigioni MD



Program coordinator of Health and Safety for the Family Farm, AFASCL, Argentine Federated Farmers, Department of Education and Training, Rosario, Argentina

Dr. Grigioni is a medical doctor, trained in head and neck surgery. He was born in a family closely related to agricultural production and teaching, and is a farmer as well as a surgeon. He began working in hospitals in Argentina, in the "pampa" (the large plain and agricultural region of South America) of that country, where he has treated over 5000 patients with different types of surgical pathologies. Most of these originated from agricultural exposures (e.g., skin cancer, injuries from machinery, animals, electricity, burns, firearms, rural roadway crashes, and zoonoses (e.g., hydatid disease)). In addition, he has treated congenital malformations and related behavioral conditions in the population, including alcoholism and smoking-related cancers. He also taught in the area of head and neck surgery and in organizations such as the League against Cancer Fights of Argentina. For the last 10 years he has focused his efforts on prevention and agricultural health and safety research, developing a program which has been incorporated into a farmers' cooperative that brings together 35,000 farmers. He has designed multiple activities to disseminate agricultural medicine among all the institutions that make up the Argentine agricultural sector (professional associations of veterinarians, agronomists, cooperatives, government institutions, private companies, universities, etc.). He is currently working with farm machinery manufacturers to create safer agricultural machinery for Argentinian farmers.

Australia and New Zealand, Section B
Susan Brumby RN, RM, DipFarm M'Ment, GradDip Women's Studies, MHM, PhD

Director National Centre for Farmer Health and Clinical Associate Professor, School of Medicine, Deakin University, Hamilton, Victoria, Australia

Dr. Brumby began her career as a registered nurse and midwife working in rural Australia and has held executive positions in health services since 1998. She has been actively involved in agriculture, running the family beef and wool property for 12 years. These two career paths provided unique insight into the health, wellbeing and safety of farm men and women, and the barriers that prevent them enjoying the same health outcomes as other populations.

Combining these two passions (health and agriculture), Sue became the founding Director of the National Centre for Farmer Health, a partnership between regional health service Western District Health Service and Deakin University. She leads the Graduate Certificate in Agricultural Health and Medicine, has obtained numerous research grants, and provides direct health services to farm men and women. She has been recognized for her contribution to rural health and has presented and published nationally and internationally on farmer health and community involvement. She has led the innovative, multi-award winning farm community wellness program called Sustainable Farm Families™. This program has been delivered across Australia and recently piloted internationally.

Dr. Brumby has published numerous articles in the field of agricultural health. She is active in several national and international working groups in the field and has received numerous awards for her work in rural and farm community health and wellness.

The European Community, Section C
Christina Lunner Kolstrup MS, PhD

Research Scientist, Department of Work Science, Business Economics & Environmental Psychology, Swedish University of Agricultural Sciences, Alnarp, Sweden

Dr. Lunner Kolstrup was raised on a small farm in Denmark. She worked for some years on dairy and pig farms. In 1991 she received a degree in animal science from the Royal Veterinary and Agricultural University (KVL) in Denmark. Her interest in agricultural health and safety brought her to the Swedish University of Agricultural Sciences (SLU). In 2008 she received her PhD degree on the topic "Work Environment and Health among Swedish Livestock Workers." For several years Dr. Lunner Kolstrup has conducted multidisciplinary research and teaching with an emphasis on physical and psychosocial hazards related to health and safety in agriculture. She serves as an associate editor for the *Journal of Agromedicine*, reviews for several scientific journals, and is a member of International Society for Agricultural Safety and Health (ISASH) and the International Dairy Research Consortium (IDRC). In 2013, she published *International Perspectives on Psychosocial Working Conditions, Mental Health, and Stress of Dairy Farm Operators*, and co-authored several other review articles on the topic health and safety in the dairy industry.

Peter Lundqvist PhD

Department Head, Department of Work Science, Business Economics & Environmental Psychology, Swedish University of Agricultural Sciences, Alnarp, Sweden

Dr. Lundqvist was born and raised on a farm in southern Sweden. He received his PhD from the Swedish University of Agricultural Sciences with a dissertation on working conditions in farm buildings (1988). He achieved his rank of full professor (work science) in 1999 and since 2007 has served as the head of his department. His research is focused on injury prevention, ergonomics, and leadership in agriculture. Recently a Swedish Center for Agricultural Business Management was established in his department. It will integrate health and safety in all aspects of agricultural business management. He also serves as associate editor for the *Journal of Agromedicine* and was named as the Peer Reviewer of the Year for 2015. He also serves on the editorial board for the *Journal of Agricultural Safety and Health*. He is heavily involved in the International Society for Agricultural Safety and Health (board of directors), the International Association of Agricultural Medicine and Rural Health (executive board), the International Section of the International Social Security Association on the Prevention of Occupational Risks in Agriculture (advisory board), and the International Ergonomics Association (vice chair and member of the Technical Committee Agriculture) and is an active member of the International Dairy Research Consortium.

About the Reviewers

General Scientific Reviewer

Jeffrey Bender DVM, MS, DACVPM
Professor – Veterinary Population Medicine, College of Veterinary Medicine, University of Minnesota, St. Paul, MN, Veterinary Public Health, Co-Director of the Upper Midwest Center for Agricultural Safety and Health, University of Minnesota, College of Veterinary Medicine and School of Public Health

Dr. Bender is a Professor at the University of Minnesota, College of Veterinary Medicine and the School of Public Health. He previously worked for the Minnesota Department of Health, as an infectious disease epidemiologist. He is currently the Co-Director for the Upper Midwest Agriculture Safety and Health Center. Previously, he was the Director for the Center for Animal Health and Food Safety and Co-Director of Human-Animal Interface Studies at the National Institutes of Health-funded Minnesota Center of Excellence for Influenza Research and Surveillance. He has had over 80 peer-reviewed publications and has received funding from the US Department of Agriculture, the Center for Disease Control and Prevention, the National Institutes of Health, the National Institute for Occupational Safety and Health, and the US Agency for International Development. He has served on several national committees related to public health and veterinary medicine, including the US Food and Drug Administration Science Advisory Board, the American Veterinary Association Companion Animal Antibiotic Stewardship Committee (Chair), and the Public Health Committee for the National Pork Board. His primary teaching and research interests include infection prevention, disease surveillance, emerging zoonotic diseases, occupational safety, food safety, and antimicrobial resistance.

External Reader

Jean Donham PhD
Professor (retired) College of Education, University of Northern Iowa, Iowa, USA

Dr. Donham received her BA degree from the University of Iowa in English and Latin. She received her MA in Library and Information Science from the University of Maryland. Her PhD was awarded from the College of Education, University of Iowa. Her career has focused on teaching and librarianship in school and college settings, and teaching at the graduate level in library and information science. She has published three books in library and information science as well as numerous articles in the field.

Chapter Reviewers

Chapter 1: Introduction and Overview
Susan Brumby RN, RM, DipFarm M'Ment, GradDip Women's Studies, MHM, PhD (see above)

Chapter 2: Special Risk Populations in Agricultural Communities

Robin Tutor-Marcom EdD(c), MPH, OTR/L

Director of the North Carolina Agromedicine Institute, Greenville, North Carolina, USA

Ms. Tutor-Marcom is responsible for ensuring that the institute is true to its mission of promoting the health and safety of farmers, fishermen, loggers, their workers, and their families through research, prevention/intervention, and education/outreach. Under her leadership, the AgriSafe Network of North Carolina was recognized as the first state affiliate of the national AgriSafe Network in 2008 with Certified Safe Farm – North Carolina coming online in 2009. These programs have been complemented by the addition of the North Carolina AgrAbility Partnership, Fit to Farm, and Risk Mitigation Measures initiatives. Ms. Tutor-Marcom is a member of the International Society for Agricultural Safety and Health, Farm Safety for Just Kids, Childhood Agricultural Safety Network, and the FReSH (Farm and Ranch Safety and Health) eXtension Community of Practice. She also serves on the Advisory Board for the North Carolina Farmworker Health Program and the Member Relations Committee for the Agricultural Health Safety and Health Council of America. In fulfilment of requirements to receive her Doctorate of Education in Agricultural and Extension Education she is investigated the social-emotional support needs of men and women farmers in North Carolina.

Chapter 3: Agricultural Respiratory Diseases

John May MD

Deputy Director of the Northeast Center and Director of the Bassett's Research Institute, Cooperstown, New York, USA

John May is a graduate of the University of Notre Dame and Case Western Reserve School of Medicine. He trained in internal medicine and pulmonary disease at the Mary Imogene Bassett Hospital in Cooperstown, New York, and the University of Colorado Medical Center, Denver, Colorado. In addition to his pulmonary practice at Bassett Hospital in Cooperstown, Dr. May began seeing patients with various farm-related occupational health problems over three decades ago. He continues to have a regular farmers' clinic that focuses on occupational issues affecting rural workers. John is a cofounder and director of the New York Center for Agricultural Medicine (NYCAMH). NYCAMH's Northeast Center, one of the national centers designated by the National Institute for Occupational Safety and Health, has active projects involving agriculture and commercial fishing in a number of northeastern and Middle Atlantic States. Dr. May has published widely in research areas that include respiratory, musculoskeletal, hearing, and other disorders affecting both family farmers and farm workers in the northeastern region of the United States. Areas of particular interest are social marketing-based interventions and the application of community-based intervention methods in addressing occupational health challenges for migrant farmworkers.

Chapter 4: Agricultural Skin Diseases

Christopher J. Arpey MD

Professor of Dermatology, the Mayo Clinic, Rochester, Minnesota, USA

Dr. Arpey began his higher education at Colgate University, receiving a BS in chemistry. He earned his medical degree from the School of Medicine and Dentistry, University of Rochester. Dr. Arpey trained in dermatology at the University Hospital in Cleveland, and the University of Iowa. He is currently Professor of Dermatology at the Mayo Clinic in Rochester, Minnesota. He is Director of Surgical Education in his department and has strong interests in education. He has been a member of the boards of directors of several large dermatological surgical boards, and recently completed a 9-year term on the American Board of Dermatology. He has a particular interest in caring for patients with skin cancer. Dr. Arpey has participated in the University of Iowa Agricultural Medicine Core Course for over 10 years. His subject in that course was agricultural-related skin diseases, focusing on sun-induced skin cancers.

Chapter 5: Cancer in Agricultural Populations
Charles F. Lynch MD, PhD
Professor of Pathology and Epidemiology, Colleges of Medicine and Public Health, University of Iowa, Iowa City, Iowa, USA

Dr. Lynch received his MD and PhD degrees from the University of Iowa in 1979 and 1984, respectively. In 1986, he received board certification in anatomic pathology. Currently, he is a professor with a joint appointment in the Department of Epidemiology in the College of Public Health and the Department of Pathology in the College of Medicine at the University of Iowa. Since 1990, he has been Principal Investigator and Medical Director of the State Health Registry of Iowa, Iowa's statewide cancer surveillance program that is part of the National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER) Program. Since 1992, he has been the Director of the Iowa Field Station for the Agricultural Health Study. Since 1995, he has led the Cancer Epidemiology and Population Science Program of the Holden Comprehensive Cancer Center, and since 2000 he has been Associate Head of Research in the Department of Epidemiology. His research interests include cancer surveillance, cancer epidemiology, and environmental epidemiology. He has co-authored over 330 peer-reviewed publications. From the College of Public Health, he received the Faculty Research Award in 2002, the Outstanding Alumni Award in 2004, and the Faculty Achievement Award in Community Engagement in 2008.

Chapter 6: Health Effects of Agricultural Pesticides
Diane Rohlman PhD
Associate Professor, Department of Occupational and Environmental Health, Director of the Graduate Training Program in Agricultural Health and Safety and Health, Director of the Healthier Workforce Center, College of Public Health, University of Iowa, Iowa City, Iowa, USA

Dr. Rohlman's research has focused on the design, development, and validation of computerized test methods to assess neurotoxic effects and neurological disorders in humans exposed to chemical and physical agents. These methods have been applied in research examining the effects of pesticide exposures in adolescent cotton workers in Egypt, migrant workers and families in the United States, and wartime stressors in Persian Gulf veterans. Her current research is focused on identifying and characterizing adverse effects of organophosphate exposure on neurobehavioral performance.

Chapter 7: General Environmental Hazards in Agriculture Communities
David Osterberg BS, MA, MS
Clinical Professor, Department of Occupational and Environmental Health, University of Iowa, Iowa City, Iowa, USA

David Osterberg is Clinical Professor of Environmental Policy in the Department of Occupational and Environmental Health, College of Public Health at the University of Iowa. He holds a secondary appointment at the University of Iowa's Department of Geography. From 1983 to 1998 Professor Osterberg served as a State Representative in the Iowa House of Representatives. During that time he served as the Chair of the Committee on Agriculture and as Chair of the Committee on Energy and Environmental Protection. He was the Iowa Farmers' Union Legislator of the Year in 1987. He later worked for the Iowa Department of Natural Resources. Professor Osterberg holds a BA in economics from Washington State University, and an MA in economics, an MS in water resources management, and an MS in agricultural economics, all from the University of Wisconsin-Madison. In 2001 he founded the Iowa Policy Project, which produces papers on the Iowa budget, empowerment of low income Iowans and improving the environment. His organization has published widely on Iowa environmental issues. His work with the University of Iowa Superfund Research Program's Research, Translation and Outreach Corps has led him to educate many diverse groups from state legislators to seventh-grade students.

Chapter 8: Musculoskeletal Disorders
Steven R. Kirkhorn MD, MPH, FACOEM
Director/Section Chief Occupational Health Minneapolis Veterans Administration Health Care System, Assistant Professor, Department of Medicine, University of Minnesota School of Medicine, Saint Paul, Minnesota, USA

Dr. Kirkhorn has responsibility for the overall supervision of occupational/employee health issues of employees for the healthcare system. He also chairs the ergonomics committee and is a National Consultant in the Veterans Hospital Administration for Occupational/Environmental Medicine (OE Medicine Consult Program). He develops the occupational health curriculum and precepts Internal Medicine and Occupational Medicine residents.

He was previously Chair of the North American Agromedicine Consortium and Editor-in-Chief of the *Journal of Agromedicine* (2004–2011).

Chapter 9: Physical Factors
Jeffrey Levin MD, MSPH, FACOEM, FACP
Professor and Chair of the Department of Occupational Health Sciences, University of Texas Health Science Center, Tyler, Texas, USA

Dr. Levin is a graduate of the University of Texas Medical School at San Antonio. He completed his internal medicine training at the University of Missouri and occupational medicine at the University of Kentucky, where he also obtained his MS degree in public health. He is board-certified in both internal medicine and occupational medicine. Dr. Levin is founding Director of the Occupational Medicine Residency Program at Tyler (since 1994). He is past President of the Texas Occupational Medical Association. He holds the Jesse H. Jones Distinguished Professorship of Occupational Health Sciences and the Houston Endowment Inc. Professorship in Environmental Science. He has been Center Director for the US National Institute of Occupational Safety and Health Southwest Center for Agricultural Health, Injury Prevention, and Education since 2002.

Presently, Dr. Levin is Senior Vice President for Clinical and Academic Affairs at the University of Texas Health Science Center. He is Medical Director of the Texas Institute of Occupational Safety and Health. He received the Marcus Key Award from the Texas College of Occupational and Environmental Medicine in 2013, and has recently been appointed as a board member to the American Board of Preventive Medicine. He is a clinician, educator, and researcher.

Chapter 10: Psychosocial Conditions in Agriculture
Michael Rosmann PhD
Private practice clinical psychology and writer in behavioral health for farmers, and academics, Harlan, Iowa, USA

Michael R. Rosmann is a clinical psychologist and farmer in western Iowa. He received his undergraduate degree in psychology from the University of Colorado and his MS and PhD degrees in clinical psychology from the University of Utah. He writes a weekly column about the behavioral health issues of people involved in agriculture that is syndicated in the United States, Canada, and Australia to about 4 million readers. He is the author of two books, numerous chapters, and many scholarly publications as well as articles for agriculture and fishing/hunting magazines.

Dr. Rosmann is Adjunct Professor in the Department of Occupational and Environmental Health at the University of Iowa. He was inducted into the Iowa Center for Agricultural Safety and Health Hall of Fame and is the recipient of leadership awards from the American Psychological Association and the National Association for Rural Mental Health for his work to improve the behavioral health of rural and agricultural people.

Brandi Janssen MA, PhD
Clinical Assistant Professor, Occupational and Environmental Health, The University of Iowa College of Public Health, and Director, Iowa's

Center for Agricultural Safety and Health (I-CASH), Iowa City, Iowa, USA

Trained as an anthropologist, Dr. Janssen conducts qualitative and ethnographic research among agricultural populations. As director of Iowa's Center for Agricultural Safety and Health, she oversees the work of a statewide coalition of public and private organizations devoted to reducing injuries and fatalities on Iowa farms.

Dr. Janssen serves on the board of directors for the Iowa Rural Health Association and eastern Iowa non-profit Local Foods Connection and is a member of the Center for Rural Health and Primary Care Advisory Board.

Chapter 11: Acute Injuries in Agriculture
LaMar Grafft MS (see above)

Chapter 12: Veterinary Pharmaceuticals: Potential Occupational and Community Health Hazards
Jeffrey Bender DVM MPH (see above)

Chapter 13: Zoonotic Diseases: Overview of Occupational Hazards in Agriculture
James Wright DVM, MPVM, DACVPM
US Air force (retired), Texas Department of Health, Austin Texas, USA (retired),

Dr. James Wright earned his BS and DVM degrees at Texas A&M University, and is a Master of Preventive Veterinary Medicine (MPVM) at the University of California at Davis. He is a Diplomate of College of Veterinary Preventive Medicine.

Dr. Wright was in private practice before entering a career in public health in the US Air Force, where he worked on food safety, industrial occupational health, communicable disease epidemiology and surveillance, disaster preparedness, medical facility employee health, and environmental health and sanitation. In 1992, he joined the Texas Department of State Health Services, where he served in the Meat Inspection and Zoonosis Control Programs until his retirement in December 2011. His duties included consulting with veterinarians, the general public, local government officials, patients, and physicians on zoonotic diseases and animal control.

Dr. Wright has taken the University of Iowa Agricultural Medicine core course, and was certified by examination. Dr. Wright remains active with the Texas Veterinary Medical Association, where he chairs the Public Health Committee, and with the Southwest Center for Agricultural Health, Injury Prevention, and Education. In 2013, the Texas A&M University College of Veterinary Medicine and Biological Sciences selected him as an Outstanding Alumnus.

Christine Petersen DVM, PhD
Associate Professor, Department of Epidemiology, Director, Emerging Infectious Diseases Center, College of Public Health, University of Iowa, Iowa City, Iowa, USA

Dr. Petersen graduated with her DVM from Cornell University in 1998, and completed her PhD in immunology and infectious diseases at Harvard School of Public Health in 2004.

With the first seeds planted as a veterinary student doing a summer research project on African trypanosomiasis at the International Livestock Research Institute in Nairobi, Kenya, Dr. Petersen's scientific career has focused on the prevention of zoonotic diseases.

Dr. Petersen is Director of the Center for Emerging Infectious Diseases, a One Health collaboration between the Iowa Department of Public Health and Regents' Colleges of Medicine, Public Health and Veterinary Medicine. As an Associate Professor at the University of Iowa College of Public Health, she also teaches joint veterinary, medical, and global public health coursework and conducts outreach related to the diagnosis, treatment, and prevention of zoonotic diseases within animal and human populations. Additionally, she collaborates with Iowa State University regarding infection control and prevention in populations ripe for the spread of zoonotic infectious diseases.

Chapter 14: International Agricultural Safety and Health
Section A and B: Kelly J. Donham (see above)
Section C: Anders Thelin (see above)

Chapter 15: Prevention of Illness and Injury in Agriculture
Jean McCandless MSW
Director, Vermont Farm Health Task Force, Burlington, Vermont, USA

During her 40 years working in medical, disability, social service, and clinical settings, Jean McCandless has learned that prevention is of critical importance. In addition to her current position running the Vermont Farm Health Task Force, Jean is a Geriatric Care Manger and Social Worker in private practice.

She began working to improve the health and safety of Vermont farmers and farm workers in 2005, when she became the Arthritis Program Manager for the Vermont Department of Health. A statewide Farmer Health Survey in 2006 confirmed that most farmers had osteoarthritis, making them the highest risk occupational group for arthritis in the state. In 2007, Jean began the Vermont Farm Health Task Force, a statewide organization with 70 members from key state agencies, community health and agricultural organizations, and, farmer representatives.

With support from the Iowa's Center for Agricultural Safety and Health, the Task Force became an organizational participant in the NIOSH-funded Building Capacity Grant Program. Both the I-CASH Program and the National AgriSafe Network helped establish regular Agricultural Medicine and Occupational Safety Trainings in Vermont. As both the training director and a faculty presenter, Jean has helped train many Vermont and New England medical and agricultural professionals.

Preface

Agricultural Medicine, second edition

Agricultural Medicine is the long-term outcome of the first known academic course in agricultural medicine initiated by Kelley Donham in 1974 at the University of Iowa. The Agricultural Health Working Group of the International Commission for Occupational Health (ICOH) proposed the need for a new text to guide education to a broad field of health and safety professionals. The experience of Dr. Thelin in agricultural health and safety made him an ideal collaborator for this project.

To provide direction, two multi-professional consensus processes were convened. The first consisted of 13 people who met in 2006 in Iowa City, Iowa, USA to establish the topics and learning objectives for the first edition of this text. Six years later, it was deemed a second edition of the book was necessary to incorporate new information in the rapidly evolving industry of production agriculture and the related occupational illnesses and injuries. In 2012 the second consensus process was formed by many of the original participants and supplemented by many more (a total of 30 persons), including an increased safety and international representation. That process resulted in the review and revision of the topics and learning objectives. The recommendations included:

- an increase in attention to regional and international coverage
- increased coverage on prevention, both in the individual chapters and an enhancement of the general prevention chapter (Chapter 15)
- increased coverage for safety professionals, especially coverage of risk management
- a text that would serve as an international standard for core topic coverage
- a recommendation that production of two additional chapters (i.e., agricultural safety and climate change effects on agriculture and the health and safety of its workers) should be pursued to serve as the basis for a more complete academic curriculum in agricultural health and safety.

The aim of the second edition was to attempt to respond to these recommendations. A new international chapter has been added to this edition. International authors have written comparative sections covering critical issues in agricultural medicine in Australia and New Zealand, South America, and the European Union. Enhanced discussion of preventive measures has been added to each chapter, as well as a detailed chapter on theory and examples of comprehensive prevention programs are included. There is increased coverage of programmatic approaches for safety professional and coverage of megatrends such as global warming and potential resulting health concerns. Over 1000 new references have been added.

The main effort to produce the manuscript for the second edition began in October of 2013, and it was submitted in manuscript form on 10 March 2015.

Specific Objectives

The authors have three central objectives for this book. The first is to provide core information on the causes and prevention of occupational illnesses and injuries to farmers, ranchers, their families, and workers. A second objective is that the book should serve as a core text for academic and continuing education courses, curricula, and workshops focusing on the occupational health and safety of those involved in production agriculture. The third objective of this text is to motivate readers to apply this information in serving the health and safety needs of agricultural populations.

The Importance of Human Resources in Agricultural Production

Agriculture is an essential industry providing basic needs (food, fiber, and fuel) for society. These essential needs were put into perspective in 1943 by the famous sociologist Abraham Maslow. His well-accepted theory of hierarchy of needs (*Psychological Review* 1943;50:370–396) is relevant to agriculture. His metaphor of a pyramid of needs suggests that agriculture is at the base, providing the essential food, clothing (fiber), and shelter (timber). Societies cannot progress to a higher level until a sustained and productive agriculture exists. Sustainability of an industry (as described by Andrew Savitz) includes not only the need for profit, but also consideration for the planet (not pollution) and people (human resources). The latter is often the last element that is considered in agriculture yet perhaps it is the most important. If we do not maintain our human capital, the others (profit and planet) are mute points. The agricultural workforce must be protected to assure a sustainable domestic and international food, fiber, and fuel source. The theme of this book is "helping to keep farmers, ranchers, their families and workers alive and well in agriculture".

The Target Audience and Geographical Coverage

The target audience includes a broad range of health and safety professionals, including healthcare providers, safety specialists, Extension workers, and insurance professionals. The geographic range of the intended audience is international, targeting those countries defined by the United Nations as "more developed", or industrialized countries, including North America (United States and Canada), countries of the European Union, Australia and New Zealand, and South America (the four major agricultural countries of the Mercosur). Agricultural medicine is highlighted in these countries in a new chapter in this second edition (Chapter 14), which contains comparative treatises on agricultural medicine relative to North America. The reason for the geographic boundaries is to maintain a focus on a very large amount of diverse information. The industrialized countries have similar agricultural industries, and thus similar occupational health and safety concerns. Agriculture in less developed countries is vastly different as general environmental and public health concerns such as inadequate sanitation, water quality, and malaria far outweigh occupational concerns in very different styles of production practices. Proper discussion of these issues would require a separate text.

Practicality and the Farm Connections of the Authors

This book has been written from the perspective of authors who have been involved with agriculture for many years, and who approach the field with direct experience and practicality.

The principal authors of this book are both from agricultural backgrounds, as well as from health profession and academic backgrounds. We are still involved with agriculture today, having more than 40 years of experience each in production agriculture and agricultural medicine. The scenarios provided throughout the text are based on our actual contact with the cases and the people who suffered these conditions. The reviewers of the chapters were chosen based not only on their experience and knowledge of the field, but also on their knowledge and experience of production agriculture and cultural awareness of the people who work in it. Our personal goal is to bring practical experience to the pages of the text so that the exposures, risks, and preventive measures are based on reality and practicality.

Kelley J. Donham

Chapter

1

Introduction and Overview

Kelley J. Donham and Anders Thelin

Reviewer: Susan Brumby

1.1 Introduction to the Professional Specialty of Agricultural Medicine (Agricultural Safety and Health)

Those working in the agricultural industry producing food, fiber, and fuel experience one of the highest risks factors among all occupations for injury, illness, and death. This is true for developed economies as well as developing and the least developed economies of the world. (Note: The categorical terms for nation state development are those of the United Nations). The aim of this chapter is to provide the introduction and background to the developing specialty field of agricultural medicine/agricultural safety and health to a multidiscipline audience of health and safety professionals and students. Our intermediate goal is to increase the knowledge of this field in health and safety among rural professionals and students, and instill passion among them to apply their skills to keep farmers, their families, and their workers alive and well in agriculture. The long-term goal is to reduce adverse occupational health, economic, social, and emotional problems to at least a level comparable to all other occupations.

1.2 Terminology and Definitions

Most countries' agricultural industrial classification schemes include production agriculture (farming and ranching), forestry, and fishing. This book is about the occupational health and safety of people working in production agriculture—those who produce food, fiber, and bio-fuels for the world. In this chapter, there are nine main topic areas that will be covered: (1) a history and definition of terms relevant to agricultural safety and health, (2) a description and background of an agricultural safety and health professional, (3) the training required of the latter, (4) the demographics of the agricultural workforce, (5) types of farms, (6) the health status of the agricultural workforce, (7) the occupational health status of the agricultural workforce, (8) persistent and emerging megatrends shaping agriculture, and (9) a brief overview of the major occupational health and injury issues in agriculture and their prevention.

Regarding historical perspectives and terminology, several terms have been used to describe the fields of endeavor aimed at the health of our rural and agricultural communities. Donham and colleagues

Agricultural Medicine: Rural Occupational and Environmental Health, Safety, and Prevention, Second Edition.
Kelley J. Donham and Anders Thelin.

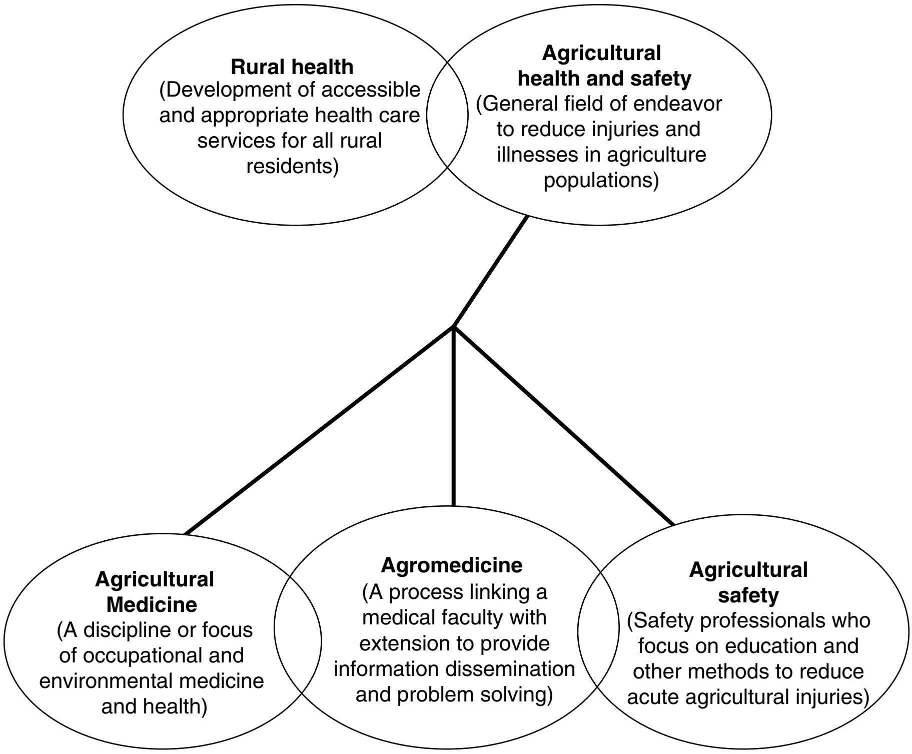


FIGURE 1.1 Terminology/fields of endeavor addressing the health of rural residents, owners/operators, and workers in production agriculture.

(1) described the historical context of these terms, although today they are often used interchangeably. Figure 1.1 illustrates the various terms used and their relationships. The two primary terms used to describe health-related activities in rural areas are rural health and agricultural health and safety. Rural health is defined by the National Rural Health Association as a field of endeavor aimed at the development and support of healthcare services (providers and facilities) that are accessible and appropriate for all rural residents (2). The field of rural health does not focus on any particular diseases, occupation, ethnic group, or prevention, but on provision of services (healthcare personnel and facilities) aimed to take care of the usual episodic illnesses of rural residents (3). Agricultural health and safety, on the other hand, is a broad term that is used to describe a field of practice and associated endeavors aimed at prevention and treatment of occupational injuries and illnesses in agricultural populations. Underneath this latter umbrella term are several interrelated terms: agricultural medicine, agromedicine, and agricultural safety. Although each term is associated with activities aiming to reduce injuries and illness in agricultural populations, each term has a slightly different history, concept, focus, professional make-up, and culture.

Within the broader field of agricultural safety and health, the term "agricultural medicine" has been used since the 1950s to describe a specialty discipline of the broader field of occupational medicine and occupational health. Table 1.1 summarizes the key dates and events in the development of the term agricultural medicine and the variant term agromedicine (4–15). Bernardo Ramazzini, an Italian physician of the early 1700s, has been generally recognized as the father

Table 1.1 A brief history of agricultural safety and health

- 1713 Bernardo Ramazzini published his book *Diseases of Workers* (4)
- 1945 Toshikazu Wakatsuki established an outreach medical and prevention program for the farming community at Saku Central Hospital, Japan (5)
- 1945 Founding of the Institute of Farm Safety Specialists, which became the National Institute for Farm Safety in 1962 and in the International Society for Agricultural Safety and Health in 2012
- 1951 Founding of the Institute of Rural Occupational Health, Lublin, Poland
- 1955 Founding of the Institute of Agricultural Medicine, University of Iowa
- 1961 Founding of the International Association of Agricultural Medicine and Rural Health in Tours, France
- 1965 Founding of the *Journal of the International Association of Agricultural Medicine and Rural Health*
- 1973 Founding of the Institute of Rural Environmental Health (Occupational Health and Safety Section), Colorado State University (now the High Plains Intermountain Health and Safety)
- 1973 The term "agromedicine" first used by John Davies (6)
- 1974 The agricultural medicine training program at the University of Iowa started
- 1976 The peer-reviewed article "The Spectrum of Agricultural Medicine" outlining the didactic areas of agricultural medicine published in *Minnesota Medicine* (7, 11)
- 1977 Founding of farmers' occupational health services in Sweden and Finland
- 1979 Article published by Elliott in the *Journal of the Royal Society of Medicine* that gave the first definition of agricultural medicine (8, 13)
- 1981 Founding of the National Farm Medicine Center, Marshfield, Wisconsin
- 1982 Article published by donham that gave a more detailed definition of agricultural medicine, differentiating it from the field of rural health (9, 14)
- 1984 Establishment of the first agromedicine program as a consortium of the Department of Family Medicine at the Medical University of South Carolina and Clemson University
- 1986 Founding of the Institute for Agricultural Medicine and Rural Environmental Health, University of Saskatchewan, Canada (now the Canadian Centre for Health and Safety in Agriculture)
- 1988 Founding of the North American Agromedicine consortium
- 1988 Agriculture at Risk Report (10)
- 1988 Founding of the Australian Center for Agricultural Health and Safety at Moree, New South Wales
- 1990 Founding of Iowa's Center for Agricultural Safety and Health
- 1990 Founding of the National Institute of Occupational Safety and Health Program on Agricultural Safety and Health, leading to 10 regional centers across the United States
- 1991 Surgeon General's Conference on Agricultural Safety and Health
- 1992 Publication of the text *Safety and Health in Production Agriculture* (11)
- 1994 Founding of the *Journal of Agromedicine*
- 1994 Founding of the *Annals of Agricultural and Environmental Medicine*
- 1995 Founding of the *Journal of Agricultural Safety and Health*
- 1997 Publication of the reference book *Safety and Health in Agriculture, Forestry and Fishing* (86)
- 2002 Founding of Norway's Farmer Health and Safety Program (Landbrukets HMS-tjeneste)
- 2003 Publication of *Looking Beneath the Surface of Agricultural Safety and Health* (13)
- 2003 Transition of the Iowa Agricultural Health and Safety Network to a new national non-profit organization, the AgriSafe Network
- 2006 Publication of the text book *Agricultural Medicine: Occupational and Environmental Health for the Health Professions* (14)
- 2006 Publication of *Agricultural Medicine: A Practical Guide* (15, 85)
- 2006 University of Iowa founded the first specifically titled MS and PhD graduate degrees and a certificate program in agricultural safety and health
- 2006 Founding of the University of Iowa's program Building Capacity in Agricultural Medicine Training, which initiated sustainable training programs in agricultural medicine. Programs have been initiated in nine US states (Iowa, Illinois, Wisconsin, North Dakota, Nebraska, Vermont, North Carolina, Alabama, and Texas), and in Australia and Turkey
- 2007 Founding of the Agricultural Safety and Health Council of America
- 2008 Founding of the Australian Center for Farmers' Health at Hamilton, Victoria
- 2011 National Institute for Farm Safety changed its name to the International Society for Agricultural Safety and Health to reflect an emphasis on safety as well as health, with an international focus
- 2012 First agricultural medicine course in the Middle East at University of Harran, Sanliurfa, Turkey

of occupational medicine. His book (*Diseases of Workers*, translated from Latin) describes in detail many occupationally related diseases (which he observed in his farm patients), many of which we still recognize today (4). The history of occupational medicine and occupational health generally (and agricultural medicine specifically) can be traced to his writings.

In more modern times, a physician named Toshikazu Wakatsuki in Japan developed a strong outreach program to his farming patients following World War II. Wakatsuki began his tenure at Saku Central Hospital in the Nagano Prefecture of central Japan in 1945. He spent his professional lifetime transforming the care of the rural farming community from what may have been considered benign neglect to a world model outreach and prevention program. He established the Japanese Rural Medicine Association, and was one of the principal founders of the International Association of Agricultural Medicine and Rural Health. His humble, dedicated, humanitarian approach to his mission earned him the Ramon Magsaysay Award (the Asian equivalent of the Nobel Peace Prize) in 1976 (5). In Europe, the Institute for Rural Occupational Health was initiated (in 1951) at Lublin, Poland, and was the first research institute to focus on the occupational health of farmers. The institute at Lublin became known as the Institute of Agricultural Medicine in 1984. This institute houses a multidisciplinary team of some 150 scientists researching the occupational and environmental health of Poland's rural and farming community (16). It also founded a new journal in 1994 titled *Annals of Agricultural and Environmental Medicine*, which publishes peer-reviewed scientific articles on a wide variety of occupational and environmental health problems among agricultural workers (16).

The first use of the term "agricultural medicine" in the United States can be traced to 1955 with the founding of the Institute of Agricultural Medicine (IAM) at the University of Iowa within the College of Medicine. This institute was organized with a multi-professional faculty (after the philosophy of the one-health approach) that included a physician, an industrial hygienist, a veterinarian, a microbiologist, an anthropologist, an agricultural engineer, and a toxicologist (17, 18). The IAM was renamed the Institute for Rural and Environmental Health, and in 1999 became a program within the newly formed College of Public Health.

Franklin Top, first director of IAM (19) set out the didactic basis of agricultural medicine, which included the importance of understanding the processes and work environment of agriculture, including acute injuries, sanitation, allergies, farm chemicals, zoonoses, and social and mental health. Rasmussen and Cole (7) expanded on Top's comments and further established the didactic content of agricultural medicine. Berry (17, 20) produced the first published articles regarding the peculiarities of agricultural employment relative to other industrial employment. He also commented on the occupational health of the farm community, and suggested a research agenda for agricultural medicine (17). Elliott (8) published the first attempt at a definition of agricultural medicine, which used a variation of the definition of industrial hygiene. In 1982, Donham expanded on Elliott's definition, to incorporate concepts of clinical medicine and public health: Agricultural medicine is "… the anticipation, recognition, diagnosis, treatment, prevention, and community health aspects of health problems peculiar to agricultural populations" (9). Agricultural medicine is an academic discipline, a specialty area of occupational and environmental medicine and public health. Multidisciplinary in its approach, it involves professionals from all the clinical and basic health and safety sciences and veterinary medicine. Agricultural medicine has a research base and a core of didactic information. This didactic core of information serves as the basis for training programs for health or safety professionals who work in the area. Early development of academic training in agricultural medicine can be traced back to the University of Iowa program (IAM). Existing in the beginning as a research institute, in 1974 a training program in agricultural medicine was initiated for healthcare professional students and graduate students (21). Two international professional organizations further the professional field of agricultural medicine. The International Association of Agricultural Medicine and Rural Health, founded in 1961 at Tours, France (8, 22), is a multi-professional group of healthcare practitioners, health and safety scientists, and agriculturalists who aim to identify and control health and environmental problems in rural and agricultural communities. The International Commission of Occupational Health, Scientific Committee on Agriculture, Pesticides and Organic Dusts has furthered the international concept of agricultural medicine (23).

Furthering the scientific basis for the field of agricultural medicine, two scientific journals have agricultural medicine in their title: *Journal of the International Association of Agricultural Medicine and Rural Health* and *Annals of Agricultural and Environmental Medicine*.

A variant on the term agricultural medicine was used with the founding of the National Farm Medicine Center in 1981 at Marshfield, Wisconsin. This medical research and outreach group to the farm community was developed within a private multi-specialty physician group, but it has evolved into a multi-professional group focusing on occupational illnesses and injuries in the farming community (24). The University of Saskatchewan in Canada has been involved in agricultural medicine since the mid-1990s, and in 2006 developed the Canadian Centre for Health and Safety in Agriculture (25).

Another variant on agricultural medicine, agromedicine, was first used in 1976 and defined in more detail in 1978 by John Davies (6). He expressed his concern over the public and agricultural producers' fears regarding the health and environmental effects of pesticides. He perceived a need for the medical and agricultural health communities to work together on this issue and called for an "agromedicine approach." Davies asserted that although pesticides were clearly a boon for agricultural production, the occupational, environmental, and public's concerns and regulations were driven by fear, rather than science, creating a barrier to their rational use. Stanley Schumann at the Medical University of South Carolina expanded on the agromedicine concept. He observed that the Cooperative Extension Service of land grant colleges had agricultural specialists in every county of the state to disseminate information from the research campuses to the farmers in the countryside. Extension agents are located in rural areas to assist with problem solving that might arise regarding production issues. Schumann thought that medical and health information and problem solving could and should be disseminated in a similar manner, but in full collaboration and in context with scientific agricultural production information (26). The South Carolina Agromedicine Program was initiated in 1984 as a joint collaboration between the Division of Family Medicine at the Medical University of South Carolina and the Agricultural Extension Service of Clemson University. The program grew, gaining first regional then national interest, and in 1988 the North American Agromedicine Consortium (NAAC) was established. This organization held annual professional conferences through 2006 and founded the scientific, peer-reviewed *Journal of Agromedicine*. However, due to decreased funding at the state level and the evolution of other related organizations, NAAC is no longer active. The *Journal of Agromedicine* still persists, and operates out of the Farm Medicine Center, Marshfield WI.

The differences between the history and concepts of agricultural medicine and agromedicine in their beginnings were clear. However, their basic goal to improve health and safety in the agricultural community was common. Both are fields of agricultural health and safety, with the objective of controlling or preventing agricultural occupational and environmental illnesses and injuries. Both are multidisciplinary in their approach. Both promote the importance and understanding of agriculture and the culture of its people. The basic difference is that agricultural medicine is a public health/medical discipline (a subspecialty of occupational and environmental health) and agromedicine is a process, an inter-professional link between the medical faculty (usually family medicine) and the agricultural college (extension).

Agricultural safety compared to agricultural medicine has had a longer history, starting in the United States in the 1940s. The first individuals involved included extension agents, insurance loss control personnel, and farm bureau representatives. Professionals who became involved in this effort brought an orientation from the field of industrial safety. The methods focused on promoting awareness of safety hazards resulting in acute injuries in the farm community. The National Institute for Farm Safety was the primary professional organization for this group of professionals. In 2012, the name of this organization was changed to the International Society for Agricultural Safety and Health (ISASH; 27) to reflect greater international participation and greater involvement of health professionals. The principal scientific journal of this group is the *Journal of Agricultural Safety and Health*.

Although the three terms described above have different histories, professional make-up, and culture, they are tied together by the common goal of reducing illnesses and injuries among agricultural populations. Furthermore, the related professional journals and societies (mentioned above) provide a common chronicle for practitioners and students interested in agricultural health and safety. Government agencies for occupational health also bring various professionals together to address agriculture. For example, the National Institute of Occupational Safety and Health (NIOSH) funds agricultural health research and education activities both internally and through its lead extramural activity, the Agricultural Health Centers Program. The latter consists of 10 multi-professional center programs in the United States (28). Demonstration of functional multi-professional collaborative solidarity within the field of agricultural safety and health was evident in 2004 and 2005 when combined national meetings were cohosted by ISASH, the NIOSH Agricultural Health Centers Group, and NAAC.

A new organization (the Agricultural Safety and Health Council of America (ASHCA), http://ashca.org/ was established in the United States in 2007. Formed as a coalition of agricultural businesses, farm organizations, federal agencies, and health and safety professionals, this organization furthered the multi-professional collaborative approach. A primary goal of ASCHA is to seek active collaborative involvement and leadership of agricultural businesses (e.g., farm supply and services, insurance, machinery manufacturers) in the formation of agricultural health and safety policy, regulations, research, and prevention interventions.

1.3 What is an Agricultural Health and Safety Professional?

The evolution of the profession of agricultural health and safety was recently reviewed (29). The following paragraphs summarize the progress in this field. Many individuals of varying backgrounds can make a difference in the health and safety of our agricultural communities, including healthcare practitioners who as a part of their practice may serve agricultural patients. There are also professionals who deal with agricultural health and safety on a full-time basis. Figure 1.2 describes the roles and relevant background education needed to fill these different niches.

1.3.1 The Primary Care Physician, Nurse, Allied Health Professionals, and Veterinary Practitioners

Healthcare professionals and veterinarians in rural communities have an excellent opportunity to address the issues of agricultural health and safety with their patients and/or clients. They have frequent contact with farmers and their families, and they are in a position of respect and credibility within their community. The agricultural health and safety training program at the University of Iowa (30) has included health

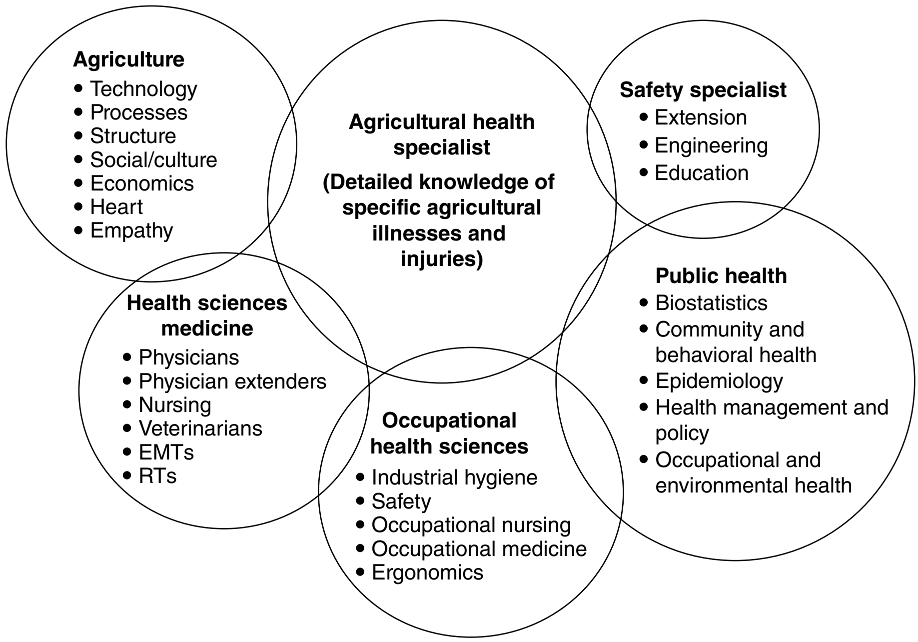


FIGURE 1.2 The components of the field of agricultural medicine (agricultural health and safety and the specialist). EMT, emergency medical technician; RT, respirator therapist.

professionals from a variety of backgrounds, including (1) primary care physicians, (2) nurses, (3) nurse practitioners, (4) physician assistants, (5) veterinarians, (6) respiratory therapists, (7) emergency medicine technicians and paramedics, (8) occupational therapists, (9) physical therapists, and (10) public health practitioners. The point is that professionals from many backgrounds can become agricultural health and safety professionals. They all can play important roles in addressing agricultural health and safety issues in their communities if equipped with some specific agricultural medicine training. The authors' goal for this text is to arm health and safety professionals with knowledge and skills that facilitate better practice of fundamental agricultural medicine, including anticipation, recognition, evaluation, diagnosis, treatment, and prevention of occupational and environmental illnesses.

Mutel and Donham (31) have proposed an expanded role for the rural practitioner incorporating agricultural medicine within their clinical work, community service, health education, and research. Simmons (32) suggests there is a need for a special residency program in rural health and agricultural medicine. Physicians in rural communities often serve as the health leader, and therefore their actions may have a profound effect on their community's health activities. Nurses also have a vital role in delivery of agricultural health services (33–36), for example the AgriSafe network (37) is a nurse-based model for delivery of occupational health services in farming communities. Veterinarians have an excellent opportunity to play a role in the health and safety of their farm clients. They frequently visit their clients' farms, they know their clients' exposures, and they have the medical background to recognize farm exposures and possible health risks. Furthermore, veterinarians are one of the most trusted professionals for the farm population in regard to human health and medical issues as well as animal health (38).

1.3.2 The Full-time Agricultural Health and Safety Specialist

Relatively small cadres of professionals (an estimated 500 world-wide) reside primarily in North America, the EU, Australasia, and South East Asia. These professionals devote the majority of their professional lives to activities dealing with the health and safety of agricultural populations. They are associated with extension services, university or hospital research programs, insurance companies, governmental occupational health regulators, public health agencies, or non-governmental for profit or non-profit occupational health programs for the farming community. These programs provide the research basis, evidence, and training for health professionals to practice in their field. They make up the professional organizations, write and publish scientific manuscripts in the field, and advocate public policy to address farmers' health issues.

1.4 Training of Agricultural Health Practitioners and Agriculture Health and Safety Specialists

1.4.1 Training for Healthcare Practitioners

Very few formal agricultural medicine training programs exist in the world. Most health professionals who practice in rural areas have to learn about these issues through on-the-job experience or informal continuing education. Although several medical schools train rural physicians, few teach agricultural medicine as a component of that training. There are exceptions that include agricultural medicine training for medical students aiming at rural practice. These programs include the University of Alabama (39), the University of Nebraska, and the University of Iowa (40, 41). These programs have initiated the 40-hour Agricultural Medicine Core Course for their Rural Medical Scholars students (39, 41). Furthermore, the University of Iowa's Building Capacity Program in Agricultural Medicine (40, 42, 43) has facilitated new training programs in nine states in the United States, Australia, and Turkey. In Australia, the Agricultural Health and Medicine course commenced in 2010 and is offered through the School of Medicine at Deakin University. It is based on the University of Iowa's course and combines a 1-week intensive in-class course with farm visits and online learning (44).

Several graduate programs and continuing education programs provide training for nurses (30, 45, 46). The University of Iowa provides a certificate program in agricultural occupational health for healthcare practitioners. The non-profit organization AgriSafe Network in the United States also provides continuing education training either by web-based presentations or as a component of other ongoing continuing education programs. Landbruksradgivning HMS (NLR-HMS) in Norway has developed a combined classroom and online interactive educational program in agricultural health and safety for farmers, farm school students, local farm advisers, and researchers and teachers at universities.

1.4.2 Training Full-time Agriculture Health and Safety Specialists

There are few formal academic training programs to prepare full-time agricultural health and safety specialists. Some organizations have workshops; some universities have a course or two in agricultural health and safety, plus research experience that can enhance training in this area. Only a few universities have a formalized didactic training specialty in agricultural medicine or agricultural safety and health that leads to a specific degree or certificate. Table 1.2 provides information about several training programs in agricultural health and safety.

As agricultural health and safety is a multi-professional field, there is a place for entry into the field of formalized agricultural health and safety training for people with backgrounds that may include but are not limited to any of the health sciences, occupational medicine and

Table 1.2 Universities with academic training programs in ASH and organizations with general ASH resources, outreach training and prevention, and professional development

	Academic program			
	Audience	Program name or courses available	Comments	Contact information/URL
		Universities with academic training in agriculture, safety and health		
North America				
University of Saskatchewan, Canada	Graduate students	Public Health and the Agricultural Rural Ecosystem (PHARE)	Collaboration with 10 other universities Course in public health and rural ecosystems; monthly web seminars, annual conference Degrees offered in various departments at collaborating institutions (http://www.cchsa-ccssma.usask.ca/trainingprograms/phare.php)	**Shelly Kirychuck, PhD** Canadian Centre for Health and Safety in Agriculture P.O. Box 23 RUH 103 Clinic Place Saskatoon SK S7N 5ES 306-966-6649 Shelley-kirychuck@usask.ca http://www.cchsa-ccssma.usask.ca/
University of Iowa	Graduate students in public health, health and safety science, education, and agriculture	ASH Training Program	MS, PhD, and Certificate in ASH Four specific courses totaling 12 graduate credits in agricultural health and safety courses This is the only known graduate degree program (listed on the diploma) in ASH	**Diane Rohlman, PhD** Department of Occupational and Environmental Health College of Public Health S161 CPHB 145 N Riverside Dr. 52242 319-335-384-4007 Diane-Rohlman@uiowa.edu http://cph.uiowa.edu/icash/
University of Kentucky	Graduate students in various fields of public health, available for MPH, MS, or PhD students from various departments in public health	Certificate program in ASH for MS or PhD students MPH ASH offered through the NIOSH-funded education center	Training in ASH is primarily researched focused	**D.M. Mannio, MD** Southeast Center for Agricultural Health and Injury Prevention University of Kentucky College of Public Health 111 Washington Avenue Suite 220 Lexington KY 40536. 859-323-6836 Fax: 859-254-3760 Dmannino@uky.edu http://www.mc.uky.edu/scahip/ http://www.mc.uky.edu/erc/trainingPrograms/

(*Continued*)

Table 1.2 (Continued)

North Carolina State University	Undergraduate students with biological and agricultural engineering, technology or related field Undergraduate industrial engineering students	No recognized ASH degree or program *BAE 432*: Agricultural and Environmental Safety and Health, three credits *IE 544*: Occupational Biomechanics is a related, but not exclusively an agriculture course	Undergraduate minor in agricultural and environmental technology, includes some ASH content	**Julia Storm**, **MS** Noth Carolina State University Department of Environmental and Molecular Toxicology Box 7633 Raleigh NC 27695-7633 919-515-7961 julia_storm@ncsu.edu
East Carolina University Agromedicine Center	Continuing education and MPH students	ASH core course offered for graduate credit or continuing education credit for health or safety professionals Online course: Pesticide-related Illnesses and Health Issues	A developing full academic program in ASH	**Robin Tutor-Marcom**, **MPH**, **OTR/L**, **PhD** North Carolina Agromedicine Institute East Carolina University West Research Campus 1157 VOA Site C Road Greenville NC 27834 252.744.1008 tutorr@ecu.edu www.ncagromedicine.org
Pennsylvania State University	Undergraduate students in agricultural and industrial health and safety Seniors/beginning graduate	No recognized ASH degree program *ASM 326*: Hazard Identification and Control in Production Agriculture and Related Business *ASM 426*: Management of Safety and Health Issues in Production Agriculture and Related Business	BA level occupational safety and health degree program Most students who take these two courses are seniors	**Dennis Murphy**, **PhD** 221 Agricultural Engineering Building University Park Pennsylvania16802 (814) 865-7157 djm13@psu.edu

The Ohio State University	Primarily agricultural students (agricultural systems management (ASM) majors) or construction systems management (CSM) majors Other students include ASM minors, landscape construction, agricultural business, animal science, agricultural education, horticulture, turfgrass management, and agronomy	No recognized ASH degree program *ASM 600*: Agricultural Health and Safety, three credits *CSM 600*: Construction Health and Safety, three credits	Mostly undergraduate students Courses do count as graduate credit	**Dee Jepsen**, **PhD** Agricultural Safety and Health Food, Agricultural, and Biosystems Engineering College of Food, Ag, and Environmental Science The Ohio State University 590 Woody Hayes Dr. Columbus OH 43210 614-292-6008 Jepsen.4@osu.edu, orosuagsafety@gmail.com
Purdue University	Undergraduates and graduates in the Colleges of Agriculture and Agricultural and Biosystems Engineering	*ASM 510*: Emergency Management for Agricultural Production Operations *ASM 350*: Agricultural Safety	This program provides research opportunities in farming disabilities, injury surveillance and other fields of agricultural safety research	**William Field**, **PhD** Purdue University Department of Agricultural and Biological Engineering 225 South University Street West Lafayette IN 47907-2093 +1 765 49-41191 field@purdue.edu https://engineering.purdue.edu/ABE/Engagement
University of Illinois	Undergraduate and graduate students	All programs award both undergraduate and graduate credit *TSM 422*: Ag Health and Illness Prevention, three credits *TSM 423*: Ag Safety and Injury Prevention, three credits *TSM 425*: Ag Safety and Health Interventions, three credits *ASH traineeships*: three or four credits *Minor in ASH*: within the College of Agriculture, Consumer and Environmental Sciences	The program's primary aim is to provide students from a variety of backgrounds with a program in ASH (e.g. industrial hygiene, secondary agriculture education, extension, public health, etc.)	**Robert** (**Chip**) **Petrea**, **PhD** Agricultural Engineering Department University of Illinois 1304 W. Pennsylvania Urbana IL 61801 (217) 333-5035 rcp@sugar.age.uiuc.edu

(*Continued*)

Table 1.2 (Continued)

University of Minnesota	Course offered to junior, senior, and graduate students No degree available ASH = three credit hours (online)	No recognized ASH degree	Online courses for nurses on zoonoses and youth safety on farms http://prep.ahc.umn.edu/cpheo/ustar.cfm?schedule_type_id=3&area_interest_id=3&area=Agricultural%20Health%20&%20Safety	
Beyond North America				
Australian National Centre for Farmer Health, in cooperation with Deakin University, Hamilton, Australia	Graduate Certificate of Agricultural Health and Medicine	*HMF701*: Agricultural Health and Medicine *HMF702*: Healthy and Sustainable Agricultural Communities		**Susan Brumby, PhD, RN, RM, Dip Farm, M'Ment** Australian National Centre for Farmer Health PO Box 283 Hamilton Victoria, 3300 (03) 5551 8533 susan.brumby@wdhs.net http://www.farmerhealth.org.au/page/education-centre
Harran University	Medical students and graduate students Health and safety practitioners, healthcare practitioners	Conference Growing interest in ASH, managed out of the Public Health Department in the College of Medicine	The conference is organized around the health and safety needs of agricultural workers	**Zeynep Simsek, MD** College of Medicine Harran University Sanliurfa, Turkey zsimsek@harran.edu.tr
Organizations with general ASH resources, research, outreach training and prevention, and professional development				
North America				
International Society for Agricultural Safety and Health (ISASH)	Extension safety specialists Insurance risk managers Machinery manufacturer product safety specialists Academic health and safety specialists	Annual meeting offers ASH continuing education sessions A three-day agricultural safety and health certificate core course offered annually	Professional organization for ASH specialists Objective is to educate the membership	Chair of the NIFS Professional Improvement Committee http://www.ag.ohio-state.edu/%7Eagsafety/NIFS/officers.htm#Standing

International Commission on Occupational Health (ICOH)	Health and safety professionals generally	Professional education, conferences Advocates for guidelines and regulations	The largest and oldest international occupational health professional organization The Agricultural Health Scientific Working Committee holds conferences	http://www.icoh.org.sg/committees/oh_in_agr.html
Pesticide Action Network	Farm workers	Advocacy, education, research	Network of over 600 participating non-governmental organizations, institutions, and individuals in over 90 countries	http://pan-international.org/
International Social Security Association, Section for Agriculture (ISSA)	Farmers, farm workers, farm managers, health and safety professionals	Advocacy, member education, research	Works within the framework of the existing ISSA international sections for prevention of illnesses and injuries in agriculture and forestry	https://www.issa.int/web/prevention-agriculture/about
Farm Worker Health and Safety Institute	Farm populations	Advocacy, professional training Functions as a training arm for migrant and seasonal farm workers	Formed in 1992 to protect the health and safety of migrant and seasonal farm worker organizations in the United States, Mexico, Central America, and the Caribbean	http://www.cata-farmworkers.org/english%20pages/fhsi.htm
Agricultural health and safety centers: North America				
National Institutes for Occupational Safety and Health supported agricultural health and safety centers in the United States				
NIOSH Centers				
California				http://agcenter.ucdavis.edu/
Colorado				http://csu-cvmbs.colostate.edu/academics/erhs/agricultural-health-and-safety/Pages/default.aspx
Iowa				http://cph.uiowa.edu/icash/
Kentucky				http://www.mc.uky.edu/scahip/
Minnesota				http://umash.umn.edu/
Nebraska				http://www.unmc.edu/publichealth/cscash/
New York				http://www.nycamh.com/
Texas				http://www.swagcenter.org/
Washington				http://depts.washington.edu/pnash/
Wisconsin				https://www3.marshfieldclinic.org/nccrahs/

(*Continued*)

Table 1.2 (Continued)

Other US centers/organizations for agricultural safety and health				
Vermont Farm Health Task Force	Health and safety professionals, farm workers	48-hour core course in agricultural medicine	One of nine building capacity sites facilitated by the University of Iowa	Champlain Valley Area Health Education Center 92 Fairfield Street St. Albans VT 05478 (802) 527-1474 http://www.uvm.edu/extension/agriculture/health-safety/taskforce/
Agriwellness, Inc.	Professional training, behavioral health services	Training for mental health professionals in agricultural issues	Promotes accessible mental health services for the farm population	(712) 236-6100 http://www.agriwellness.org/
Farm Safety 4 Just Kids	Farm children, youths and parents	Promotes a safe farm environment	Prevention of health hazards, injuries, and fatalities among farm youth	(800) 423-5437 http://www.fs4jk.org/
Iowa's Center for Agricultural Safety and Health (I-CASH)	Farmers, farm workers, agricultural medicine students	Professional agricultural medicine training, and training of farmers	Combines College of Public Health, Iowa Department of Public Health, Department of Agriculture, and Agricultural Extension	Brandi Janssen, PhD (319) 335-4438 http://www.public-health.uiowa.edu/ICASH/
National AgrAbility Project	Health and rehabilitation of professionals	Professional training Direct services to disabled farmers	Technical consultation to accommodate disabilities in farmers	http://www.agrabilityproject.org/
National Center for Farmworker Health, Inc.	migrant and seasonal farm worker families	Information services and products	Improving the health status of migrant and seasonal farm worker families, center service sites in the United States and other organizations and individuals serving migrant and seasonal farm worker	http://www.ncfh.org/
National Children's Center for Rural and Agricultural Health and Safety	Children and parents exposed to ASH hazards	Advocacy, training of professionals, youths, and parents	Strives to enhance the health and safety of rural and agricultural youths	http://research.marshfieldclinic.org/children/

National Education Center for Agricultural Safety (**NECAS**)	Health professionals, emergency medical technicians/first responders Producers and agri-businesses	Grain and manure pit safety and rescue training Farm machinery training	Conducts education and outreach addressing ASH	http://www.necasag.org/
National Farm Medicine Center	Health professionals, producers, and farm worker training	Dairy worker health Agricultural medicine training	Conducts research addressing human health and safety associated with rural and agricultural work	https://www3.marshfieldclinic.org/NFMC/
National Rural Health Association	Rural healthcare providers and healthcare facility managers	Annual conference Professional peer review journal, *Journal of the National Rural Health Association*	Advocacy, information forum	http://connect.nrharural.org/home
Agricultural health and safety centers: European Union				
Health & Safety Executive: Agricultural and Food Sector (UK)	Farm population education Professional training	Health, education, and employment, safety, and forestry, strategy and evaluation	Protect people's health and safety by ensuring risk in the changing workplace is properly controlled	http://www.hse.gov.uk/agriculture/
Norwegian Farmers´ Association for Occupational Health and Safety (**Norsk Landbruksradgiving**)	Farm population education Some ASH professional training	On-farm technical services and occupational health services Preventive health services	Norwegian occupational health service for farmers Cooperates with local occupational health services and farm organizations	http://www.lhms.no/
Finnish Agricultural Health and Safety Centers	Farm population education	Preventive health services	Connected to regional health centers Provides comprehensive occupational health services to farm families	http://www.jstor.org/stable/40958851?seq=1#page_scan_tab_contents
Agricultural health and safety centers: Australia				
Australian Centre for Agricultural Health and Safety	Farmers, farm families	Research, farm injury data collection, reports	A centre within the University of Sydney at Moree, New South Wales	http://www.aghealth.org.au/
Farmsafe Australia, **Inc**.	Farm population education, professional training	Lead and coordinate national efforts to enhance the ASH of Australian farmers	Aims to improve health and safety awareness and practices	http://www.farmsafe.org.au/content/about-us

(*Continued*)

Table 1.2 (Continued)

National Center for Farmer Health				http://www.farmerhealth.org.au
National Rural Health Alliance, Inc.	Rural healthcare providers, rural healthcare facility managers, researchers, and non-government agencies	Strengthen collaboration between and among rural and remote communities and service providers	Working to improve the health of people throughout rural and remote Australia	http://ruralhealth.org.au/
Agricultural health and safety centers: South America				
Argentina: Cooperative Federated Farmers Argentinos (AFA SCL)	Farmers, farm families, farm workers	Health and safety programs in machinery, livestock, zoonoses, and child safety	Primarily a production-oriented organization of 36,000 members The health and safety program began in 2013	http://www.securities.com/php/company-profile/AR/Agricultores_Federados_Cooperativa_Ltda_en_1100259.html

ASH, agricultural safety and health.
Note: This is not intended to be a comprehensive list of all organizations or individuals who practice agricultural safety and health.

health, veterinary medicine, public health, agricultural engineering, education, social sciences, or agriculture. The key is to have a combination of agricultural training, or at least a background and cultural familiarity of the people, along with one of the related fields above. Also essential to the training of an agricultural health and safety specialist is core knowledge in occupational exposures, resulting illnesses and injuries, and prevention. Core topics, objectives, and competencies have been developed by a consensus process of 38 agricultural health and safety professionals as the national core course in the field of agricultural health and safety (47). Figure 1.2 provides a diagram of this author's (KJD) concept of a recommended background and training to make up an agricultural health and safety specialist.

1.5 Demographics of the Agricultural Workforce

Worldwide, agriculture employs the largest number of workers compared to all other industries. Over 40% (450 million) of the world's workers are employed in agriculture (48). Over half of these workers are women. In developing countries, 40% of the total population is engaged in agriculture, compared to 20% in transitioning economies, and 3% of the workers in developed industrialized countries (49). However, even in industrialized countries the agricultural sector is a significant portion of the total workforce. The 27 countries of the European Union (EU27) has about 12 million farms (2013) with a mean size of 14.2 Ha, and 95% are family farms (50, 51). Mexico has about 4 million farms (2007), the United States has about 2.2 million farms (2007), and Canada has about 229,000 farms (2006) (52–54). Australia has 135,000 farms (2011) (55), and New Zealand had 78,549 farms in 2012 (56).

In order to comprehend the demographics of the agricultural workforce, it is important to understand the evolving structure and terminology used within the agricultural industry. The agricultural workforce includes principal operators (also called owner-operators), unpaid family members, and wage-earning employees or farm workers (indigenous and foreign-born nationals). Additionally, large and corporate-style farms employ *farm managers*. The vast majority of the agricultural workforce across industrialized countries is involved in family-style operations. These operations include a principal operator, who is also the owner-operator, and unpaid family members (although some larger family farms may have a few part-time or full-time employees). Another growing style of agricultural enterprise is *alternative* or *niche* farming, which is a growing variant of the traditional family farm operation. These operations produce and market products locally (e.g., fresh fruit and vegetables, organic foods, exotic food crops, eggs, milk and meat), markets not met by the traditional large family or corporate family operations (57).

The decline in the number of farms began in the early 1900s as the industrial revolution enabled powered farm machinery to be incorporated into agriculture, reducing the amount of manual labor needed to farm and increasing the amount of land a farmer could manage. Beginning in the 1970s agricultural economic policies in the United States began a shift from a supply management policy (to bolster farm commodity prices) to an emphasis on a market-driven, supply-side economic policy. This meant that the lowest cost producer had the advantage. This resulted in increased global competition and demand for increasing productivity (more products with less labor), narrowing profit margins, and a force to get bigger to be able to stay in business. The 1990s was a period of increased globalization of economies, exacerbating the forces previously mentioned. International trade agreements also further enhanced these forces, which created economic stress on traditional family farm operations, increasing the decline in their numbers that has continued into the current millennium. However, some of the traditional small family farms have grown to become family corporations in order to compete, adopting

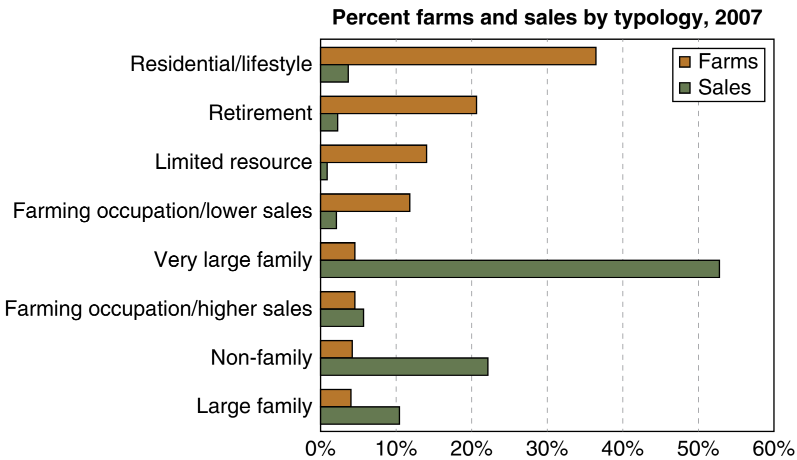


FIGURE 1.3 Demographics (in percentages) of farm types (United States). (Source: USDA 2007 Census of Agriculture accessed at http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Fact_Sheets/Farm_Numbers/farm_numbers.pdf. Last modified 30 January 2012; accessed 10 February 2014.)

the management systems of large corporate-style operations (58). These types of operations separate labor and management, as well as the farm and residence. Some large corporate-style vertically integrated food companies may produce the raw products, process them, as well as retail the finished food products. Some individual private farms are connected to these large farms as contract growers (59, 60). The corporate-style farms employ the majority of hired farm workers. These workers may come from the local area or foreign countries, and they travel for employment purposes (migrant seasonal workers).

Figure 1.3 (61) illustrates the breakdown of these types of operations for the United States. This pattern is similar in all the developed countries discussed in this book. However, large corporate-style agriculture has developed more rapidly in the United States compared to other industrialized countries. These large farms make up less than 5% of the total farms, but they contribute about 50% to the total US commodity production (57). Additional details of the evolving structure of production agriculture are discussed in the Persistent and Emerging Megatrends section of this chapter.

1.6 The Evolution of Production Agricultural, Workforce, and Types of Farms

1.6.1 Family Farms

Family farming in Western industrialized countries developed as Northern Europe evolved from a feudal system to democratic nation states in the late 1700s and early 1800s. Opportunities for land ownership, farming, and religious freedom in the 1800s drew many Northern Europeans to North America, Australia, New Zealand, and South America, where they developed family farming mixed with plantation farming. Some came with facilitation from early colonial regimes and later new indigenous governments with the aim to "settle the land"; some came into direct conflict with the indigenous peoples. Millions of emigrants came to these countries and found the "New World dream." Later in this period in Western Europe, greater democratization, reformed social and land tenure allowed family farming to develop in those countries. History, political and social change, and perhaps genetics resulted in a similar culture among family farmers. Rosmann (62) has written on the factors of common culture of family farms, with an emphasis on the probable heritability of an agrarian type of psychosocial make-up. Family farms remain the dominant type of farm today worldwide, and comprise 95% of the total farm operations in developed countries. However, the trend in industrialized countries is that the number of small family farms has been decreasing by approximately 10% each decade with a corresponding decrease in the number of farm residents and relative increase in farm size.

There is an important culturally relevant point as to the terms that should be used in reference to a member of a family farm or ranch unit. Farm family members consider themselves to be owner-operators, managers, and self-employed businessmen/women (not farm workers). A farm worker, to them, is an employee, a person with less socioeconomic status. Family farm members are proud and may find being referred to as a farm worker an indication that you do not understand their role and work. They may think you are disrespectful or naïve of their culture and the structure of agriculture. This is important for practitioners to understand to enable meaningful communication. Acceptable terms for adult farm family members include farmer, producer (with a prefix of specific commodity such as pork, wheat, etc.), rancher, grower, owner-operator, or principal operator. As gender equality has evolved in the past two decades, women also want to be recognized in a similar fashion. "Farm wife" may not always be an acceptable term, as women also are principal operators or joint principal operators. Children under teenage years may be referred to as "farm children," but adolescents who are actively involved in the operation would be proud to be referred to as a farmer, rancher, etc., just as an adult would.

1.6.2 Principal Operator

Approximately 70% of the principal operators of family farms in developed countries are male. However, the percentage of women principal operators has been growing over the past two decades. In most operations, the principal operator puts in the majority of hours of work on the farm and they typically are older than the general mean of the workforce in their country. For example, the average age in 2007 of male principal operators in the United States was 57 years (similar in other industrialized countries), and the trend is toward an increasing age (51, 53, 63). This compares to a mean of about 45 years in the general workforce (57). A total of 28% of the farmers in the EU are over 65 years old and only 9% are under 35 (51). Similar demographics are seen in Australia, where the median age is 55 years (55).

The vast majority (over 95%) of the US family farm workforce is Caucasian, primarily of Northern European descent. In the United States about 2.4% of principal farm operators are of Hispanic origin, 1.2% are black, and about an additional 0.5% include Native American Indians and Asian or Pacific Islanders. Over 70% of the principal operators live on their farm (57).

1.6.3 Farm Family Members

Women have long been a vital component in the family farming enterprise. Worldwide, the Food and Agriculture Organization has reported that over 60% of economically active women in developing countries work in agriculture (64). Although the percentage is less in industrialized countries, that figure is growing. In industrialized countries, women's roles include part-time laborer, management assistant, bookkeeper, homemaker, full partner in the operation, co-principal operator, and principal operator. Women principal operators have been increasing in both North America and Europe. Although only 5% of principal farm operators in Canada are women, 27.8% of farms are jointly operated by a man and a woman (54). In the 30% of farms in the United States where multiple operators are reported, 30% of the operators are women (64). On those farms where just a principle operator is reported, 14% are women. In Finland, a high percentage of women consider themselves to be full-time farmers. In Poland, over 60% of the farms are operated by women (51) as they tend to stay on the farm if their husband dies or takes a job off the farm.

A high percentage of both men (30–50%) and women (45–60%) on family farms in North America have additional employment off the farm (57). Fifty-six per cent of those working off farms have either management or professional positions, much higher than the average for the workforce as a whole (65, 66). This has been an increasing trend over the past three decades in all industrialized countries, as profit margins have decreased, making it a necessity to have additional off-farm income for the family. In the United States, taking an off-farm job is also motivated by the possibility of obtaining health insurance from the employer, as insurance may otherwise cost a family up to $12,000 per year (64). This additional employment has increased the total workload and stress on modern family farm members, and it increases risk for adverse mental and physical health outcomes (66–68), as is discussed in Chapters 10 and 11.

Children typically begin more independent work on farms at about the age of 10 years. Boys are usually more involved in the heavier farm work than girls, and their farm injury rates bear that out as they are about twice as high compared to those for farm girls (68). In Sweden, girls of 14–16 have the same high injury rate as boys in the same age group. However, the source of injury for girls is primarily from contact with horses.

1.6.4 Farm Workers

Farm workers are employees and receive wages for work. Of the estimated 1.3 billion persons employed in agriculture worldwide, nearly half are farm workers, 38% are migrant/seasonal farm workers, and 50% are women (69). Farm workers make up an important part of the agricultural labor force in all industrialized countries. Of these workers, about 50% come from the local area (indigenous) and about 50% are migrant or seasonal workers, some who are foreign-born but citizens living in the country where they work and some who are citizens from neighboring or distant countries.

1.6.5 Indigenous Farm Workers

Indigenous farm workers may have the same culture and socioeconomic status as the owner/operator. They may be farm youths who work seasonally or part-time on another person's farm. These workers may be exposed to the same hazards as other workers but do not have the same inherent lower socioeconomic status as migrant or seasonal or foreign-born workers. Generally speaking in the United States, indigenous farm workers are similar in number to foreign-born migrant or seasonal workers.

1.6.6 Migrant and Seasonal Farm Workers

The International Labour Organization (69, 70) published a detailed global report on migrant workers. The following review provides additional focus on the situation in the EU and North America.

Developed countries depend highly on migrant and seasonal workers to conduct farm work. Migrant and seasonal workers are defined by their movement from farm to farm as seasons change and labor demands change with production cycles. They often return to their home place in the "off season." The EU employs 4.5 million migrant and seasonal workers; about 500,000 of these are from outside the EU. Farm operators in the United States hire (at some time during a year) about 317,750 (2012 data) foreign-born migrant and seasonal workers (69, 71). In North America, migrant and seasonal workers make up nearly a quarter of the agricultural workforce. Many of these workers have found more permanent employment in larger industrial-style farms and have or are in the process of "settling out" in the community. For Europe and Australasia, the percentage of migrant and seasonal workers in the agricultural workforce is somewhat lower than in the United States (69). In North America, migrant and seasonal workers are largely Hispanics from Mexico. However, Central and South America contribute workers as well as Bosnia, Asia, Africa, and the Caribbean Islands. The US Department of Agriculture (71) indicates that only 22% of US farmers hire one or more employees, and just over 8% of the farms hire more than 10 employees. The latter figure is significant in the United States because federal Department of Labor worker protection laws can be enforced only on those farms with more than 10 employees (or which have a temporary labor camp). Australian orchardists often depend on student labor (backpackers) from the EU or North America who work part-time to help pay for their vacation travel expenses.

1.6.7 Large Farms and Industrial-style Farms

As mentioned above, large farms have been increasing in number relative to small family farms. Some large farms have taken on the general management structure and work organization of private industry or a factory. The emphasis is on high productivity based on specialization, routine and tightly managed work processes, and replacement of much of the labor with mechanization and technology. Labor and management are separated, as are the residence and the farm business. The operation may be a link in a vertically integrated food company or it may be a large family corporation (see below). These farms are often more specialized than small family farms, and are sometimes referred to as "factory farms" by those who prefer traditional family farms. There may be stockholders or other investors involved in these corporations as the farm may rely on outside funds to expand its operations.

1.6.8 Family Corporations

Family corporations are usually enterprises that have grown from family farms over the years to involve multiple generations and extended family members. Their management scheme differs little from private corporate farms.

1.7 Other Occupations Exposed to the Agricultural Environment

Although this book is primarily about the occupational health and safety of those who work producing food, fiber, and bio-fuels, many other workers in agricultural support businesses have similar exposures to those of farmers and ranchers (72). Agricultural support businesses include services, sales, and processing of agricultural commodities. These occupations and potential exposures are included in, but are not limited to, those listed in Table 1.3.

1.8 General Health Status of the Agricultural Population

Several studies from different countries suggest that the rural and agricultural populations have better general health status compared to urban populations, rural non-farm populations, and other occupational groups based on the major causes of death and morbidity. The farm population has lower cancer rates and cardiovascular disease rates, including ischemic heart disease and stroke (73, 74). Details of lower overall cancer risks are seen in Chapter 5. In Sweden, Stiernstrom and colleagues (75) have found lower morbidity in the farm population due to lower rates of cancer, alcohol-related diseases, psychological conditions, cardiovascular conditions, and urinary conditions. The "farmer health effect" for these health benefits ranges from 20% to 50% lower relative risk, depending on the study and the country (76).

The reasons for these health benefits are thought to be lifestyle factors, including (1) decreased smoking, (2) less alcohol consumption, (3) more exercise, and (4) healthier diet (75). It is clear that farmers smoke significantly less (approximately 50% less) compared to the general population (77, 78). They also appear to consume less alcohol (79). Increased exercise might also be a benefit for farmers, primarily from their work, as they expend as much as 30% more calories per day

Table 1.3 Agricultural support and service occupations that may have similar occupational exposures to farmers and ranchers

Agricultural–exposed occupations	Potential exposures
Veterinarians, veterinary assistants	Animal-related injuries Rural roadway crashes Organic dusts (e.g., livestock confinement buildings Zoonotic infections Antibiotics and resistant organisms Veterinary biologicals and therapeutics Insecticides used on animals Excessive noise inside livestock buildings (mainly swine)
Livestock and poultry production/animal health technicians (employees of large integrated livestock production companies who service the companies' animals and contract growers)	Animal-related injuries Rural roadway crashes Organic dusts (e.g., livestock confinement buildings Zoonotic infections Antibiotics and resistant organisms Veterinary biological and therapeutics Insecticides used on animals Excessive noise inside livestock buildings (mainly swine)
Livestock auction sale employees	Animal-related injuries Organic dusts (e.g., inside livestock sales buildings) Antibiotic-resistant organisms Zoonotic infections Excessive noise inside livestock sales buildings (mainly swine)
Meat and poultry processing plant workers • Those handling live animals • Those killing and processing animals	Animal-related injuries Organic dusts Antibiotic-resistant organisms Zoonotic infections Excessive noise (mainly swine)
Livestock transporters	Animal-related injuries Organic dusts Antibiotic-resistant organisms Zoonotic infections Excessive noise (mainly swine)
Crop production service workers • Pesticide formulators, mixer/loaders, applicators • Crop scouts	Pesticides Fertilizers Stinging/biting arthropods
Grain elevators/animal feed mixing, loading, and delivery	Rural roadway crashes Organic dusts (grain dust) Antibiotics and other growth-promoting feed additives

than the general population (75). However, their leisure time is less likely to include vigorous aerobic cardiovascular exercise (75). Farmers' body mass indexes are similar to those of the general rural population (79). Although there are no large-scale definitive dietary studies relative to health outcomes in the farming population, there is slight evidence that farmers' diets may be a health benefit (73).

Contrary to the positive health benefits associated with farming, studies in Australia have revealed a different picture, as farmers there appear to have greater obesity (with larger girths) and higher risk for diabetes and metabolic syndrome, binge drinking (80–82), and suicide (83).

1.9 Occupational Health Status of the Agricultural Workforce

Although the general health status of farmers (owner/operators) appears to be better than comparison populations (Table 1.4), their occupational health appears to be one of the worst

Table 1.4 Overall health status (morbidity and mortality) of the farm population relative to comparison populations

Comparison population	Location	Findings	Reference
Rural compared to urban populations	New York Kentucky United States overall Poland Costa Rica United States	Lower overall mortality Lower cancer mortality Lower cardiac mortality and risk factors	70, 71 86, 87 88
Agriculture compared to the general population	Scandinavia New York Iowa and North Carolina Australia	Lower mortality by 10% Lower mortality (40%) Lower mortality (50%) Higher risk for cardiovascular disease, diabetes, and binge drinking Male farmers higher for all causes of death (33%), especially circulatory and neoplasms	89 85 90 77 78, 79
Agriculture compared to the rural population	New York Sweden Iowa	Lower overall mortality Lower morbidity Lower mortality overall and cardiovascular (20%)	85 72 73, 74
Agriculture compared to other occupations	Italy Sweden Sweden	Lower mortality: cardiovascular (50%), cancer (28%), overall (46%) Lower mortality Lower morbidity (15–70%)	91 92 75

among all occupations (84–86). Since the writings of Olaus Magnus (87) of Sweden in the mid-1500s and Ramazinni in the 1700s (4) on occupational diseases, there have been numerous reports, review articles, books, and book chapters documenting the low occupational health status of the agricultural workforce (3, 11, 15, 68, 88, 89). Agriculture in every industrialized country is one of the most hazardous occupations, based on occupational fatality rates, non-fatal occupational injury rates, and occupational illness rates.

1.10 Occupational Injury and Illness Statistics

There were 479 occupational fatalities in 2013 in the US agricultural industry, resulting in a fatality rate of 22.2/100,000 (90). This compares to 3.2/100,000 (2013) for all US occupations, making the US farm fatality rate over seven times higher. Fatality rates for youths under 20 years of age are about 8/100,000, over twice the fatality rate for all occupations. Fatal injuries in most other developed countries are lower than the United States, for example, fatality rates among farmers in Canada are 11.6/100,000 (92) and in Finland are 6.5/100,000 (91).

Accurate reporting of non-fatal injuries and illness is more challenging than for fatal injuries. There are large variations in reporting regarding rates of non-fatal injuries. For the United States, rates vary from about 5/1000 to 170/1000 (90, 93–95). Studies that had an active injury surveillance process recorded 420/1000 (91, 94). Most studies fall somewhere in the middle of this range, around 100/1000. In other words, one out of 10 farmers suffers a disabling injury every year.

Comparing non-fatal injury rates in the United States to other countries, the United States rate is comparatively high. For example, Canadian farmers report 03.9/1000, compared to 3.2/1000 for all occupations (53, 92).

Occupational illness rates are even more difficult to quantify than non-fatal injuries because such illness in self-employed people would rarely be identified as occupation related (there is no mechanism to create a need to report). Therefore, objective data is mainly based only on employed workers, where the employers are required to report. Other data are based on self-reported surveys, which have inherent sensitivity and specificity problems. Given these caveats, the US Bureau of Labor Statistics (90) indicates an illness rate of 3.1/1000. The top three conditions causing these illnesses were skin conditions (56%), cumulative trauma (14%), and respiratory diseases (13%). Data from the Finnish insurance company Mela indicate that occupational illnesses in agriculture occur at a rate of 6.4/1000. Respiratory illnesses make up nearly 40% of these conditions, followed by skin (21%) and joint illnesses (31%) (96, 97).

Not only is there an important loss of human resources from agricultural injuries and illnesses, there is also an enormous economic consequence. Leigh (98) found that each agricultural fatality creates an expense for the family on average of $29,904 direct and $555,770 indirect costs (in 2013). When multiplied by all the fatalities that occur annually in the United States, this adds up to $306 million. Adding the estimated costs for disabling injuries brings the annual total to nearly $4 billion.

1.11 Persistent and Emerging Megatrends in Agriculture: Health—Safety Implications

Domestic and international economic, technological, and policy changes have caused major changes in the agricultural industry over the years. Some of the economic policies were reviewed earlier in this chapter. These changes have not only had an effect on the structure of agriculture, but also have affected the socioeconomic status, health, and safety of the agricultural workforce (58, 60, 99). The authors of this chapter have chosen 11 persistent or emerging megatrends, which are discussed below. Along with describing the megatrends, the authors will discuss how these megatrends have or may affect the health, safety, and general wellbeing of producers and the agricultural workforce.

Persisting Demographic Trends in Farm Type, Size, and Human Capital

Decreasing Number of Traditional Family Farms

Small traditional family farms are sometimes referred to as "the farms in the middle," as large industrial-style farms increase at one end of the scale and small alternative niche farms increase at the other end. Factors that influence this trend include increased production costs (replacing labor with powered machines and a vast array of technologies and production inputs) and increased costs for compliance with stricter environmental and worker health standards. With the increase in employed farm workers that accompanies large farms, the general make-up of the rural population remaining in agriculture is moving from a relatively high socioeconomic self-employed, owner-manager occupation to a wage-earning farm worker base and a shift to an overall lower socioeconomic status of the farm workforce (100).

These factors combined have resulted in not only economic stress, but also social stressors within communities who struggle to meet the social needs of the new workforce, with dwindling economic resources and infrastructure. Furthermore, these issues have increased the risk for mental as well as physical health issues for the remaining farmers. Additionally, as there is less economic incentive for new farmers to come into the industry, the family farm sector continues to consist of older producers. Geriatric health issues have become complexed with occupational health issues in the owner/operator agricultural workforce.

As these challenges to traditional family farms persist, it is very important to note that this group still comprises the majority of people involved in production agriculture, over 80% in most industrialized countries.

Increase in Large Industrial-style Farms

With increasing farm size and transition to more industrial-style operations there also comes a separation of management and labor, and increased numbers of farm employees. A second trend accompanying agricultural industrialization has been increasing economic and political control of the agricultural industry based on a greater economic base through consolidation and vertical integration. Domestic and international economic and trade policies have facilitated the rise of international vertically integrated food corporations (101, 102). These food companies have political power and can affect the policies and international trade agreements that facilitate their style of operations (103, 104). This is in sharp contrast to smaller family operations that have little control over their situations. Such lack of self-determination exacerbates their personal stress.

Farm Government Policy Issues

Government Subsidization of Agriculture

Subsidization of agriculture in industrialized countries has affected both domestic and foreign markets. Many countries are conflicted about the direction that policies are pushing agriculture (103, 105). For historical, social, political, and domestic food security purposes, many nations would like to maintain a family farm structure (106, 107). However, this requires a large farm subsidy, which is a significant economic cost (108, 109). These subsidies create difficulties for developing countries, as they often are challenged to compete on the world markets with subsidized products from the industrialized countries, thus challenging their domestic food security efforts. The international lenders (e.g., the World Bank) to developing countries often require that their loans support potentially exportable commodities, which have the potential to create cash flow, and help service their loans. However, these exportable commodities may differ from those products that are important to their domestic food supply, thereby adding additional barriers to the development of the domestic food security system.

In some countries (e.g., the United States), conservative and liberal political voices disagree on domestic farm policy. The liberal side argues for food polices to feed the less privileged. The conservative side favors policies supporting strong production, larger commodity producers, and enhanced export markets (102). This division has created uncertainty in the markets and additional stress on farmers. In recent years, US farm policy has included subsidized crop insurance, replacing gradually diminishing direct support payments. The government pays a major portion of the premiums for crop insurance for those who sign up for it. This policy significantly reduces the risk of economic loss with crop failure (and therefore reduces excess psychological stress) from adverse weather or other acts of God. This policy will become more important as climate change promises the probability of increased adverse and severe weather conditions. The negative aspect of this policy is that it encourages farmers to produce crops on marginal lands, which may lead to increased environmental stress.

International Trade Agreements

International trade agreements have been in existence since the early 1900s. These agreements have been growing and involving agriculture since 1948, beginning with the General Agreement on Tariffs and Trade (GATT). This agreement gave rise to World Trade Organization (WTO) (110) in 1994. The WTO is composed of 154 member nations who negotiate general rules to keep trade flowing between nations while guarding against undesirable economic, social, and environmental side effects. Individual nations promulgate numerous separate trade agreements with neighboring countries or individual distant partners to form economic blocks. For example, the European Community (EU) has agreements in place or pending with well over 200 nations (111). As of 2015, the United States has current agreements with 17 countries, with 12 additional agreements in process (112). All these separate agreements are to be based on the general principles of the WTO, which helps promote oversight and discipline in the agreements. Although these agreements have generally facilitated economic advancement of the agricultural industry, critics claim they are too highly influenced by and give favorable treatment to large multinational corporations at the expense of family farm producers and farm workers (103). In addition, these agreements distort markets for certain commodities and drive up food prices in other instances. However, international trade agreements are a growing trend that in all likelihood will continue well into the future. If so designed, these agreements could help promote the health and safety of farmers and farm workers. For example, the agreements could include standards for the health and safety of farmers and farm workers, and environmental protection standards among the member states. However, this has not been a component of these agreements in the past. Perhaps with influence from relevant nations' health and safety governmental organizations and NGOs, these agreements could be a component of future agreements. The trans-Pacific partnership being negotiated (as of December 2015) between the United States and 12 Asian nations includes statements on enhanced labor and environmental protection. This agreement might be a model for future agreements that could counteract some of the negative aspects of trade agreements on the human capital in production agriculture.

Occupational Health and Safety Standards

Occupational health and safety standards are varied among nation states. Developed countries generally pay more attention to occupational health and safety than less developed countries. Industrialized countries generally have some standards, but they often do not pertain to small family farms. However, as farms become larger and have more employees, and social and democratic systems become stronger, occupational health and safety standards and enforcement will likely become more prominent. (This issue is discussed in more detail in Chapter 15.)

The Rising Voice of the Consumer, the General Public, and Powerful Food Retailers

Since the 1990s there has been an increasingly powerful consumer voice calling for "unadulterated" food and food produced in a sustainable and humane way (e.g., public demand for products free of antibiotics, infectious organisms, antibiotic-resistant organisms, pesticides, growth promotants, genetically modified organisms (GMOs), and for food animals to be raised under humane conditions; 113). Demand for more "naturally produced products" has created new niche markets for a variety of producers (114). Organic products are increasingly in demand by consumers (115). Food animals grown under more "natural conditions" are increasingly in demand by consumers. This helps provide more market opportunities for many new and transitioned traditional small family farms. These types of operations in this growing sector of agriculture are called "alternative farms." Unfortunately, from the producer health aspect, the equipment and methods for these alternative farms are similar to those used in farming several generations ago. The equipment may be old and lack modern safety features, for example old tractors without roll over protection (ROPS) and with unguarded drive lines (power take-off shafts). Also, the nature of the work is largely heavy manual labor, often conducted with poor ergonomic standards and leading to a high risk for musculoskeletal conditions such as low back pain. Furthermore, some of these operations may be worked by persons new to agriculture. They may have come from the city to seek a new lifestyle and may not be familiar with agricultural machines and the necessary safety devices and precautions. This group of new alternative farmers is potentially at higher risk for occupational injuries compared to other workers. However, there is little surveillance or research to provide guidance as to their risks and prevention. These generalizations are based on this author's (KJD) experience and observations. As an evidence basis is currently lacking for these generalizations, this is an important area for new research, surveillance, and intervention.

Many food retailers and restaurants have responded to consumers concerns and are finding a market advantage by demanding from their suppliers products grown free of "contaminants" (hormones, antibiotics, pesticides, GMOs, i.e. organic). An example in Australia is the Coles supermarket chain, which has moved to only stocking hormone-free meats. Some restaurants are seeking sources of meat from animal raised humanely, for example McDonald's has dropped a supplier because of allegations of animal cruelty (116). Some farmers are also responding to this demand, for example Niman Ranch markets pork and beef "certified" to be grown organically and with high humane standards (117). A number of terms are being used by marketers to attract those interested in what they perceive as more healthy foods. However, few of these terms have an official definition or value of assurance. The states/countries governmental departments of agriculture are a good source to determine the meaning and value of various labels and claims.

In addition to individual consumer concerns, there is increasing public scrutiny of agricultural operations regarding environmental contamination, consumer and public health, and occupational health. The general public in most industrialized countries is no longer willing to give agriculture special "exempt" status for polluting the environment. Many people feel that agriculture should be held to the same standards as any other industry. The popular press features many authors who advocate for sustainable food systems, for example Michael Pollan's *Omnivores Dilemma* (118) and McFague's *Blessed are the Consumers* (119). Furthermore, the burgeoning field of information and communications technology, the internet, and social media have enabled the breadth and strength of the public's concern and voice to be heard. Although much of the public's concern is driven by emotion rather than science, they maintain a strong effect on how and what the farmer produces and how it is done. Consequently, new regulations have/are being developed, such as required minimal requirements for the size and dimensions of animal pens, stocking densities, humane kill processes at slaughter, and labeling requirements for the source and content of foods. These requirements are creating the need for farms to expend resources to meet these regulations. Although the regulations will focus more on large operations, they may have a greater economic impact on small farms. They will increases economic stress and may force some out of farming. A new way forward will be to see how these interests can work together with farmers. An important positive result of this trend could be a new direction for increased sustainability of agricultural production.

The Rise of Niche Markets and Local Food Production

The consumer demand for alternative agricultural products and more ecologically sustainable production has linked the alternative agricultural producer to new-found niche markets for organic crops, exotic crops, and locally produced food. One example of these local markets are community groups who share in sponsoring a local farm and consuming its produce (community sponsored agriculture). The 2011 US Census of Agriculture revealed 45,640 new farms were initiated since 2002; most of these were in the category of alternative agriculture (63). A higher percentage of these farms are owned and operated by women compared to traditional farms. This movement is related to the growing public concern and interest in more sustainable agriculture and "local food" with fewer "food miles." Additional to the demand for organic products, there are also new markets for products such as ginseng, meat from ostriches, emus, deer, and buffalo, and many other exotic products. Furthermore, there is a new demand for a closer connection between the grower and the consumer (120, 121). Farmers' markets and local farms are linking with local urban dwellers, increasing opportunities for small farms to provide fresh farm products to their local community. Energy production is also a developing sector. Wood chips and oats are being used for fuel in Europe. Farmers in many areas of North America, Australasia, and Europe are growing grains for biofuels, producing methane from animal wastes for fuel, and installing wind generators and solar panels to power their own farms and to sell power commercially.

Food costs for the consumer from alternative farms are usually higher than traditional sources. However, as long as the consumer economy can afford this extra cost and the social values of the consumer hold, this type of farming will continue. This style of production has even spread to abandoned available urban spaces, with urban agriculture emerging in some of our large cities (122).

Efforts toward investigating the issues and developing appropriate interventions to promote the health and safety of these new-style producers is an important evolving issue in the field of agricultural health and safety.

Consumer Dietary Habits

International dietary habits include a continually rising consumption of fast food. Consequently, the fast-food industry continues to expand internationally. This industry demands very strict uniform standards of product, delivery times, and amounts. These attributes are most effectively supplied by industrial-style agriculture. Individual family farms find it difficult to reliably supply under these strict specifications. This trend therefore favors the large compared to the small family or alternative farms.

The rapidly developing economies (e.g., China, India) have created more wealth in these countries, and thus an increased demand for animal protein compared to plant and fish protein (105). While these countries may export grains (e.g., rice), their improved economies have increased their appetite for and ability to purchase red meat and poultry (123, 124). This in turn has increased the markets for livestock producers in industrialized countries, where livestock production has expanded to fill new market demands (125). As this trend continues, there will be a greater demand on grain production to feed the animals, as it takes approximately 2.5 times the amount of grain to produce the same nutritional output compared to eating a plant-based diet (126).

Increased health consciousness and diet fads of industrialized countries (e.g., low-fat diets in the 1970s, and low-carbohydrate, high-protein, and gluten-free diets in the 2000s) have also created new product demands. The agricultural industry has responded by dramatically increasing the amount of chicken produced and selecting for genetics of leaner pork and beef. These trends favor larger and more industrialized farms, which can respond more rapidly to consumer product demands.

The Rise of New Players in the World Market of Agricultural Commodity Producers

Brazil, Argentina, India, and China have emerged as major agricultural exporting nations (127). As these countries are lower-cost producers, and the industrialized countries have depended heavily on export markets, this emerging and expanding competition continually demands higher productivity of the traditional agricultural exporting countries. Globally, this results in lower prices for commodities and decreasing profit margins, which adversely affects small farms in more developed countries.

The Advancing Technological Tools for Production Agriculture

Advance technology tools (precision technologies) are evolving largely as a means to increase productivity by decreasing labor and increasing crop input (128). Genetically modified crops, new plant protection products, global positioning technology creating near robotic planting and harvesting machines, robotic dairies, drone airplanes for surveillance of crops and livestock, and biofuel production are all current realities. Mechanization of agriculture has been ongoing since the mid-1800s, but this new phase of machines replacing human labor is occurring at a much higher rate in industrialized countries. This may diminish the opportunities for work in agriculture for many populations, particularly the lower socioeconomic contingent of the labor force. However, these interventions may reduce health and safety issues by distancing the worker from hazardous work places or exposures. There is currently no research to identify the benefits, or unknown unintended consequences, relative to the health of farm operators or workers of these new technologies. There are certain potential environmental benefits of precision agriculture, such as more efficient and safe use of fertilizers and crop protection products.

Climate Change

There is little doubt among the scientific community that global climate change is real. The following facts relative to agriculture are within the realm of high probability (129):

1. The oceans are warming and the polar ice fields are melting.
2. There is an increasing frequency of severe weather incidents, including heavy rain, flooding, droughts, tornados, typhoons, temperature elevations and cyclones.

The effects on production agriculture will vary geographically and temporally. There may be a benefit in some areas as warm-weather cereals such as corn (maize) will be able to be grown further north. However, in other areas, current crops will not be able to be grown, and new varieties or species will have to be investigated as possible substitutes for previous crops. Models and predictions for this change are not precise, leading to uncertain growing seasons. These circumstances lead to additional economic and thus psychological stress through possible and actual decreased yields. For example, the psychosocial health of the farm population has been challenged in Australia as a result of the persistent 10-year drought (now referred to as the millennium drought). Over 60% of the nation was declared in exceptional drought in 2007. Certain sectors of the farm population have suffered extreme stress, including increased suicides (80, 81). However, in general the adverse effects of climate change will be unevenly distributed toward developing countries, as they have fewer resources to counteract the issues, such as advanced harvest equipment, crop storage, and technology such as genetically adapted seeds and crops. The greater effects of climate change challenge global food security in the short and long term as the world grapples with adequate food production for the expanding world population.

Challenges of Producing Food for Nine Billion People by 2050

The scientific and public health communities share concern about population growth and the ability of our agricultural enterprises to be able to provide sufficient nutrition in the future. With the 2015 world of six billion projected to grow to nine billion by 2050 (123) the agricultural industry is at the forefront of this challenge to produce sufficient food, fiber, and fuel to sustain the projected 50% increase in population. According to the WHO World Food Program (130) nearly 18% of the people currently on the planet are malnourished. The current industrial agriculturalists are building on native Iowan's Norman Borlaug's "Green Revolution" of the late 1960s with new biological and mechanical technologies. This assumes, however, that our world's agricultural industries are sustainable. This assumption is not a given, as there are many challenges to creating a sustainable world food system. Grain production has declined in many developing countries (and less developed countries; LDCs), with slowing growth in production in the United States, Australia, and Canada, and uncertain performance in the former Soviet bloc countries. However, production is increasing in Brazil, Argentina, and China (127). Tillman (126) suggests that the global agricultural industry has the potential capacity to produce enough for eight to ten billion people. However, there is little consensus on how to sustainably produce food at these high demands. Challenges include food safety, degradation of the environment and depletion of biodiversity (131), climate change, depleting water resources, and lack of transportation and storage infrastructure. However, an extremely significant factor seldom mentioned in sustainability and growth in agricultural productivity is sustaining the health and safety of the people who do the work—the human capital in the agricultural industry.

Emerging and Re-emerging Zoonotic and Livestock Infectious Diseases, and Food Safety

Infectious diseases re-emerged in the early 1980s as an important public health issue in developed countries, coincident with the emergence of the human immunodeficiency virus (HIV) (132). Like HIV, over 60% of the new and emerging infections are of zoonotic origin (diseases originating in animals and/or in common with humans) (132). The emergence of these infections is in some cases associated with ecologic changes and human activity (133), including agriculture. Some of these agents affect only livestock but can cause extreme economic and psychological stress to the farmer. The following list includes some of the emerging and persistent infections of interest for agricultural populations.

- *NIPAH and Hendra virus infections* in animals and people have created animal and human illnesses in Malaysia, Australia, and other South-East Asian countries.
- *Bovine spongiform encephalopathy* or mad cow disease in the UK, other EU countries, Japan, and North America among other countries has created an economic burden as well as a public health concern (currently under control by virtue of a stringent surveillance and eradication program).
- *Foot and mouth disease* is endemic in many developing countries and emerges sporadically in developed countries. Although not infectious for humans, it causes severe economic and emotional burden to cattle, sheep, and swine producers.
- *Food-borne infections* of animal origin include *Escherichia coli* (strain 0H157-H7), *Salmonella*, *Listeria*, and *Campylobacter*. These agents are often carried from the farm to the fork, creating public health, economic, and producer public-image concerns for both livestock and crop producers.
- *Avian and swine influenza* remain on the global public health radar as potential agricultural sources of an infectious epidemic.

These infections are examples of persistent and emerging zoonotic agents that have significant physical and psychological occupational health concerns for farmers, their families, and the general public. They also have significant implications for markets. For example, Canada's and England's beef export markets (among other countries) were closed because of mad cow disease (bovine spongiform encephalopathy) for several years in the early 2000s, creating a critical economic burden on the beef producers as they had no markets for their cattle. The 2001 response to the outbreak of foot and mouth disease in the UK resulted in the destruction of thousands of cattle and sheep herds. The associated economic and mental stress among the farming population was severe, leading to increases in suicide (134).

Human Capital (Farmer and Farm Worker Health and Safety): The Missing Component of Sustainability Discussions

The discourse on the health of agricultural people has long been lacking among production agricultural scientists and policy makers. This issue was first written about in publications in the 1990s (58). However, the term "sustainability" is now reaching common discourse and there is new promise that the issue of farmer health can be included in the context of sustainable practices. Andrew Savitz (135) condenses sustainability of industries to sustaining three essential components: (1) profit, (2) planet, and (3) people. Profit, of course, is self-explanatory. If a profit is not made, a business will close very quickly. Savtiz posits that a business must not make a profit at the expense of the environment or public health. The third of Savitz's three Ps is people, referring to the health and maintenance of those who do the work. Particularly within the agricultural industry, agricultural health and safety (the people, the human capital) is highly underrepresented in investments and policy around discussions of sustainability of the industry. Susan Brumby, the director of the Australian National Center for Farmer Health, recognizes this issue. The flagship program of that center is Sustainable Farm Families™ (136–138). This program recognizes the fact that if farmers do not have their health, they do not have a sustainable operation. However, the sustainable health of farmer and worker is slow work, as globally agriculture remains one of the world's most hazardous industries. Although some strides have been made in this arena in the past decades, agriculture health and safety still lags far behind that of other industries. The way forward is to raise awareness of this situation and prepare a broad, multidisciplinary group of professionals to challenge the issue in their daily work. That is the essence of the remainder of this book.

The following section is a brief overview of the major health and safety issues in production agriculture. This section leads to a detailed treatment of each of these health and safety areas in the following chapters.

1.12 A Preview of Specific Occupational Health and Safety Risks and Conditions

The section provides an overview of the specific conditions that will be covered in the following chapters of this book. The objectives are to assist the reader to understand the exposures and risks, and, most importantly, prevent these conditions. The topics were chosen by consensus of our 38 member advisory group (47) to this text, along with an extensive literature review (over 1300 references searched). Additional input comes from the over 80 years of combined direct practical farm experience of the two principal authors of this book (KJD and AT), as well as research, teaching, clinical, and preventive aspects in the field of agricultural medicine. The following paragraphs provide a brief overview of each of the conditions and injuries and the referent chapter where they are discussed in depth. Other references for this overview are found in the several reviews and books (12, 15, 68, 139, 140).

1.12.1 Special Risk Populations in Agriculture (Chapter 2)

Children, women, the elderly, migrant and seasonal farm workers, and Anabaptist religious groups are populations at increased risk for illness or injury from exposure to the farm environment. Children are at risk because they live, play, and may work in the same hazardous work environment as their parents (141). Children may not have the physical or mental developmental capacity to play or work safely in this environment without close informed parental supervision.

Pregnant women exposed to certain zoonotic infectious agents or veterinary pharmaceuticals (oxytocin or prostaglandins), carbon monoxide, and certain insecticides or herbicides may risk damage to an unborn fetus.

Elderly farmers are at increased risk because as they age their physical and cognitive faculties might be diminished, increasing their risk of injury in a hazardous working environment. Also, they may have co-morbidities such as poor eyesight, hearing loss, arthritis, and diabetes that may increase their risk of injury. Furthermore, the elderly often use the older equipment they are used to, which is often less safe than newer equipment.

Migrant and seasonal workers are at risk because they are generally of a poorer economic and social circumstance (one of the most common links to general health status is socioeconomic status), have language barriers, lack education, and have physically hard jobs in hot environments.

Anabaptist groups are at increased risk because the equipment they use is often old or homemade and without safety features. Furthermore, their cultural and spiritual beliefs include minimal use of mainstream health care, which decreases their probability of having up-to-date immunizations, prenatal care, and early diagnosis of chronic disease.

1.12.2 Agricultural Respiratory Conditions (Chapter 3)

Based on research and surveillance data, and the authors' experience, respiratory illnesses are the most important occupational illness of agricultural workers. Available data reveal that 10–30% of agricultural workers experience one or more occupational respiratory conditions (142). The most frequent causative agent of respiratory illness is organic (agricultural) dust from livestock production and handling grain, silage, or hay. There is a syndrome of respiratory conditions caused by agricultural dust that includes bronchitis, asthma-like condition, and irritation of the upper airways mucosa and eyes (mucous membrane irritation, MMI), organic dust toxic syndrome (ODTS), and farmer's lung (hypersensitivity pneumonitis). The former two conditions are usually chronic, and the latter two are usually acute influenza-like conditions lasting one to several days. However these conditions may also have chronic components.

Less common hazards that add to the library of risks for respiratory conditions include (1) silo gas from non-airtight silos, (2) hydrogen sulfide and ammonia from decomposing livestock manure, (3) fumigant pesticides or biocides, (4) zoonotic infectious agents, and (5) the herbicide paraquat.

1.12.3 Agricultural Skin Diseases (Chapter 4)

Several reports indicate that skin conditions are the most frequently reported type of agricultural illness (143, 144). The most common skin condition is contact dermatitis, which may occur as an irritant or allergic contact dermatitis. The latter can occur within minutes or over the course of days or months. Contact dermatitis may also occur concurrently with sun exposure causing a chemical change to the offending substance on the skin, which then becomes an irritant or allergen (e.g., furocumarins in the sap of plants of the Umbelliferae family). Some irritant or allergenic substances may be contracted from airborne exposures (airborne contact dermatitis), such as cape weed in South Australia and ragweed in North America. Several plants cause delayed allergic contact dermatitis, including those that contain the allergen erushiol (poison ivy, poison oak, poison sumac).

Sun and heat exposure are the second most common causes of skin conditions. Sunburn and miliarial rubra (prickly heat) are the two most common acute skin conditions caused by sun and heat. Chronic sun exposure causes wrinkling and thickening of the skin, precancerous lesions called actinic keratoses, and the skin cancers squamous cell carcinoma and basal cell carcinoma. Melanoma is thought to be caused by multiple sunburns at an earlier age in life, but may also be related to total impact of sunshine.

Ringworm (dermatophytosis) contracted from cattle is the most common zoonotic fungal infectious skin problem among farmers handling animals, especially dairy farmers. There are numerous arachnids and insects (including mites, ticks, spiders, and stinging or biting insects, i.e. wasps, ants, and mosquitoes) that may cause minor to very severe irritation of the skin.

1.12.4 Cancer in Agricultural Populations (Chapter 5)

The farming population (primarily because they smoke less) benefits from lowered overall cancer because they have less lung cancer (one of the most common cancer fatalities) and other smoking-related cancers (e.g., bladder, esophageal, kidney). Overall colon and rectal cancer seems to be lower (except in Australia), and farm women have less overall breast cancer. Besides not smoking, there may be other cancer protective factors in farming, but they have not been clearly identified. However, there are several cancers for which the farming population may be at increased risk, including lymphoma, leukemia, multiple myeloma, prostate, skin, and brain. Of various speculative risk factors for these cancers, only excessive sun (skin cancers), methyl bromide, fonophos and family history (prostate cancer), and acetic acid herbicides (non-Hodgkin's lymphoma and soft-tissue sarcoma) exposures are relatively proven risk hazards.

1.12.5 Toxicology of Pesticides (Chapter 6)

Although the issue of pesticide exposure is often a dominant concern among the farming population, acute poisonings and fatalities are far less common than acute traumatic injuries or respiratory illnesses. Whilst some of the pesticides (especially the cholinesterase-inhibiting chemicals) used are very toxic, they are largely being replaced by less toxic insecticides (e.g., pyrethroids, and neonicotinoids). The most common health hazard of the latter two insecticides classes and herbicides (chemicals that kill weeds) is contact dermatitis. Herbicides are used in far larger quantities than insecticides.

1.12.6 General Environmental Health Hazards in Agriculture (Chapter 7)

Adverse water quality from nitrate contamination is the most important general environmental health hazard for agricultural workers and those living in a rural environment. Consumed nitrates are converted to nitrites in the gastrointestinal tract, which can lead to methemoglobinemia, which limits the red blood cells' ability to carry oxygen. The condition is most critical in infants (causing the condition "blue baby"). Nitrates may also be a carcinogenic risk, as nitrates in the presence of amino acids or the herbicide atrazine may form nitrosamines, which are known carcinogens.

There are other water, air, and solid waste problems in agriculture, but these are more directly related to environmental quality degradation and ecologic change, rather than direct individual worker health hazards.

1.12.7 Musculoskeletal Diseases in Agriculture (Chapter 8)

Low back pain and degenerative osteoarthritis of the hip and knee are common among the agricultural workforce problems along with a number of other musculoskeletal disorders. Related to physical work these conditions are worsened by poor ergonomic working conditions, long working days, and heavy workloads. Furthermore, carpal tunnel syndrome is common among those working in meat and poultry processing. Musculoskeletal diseases (MSD) is one of the most common reasons for farmers to contact a healthcare professional. Managing these conditions includes modifying work practices with sound ergonomic practices.

1.12.8 Physical Factors Affecting Health (Chapter 9)

The work environment in production agriculture can be a hot or cold, vibrating and noisy place. All of these physical elements bring the risk of injury to the farm worker.

Heat Exposure Risks

Agricultural work is often undertaken in hot environments and/or in direct sunlight. As agricultural work requires a great deal of energy consumption, the risk for heat-induced illnesses is common. Heat exhaustion may be a minor problem prevented by protection from the sun, periodic rest from a hot environment, and increasing fluid intake. Untreated heat exhaustion may lead to the more serious condition of heatstroke, which physiologically includes incapacitation of the body temperature regulatory mechanism. The body temperature may raise high enough to cause brain damage, and combined with dehydration and electrolyte imbalance may result in death if not treated as an emergency condition.

Cold Exposure Risks

Work outdoors in extremely cold environments is often a requirement in the agricultural industry. Frostbite, which is the freezing of skin and subcutaneous tissues, is a risk. Furthermore, cold environments exacerbate a condition called "white finger" or Raynaud's phenomenon, which may be a result of chronic high-frequency vibration damage (from operating powered hand tools or chainsaws) to the nerves and blood vessels in the hand (today often referred to as hand-arm vibration syndrome, HAVS). When the hands become cold, the vessels of the affected hands "shut down" circulation, leading to painful symptoms and loss of refined hand movements.

Vibration-related Injuries

Additional to Raynaud's injury to the hands, vibration-associated symptoms may also be seen in the arm and shoulder. Low-frequency vibration can lead to subtle internal whole-body vibration symptoms that might include back pain, nausea, and fatigue.

Noise-induced Hearing Loss

The agricultural work environment is noisy, leading to the very common problem among farmers of noise-induced hearing loss. Excessive noise and exposure over time causes direct damage to the hair cells of the middle ear, which transmit sound energy to the brain. Once damaged, the cells will not repair themselves and the loss is permanent. Loss of hearing increases the risk of injury to farmers, and communications problems in the home and social settings, leading to social isolation.

1.12.9 Mental, Social, and Behavioral Health in Agriculture (Chapter 10)

Farming is an occupation that is increasingly filled with stress, mainly due to the unpredictability of the climate and diminishing profit margins. The culture of the agriculturalist is to persevere, rather than to seek help. Mental health issues carry more of a stigma in farming communities than in urban communities. The social structure of the rural community is changing, as the population becomes sparser and the social structures and customs that enhance "neighboring" change. As old social support structures are declining (e.g. church, neighbors) and formal mental health services are rare, many farmers and family members suffer as chronic stress builds to depression. The most severe outcome of this situation is suicide, as chronicled in the true account of a stressed farmer in a Midwestern community in the United States (145). Gunderson documented higher rates of suicide compared to the general population in the north central states of the United States (146).

1.12.10 Acute Agricultural Injuries (Chapter 11)

Acute physical injuries are the primary occupational health concern in agriculture, causing more fatalities and disabilities than any other category. Tractor-related events account for the majority of fatalities in the United States and quad bikes cause most in Australia. Regarding non-fatal injuries, the primary sources include farm machinery and animal-related contact, each accounting for about equal numbers of injuries. However, machinery injuries are usually more serious and account for more disabling injuries than animal-related injuries.

In northern European countries farming is commonly combined with forestry. The risk of injuries is very high for farmers active in forestry.

Medical treatment of agricultural injuries is complicated by the extreme severity of tissue damage and even amputation. Severe trauma often combined with extensive contamination with soil and animal fecal material increases the risk for wound infections with anaerobic organisms and antibiotic-resistant organisms. Delayed location, rescue, and emergency transport of victims to appropriate medical facilities further complicate the prospects for good outcomes of these cases. Finally, rehabilitation of these victims often falls upon the rural primary care physician. Almost all injured farmers want to resume their farming activities, and it is up to the primary care provider in conjunction with public and private rehabilitation organizations to help injured farmers return to farming.

1.12.11 Human Health Hazards of Veterinary Pharmaceuticals (Chapter 12)

Many products used for animal health or growth promotion may cause illness in humans who come in contact with these products. Accidental needle sticks are common among veterinarians and animal handlers, and they carry the consequence of unintended trauma, infections, and toxicity or inflammation. Antibiotics, immunization products, and hormones used in obstetrical procedures are common substances that may result in unintended illness in veterinarians or animal handlers. The largest concern with antibiotic use is the enhancement of resistant organisms and resulting resistant infections. Other concerns include severe toxic reactions (such as the antibiotic tilmicosin, which is cardiotoxic to humans) and allergies. Accidental inoculation with immunization products may result in an infection of the product itself (live products), inflammation, or allergic response. The hormones oxytocin and prostaglandin are two products that may cause abortion in pregnant women if they are accidentally inoculated.

1.12.12 Agricultural and Rural Zoonotic and Emerging Infectious Diseases (Chapter 13)

Over 25 different infectious diseases can be transmitted from animals or the environment that may produce occupational illnesses in agricultural workers. At least 24 different zoonotic diseases are occupational hazards in agriculture. These diseases are often difficult to diagnose as they have few characteristic symptoms. A basic knowledge of the general epidemiologic characteristics of these diseases and work that results in exposure will be reviewed in this text.

1.12.13 Prevention of Illness and Injury in Agricultural Populations (Chapter 15)

Farming (especially small family farms) is relatively unregulated compared to other industries in regard to occupational health and safety. The reasons for this are multifaceted, including the fact there are thousands of self-employed operations with few employees, scattered across the countryside, creating logistical difficulty for inspection. Furthermore, governments recognize the independent culture of farmers, and thus are sensitive of regulations impacting on farm family work and the right of parents and families to make their own decisions. The most common regulation (internationally in developed countries, but not in the United States) is the requirement of rollover protective structures on farm tractors.

Most countries have regulations that apply to children's work and hired agricultural workers. However, some countries have a minimum number of workers per operation before the regulations take effect. For example, in the United States there must be at least 11 employees in an operation before federal funds can be used to inspect and enforce occupational safety and health regulations. The International Labor Organization has produced model guidelines for member countries to adopt for the protection of agricultural workers and children. Details of regulations applicable to agricultural health and safety are given in Chapter 15.

1.12.14 Agricultural Health and Safety Organizations

The past two decades have witnessed extensive growth in agricultural health and safety activities in industrialized countries, in both governmental and non-governmental organizations. The sum effort of these organizations has advanced the field significantly, creating a new discipline and changing the field to include a public health approach from a previously low-profile interest of farm safety in agricultural colleges. Chapter 15 discusses in detail these organizations and how they have advanced the field of occupational safety and health.

1.13 Summary

This chapter provides a broad overview of agricultural health and safety. Aided by this overview, the reader can approach the subsequent chapters with a background that provides broad connections to the field of agriculture and a perspective that enhances greater comprehension of the material.

The following key points are made to help summarize the essential information in this chapter.

Key Points

1. The history and evolution of field of agricultural safety and health/agricultural medicine includes the following terms and concepts:
   a. *Agricultural safety* emerged in the mid-1940s with extension, insurance professionals, and farm groups.
   b. The term *agricultural medicine* arose internationally in the mid-1950s, mainly led by healthcare professionals.
   c. The term *agromedicine* arose in the mid-1980s as a collaboration between primary care medicine and agricultural extension to provide outreach information to the farm community. Several such programs formed the non-profit organization the North American Agromedicine Consortium (NAAC; terminated in 2014). The *Journal of Agromedicine* originated as the organ of NAAC.
   d. These different terms and professionals associated with these organizations are joining in a common goal of prevention, and the generic term agricultural safety and health pulls these segments together, for example the International Society of Agricultural Safety and Health (ISASH; formerly the National Institute for Farm Safety).
2. Agricultural health and safety is an evolving profession and includes at its core a knowledge and understanding of production agricultural processes, the culture of farmers, their families and workers, core knowledge of the specific occupational exposures, risks, and prevention, along with professional education that may be from a variety of areas including health sciences, safety, education, engineering, veterinary medicine, and social sciences.
3. Worldwide, 1.3 billion people are employed as wage earners in agriculture. They are diverse culturally and socioeconomically. Thirty-eight per cent are migrant workers, and 50% of these are women. In the United States there are 775,000 farm workers and 59% of them are local non-migrants.
4. In most developed countries, farm owner/operators have lower fatality rates from cardiovascular disease (heart attacks and stroke) and lower overall cancer compared to the general population. The reasons for these lower rates appear to be due to lower prevalence of smoking and alcohol consumption, better diets, and more exercise.
5. In most developed countries occupational fatalities in agriculture are higher (two to seven times higher) than for all occupations (fatality rates for all occupations generally are in the range of three to six fatalities per 100,000).
6. Persistent and emerging mega trends that are shaping agriculture include the following:
   a. International trade agreements in agriculture.
   b. Government programs/regulations, including farm support programs, occupational safety regulations, and environmental regulations.
   c. Consumer power and the general public's concern are important forces in how agriculture may be done in the future (e.g., humane livestock husbandry methods, food safety concerns, food "contaminants" and the negative view of GMOs, pesticides, hormones, and the positive perception of "organic" production).
   d. Climate change prediction means more volatile weather patterns and extreme scenarios. Some areas may benefit from a warmer or drier climate, as others

may experience extreme difficulties for sustainable agricultural production.

e. Emerging zoonoses, including influenza, Hendra virus, West Nile virus, and livestock-associated methicillin-resistant *Staphylococcus aureus*, are just a few of the over 24 different zoonoses of occupational risks for agricultural workers. Seventy-five per cent of the world's emerging diseases are zoonotic. Appropriate surveillance and improved systems for detection are required.

f. Advanced technology in agriculture (e.g., GMOs, designer pesticides, global positioning precision and robotic machines) are changing the way farming is done. Increased productivity may be realized, but in exchange for less physical exercise and more mental stress on farmers.

g. There will be a requirement to feed nine billion mouths in the world of 2050 from the six billion of 2015. The challenge to our farmers is to do this while maintaining a sustainable system that supports their economic viability, their health, and the health of their families and workers, while maintaining the ecologic health of the planet. Our main job as health and safety professionals is to find new and innovative ways to help keep farmers, their families, and workers alive and well in agriculture. We can start with the study of agricultural medicine as documented in the rest of this book.

References

1. Donham KJ, Wheat JR, Simpson W, Jr., James P. What's in a name? Revisited: terms used to describe activities related to the health and safety of agricultural-associated populations and consumer. J Agromedicine. 2005;10(1):5–11.
2. National Rural Health Association; 2014 (accessed 18 January 2014). Available from: http://www.ruralhealthweb.org/.
3. Mutel C, Donham K. Medical Practices in Rural Communities. New York: Springer-Verlag; 1983.
4. Ramazzini B. Diseases of Workers. Translated from the Latin text *De Morbis Artificum* (1713) by W.C. Wright. New York: Hafner Publishing Company; 1964. 550 p.
5. Wakatsuki T. Getting Among Farmers. Usuda, Japan: Saku Central Hospital; 2003. 313 p.
6. Davies J, Smith RF, Freed V. Agromedicine Appr Pest Man. 1978; 23:353–66.
7. Rasmussen R, Cole G. The spectrum of Agricultural medicine. Minnesota Med. 1976;59(8):536–539.
8. Elliott CK. Agricultural medicine. J Roy Soc Med. 1979;72(12):949.
9. Donham KJ, Mutel CF. Agricultural medicine: the missing component of the Rural Health Movement. J Fam Pract. 1982;14(3):511–20.
10. Donham KJ. Introduction: Agricultural, occupational, and environmental health: Policy strategies for the future (9). Am J Ind Med. 1990;18(4): 363–64.
11. Murphy DJ. Safety and Health for Production Agriculture. St Joseph, MI: American Society of Agricultural Engineers; 1992.
12. Langley R, McLymore R, Meggs W, Roberson T. Safety and health in agriculture, forestry, and fishing. 1st edition. Rockville, MD: Government Institutes; 1997.
13. Murphy, D. Looking Beneath the Surface of Agricultural Safety and Health. St Joseph, MI: American Society of Agricultural Engineers; 2003.
14. Donham KJ, Thelin A. Agricultural Medicine: Occupational and Envitronmental Health for the Health Professions. Ames, IA: Blackwell; 2006.
15. Lessenger JE (ed.). Agricultural medicine: a practical guide. 1st edition. New York: Springer; 2006.
16. Annals of Agricultural and Environmental Medicine home page; 2005 (accessed 16 Janusry 2014). Available from: http://www.aaem.pl.
17. Berry CM. Organized Research in Agricultural Health and Safety. Am J Public Health Nations Health. 1965;55(3):424–8.
18. Knapp Jr L. Agricultural injury prevention. J Occup Environ Med. 1965;7(11):545–53.
19. Top FH. Occupational health in agriculture. Arch Environ Health. 1961;2:150–4.
20. Berry C. Rural employment. Am J Public Health. 1971;61(12):2474–6.
21. Donham KJ, Venzke J. Agricultural occupational health nurse training and certification. J Agromedicine. 1997;4(1–2):105–16.

22. International Association of Agricultural Medicine and Rural Health home page (accessed 22 December 2015). Available from: http://iaamrh.org/www/index.html.
23. Agricultural Scientific Committee. International Commission of Occupational Health; 2005 (accessed 18 January 2014). Available from: http://www.icohweb.org/site_new/ico_homepage.asp.
24. National Farm Medicine Center; 2005 (accessed 18 Janusry 2014). Available from: http://www3.marshfieldclinic.org/NFMC/.
25. Canadian Centre for Health and Safety in Agriculture home page; 2007 (accessed 22 December 2015). Available from: http://www.cchsa-ccssma.usask.ca/.
26. James PA. Agromedicine. J Agromedicine. 1994; 1(3): 81–7.
27. International Society for Agricultural Safety and Health home page; 2005 (accessed 18 January 2014). Available from: http://www.isash.org/.
28. NIOSH Extramural Research and Training Programs. Centers for Disease Control and Prevention, NIOSH Agricultural Safety and Health Centers; 2014 (accessed 29 January 2014). Available from: http://www.cdc.gov/niosh/oep/agctrhom.html.
29. Donham KJ. Agricultural safety and health: a profession? J Agromedicine. 2009;14(1):5–8.
30. Agricultural Safety and Health. Heartland Center for Occupatioinal Safety and Health, University of Iowa; 2015 (accessed 19 November 2015). Available from: http://www.public-health.uiowa.edu/heartland/academic-programs/ag-safety.html.
31. Mutel C, Donham K. An extended role for the rural physician. In: Stone JL, editor. Medical Practice in Rural Communities. New York: Springer-Verlag; 1983. p. 117–39.
32. Simmons PD. Rural Medicine: Its Own Specialty? J Rural Health. 2009;25(3):231–2.
33. Fleming MJ. Agricultural health: a new field of occupational health nursing. AAOHN J. 2004;52(9): 391–6.
34. Gay J, Donham KJ, Leonard S. Iowa Agricultural Health and Safety Service Project. Am J Ind Med. 1990;18(4):385–9.
35. Lundvall A, Olson D. Agricultural health nurses: job analysis of functions and competencies. AAOHN J. 2001;49(7):336–46.
36. Walsh M. Farm accidents: their causes and the development of a nurse led accident prevention strategy. Emerg Nurse. 2000;8(7):24–31.
37. AgriSafe Network home page; 2015 (accessed 19 November 2015). Available from: http://www.agrisafe.org/training.
38. Thu K, Donham K, Yoder D, Ogilvie L. The farm family perception of occupational health: A multistate survey of knowledge, attitudes, behaviors and ideas. Am J Ind Med. 1990;18:427–31.
39. Wheat J, Turner T, Weatherly L, Wiggins O. Agromedicine Focus Group: Cooperative extension agents and medical school instructors plan farm field trips for medical students. South Med J. 2003; 96(1):27–31.
40. Fisher EL, Donham, KJ. Agricultural medicine core course: building capacity for health and safety professionals. J Agromedicine. 2011;16(2):106–16.
41. CCOM Rural Iowa Scholars Program (CRISP). Carver College of Medicine, University of Iowa; 2011 (accessed 28 January 2014). Available from: http://www.medicine.uiowa.edu/md/CRISP_introduction/.
42. Fisher EL, Donham KJ. Agricultural medicine core course: building capacity for health and safety professionals. J Agromedicine. 2011;16(2):106–16.
43. Rudolphi, JM, Donham, KJ, Toward a National Core Course in Agricultural Medicine and Curriculum in Agricultural Safety and Health: The "Building Capacity" Consensus Process. J Agromedicine. 2015; 20(1): 77–83.
44. McCoombe S, Brumby S. Agricultural health and medicine – a multidisciplinary approach to educating tomorrow's rural and remote health leaders. 11th National Rural Health Conference, 13–16 March, Perth, Australia. National Rural Health Alliance; 2011.
45. Jones S, Dunn D, Coffey D. Strengthening the nursing curriculum: an interdisciplinary course addressing agricultural health and safety. AAOHN J. 2004; 52(9):397.
46. Rural communities. Health Sciences, Academic Health Center, University of Minnesota; 2014 (accessed 19 November 2015). Available from: http://www.health.umn.edu/our-impact/rural-communities.
47. Rudolphi J, Donham K. Increasing the number of trained health and safety professionals in agricultural medicine: Evaluation of the "Building Capacity" Program, 2007–2013. J Agromedicine. 2015; 20(1):21–30.
48. Hurst P, Termine P, Karl M. Agricultural workers and their contribution to sustainable agriculture and rural development. International Labour Organization, Food and Agriculture Organization, International Union of Food, Agricutlural, Hotel, Restaurant, Catering, Tobacco and Allied Workers' Associations; 2007.
49. Employment in agriculture (percentage of total employment). The World Bank; 2014 (accessed 18 January 2014). Available from: http://data.worldbank.org/indicator/SL.AGR.EMPL.ZS.
50. Matthews A. Family farming and the role of policy in the EU. CAP Reform.eu; 2013 (accessed

18 January 2014). Available from: http://capreform.eu/family-farming- and-the-role-of-policy-in-the-eu/.
51. Eurostat Year Book 2004: The statistical guide to Europe 1992–2004. European Commission; 2004 (accessed 19 November). Available from: http://ec.europa.eu/eurostat/documents/3217494/5648861/KS-CD-04-001-EN.PDF/ 05371ffe-c41c-4bec-9093-f507c11cf3ca.
52. Number of Farms: Canada, United States and Mexico. Mexico's Servcio de information agroalimentacio'n (SIAP); 2010 (accessed 15 November 2015). Available from: http://webpage.siap.gob.mx/opt/mapas/Map_PuntosGranja_en.pdf.
53. Agricultural Census 2001. Statustics Canada; 2001 (updated 24 March 2015; accessed 19 November 2015). Available from: http://www.statcan.gc.ca/ca-ra2001/index-eng.htm.
54. Snapshot of Canadian agriculture. Statistics Canada; 2009 (accessed 18 January 2014). Available from: http://www.statcan.gc.ca/ca-ra2006/articles/snapshot-portrait-eng.htm.
55. Australian Farmers and Farming 4102.0. Australian Bureau of Statistics. Australian Social Trends; 2012 (accessed 19 November 2015). Available from: http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4102.0Main+Features10Dec+2012.
56. Farm Numbers, Evnironmnental indicators, New Zealand Environemntal Report Series. 2015; (acccessed December 22, 2015), Available from: http://www.stats.govt.nz/browse_for_stats/environment/environmental-reporting-series/environmental-indicators/Home/Land/land-use/farm-numbers.aspx.
57. Occupational Outlook Handbook. US Department of Labor. December 17, 2015; (accessed 23 December 2015). Available from: http://www.bls.gov/ooh/about/ooh-faqs.htm.
58. Donham KJ, Thu K. Agricultural Medicine and Environmental Health: The Missing Component of the Sustainable Agricultural Movement. In: H.H. McDuffie et al., editors. Agricultural Safety: Workplace, Environmnet, Sustainability. Boca Raton, FL: CRC Press Lewis Publishers; 1995.
59. Wesley E, Peterson, F. A BIllion Dollars a Day: The Economics and Politics of Agricultural Subsidies. Chichester, Malden, MA: Wiley-Blackwell; 2009.
60. Thu K. The Centralization of Food Systems and Political Power. Culture & Agriculture. 2009; 31(1):13–6.
61. Farm Numbers. US Department of Agriculture. Census of Agriculture; 2007 (accessed 22 December 2015). Available from: http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Fact_Sheets/Farm_Numbers/farm_numbers.pdf.
62. Rosmann M. The agrarian imperative. J Agromedicine. 2010;15(2):71–5.
63. Demographics. United States Environmental Protection Agency; 2013 (updated 29 July 2015; accessed 19 November 2015). Available from: http://www.epa.gov/agriculture/ag101/demographics.html.
64. The State of Food and Agriculture 2010–2011. Women in Agriculture: Closing the Gender Gap for Development, Rome, 2011. Food and Agriculture Organization of the United Nations; 2011 (accessed 19 November 2015). Available from: http://www.fao.org/docrep/013/i2050e/i2050e00.htm.
65. Visack Y, Clark ZF. 2007 Census of Agriculture: Women Farmers. United States Department of Agriculture, National Agricultural Statistics Service; 2007 (accessed 19 November 2015). Available from: http://www.agcensus.usda.gov/Publications/2007/Full_Report/usv1.pdf.
66. Weber J, Brown J. When working off the farm, farm operators most commonly work in the management and professional occupations. USDA Economic Research Service; 2013 (accessed 21 January 2014). Available from: http://www.ers.usda.gov/amber-waves/2013-september/when-working-off-the-farm,-farm-operators-most-commonly-work-in-management-and-professional-occupations.aspx#.Ut59UrTnaUl.
67. Spengler SE, Browning SR, Reed DB. Sleep deprivation and injuries in part-time Kentucky farmers: impact of self reported sleep habits and sleep problems on injury risk. AAOHN J. 2004;52(9):373–82.
68. Frank AL, McKnight R, Kirkhorn SR, Gunderson P. Issues of agricultural safety and health. Annu Rev Public Health. 2004;25:225–45.
69. Towards a fair deal for migrant workers in the global economy. Geneva: International Labour Office; 2004 (accessed 19 November 2015). Available from: http://www.ilo.org/public/english/standards/relm/ilc/ilc92/pdf/rep-vi.pdf.
70. Labour Migration. International Labour Organization; 2014. Podcast. Available from: http://www.ilo.org/global/topics/labour-migration/lang--en/index.htm.
71. Farm Labor 2012. USDA Economic Research Service; 2012 (updated 14 February 2013; accessed 22 February 2014). Available from: http://www.ers.usda.gov/topics/farm-economy/farm-labor/background.aspx#Numbers.
72. Frank AL, McKnight R, Kirkhorn SR, Gunderson P. Issues of agricultural safety and health. Annu Rev Public Health. 2004;25:225–45.
73. Blondell JM. Urban-rural factors affecting cancer mortality in Kentucky, 1950–1969. Cancer Detect Prev. 1988;11(3–6):209–23.

74. Doll R. Urban and rural factors in the aetiology of cancer. Int J Cancer. 1991;47(6):803–10.
75. Stiernstrom EL, Holmberg S, Thelin A, Svardsudd K. Reported health status among farmers and non-farmers in nine rural districts. J Occup Environ Med. 1998;40(10):917–24.
76. Burmeister LF, Morgan DP. Mortality in Iowa farmers and farm laborers, 1971–1978. J Occup Med. 1982;24(11):898–900.
77. Pomrehn PR, Wallace RB, Burmeister LF. Ischemic heart disease mortality in Iowa farmers. The influence of life-style. J Am Med Assoc. 1982;248(9):1073–6.
78. Thelin A. Morbidity in Swedish farmers, 1978–1983, according to national hospital records. Soc Sci Med. 1991;32(3):305–9.
79. Thelin A, Höglund S. Change of occupation and retirement among Swedish farmers and farm workers in relation to those in other occupations. A study of 'elimination' from farming during the period 1970–1988. Soc Sci Med. 1994;38(1):147–51.
80. Brumby S, Kennedy A, Chandrasekara A. Alcohol consumption, obesity, and psychological distress in farming communities – an Australian study. J Rural Health. 2013;29(3):311–9.
81. Brumby S, Chandrasekara A, McCoombe S, Kremer P, Lewandowski P. Cardiovascular risk factors and psychological distress in Australian farming communities. Aust J Rural Health. 2012;20(3):131–7.
82. Fragar L, Depczynski J, Lower T. Mortality patterns of Australian male farmers and farm managers. Aust J Rural Health. 2011;19(4):179–84.
83. Miller K, Burns C. Suicides on farms in South Australia 1997–2001. Aust J Rural Health. 2008;16(6):327–31.
84. McCrone JC. A case-control study of the health status of male farmers registered at Ash Tree House Surgery, Kirkham, Lancashire. J R Soc Prom Health. 1999;119(1):32–5.
85. Reed DB. The risky business of production agriculture: health and safety for farm workers. AAOHN J. 2004;52(9):401–9; quiz 10–1.
86. Reed DB. Caring for the families that feed the world. AAOHN J. 2004;52(9):361–2.
87. Rylander R. Organic dusts – from knowledge to prevention. Scand J Work Env Health. 1994;20(9): 116–22.
88. Stark A, Change H-G, Fitzgerald E, Ricardi K, Stone R. 1987. A retrospective cohort study of mortality among New York state farm bureau members. Arch Environ Health. 42:204–212.
89. Rywik S, Kupsc W. Coronary heart disease mortality trends and related factors in Poland. Cardiology. 1985;72:81–87.
90. Census of Fatal Occupational Injuries Summary 2013 [Internet]. Department of Labor; 2013 (accessed 22 November 2014). Available from: http://www.bls.gov/news.release/cfoi.nr0.htm.
91. Waggoner JK, Kullman GJ, Henneberger PK, Umbach DM, Blair A, Alavanja MC, et al. Mortality in the Agricultural Health Study 1993–2007. Am J Epidemiol. 2011;173(1):71–83.
92. Pickett W, Hartling L, Brison RJ, Guernsey JR. Fatal work-related farm injuries in Canada, 1991–1995. Canadian Agricultural Injury Surveillance Program. Can Med Agric J. 1999;160(13):1843–8.
93. McCurdy S, Carroll D. Agricultural Injury. Am J Ind Med. 2000;38:463–80.
94. Rautiainen R, Lange J, Hodne C, Schneiders S, Donham K. Injuries in the Iowa Certified Safe Farm Study. J Agric Saf Health. 2004;10(1):51–63.
95. Rautiainen RH, Reynolds SJ. Mortality and morbidity in agriculture in the United States. J Agric Saf Health. 2002;8(3):259–76.
96. Notkola VJ, Husman KR, Laukkanen VJ. Mortality among male farmers in Finland during 1979–1983. Scand J Work Envrion Health. 1987;13(2):124–8.
97. Taattola K, Rautiainen R, Karttunen J, Suutarinen J, Viluksela M, Louhelainen K, Mäittälä J. Risk factors for occupational injuries among full-time farmers in Finland. J Agric Saf Health. 2012;18(2):83–93.
98. Leigh JP, McCurdy SA, Schenker MB. Costs of occupational injuries in agriculture. Public Health Rep. 2001;116(3):235.
99. Cleveland D. Balancing on a planet: toward an agricultural anthropology for the twenty-first century. Hum Ecol. 1998;26(2):323–40.
100. Baxter V, Mann S. The survival and revival of non-wage labour in a global economy. Sociologia Ruralis. 1992;32(2–3):231–47.
101. Gregory PJ, Ingram JSI. Global change and food and forest production: future scientific challenges. Agric Ecosyst Environ. 2000;82(1–3):3–14.
102. Viatte G. Global economy in the new millennium: a dynamic context for food and agricultural policies. Outlook Agric. 2001;30(1):21–5.
103. Khor M. Analytical note, November 2013. South Centre; 2013 (accessed 18 January 2014). Available from: http://www.southcentre.int/analytical-note-november-2013-4/.
104. Moran W, Blunden G, Workman M, Bradly A. Family farmers, real regulation, and the experience of food regimes. J Rural Studies. 1996;12(3): 245–58.
105. Bindraban PS, Rabbinge R. Megatrends in agriculture – Views for discontinuities in past and future developments. Global Food Security. 2012; 1(2): 99–105.

106. Jussaume R. Globalization, agriculture, and rural social change in Japan. Environ Plan A. 1998; 30(3):401–13.
107. Kim JM. Sustainable agriculture development in Korea in a global economy. J Sustain Agric. 1999; 13(3):73–84.
108. Edwards C. Agricultural subsidies. CATO Institute; 2009 (accessed 18 January 2014. Available from: http://www.downsizinggovernment.org/print/agriculture/subsidies.
109. Bruhnsma J. World Agriculture: towards 2015/2030. London: Earthsan Publications; 2003.
110. World Trade Organization home page 2014 (accessed 18 January 2014). Available from: http://www.wto.org/.
111. Trade. European Commission; 2014 (updated 6 January 2014; accessed 18 January 2014). Available from: http://ec.europa.eu/trade/.
112. Free trade agreements. Office of the United States Trade Representative; 2014 (accessed 21 January 2014). Available from: http://www.ustr.gov/trade-agreements/free-trade-agreements.
113. Buttel F. Agricultural biotechnology: Its recent evolution and implications for agrofood political economy. Sociolog Res Online. 1999;4(3):u292–u309.
114. Nielsen CP, Anderson K. Global market effects of alternative European responses to genetically modified organisms. Weltwirtschaftliches Archiv. 2001;137(2):320–46.
115. O'Hara S, Stagl S. Global food markets and their local alternatives: A socio-ecological economic perspective. Popul Environ. 2001;22(6):533–54.
116. Madhani A. McDonald's cuts ties with chicken supplier accused of cruelty. USA Today; 2015, August 28 (accessed 19 November 2015). Available from: http://www.usatoday.com/story/money/2015/08/27/activists-mcdonalds-tyson-chicken-abuse/32449069/.
117. Compassionate family farmers raising animals with respect for the land. Niman Ranch; 2014 (accessed 2 February 2014). Available from: http://www.nimanranch.com/Index.aspx.
118. Pollan M. The Omnivore's Dilemma. London: Penguin Press; 2006.
119. McFague S. Blessed are the consumers: climate change and the practice of restraint. Minneapolis: Fortress Press; 2013.
120. Hinrichs CC. Embeddedness and local food systems: notes on two types of direct agricultural market. J Rural Studies. 2000;16(3):295–303.
121. La Trobe HL, Acott TG. Localising the global food system. Int J Sustain Dev World Ecol. 2000;7(4): 309–20.
122. Urban Agriculture. US Department of Agriculture; 2014 (accessed 29 January 2014). Available from: http://afsic.nal.usda.gov/farms-and-community/urban-agriculture.
123. Bradford GE. Contributions of animal agriculture to meeting global human food demand. Livestock Prod Sci. 1999;59(2–3):95–112.
124. Zijpp AJ van der (ed.). Role of global animal agriculture in the 21st century. Proceedings of 2000 International Symposium Recent Advances in Animal Nutrition, Seoul, Korea, 20–22 April 2000. Rome: Food and Agricultural Organization of the United Nations; 2000 (accessed 19 November 2015). Available from: http://agris.fao.org/agris-search/search.do?recordID=NL2001001613.
125. Meeker DL. What are the livestock industries doing, and what do they need from us? J Anim Sci. 1999;77(2):361–6.
126. Tilman D, Cassman KG, Matson PA, Naylor R, Polasky S. Agricultural sustainability and intensive production practices. Nature. 2002;418(6898): 671–7.
127. Fuglie, KO. Total factor productivity in the global agricultural economy: Evidence from FAO data. In: Alston J, Babcock B, Pardey P, editors. The Shifting Patterns of Agricultural Production and Productivity Worldwide. Ames, IA: The Midwest Agribusiness Trade Research and Information Center;. 2010. pp. 63–95.
128. Gunderson PD. Biofuels and North American agriculture – implications for the health and safety of North American producers. J Agromedicine. 2008;13(4):219–24.
129. Wheeler T, Von Braun J. Climate change impacts on global food security. Science. 2013;341(6145): 508–13.
130. Hunger. United Nations, World Food Programme; 2015 (accessed 19 November 2015). Available from: http://www.wfp.org/hunger.
131. Securing sustainability through the conservation and use of agricultural biodiversity. United Nations Environment Programme; 2014 (accessed 26 January 2014). Available from: http://www.unep.org/dgef/SecuringSustainability/tabid/6401/Default.aspx.
132. Jones KE, Patel NG, Levy MA, Storeygard A, Balk D, Gittleman JL, et al. Global trends in emerging infectious diseases. Nature. 2008;451(7181):990–3.
133. Morens DM, Folkers GK, Fauci AS. Emerging infections: a perpetual challenge. The Lancet Infectious Diseases. 2008;8(11):710–9.
134. Economic impact of the 2001 foot and mouth disease outbreak – Final Report. The Scottish Government; 2003 (accessed 19 November 2015). available from: http://www.gov.scot/Publications/2003/07/17383/22560).

135. Savitz A, Weber K. The Triple Bottom Line. San Francisco: Josey-Bass; 2006.
136. Australian National Center for Farmers' Health home page 2014 (accessed 20 November 2014). Available from: http://www.farmerhealth.org.au.
137. Brumby SA, Willder SJ, Martin J. The sustainable farm families project: changing attitudes to health. Rural Remote Health. 2009;9(1):1012.
138. Brumby S, Martin J, Willder S. Milking their health for all its worth? Improving the health of farming families through facilitated learning. Exten Farm Sys J. 2010;61(1).
139. Donham K, Horvath E. Agricultural Occuopational Medicine. In: Zenze C, editor. Occupational Medicine: Practices and Principles. 2nd edition. Chicago: Year Book Medical Publishers; 1988. 1273 pp.
140. Popendorf W, Donham K. Agricultural hygeine. In: Rose V, Cohrssen B, editors. Patty's Industrial Hygiene and Toxicology. 6th edition. New York: John Wiley and Sons; 2010.
141. Gwyther ME, Jenkins M. Migrant farmworker children: health status, barriers to care, and nursing innovations in health care delivery. J Pediatr Health Care. 1998;12(2):60–6.
142. Gomez MI, Hwang SA, Lin S, Stark AD, May JJ, Hallman EM. Prevalence and predictors of respiratory symptoms among New York farmers and farm residents. Am J Ind Med. 2004;46(1):42–54.
143. Burke W. Skin diseases in farmers. In: Langley R, McLymore R, Meggs W, Roberson G, editors. Safety and Health in Agriculture, Forestry, and Fisheries. Rockville, MD: Government Institutes; 1997. p. 322–52.
144. Irby CE, Yentzer BA, Vallejos QM, Arcury TA, Quandt SA, Feldman SR. The prevalence and possible causes of contact dermatitis in farmworkers. Int J Dermatol. 2009;48(11):1166–70.
145. Brown B. Lone Tree: A True Story of Murder in Anerica's Heartland. New York: Crown Publishers; 1989.
146. Gunderson P, Donner D, Nashold R, Salkowicz L, et al. The epidemiology of suicide among farm residents or workers in five north-central states, 1980–1988. Am J Prev Med. 1993:9(3,Suppl.):26–32.

Chapter

2

Special Risk Populations in Agricultural Communities

Kelley J. Donham and Anders Thelin

Reviewer: Robin Tutor-Marcom

2.1 Introduction

Several special agriculture risk groups reside in the shadow of the mainstream of agricultural health and safety research and prevention programming. The public health goal is to take care of even the most vulnerable populations in society. The agrarian groups considered here have special risks associated with age, gender, low socioeconomic status, ethnicity, race, culture, or religious beliefs. This chapter intends to feature these populations, their special health issues, and their special considerations for methods of prevention. The US Department of Agriculture (USDA) Census of Agriculture 2012 profiles the demographics of various minority groups in production agriculture in the United States (1). Additional special risk populations in agriculture not discussed here include the Lapps in the northern regions of Scandinavia crossing over into Finland and Russia, and the Romans or Gypsies who live across Central and Eastern Europe. Other special risk farming populations include Native Americans in North and South America, new immigrant farmers in North America from Japan and China on the West Coast, and new immigrant farm workers from Somalia, Bosnia, the Hmong people from Laos, Vietnam, and other South-East Asian countries that inhabit the Midwest primarily, but are also located in other parts of the country. Haitian farm workers are located primarily in the south-eastern states of the United States. Furthermore, African-Americans as well as Anglos operating very small family farms (USDA designation of limited resource farms) scattered mainly across the southern United States. also have special risks. However, it is beyond the scope of this text to cover all these groups. We have therefore chosen five special-risk populations to profile here: (1) women, (2) children, (3) the elderly, (4) migrant and seasonal farm workers, and (5) Anabaptist religious groups. The first four of these are common to all industrialized agricultural countries with similar agricultural systems (i.e., countries in the EU, Australia, New Zealand, Canada, Brazil, Argentina, Uruguay, and Paraguay).

Women experience certain reproductive risks from agricultural exposures, including infertility and abortion. *Farm youths* may experience

Agricultural Medicine: Rural Occupational and Environmental Health, Safety, and Prevention, Second Edition.
Kelley J. Donham and Anders Thelin.

illnesses and injuries not only from farm work, but also because of living and playing in or adjacent to hazardous work sites. Their cognitive, emotional, and physical skills may not be adequately developed to safely handle certain kinds of work. The *elderly* may have lost certain physical, cognitive, and emotional skills, which increases their risk for injury or illness. Additionally, they may have co-morbidities and prescribed medications that, because of side effects, could further conflict their safe functioning in a hazardous workplace. Furthermore, the elderly often operate older machinery on the farm (more hazardous because it may lack modern safety features) with which they are familiar, and they may perform more hazardous tasks such as mowing ditches and waterways. *Migrant and seasonal farm workers* often have cultural and language barriers they must overcome before they can safely perform their jobs. Furthermore, they may feel powerless, unable to complain of hazards for fear of losing their jobs or being deported. Old-order *Anabaptists* often use older farming methods and more hazardous machines. In addition, their spiritual and/or cultural beliefs may stop them from seeking health care, including recommended immunizations.

These are a few of the hazards these special risk populations experience. This chapter will elaborate on the demographics of these populations, their exposures, and the subsequent risks and epidemiology of related illnesses and injuries. Finally, we describe special considerations for treatment and recommendations for prevention.

2.2 Women in Agriculture

Women play important roles in production agriculture as principle or co-owner/operators of farming enterprises, members of family farming units, or farm workers. However, women have some health issues that differ from men's health generally, and specific gender differences in agricultural health issues.

World-wide, 50% of economically active women work in agriculture, and this is over 60% in developing countries (2). Research into the role of women in agriculture in developed countries appeared in peer-reviewed literature in the mid-1970s. Smith (3) reported a natural traditional anthropologic gender division in agriculture: women acted as care takers of plants, small animals, and family; men adopted technology, power equipment and large commodity production. Although this gender division may still be present to some extent, it has been diminishing over the past three decades. Women are clearly increasing their role in the ownership and management of agricultural operations in North America and most industrialized countries (4, 5). The number of women in New Zealand employed full-time in agriculture increased from 13% in 1973 to 20% in full-time and 32% in part-time employment more recently, along with increased roles in leadership as principal operators, extension agents, and researchers (3). The women's movement of the late 1970s and 1980s facilitated a law in Italy that put men and women as equal partners in family businesses, a principle that has now been assumed in most developed countries, thus increasing the documentable role of women in agriculture (6). Gasson (7) reported that the increasing role of women in agriculture is an international trend. In Canada between 1951 and 2006, the percentage of women reported to be employed in agriculture grew from 4% to 27.8% (2) (including spouses recorded as joint operators).

Similar demographic changes in females as primary operators have occurred in the United States. The USDA 2007 Census of Agriculture indicated that 27% of all farm operators (principal or co-operators) were women. By 2012, 29% of all farm operators (principal or co-operators) were women. An additional 17% of women living on the farm also contributed to the farm labor, even though they may not be considered an operator, therefore women have a significant involvement in 47% of the farms in the United States (8). Farm women in Wisconsin contribute on average 20 hours/week to farm labor versus 50 hours/week for men (9). In a survey conducted by Reed and colleagues (10) of rural farm households in Kentucky and Texas, about 50% of the 1600 women surveyed described themselves solely as homemakers, yet 40% reported regularly working with farm animals and 30% reported regularly driving tractors, leading to potentially dangerous situations.

Women are also extensively involved in European agriculture. Farm women in Finland are listed as operators on 34% of the farms (11). Sixty-six per cent of Polish women living in rural areas are associated with agriculture (12). Many of these women are farm managers because they have taken over the running of the farm if a husband is killed or injured (66% of cases studied) or because husbands and sons work off-farm (30% of cases studied).

Many farm women have a combination "triple duty" of family, farm, and off-farm careers. Many farm women (57% of female principal operators and 63% of all farm women) find it necessary to increase their off-farm work. An increasing number of male farm operators (61% in 2012) also have off-farm employment. Spouses work off-farm to supplement the farm income and to receive benefits not provided by self-employment, such as health insurance and pension plans (13–15). The farm triple-duty life style has led to an increased risk of stress and agricultural injury (16–18). However, one possible positive outcome of full-time off-farm work has shown a protective factor for young children, as they have greater accessibility to safe childcare in the towns or villages where the parent works (13–16, 19). The pattern of off-farm employment in the United States is similar to that experienced by many farm families in other industrialized countries.

2.2.1 Work Exposures/Risk Factors for Farm Women

As with many areas of health research, farm women have been studied less than men. However, the research available suggests that women do have significant exposure to agricultural work and thus related health and safety risks from farm exposures(17).

Acute Injuries

Data from Finland revealed that livestock-related injuries to women are the most prevalent causes of acute injuries (40% of injuries and 50% of "near misses") (11). High risk is found in working directly with large animals in enclosed spaces, during feeding, cleaning, or milking (20). Injuries to women are most likely to occur in the lower extremities. In a 2-year case-control study in central Wisconsin, 40 acute injuries were studied in adult women (18). Most (55%) of the injuries occurred in a barn, and in 42.5% cases a cow was the main agent of injury. Being crushed or stricken by an animal is the most common cause of injury for women ages 15–59. For women above 60, falls are the most common cause of non-machinery injury and fatality. Tractors also are the most common cause of machine-related non-fatal injuries, causing 28% of the farming-related hospitalizations for females. Tractors are also the most common agent of death for adult women (21). Of machine-related fatalities, 48% are the result of tractor run-overs.

Pesticide Exposures

Women are highly concerned about pesticide exposures to them and their families (22–28). Forty per cent of the wives of agricultural producers in rural Iowa and North Carolina have assisted with mixing or application of pesticides (29, 30). Furthermore, about 45% of farm wives in North Carolina performed at least one or more of the following activities that could expose them to pesticides: worked in the fields tilling the soil (16%), planting (55%), and hand picking crops (54%). Other tasks noted that may cause either increased exposure to other potentially hazardous chemicals or injuries, include applying manure fertilizer (27%), applying chemical fertilizer (26%), and driving combines (4%). Indirect exposures of women to pesticides include drinking water from wells located at close proximity to areas where pesticides are stored, mixed, or applied, storage of pesticides in the home, and contamination of the home by pesticides brought in on boots or clothing.

Kasner and colleagues (31) reported on the relative risk of pesticide poisonings, combining data from the California Department of Pesticide Regulations and the US Center for Disease Control, and the Sentinel Events Notification System for Occupational Risks (SENSOR) – Pesticide Program. They found that of 30% of a total of 2534 pesticide poisonings were in women. The relative risk in women farmers was 2.8/100,000 compared to 5.3/100,000 in men. The respective relative risks of pesticide poisoning for farm workers were 67.2/100,000 in women and 56.1/100,000 in men (most of the pesticide poisonings reported by SENSOR are mild, e.g. skin or eye irritation). The following paragraphs review adverse reproductive outcomes and cancer associated with (not necessarily cause-effect) pesticide exposures.

Fecundity was reported lower (20%) among women who were exposed to the herbicides dicamba, glyphosate, phenoxy acetic acids, and thiocarbamates (rate ratio 0.5–0.8 compared to expected) (32). Notably, when women on farms did not report having these exposures, reported fecundity ratios were higher (0.75–1.50). Mixing and applying herbicides and fungicides up to 2 years before attempting conception was associated with an observed lower fertility (33). An increase in early abortion (<12 weeks) was observed when preconception exposures occurred with phenoxy acetic acids (e.g., 2,4-D), triazines (e.g., Atrazine), and other herbicides. Observed elevated late abortion (12–19 weeks) was associated with preconception exposures to glyphosate, thiocarbamates, and a miscellaneous class of pesticides (34). The observed critical window of exposure to pesticides associated with spontaneous abortion appears to be during the fourth through sixth month of gestation (34).

Chapter 5 reviews in detail cancer outcomes in the farm population. Summarizing Chapter 5, mortality for all cancers is lower in farm women as well as farm men. Risks in one study were 0.84 (CI 0.76–0.92) for all cancers, 0.32 (CI 0.20–0.50) for lung cancer, and 0.33 (CI 0.12–0.92) for bladder cancer, compared to non-farm residents. Summarizing cancer in farm women, the overall risk for breast cancer is lower than expected. In fact, there seems to be a protective factor in farming such that breast cancer risk declines with increased duration of farming. However, there is an elevated risk of breast cancer in those women who reported being present in fields during or shortly after pesticide application, and for those who reported not using protective clothing while applying pesticides (35). Furthermore, risk in female farm residents is elevated for non-Hodgkin's lymphoma (RR = 1.52, CI 0.96–2.39) (36). Additional details of the health effects of pesticides are discussed in Chapter 6.

Agricultural Dust Exposures

Dust-related respiratory diseases are a major concern for women on the farm (37). A study of ten selected family farms in Poland indicated that women spend a significant amount of their farm work time involved in dust-generating activities, including care of animals, sowing, planting, and harvesting of crops, and manual loading (30 hours/month) of grain (12). These women were exposed to levels of dust ranging from 3.5 to 9.3 mg/m^3. The exposure limit for grain dust in most industrialized countries is 4.0 mg/m^3, but 2.5 mg/m^3 is the recommended limit for exposure to dust in livestock and poultry confined animal feeding operation (CAFO) facilities (38). Although there has been little research on farm women to determine the specific prevalence of organic dust-related respiratory illnesses, one study suggests that farmer's lung is highly prevalent among Finnish farm women (39). The probable risk factor is cow milking and exposure to moldy hay among other organic dust exposures.

Although women are commonly exposed to agricultural dusts, one survey report indicates that women farmers have significantly lower respiratory illness prevalence compared to the general population (40). However, as livestock production has become more confined, one might expect a future increase in the prevalence of respiratory illness in women from agricultural dusts. Women's work (as hired labor) on farms is expanding in the area of swine production and large dairies as they are sought out for their skills in working with the birthing (farrowing and calving) tasks in swine and dairy production respectively.

Risk of Adverse Pregnancy Outcomes and Perinatal Illness

Carbon monoxide, nitrate toxicity, oxytocin and prostaglandin exposures are hazardous to pregnant women who work in agriculture and/or their unborn fetuses. *Carbon monoxide (CO)* is a toxic gas frequently encountered in livestock buildings where fossil-fuel heating units or high-pressure washers powered by internal combustion engines are used (41, 42). Although the risk of acute CO poisoning to women is small, the risk of poisoning to an unborn fetus is much higher: because of the physiology of the human placenta the effective CO level experienced by the fetus may be twice as high as that experienced by the mother. Exposures to levels of 250–450 ppm CO (levels commonly found in swine barns with propane-powered radiant heaters, see Figure 2.1) may result in 20% carboxyhemoglobin in women. That concentration has been associated with lowered birth weights and retarded mental development in their newborn infants. Higher levels (above 450 ppm) may be associated with acute abortion (42).

Young infants who are fed formula made up with water high in *nitrate* concentrations (>10 mg/L) have the potential to be poisoned. The nitrate becomes reduced in the gut to nitrite, which when absorbed into the bloodstream of the fetus chemically bonds to the hemoglobin molecule of red blood cells, displacing oxygen and resulting in an anoxic condition. Light-skinned babies develop a blue tinge to their skin, thus the condition called "blue baby". This situation is covered in more depth in Chapter 7.

Women working in livestock production are likely to administer hormones used to assist parturition in swine and cattle. *Oxytocin* is a commonly used product that assists uterine contractions and milk let-down. *Prostaglandins* are also commonly used in livestock production to induce partition, terminate a pregnancy, or stimulate and synchronize estrous. An unintended needle stick of a pregnant woman with

FIGURE 2.1 A propane-powered radiant heater, which increases the level of CO in swine barns. Exposure to CO has a risk of prenatal and birthing complications in women.

either of these products can cause her to miscarry or abort (20). Furthermore, skin or mucous membrane contact with prostaglandins may result in abortion (43). Details of these needle stick hazards are described Chapter 12.

Zoonotic Infections

Contracting any zoonotic or environmental infections, including brucellosis, Q fever, or Listeria, may cause abortion. Pregnant women working with cattle, sheep, and goats need to be especially aware of this risk (20) (see Chapter 13).

Behavioral Health and Farm Women

Generally speaking, farm life appears to be protective of severe adverse behavioral/mental health. More specifically, Hillemeier (44) found that farm life was protective of depression and anxiety compared to rural non-farm life. Specific protective factors associated with farm life include (1) a positive spirituality and religious practice, (2) high self-esteem, (3) a strong social support network, and (4) being married. However, farm life has stressful components which if endured chronically can lead to anxiety and depression among both men and women. However, anxiety and depression are more common (two- to threefold) in farm women than in the general population. Data from a study of 764 rural women in Pennsylvania revealed 28% of respondents reported having had a diagnosis of anxiety or depression (44). The gender difference in depression among the farming population appears to be similar for all industrialized countries (45). A major cause of depression for women is chronic stress associated with the decreased economic, social, emotional, and physical well-being of family members (45). Women commonly feel responsible for their family's health, and poor access to adequate healthcare services in many rural areas may add to a woman's stress level. Other risk factors for depression and anxiety include obesity, diabetes, not being married, and poverty (44). Lack of access to mental health services likely exacerbates the risk. One survey (46) revealed more than half of rural women were unsatisfied with the healthcare services available to them, a strong determinant of stress for them. Women may feel the strain of the financial burdens on the family, also a major contributor to stress (47). Fatigue also increases stress. Fatigue can originate from the woman's often triple workload of jobs on the farm, in the home, and (in many instances) in off-farm employment. As mentioned above, in North America nearly 60% of farm women work off the farm either part-time or full-time. These multiple roles must balance, or there is an increased risk for stress and depression. Farm pressures have a tendency to strain marital and family relationships, influencing the happiness of children. This may lead to additional tension build-up and increases the likelihood of depressive symptoms and substance abuse (45). The symptoms of depression most likely to be reported are headaches, backaches, muscle pain, sleep problems, fatigue, and abdominal pain (48). However, rural women are not likely to discuss depression with their primary healthcare providers (49) due to a perceived lack of time of the provider, geographic isolation, stigma about depression, and perceptions that primary providers are not interested (50).

Prolonged depression can lead to more severe illness. Women with severe and persistent mental illness have more physical medical illnesses and earlier mortality than women in the general population (51). They can also be very troubled over gender-related health concerns, such as unresolved grief over child loss, isolation from family, bodily changes, lack of sexual partners, and diminished sexuality. Few studies have been performed on investigating preventive health care for rural women with mental illness (52, 53).

Misconceptions and lack of information about health care and farming risks can be health risks. In a study of 102 rural women, most underestimated their risk of certain chronic illnesses (54). Farm women generally perceive they have a low risk for coronary heart disease, stroke, breast and colorectal cancer, osteoporosis, and depression. This perception can lead farm women to not seek professional health care for themselves and their families, and can lead to physical decline and increased mental strain. Additional details of mental and behavioral health are discussed for agrarian people generally in Chapter 10.

2.2.2 Prevention

Too often, safety education for the farmer is aimed at men. As previously mentioned, women may be undereducated about risks in farming. Women on the farm need to be trained to perform their own agricultural work more safely, such as safe animal-handling (11) and safe pesticide application and laundering of contaminated clothing. Ideally, farm safety education should include women, the rest of the family and hired workers together. This family focus will not only help women directly, but will indirectly help the entire family, as social support is important in promoting safe behavior. Furthermore, as women often take on a special care-taker role in the family, this information can provide them with the support and confidence to be the family safety and health advocate, enabling management of their farm health and safety concerns, helping them to feel more in control, and thereby reducing stress (54).

Examples of helpful information for women include not only general injury prevention measures on the farm, but also the importance of cancer screenings and other wellness care services. Knowledge of the availability of general health and mental health care services in the area for agricultural families may be sparse. However, knowledge of availability and access to appropriate healthcare services is essential for effective utilization (55, 56). Assurance of adequate health services for farm women and their families may secondarily help reduce stress and depression.

The risk of women's exposures to agricultural chemicals such as pesticides can be significantly reduced if general preventive measures are taken, as detailed in Chapter 6. Women, men, and children who wash the clothes of those exposed to pesticides should wear protective gloves. The clothes should be washed separately and rinsed at least three times. Unfortunately, only about 6% of farm families practice this method (31). When working in operations where there are respiratory exposures, appropriate respirators should be worn, as described in Chapter 15.

In addition to standard safety practices, pregnant women must take extra precautions to prevent accidental needle sticks with oxytocin or prostaglandins. Veterinarians dispensing these drugs to farm operators should be sure to transmit appropriate safety precautions for women. Furthermore, pregnant women should not work in livestock or other buildings where heaters, internal combustion engines, or another source of carbon monoxide is present unless an observational evaluation or an environmental assessment indicates the environment is free of CO.

Finally, education of health care and public health practitioners about farm women and their health exposure risks is important (57). Providers generally have little knowledge of farm women's exposures and resultant health risks, and they rarely take an occupational history. Providers who have knowledge and demonstrate an interest and understanding of the farm environment will be more able to elicit health information and increase the trust and respect of their female farm worker patients (58).

2.3 Youths in Agriculture

Youths (under age 19) commonly work on farms as part of a family operation, as part-time or full-time farm workers, or as labor, accompanying their parents, who may be migrant or seasonal workers (59). Children living on farms may be exposed every day to potential hazards just by living or playing on the farm (Figure 2.2). Children not living on farms may be exposed to farm hazards while visiting a farmer relative or on a casual farm visit such as to a farm involved with agritourism or community supported agriculture (CSA). Agritourism is a growing international phenomenon that provides an alternative economic base for small farms while providing non-farm people with a farm experience. CSA farms link with community residents, providing them with weekly baskets of fresh produce and allowing the customers to visit and possibly work on the farm. In the United States (2007), more than 23,000 farms provide agritourism and nearly 13,000 farms provide CSA opportunities (60). This phenomenon has expanded the population at risk to farm health and safety hazards. In the United States (2012) an estimated 2.5 million youths were exposed to a farm environment (61). This included 955,400 living on farms (49% of these also work on the farm), 258,800 youths hired as farm workers, and 1.2 million farm visitors as relatives, friends, or for other purpose such as agritourism (62). Detailed statistics of youths injured on US farms are collected by the National Institute for Occupational Safety and Health (NIOSH) and the USDA, with review and dissemination by the National Children's Center for Rural and Agricultural Health and Safety (62, 63).

FIGURE 2.2 A child on a farm. (Source: Medical Practice in Rural Communities, Chapter 2, page 20 top, book authors: Cornelia F. Mutel, Kelley J. Donham, Rural Health and Agricultural Medicine Training Program, Department of Preventive Medicine and Environmental Health, College of Medicine, The University of Iowa, Iowa City, Iowa 52242, U.S.A., © Springer-Verlag New York Inc., 1983. Image reprinted with kind permission of Springer Science and Business Media.)

Most farms are still family businesses; the practice of children to work on the farm is embedded in the culture and tradition of farming. Parents want children to be with them so they can teach, share, and develop traditional farm values. Children typically want to work on their farm. They want to be with their parent(s), and their work creates appreciation and acceptance by the adult world and thereby builds their self-esteem, extending to generations forward the benefits of growing up on a farm (2). Another reason why children may be with their parents working on the farm is the lack of an alternative for childcare. In other instances, youths working on the farm may be an economic necessity.

Table 2.1 Things children learn when growing up on a farm

Responsibility
How to work
Independence
Understanding of life and food cycles
Initiative
Problem solving
Parental connections
Neighborhood connections

In addition to the cultural and social values gained from growing up and working on a farm (64), there is increasing evidence of protection against allergic asthma and other allergy-mediated illnesses. Being born and raised on a farm seems to afford a lifelong protective factor for the development of allergy and other atopic-mediated allergic conditions (65–68). Furthermore, the protective factor may extend beyond the farm gate, as one study has shown evidence for a general rural asthma protective factor (69). Genuneit and colleagues (70) published a meta-analysis of 39 studies on the farm protective factor. They found that the weight of evidence is statistically significant and affords approximately a 25% lower risk for atopic asthma. This phenomenon has been called the "hygiene hypothesis" of protection and relates to exposure modulation of the immune system control mechanisms and inflammation (71). It is hypothesized that early exposure down-regulates the usual mediators of inflammation (especially the toll-like receptors) and the cellular immune system. A more detailed discussion of this observation is given in Chapter 3.

Table 2.1 lists the positive things children who work on farms can learn. Children can work safely on farms if the work is developmentally appropriate and if there is quality parental supervision.

As well as the advantages of growing up and working on a farm there are challenges in keeping these youths alive and well in the midst of a hazardous environment. In recent years, approximately 100 people under 19 years of age have been lost to fatal farm-related incidents. The fatal injury rate for farm youths is 10.1/100,000 (61) (about three times higher than the occupational fatality rate of all US workers under 19 years). The highest risk age groups for fatal incidents are preschoolers and late teenagers (61, 62, 72).

Over 20,000 non-fatal injuries and illnesses in farm youths have occurred annually in recent years (22,894 in 2006) (62, 72). Fifty-one per cent (11,676) of those injuries occurred in youths living on farms, of which 20% (2335) were work-related, 6% were young hired workers, and the balance (43%) were farm visitors (72). Boys were the victims in about 66% of the total injuries.

Besides the emotional stress related to youth injuries (loss of a child is one of the most emotionally stressful events a parent can experience), there are serious economic consequences. Zaloshnja (73) has calculated that farm injuries and fatalities create expenses of $1.4 billion per year in the United States (2005 dollars).

In spite of the current challenges in keeping children safe on farms, there have been some encouraging trends over the past two decades. Comparing 1998 data to 2012 data, there has been a 30% decline in the number of injuries and a decrease in injury rates (non-fatal and fatal combined) from 16.6/1,000 to 6.4/1,000 (a 61% reduction). However, there has been a slight increase in rates for the under 10 years of age group. Whereas boys historically have experienced over twice the injury rate of girls, the injury rate gap between genders has narrowed (61, 62, 72).

2.3.1 Work Exposures/Risks Factors

Physical injuries, drowning, and pesticide exposures are the major risks for farm youths. The principal sources of physical injury exposure for youths include tractors and other farm machinery, large livestock, motor vehicles such as all-terrain vehicles and pickup trucks, and work/falls from high places. Nearby water (e.g., farm ponds, manure storages) are important drowning hazards. Electrical exposures and resultant flash burns, and mixing or applying pesticides are other minor youth exposure hazards (74).

Physical injuries are the main hazardous risk for youths on farms. As previously mentioned, farm-related injuries are more common among boys (about a ratio of 3:1). Most boys begin working on family farms around the age of 10. Sixty-seven per cent of boys ages 15–18 operate tractors unsupervised (13). Girls commonly start working at age 15 (13).

According to several studies, fatal and non-fatal injuries in farm youths are related most commonly to animals and tractors (75–77). Thirty per cent of the fatalities are related mainly to tractor incidents (with a small percentage for other machines) and 17% to motor vehicles (mainly all-terrain vehicles). Boys tend to perform tractor-related chores more often than girls. Boys aged 16–18 have the highest risk of injury from tractors (78). Injuries involving tractors are most likely rollovers or run-overs, and these incidents result in a very low (33%) survival rate (75).

Drowning accounts for 16% of farm youth fatalities. Non-fatal events result from three primary exposures: (1) trips and falls, (2) motor vehicles (mainly all-terrain vehicles; 11% or 2458), and (3) animals (mainly horses; 26% or 5913) (72).

Girls are more often involved in animal-related tasks (79). One in five youth injuries on farms is animal related, and of these injuries, 69% are work-related (80). Work-related injuries are mainly associated with cattle, and non-work-related injuries for girls commonly involved horses (80).

Flower (81) conducted a nested cohort study of farm injuries in 21,360 farm youths within the Agricultural Health Study. The Agricultural Health Study is a long-term (over 20 years) prospective cohort study containing over 89,000 private (mostly farmer) and commercial pesticide applicators from Iowa and North Carolina. They found the risk of a fatality in farm youths was elevated nearly four times (OR 3.9) if they were doing farm work. Machinery–related fatalities were elevated over nine times (SMR 9.25, CI 5.1–16.7). Other fatal risk factors included if the child's mother was less than 25 years old at the child's birth (OR 2.2) and if there were three or more children in the family (OR 2.8). These latter data suggest that not only work exposure, but maternal experience and supervisory ability with several children increased the risk of a fatal injury or illness in a farm child.

Youths who work on family farms or are employed on non-family farms are at risk for injury (82–84). However, young hired farm workers have a lower risk rate than those living or working on their own family farm (61). Teenage workers on a family operation are likely to work fewer hours per week but more seasons out of the year, and perform a greater variety of (potentially hazardous) tasks compared to teens working on non-family owned farms (85).

Common serious injuries and those most often requiring hospitalization include orthopedic, neurological, thoracic, and abdominal injuries (75). A large portion of injuries on farms occur during times when school is not in session and/or during intensive seasons of farm work such as in the summer (44%) or on weekends (27%) (76).

Drowning is an important source of fatal incidents in farm youths for both young farm residents and farm visitors (86). An average of 32 farm youth drowning deaths occur annually (2.2 deaths/100,000), a slightly higher annual rate than for the United States overall (2.3 deaths/100,000) (86). Drowning was found to be the most common cause of death for farm youths under 10 years of age in Australia (87). Drowning fatalities most commonly occur in dams, farm ponds, manure storage structures, tanks, creeks, or rivers.

Pesticide exposure is a possible concern for children working, playing, or just living on farms. Some child activities that increase pesticide exposure are playing near unsecured pesticide storage facilities and playing in farm fields, in dirt near fields, and in irrigation channels (88, 89). Exposure may also occur by eating while working, eating fruits and vegetables without washing, and applying pesticides. Children may not be provided with protective clothing for work activities where exposure may be possible.

Pesticide sampling in homes indicates the possibility of in-home exposure. However, most samples have revealed herbicides such as atrazine in vacuum samples, which are much less toxic than insecticides. Urine tests indicate there is little absorption among children from this exposure (90). Several researchers have investigated the risk of cancer in children whose parents have been exposed to pesticides. Vinson (91) and colleagues conducted a meta-analysis of over 40 such studies. They found no relationship between parent contact with pesticides and cancer in children in cohort studies. However, in case-control studies (usually less robust than cohort studies) they found a slight elevation of leukemia and lymphoma in the children of mothers exposed to pesticides in the prenatal period. In addition, they found a slight increase in brain cancer in children whose fathers were exposed to pesticides.

Zoonotic infections are another risk for young children. Those under 10 have an increased risk (two to ten times) compared to the general population for acquiring infections and particularly the animal fecal-associated organisms *Campylobacter, E.coli,* and *Salmonella* (92–94). Furthermore, young children are at risk of developing infections from antibiotic-resistant organisms (95).

There are conflicting reports of *respiratory exposure risk* in farm youths. Contrary to the protective findings for atopic allergic conditions, one study revealed a higher rate of doctor's diagnosed asthma in farm youths, especially from those farms that used antibiotics in animal feed (96). The reason for the discrepancy with previous findings is uncertain. The biological plausibility of this finding is not clear, and the methods of asthma diagnosis were different from previous studies, which may explain the variant results. Atopic status was not determined in the later study.

As mentioned previously, the weight of evidence indicates that farm exposures for children are protective for atopic allergic diseases (hygiene hypothesis) and perhaps other non-allergic inflammatory airway conditions. One should understand, however, that asthmatic symptoms in agriculture populations are often not of atopic mechanisms, but are inflammatory processes, for which farm exposure may also be protective. Down-regulation of inflammatory reactions as well as allergic-mediated illnesses can and does occur.

2.3.2 Prevention

Farm Safety for Just Kids (FS4JK), NIOSH (Childhood Agricultural Injury Prevention Initiative), the National Children's Center for Agricultural Health and Safety (97), the Childhood Agricultural Safety Network (CASN) (98), and the Progressive Agriculture Foundation Safety Day (99) among others have led a robust effort for farm youth safety in North America. Effective prevention strategies, progress to date, and future directions are laid out in the 2012 National Action Plan for childhood agricultural injury prevention (100). Furthermore, there have been numerous publications on interventions and evaluation in the field. The following paragraphs summarize these efforts and recommend best practices.

The general principles of prevention are reviewed in Chapter 15. They can be applied to any subgroup of the agrarian population. However, prevention of injuries and illnesses in farm youths is an especially complex proposition. There are five key critical considerations that determine effective interventions for this population:

1. Methods of intervention must vary with different exposed subpopulations. These include children on family farms, non-working children accompanying migrant and seasonal farm workers, hired youth farm workers, and children as farm visitors.
2. Most injuries to farm youths are not a result of farm work, but arise from living and playing on their own and other farms.
3. The divide between farm culture and the culture of health and safety professionals and urban populations has to be managed.
4. An extensive array of resources and assistance exists for youth farm safety in the United States and most developed countries but is under-used.
5. Awareness-level education alone (although by far the most practiced intervention) has generally proven of little value in long-term prevention. Comprehensive community programs with multiple modalities are the way to effective prevention.

These considerations will be dealt with in the following sections.

Different Methods of Intervention for Different Groups of Farm Youths

As mentioned above, prevention strategies must fit the youth subgroup targeted to have the best chance of making a difference.

The largest subgroup by far (nearly 1 million in the United States) of children exposed to farm hazards are those living and working on family farms. About half of these children are under 10 years of age. This age group of children may not do a lot of actual work on the farm, but they live and play on the farm, often without parental supervision. Hazards are present in their living and playing environment. Ponds, farm animals, and machine shops present "inadvertent" injury hazards. Parents and guardians are the responsible persons and the essential link separating children from hazards. Basic prevention for farm youths can be categorized in efforts to (1) identify and remove the hazards, (2) create barriers to hazards that can't be removed, (3) afford effective supervision, (4) model/mentor safe behaviors, and (5) advocate for effective policies and practice existing policies and safe practices at the farm level.

Removal of Hazards

The most effective intervention is to identify and remove the hazards. This requires a parent or trained unattached third party observer to audit the farm, identify hazards, and invest resources into removing them. As it is common for people to walk by unnoticed hazards daily in their living and working space, several programs have been developed to assist the parent/farm owner operator to identify and remove hazards. A checklist used by a trained third party auditor or family can assist the auditor to identify the hazards (e.g., accessible chemical containers, potential unguarded fall or trip hazards, etc.) and remove them. The Farm Safety Walk About was developed by Iowa's Center for Agricultural Safety, but now has been adapted and disseminated by the Iowa Department of Public Health among other organizations (101). The Certified Safe Farm is a program with over 15 years of practice that uses trained auditors to work with families to identify hazards for all family members and develop a plan to remove them (102).

Creating Barriers

A farm safety walkabout might reveal hazards that cannot be removed, but can be guarded to prevent access. Examples of hazards for which barriers could be erected include fences around ponds and manure pits, and locked access to stored farm chemicals. Safe, secured play areas are another barrier to farm hazards. Directions for developing safe play areas are available at the National Children's Center for Agricultural Health (103). Other barriers include preschool, school, and after-school programs. These are critical as 60% of women and nearly 40% of men are working off the farm and not available for child supervision on the farm. As farm families have increasing multiple roles involving on- and off-farm work, the need for rural childcare becomes more important. As mentioned previously, full-time off-farm parental employment implies that off-farm childcare is in place, reducing child exposure to farm hazards. Hawk (16) has found that full-time working mothers usually have off-farm safe daycare, separating children from unsupervised farm activities. However, part-time off-farm employment or no off-farm employment dramatically increases the potential exposure of children to farm hazards, as childcare may be non-existent or with casual arrangements such as a local relative (e.g., a grandparent) who also lives on a farm, allowing farm exposure. Solutions may include the involvement of retired persons or high school age children in the home or in day care facilities outwith the home. Parents and school organizations need to advocate and work toward the accessibility and quality of such programs in their school districts.

Effective Safety Supervision

Effective safety supervision of children on farms is compromised by the following realities: (1) parents commonly work off the farm, (2) intense seasonal farm work periods demand the total attention of the farmer to farming, (3) the tradition and culture of children (including preschool ages) to accompany and work with parents (up to 80% of children) on the farm, (4) parents have inflated confidence in their ability to keep their children safe under their supervision, and (5) there is a disconnect between parents allowing certain farm tasks, and the actual developmental readiness of children to safely perform these tasks.

Effective supervision is about being available, determining when, what, and how much supervision is needed, and anticipating danger. Every year farm children are injured, many fatally, even in the presence of a parent and sometimes as the unintended consequence of a parental action. The extent of supervision practices obviously vary with the age of the child. Very young children may need to be at arm's length. Physical distance or supervision will lengthen with age and the nature of the child.

Modeling and Mentoring Safe Behavior

As children attain working age, supervision in this author's experience (KJD) does not include the parent evaluating the "developmental readiness" for the task or teaching the child how to do it safely. This observation was verified by a study on family farms in Canada (104). The authors of this study suggest that supervision of children as they enter farm work should be modeled after an apprenticeship. The parent should teach the correct way to accomplish the task, model the behavior, and teach safety practice and risks. The authors suggest that good parental modeling (apprenticeship) is a much stronger predictor of children adopting safe behaviors than awareness education aimed at the child. The emphasis on education and behavior change may therefore be better focused on parents. Children develop physically, cognitively, socio-culturally, and perceptually at various ages. All these developmental aspects directly relate to the injury risk of conducting different agricultural tasks (North American Guidelines for Children's Agricultural Tasks, NAGCAT) (105). The key to success of the NAGCAT program is to teach parents about these developmental stages so that they will adopt the recommendations, and assign and supervise tasks relative to their children's developmental age. In this way kids receive the benefits of work that they should be able to accomplish safely, with appropriate quality parental supervision. Several barriers stand in the way of broad adoption of this program, including matching parental perception and guideline value with actual behavior. A survey of farm parents (13, 106) revealed that parents think kids should be 15 to safely operate a tractor. However, most male children begin to operate tractors at age 10–11. Fathallah (107) further described the disconnect, pointing out that most kids of 12–16 years of age may not be able to reach the controls on many different tractor models. Engaging parents as supervisors promises to be more effective in the prevention of injuries and illnesses to children on farms relative to awareness-level education directed only to children.

Practicing Existing Policies

For children working on their own family farms in the United States, no federal or state regulations apply. However, a national policy conference held in Iowa in 1997 (Tractor Risk Abatement and Control: The Policy Conference) (108) included recommendations that youths under 16 should not be allowed to operate a tractor without a rollover protective structure (ROPS) and seat belts. An additional recommendation was that a valid driver's license should be required (a minimum 16 years of age is required for a driver's license in most US states) to operate a tractor on a public road. Although most of these recommendations were never enacted nationally, the state of Wisconsin does have the latter rule in effect. These recommendations could and perhaps should be adopted in intensive agricultural states to protect youths driving tractors.

US health and safety regulators and the general public are increasingly concerned about the protection of farm youths. The US Department of Labor (DOL), under the Fair Labor Act, Child Labor Law, has had regulations for many years (discussed in more detail in Chapter 15) intended to cover children under 16 who work on farms other than the home family farm (109). This law forbids children under 16 from working at highly hazardous tasks, such as driving tractors over 20 HP, running power take off machines, and working with bulls and boars. However, 14 and 15-year-old minors who hold certificates of completion of either the tractor operation or machine operation programs of the US Office of Education Vocational Agriculture Training Program (provided mainly by State Extension and 4H programs) may work in tasks for which they have been trained (110). Eligible tasks are listed in items 1 and 2 of the Hazardous Occupations Order for Agricultural (HOOA) (details of HOOA are given in Chapter 15). Individual states may have some additional restrictions for young agricultural workers, but those regulations primarily pertain to maximum work hours, minimum wages, and assurance that work does not conflict with school hours. In 2012, the DOL attempted to upgrade the agricultural youth work laws to make them equivalent to protective standards for youths working in occupations other than agriculture. The basic change was increasing the age of working on non-family farms without training from 16 to 18. However, there was a strong push back from several elements of the farming community, fearing government intrusion on private rights and hindering the training and acculturation of children in farm operations. The lack of farmer consultation in bringing in the new proposed regulation serves as an example of the disconnect between the culture of the farm community and regulators.

The past decade has seen an increasing non-farm/general public concern about youth safety on farms. Occasionally, anecdotal accounts of discussions among individuals and in the newspapers arise when a child dies in a farm incident where there was apparent parental neglect. Some advocate legal action for child endangerment. The public's concern may lead to more stringent rules in the future.

All of the points mentioned above dealing with youths working off the family farm (children under 16) apply to children of migrant and seasonal farm workers who may be hired as farm workers. However, there are different considerations for young and non-working children who accompany migrant and seasonal workers.

Non-working Children of Migrant and Seasonal Workers

For protection of children of migrant and seasonal farm workers, provision of sanitary and safe housing, preschool, and school programs are essential. Migrant housing has historically been poor. However, some voluntary standards (e.g., the Gold Star Program in North Carolina) have helped to raise the standard for farm worker housing (111). Furthermore, new standards are now in force from the US DOL under the Migrant and Seasonal Agricultural Worker Protection Act (112). In addition, the Employment and Training Administration of the US DOL provides assistance for social services, which could include child services and education for migrant and seasonal farm worker communities (113).

Injuries to Farm Youths not as a Result of Farm Work

As mentioned above, preventing non-work farm injuries to children requires the education of parents, the removal of hazards, and the creation of safe barriers. Injuries that are not work-related can be diminished by proper adult supervision of play, instructing children in safety rules, and designation of specific play areas out of harm's way (13, 103, 106). Supervisors of young children who are around farm machinery or farm animals also should keep them from life-threatening situations. Taking children (or anyone) as an extra rider on a tractor is very common, but it comes with risk, as 25% of all tractor-related deaths are a result of run-over, many because of extra riders. Farm safety specialists oppose extra riders without a properly designed extra rider (training) seat and accompanying seat belt.

The Cultural Divide Between Farm Populations, Health and Safety Professionals, and the General and Urban Population

The tradition of family participation in farm work is strong. Parents want to maintain this tradition (2, 25) and it is important for the development of child and family, and for preparing the next generation of farmers (104). Additional cultural factors (as reviewed in more depth in Chapter 15) create challenges to establishing prevention programs for farm youths. These include (1) independence, (2)aversion to regulations and mistrust of advocates for regulation, or people who lack a farm background or understanding of production agriculture, (3) acceptance of farm work as hazardous and the injuries and illnesses that might result, (4) maintaining the positive economic status of the farm rather than focusing on safety, and (5) acceptance of awareness-level education for children but not recognizing more effective intervention options.

Given these sociocultural barriers, how can one best work to develop effective interventions? One can challenge it straight on as was done in a fairly recent poster campaign that showed a photograph of a man (perhaps a grandfather) driving a tractor without ROPS or cab holding a preschool aged child on his lap. The title above the picture was "It is easier to bury a tradition than to bury a child" (114). The effectiveness of this campaign is not known, but it is only one component of an intervention. Interventions must be compatible with the culture and cannot interfere with the farming operation. The views of farmers should be considered. Interventions should be seen as something positive (or at least not costly) for the economics of the operation. Finally, multiple modalities should be planned as opposed to a single modality. These factors are reviewed in detail in Chapter 15.

Utilizing the Extensive Library of Resources and Assistance for Youth Farm Safety

As mentioned previously, there is an extensive array of resources and organizations to facilitate prevention of injuries to young people on farms. The majority of these programs are single modality awareness-level education programs, aimed at farm youths without a theoretical basis or good design to allow a critical evaluation. Gallagher (115) conducted a meta-evaluation of 26 published farm youth interventions. Eighteen of these studies were awareness education only, three had an engineering component, and only two involved enforcement or multiple modalities. The outcomes generally showed some short-term gains in knowledge, but none identified any gains in higher orders of prevention, the most important being actual reduction of injuries or illness. Gallagher felt those involved in youth safety were "stuck" in the education mode, while interventions more rigorously designed with a theoretical framework and multiple modalities have more proven potential to reduce illness and injuries. There are some critical barriers to advancing the field of intervention in agricultural safety and health. First of all, higher order levels of intervention (i.e., engineering and regulations) are expensive and difficult to fund. Second, regulations are culturally invasive to farmers and provoke a strong negative and defensive reaction. However, the farm community will generally accept voluntary safety education (which has shown a very low level of long-term improvement in safety behavior). This leaves us with difficult choices to know how to proceed with sustainable and effective prevention.

2.3.3 Going Beyond Awareness-level Education Aimed at Farm Youths

This author agrees with Gallagher (115) and Sanderson (104) that if education is used, it may be better to focus on the parents than the children. In addition, education should just be one part of a multi-modal intervention. Such programs should be community-based with leadership that helps assure sustainability. The Iowa model of multiple modalities of intervention (see Chapter 15) discusses a framework for developing such a comprehensive program within a community. There are many potential community leaders to help develop and lead such a community-based effort. Examples include a school parent–teacher association, a farm organization with local chapters such as Farm Bureau, a 4H chapter, a Future Farmers of America (FFA) chapter, a local AgriSafe provider, or a local FS4JK chapter. Based in Urbana, Iowa, FS4JK advocates for farm children and produces numerous programs with special methods designed (116) to help families create and maintain a safe environment for farm children. This organization has developed and maintained a network of some 110 local chapters in North America, with activities also in Europe and Australia. Local communities collaborating with this organization can help to obtain the support, advocacy, and information dissemination of parents and children to develop and maintain safe environments for farm children. Whereas FSFJK is primarily aimed at families and children up to high school-aged youths, another curriculum for high school-age youths has been developed called Agricultural Disability Awareness and Risk Education (AgDARE) (117). Students participating in this program perform two types of simulations. In one simulation students make decisions about actions they would take in hazardous farm work situations. The other simulation is a physical one where the student assumes a disability and performs simulated farm work (118, 119).

Although a meta-analysis of 26 published programs found little evidence of long-term effectiveness (115, 120), the results of a few programs have shown some longer-term changes that point to potential positive approaches to youth safety on farms (119, 121). Parent involvement in educating children on safety measures is essential. Educating children requires that the parents must educate themselves about the dangers in agricultural work, and they must value and practice safe

Table 2.2 Farm youth prevention resources, organizations, and program materials

Title	Comments
Resources available from The National Children's Center for Rural and Agricultural Health and Safety (NCCRAHS; http://www3.marshfieldclinic.org/NCCRAHS/)	
Safe Play	The Safe Play booklet is a resource to assist in designing a play area that is based on the characteristics of children who will use the area, adult supervision, and the site's agricultural and environmental conditions. Recommendations for play activities are provided.
Creating Safe Play Areas	This mini edition contains information on child development, selecting a site, planning and designing play areas, fencing, and ground cover. It also contains play ideas and links to additional information.
Agritourism Health and Safety Guidelines	Along with the Agritourism Policies and Procedures Checklist Guide and the Worksite Checklist Guide, these resources can be utilized to identify safety issues so actions can be taken to prevent or control hazardous exposures to guests visiting the farm. General safety information has been integrated into the Agritourism guides (http://www.safeagritourism.com/).
Pesticides Nearby	This comic book targets migrant and seasonal farmworker families and helps educate parents about pesticide safety and ways to minimize risks to their children.
North America Guidelines for Children's Agricultural Tasks (NAGCAT)	The NAGCAT professional resource manual provides comprehensive information and detailed analyses of agricultural hazards, supervision, and parental responsibilities for 62 different tasks (http://www.nagcat.org/nagcat).
NAGCAT posters	NAGCAT posters are a resource to assist parents in assigning farm jobs to their children (7–16 years of age). They help answer questions regarding the role of their child in developmentally appropriate work. They also assist clinicians who advise parents on practices regarding working children.
Safety Guidelines for Hired Adolescent Farm Workers (available in English and Spanish)	These guideline posters address supervisor responsibilities, teen characteristics, training and supervision tips, and pertinent federal regulations with communication links to local agencies to obtain state-specific child labor regulations.
Seeds of Safety	These safety sheets contain basic facts and prevention strategies to assist states and communities with preventing injury to children and adolescents. They can be distributed at clinics, hospitals, etc.
Bury a Tradition campaign posters	This national campaign aims to keep kids younger than 12 away from tractors.
I Didn't Know campaign	The American Academy of Pediatrics recommends that children under 16 years of age do not operate all-terrain vehicles.
Harvesting Health	Harvesting Health is a series of single-page sheets that answers frequently asked questions about health and safety issues commonly found on farms.
The Childhood Agricultural Safety Network (CASN)	Facilitated by NCRAHS, CASN is a coalition of organizations to help prevent injuries to farm youths. This organization provides useful information and collaboration among stake holders (http://www.childagsafety.org/).
Resources from Farm Safety for Just Kids (http://www.farmsafetyforjustkids.org/?page_id=32)	
Animal Safety	Animal safety is an issue for rural and urban youth. This educational package includes demonstrations and animal safety brochures with teaching resources. New games and puzzles, safety information, and a wildlife section have been included.
Chemical Safety	Use this package to teach kids how to identify safe substances from their chemical look-a-likes, how to read a product label, and more.
Rural Roadway Safety	Use these resources to teach kids about the hazards of driving in rural areas, whether they're driving farm equipment or standard vehicles.
ATV Safety	All-terrain vehicle (ATV) use is on the rise and so is the need for ATV education and training. This package teaches children the importance of personal protective equipment (PPE) and certification courses.
Tractor Safety	This educational package is designed to teach tractor safety to elementary through middle-school students. The main objective of educating children, especially young ones, about tractor safety is to teach them to stay away from tractors. Tractors hold potential hazards not only to the driver, but to those in close proximity.
Resources from eXtension (http://www.extension.org/farm_safety_and_health)	
eXtension	eXtension is an interactive learning environment. This website has resources and information on farm youth safety in addition to a portfolio of wide-ranging topics produced by university professionals.

behaviors. Furthermore, families planning to have children should also know of the preconception and prenatal risks involved in agricultural exposures and take measures to prevent and avoid unnecessary exposure.

Assignment of tasks to children must match the developmental capabilities of the child (discussed previously), accompanied with affective supervision. Mason *et al.* (122) studied a group of young farm workers over a 6-year period and found about half of the children injured were below the appropriate developmental ages recommended for those tasks. To assist farm parents and supervisors of young workers in assigning safe tasks and supervising those tasks, a group of farm safety specialists and developmental specialists developed the North American Guidelines for Children's Agricultural Tasks (NAGCAT) guidelines (105, 123). These guidelines list the appropriate developmental stages of a child to allow parents to match these to their ability to perform specific tasks safety. Examples of some of the guidelines include (1) children must be 16 or older to drive an articulated tractor or to drive on a road, (2) children should be at least 16 to work in a CAFO unsupervised, and (3) children should be at least 16 to clean grain bins unsupervised. More guidelines for determining appropriate tasks can be found at the NAGCAT website (97). Contact information for NAGCAT and other organizations along with available resources are given in Table 2.2.

2.4 Elderly Farmers

Farming is the occupation with the oldest workers in the United States (124) (Figure 2.3). This applies primarily to owner operators of family farming, rather than hired farm workers. In the year 2012, the USDA reported (8) that 29% of all farmers were in the 55–64 age bracket (the largest age group), 21% were 65–74, and 12% were 75 and older. The mean age in 2012 was

Figure 2.3 Farmers often keep working well past the usual retirement age. The man on the far right in this photo was 91 years old and still worked daily.

58.3 years for all farmers and 60.1 for women farmers. Farmers on average are 16 years older than the average for all workers. The farming population's average age has been increasing every census. The average age was 39 in 1945, 45 in 1974, 57 in 2007, and 58.3 in 2012 (125). The longevity in farming is not as pronounced as in many European countries because the culture and social systems make it easier to retire and transfer the holdings compared to North America. However, there are similar trends in all developed countries for outmigration of the advanced educated young and staying in place of the elderly (126). An additional reason for longevity in farming is that family farming is a way of life and not just a job. Farmers do not retire because they find great satisfaction in work that gives purpose and meaning to their lives. For many, it is their life. Many want to work until they die. As one older man said in a study of elderly farmers, "If I die in a farming accident, it would be an honorable way to die; better than being hooked up to tubes and machines in a hospital bed." One thing that seems to make them stop to think about their own health risks is their grandchildren (127).

In some cases, elderly farmers think they must work to augment their retirement resources. In some cases, they may work because there is a child they hope will take over the farm in the future, or is in the process of taking over the farm, and the senior stays on to help in transition and "phase out" of the operation over several years, but remains working as long as they feel able. They may work because there is not a young person available to take over the operation. Elderly farmers work 50–100% the amount of time worked by younger farmers, and they work with arthritis and hearing loss, among other geriatric health conditions (128). They work even when injured (129). The risk for fatal injury begins to increase at age 55. A review of trends of farm fatalities over a 12-year period (1992–2004) defined the range of fatal injuries in the under-55 age group with 18–20 per 100,000, while for those over 55 it was 45–55 per 100,000 annually (130). At 65, the fatality rate is 58/100,000. The fatality rate continues to increase as farmers continue to work beyond 65. The age group 65–84 years is the highest risk age group for fatal injuries (126, 131, 132). It is clear that elderly farmers are the norm rather than the exception, and that they have special health and safety risks. Although they understand the health and safety risks of farming, their self-perceived risk does not match the actual risk (133). Risk for injury increases if the farmer has had a previous injury, perhaps due to the increased disability from the previous injury, that is, a secondary injury (134). Even though acute injuries from machinery or animals are by far their highest occupational risk, elderly farmers perceive their greatest on-farm safety risks are from electrocutions and chemical exposure (135).

2.4.1 Work Exposures/Risks

Tractor-related injuries are the most common cause of fatal injuries (87, 131, 135–137). As within all age groups, fatal tractor injuries are due to rollovers, being run over, or falling from a moving tractor or implement. Falls are also a common cause of fatalities (138), especially in the group of farmers 65 and older. Many of these fatal falls are from tractors or farm equipment. Other causes of death are moving vehicles, other machinery, livestock, electrocution, or being struck by falling objects.

Epidemiology of non-fatal injuries in elderly farmers reveals hazard sources and risks similar in pattern to fatal injuries. Falls account for 18–21% of these injuries, compared to 5% for all other workers (130, 139, 140). Most of these falls are from machinery or from heights in barns. Tractors are associated with only 11% of non-fatal injuries. Animals are also an important cause of non-fatal injuries, with elevated risk on beef and dairy farms. Injuries from animals most often involve the arm or shoulder, and hip or leg (141). Associated co-morbidities which are risk factors for injuries in elderly farmers include the effects of normal aging (e.g., loss of hearing, vision, smell, and touch, loss of muscle mass, strength and dexterity, reaction time, and cognition).

Arthritis and use of prescription medications may also increase risk (132, 134, 138, 142–146).

Fifty-six per cent of farmers over 54 years of age use prescription medications. Relative to a comparison group, the odds ratio for injuries among farmers using prescription medications was 2.8 (CI 1.0–7.7) (141). The reasons are likely some combination of impairments for which the medication is intended, and associated co-morbidities. Also, the side effects of the medications could increase risk (e.g. sedation, impaired balance, decreased reaction time). Adverse interactions of multiple medications (polypharmacy is common in the elderly) could also increase risk. Prescribing physicians should consider drug reactions and interactions in light of what the elderly farmer does in their work. Side effects and adverse drug interactions could increase the risk of injury while operating tractors or working around livestock, or doing other hazardous tasks that require a high level of function.

Epidemiology studies reveal that degenerative osteoarthritis (OA) is an important chronic injury issue in the elderly farmer. Generally, OA is associated with the aging process and heredity, and is exacerbated by long-term heavy workloads resulting in excessive chronic wear on the joint surfaces. The strenuous requirements of farm work may contribute to the development of OA. Specific risk factors include repeated lifting of heavy weights, kneeling, bending, squatting, long work hours, starting heavy work as a young person and continuing into years well past usual age of retirement. Activity in competitive sports earlier in life (e.g., American football, soccer, and wrestling) is also a contributing factor (147–149).

More specifically for farmers, degenerative osteoarthritis of the knee and hip is common, as research has defined in Europe as well as in the United States (Details of the pathophysiology of hip and knee osteoarthritis are given in Chapter 8.) All of the risk factors of osteoarthritis related to farming are unclear, but there is evidence that both male and female dairy farmers have higher risk for degenerative osteoarthritis of the knee (150). Knee replacement surgery is common in this population (147). Forestry and construction work are other occupations with high risk for degenerative osteoarthritis of the knee.

Degenerative osteoarthritis of the hip is also a common problem among farmers in Europe and the United States (148). The risk for this condition is similar to that for osteoarthritis of the knee, but tractor driving along with family history and prior competitive sports are known strong risk factors. Total hip replacement surgery as well as knee replacement surgery is common among farmers.

A study was conducted comparing loss of function among farmers relative to a comparison population of age-matched white-collar workers (151). Elderly farmers had a mean of 2.0 functions lost, compared to 0.61 functions lost for age-matched white-collar workers. Examples of function losses were demonstrated in a study of Kentucky farmers age 55 and older, which revealed that 34.2% had hearing loss, 11.4% had vision difficulty, and 50.4% had arthritis (134). Cognition deficiencies in elderly farmers may impede safety judgment and proper care of medical conditions (152). Difficulty seeing may impede avoidance reactions to impending hazards in time to prevent injury.

Depression affects 19% of Americans 65 years or older (19%). Older women are twice as likely to report depressive symptoms as older men (153, 154). Elderly Hispanics and blacks (males and females) are more likely to have depression than elderly whites. The causes of these changes are biological (body, hormone, neurotransmitter changes), environmental (social isolation, not feeling appreciated), psychological, and environmental (155). As women generally tend to outlive their spouses, many farm women are left alone, increasing their isolation. Depression in the elderly may have unique manifestations, characterized by and exacerbating the usual aging changes, including memory problems, confusion, social withdrawal, inability to sleep, delusions, or hallucinations. All of these factors can increase risk for injury when performing dangerous work tasks (156). Depression in the elderly may also be complicated with co-morbidities, such as heart disease, stroke, diabetes, cancer, and Parkinson's disease. Health screenings such as blood chemistry, cholesterol, and cancer screening are important for early diagnosis of chronic health conditions. However, like farmers in general, some elderly farmers resist seeking health care and/or wellness screening as they may perceive this as "weak" and do not want to "give in" to sickness. They may fear that a serious illness will be discovered, so they procrastinate. Furthermore, they may think they are too old to receive expensive treatment if an adverse health condition is found. Any combination of these reasons will delay appointments until they feel quite ill (157).

Elderly farmers are reluctant to adopt use of personal protective equipment (PPE) or retrofit equipment with safety and guarding structures. They may not value the protective benefit of wearing ultraviolet (UV)-protective sunglasses and ear, eye, and respiratory protection because they think their damage is already done. However, they are supportive that their children, grandchildren, and other younger people use PPE and proper machine guarding.

2.4.2 Recommendations for Prevention

Prevention for elderly farmers has been incorporated in a special version of the Certified Safe Farm (CSF) Program for Senior Farmers (102). The following recommendations are incorporated in that program. Elderly farmer prevention should encourage short breaks and not working when ill, as fatigue and cold or flu can increase their risk of injury. The vaccination history for elderly farmer should be reviewed to assure that they are up to date for pneumonia, influenza, tetanus, and shingles immunization.

As elderly farmers in general (as most farmers do) work alone, they may have a significant risk of delayed treatment from an injury, and an increased risk for serious complications or death. There should be an emphasis to structure work so that the elderly do not work alone or a communication system should be in place (such as where and when the elderly person is working and times of expected return) or a portable communication device (cell phone or two-way radio) to alert need for assistance should it arise. Note there are applications for smartphones (e.g., Find my iPhone) that will give the location of the cell phone to a remote computer (158).

An innovative program that seems to attract elderly together with their grandchildren is the Generations Project (159). This project requires grandparents and their grandchildren to work together through teaching by stories and to correct hazards on the farm.

Specific Prevention Activities for the Elderly

Tractor Safety Programs: Since tractor overturns are the number one cause of fatality in elderly farmers (North America), emphasis should be placed on installing ROPS with seat belts on tractors, retiring tractors without ROPS, or strongly discouraging the elderly from operating tractors without ROPS. Over 60% of elderly farmers commonly operate tractors lacking ROPS, seatbelts, working lights, slow-moving vehicle (SMV) emblems, and power take-off (PTO) shields (133). Only 26% of elderly farmers believe the benefits of ROPS outweigh the costs of installation (even though 88% believe they are effective). Cheril Tevis, a former editor of *Successful Farming Magazine* interviewed many farmers about their risks of farm injuries and has written numerous articles on her findings: "In general, senior farmers rate tractor operation as a moderate to low-level risk—much like the perceived risk of driving in a car without a seatbelt" (133).

Several tractor safety programs have shown some effectiveness in ROPS installation. One that is applicable to the elderly is the Tractor Risk Abatement and Control (TRAC-SAFE) program at the University of Iowa (160, 161). This community-based program includes in-depth education, involvement of local machinery dealers, and community incentives. It also emphasizes reassigning tractors without ROPS away from use in hazardous tasks, like operating on inclines, mowing ditches, banks, or waterways, and with front-end loaders.

Decreasing Risks of Falling: Falls are a critical risk for the elderly farmer. Falls on ice are common in northern climates. These can be reduced by ensuring that places where water can collect and freeze are eliminated by drainage, rain gutters and down spouts are in proper working order, walkways are covered, and a container of sand or salt is kept at sites that may be slippery during cold weather. Using traction treads on shoes and strap-on ice grips may be very beneficial. Other general fall prevention measures include safe ladder usage and wearing a safety harness when working on high places, as well as high-quality lighting, especially where there might be trip hazards.

Physical Fitness: Although farming is hard work, the work involved in modern farming, which is highly mechanized, may not maintain muscle tone, bone density, and cardiovascular fitness. Elderly farmers should be encouraged to participate in either home programs or group programs that encourage weight-bearing exercise and cardiovascular fitness.

The general prevention principles for elderly farmers discussed above can be summarized in the best practice points below.

1. Practice prevention early in life to reap benefits in later life, as early physical trauma will exacerbate the normal aging processes (e.g., hearing, sun, and chemical protection).
2. Install good lighting in all work and walk areas, with handrails and marked steps.
3. Institute new work activities to stimulate mental activity.
4. Ensure annual medical exams, stressing geriatric changes relative to work status (discussed in more detail below).
5. Ensure annual review of prescription and over-the-counter medications by a competent medical provider (knowledgeable in the principles of agricultural medicine) relative to interactions and adverse reactions, and relative to current work tasks.
6. Ensure clothing is in good repair and weather-appropriate.
7. Ensure appropriate PPE is used for the specific agricultural exposures, and that the PPE is properly maintained.
8. Ensure frequent rest periods.
9. Ensure adequate and balanced nutrition.
10. Ensure regular exercise for strength, prevention of bone loss, and cardiovascular health.
11. Ensure cessation of smoking and moderate alcohol use (not more than 1–2 drinks per day).
12. Ensure annual dental exam and care.
13. Ensure social and/or faith-based connections if possible.
14. Involve community prevention programs, as this might be the best way to achieve 1–13.

Issues for Clinical Screening of Elderly Farmers: When conducting physical examinations and screenings for elderly farmers, several points should be considered. Many of these points have been mentioned above, but are included here for a clinical perspective.

1. Screen all medications, current and new, for side effects that may impair farmers physically, increasing their risk of injury in their work. Screen also for use of over-the-counter medications and home remedies.
2. Check vision and hearing regularly.
3. Examine skin for keratoses and cancers.
4. Review annually immunization record for influenza, pneumonia, tetanus, and shingles, and provide immunizations as necessary.
5. Examine for arthritis and balance ability.
6. Consider the following screenings (note current screening recommendations for c, d, and e below are being deliberated by public health professionals as of 2014 and may change):
   a. Diabetes (blood sugar level).
   b. Hypertension (blood pressure).
   c. Osteoporosis (bone density).
   d. Prostate cancer (PSA for men).
   e. Breast cancer (mammograms for women).
7. Question and counsel on the following:
   a. Regular exercise to maintain strength and bone density.
   b. Sleep disorders.
   c. Depression and opportunities to manage it.
   d. Wearing appropriate PPE for relevant work (e.g., UV-protective glasses, hearing, and respiratory protection).

e. Proper posture to reduce risks of sprains and strains.
f. Advise on the realities of presbycusis and how to manage it.
g. Advise on prevention of hyper- and hypothermia.
h. Advise on symptoms of stroke and heart attack.

Note that recommendations from general medicine practice may vary from country to country, and that some of these recommendations are also appropriate for general medical screening.

2.5 Migrant and Seasonal Farm Workers

With the trending decrease in the number of farms, number of farmers, and corresponding increase in farm size, production in agriculture has been buoyed by the input of a large cadre of farm workers (162, 163) (Figure 2.4). Note that, as discussed in Chapter 1, approximately half of the farm workers in the United States are indigenous, local workers, and half are foreign (Table 2.3; 164, 165). The general term used for the latter is migrant and seasonal farm workers (MSFW). However, many of these have now settled out and work on a single farm year round, such as large swine or dairy farms. The trend toward fewer, larger, more specialized farms in the United States is also evident in many industrialized countries around the world, with migrant and seasonal labor in general estimated at more than 200 million persons living and working outside their country of birth (a 23% increase in the past two decades) (166). This phenomenon has been prominent not only in industrialized countries, but also in some developing countries as available labor from low-wage areas within countries or from low-wage countries seek opportunities to better their income. Migrant and seasonal farm labor has been a global reality for generations. However, an increased demand for low-wage labor has been realized over the past two decades because of the increased competition of our global economy. Movement of low-wage labor is also enhanced as a result of the unbalanced global economy, wars, and famine. This expansion in the use of hired farm labor has been prominent in North America, where consolidation and industrialization of farming enterprises has proceeded at a rapid rate. Also, growth in labor-intensive crops has increased farm labor demands, evidenced by a 66% increase in the US annual production of fruits and vegetables (167). In the United States, migrant and seasonal workers are predominantly Latino (30% in the United States generally, but 90% in California), mainly from Mexico (65%) and Central America (3%), though there are also many African-American, Haitian, Anglo, and Asian farm workers (164). Once only prominent in states like California, Arizona, Texas, and Florida, hired farm labor has expanded into the whole of the south-east, north-east and upper Midwest of the United States and Eastern Canada.

Hired farm workers are defined by the US Census Bureau as "people employed to perform tasks on farms for the purpose of producing an agricultural commodity for sale." The USDA and the US DOL list the official number as about one million total farm workers in the United States. About 50% of these workers are local or indigenous, usually of white race. The US DOL National Agricultural Workers Survey presents the best demographic data and trends for MSFWs in the United States (168). About 50% or 500,000 of farm workers are MSFW. Note that some private organizations estimate a higher number of MSFW in the United States, three to five million, when counting children and dependents. However, accurate data are difficult to obtain, and these higher numbers are subject to interpretation (169–171). As mentioned above, farm workers may be divided into several categories: (1) indigenous or local workers, (2) migrant farm workers (those required to travel more than 75 miles and stay away from their home), (3) seasonal farm workers (those performing agricultural work of a seasonal or temporary nature, but not required to be away overnight from their

FIGURE 2.4 Migrant worker. (Source: Jerry Horbert/Schutterstock.com.)

home.), and (4) immigrant or foreign farm workers who have come to stay and have settled to work in permanent jobs in one location, or have initiated their own operations. The groups described in (2) and (3) are the MSFWs and they make up about 50% of all hired farm workers in the United States. They are considered minority groups in society, and are usually foreign born (172). People may come from outside the country for agricultural work at certain times, depending on the crop cycle, and return to their homes at intervals. Nearly half the MSFWs (48%) do not have legal status (undocumented) to be in the United States. Although a guest worker program in the United States (the H-2A program) allows legal entry for work for a defined period of time, only a small percentage of the immigrant workers in the United States have this status. The program is employer driven, and it takes time and effort to obtain and maintain that status for specific workers. Only about 30% of MSFWs report that they speak English well. The mean education level for MSFWs is 8th grade. Many (23%) have incomes below the federal poverty guidelines. Only 8% report having health insurance, and most are not covered by workers' compensation laws or other social services, but this varies from state to state (169). Details of the demographics of this population are found in Table 2.3. Many of the "settled out" foreign-born farm workers are working in large swine, poultry, and dairy operations, or meat and poultry processing plants. Women and children are a part of this work force, mainly as members of family units that have settled and stay in limited geographic areas (173).

The traditional migration patterns of MSFWs have been described using a "three streams" concept (west coast, Midwest, and east coast streams),

Table 2.3 Migrant and seasonal farm workers (MSFWs) in crop production in the United States: cultural, legal, and demographic characteristics by percentage of the total (2007–2009 data unless otherwise noted)

Demographic data		Trends since 2002–2004 survey
Birthplace		
United States/Puerto Rico	29%	Relatively stable
Foreign borne	72%	Relatively stable
Mexico (total)	68%	
West Central (states surrounding Mexico City)	45%	Slight decrease
Central North	35%	Slight decrease
Southern Pacific States	20%	Relative increase
Central America	3%	Steady
Other	1%	Steady
Years since arrival (mean) >20 years	29%	Increase by 200%; more long-term workers[a]
Age in years (mean)	36	Slight increase
Legal status overall		Little change overall
US citizen	33%	
Authorized, e.g., Green card/H2A/other	19%	
Unauthorized[b]	48%	
Employment type		
Seasonal/follow-the-crop	19%	
Shuttle between work and home (home in Mexico 29%; home in US 17%)	46%	
Direct hire by farmer	88%	Increased direct hire by employer; increased multiple-year employment by the same farmer
Hired by labor contractor	12%	Less labor contractor employment
First-year migrant	35%	Slight decrease
Language		Increase in proficiency 10 years after arrival
Spanish native	81%	
No English	48%	
Limited English	37%	
English working proficiency	14%	
Housing (2002–2004)		
Rental on open market	58%	
Home owner	19%	
Employer-supplied housing	21%	Trends toward less employer-provided housing
Gender		Steady
Male	79%	
Female	21%	
Marital status		Steady
Single	41%	
Married	59%	
Mixed status	24%	
Family status		Steady
Family with children	51%	
Average family size	2	
Working separated from family	34%	

(*Continued*)

Table 2.3 (Continued)

Demographic data		Trends since 2002–2004 survey
Birthplace		
Education (highest level)		Trends toward more workers with high-school education
None	5%	
1–6 years	40%	
7–9 years	17%	
10–12 years	28%	
Post-high school	9%	
Wages		Wages have increased, but less than for non-agricultural employment
Hourly mean $8.50	33%	
Annual mean income $15,000–$17,500		The mean income of MSFW
Family income < poverty level	23%	
Health insurance		
Paid by employer	8%	Decline in employer-paid health insurance
Government (2000–2002)	19%	
Spousal coverage (2000–2002)	12%	
Self-pay (2000–2002)	15%	
Unemployment insured	39%	

Source: 2007–2009 data, http://www.ncfh.org/docs/fs-Migrant%20Demographics.pdf; 2000–2002 data National Agricultural Workers Survey conduced by the US Department of Labor, www.doleta.gov/agworker/report9/toc.cfm.
[a] 10% or more increase from 1993–1994 survey.
[b] 10% or more decrease from 1993–1994 survey.

although this pattern seems to be changing with changing availability of work. Generally MSFWs move through the country from south to north: from South California to Northern California, Oregon, and Washington, from Texas and Arizona to Ohio, Michigan, Indiana, Illinois, Wisconsin, and other states in the upper Midwest, and from Florida to Georgia, the Carolinas, and New England in the east (174, 175). Other migration patterns within these main streams are restricted circuits, point-to-point, and nomadic patterns. The restricted circuit pattern is defined as MSFWs travel throughout a relatively small geographic area to find work. MSFWs who are on a point-to-point pattern follow the same route through the country to find work each season, usually with home bases in Florida, Texas, Mexico, Puerto Rico, or California. The nomadic farm worker travels from farm to farm and crop to crop, living away from home for extended periods of time (175).

As previously mentioned, migrant and seasonal workers and immigrant farm workers are common in many other countries as well. For example, Brazil (perhaps the most rapidly developing industrialized agriculture sector in the Western Hemisphere), is utilizing migrant and seasonal labor. The UK utilizes migrant and seasonal farm workers originating from many different European and Commonwealth countries. The horticultural industry alone employs about one million workers every year. Other farm labor jobs within the European community include fruit picking (e.g., strawberries and gooseberries) and vegetable picking (e.g., cauliflower) (176, 177). French farmers employ migrant and seasonal workers to pick fruit such as grapes, blueberries, raspberries, and strawberries. Denmark uses migrant and seasonal labor to pick strawberries among other crops, and the Netherlands employs migrant and seasonal labor to pick fruit and flowers. The primary countries of origin for the bulk of these workers in the UK are India, Australia, and South Africa. Australia has a developed a tradition of the “backpacking temporary” farm worker. These typically are students from Europe and North America traveling in Australia who stop to work for a few weeks to gain money to continue their travels. They work at picking fresh fruits and vegetables. Australia fruit growers also hire “boat people” from surrounding Asian countries as seasonal labor (178). There is concern from the Australian government for the protection of these people regarding work exposures. On the other hand, the government is trying to manage the illegal immigration of these people into the country, causing the boat people to live in the bush, where living conditions are not necessarily safe and sanitary. New Zealand producers hire seasonal workers to pick fruit such as apricots, cherries, and apples (178).

2.5.1 Work Exposures/Risks

There are numerous occupational and environmental hazards for MSFWs (163). Although detailed and accurate data are not readily available (179), the following paragraphs review the major risk concerns documented in the literature.

Housing

Adequate, safe, and sanitary housing has been a long-standing problem for MSFWs. Often the employer provides the housing. Although most countries have standards for worker housing, many labor camps still have marginal environmental conditions. Lack of potable water and sanitary toilet and bathing facilities are often a concern. MSFWs who rent housing on the available market may also be relegated to less than standard housing, as they look for low-rent facilities as wages are minimal and they want to save money to send home. Housing may be located close to fields where pesticides are stored and applied, creating exposure risk through contamination of the local premises, air, and water (180). Environmental sampling of homes has revealed low levels of the pesticides used on crops in the region within housing units. Azinphos-methyl (AZM; 180) is one chemical commonly found in farm worker housing in California (AZM is being phased out by the Environmental Protection Administration (EPA)).

Toxic Exposures

Pesticide Exposures: The majority of publications and worker protection activity for MSFWs has addressed pesticide exposure through work. Health outcomes and lower toxicity of new pesticides suggest that illnesses from work exposure to pesticides are not a leading MSFW acute health risk. The most toxic insecticide chemicals (cholinesterase-inhibiting compounds) have largely been replaced with less toxic pyrethroid or neonicotinoid insecticides. The primary potential for pesticide exposure is through contact with fruit and vegetable crops that have been treated with pesticides (181) or through mixing and loading or applying pesticides. There are important geographic and production-specific work exposures. California and the south-west and south-east states have the type of agriculture where worker pesticide exposure may be an increased risk. Caution should continue for employers to evaluate the potential exposure risk to protect MSFWs. Evaluation of potential exposure should include the toxicity of chemicals used and work practices that may bring workers into contact with the pesticide. Generally, MSFWs on their own are not as likely to wear PPE and may not follow hygienic practices at home (showering, washing clothes frequently, etc.). Though US farm operators are required by the Occupational Safety and Health Administration (OSHA) to provide safe hand washing facilities in the fields, not all comply, increasing hazardous exposures (167). Acute and chronic pesticide health effects are covered in detail in Chapter 6.

Green Tobacco Sickness

Green tobacco sickness (GTS) was first described in 1970 in a tobacco MSFW in Florida. In the late 1990s and 2000s, more reports in the tobacco-growing regions of the south-eastern states (mainly North and South Carolina, Kentucky, and Florida) have prompted research and preventive recommendation for this health risk. The health risks for tobacco workers extend to many workers around the world. The top six tobacco-producing countries include China, Brazil, India, the United States, Malawi, and Zimbabwe. Tobacco is grown to a lesser extent in 118 other countries. Arcury (182) surveyed MSFWs in North Carolina and found that 25% of tobacco workers have experienced GTS and 8% of workers experience GTS during any given week. During the harvest season (August and early September), 11% of the exposed workers may experience GTS during a given week.

GTS is caused by skin absorption of nicotine during handling or contact with tobacco leaves (which are laden with nicotine, especially close to maturation of the plants). Symptoms of GTS include several of the following: nausea, vomiting, abdominal cramps and pain, diarrhea, headache, weakness, variable blood pressure and heart rate, difficult breathing and possibly excessive sweating and salivation. GTS is usually a self-limiting, non-threatening illness lasting 2–4 days. However, it could enhance the risk of or exacerbate heat-related illnesses and dehydration. The diagnosis of GTS requires ascertaining several of the clusters of symptoms mentioned above, along with a compatible occupational history, especially if the following risk factors are complicit.

1. Harvesting (priming) the leaves by hand (harvest season is August and early September in the south-eastern United States).
2. A high degree of skin contact with the leaves (e.g., no shirt, short pants, open shoes without socks while working in the tobacco fields).
3. Skin damage on areas of plant contact (e.g., skin abrasions, rash, cuts, etc. on hands or arms).
4. Working in wet conditions (heavy dew, rain).
5. No personal protection used.
6. No or little previous exposure during the current season.
7. Non-smoker or other tobacco user.
8. Hot temperatures during field work.
9. Alcohol consumption within the 48 hours prior to work.
10. Obesity.

Treatment of GTS: The first goal is to remove the person from the work that results in exposure. Next, the person needs to shower with soap and water, and don clean clothes. In more severe cases, the patient may need IV rehydration with a balanced electrolyte. An antiemetic may be used to dispel vomiting and nausea, for example diphenhydramine (sold over the counter as dephenhydrinate or dramamine, which may include theophylline) or meclizine (sold over the counter as Dramamine or other brand names) (183).

Prevention of GTS: The following recommendations help to prevent GTS (182, 184):

1. If possible, avoid harvesting when there is heavy dew or rain.
2. Wear a long-sleeved shirt, long pants and a hat while harvesting or in contact with the mature plants.
3. Wear PPE, especially in wet conditions, including a rain coat and chemical-resistant gloves (e.g., of neoprene or nitrile material). Note there must be a balance between effective use of PPE and putting the worker at risk of a heat-related illness.
4. Cover skin abrasions, cuts or other skin lesions with a non-absorptive material.
5. Avoid alcohol consumption.

Other Common Health Problems of MSFWs

Eye problems are commonly reported (up to 40% prevalence) by MSFWs. These include physical trauma (corneal scratches or ulcerations) and conjunctivitis. Causes include punctures with foreign objects (from working amongst foliage and other plant materials), pesticide chemicals such as sulfur and propargite, and field dust. Working in bright sunlight carries a risk of retinal and corneal exposure to UV light, which can lead to long-term damage to the cornea, lens, and formation of pterygium. The latter is a condition of scar tissue evolving from the sclera (white portion of the eye) usually initiating from the nasal side and eventually proceeding over the cornea, which can impair vision. Wearing hats and safety/sunglasses would be helpful, but nearly 99% of workers do not wear eye protection. Part of the reason for this may be the negative cultural connotation for wearing sunglasses, as drug dealers in Mexico and Central America wear sunglasses and workers do not want to be associated with them (185).

Heat-related Illnesses

Heat-related illnesses range in severity from muscle cramps, heat exhaustion, and heat syncope, to heat stroke (the latter is a medical emergency). There were 68 heat–related fatalities reported in agricultural workers from 1992 to 2006 (0.3/100,000 workers per year). The highest rate of heat fatalities was recorded in North Carolina (2.4/100,000), where manual work with tobacco, for example tending and harvest, is conducted during the sunny, hot, and humid summer months, creating a risk of harmful heat stress. The fatalities occurred mostly in males (74%), white-skinned non-Hispanics (48%), Hispanics (31%), and blacks (16%) (186). The pathophysiology of heat-related illness and prevention is covered in detail in Chapter 9.

Musculoskeletal Injuries

The labor-intensive nature of MSFW employment results in heavy and chronic strain on the musculoskeletal system. Thirty-one per cent of MSFWs report muscle and joint strain (187). Approximately half of the musculoskeletal injuries experienced are back injuries (188). Causes include heavy lifting, working in stressful postures, such as reaching above the head to pick with a heavy sack on the back or bending at the waist for long periods, working at an excessively fast pace, whole-body vibration from operating or working on farm machines, and working in hot or cold climates (167, 181). Details of musculoskeletal diseases and ergonomics in agricultural workers are covered in Chapter 8.

Skin Conditions

A survey of North Carolina MSFWs revealed that 24% experienced skin conditions early in their seasonal farm work. However, a follow-up survey revealed a prevalence of 37% for skin conditions at the end of their seasonal work (189). Specific outbreaks of skin conditions have been noted in California related to the harvest of grapes, tomato, and citrus. Most of these conditions are irritant contact dermatitis. A number of different insecticides and herbicides are known causes of contact dermatitis (see Chapters 6 and 4). Elemental sulfur and the insecticide/fungicide propargite are known strong dermal irritants. Furthermore, there are plant components that can also cause dermatologic problems. Plants including carrots, celery, and parsnips contain the chemical furocoumarin, which can cause severe irritant photo-contact dermatitis in combination with sun exposure. Details of skin conditions are covered in Chapter 4.

Respiratory Illnesses

MSFWs have similar respiratory exposures to other farmers, but some specific risks are of special concern for this population. MSFWs who work in large-scale swine and poultry production and dairies are exposed to organic dusts and risk the syndrome of organic dust disease, as described in Chapter 3 (including bronchitis, non-allergic asthma-like conditions, and mucous membrane irritation). Schenker (190) has identified that inorganic dust exposure (particularly in dry climates) in California is a risk for pneumoconiosis. Silica is a component of most soils, and in dry climates soils aerosolized from tillage and wind erosion may settle out on plant foliage. During harvest of grapes and other fruit and vegetable crops, this dust can be re-aerosolized and inhaled, creating the risk of small airways diseases and pneumoconiosis (190, 191). Long-term risks include loss of lung capacity form scarring and possible chronic obstructive lung disease (COPD). Additional to these occupational exposures, lifestyle and general health are also contributors to adverse respiratory health. Smoking is a contributing factor to almost any occupational respiratory exposure. Smoking prevalence in MSFWs is similar to the general Hispanic population, which was 15% in 2004 (CDC 2005). This compares to around 5% prevalence for the general farming population. Pulmonary function screenings of MSFW show reduced forced vital lung capacities, which may be explained by exposure to agricultural organic and inorganic dusts. These changes are independent, but in the magnitude of that expected for cigarette smoking (181). There is no Hispanic normal comparison population for pulmonary function, which may result in false low pulmonary function values. To determine occupationally-related acute obstructive pulmonary function deficits it is therefore best to compare before- and after-work measures.

MSFWs have a six-fold risk of tuberculosis compared to other employed adults (192, 193). The risks include having been born in a country with a high prevalence of tuberculosis. Co-mingling of tuberculosis-infected persons in migrant camps or in the workplace creates a risk of infecting other workers. Additional risk factors include poverty, crowded living conditions, mobility, poor access to health care, and non-compliance with tuberculosis medications. Additional social factors in some MSFWs, such as homelessness and alcohol abuse, increases the risk of tuberculosis in some workers (194).

Mental and Behavioral Health

MSFWs endure many stressors that can lead to depression, including uprooting and separation from nuclear and extended family, separation from community and cultural origins, and adapting to a host culture. Additional stressors include low and unpredictable income, language barriers, discriminatory treatment, inadequate housing, rigid work demands, and fear of deportation (195, 196). The native Hispanic culture is a "collectivist society" and people thrive on strong family connections which include a strong support system (197). Many of the previous factors take them out the realm of self-control (a strong stressor) and transfer control to their employer or labor contractor, their guest culture and a society foreign to them. Several surveys of MSFWs have revealed a prevalence of depressive symptoms from 20% to 40% (197–199). Additional to depression and alcohol issues, Hiott and colleagues found 18% of surveyed MSFWs in North Carolina had impairing anxiety (196). Other research has shown that social isolation and work conditions are strong correlates to adverse mental health conditions in MSFWs (198, 199). Vega (200) found rates of various psychiatric disorders far lower in Mexico and in recent immigrants relative to immigrants with lengthy US residence or those of Hispanic workers born in the United States.

Children of MSFWs are at risk because of the social and environmental conditions in which they live (59, 201). Dental caries is a problem in these children (202). Regular dental check-ups are rare. Lukes and Miller (203) found that 51% of MSFW children had not sought oral health care in the previous year as they typically do not see a dentist unless there is pain. Also, nearly 50% of adult MSFWs had symptoms of periodontal disease. Caries in MSFW children has followed a world-wide decrease, but this was primarily seen in permanent teeth and not in deciduous teeth. School age children of MSFWs are still at high risk of dental caries (204).

Barriers to Healthcare Services

Language barriers to healthcare services persist (205) even though most hospitals employ translators. There are also transportation barriers as most MSFWs do not have automobiles, and if they do drive, they often do not have a valid driver's license or automotive insurance. Most (85% by one survey) MSFWs do not have health insurance (206). The fact that many MSFW are not authorized to work in the United States keeps them from utilizing governmental healthcare agencies or sometimes from seeking any health care, for fear of being identified and deported (167). Cultural barriers include the fact that Hispanics do not like to be examined by a person of the opposite gender. Furthermore, folk medicine beliefs remain strong in many Hispanic communities, which might interfere with healthcare treatment. Because of the migrant nature of this population, medical records may not be available. MSFWs primarily live in the present, and the concept of preventive care is not relevant to their frame of reference. Lack of information and cultural barriers exacerbate this problem therefore their medical care is primarily acute illness care. This is a concern for chronic condition care. For example, Hispanics (also Native Americans) have a genetic predisposition for diabetes, which is exacerbated by the North American diet. Early diagnosis and long-term treatment of diabetes is critical to preventing the numerous complications of the condition later in life. Another example of the barriers to health care is the finding that MSFW women underutilize mammograms and Pap tests because of cultural beliefs and limited awareness or belief of the benefits (174). In spite of these barriers to health care, neonatal survivability and birth weights of Hispanic farm worker babies are significantly greater than in the general population (207). The reasons for this observation are not known.

2.5.2 Prevention and Protection of MSFWs

Protection of MSFWs includes effective and enforced policies and additional interventions to address particular hazards and risks. Concerning policy at the international level, the Commission on Human Rights of the World Health Organization (WHO) held an International Convention on the Protection of Migrant Workers and Members of their Families. This convention developed a document laying out a series of rights that should be afforded to all migrant workers. It was adopted by the General Assembly of the WHO in December of 1990, and has been ratified by 25 member states. The resolution went into force on 1 July 2003. The primary points of the International Declaration of Migrant Workers Human Rights include the following human rights provisions, which are considered universal, indivisible, interconnected, and interdependent (208):

- Assurance of a sufficient wage that contributes to an adequate standard of living.
- Freedom from discrimination based on race, national or ethnic origin, sex, religion or any other status in all aspects of work, including in hiring, conditions of work, and promotion, and in access to housing, health care, and basic services.
- Equality before the law and equal protection of the law, particularly in regard to human rights and labor legislation, regardless of a migrant's legal status.
- Equal pay for equal work.
- Freedom from forced labor.
- Protection against arbitrary expulsion from the state of employment.
- Right to return home if the migrant wishes.
- The human right to a standard of living adequate for the health and well-being of the migrant worker and his or her family.
- Safe working conditions and a clean and safe working environment.
- Reasonable working hours, rest, and leisure.
- Freedom of association and to join a trade union.
- Freedom from sexual harassment in the workplace.
- Protection during pregnancy from work proven to be harmful.
- Protection for the child from economic exploitation and from any work that may be hazardous to his or her well-being and development.
- Education for the children of migrant workers.
- Reunification of migrants and their families.

If this "Bill of Rights" for MSFWs is universally practiced, the health risks for this population should significantly improve.

Culp and Umbarger (172) provide a review of the laws affecting the health and welfare of MSFWs. In the United States, the DOL enforces the Migrant and Seasonal Agricultural Worker Protection Act (MSWPA), which provides employment-related protection to migrant and seasonal agricultural workers. Every non-exempt farm labor contractor, agricultural employer, and agricultural association who employs farm workers must (209):

- provide written disclosure of the terms and conditions of employment in the worker's language
- post information about the Worker Protection Standard at the work site in the worker's language
- pay workers the wages owed when due and provide an itemized statement of earnings and deductions
- comply with the terms of any working arrangement made with the workers
- make and keep payroll records for 3 years for each employee
- set standards for safe housing for MSFWs.

OSHA has created standards for field sanitation and potable water provision. Furthermore, although OSHA exempts farms with fewer than 11 employees, they do not exempt them, regardless of number of employees, if they have a temporary labor camp. The EPA has set Worker Protection Standards (WPS), which are designed to protect workers from pesticide exposures. The Health Resources and Services Administration (HRSA) (210) operates a special populations division which includes 165 migrant health clinics scattered across the United States charged to provide comprehensive high-quality and culturally competent preventive and primary care to farm workers. They are also charged to focus on the occupational health and safety needs of this population. Two non-profit organizations (the Migrant Clinicians Network (211) and the National Center for Farm Worker Health)(212) work to advocate and provide resources for the health and welfare of this population.

Even with the above stated public and private resources for the health of MSFWs, lack of health and safety training has been cited as a major concern. Several studies have shown that only 7% of farm operations who hire MSFWs provide health and safety training for their workers, and less than 30% of MSFWs have had adequate health and safety training for jobs they do (213–215). One of the most important factors in improving this situation is to educate farm owners how to better teach occupational health and safety to MSFWs. Culturally and linguistically appropriate and translated materials are needed (216). Although Spanish is the primary language of Hispanic MSFWs, some use regional Native American languages (e.g., Aztec or Mayan-related dialects) in their home communities therefore translation resources and training programs must accommodate these realities. Explicit safety rules should be developed and effectively communicated to the workers. In this author's opinion (KJD), pesticide safety exposure has dominated the discourse on MSFW safety, to the detriment of developing more comprehensive prevention that includes eye protection, skin protection, musculoskeletal injuries, heat-related illnesses, infectious diseases and respiratory illnesses. Finally, there needs to be a renewed emphasis to assure that MSFWs have safe and sanitary housing, water, and sanitary facilities.

The following suggestions from the Migrant Health News line (a product of the National Center for Farm Worker Health) (217) are listed below to assist rural health practitioners to provide quality health services to MSFWs.

1. To better understand this patient population, seek information and skills on cultural competency for MSFWs in your area.
2. Be aware of the living and working situations of MSFWs in your area by asking your patients and the MSFW employers' questions. Use this information to provide care and advice to your patients, e.g., be sure a patient has a refrigerator before prescribing medication that needs refrigeration or asking them to apply ice to an injury.
3. The first visit of an MSFW and family members may take extra time because of language and transportation barriers. Consider booking two time slots for them.
4. When communicating to the patient or interpreter, look directly at the patient and speak slowly but not loudly. Communicate in simple but organized sentences, e.g. "You have ________ because of ______. You must do three things to get better: 1.______, 2.______and 3. _____."

Research on computer-based training for MSFWs has been conducted by Anger, Rohlman, and colleagues (218, 219). This technique should address literacy concerns, as well as language and culture. Arcury (216) suggests that farm workers should be included as presenters as a part of the program. Further research is required to identify the most effective ways to deliver education to MSFWs.

2.6 Old-order Anabaptists

Members of Anabaptist religious groups number 1.7 million people and are distributed over 83 countries. Thirty per cent live in North America,

FIGURE 2.5 Old-order Anabaptists, e.g., the Amish, are culturally and religiously attached to farming. They make minimal use of powered machines and technology. Animal traction is used in many communities and others use tractors with steel wheels. The nature of their work and equipment creates injury risks. Children are also at increased injury risk. (Source: Hutch Photography/Shutterstock.com.)

38% in Africa, 18% in South-East Asia, 10% in the Caribbean and South America, and 4% in the EU (220). A large number of Anabaptists live in agrarian farming societies (Figure 2.5). Anabaptists are just one of many religious groups spawned out of the Protestant Reformation of 1517 (221). The Anabaptist movement began in Switzerland following reforms begun by the ideas of Ulrich Zwingli (222). The term "Anabaptist" has its origin in the Greek word meaning "rebaptized," referring to the belief that adult instead of child baptism is essential to the Christian faith (223). Although at least 50 Anabaptist sects originally evolved, there are four main sects discussed here: Amish, Mennonites, Brethren, and Hutterites. These people reside in agrarian communities scattered mainly in North America, and to a lesser extent South America. (Although 4% of current Anabaptists reside in Europe, the last European Amish settlement dissolved in 1937.) The values that link these groups are both religious and philosophical. Besides the religious practice of adult baptism, the Amish live by church doctrine called "the Ordnung" (224, 225). These groups value forgiveness and pacifism (they are conscientious objectors relative to the military), separation of church and state, separation from the general society, agricultural/agrarian lifestyle, and hard work. Many Mennonite and Brethren groups moved to a "new order" many generations past, and live much closer to mainstream protestant religious traditions, clothing, and life styles. However, several branches of these groups, the Amish, some Mennonites, and Hutterites, adhere to their early beginnings ("old order") and are centered in agriculture, practicing social, economic, and political separation from the society around them. Collectively, these groups can be referred to as old-order Anabaptists (OOAs). They aim to live a "non-worldly" life style. They also practice a similar plain clothing dress. Although they speak and read English, in the home and their community they speak and read a German dialect (called Pennsylvania Dutch or German Dutch). As a method of cultural separation, Amish people refer generically to non-Amish as the "English". OOA groups practice limited formal education (through the 8th grade).

The various Anabaptist groups that exist today were derived and separated by followers of different leaders. The Mennonites are originally followers of Menno Simons. The Amish, followers of Jakob Ammann, split from the Mennonites in 1693. The Hutterites (from 1528 in Austria) are originally followers of Jakob Hutter (226). The Brethren (from 1708 in Central Germany) are followers of Alexander Mack. As these groups were counter to state and religious doctrine at the time, they survived by fleeing from persecution, moving many times around Europe during the 16th and 18th centuries. During the 19th century many Anabaptists immigrated to North America, and later Mennonites moved to South America, where they were able to benefit from greater religious freedom and more available farmland (227, 228).

Many other agrarian groups of this same time period split from the state church and practiced a communal social structure of living (some 500 of these groups existed in the United States in the past, most not associated with the Anabaptist groups discussed here). Most of these groups no longer function as a communal society. For example, the Amana Colonies in Iowa is now a private farm and multiple business corporation owned by family members of the original colony members. The Hutterites (an Anabaptist group) still practice a communal form of life and are growing in number in North and South Dakota, Montana, and Wyoming in the United States, and the Prairie Provinces of Canada. Nearly all of the research about Anabaptists has been reported on the more traditional, OOA communities, such as the Amish and old-order Mennonites. Consequently, the discussions of this text will be centered on these groups, who define themselves partially by their value for being "non-worldly" and their selective use of technology (seen as a threat to their value of hard work). These groups primarily practice farming (with some allowance for such other basic supporting occupations as carpentry, horse breeding and training, etc.). They practice limited use of modern conveniences in the home. They do not use electric power in the home or farm, although some use gasoline-powered electric generators for limited farm power. They continue to use animal labor for transportation or field work. However, there is variance among groups, with some using cars and some using tractors with steel wheels. Most travel is accomplished by horse and buggy, but trips to town are infrequent since many of these communities are nearly self-sufficient.

The Amish are the largest of the OOA groups, with 448 settlements in 29 states and more than 226,000 individuals living in the United States and the Province of Ontario, Canada (224, 229). OOA Mennonites live in 10 different Midwest and Eastern states and Ontario, with 40,000 total members (224, 230). Most reside in the central United States, with the highest populations in Ohio, Pennsylvania, Missouri, Northern Indiana, and Iowa (231). The Amish in North America have been growing about 6% per year. Scholars of the Amish predict a doubling of their population in the next two decades (232). The last Amish settlement in Europe dissolved in 1937.

Approximately 38,000 Hutterites live in 425 different communal colonies of about 90 members each in Minnesota, North and South Dakota, Montana, Wyoming, and the Prairie Provinces of Canada. Maps of the locations of these groups in North America are seen in Figure 2.6 (233).

Approximately 6000 of the some 190,000 Brethren in North America are considered old order or old German Baptist Brethren. They have a similar life style to the OOA Amish and OOA Mennonites and live primarily in the Eastern United States.

FIGURE 2.6 These three maps depict the locations of Old-order Anabaptist congregations in North America and include Amish, Old-order Mennonites, and Hutterites in 2012. All three maps are reprinted with permission from Cory Anderson and Joseph Donnermeyer, published in Anderson, C. and Donnermeyer, J. (2013). Where Are the Plain Anabaptists? *Journal of Amish and Plain Anabaptist Studies* 1(1): 1–25.

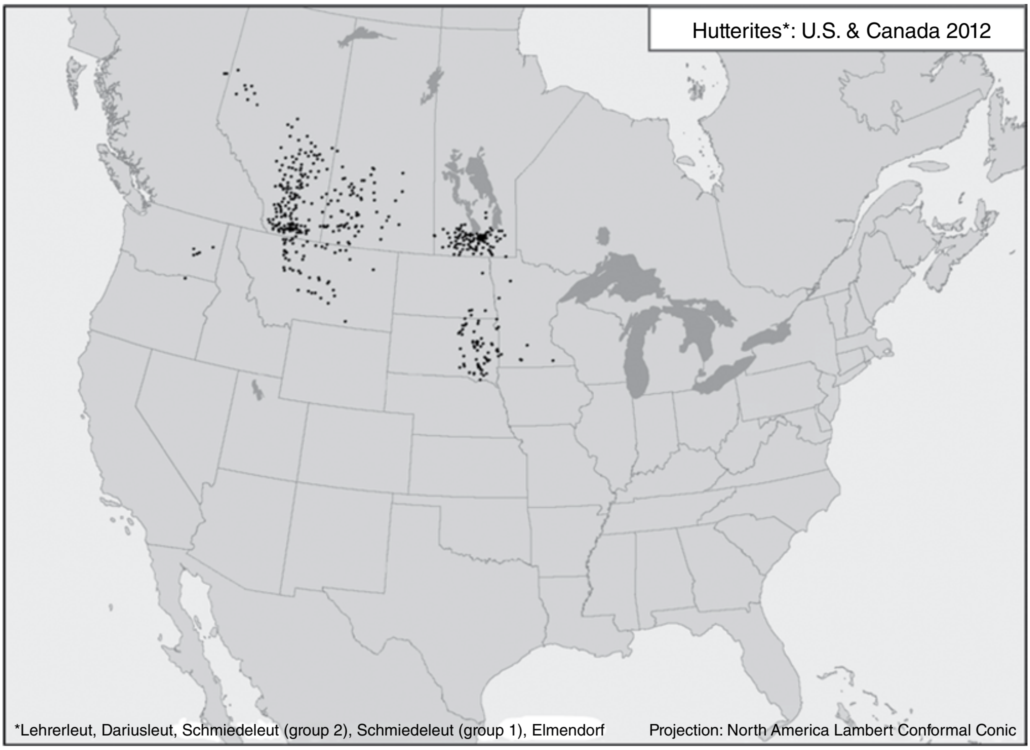


FIGURE 2.6 (Continued)

2.6.1 Work Exposures/Risks

Although Hutterite communal farms are large and conduct modern farming practices, other OOA farms are generally small (e.g.,80–200 acres) and fit well into and participate with the expanding local market food production trend. Farming is central to the way of life for OOA communities. Farm, family, and culture are anchored to the Church, where everyone works in cooperation as a community. The community act of farming pulls members together, and it is on the farm where families work, play, and worship (234, 235). An unwritten agreement among groups such as the Amish seems to require a living to be made from farming, rural, or semi-rural occupations (235). Agricultural production is reminiscent of practices 80–90 years ago among all family farms. Work exposures and health and safety risks are similar to non-Anabaptist family farming in the United States in the 1930s and 1940s. Most groups shun modern technology, except when it is required by state health laws, such as in the pasteurization and refrigeration of milk (236). Although they only have formal 8th grade education, these farmers have developed their own technology or modified technology that is consistent with their traditional ways. For example, they will use electrical generators in barns for feed grinding and cooling milk for bulk storage, put steel wheels on tractors (taking the rubber off wheels), and use horses to pull modified modern machinery (e.g., they might put a gasoline engine on a hay baler so it can run with independent power but still be pulled by horses; see Figure 2.5). In short, older and/or modified or homemade machines are typically used. This equipment often lacks the more faultless functioning and safety features of newer equipment and therefore may be more hazardous. As a result, injury from this alternative farming style is a major concern (236). OOAs believe in sparing use of agricultural chemicals, preferring to farm and live as naturally as possible.

Collecting injury statistics from OOA communities is difficult because they live inconspicuously, not voluntarily reporting problems or inviting outsiders to collect information from them (232, 237). However, a study of Amish health records by Jones and Field (223) revealed 39% of Amish farm-related fatalities were due to being run over by a vehicle. The second most prevalent source of injury was direct animal injury. Only 11% of Amish farming-related fatalities involved agricultural tractors (compared to nearly 50% on non-Amish farms) (223).

OOA children often begin participating in farm work at 5–6 years; several years younger than non-OOA children (236). Since formal OOA schooling ends with 8th grade, by age 14 boys are able to work full-time on the farm and girls can work in the garden and in the home (224, 234). Amish families are large, with a typical family of six or seven children. Large families increase the potential for unsupervised hazardous farm exposures to children. Older children often are the supervisors of their younger siblings (224). Unlike non-Anabaptist groups (i.e., English, the term the OOA use) farm family mothers and fathers are much less likely to work off the farm. Furthermore, OOAs have their own schools in their communities, with their own school boards. Children have few extracurricular activities in their schools, and thus have more time available for farm work. Available statistics indicate that these children are even more at risk of injury than are children on "English" family farms (238). Amish children under age 16 accounted for 64% of occupational injuries in their community according to one study (223). Gilliam and colleagues (224, 237) reported on 217 Amish youth injuries (14 fatal) in 18 states and Canada. The peak age for injuries was the 13–14 age group (mean age of 14), consistent with completion of their formal schooling and increased availability for heavy farm work. Males (87%) were most commonly injured. The most common injury source was falls (38%), often from the haymow through the hay hole to the floor below. Livestock and horse-related injuries accounted for 13% of injuries (239), machinery for 21%, struck by or cut 9%, crushed or pinned 7%, entanglement 5%, and run-overs 7%. Run-overs were mainly by horse-drawn buggies or farm equipment (224, 232).

Most fatal farm injuries occur in children under 9 years of age. Other surveys corroborate the trends and distribution of injury sources (223, 240). These can be a result of hazards such as children riding without proper restraints and children being unseen by operators. From the available research, we can conclude that danger of injury and death exists, especially for children, around vehicles and animals, and especially around animal-drawn vehicles.

As OOAs use horse-drawn vehicles for transportation, they share the road with motorized vehicles. Crashes between cars/trucks and horse-drawn buggies are a major hazard to the Amish (231). In the state of Ohio, over 20 crashes between motorized vehicles and buggies occur annually, resulting in severe property damage, injury, and death (241). The injuries from these crashes are usually severe, as the buggy offers little protection and the victims are often thrown out upon impact. To assist in prevention of road way crashes, the local or state governments in most OOA communities provide widened shoulders on the roads where possible, so buggies can get off the heavily traveled portion of the road. Crash prevention actions of the Amish involve lighting and marking of the buggy to increase visibility by motor vehicle drivers. Acceptance of these practices varies among communities depending on local religious interpretations and the Bishops' rulings relative to obtrusiveness and bright colors. At a minimum, a SMV sign must be attached on the rear of the buggy (a state law for all SMVs). Additional lighting and marking in some communities may include reflective tape, lanterns, and sometimes strobe lights to increase visibility to motorists (242).

2.6.2 Effects and Special Considerations for Treatment of Injuries

OOA religious and cultural beliefs may have both positive and negative effects on their health. The belief in "worldly separation" puts mainstream health care in the category of secondary consideration relative to folk and traditional healing. The common belief in predetermination or "God's will" and a delayed gratification in the afterlife creates a restrained use of modern medical technology and preventive measures (243). Most often, when injuries are mild, such as strains and minor trauma, OOA groups rely on their own traditional self-medicine. Amish women traditionally are the unofficial, untrained "health aides" in the community. The forms of this traditional healing style most often reported are dietary interventions, nutrition programs, and herb therapies. Their national newspaper publications (e.g. *The Budget*, *The Diary*) often contain traditional folk remedies. These traditional therapies may have adverse effects, especially for pregnant women and the elderly. When OOAs seek outside care, they generally first seek non-mainstream medicine, more "natural healing", for example chiropractic, naturopathy, and other complementary and alternative medicine. In one report (244), 36% of 66 Amish women used at least one form of complementary or alternative medicine in the past year.

Wenger (245) reported in one Ohio community on the minimal use of immunizations. He reported that all children in 68% of Amish families had at least one immunization, but 16% of families had no children vaccinated. The reasons given for not immunizing children included fear of adverse reactions and taking away the trust in God. The lack of immunization in mothers has resulted in a few reported cases of tetanus in newborns from infected umbilical stumps following home birthing. Lack of immunization in children has also put them at risk of tetanus, measles, and pertussis (246).

The remarkably strong religious beliefs of OOA groups ground them in the value of faith and prayer in healing. The majority in a study by Gerdner *et al.* (247) reported that faith has a major role in curing and healing in their lives. They also hold in a life after death and that "the best is yet to come." This idea, in some instances, may keep them from readily seeking advanced health care (223, 248).

However, Amish do use modern allopathic healthcare services, but conservatively. They use it when they perceive it necessary, but often late in the course of disease after other more "natural methods" have failed. "Unnatural" or heroic interventions for a health condition may sometimes be unwanted (249). They typically do not seek out the full course of recommended immunizations, although this varies among the different groups and between individuals (250).

Recently there has been a trend in some communities of increasing use of modern allopathic services (243). This is true especially for pregnancy healthcare services, although home births are still preferred (251). One creative service in Ohio (the Amish birthing center) has provided excellent value in the community with its service blend of Amish cultural values with modern obstetrical standards (252). Health services for OOAs generally are best adopted if they balance quality health care with the Amish values of simplicity, low cost, closeness to community, accommodation to use of horse and buggy, and agrarian life style (253). In communities where Amish are employed in off-farm work, there has been a trend of the "English" employers providing health insurance. There has also been a minor trend in the development and use of major medical insurance plans administered by businessmen within Anabaptist churches. Examples of these plans are called Amish Aid or Mennonite Aid (243, 254).

Healthcare providers who serve OOA groups need to strive to understand, accept, and respect the OOA culture and beliefs, rather than judge. Failing to do so will serve only to engender mistrust and reluctance to use modern allopathic health services.

Regarding health emergencies, lack of telephones (although some communities allow cell phones if not carried and kept out of the house) can delay outside healthcare assistance in emergencies (255).

General Health of OOA Communities

OOAs have lower rates of cancer fatalities compared to the general population (256). They also have at least 30% less cancer screening in comparison to a non-Amish rural community. When queried why they use less cancer screening, the main reason given is they do not think they need it (256). Generally, the OOA are more positive about their health in that they do not worry about it, putting their faith in God rather than the healthcare system. As they still typically do not carry health insurance, they usually pay for healthcare services. If there is a large medical expense (cancer, major surgery, etc.), the collective community will often pay the bill for the individual. Mentioned previously most OOA community members lack immediate access to telephones, which can result in delayed access to emergency healthcare services (255).

The strong family and community social support system of the Amish assists family health maintenance (257). High levels of social self-care in the Amish communities include feelings of hope, satisfaction, and control in a tightly knit, nearly self-sufficient culture. All of the social support within the community greatly diminishes the need to seek outside health care (258).

2.6.3 Other General Health Concerns

Genetic disorders: Some Anabaptist populations have been relatively closed over time (259), creating concern for specific genetic illnesses in some communities (228). Infantile refsum disease (260) is an autosomal recessive genetic disorder that is more common in the OOA Amish populations. Refsum disease is one of a group of leukodystrophy diseases that affects the myelin sheath covering of nerve fibers in the brain. The condition results in varying degrees of impaired vision, hearing loss, delayed development, and neuromotor deficiencies. A yellow to orange stain of the teeth is common among affected females. Other inherited metabolic diseases seen in the Anabaptist population include maple syrup urine disease (inability to metabolize certain amino acids, resulting in acidosis and mental retardation) and glutamic aciduria type 1 (inability to metabolize lysine and tryptophan). Either can result in central neurological dysfunction and abnormal muscle control (254).

A positive observation that could have a genetic basis is that children of Hutterites in Saskatchewan, Canada are observed to experience less asthma (2.4% vs 9.2% in a neighbor comparison group) (261). However, this could be related more to exposure to the farm environment and its allergens at an early age of life (see the hygiene hypothesis in the youth section of this chapter and Chapter 3).

In spite of the perception that genetic disorders may be a common problem in OOA groups, overall genetic disease prevalence among these populations is relatively low and clustered in only a few families.

Lifestyle and Wellness: General lifestyle promotes good health in most OOA communities. Smoking, alcohol consumption, and other substance abuse is extremely low. However, one Ohio study reported 7% of Amish men were current smokers, and 10% were smokeless tobacco users. This compares, respectively, to 13% and 26% in a non-Anabaptist rural comparison group, and 26% and 7% in the general US population (262).

Teenage Amish substance use is minimal until the potential usage during "rumspringa", which is a time for children to experience life outside the Amish community. This occurs around the age of 16–18. Following that period, the youths either choose to come back into the community and be baptized, or leave the community. Cates (263) followed a group of children of this age and queried them on their expectations of using substances. Most revealed they would probably try tobacco and alcohol but not marijuana or other drugs. Actual usage and persistent usage of substances following rumspringa was not reported.

OOA traditional diets are low in simple sugars but high in protein, fat, and complex carbohydrates.

It is apparent that their total caloric intake is high relative to their caloric expenditures with increasing simple sugars. However, obesity remains less common in OOA groups relative to the general population, but the relative low level of obesity in many OOA communities is not shared among all groups. Those people highly engaged in farming, particularly those still using horses for power, expend more energy per capita than those living in communities that use tractors or have become less agrarian as urbanization has invaded around them (e.g. northern Ohio, eastern Pennsylvania, and areas of Ontario). In an Ontario (Canada) Amish community, percentages of those overweight (>25 mean body mass index (BMI)) were 25% for men and 27% for women. This is nearly half the prevalence of overweight persons (BMI >25) in the general population of North America (51% in Canada and 63% in the United States). Only 4% of this Amish community was considered obese (>30 mean BMI), compared to 35% and 23% of the general populations of the United States and Canada, respectively (264). This can be explained by the increased caloric expenditures of Amish (3100 kcal/day for men and 1850 kcal day for women) relative to the general population. Amish men and women took about 50% more steps per day than a comparison population, and about 80% more than the recommended 10,000 steps per day for cardiovascular fitness (265). A more encompassing study of physical health (PCS SF-12 survey) (266) in an OOA Mennonite community in Ontario revealed a smaller healthy advantage. The PCS SF-12 measures physical, social, and mental health with a combined score (A higher number indicates a higher health status). The OOA Mennonite farm group average score was 47.39, relative to a rural comparison group score of 49.24. This was a small, but significant difference (267).

Relative to physical health, the family/faith-based life style seems protective to the OOA. They tend to live in the present and not worry about future health and life circumstances, trusting in their faith. An example is a situation in Ontario where there was a high level of non-Anabaptist citizen concern about community health risks because of polluted rivers in the area. However, interviews of OOA women in the community revealed them unconcerned for their families' health about this issue (268). OOAs experience seasonal mood changes, 75% reporting the lightest mood in month of May and only 25% reporting a dark mood. These percentages were generally reversed in the months of January and February (269). These findings were consistent with general Caucasians living in a comparable latitude.

As the general life style is family oriented and social in nature, a great deal of the elderly care is conducted by the family and is often mentally healthy for the elderly (270).

2.6.4 Recommendations for Prevention

Safety and healthy practices for OOA groups must be developed and implemented in harmony with their culture, for example research is needed to develop effective, culturally sensitive ways to signal to roadway vehicular traffic approaching slow-moving horse drawn buggies. Installing mirrors on buggies has been suggested (but may not be culturally acceptable in some groups). Further expansion of roads with wide shoulders for use by buggies is needed in many areas (241).

The major perceived health and safety problems on OOA farms are in children. As previously mentioned, 68% of the injuries occur in young people. Important research and interventions with safety and health education programs and delivery methods have been conducted by the Ohio State University and Elizabethtown College in Pennsylvania among others. The overarching message in the research and practice of interventions in OOA communities is to understand, respect, and practice within the framework of OOA cultural norms. There are general components of the culture across communities, but each community has differences, and it is important to understand and work within the local cultures. The following points consolidate and summarize recommendations on preventive interventions (mainly for youths) from four different scholarly and safety specialists who have had extensive experience in working with OOA communities (224, 232, 235, 237, 271, 272).

1. Prevention programs must be adopted and governed by the community and approved by the community leaders and the Bishop, and aimed at the most common hazards as perceived by the Amish.
2. Non-Anabaptist "outsiders," e.g., extension, public health and other government organizations, can work with the OOA communities best by providing resources and programming, but allowing the community to lead.
3. Establish a relationship and trust with the community by face-to-face communication. It may take several meetings to gain the trust and acceptance to be able to work with the community.
4. Utilize (or help develop) a safety committee within the OOA community (several OOA communities have safety committees) and work with them as the lead to develop and deliver their own program. Experience has shown greater success of gaining a receptive audience and focus on hazards from the Amish perspective through work with the safety committee.
5. Programs must be developed with cultural sensitivity and relevancy and by a facilitator that has credibility within the Amish community. This may be a church leader or leader of the safety committee.
6. Work with the safety committee to find acceptable and effective lighting and marking for greater visibility of buggies and other horse drawn equipment on roads.
7. Work with the community/safety committee to develop OOA culturally and age-appropriate tasks, which will likely differ from the North American Guidelines for Children's Agricultural Tasks (see the section on youth earlier in this chapter).
8. Work with the community/safety committee to develop/adopt a culturally and age-appropriate hazardous occupational order for agriculture task list (i.e., analogous to the DOL Child Labor Laws, a list of tasks a child should not do until reaching an appropriate age).
9. Work with the safety committee to address the safety issues that they think are most important. (Safety committees in some areas have identified hazards that most safety specialists would not think of, e.g., string mower/trimmers, feed carts, pony carts, hay hole guarding).
10. Use resources within the community, not free government materials. This is due to OOA belief in separation of church and state; they prefer to not use government support.
11. For materials developed and or delivered on the outside (e.g., extension), do *not* use high color or technology as this will go against their non-worldly perspective. Use examples and pictures that are OOA relevant (Amish farm sites, machines, etc., but not photographs of Amish people, as photographing of Amish people is against their religious culture).
12. Time training in February–March and June before high farm risk periods.
13. Training for youths should focus on the age group at greatest risk (under 9 and 14–15 years).
14. Aim youth training at parents to include:
    a. The importance of parents as critical role models and child supervision, and aides to manage their tasks such as:
        - identifying safe and secure play areas for young children
        - identifying common sources of injuries and illnesses
        - holding a farm safety walkabout to guide families to identify and remove hazards they find, e.g., safe chemical storage, fencing around ponds and manure lagoons
        - first aid and cardio-pulmonary resuscitation training
        - identifying the causes and effects of genetic disorders
        - identifying the potential adverse effects of traditional therapies (It is important that health professionals understand the

cultural roots that affect the health behavior of Anabaptist groups in order to establish effective health promotion (273). Conversely, Anabaptist groups need to seek out and be informed of healthcare providers in the community who understand and accept their beliefs and will work to provide therapy within their belief system.)

15. Involve and provide materials to the school board and teachers to encourage and assist teachers to include safety in their programming.
16. Use local input such as fire and sheriff departments, teachers, and State Extension agents.
17. Use active learning techniques, demonstrations, and hands-on exercises.
18. Facilitate publication of messages and locations of resources and ideas about safety in OOA national newspaper publications (e.g., *The Budget*, *The Diary*, *Die Botschaft*).

In summary, OOA groups are a longstanding and important component of the farming population in North and South America. Their culture creates increased risk for injuries and illnesses, especially for their youths. Furthermore, their culture and social structure create barriers for non-Anabaptists who would intervene to help prevent farm injuries and illnesses. Understanding, respecting, and working within their cultural and social framework is essential for effective interventions.

Key Points

1. Special risk populations in agriculture include diverse minority groups that experience distinctive occupational hazards that require tailored approaches for effective clinical and preventive interventions. Characteristics and attributes placing them at special risk include one or more of the following: age, gender, ethnicity, socioeconomic status, race, culture, religious beliefs. Although there are numerous special-risk populations among the developed countries, the ones chosen here include several in common with most countries (women, children, the elderly, and migrant and seasonal farm workers) and one mainly limited to North America (old-order Anabaptists).
2. Women have had an expanding role in production agriculture over the past few decades and now make up nearly 50% of the population involved in production agriculture in one or more of several roles, including principal operator, co-operator, unpaid family labor, hired labor, and State Extension advisors, educators, or researchers.
3. Although large animals are a major source of acute injuries to women, tractors (as with men, youths, and the elderly) are the major machine-related source of severe or fatal injuries.
4. Pregnant women are at risk of abortion resulting from exposure to hormones used in livestock production (oxytocin, prostaglandins), carbon monoxide from fossil-fuel burning heaters or internal combustion engines, high nitrate concentrations in drinking water, or zoonotic infections (brucellosis, Q fever, listeria, Leptospirosis).
5. Youths exposed to farm hazards include children of farm parents who live, play, and work on the farm. Additional exposed youths include relatives, friends, or visitors who attend activities such as agritourism or community-supported agriculture.
6. Recent research suggests that enhancing youth safety on farms to a higher level may require a paradigm shift from focusing on awareness-level education of children to enabling parents to become better supervisors, and to model/mentor prevention to their children as an important component of an apprenticeship.
7. Farmers typically work well beyond the usual retirement age. Age-related physical

and mental changes and working with older equipment place them at an increased risk for serious and fatal injuries. Prevention includes a carefully crafted (culturally attuned to the geriatric personality) integrated medical and physical work environment program. Clinical aspects should involve an attuned healthcare professional to deal with physical and mental issues, including prescription medications that are matched with the farm work the person does or should not do according to the person's current abilities. Managing the physical environment includes matching the work with the person's abilities and auditing the work environment to remove hazards (trip and fall hazards, poor lighting, lack of ROPS on tractors, etc.).

8. Migrant and seasonal farm workers are common among all industrialized countries and some developing countries. In North America many former migrant and seasonal worker opportunities have transitioned to more permanent employment, including work on large dairies, swine or poultry farms, and work in meat- and poultry-processing plants. The importance of pesticide-exposure hazards to MSFWs has declined because of new less-toxic products, safer formulations, and better application methods. Skin conditions, eye lesions, health-related illnesses, green tobacco sickness, and respiratory conditions from organic and inorganic dust should be considered in clinical settings as well as in designing the prevention of occupational hazards in this population.
9. Old-order Anabaptists consist of agrarian populations that number over 300,000 in North America. The Amish, old-order Mennonites, and Hutterites have in common a desire for separation from mainstream society to live a "less worldly and more natural" way of life. However, details of individual community-based religious interpretations reflect variances in farming practices and lifestyle. A strong faith community, predetermined religious propensity, large families, use of animal-drawn equipment, and old and modified equipment all help create on one hand a socially positive effect, but also a physically hazardous environment. Children are at especially high risk as they begin working in this environment at an earlier age. Run-over by vehicle (usually horse drawn), road crashes between buggies and cars, and animal injuries are common for all age groups. For youths, falls from high places (e.g., through the hay hole in a barn), animal injuries, machinery and run-overs are prominent injury risks. Prevention must include an understanding and acceptance of the OOA culture, and facilitate their lead in prevention programming.

References

1. Race/Ethnicity/Gender Profile. Washington, DC: National Agriculturual Statisitic Service, US Department of Agriculture; 2014 (accessed 15 February 2015). Available from: http://www.agcensus.usda.gov/Publications/2012/Online_Resources/Race,_Ethnicity_and_Gender_Profiles/cpd99000.pdf.
2. Garkovich L, Bokemeir, J, Foote, B. *Harvest of Hope: Family Farming/Farming Families*. Lexington: Kentucky University Press; 1995.
3. Smith JR. The contribution women make to New Zealand's agriculture. NZ Agric Sci. 1975;9(4):121–22.
4. Dimich-Ward H, Guernsey JR, Pickett W, Rennie D, Hartling L, Brison RJ. Gender differences in the occurrence of farm related injuries. Occup Environ Med. 2004;61(1):52–6.
5. Tutor-Marcom R, Bruce J, Greer A. North Carolina farm women: opportunities for support and farm-related education. J Agromedicine. 2014;19(2):191–200.
6. Pela G. Realizing the potential of farm women. World Agriculture. 1979;28(1–2):6–9.
7. Gasson R. Roles of women on farms: a pilot study [England and Wales]. J Agric Economics. 1981;32(1): 11–20.

8. Data on women farmers, and age of farmers. 2012 Census of Agriculture Prelimiary Report. US and State Statistics; 2012 (accessed 8 March 2014). Available from: http://www.agcensus.usda.gov/Publications/2012/Preliminary_Report/Full_Report.pdf.
9. Nordstrom DL, Layde PM, Olson KA, Stuland D, Brand L, Follen MA. Incidence of farm-work-related acute injury in a defined population. Am J Ind Med. 1995;28:551–64.
10. Reed D, Westneat SC, Browning SR, Skarke L. The hidden work of the farm homemaker. J Agric Saf Health. 1999;5:317–27.
11. Kallioniemi MK, Raussi SM, Rautiainen RH, Kymalainen HR. Safety and animal handling practices among women dairy operators. J Agric Saf Health. 2011;17(1):63–78.
12. Sawicka J. The role of rural women in agriculture and rural development in Poland. Elec J Polish Agric Uni Series Economics. 2001;4(2).
13. Hawk C, Donham KJ, Gay J. Pediatric exposure to agricultural machinery: Implications for primary prevention. J Agromedicine. 1994;1(1):57–73.
14. US Census of Agriculture Farm Demographics – US Farmers by Gender, Age, Race, Ethnicity, and More. Washington, DC: National Agriculturual Statisitic Service, US Department of Agriculture; 2014 (updated 16 May 2015; accessed 14 February 2015). Available from: http://www.agcensus.usda.gov/Publications/2012/Online_Resources/Highlights/Farm_Demographics/.
15. Fernandez-Cornejo J. Off-Farm Income, Technology Adoption, and Farm Economic Performance. In: *Economic Research*. Washington, DC: Economic Research Service, US Department of Agriculture; 2007. p. 53.
16. Hawk C, Gay J, Donham KJ. Rural Youth Disability Prevention Project Survey: Results from 169 Iowa farm families. J Rural Health. 1991;7(2):170–9.
17. Carruth AK, Skarke L, Moffett B, Prestholdt C. Women in agriculture: Risk and injury experiences on family farms. J Am Med Womens Assoc. 2001;56(1):15–8.
18. Stueland DT, Lee BC, Nordstrom DL, Layde PM, Wittman LM, Gunderson PD. Case-control study of agricultural injuries to women in central Wisconsin. Women Health. 1997;25(4):91–103.
19. Hawk C, Donham KJ, Gay J. Pediatric exposure to agricultrual machinery. J Agromedicine. 1994;1(1):57–74.
20. Fenton GD, Brasier KJ, Henning GF, Radhakrishna RB, Jayarao BM. Occupational health characteristics of women on dairy farms in Pennsylvania. J Agromedicine. 2010;15(1):7–15.
21. Dimich-Ward H, Guernsey JR, Pickett W, Rennie D, Hartling L, Brison RJ. Gender differences in the occurrence of farm related injuries. Occup Environ Med. 2004;61(1):52–6.
22. Alavanja M, Akland G, Baird D, Blair A, Bond A, Dosemeci M, et al. Cancer and noncancer risk to women in agriculture and pest control – the agricultural health study. J Occup Med. 1994;36(11):1247–50.
23. Castorina R, Bradman A, McKone TE, Barr DB, Harnly ME, Eskenazi B. Cumulative organophosphate pesticide exposure and risk assessment among pregnant women living in an agricultural community: A case study from the CHAMACOS cohort. Environ Health Perspect. 2003;111(13):1640–8.
24. McDuffie H. Women at work – agriculture and pesticides. J Occup Med. 1994;36(11):1240–6.
25. Thu K, Donham K, Yoder D, Ogilvie L. The farm family perception of occupational health: a multistate survey of knowledge, attitudes, behaviors, and ideas. Am J Ind Med. 1990;18(4):427–31.
26. Curtis KM, Savitz DA, Weinberg CR, Arbuckle TE. The effect of pesticide exposure on time to pregnancy. Epidemiology. 1999;10(2):112–7.
27. Greenlee AR, Arbuckle TE, Chyou PH. Risk factors for female infertility in an agricultural region. Epidemiology. 2003;14(4):429–36.
28. Arbuckle TE, Lin Z, Mery LS. An exploratory analysis of the effect of pesticide exposure on the risk of spontaneous abortion in an Ontario farm population. Environ Health Perspect. 2001;109(8):851–7.
29. Gladen BC, Sandler DP, Zahm SH, Kamel F, Rowland AS, Alavanja MC. Exposure opportunities of families of farmer pesticide applicators. Am J Ind Med. 1998;34(6):581–7.
30. Castorina R, Bradman A, McKone TE, Barr DB, Harnly ME, Eskenazi B. Cumulative organophosphate pesticide exposure and risk assessment among pregnant women living in an agricultural community: A case study from the CHAMACOS cohort. Environ Health Perspect. 2003;111(13):1640–8.
31. Kasner EJ, Keralis JM, Mehler L, Beckman J, Bonnar-Prado J, Lee SJ, et al. Gender differences in acute pesticide-related illnesses and injuries among farmworkers in the United States, 1998–2007. Am J Ind Med. 2012;55(7):571–83.
32. Curtis K, Savitz DA, Weinberg CR, Arbuckle TE. The effect of pesticide exposure on time to pregnancy. Epidemiology. 1999;10(2):112–7.
33. Greenlee A, Arbuckle TE, Chyou PH. Risk factors for female infertility in an agricultural region. Epidemiology. 2003;14(4):429–36.
34. Arbuckle T, Lin ZQ, Mery LS. An exploratory analysis of the effect of pesticide exposure on the risk of spontaneous abortion in an Ontario farm population. Environ Health Perspect. 2001;109(8):851–7.

35. Duell E, Millikan RC, Savitz DA, Newman B, Smith JC, Schell MJ, Sandler DP. A population based case-control study of farming and breast cancer in North Carolina. Epidemiology. 2000;11(5):523–31.
36. Folsom A, Zhang SM, Sellers TA, Zheng W, Kushi LH, Cerhan JR. Cancer incidence among women living on farms – finding from the Iowa women's health study. J Occup Environ Med. 1996;38(11):1171–6.
37. Molocznik A, Zagorski J. Exposure of female farmers to dust on family farms. Ann Agric Environ Med. 2000;7(1):43–50.
38. Donham KJ, Cumro D, Reynolds SJ, Merchant JA. Dose-response relationships between occupational aerosol exposures and cross-shift declines of lung function in poultry workers: recommendations for exposure limits. J Occup Environ Med. 2000;42(3): 260–9.
39. Terho E, Husman K, Vohlonen I. Prevalence and incidence of chronic bronchitis and farmer's lung with respect to age, atopy, and smoking. Eur J Respir Diseases. 1987;71(Suppl.152):19–28.
40. Dare Project website. Kentucky University (updated 17 October 2013; accessed 6 March 2014). Available from: http://www.mc.uky.edu/scahip/agdare.html.
41. Fierro M, O'Rourke MK, Burgess JL. *Adverse health effects of exposure to ambient carbon monoxide*. University of Arizona, College of Public Health; 2001.
42. Donham KJ, Carson TL, Adrian BR. Carboxyhemoglobin values in swine relative to carbon monoxide exposure: Guidelines for monitoring animal and human health hazards in swine-confinement buildings. Am J Vet Res. 1982;43(5):813–816.
43. Maas J. Cautions, precautions, adverse and untoward reactions: UCD vet views. California Cattlemen's Magazine. Nov 2006 (accessed 14 March 2014). Available from: http://www.vetmed.ucdavis.edu/vetext/local-assets/pdfs/pdfs_beef/cca0611-cautions-reactions.pdf.
44. Hillemeier MM, Weisman CS, Chase GA, Dyer AM. Mental health status among rural women of reproductive age: findings from the Central Pennsylvania Women's Health Study. Am J Public Health. 2008;98(7):1271–9.
45. Carruth A, Logan CA. Depressive symptoms in farm women: Effects of health status and farming lifestyle characteristics, behaviors, and beliefs. J Community Health. 2002;27(3):213–28.
46. Hemard J, Monroe PA, Atkinson ES, Blalock LB. Rural women's satisfaction and stress as family health care gatekeepers. Women Health. 1998;28(2):55–77.
47. Melberg K. Farming, stress and psychological well-being: The case of Norwegian farm spouses. Sociologia Ruralis. 2003;43(1):56–76.
48. Van Hook M. Challenges to identifying and treating women with depression in rural primary care. Soc Work Health Care. 1996;23(3):73–92.
49. Elger U, Wonneberger E, Lasch V, Fuhr D, Heinzel W. [Stresses and health risks of farm women]. Soz Praventivmed. 1995;40(3):146–56.
50. Coakes S, Kelly GJ. Community competence and empowerment: strategies for rural change in women's health service planning and delivery. Aust J Rural Health. 1997;5(1):26–30.
51. Dalmau A, Bergman B, Brismar B. Somatic morbidity in schiophrenia – a case control study. Public Health. 1997;111(6):393–7.
52. Lyon D, Parker B. Gender-related concerns of rural women with severe and persistent mental illnesses. Arch Psychiatr Nurs. 2003;17(1):27–32.
53. Hauenstein E. Testing innovative nursing care: home intervention with depressed rural women. Issues Ment Health Nurs. 1996;17(1):33–50.
54. Fiandt K, Pullen CH, Walker SN. Actual and perceived risk for chronic illness in rural older women. Clin Excell Nurse Pract. 1999;3(2):105–15.
55. Rosenman K, Gardiner J, Swanson GM, Mullan P, Zhu ZW. US farm women's participation in breast cancer screening practices. Cancer. 1995;75(1): 47–53.
56. Carr W, Maldonado G, Leonard PR, Halberg JU, Church TR, Mandel JH, Dowd B, Mandel JS. Mammogram utilization among farm women. J Rural Health. 1996;12(4Suppl.S):278–90.
57. Kelley MA, Flocks JD, Economos J, McCauley LA. Female farmworkers' health during pregnancy: Health care providers' perspectives. Workplace Health Saf. 2013;61(7):308–13.
58. Tutor RP, Zarate, MA, Loury S. Pesticide exposure surveillance and prevention skills of staff in eastern North Carolina health departments. J Public Health Manag Pract. 2008;14(3):299–310.
59. Berman S. Health care research on migrant farm worker children: Why has it not had a higher priority? [comment]. Pediatrics. 2003;111(5Pt1):1106–7.
60. Geisler M. *Agritourism Profile*. Agricultural Marketing Resources Center, Iowa State University; 2014 (updated June 2013; accessed 25 November 2015). Available from: http://www.agmrc.org/commodities__products/agritourism/agritourism-profile/.
61. Wright S, Marlenga B, Lee BC. Childhood agricultural injuries: an update for clinicians. Curr Probl Pediatr Adolesc Health Care. 2013;43(2):20–44.
62. Fact Sheet: Childhood agricultural injuries in the US. Marshfield, WI: National Childrens' Center for Rural Agricultural Health and Safety; 2014 (accessed 29 November 2015). Available from: https://www3.

marshfieldclinic.org/proxy/MCRF-Centers-NFMC-NCCRAHS-2014_Child_Ag_Injury_FactSheet.1.pdf.
63. Hard DL. Partnering strategies for childhood agricultural safety and health. J Agromedicine. 2012; 17(2):225–31.
64. Garcovich L, Bokemeir J, Foote B. *Harvest of Hope: Family Farming/Farming Families*. Lexington: Kentucky University Press; 1995.
65. Klintberg B, Berglund N, Lilja G, Wickman M, van Hage-Hamsten M. Fewer allergic respiratory disorders among farmers' children in a closed birth cohort from Sweden. Eur Respir J. 2001;17(6):1151–7.
66. Horak FJ, Studnicka M, Gartner C, Veiter A, Tauber E, Urbanek R, Frischer T. Parental farming protects children against atopy: longitudinal evidence involving skin prick tests. Clin Exp Allergy. 2002;32(8): 1155–9.
67. Portengen L, Sigsgaard T, Omland O, Hjort C, Heederik D, Doekes G. Low prevalence of atopy in young Danish farmers and farming students born and raised on a farm. Clin Exp Allergy. 2002;32(2): 247–53.
68. Leynaert B, Neukirch C, Jarvis D, Chinn S, Burney P, Neukirch F. Does living on a farm during childhood protect against asthma, allergic rhinitis, and atopy in adulthood? Am J Respir Crit Care Med. 2001; 164(10Pt1):1829–34.
69. Chrischilles E, Ahrens R, Kuehl A, Kelly K, Thorne P, Burmeister L, et al. Asthma prevalence and morbidity among rural Iowa schoolchildren. J Allergy Clin Immunol. 2004;113(1):66–71.
70. Genuneit J. Exposure to farming environments in childhood and asthma and wheeze in rural populations: A systematic review with meta-analysis. Pediatr Allergy Immunol. 2012;23(6):509–18.
71. Lauener R, Birchler T, Adamski J, Braun-Fahrlander C, Bufe A, Herz U, von Mutius E, Nowak D, Riedler J, Waser M, Sennhauser FH, Alex study group. Expression of CD14 and Toll-like receptor 2 in farmers' and non-farmers' children. Lancet. 2002;360(9331): 465–6.
72. Hendricks KJ, Goldcamp EM. Injury surveillance for youth on farms in the US, 2006. J Agric Saf Health. 2010;16(4):279–91.
73. Zaloshnja E, Miller TR, Lawrence B. Incidence and cost of injury among youth in agricultural settings, United States, 2001–2006. Pediatrics. 2012;129(4): 728–34.
74. Park H, Reynolds SJ, Kelly KM, Stromquist AM, Burmeister LF, Zwerling C, Merchant JA. Characterization of agricultural tasks performed by youth in the Keokuk County Rural Health Study. Appl Occup Environ Hyg. 2003;18(6):418–29.
75. Meiers S, Baerg J. Farm accidents in children: eleven years of experience. J Pediatr Surg. 2001;36(5):726–9.
76. Little D, Vermillion JM, Dikis EJ, Little RJ, Custer MD, Cooney DR. Life on the farm – children at risk. J Pediatr Surg. 2003;38(5):804–7.
77. Pryor S, Caruth AK, McCoy CA. Children's injuries in agriculture related events: the effect of supervision on the injury experience. Issues Compr Pediatr Nurs. 2002;25(3):189–205.
78. Browning S, Westneat SC, Donnelly C, Reed D. Agricultural tasks and injuries among Kentucky farm children: results of the Farm Family Health and Hazard Surveillance Project. South Med J. 2003; 96(12):1203–12.
79. Marlenga B, Pickett W, Berg R. Agricultural work activities reported for children and youth on 498 North American farms. J Agric Saf Health. 2001;7(4): 241–52.
80. Hendricks K, Adekoya N. Non-fatal animal related injuries to youth occurring on farms in the United States, 1998. Inj Prev. 2001;7(4):307–11.
81. Flower KB, Hoppin JA, Lynch CF, Blair A, Knott C, Shore DL, et al. Cancer risk and parental pesticide application in children of Agricultural Health Study participants. Environ Health Perspect. 2004;112(5): 631–5.
82. Munshi K, Parker DL, Bannerman-Thompson H, Merchant D. Causes, nature, and outcomes of work-related injuries to adolescents working at farm and non-farm jobs in rural Minnesota. Am J Ind Med. 2002;42(2):142–9.
83. Chapman L, Newenhouse AC, Meyer RH, Karsh BT, Taveira AD, Miquelon MG. Musculoskeletal discomfort, injuries, and tasks accomplished by children and adolescents in Wisconsin fresh market vegetable production. J Agric Saf Health. 2003;9(2): 91–105.
84. Gerberich S, Gibson RW, French LR, Renier CM, Lee TY, Carr WP, Shutske J. Injuries among children and youth in farm households: Regional Rural Injury Study – I. Inj Prev. 2001;7(2):117–22.
85. Bonauto D, Keifer M, Rivara F, Alexander B. A community-based telephone survey of work and injuries in teenage agricultural workers. J Agric Saf Health. 2003;9(4):303–17.
86. Adekoya N. Trends in childhood drowning on US farms, 1986–1997. J Rural Health. 2003;19(1):11–4.
87. Mitchell R, Franklin R, Driscoll T, Fragar L. Farm-related fatalities involving children in Australia, 1989–92. Aust N Z J Public Health. 2001;25(4): 307–14.
88. Dunn A, Burns C, Sattler B. Environmental health of children. J Ped Health Care. 2003;17(5):223–31.

89. Cooper S, Darragh AR, Vernon SW, Stallones L, MacNaughton N, Robison T, Hanis C, Zahm SH. Ascertainment of pesticide exposures of migrant and seasonal farmworker children: findings from focus groups. Am J Ind Med. 2001;40(5):531–7.
90. Fenske R, Lu C, Barr D, Needham L. Children's exposure to chlorpyrifos and parathion in an agricultural community in central Washington State. [see comment]. Environ Health Perspect. 2002;110(5):549–53.
91. Vinson F, Merhi M, Baldi I, Raynal H, Gamet-Payrastre L. Exposure to pesticides and risk of childhood cancer: a meta-analysis of recent epidemiological studies. Occup Environ Med. 2011;68(9):694–702.
92. Hemard JB, Monroe PA, Atkinson ES, Blalock LB. Rural women's satisfaction and stress as family health care gatekeepers. Women Health. 1998;28(2):55–77.
93. FSIS/CDC/FDA Sentinel Site Study: The establishment and implementation of an active surveillence system for bacterial foodborne diseases in the United States 1997. US Department of Agriculture (accessed 24 November 2015). Available from: www.fsis.usda.gov/OPHS/fsisrep2.htm.
94. Report to Congress. Food Net: An Active Surveillance System for Bacterial Foodborne Diseases in the United States. US Department of Agriculture Food Safety and Inspection Service (accessed 24 November 2015). Available from: www.fsis.usda.gov/ophs/rpcong98/rpcong98.htm.
95. Shea K. Antibiotic resistance: What is the impact of agricultural uses of antibiotics on children's health? Pediatrics. 2003;112(1Suppl.S):253–8.
96. Merchant JA, Naleway AL, Svendsen ER, Kelly KM, Burmeister LF, Stromquist AM, et al. Asthma and farm exposures in a cohort of rural Iowa children. Environ Health Perspect. 2005;113(3):350–6.
97. North American Guidelines for Children's Agricultural Tasks. National Children's Center for Rural Agricultural Health Safety; 2014 (accessed 20 January 2014). Available from: http://www.nagcat.com/.
98. Childhood Agricultural Safety Network home page; 2015 (accessed 22 November 2015). Available from: http://www.childagsafety.org/.
99. Progressive Agriculturel Safety Day home page; 2015 (accessed 24 November 2015). Available from: http://www.progressiveag.org/.
100. Lee BC, Gallagher SS, Liebman AK, Miller ME, Marlenga B. Developing the 2012 national action plan for protecting children in agriculture. J Agromedicine. 2012;17(2):88–93.
101. Hawk C, Gay J, Donham K. Farm Safety Walk About; 1992. Available from the Iowa Deparment of Public Health, Disabiltiy Prevention Division, Lucas State Office Building, Des Moines, IA. 80 pp.
102. Certified Safe Farm home page. North Carolina Agromedicine Insitute (updated 11 June 2012; accessed 24 November 2015). Available from: http://www.ecu.edu/cs-dhs/agromedicine/CSF.cfm.
103. Esser N, Hieberger S, Lee B. *Creating safe play areas on farms*. 2nd edition. Marshfield, WI: Marshfield Clinic; 2003.
104. Sanderson LL, Dukeshire SR, Rangel C, Garbes R. The farm apprentice: Agricultural college students' recollections of learning to farm "safely." J Agric Saf Health. 2010;16(4):229–47.
105. Gadomski A, Ackerman S, Burdick P, Jenkins P. Efficacy of the North American Guidelines for Children's Agricultural Tasks in Reducing Childhood Agricultural Injuries. J Public Health. 2006;96(4):722–727.
106. Hawk C, Gay J, Donham KJ. Rural Youth Disability Prevention Project survey: Results from 169 Iowa farm families. J Rural Health. 1991:170–9.
107. Fathallah FA, Chang JH, Pickett W, Marlenga B. Ability of youth operators to reach farm tractor controls. Ergonomics. 2009;52(6):685–94.
108. Donham K. *Tractor risk abatement and control; the policy conference*. Iowa City: Iowa Center for Agricultural Safety and Health, College of Public Health, University of Iowa; 1997.
109. Youth and Labor, Agricultural Employment. US Department of Labor (accessed 24 November 2015). Available from: http://www.dol.gov/dol/topic/youthlabor/agriculturalemployment.htm.
110. Jepsen D. The US Department of Labor's Tractor and Machinery Certification Program: management styles and perceptions held by community stakeholders and instructor. J Agric Saf Health. 2012;18(3):217–32.
111. Cullen RC. The North Carolina Gold Star Grower Program. N C Med J. 2011;72(6):467–70.
112. Migrant and Seasonal Agricultural Workger Protection Act (MSPA). US Department of Labor; 2015 (accessed 24 November 2015). Available from: http://www.dol.gov/compliance/laws/comp-msawpa.htm.
113. Employment and Training for Migrant and Seasonal Farm Workers. Employmemt and Training Administration, US Department of Labor; 2014 (accessed 24 November 2015). Available from: http://www.doleta.gov/MSFW/.
114. It is easier to bury a tradition and bury a child (campaign poster). National Children's Center for Rural Agricultural Health and Safety; 2006 (accessed 11 November 2015). Available from: https://www3.marshfieldclinic.org/proxy/MCRF-Centers-NFMC-

NCCRAHS-CASN-Bury_a_Tradition_Tractor_Poster.1.pdf.
115. Gallagher SS. Characteristics of evaluated childhood agricultural safety interventions. J Agromedicine. 2012;17(2):109–26.
116. Farm Safety for Just Kids (accessed 25 November 2015). Available at: http://www.farmsafetyforjustkids.org/.
117. Reed D, Kidd PS, Westneat S, Rayens MK. Agricultural Disability Awareness and Risk Education (AgDARE) for high school students. Inj Prev. 2001;7(Suppl.1):i59-63.
118. AgDARE. University of Kentucky (accessed 14 March 2014). Available from: http://www.mc.uky.edu/scahip/agdare.html.
119. The Role of Cognitive Development in Safe Tractor Operation: A Simulation Study. Marshfield Clinic Research Foundation; 2104 (accessed 25 November 2015). Available from: http://www.marshfieldresearch.org/nfmc/the-role-of-cognitive-development-in-safe-tractor-operation-a-simulation-study.
120. DeRoo LA, Rautiainen RH. A systematic review of farm safety interventions. Am J Prev Med. 2000; 18(4Suppl.):51–62.
121. Baker A, Esser N, Lee B. A qualitative assessment of children's farm safety day camp programs. J Agric Saf Health. 2001;7(2):89–99.
122. Mason C, Earle-Richardson G. New York State child agricultural injuries: How often is maturity a potential contributing factor? Am J Ind Med. 2002;(Suppl.2):36–42.
123. Lee B, Marlenga B. *North American guidelines for children's agricultural tasks*. Marshfield, WI: Marshfield Clinic; 1999.
124. Occupation with Oldest Workers: Farmers. Occup Health Safety. 2000;69(10):44.
125. Vilsack T. Briefing on Status of Rural America. Factual highlights from agricultural statisices, with graphs. US Department of Agriculture; 2009 (accessed 24 November 2015). Available from: http://www.usda.gov/documents/Briefing_on_the_Status_of_Rural_America_Low_Res_Cover_update_map.pdf.
126. Peters KE, Gupta S, Stoller N, Mueller B. Implications of the aging process: opportunities for prevention in the farming community. J Agromedicine. 2008;13(2):111–8.
127. Huneke J, Von Essen S, Grisso R. Innovative approaches to farm safety and health for youth, senior farmers and health care providers. J Agromedicine. 1998;5(2):99–106.
128. McLaughlin A, Mayhorn, C. Avoiding harm on the farm: Human factors. Gerontechnology. 2011;10(1): 26–37.
129. Voaklander D, Hartling L, Pickett W, Dimich-Ward H, Brison R. Work-related mortality among older farmers in Canada. Can Fam Physician. 1999;45:2903–10.
130. Myers JR, Layne LA, Marsh SM. Injuries and fatalities to US farmers and farm workers 55 years and older. Am J Ind Med. 2009;52(3):185–94.
131. Horsburgh S, Feyer A, Langley J. Fatal work-related injuries in agricultural production and services to agriculture sectors of New Zealand, 1985–94. Occup Environ Med. 2001;58(8):489–95.
132. Voaklander DC, Umbarger-Mackey ML, Wilson ML. Health, medication use, and agricultural injury: A review. Am J Ind Med. 2009;52(11): 876–89.
133. Tevis C. Why veteran farmers fall victim to ag injuries. Successful Farming. 1995;93(3):24.
134. Browning S, Truszczynska H, Reed D, McKnight R. Agricultural injuries among older Kentucky farmers: The farm family health and hazard surveillance study. Am J Ind Med. 1998;33(4):341–53.
135. Fiedler D, Von Essen S, Morgan D, Grisso R, Mueller K, Eberle C. Causes of fatalities in older farmers vs. perception of risk. J Agromedicine. 1998;5(3):13–22.
136. Mitchell B, Hsueh W, King T, Pollin T, Sorkin J, Agarwala R, et al. Heritability of life span in the Old Order Amish. Am J Med Genet. 2001;102(4): 346–52.
137. Janicak C. Occupational fatalities to workers age 65 and older involving tractors in the crops production agriculture industry. J Saf Res. 2000;31(3):143–8.
138. Sprince N, Zwerling C, Lynch C, Whitten P, Thu K, Gillette P, et al. Risk factors for falls among Iowa farmers: A case-control study nested in the Agricultural Health Study. Am J Ind Med. 2003; 44(3):265–72.
139. US Department of Labor home page; 2015. Available from: http://www.bls.gov/
140. Myers JR, Layne LA, Marsh SM. Injuries and Fatalities to US Farmers and Farm Workers 55 years and Older. Proceedings of the Conference on the Aging Farm Community: Using Current Health and Safety Status to Future Action, March 6–8, 2007. Indianapolis, IN; 2007 (accessed 29 November 2015). Available from: http://www.agsafetyandhealthnet.org/Myers%20Old%20Farmers%20Conference%20Version%20071015%20Final.pdf.
141. Xiang H, Stallones L, Chiu Y. Nonfatal agricultural injuries among Colorado older male farmers. J Aging Health. 1999;11(1):65–78.
142. Mitchell R, Franklin R, Driscoll T, Fragar L. Farm-related fatal injury of young and older adults

in Australia, 1989–1992. Aust J Rural Health. 2002;10(4):209–19.
143. Pickett W, Chipman M, Brison R, Holness D. Medications as risk factors for farm injury. Accident Anal Prev. 1996;28(4):453–62.
144. Voaklander D, Day L, Dosman J, Hagel L, Pickett W. Older farmers and machinery exposure – cause for concern? Am J Ind Med. 2012;55(11): 1044–50.
145. Mitchell J, Bradley D, Wilson J, Goins RT. The aging farm population and rural aging research. J Agromedicine. 2008;13(2):95–109.
146. McLaughlin A, Mayhorn, C. Avoiding harm on the farm: Human factors. Gerontechnology. 2011; 10(1):26–37
147. Sandmark H, Hogstedt C, Vingard E. Primary osteoarthrosis of the knee in men and women as a result of lifelong physical load from work. Scand J Work Env Health. 2000;26(1):20–5.
148. Axmacher B, Lindberg H. Coxarthrosis in farmers. Clin Orthop Relat Res. 1993;February(287):82–6.
149. Homberg S, Thelin A, Steiernstrom E, Svardsudd K. The impact of physical work exposure on musculoskeletal symptoms among farmers and rural non-farmers. Ann Agric Environ Med. 2003;10(2):179–84.
150. Homberg S, Thelin A, Steiernstrom E, Svardsudd K. The impact of physical work exposure on musculoskeletal symptoms among farmers and rural non-farmers. Ann Agric Environ Med. 2003;10(2):179–84.
151. Geroldi C, Frisoni G, Rozzini R, Trabucchi M. Disability and principal lifetime occupation in the elderly. Int J Technol Aging. 1996;43(4): 317–24.
152. Sinclair A, Bayer A, Girling A, Woodhouse K. Older adults, diabetes mellitus and visual acuity: a community-based case-control study. Age Ageing. 2000;29(4):335–9.
153. Depression in Older Persons fact sheet. National Mental Health Alliance; 2009 (accessed 24 November 2015). Available from: http://www.nami.org/Template.cfm?Section=By_Illness&template=/ContentManagement/ContentDisplay.cfm&ContentID=17624.
154. Bartels S, Dums A, Oxman T, Schneider L, Arean P, Alexopoulos G, et al. Evidence-based practices in geriatric mental health care: an overview of systematic reviews and meta-analyses. Psychiatr Clin North Am. 2003;26(4):971–90.
155. Turner M. Female farm operators: Attitudes about social support in their retirement years. J Women Aging. 1996;8(3–4):113.
156. Depression. National Institute of Mental Health; 2015 (accessed 24 November 2015). Available from: https://www.nimh.nih.gov/health/topics/depression/index.shtml.
157. Engler J. The Medicaid bind. Fiscally burdened states need short-term help, long-term fix for program. Mod Healthcare. 2002;32(30):35.
158. Find my iPhone, iPad, and Mac (app). Apple Computers; 2015 (accessed 24 November 2015). Available from: https://www.apple.com/icloud/find-my-iphone.html.
159. Home safety checklist for grandparents of children 0–4 years of age. Child Accident Prevention Foundation of Australia; 2010 (accessed 24 November 2015). Available from: http://www.kidsafesa.com.au/__files/f/2285/Home_Safety_Checklist_for_Grandparents.pdf.
160. Myers ML. Tractor risk abatement and control.J Agric Saf Health. 2002;8(2):185–189.
161. Lehtola C, Rautiainen R, Olson G, Sessions J, Miller L. Trac-Safe 1996, Pub. No. 96-108. National Institute for Occupational Safety and Health (accessed 24 November 2015). Available from: http://www.cdc.gov/niosh/pdfs/tracsafe.pdf.
162. Schenker M. Preventive medicine and health promotion are overdue in the agricultural workplace. J Public Health Policy. 1996;17(3):275–305.
163. Arcury T, Quandt SA, Mellen BG. Occupational and environmental health risks in farm labor. Hum Organ. 1998;57(3):331–4.
164. Migratory and Seasonal Farm Worker Population. National Center for Farm Worker Health; 2012 (accessed 29 November 2015). Available from: www.ncfh.org/docs/fs-Migrant%20Demographics.pdf.
165. National Agricultural Workers Survey 2001–2001. US Department of Labor, Employment and Training Administration (updated 11 January 2010; accessed 29 November 2015). Available from: http://www.doleta.gov/agworker/report9/toc.cfm.
166. Schenker MB. A global perspective of migration and occupational health. Am J Ind Med. 2010;53(4):329–37.
167. Villarejo D, Baron SL. The occupational health status of hired farm workers. Occup Med. 1999;14(3):613–35.
168. Darroll D, Georges, A., Saltz, R., editors. Changing Characteristics of US Farm Workers: 21 Years of Findings from the National Agricultural Workers Survey. Immigration Reform and Agriculture Conference: Implications for Farmers, Farm Workers, and Communities, 12 May 2011. University of California; 2011.

169. Farm Worker Health Fact Sheet. Summary of National Agricultural Workers Survey. National Center for Farm Worker Health; 2012 (accessed 11 November 2015). Available from: http://www.ncfh.org/uploads/3/8/6/8/38685499/fs-migrant_demographics.pdf.
170. Enumeration and Population Estimates 2014. National Center for Farm Worker Health; 2014 (updated March 2014; accessed 11 November 2015). Available from: http://www.ncfh.org/?pid=23.
171. Hansen E, Donohoe M. Health issues of migrant and seasonal farmworkers. J Health Care Poor Underserved. 2003;14(2):153–64.
172. Culp K, Umbarger M. Seasonal and migrant agricultural workers: a neglected work force. AAOHN J. 2004;52(9):383–90.
173. Farr K, Wilson-Figueroa M. Talking about health and health care: Experiences and perspectives of Latina women in a farmworking community. Women Health. 1997;25(2):23.
174. Coughlin S, Wilson KM. Breast and cervical cancer screening among migrant and seasonal farmworkers: a review. Cancer Detect Prev. 2002;26(3):203–9.
175. Migration Patterns 2005. Migrant Clinicians Network; 2005 (accessed 29 November 2015). Available from: http://www.migrantclinician.org/migrant_info/migration_patterns.php.
176. Statistical Bulletin, Mirgration Statistics Quarterly Report, 27 November 2014. Office for National Statistics; 2014 (accessed 25 November 2015). Available from: http://www.ons.gov.uk/ons/dcp171778_386531.pdf.
177. Temporary harvest, seasonal and farm jobs. PickingJobs; 2005 (accessed 25 November 2015). Available from: www.pickingjobs.com.
178. Farm Index home page; 2005 (accessed 1 March 2005). Available from: www.farmindex.com.au.
179. Occupational Health of Hired Farmworkers in the United States. National Agricultural Workers Survey Occupational Health Supplement, 1999. Publication Number 20009-119. National Institute for Occupatioanal Safety and Health (accessed 25 November 2015). Available from: http://www.cdc.gov/niosh/docs/2009-119/pdfs/2009-119.pdf.
180. McCauley L, Lasarev MR, Higgins G, Rothlein J, Muniz J, Ebbert C, Phillips J. Work characteristics and pesticide exposures among migrant agricultural families: A community-based research approach. Environ Health Perspect. 2001;109(5):533–8.
181. Mobed K, Schenker MB. Occupational-health problems among migrant and seasonal farmworkers. West J Med. 1992;157(3):367–73.
182. Arcury TA, Vallejos QM, Schulz MR, Feldman SR, Fleischer AB, Jr., Verma A, et al. Green tobacco sickness and skin integrity among migrant Latino farmworkers. Am J Ind Med. 2008;51(3):195–203.
183. McBride J, Altman DG, Klein M, White W. Green tobacco sickness. Tob Control. 1998;7 294–8
184. Arcury TA, Quandt SA, Preisser JS. Predictors of incidence and prevalence of green tobacco sickness among Latino farmworkers in North Carolina, USA. J Epidemiol Community Health. 2001;55:818–24.
185. Quandt S, Elmore RC, Arcury TA, Norton D. Eye symptoms and use of eye protection among seasonal and migrant farmworkers. South Med J. 2001;94(6):603–7.
186. Jackson LL, Rosenberg HR. Preventing heat-related illness among agricultural workers. J Agromedicine. 2010;15(3):200–15.
187. Earle-Richardson G, Jenkins PL, Slingerland DT, Mason C, Miles M, May JJ. Occupational injury and illness among migrant and seasonal farmworkers in New York State and Pennsylvania, 1997–1999: Pilot study of a new surveillance method. Am J Ind Med. 2003;44(1):37–45.
188. Isaacs L, Bean TL. An overview of the Ohio migrant farmworker safety needs assessment. J Agric Saf Health. 1995;1(4):261–72.
189. Arcury T, Quandt SA, Mellen BG. An exploratory analysis of occupational skin disease among Latino migrant and seasonal farmworkers in North Carolina. J Agric Saf Health. 2003;9(3):221–32.
190. Schenker M, Pinkerton K, Mitchell D, Vallyathan V, Elvine-Kreis B, Green F. Pneumoconiosis from agricultural dust exposure among young california farmworkers. Environ Health Perspect. 2009; 117(7):988–94.
191. Schenker M. Inorganic agricultural dust exposure causes pneumoconiosis among farmworkers. Proc Am Thoracic Soc. 2010;7(2):107–10.
192. Schulte J, Valway SE, McCray E, Onorato IM. Tuberculosis cases reported among migrant farm workers in the United States, 1993–97. J Health Care Poor Underserved. 2001;12(3):311–22.
193. Morbidity Mortality Weekly Report, June 6, 1992/41(rr10). Prevention and Control of Tuberculosis in Migrant Farm Workers. Recommendations of the Advisory Council for the Elimination of Tuberculosis. Center for Disease Control (accessed 25 November 2015). Available from: http://www.cdc.gov/mmwr/preview/mmwrhtml/00032773.htm.
194. Poss J. The meanings of tuberculosis for Mexican migrant farmworkers in the United States. Soc Sci Med. 1998;47(2):195–202.

195. Magana C, Hovey JD. Psychosocial stressors associated with Mexican migrant farmworkers in the midwest United States. J Immigrant Health. 2003;5(2):75–86.
196. Hiott AE, Grzywacz JG, Davis SW, Quandt SA, Arcury TA. Migrant farmworker stress: mental health implications. J Rural Health. 2008;24(1): 32–9.
197. Alderete E, Vega W, Kolody B, Aguilar-Gaxiola S. Depressive symptomology: Prevalence and psychosocial risk factors among Mexican migrant farm workers in California. J Community Psychol. 1999;27(4):457–71.
198. Vernon S, Roberts R. Use of the SADS-RDC in a tri-ethnic community survey. Arch Gen Psychiatry. 1982;39(1):47–52.
199. Magana CG, Hovey JD. Psychosocial stressors associated with Mexican migrant farmworkers in the midwest United States. J Immigr Health. 2003;5(2):75–86.
200. Vega W, Kolody B, Aguilar-Gaxiola S, Alderete E, Catalano R, Caraveo-Anduaga J. Lifetime prevalence of DSM-III-R psychiatric disorders among urban and rural Mexican Americans in California. Arch Gen Psychiatry. 1998;55(9):771–8.
201. McCurdy S, Samuels SJ, Carroll DJ, Beaumont JJ, Morrin LA. Injury risks in children of California migrant Hispanic farm worker families. Am J Ind Med. 2002;42(2):124–33.
202. Quandt SA, Hiott AE, Grzywacz JG, Davis SW, Arcury TA. Oral health and quality of life of migrant and seasonal farmworkers in North Carolina. J Agric Saf Health. 2007;13(1):45–55.
203. Lukes S, Miller FY. Oral health issues among migrant farmworkers. J Dent Hyg. 2002;76(2): 134–40.
204. Chaffin J, Pai SC, Bagramian RA. Caries prevalence in northwest Michigan migrant children. J Dent Child. 2003;70(2):124–9.
205. Weathers A, Minkovitz C, O'Campo P, Diener-West M. Health services use by children of migratory agricultural workers: Exploring the role of need for care. [see comment). Pediatrics. 2003;111(5Pt1): 956–63.
206. Rosenbaum S, Shin P. *Migrant and Seasonal Farmworkers: Health Insurance Coverage and Access to Care*. Washington, DC: Kaiser Comission on Medicare and the Unsured, Center for Health Services Research and Policy, George Washington University; 2005 (accessed 25 November 2015). Available from: http://hsrc.himmelfarb.gwu.edu/cgi/viewcontent.cgi?article=1274&context=sphhs_policy_facpubs.
207. Ronda E, Regidor E. Higher birth weight and lower prevalence of low birth weight in children of agricultural workers than in those of workers in other occupations. J Occup Environ Med. 2003;45(1): 34–40.
208. International convention on the protection of the rights of all migrant workers and members of their families. Office of the High Commissioner for Human Rights (accessed 25 November 2015). Available from: http://www2.ohchr.org/english/bodies/cmw/cmw.htm.
209. Compliance Assistance – The Migrant and Seasonal Agricultural Worker Protection Act (MSPA) 2005. US Department of Labor; 2005 (accessed 1 March 2005). Available from: http://www.dol.gov/dol/compliance/comp-msawpa.htm.
210. Special Populations. Health Resources and Services Administration (accessed 10 March 2014). Available from: http://bphc.hrsa.gov/about/specialpopulations/.
211. Migrant Clinicians Network home page (accessed 5 November 2014). Available from: http://www.migrantclinician.org/.
212. National Center for Farm Workers Health home page (accessed 10 March 2014). Available from: http://www.ncfh.org/.
213. Salazar M, Napolitano M, Scherer JA, McCauley LA. Hispanic adolescent farmworkers' perceptions associated with pesticide exposure. West J Nurs Res. 2004;26(2):146–66.
214. Bean T, Isaacs LK. An overview of the Ohio migrant farmworker needs assessment. J Agric Saf Health. 1995;1(4):261–72.
215. Arcury T, Quandt SA, Rao P, Russell GB. Pesticide use and safety training in Mexico: The experience of farmworkers employed in North Carolina. Hum Organ. 2001;60(1):56–66.
216. Arcury TA, Estrada JM, Quandt SA. Overcoming language and literacy barriers in safety and health training of agricultural workers. J Agromedicine. 2010;15(3):236–48.
217. Hansen E, Donohoe M. Health Issues Among Migrant and Seasonal Farm Workers. J Health Care Poor U. 2003;14(2):153–64.
218. Anger WK, Tamulinas A, Uribe A, Ayala C. Computer-based training for immigrant Latinos with limited education. Hispan J Behav Sci. 2004:26(3):373-89.
219. Anger WK, Ammerman T, Tamulinas A, Bodner T, Rohlman DS. The suitability of computer-based training for workers with limited formal education: A case study from the US agricultural sector. Int J Train Dev. 2006;10(4):269–84.

220. World Dictionary 2015. World Menonite Conference (accessed 26 November 2015). Available from: http://www.mwc-cmm.org/article/world-directory.
221. Anderson C. Who Are the Plain Anabaptists? What Are the Plain Anabaptists?. J Amish Plain Anabaptist Studies. 2013;1(1):26–71.
222. Schwieder E, Schwieder D. *A Peculiar People*. Ames, IA: Iowa State University Press; 1975.
223. Jones P, Field W. Farm safety issues in Old Order Anabaptist communities: Unique aspects and innovative intervention strategies. J Agric Saf Health. 2002;8(1):67–81.
224. Kraybill DB, Gilliam JM. Culturally competent safety interventions for children in Old Order Anabaptist communities. J Agromedicine. 2012;17(2):247–50.
225. Jepsen SD, Henwood K, Donnermeyer J, Moyer K. Identifying culturally and age appropriate farm safety curricula for Amish and other conservative Anabaptist youth. J Agric Saf Health. 2012;18(1):57–67.
226. Hostetler J. *Hutterite Society*. Baltimore: Johns Hopkins University Press; 1974.
227. Ober T, Hyslop T, Hauk W. Inbreeding effects on infertility in humans: Evidence for reproductive compensation. Am J Hum Genet. 1999;64:225–31.
228. Agarwala R, Schaffer A, Tomlin J. Towards a complete North American Anabaptist genealogy II: Analysis of inbreeding. Hum Biol. 2001;73(4):533–45.
229. Hostetler J. *The Amish*. Scottdalse, PA: Herald Press; 1995.
230. Anderson C, Donnermeyer, J. Where Are the Plain Anabaptists? J Amish Plain Anabaptist Studies. 2013;1(1):1–25.
231. Aaland M, Hlaing T. Amish buggy injuries in the 21st century: A retrospective review from a rural level II trauma center. Am Surg. 2004;70(3):228–34; discussion 34.
232. Gilliam JM Jones JA, Field WE, Kraybill DB, Scott, SE. Farm-related injuries among Old Order Anabaptist children: Developing a baseline from which to formulate and assess future prevention strategies. J Agromedicine. 2007;12(3):11–23.
233. Anderson C, Donnermeyer J. Where Are the Plain Anabaptists? J Amish Plain Anabaptist Studies. 2013;1(1):1–25.
234. Fisher K, Hupcey J, Rhodes D. Childhood farm injuries in Old-Order Amish families. J Pediatr Nurs. 2001;16(2):97–101.
235. Hostetler J. A new look at the Old Order. The Rural Sociologist. 1987;7(4):278–92.
236. Rhodes D, Hupcey J. The perception of farm safety and prevention issues among the Old Order Amish in Lancaster County, Pennsylvania. J Agric Saf Health. 2000;6(3):203–13.
237. Gilliam JM, Jones PJ, Field WE, Kraybill DB, Scott SE. Farm-related injuries among Old Order Anabaptist children: developing a baseline from which to formulate and assess future prevention strategies. J Agromedicine. 2008;12(3):11–23.
238. Hubler C, Hupcey J. Incidence and nature of farm-related injuries among Pennsylvania Amish children: Implications for education. J Emerg Nurs. 2002;28(4):284–8.
239. Fisher K, Hupcey JE, Rhodes DA. Childhood farm injuries in Old-Order Amish families. J Pediatr Nurs. 2001;16(2):97–101.
240. Forward K, Chan M, Stewart TC, Gilliland J, Campbell C, Fraser DD. Injury analyses in rural children: Comparison of Old-Order Anabaptists and non-Anabaptists. J Trauma. 2010;69(5):1294–9.
241. Eicher C, Bean T, Buccalo S. Amish buggy highway safety in Ohio. J Multicult Nurs Health. 1997;3(2):19–24.
242. Donnermeyer J. Amish society: An overview. J Multicult Nurs Health. 1997;3(2):6–12.
243. Greksa L, Korbin J. Influence of changing occupational patterns on the use of commercial health insurance by the old order Amish. J Multicult Nurs Health. 1997;3(2):13–8.
244. von Gruenigen V, Showalter A, Gil K, Frasure H, Hopkins M, Jenison E. Complementary and alternative medicine use in the Amish. Complementary Therapies in Medicine. 2001;9(4):232–3.
245. Wenger OK, McManus MD, Bower JR, Langkamp DL. Underimmunization in Ohio's Amish: parental fears are a greater obstacle than access to care. Pediatrics. 2011;128(1):79–85.
246. Fair E, Murphy, T, Golaz, A, Wharton, M. Philosophic objection to vaccination as a risk for tetanus among children younger than 15 Years. Pediatr Neonatol. 2002;109(1):1–3.
247. Gerdner L, Tripp-Reimer T, Sorofman B. Health beliefs and practices: the Iowa Old Order Amish. J Multicult Nurs Health. 2002;8(3):65–71.
248. Schwartz K. Breast cancer and health care beliefs, values, and practices of Amish women. PhD dissertation. Detroit: Wayne State University; 2002.
249. Huntington G. Cultural interaction during time of crisis: Boundary maintenance and Amish boundary definition. In: Enninger W, editor. *Internal and External Perspectives on Amish and Mennonite Life*. Essen: Unipress; 1984. p. 92–118.
250. Kulig J, Meyer C, Hill S, Handley C, Lichtenberger S, Myck S. Refusals and delay of immunization

within southwest Alberta. Understanding alternative beliefs and religious perspectives. Can J Public Health/Revue Canadienne de Sante Publique. 2002;93(2):109–12.
251. Donnermeyer J, Friedrich L. Amish society: An overview reconsidered. J Multicult Nurs Health. 2002;8(3):6–14.
252. Campanella K, Korbin J, Acheson L. Pregnancy and childbirth among the Amish. Soc Sci Med. 1993;36(3):333–42.
253. Kreps G, Kreps M. Amishizing “medical care.” J Multicult Nurs Health. 1997;3(2):44–7.
254. Morton D, Morton C, Strauss K, Robinson D, Puffenberger E, Hendrickson C, et al. Pediatric medicine and the genetic disorders of the Amish and Mennonite people of Pennsylvania. Am J Med Genet. 2003;121C(1):5–17.
255. Brewer J, Bonalumi N. Cultural diversity in the emergency department: Health care beliefs and practices among the Pennsylvania Amish. J Emerg Nurs. 1995;21(6):494–7.
256. Katz ML, Ferketich AK, Paskett ED, Harley A, Reiter PL, Lemeshow S, et al. Cancer screening practices among Amish and non-Amish adults living in Ohio Appalachia. J Rural Health. 2011; 27(3):302–9.
257. Armer J, Radina M. Definition of health and health promotion behaviors among midwestern Old Order Amish families. J Multicult Nurs Health. 2002;8(3):43–52.
258. Baldwin C, Hibbeln J, Herr S, Lohner L, Core D. Self-care as defined by members of the Amish community utilizing the theory of modeling and role-modeling. J Multicult Nurs Health. 2002;8(3): 60–4.
259. Sivakova D, Pospisil M. Dermatoglyphic analysis of Habans (Hutterites) from Slovakia. Anthropol Anz. 2001;59(4):355–63.
260. Bader P, Dougherty S, Cangany N, Raymond G, Jackson C. Infantile refsum disease in four Amish sibs. Am J Med Genet. 2000;90(2):110–4.
261. Anthonisen N. Asthma in Hutterites. Can Respir J. 2002;9(5):289–90,93–4.
262. Ferketich AK, Katz ML, Kauffman RM, Paskett ED, Lemeshow S, Westman JA, et al. Tobacco use among the Amish in Holmes County, Ohio. J Rural Health. 2008;24(1):84–90.
263. Cates JA, Weber C. A substance use survey with Old Order Amish early adolescents: perceptions of peer alcohol and drug use. J Child Adolesc Substance Abuse. 2012;21(3):193–203.
264. Bassett DR, Schneider PL, Huntington GE. Physical activity in an Old Order Amish community. Med Sci Sports Exerc. 2004;36(1):79–85.
265. Bassett D, Schneider P, Huntington G. Physical activity in an Old Order Amish community. Med Sci Sports. 2004;36(1):79–85.
266. Gandek B, Ware J, Aronson N, Apolone G, Neil K, Bjorner J, et al. Cross-validation of item selection and scoring for the SF-12 health survey in nine countries: Results from the IQOLA Project. J Clin Epidemiol. 1998;51(11):1171–8.
267. Fisher KA, Newbold KB, Eyles JD, Elliott SJ. Physical health in a Canadian Old Order Mennonite community. Rural Remote Health. 2013;13(1):2252.
268. Dabrowska E, Wismer SK. Inclusivity matters: perceptions of children’s health and environmental risk including Old Order Mennonites from Ontario, Canada. Health Risk Soc. 2010;12(2):169–88.
269. Patel F, Postolache N, Mohyuddin H, Vaswani D, Balis T, Raheja UK, et al. Seasonality patterns of mood and behavior in the Old Order Amish. Int J Disabil Hum Dev. 2012;12(1):53–60.
270. Andreoli E, Miller J. Aging in the Amish community. Nursing Connections. 1998;11(3):5–11.
271. Carrabba J, Wyckoff S, Scribani M, Jenkins P, May J. Farm safety education in New York Mennonite schools. J Agromedicine. 2012;17(3):338–44.
272. Yiin JH, Ruder AM, Stewart PA, Waters MA, Carreon T, Butler MA, et al. The Upper Midwest Health Study: A case-control study of pesticide applicators and risk of glioma. Environ Health. 2012;11:39.
273. Brunt J, Shields L. Preventive behaviours in the Hutterite community following a nurse-managed cholesterol screening program. Can J Cardiovasc Nurs. 1996;7(2):6–11.

Chapter

3

Agricultural Respiratory Diseases

Kelley J. Donham and Anders Thelin

Reviewer: John May

3.1 Introduction and Overview

Respiratory diseases are perhaps the most important occupational health hazard among farmers and agricultural workers when considering their combined high frequency and risk of functional impairment (1). Knowledge of agricultural exposures resulting in occupational respiratory disease is important for the purposes of diagnosis, control, prevention, and workers' compensation issues. Because repeated attacks of acute illness and chronic impairment can be best controlled through mitigating the source of exposure, discovering the source(s) is a critical step in secondary as well as primary prevention. The emphasis on prevention in this book explains the inclusion of agricultural processes and structures as exposure sources. Assessment of (measurement) of respiratory exposures, and selection and use of respiratory personal protection equipment (components of a generic prevention program) are introduced in this chapter and detailed in Chapter 15.

3.1.1 Introduction to Respiratory Hazards in Agriculture

Perhaps more than any other occupational group, agricultural workers are exposed to an extensive array of agents potentially harmful to their respiratory system. Depending on the type of agricultural operation, workers are likely to inhale dusts on a daily basis that originate from soil, animals, animal feeds, their wastes, plants, products of decay or fermentation of stored plant materials, applied pesticides and fertilizers, their residues, and exhaust fumes from operation of farm machinery. Table 3.1 summarizes some of the primary substances and sources of hazardous aerosol exposures in agriculture that may lead to respiratory disease (2–11).

A principal objective of this chapter is to facilitate the reader to grasp a foundational understanding of the agricultural processes and variables in exposures to enhance their abilities to ascertain an accurate occupational history leading to accurate recognition, diagnosis, treatment, and prevention. Farmers, their families, and workers are potentially exposed to a combination of hazardous inhalable substances when performing various farm tasks. Although agricultural dusts are ubiquitous exposures in agriculture, the sources and constituents of the dust may vary among regional types of agriculture. Fundamental toxicological principles relative to injury risk include exposures to high concentrations of the offending substances and greater length of exposure time. We will describe chronic low-level concentrations (CLLC) and periodic acute massive and moldy (PAMM)

Agricultural Medicine: Rural Occupational and Environmental Health, Safety, and Prevention, Second Edition.
Kelley J. Donham and Anders Thelin.

Table 3.1 Hazardous agricultural aerosol exposures: substances and their sources

Animals	Plants	Insects	Microbes and metabolites	Pesticides	Infectious agents	Feed additives	Gases and fumes
Dander	Grain dust	Feces of mites, roaches	Microbes: Gram-positive and Gram-negative bacteria, mold spores, fungal elements	Residues on crops	Rickettsia (ornithosis, Q fever)	Antibiotics	Anhydrous ammonia fertilizer
Broken bits of hair	Plant particles	Insects parts	Endotoxins Glucans Mycotoxins	Fumigants: (methyl iodide), phosphine, formaldehyde, carbon tetrachloride	Bacteria (tularemia, anthrax)		Ammonia from animal wastes
Dried fecal material	Tannins Glucans				Fungi (histoplasmos, blastomycosis) Virus (avian and swine influenza, hanta virus)		Hydrogen sulfide from animal waste Nitrogen oxides from silo gas Welding fumes Diesel exhaust

exposures, and the resultant health outcomes of each. Examples of chronic low-level exposure include working in livestock or poultry (12, 13) confinement structures, mixing feed, feeding animals, and working in grain-handling facilities. Examples of PAMM exposures are breaking open bales of spoiled hay, cleaning moldy grain from storage structures, and opening (uncapping) non-airtight silos. Additional to agricultural dusts, gaseous or mist exposures include applying pesticides or anhydrous ammonia fertilizer, working near or in manure storage structures, and working in a newly filled non-airtight silo. Respiratory infectious hazards can occur working with infected animals, working in their housing, or working with contaminated soils.

Airborne exposure to any substance is likely to be more intense, and its effects more damaging, if it occurs within an enclosed structure (because of its increased concentration). Seasonal changes are important variables, for example exposures in livestock structures are more concentrated in cold weather as the buildings are tightly closed to conserve heat. Some hazardous exposures occur only during specific seasons (e.g., silo filler's disease occurs in late summer or early fall). Silo unloader's disease (a type of organic dust toxic syndrome, discussed later in this chapter) most commonly occurs in the period from fall through early spring (some time after filling and other fodder sources have been depleted).

It is important to recognize that many hazardous exposures discussed in this chapter extend to family and workers and beyond the farm or ranch gate to the general rural community members and to other agricultural support businesses, such as grain elevator workers, animal slaughterhouse workers, truckers, professional pesticide applicators, and veterinarians. As an example of the breadth of potentially exposed persons to agricultural respiratory hazards, consider the production cycle of grain. From harvest to end use, all those who handle the grain may be exposed to the dust generated from it. Grain dust exposure starts with farmers and farm workers, who grow, harvest, sometimes store, and transport grain to local commercial storage (elevator) and feed mill facilities. Grain transport workers (truck, rail, barge, ocean going vessel) are also exposed as well as grain-processing plant workers. The latter include those who work in processing wheat to flour and grain to alcohol, sweeteners, and breakfast cereal. Bakers and food handlers are also exposed to grain dusts (14, 15) and suffer from respiratory responses similar to those of exposed farmers. Furthermore, residents in the vicinity of grain operations may also be exposed, as evidenced by a few community outbreaks downwind from grain-handling and storage facilities (16). As the respiratory system has a limited number of responses to inhaled substances all the people mentioned above have in common the same potential symptoms and disease outcomes from these exposures. The particular responses are modulated by the concentration, length of time exposed, type of inhaled matter, particle size, and biological variation among individuals. Details of the respiratory system pathological responses to inhaled substances are provided later in this chapter.

Agricultural dusts are one of the most ubiquitous and important hazardous exposures in agriculture. The great majority of agricultural dusts are organic (from a living source) particles. (Henceforth, in this book we consider agricultural dusts as organic dusts.) However, inorganic mineral particles from soils are also common exposures. Most of these exposures are considered nuisance dusts (of low biological activity, and thus low hazard), but some soils may contain hazardous minerals (silica and asbestos) that have known biological activity. Asbestos has been found in field dust in some farming regions in Canada and Finland. Health hazards for farmers in these regions have not been quantified. Silica particles have been found in some dry climate areas (Central Valley) in California. Some subsets of workers in this region may experience chronic bronchitis and pneumoconiosis from these exposures (17).

Agricultural organic dusts are present globally in most farming regions. They are biologically active, causing irritation, inflammation, allergies, toxicity, infections, or some combination of these conditions. Responses may be acute or chronic, resolving completely or resulting in permanent impairment and disability, but rarely ending in acute death. Agricultural dust particles are relatively large compared to inorganic dust (mass median diameter approximately 10 microns) (18) and are inhalable, being deposited primarily in the airways rather than the lung tissue proper. Therefore, the most common respiratory conditions among farmers are airways conditions, not diseases of lung parenchyma per say. Agricultural dusts contain inflammatory substances and components of microbial origin (e.g., endotoxin and glucans). Unlike most industrial dust exposures where there are usually just single agents and they are well characterized (e.g., dust of silica, asbestos, coal) agricultural dusts are complex, with multiple agents that are often not well defined. The dust components and concentrations vary with the season, type of farming operation, geographical regions, and type of task being performed. Furthermore, a gaseous component may accompany the agricultural dust exposure (mixed exposure), which may result in a synergistic response, as has been shown with combined exposures to dust and ammonia in livestock buildings (19).

In addition to dust exposure, there are also gases, pesticides, fertilizers, and several infectious diseases common to animals and man (zoonoses) that can cause respiratory disease. Histoplasmosis, swine influenza, and ornithosis are just three of at least eight zoonoses affecting the respiratory tracts of agricultural workers.

3.1.2 Respiratory Responses to Inhaled Agricultural Substances

The respiratory system has a limited range of pathologic responses, which results in a limited range of disease outcomes. Therefore (as will be described later in this chapter) there are only a few conditions that result from agricultural dust exposures. However, there is variability in an individual's biological response, which is also dependent in part on the particular physical and toxic properties of the inhaled dusts. For example variable qualities of the dust include its relative irritant or inflammatory qualities, antigenicity, size and shape of the particles, location of deposition in the respiratory tract, concentration, and duration of exposure. Biological variables include the individual's relative genetic susceptibility to endotoxin and immunologic status. Personal behavioral qualities include smoking history and occupational, recreational, or other environmental exposures off the farm. For all of these reasons, respiratory responses to dusts and gases in agricultural settings are complex. Nevertheless, research in recent years has documented clusters of symptoms and specific conditions that clearly make up a well-recognized group (complex) of agricultural occupational respiratory conditions (1, 7, 8, 20). Respiratory illness conditions resulting from agricultural dusts and gas exposures are listed in Table 3.2 and described in the following sections. Specific exposure circumstances and resulting disease entities are outlined in Sections 3.2–3.8 of this chapter. Details of the diagnosis, treatment, and prevention of these conditions are also explained in these sections.

3.2 Agricultural Structures and Respiratory Hazards

3.2.1 Introduction

As mentioned previously, agricultural respiratory problems are often associated with work in agricultural structures because the confined-space environment results in concentrated exposures. The following section describes common agricultural structures associated with common respiratory health problems. Table 3.3 presents a summary of various agricultural structures and resultant respiratory disease conditions associated with work within these structures.

3.2.2 Feed Grain, Silage, and Other Commodity-storage Structures

Feed grain and silage storage structures are common sources of hazardous concentrations of agricultural dusts. There are several types of these structures, each with a different exposure profile.

Table 3.2 Agricultural respiratory conditions

1. Organic dust exposure associated respiratory conditions
   a. Mucous membrane irritation (MMI)
      - Sinusitis
      - Rhinitis
      - Pharyngitis
      - Laryngitis
      - Tracheitis
   b. Bronchitis
      - Acute/subacute bronchitis (symptoms of dry cough)
      - Chronic bronchitis (cough with phlegm lasting at least 3 months for more than 2 years)
   c. Non-allergic asthma-like condition (NALC, also called hyper-responsive airways or reactive airways disease)
   d. Monday morning disease (MMD)
   e. Organic dust toxic syndrome (ODTS, also called mycotoxicosis, silo unloader's disease or toxic alveolitis)
   f. Allergic-mediated illnesses
      - Extrinsic asthma (atopic-related disease)
      - Allergic rhinitis
      - Hypersensitivity pneumonitis (HP, also called farmer's lung or extrinsic allergic alveolitis) may result in:
        – acute HP (a delayed influenza-like illness clinically similar to ODTS)
        – chronic HP (interstitial fibrosis)
2. Conditions arising primarily from inhaled agricultural gases
   a. Hydrogen sulfide
      - Respiratory depression/respiratory arrest
      - Pulmonary edema (acute or delayed)
   b. Anhydrous ammonia
      - Laryngeal edema
      - Pharyngitis
      - Tracheitis
      - Bronchitis
      - Pulmonary edema (acute)
      - Bronchiectasis (delayed)
   c. Silo gas (nitrogen oxides)
      - Pharyngitis
      - Tracheitis
      - Bronchitis
      - Pulmonary edema (acute or delayed)
      - Bronchiolitis obliterans (delayed)
   d. Fumigant pesticides
      - Pharyngitis
      - Tracheitis
      - Bronchitis
      - Pulmonary edema
   e. Ingested paraquat
      - Progressive malignant pulmonary fibrosis
3. Respiratory response conditions to infectious agents
   a. Pneumonitis/pneumonia

Grain Bins

Grain bins (Figure 3.1) are used to dry and store shelled corn, oats, beans, rye, barley, wheat, sorghum, and other small grains. Typically, grain bins are cylindrical galvanized steel structures placed on cement slabs. Bins cannot be emptied completely by mechanical means. To empty the last several inches of grain, the grain must be hand shoveled or vacuumed. (Note: grain bin physical injury hazards and safety details are covered in Chapter 11.) During this operation, large quantities of aerosolized grain dusts, microorganisms, and their by-products (primarily endotoxin and glucans) may be inhaled, creating a

Table 3.3 Agricultural structures and respiratory problems

	Agricultural structures	Activities resulting in respiratory exposures	Major resulting respiratory problems	Cause of respiratory problems	Detailed discussion
Feed grain, silage, and grain-storage and -handling buildings	Corn cribs	Moving and shelling corn out of crib; cleaning out crib	Asthmatic attack NALC Bronchitis ODTS Hypersensitivity pneumonitis (rare)	Grain dust, including bacterial and fungal spores and by-products (e.g., endotoxins, glucans)	Section 3.3 (agricultural dusts) Section 3.4 (confinement animal feeding operations)
	Grain bins	a. Moving grain out of storage, cleaning out moldy residual grain	Asthmatic attack ODTS Bronchitis Acute inflammatory response Airways obstruction Increased airways reactivity Hypersensitivity pneumonitis (rare)	Grain, dust, including bacterial and fungal spores and by-products (e.g., methyl bromide)	Section 3.3 (grain dusts)
		b. Entering bin that is being emptied (entrapment)	Suffocation	Grain entrapment	Section 3.2 (structures)
		c. Grain fumigation; entering a fumigated structure too early	Irritation Laryngeal edema Bronchospasm Pulmonary edema Respiratory depression Death	Fumigants (e.g., methyl bromide)	Section 3.6 (pesticides)
	Grain elevators and feed mills	a. Loading or unloading grain, cleaning grain bins, grinding and mixing feed	ODTS NALC Bronchitis COPD Occupational asthma Hypersensitivity pneumonitis (rare)	Grain dust, including bacterial and fungal spores and by-products (e.g. endotoxin, glucans)	Section 3.3 (grain dusts)
		b. Improper application of fumigants; entering a recently fumigated structure	Irritation Laryngeal edema Bronchospasm Pulmonary edema Respiratory depression Death	Fumigants (e.g., methyl bromide)	Section 3.6 (pesticides)
	Airtight silo	Entering silo filled with silage or high-moisture grain	Asphyxiation	Anoxia	Section 3.2 (structures)
	Upright, non-airtight silos	a. Entering silo within 2 weeks of filling with silage	Sudden death, pulmonary edema, delayed reaction with bronchiolitis obliterans (silo filler's disease)	Oxides of nitrogen (silo gas)	Section 3.5 (oxides of nitrogen)

		b. Unloading silage, throwing off top layers of moldy silage	ODTS Hypersensitivity pneumonitis	Bacteria, fungi, and their by-products	Section 3.3 (spoiled grains)
	Fruit and root storage buildings	Operating machinery or working in buildings with improperly working heaters (CO poisoning)	CO poisoning	CO	Section 3.2
Confinement animal feeding operations and processing	Confinement houses: swine and poultry	Working inside building	ODTS MMI NALC Bronchitis COPD	Organic dusts from animals, their feed and wastes, and gases (e.g., endotoxins, glucans, NH_3, H_2S < 500 ppm)	Section 3.4 (livestock confinement)
	Confinement houses and manure storage pits (swine, sheep, veal calf, dairy or beef cattle with liquid manure system)	Entering building during manure pit agitation; entering manure pit	Pulmonary edema, possibly respiratory arrest and death	H_2S > 250 ppm	Section 3.4 (livestock confinement)
	Confinement houses: poultry	a. Administering aerosol vaccines; working inside building during disease outbreak	Newcastle disease	Infection with Newcastle disease virus	Section 3.7 (infectious diseases)
		b. Working with diseased animals	Ornithosis (turkey only) (rare)	Infection with *Chlamydia psittaci*	Section 3.7 (infectious diseases)
	Sheep and dairy cattle housing	Cleaning buildings, especially those where animals are born; assisting during birth process (Q fever)	Q fever	Infection with *Coxiella burnetii*	Section 3.7 (infectious diseases)
	Conventional chicken coops (or other structures where wild birds have roosted)	a. Cleaning or razing houses not in use for several years	Histoplasmosis Ornithosis	Infection with *Histoplasma capsulatum*	Section 3.7 (infectious diseases)
		b. Working with infected poultry		Infection with Newcastle disease virus	Section 3.7 (infectious diseases)
	Turkey-processing plants	Slaughter operations	Ornithosis	Infection with *Chlamydia psittaci*	Section 3.7 (infectious diseases)
	Cattle, sheep, or goat slaughterhouses	Slaughter operations	Q fever (rare) Brucellosis	Infection with *Coxiella burnetii* or *brucella* spp	Section 3.7 (infectious diseases)

(*Continued*)

Table 3.3 (Continued)

	Agricultural structures	Activities resulting in respiratory exposures	Major resulting respiratory problems	Cause of respiratory problems	Detailed discussion
Equipment and supply buildings on farms	Machine shops, garages, machine storage buildings	a. Running gasoline- or diesel-fuel-powered engines when buildings are not adequately ventilated; heating buildings with heaters that are not working properly (CO_2)	CO poisoning	CO	Section 3.2 (structures)
		b. Welding galvanized iron (metal fume fever)	Metal fume fever	Zinc oxide	Section 3.2 (structures)
Barns	Barns	Moving or feeding hay or grain; grinding and mixing feed (organic dust); caring for animals	ODTS Allergic rhinitis NALC Bronchitis COPD Occupational asthma Hypersensitivity pneumonitis	Hay dust Grain dust Bacteri, fungi, and their by-products in moldy fodder Dusts from animals, their feed and wastes	Section 3.2 (spoiled hay, grain) Section 3.3 (grain dusts) Section 3.4 (livestock confinement)
			Q fever	Infection with *Coxiella burnetii*	Section 3.7 (infectious diseases)
			Histoplasmosis	Infection with *Histoplasma capsulatum*	Section 3.7 (infectious diseases)

NALC, non-allergic asthma-like condition; ODTS, organic dust toxic syndrome; COPD, chronic obstructive pulmonary disease; CO, carbon monoxide; MMI, mucous membrane irritation.

FIGURE 3.1 Agricultural respiratory conditions often result from work inside agricultural structures where aerosols are concentrated, increasing hazardous exposures. Grain bins are a common confined space on many farms (Source: Charles Brutlag/Shutterstock.com.)

high risk for organic dust-related respiratory diseases (discussed later in this chapter). Grain truckers also may inhale these dusts while helping a farmer empty the bin or while leveling grain that is filling the truck (Figure 3.2). Prevention of dust exposure includes drying the grain down to at least 15% moisture prior to storage, aeration of grain as needed (humidity monitors can be integrated into the system to monitor moisture content) while in storage, and bin maintenance to prevent water leakage and condensation. Grain vacuums may be used in place of shovels, and will help reduce, but not eliminate, dust exposures, therefore particulate (dust) respirators should be used during these tasks (see Chapter 15 for more detail on respirator selection and use).

Farmers and grain elevator employees often apply fumigants (a type of insecticide) to grains in long-term storage to control the insects and vermin that degrade the grain. These highly toxic and irritant insecticides, if inhaled, can cause respiratory tract irritation, laryngeal edema, bronchospasm, pulmonary edema, respiratory depression, and sudden death. The details of this hazard are covered in Section 3.6.

Grain Elevators and Feed Mills

Grain elevator and feed mill enterprises are commonly found in grain and livestock production areas. Elevator operators either store grain for producers or purchase grain from producers (farmers) that they dry, store, grind for animal feed or transport and sell to larger terminals. Farms and ranches that raise or feed out large numbers of livestock may also have extensive grain-handling facilities, including a system of grain dryers, storage bins, tanks, and hoppers for grain and feed similar to a commercial grain elevator, offering similar hazardous work exposures. Commercial grain elevators and mills in the northern United States and Canada often use

FIGURE 3.2 Grain is commonly transported locally and regionally by truck.The drivers of these vehicles are exposed to grain dusts, as well as the grain farm operators. (Source: VT750/Shutter stock.com.)

FIGURE 3.3 Grain elevators are regional businesses that store and market grain. Elevators in the northern U.S. and Canada are often constructed of wood. Employees of these facilities are exposed to hazardous grain dust.

FIGURE 3.4 A common style of elevator in the U.S. These elevators are commonly constructed of steel and concrete. Worker exposure to grain dust is apparent in this photograph, and can be more concentrated in enclosed spaces. (Source: Charles Brutlag/Shutterstock.com.)

wooden structures (Figure 3.3) or steel buildings and bins (Figure 3.4) for storage of bagged feed, seed, pesticides, and other products.

Since grain elevator and feed mill workers are exposed to grain dusts regularly over an extended time period, chronic as well as acute respiratory responses may result (see Section 3.3 in this chapter for details) (21, 22). High concentrations of dust are especially prominent whenever moving or grinding the grain.

Tower Silos

Rising 30–50 feet (9–15 meters) above the farmstead (primarily dairy and beef cattle) are cylindrical structures for storage of silage or grain. There are two basic types of tower silos: (1) oxygen-limiting or airtight silos and (2) non-airtight silos.

Oxygen-limiting silos are made of porcelain fused to steel or concrete-stave constructions sealed with an epoxy lining (see Figure 3.5). They can be tightly closed to limit the entrance of air. Air inside the silo is displaced by a large vinyl bag that collapses as the silo is filled. Plant materials placed in the silo continue aerobic respiration using the residual oxygen until a low-oxygen, high-carbon-dioxide atmosphere develops, ceasing aerobic metabolic processes and preserving the stored product. Silage or high-moisture corn is blown or augured into the silo at the top and removed from the bottom with an auger. Because these bottom unloaders often need repair, top unloaders are now available for conversion. Silage consists of the whole, chopped plant (usually corn, but may also be alfalfa, clover, mixed grasses and legumes, sorghum, oats, wheat, or milo) harvested at a relatively high moisture content compared to conventionally stored hay or grain. Silage is fed to ruminant animals, mainly to dairy and beef cows, although alfalfa haylage may also be fed to sheep. Corn silage is harvested during late summer or early fall and typically fed out in fall, winter or early spring (when pastures are depleted), but may be fed out all year long. High-moisture corn is fed to feeder cattle or swine and may be used year round.

This atmosphere is oxygen deficient and there is a high potential for asphyxiation for anyone who enters. As long as feed stuffs remain in the

FIGURE 3.5 An oxygen-limiting silo (black) and a non-oxygen-limiting silo (gray). These present different occupational exposures to farm workers. (Source: John Bilous/Shutterstock.com.)

structure, airtight silos should not be entered under *any* circumstances, except by a trained repair technician properly equipped and experienced in the use of oxygen-measuring devices, with self-contained breathing apparatus.

Non-airtight (conventional) tower silos are constructed of concrete slabs held together with steel staves. Older versions may be made of wood, brick, or metal. These silos are used to store the same kinds of silage as airtight silos, and occasionally are used to store grain (see Figure 3.5).

When freshly chopped plant material (silage) is placed in these silos, the metabolic processes of microbes in the plant material can result in the formation of oxides of nitrogen (NOx) from nitrates in the plant material. Anyone who enters a silo to level out silage when these gases are present may inhale enough silo gas to cause sudden death, acute or delayed pulmonary edema, or latent bronchiolitis obliterans, reactions commonly called silo filler's disease. The danger period extends for 2 weeks after filling. (Details of silo filler's disease are given in Section 3.5.) After the silo is filled, a sheet of plastic is placed over the top and weighted down with an additional 6–12 inches of silage, chains, or other weights. The purpose is to help preserve the silage underneath. However, the top 5–10 inches of silage (regardless of whether plastic has been placed over the top) will spoil. This material must be discarded before the feed-grade material underneath can be used. Manual unloading of this material leads to massive exposure to bioaerosols and the resultant organic dust respiratory diseases. Organic dust toxic syndrome (ODTS; also called silo unloader's disease or mycotoxicosis) and hypersensitivity pneumonitis (farmer's lung) have been associated with this exposure. Detailed descriptions of ODTS and other organic dust respiratory conditions are given in Section 3.3.

Other Silage Storage Structures

Bunker or pit silos (Figure 3.6) and agricultural storage bags (Figure 3.7) are alternatives to tower silos. Bunker silos are variable-sized three-sided

FIGURE 3.6 Bunker silos are an alternate form of silage storage that offer a decreased hazard to exposure to nitrogen oxides (silo gas). However, there are increase risks for physical injury from roll-over of tractors driven on the silage to pack it down. Other hazards include risk from caving in of the silage wall during load out. (Source: Josien/Shtterstock.com.)

FIGURE 3.7 Agricultural plastic bags offer a convenient storage option, with reduced hazardous nitrogen oxides (NO_x) exposure. However, the bags are expensive and there is a management and labor cost for disposing or recycling the used bags (Source: Alistair Scott/Shutterstock.com.)

bins (without a roof) with concrete, wooden, or earthen walls of 10–15 feet (3–5 meters) high and 20–40 feet (6–12 meters) in side length. As bunkers and agricultural bags do not present enclosed spaces, the hazard of acute toxic respiratory exposure to silo gas is minimal, compared to tower silos. However, it should be noted that spoilage may be increased with pit storage, lowering its feed quality. Furthermore, pit silos add the risk of falls from the silage, tractor overturns as they are used to drive over and pack the silage, and the silage wall collapsing on the person during load-out tasks.

Agricultural storage bags are becoming popular for silage, hay, and small grains. Agricultural storage bags are hermetically sealed (air and water tight), thus the stored material is usually in good condition, reducing microbial contamination and thus reducing worker exposure to agricultural dusts and nitrogen oxides (silo gas). Furthermore, the agricultural bags are usually outside, and do not present a confined space hazard.

3.2.3 Fruit and Root Storage Structures

In orchard and root-crop growing regions special buildings are used for the storage of potatoes, apples, and bananas among other crops (see Figure 3.8). These structures are often large enough for a forklift truck, tractor and wagon, or large straight truck to enter. They present a low-oxygen atmosphere (3% or less) and a high-carbon-dioxide asphyxiation or carbon monoxide intoxication hazard. Fumigant insecticides may occasionally be used in these facilities, presenting an additional toxic exposure.

3.2.4 Livestock and Poultry Housing and Processing Plants

Confined animal feeding operations (CAFOs) differ from conventional animal housing in that large numbers of animals are housed inside buildings for most or all of their lives. The buildings include systems for ventilation (for control of heat and humidity), watering the livestock,

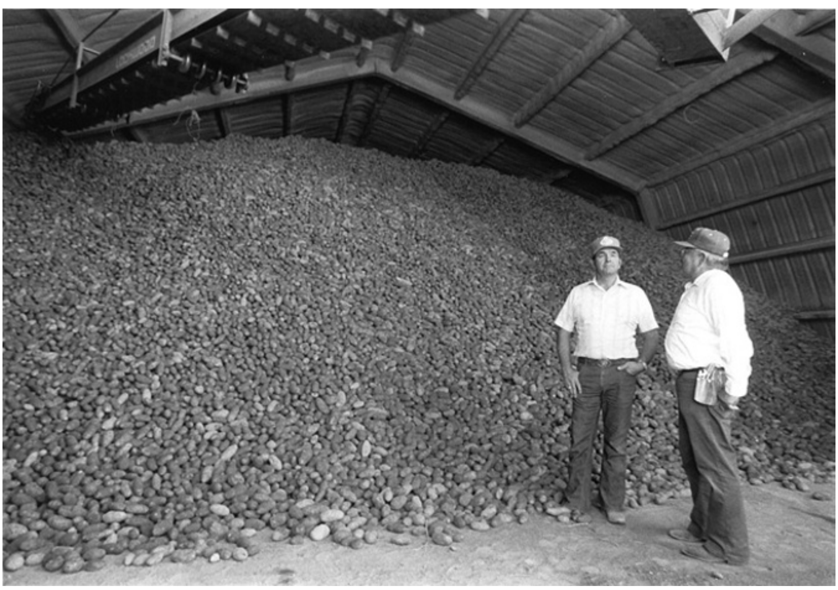


FIGURE 3.8 Potato and other fruit (e.g., apple) storage facilities may have high carbon dioxide concentrations to preserve the product, which may result in asphyxiation hazard to workers.

feeding the livestock, and handling animal wastes. Extensive management and maintenance are needed to insure all systems are working to create a healthy and safe environment for animals and workers. Tasks for workers include feeding, monitoring the animals, assisting in birthing, and veterinary treatments. As the ventilation system is designed only to control humidity and heat, environmental control of the dusts and gases generated by the animals, their feed, and their wastes is often a health hazard, especially in cold weather as ventilation is reduced to conserve heat and energy. Thus, workers in confinement buildings, especially those housing swine or poultry, and to a lesser extent dairy, often experience acute and chronic respiratory reactions to the aerosolized dusts and gases. Organic dust diseases are described in Section 3.4.

Workers in swine- or poultry-confinement buildings may be exposed to the swine or avian influenza viruses, which typically cause subclinical or mild transient illness in humans (see Section 3.7). However, certain strains of avian influenza can be severe in humans as over 100 fatalities have been reported, mainly from South-East Asian countries. Poultry-confinement workers may also be exposed to Newcastle disease virus, particularly when applying live attenuated vaccines (often administered by aerosol or in the water). Veterinarians working with infected birds or performing a diagnostic postmortem are at risk of exposure to ornithosis or avian influenza (23). Furthermore, carbon monoxide poisoning has been a hazard in confined livestock buildings arising from inadequate ventilation when using internal combustion engines to power high-pressure washers or from malfunctioning fossil-fuel heaters.

3.2.5 Sheep and Dairy Cattle Housing

Dairy barns and other conventional buildings sheltering cattle or sheep may be used to confine animals while they give birth. Farmers may assist with the birth or clean out bedding after a birth, and may come in contact with the rickettsia *Coxiella burnetii* which causes Q fever.

3.2.6 Conventional Chicken Coops

Conventional chicken coops are not used much today, having been largely replaced by large confinement structures. However, the local and organic food movement and public concern for more humane housing for animals has renewed use of these facilities. Old unused poultry buildings may harbor the fungus *Histoplasma capsulatum*, which grows in dried avian feces or soil contaminated by same. Inhalation of fungal spores released into the air when these houses are cleaned or torn down has caused histoplasmosis.

3.2.7 Poultry- and Meat-Processing Plants

Workers in plants where turkeys are slaughtered and processed, especially workers eviscerating birds, may inhale the chlamydial organism that causes ornithosis (*Chlamydia psittasi*), an infectious disease ranging from influenza-like infection to acute fulminating pneumonia. The risk is especially high in those plants processing the breeding birds from range-reared flocks as these birds are at higher risk of contracting ornithosis. Workers in cattle, sheep, and goat slaughterhouse operations could also contract Q fever from infected animals. Workers at poultry- or red-meat-processing plants could be exposed to ammonia as this is commonly used as the refrigerant in the cooling system. Leaks in the system have resulted in respiratory exposures for workers.

3.2.8 Equipment and Supply Buildings on Farms

Machine Shops, Garages, and Machine Sheds

Since farmers are occupied from spring through fall with the cycle of crop production, they use the winter season to do the bulk of their machinery repair and maintenance work. This usually means working inside closed garages, machinery shops, machine storage buildings, or any other available structure. Operating gasoline- or

FIGURE 3.9 Welding is commonly practiced on many farms and may create a risk for metal fume fever, skin burns, and retinal inflammation.

diesel-fuel engines indoors can result in carbon monoxide poisoning when the buildings are closed to prevent heat loss and when heaters are not working properly. Adequate ventilation of buildings is necessary at all times. Welding is a task for which farm shops may not be safely ventilated. Welding galvanized steel (which contain zinc) produces zinc oxide fumes which, when inhaled, cause metal fume fever (24). Symptoms begin 4–12 hours following exposure (see Figure 3.9). The exposed person first notices a sweet or metallic taste in the mouth, followed by throat dryness or irritation. Later symptoms include cough and shortness of breath, general malaise, weakness, fatigue, and muscle and joint pains. Leukocyte count and serum lactate dehydrogenase may be elevated. Fever and shaking chills then develop, followed by profuse sweating. Resolution occurs in 24–48 hours. Inhaling fumes from welding steel can result in iron deposits in the lung, which usually do not result in a health hazard. Welding chrome can result in eye and upper respiratory irritation. Welding-related respiratory health risks can be mitigated through adequate ventilation, welding outdoors, and use of a dust and fume respirator (see Chapter 15 for respirator selection).

Barns

Barns are multipurpose farm structures. They may be used to store straw and hay, to mix or grind feed, as farm shops, or (especially in winter) to house livestock or milk cows. Although many farms now have specialized storage structures for agricultural chemicals, many barns are used to store various potentially hazardous chemicals to clean milk lines, pesticides, and chemically treated seeds. Chemical dust residue from open or broken containers may be present. Respiratory or toxic exposures associated with any of these activities may therefore occur in barns as well as in other more specialized structures.

Dairy barns are the most common type of barn in use. Any activity associated with milking and caring for dairy cattle can be done in the typical multi-storied dairy barn. Dust can be aerosolized from the hay and grain often stored here and from animals housed and fed in the barn. If grain or hay has spoiled, shoveling the grain or breaking open moldy bales releases clouds of dust containing bacteria, fungal spores, endotoxin, glucans, and possibly mycotoxins, producing respiratory exposures (3). (Mycotoxins are substances produced by various mold species with unknown human health effects from inhalation (25).) On the barn's ground floor there may be cow stanchions or a milking parlor, free stalls, holding and sorting pens, an area with feeding bunks, box stalls for calving, calves, or other cow isolation, and areas for storing, mixing, and grinding feed. In some dairy operations, structures inside or outside the main barn "free stalls" or "loafing sheds" are used where cattle can go to feed and be out of the elements. Bedding for the cattle may be blown into these areas with a bale shredder. This device takes a whole bale of straw, chops it up, and blows it into the stall area. If the straw of hay is in poor condition (high microbial growth) this task can create a massive organic dust aerosol and risk of acute or chronic organic dust respiratory disease for the operator. Saw dust or wood chips may also be used for bedding and may present respiratory hazards similar to hay or straw. Recycled gypsum wall board may also be used for bedding, but has been incriminated as a cause of excess hydrogen sulfide in manure storages, resulting in several human toxic exposures. Sand may also be used for bedding and is free of any known respiratory hazards. A fume hazard in the milk house of a dairy can result when workers inadvertently mix a highly alkaline milk line cleaner with a chlorine solution. (The former is used to dissolve solids in the line, the chlorine is a disinfectant.) This mixture results in immediate production of chlorine gas (a highly irritant material), leading to upper airway and eye irritation.

The complex mixture of organic dusts inhaled during these activities can result in the complex organic dust diseases described in Section 3.3. Dust exposures are often mixed with fumes or infectious exposures as described above.

A number of infectious diseases could be transmitted to humans from animals housed in barns. If sheep or cattle give birth there, Q fever could be contracted while assisting in the birth or from contact with infected placentas, reproductive discharges, or contaminated bedding. Bovine tuberculosis (TB) was an important health hazard in past years, but it has been nearly eradicated in the developed world. Old barns where chickens or wild birds have roosted are ideal sites for proliferation of the fungus causing histoplasmosis.

Newer steel dairy buildings contain the same types of areas as older barns, but they are usually single-storied buildings. Workers can experience the same respiratory responses listed previously in these newer buildings.

3.3 Agricultural Dusts

3.3.1 Introduction

Mentioned previously, dust in the work environment is by far the most common respiratory hazard for agricultural workers. Agricultural dusts are complex mixtures of organic materials (see Table 3.1), which vary somewhat as to the specific source, but have in common biological byproducts of microbial and plant contaminants that are irritants, or inflammatory or allergenic agents. Lipopolysaccharides, primarily endotoxin, are generally considered the principal inflammatory agent among others that include glucans, tannins, proteases, and histamine (18, 26–28). Endotoxin is a structural components of the cell wall of Gram-negative bacteria. Glucans are structural components of the cell wall of yeasts, fungi, and bran of cereal grains among other sources (29–31). Often agricultural dusts occur as mixed exposures with gases (such as hydrogen sulfide or ammonia) that may be additive or synergistic with dust in regard to health effects (19). It is important to note (often divergent from the general perception in the health professions) that agricultural dust exposure mainly cause inflammatory conditions of the airways and to a much lesser extent allergic conditions or diseases of the lung per se, therefore relatively large particles 5–10 microns in size (inhalable into the upper airways, but not respirable into the lung tissue) are the cause of most agricultural dust-related disease. Note this is much different from general outdoor urban particle exposures from industrial sources where fine particles (2.5 microns) are the primary agents of concern relative to lung diseases. This is an important concept to note as it provides directions for treatment, prognosis, and prevention of respiratory conditions in farmers. The following section will discuss the toxic mechanisms of agricultural dusts and the generic health conditions that result from exposure. Special risk factors and other variables that modify the health outcomes of exposures will also be discussed. Furthermore, clinical aspects, treatment, environmental assessment, and prevention will be discussed.

3.3.2 Mechanisms of Agricultural Dust Toxicity

The toxic mechanisms of aerosolized agricultural dusts are a combination of direct damage caused by inhaled materials and the subsequent secondary "collateral injury" to the immune response of the exposed person to these substances (32). The direct damage to tissues comes from the extrinsic trauma induced by inhaled particles, gases, and other substances associated with the particles. Additional to the trauma to cell membranes, the cells of the airways use excess energy to remove the foreign material by producing mucous from goblet cells to trap the particles, and activating cilia to transport the particles upward away from the lungs so they can be expectorated (32). Long-term exposures may result in cell apoptosis and necrosis (33). Ammonia may accompany particles from livestock and poultry sources, both as a gas or adsorbed to the particles (19, 34). Either way, ammonia is an irritant that can cause additional damage to cell membranes. It can also penetrate the cell membrane and damage intracellular structures, resulting in cell death (35). Hydrogen sulfide may also accompany dust from livestock buildings if there is liquid waste storage in the building. It can cause cell damage as an irritant or inhibit the respiratory mechanism of the cells (36, 37). Tannins and histamine are found in most plants. The former can denature proteins; the latter can enhance the inflammatory process (26, 27). Beta glucans (usually 1,3-beta-D glucan), a common component of agricultural dust, are found in cereal grains and fungal agents. They are direct irritants as well as potentiators of inflammation.

The second mechanism of toxicity is the collateral cellular damage resulting from the person's immune system. The mammalian immune system is extremely complex. As this book is aimed at a multidiscipline audience, the complex mechanisms involved have been abbreviated (3, 7, 32, 38). The immune system can be divided into the innate and adaptive components. The innate system responds non-specifically to external agents perceived as harmful, while the adaptive system responds to specific, mainly protein, materials (e.g., bacteria, pollen, etc.) to which there has been a prior exposure. The bulk of the adverse damage is a result of inflammation processes of the innate system (39), which is engaged as inhaled dust particles contact the cell surfaces of the airways or the alveoli of the lung tissue. Neutrophils (a type of white blood cell) are initially recruited to the area to "attack" the perceived invaders. They release cytokines, which attract other white cells (mononuclear cells). These mononuclear cells have in their cell membranes "receptors" (e.g., toll-like receptors (TLRs) among others) that allow the cell to identify foreign, possibly hazardous, substances (especially bacterial-associated substances like endotoxin, glucans, and allergens) to "turn on" the immune system, initiating a chain of reactions (complement cascade) which results in the non-specific inflammation process. TLR 2 and TLR 4 are the principal cell receptors, the "initiators and directors" of the immune response with assistance from other receptors identified as nucleotide-binding oligomerizationdomains (NODs). The triggered inflammatory response results in recruitment of more white blood cells to the region, more chemical mediators released (e.g., tumor necrosis factor and TNF-alpha) and resultant inflammation and associated reddening, swelling, pain, and dysfunctional cells and tissues. If the exposure is acute and temporary, the inflammation will reside without lasting damage to the tissues. If the inflammation is chronic with long-term exposure, the chemicals released and reactive oxygen species generated by the process will result in severe cell and tissue stress, apoptosis, necrosis, and possibly will be replaced by scar tissue over the long term (40).

3.3.3 Occupational Respiratory Diseases and Conditions Caused by Agricultural Dust Exposures

In 1985, an international conference was held in Skokloster, Sweden to seek consensus among scientists on the respiratory health effect of organic dust exposure (8, 41). This process led to an unprecedented surge in research on the health effects of agricultural dust exposures over the following three decades, recently reviewed by Rylander and Schilling (8). A major outcome of the Skokloster conferences was a consensus definition of the cluster of symptoms, conditions, and terminology used to describe the health outcomes of agricultural dust exposures. These conditions are generic, common with exposures to agricultural organic dusts whether it is cotton dust, grain dust, livestock dust, or any other plant and or animal source dust. The cluster of seven symptoms and conditions associated with agricultural dust exposures are (see Table 3.2):

1. bronchitis (acute and chronic)
2. mucous membrane irritation
3. Monday morning disease
4. non-allergic asthma-like condition
5. allergic asthma (atopic individuals)
6. organic dust toxic syndrome
7. farmer's lung.

Bronchitis is by far the most common of these agricultural dust conditions, affecting between 15% and 25% of exposed persons (7, 42–45). The condition causes inflammation and cell damage to the major and minor bronchi of the airways. The goblet cells produce excess mucus so the cilia are damaged and rendered minimally or totally non-functional. Symptoms include excessive coughing and sputum production. Continuance of these symptoms more than three months out of the year for over 2 years defines chronic bronchitis. Chronic bronchitis can lead to chronic obstructive pulmonary disease (COPD), which is often associated with and/or increases the risk of emphysema.

Mucus membrane irritation (MMS) is nearly as common as bronchitis. It is an inflammatory condition of mucous membranes impacted by organic dust, and may include rhinitis, sinusitis, pharyngitis, and conjunctivitis. Sinusitis is often the most clinically significant condition, manifested as sinus headache, ears popping, with patient complaints of "a head cold that won't go away".

Monday Morning syndrome (MMS) is manifested by a cyclical pattern of symptoms in workers on a regular work schedule (e.g., 8-hour work shift, 5 days per week). On return to work following a weekend off or vacation, workers feel ill, feverish, with headache, and muscle aches. Symptoms diminish over the week of work only to return again on, for example, Monday morning. For workers in cotton gins and mills, this is a component of the condition called byssinosis (8). However, MMS can be seen in confinement livestock workers, grain workers, and others with similar exposures and work cycles.

Non-allergic asthma-like condition (NAALC), also referred to as non-allergic occupational asthma or reactive airways disease, is a type of asthma (a chronic airways disorder marked by recurring episodic bronchospasm causing airway obstruction). Differing from atopic asthma, NAALC is a non-specific inflammatory-mediated response to inhaled irritants in agricultural dusts. Symptoms include labored breathing, wheezing, coughing, and a sense of constriction in the chest. Symptoms appear with organic dust work exposure and dissipate over several hours following work. Reactive airways disease is a term for a similar condition, but it is usually related to irritants other than agricultural dusts.

Allergic (atopic) asthma has the same symptoms as NAALC but is caused by a specific allergen (e.g., house mites, storage mites, dust, molds, animal dander etc). In this author's experience (KJD) allergic or atopic asthma is relatively rare among farmers, probably for two reasons: (1) atopic farmers would find it hard to stay in the workforce (healthy worker effect) and (2) children exposed to farm environments at an early age are likely to be protected from atopic disease for life (the hygiene hypothesis) (46).

Organic dust toxic syndrome (ODTS) has also been called toxic alveolitis, silo unloader's disease, mycotoxicosis, inhalation fever, and atypical farmer's lung (47–49). ODTS is a delayed-onset influenza-like condition, a non-allergic inflammatory reaction of the airways and the alveoli with systemic influenza-like symptoms. It is due to periodic inhalation of high concentrations of organic dust and endotoxin exposure (50). ODTS is extremely common among farmers, with 30% having reported such cases and many reporting multiple episodes. Clinically, acute cases present very much like acute farmer's lung disease, with cough, fever and chills, headache, fatigue, myalgia, and anorexia occurring 4–6 hours following exposure to high concentrations of organic dusts with high microbe content. Severity varies from a mild, influenza-like illness to profound illness with dyspnea, but rarely death (51, 52). The peripheral blood neutrophil count is elevated but there is no eosinophilia. Symptoms subside in 2–5 days. Although the pathology may involve primarily the airways (bronchitis may result) there may be an accompanying alveolitis along with the generalized symptoms. In extensive exposures symptoms may persist, diminishing over several weeks, but permanent lung damage does not appear to occur. Subsequent exposures simply produce repeated episodes, often with more severe symptoms, with lower exposures. ODTS cases may occur simultaneously with acute farmer's lung or may be the sensitizing incident for a possible subsequent farmer's lung case.

There are anecdotal reports of a chronic form of ODTS, which this author (KJD) has observed. This poorly documented condition is characterized by chronic fatigue, a persistent pulmonary infiltrate, and elevated white blood cell count (mainly excess neutrophils) in workers with chronic agricultural dust exposures (such as livestock confinement workers) (53).

ODTS may occur at any time of the year though some exposures may be more common in late summer through early spring during processes where vast amounts of respirable organic dust are released in an enclosed workspace. Typical work situations include silo uncapping and grain-bin cleaning (Figure 3.10), both of which entail strenuous physical activity within an enclosed space.

Silo uncapping involves removing moldy silage from a conventional non-airtight upright silo in preparation for mechanical unloading and feeding to cattle. The silage will have been stored for weeks or months in the silo beneath a "cap" of silage a foot or so in depth, atop a plastic sheet which covers the silage underneath. Low-oxygen conditions beneath this cap impede fungal growth, but the exposed, upper silage layer becomes grossly contaminated with microorganisms. Before dispensing the silage for feeding, someone must climb into the silo, pitch off this molded silage cap, and lower the mechanical unloader into place. High concentrations of microorganisms and their by-products can be inhaled during this task, possibly exacerbated by the greater respiratory load.

ODTS resulting from exposure to spoiled plant material has been recognized as a response distinctive from farmer's lung only as recently as 1984 (54, 55). It is far more common than farmer's lung or other illnesses associated with feed storage. A 5-year prospective study of nearly 1000 Iowa swine farmers revealed a self-reported prevalence rate of approximately 30% (10). In a study of New York dairy farmers, 14 of 26 feed-related episodes of respiratory illness were identified as ODTS (48). Ten per cent of Finnish farmers are reported to have experienced symptoms indicative of ODTS.

Farmer's lung (FL) is a different condition from ODTS in that it is a type of allergic condition in the category of hypersensitivity pneumonitis (HP) that occurs among farmers (also called extrinsic allergic alveolits) (47, 52, 54, 56, 57). FL is uncommon (less than 5% of famers) compared to ODTS (30%). FL is a delayed allergic response at the alveolar level, with a variable systemic presentation depending on host factors and specific circumstances of exposure. Although several

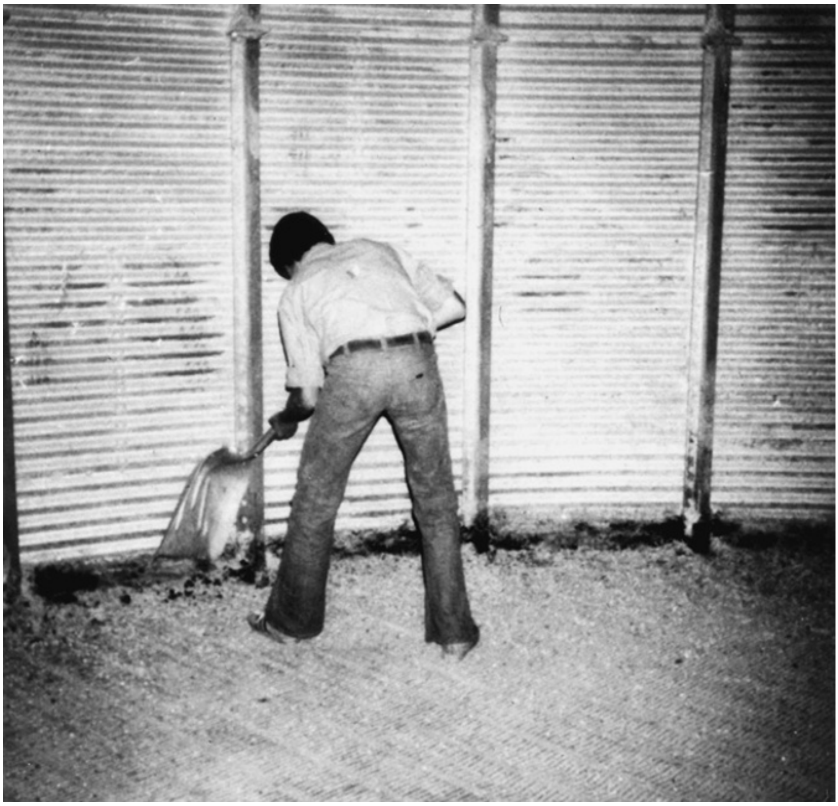


FIGURE 3.10 Cleaning out a grain bin is one of the most common tasks associated with organic dust toxic syndrome.

alternative pathways to FL disease have been proposed (58–60), the commonly accepted pathogenesis of FL is a multiple-step process that includes, first, formation of IgG antibodies to inhaled antigens found in agricultural dusts (56, 61–65). The second step in the disease pathogenesis is that on a subsequent exposure, the antibodies attach to the specific invading antigens, forming antigen-antibody complexes. The third step is that the antigen-antibody complexes are recognized by macrophages as foreign and thus engulfed, initiating a type IV (delayed) immunologic response. Compared to ODTS, FL does include a specific allergic response but it differs from atopic asthma, which is a type I immediate allergic response.

FL is the specific HP that farmers in general experience from their work environment exposures (usually thermophilic bacteria, including actinomycetes species, *Micropolyspora faeni* (renamed *Saccharopolyspora rectivirgula*), and *Lichtheimia corymbifera*). Other agricultural–related exposures have different names according to their specific occupational exposures (e.g., bagassosis (exposure to sugar-cane wastes), mushroom worker's lung, malt worker's lung, cheese worker's lung, and bird breeder's lung). At least 15 other occupational HP conditions specific to agriculture have been recognized (e.g., wood worker's lung, paint finisher's lung (isocyanate exposure), and paprika splitter's lung).

The clinical appearance of FL can manifest in three forms: acute, subacute, and chronic (66). The acute FL response follows a highly concentrated agricultural dust exposure, similar to that resulting in ODTS. Influenza symptoms nearly identical to ODTS are delayed 4–8 hours after exposure. Histologic appearances of lung tissue reveal granulomas with giant cells in the interstitium. Acute symptoms usually resolve in 48–72 hours. Sub-acute responses may follow recurrent, even low-dose, exposures without acute systemic symptoms that stimulate further macrophage infiltration into the lung tissues. A silent pathogenesis may follow including macrophage transformation into fibrous tissue and a progressive interstitial fibrosis. Symptoms include gradual onset over several weeks of progressive cough and dyspnea with possible cyanosis. Chronic FL is marked by several months' progression of cough, exertional dyspnea, fatigue, and weight loss (66). Chronic FL may lead to a permanent irreversible interstitial fibrotic debilitating disease, noted by restrictive pulmonary function, impaired diffusion capacity, and possible emphysematous changes (67).

A lack of consistency exists in published epidemiologic data in regard to the incidence and prevalence of FL (68–71). Because the exposure history and symptoms of acute FL and ODTS may be nearly identical, many of the FL studies, particularly those prior to the mid-1980s, probably included many ODTS cases. The prevalence of FL in the United States has been considered to be below 5% of the farming population, for example 3.9% of one surveyed group of Wyoming farmers and dairy producers gave a history typical of FL. A population-based prospective survey of over 1500 Wisconsin farmers that began in 1976 revealed a case prevalence rate of 4.2 per 1000 farmers (0.42%) (61). The 1984 follow-up study revealed a prevalence of clinical cases at 0.9%. Although the prevalence is quite low in the United States, it appears higher in Europe, according to surveys in England, Scotland, and Finland (72).

Serologic surveys have been used to estimate prevalence. Ten per cent of the Wisconsin farm cohort mentioned above had circulating antibodies to one or more FL-associated antigens (71). However, it is clear that sero-positivity to FL antigens is poorly correlated to FL disease. Sero-positivity only indicates antigen exposure, not disease.

Risk factors for FL include work with barn-enclosed dairy cattle. In some populations (e.g., Finland), this task is often performed by women (72). Examples of dust-disturbing activities attributable to HP disease include breaking open bales of hay for feed or bedding, generally in winter or spring of the North Temperate Zone. Tightly packed large round bales and wet harvest season are also risk factors (73).

The disease is extremely rare in children. Two cases in Denmark (ages 10 weeks and 3 years) led researchers to incriminate causal exposures to on-farm storage of grain and storage of overly moist grain in silos adjacent to the residence (74). A case in a 10-year-old boy was diagnosed in New York State.

Interestingly, it has been observed that there is an unexpected, significantly lower prevalence of *M. faeni* antibodies and lower disease prevalence among tobacco smokers (75, 76). The reason for this protective factor is thought to be that smoking down-regulates the cellular immune system (77).

3.3.4 Risk Variables for Agricultural Dust-related Respiratory Diseases

Risk variables include exposure characteristics (concentration, content, and length of exposure) and the individual characteristics of the exposed person (age of first exposure, atopic status, genetic susceptibility, co-morbidities) among others.

The hazardous potential of agricultural dusts largely depends on the extent of microbial contamination. Animal feed (hay, silage, and grain) that is put into storage with a high moisture content favors the growth of bacteria and fungi. Whole grains should be put into storage of non-airtight structures at 15% or lower moisture and hay below 22% moisture to prevent excess microbial growth. Feed grains and silage (whole chopped corn plant or other fodder) may be stored at a much higher moisture level if it is an airtight silo, which prevents most microbial growth. Silage may also be stored with high moisture content in a non-airtight silo, as the ensilage process results in acidic conditions, inhibiting further microbial growth (34, 60, 78). Any fault of the equipment, facilities, or human error may result in conditions that favor microbial growth, which increases the endotoxin, glucans, and other hazardous substances within the dust from these materials, and of course lowers the animal-feed quality of the material. Considering microbial concentration and length of exposure time, hazardous exposure variables can be classified into two different situations: (1) PAMM and (2) chronic exposures to lower-level concentrations (CLLC). Each of the exposure parameters result in potentially different disease outcomes. PAMM exposures are characterized by dust highly contaminated with bacteria and fungi and their by-products, and tasks associated with these exposures occur only periodically and are usually relatively short term (see Table 3.4). CLLC exposures are characterized by a lower microbial concentrated dust, but exposures are chronic and long term. The first situation (PAMM) may result in ODTS and/or FL. The second (CLLC) results in bronchitis, NAALC, MMS, MMI, and possible chronic forms of ODTS or FL. The relative range of concentrations air contaminant exposures are several times higher in PAMM compared to CLLC (see Table 3.5). For example,

Table 3.4 Agents and common names for hypersensitivity pneumonitis among agricultural workers and food product processors

Exposure	Agent[a]	Common name or condition
Moldy hay or silage	*Thermophilic actinomycetes* *Micropolyspora faeni* Others	Farmer's lung
Mushroom production/ mushroom compost	*Thermoactinomycetes vulgaris* Others	Mushroom worker's lung
Moldy sugar cane plant residue – post-processing	*T. viridis* *T. sacharii* Others	Bagassosis
	Fungi	
Moldy maple bark	*Cryptostroma corticale* Others	Maple bark stripper's disease
Moldy malt	*Aspergillus clavatus* Others	Malt worker's lung
Moldy dust	*Penicillium frequentans* Others	Suberosis
Surface mold on cheese	*P. caseii* Others	Cheese worker's lung
Moldy wood chips	*Altervaria* spp. Others	Wood worker's lung People using wood chips for heating fuel
Moldy redwood dust	*Pullularia* spp. Others	Sequiosis
Paprika dust	*Mucor* spp. Others	Paprika splitter's lung
	Arthropods	
Infested wheat	*Sitophilus granarius* Others	Wheat weevil disease
Fresh avian droppings	Avian proteins	Bird breeder's lung

[a]There are probably multiple agents of hypersensitivity pneumonitis for each specific condition. The specific agents listed here have been associated with the condition, but are probably just one of several agents involved.

Table 3.5 Comparisons of tasks and resulting exposures to agricultural dusts, relative to time and concentration

Specific tasks or structure	Exposure characteristics
PAMM exposures to agricultural dust	
Silo unloading	3–4 times/year
Moving moldy grain	30 minutes to 2 hours duration
Emptying grain bins	Total dust 10–50 mg/m^3
Moving and sorting pigs in a confinement building	Total viable microbial count 10^7–10^{10} $microbes/m^3$
Power washing the inside of a swine-confinement building	Endotoxin concentration 500–45,000 EU
Loading or caging chickens or turkeys	Micrograms concentration 10^6–10^9 $organisms/m^3$
Reconditioning litter in floor-housed poultry buildings	
Moving or loading wood chips	
CLLC exposures to agricultural dust	
Swine confinement buildings	Daily exposures
Poultry confinement buildings	2–8 hours/day duration
Dairy barn	Total dust 1–9 mg/m^3
Work in a grain elevator or feed mill	10^3–10^5 $microbes/m^3$
	Endotoxin concentration 100–400 EU/m^3

PAMM, periodic, acute, massive and moldy; CLLC, chronic lower level concentration.

CLLC exposures to dust, endotoxin, and microbes may range from 0.5 to 10.0 mg/m^3, 50 to 1000 EU, and 10^4 to 10^6 $organisms/m^3$ respectively (79, 80). Comparatively, PAMM exposures to agricultural dust endotoxin and microbes range from 10 to 100 mg/m^3, 1000 to 45,000 EU and 10^6 to 10^9 $microbes/m^3$ (81).

Examples of situations which generate PAMM exposures include opening moldy bales of hay in a confined space, removing the top layer of silage from a silo (silo unloading), shoveling moldy grain (Figure 3.11), cleaning out the residual (often spoiled) grain from storage structures, power washing a swine or poultry building (Figure 3.12), moving, sorting, or load out (moving animals out of the building into trucks for transport to market) of hogs or poultry, rototilling (reconditioning) the litter in a chicken- or turkey-growing structure, and mechanically shredding bales of hay or straw for dairy cow bedding. The agents are found not only in moldy feed products but also in wood chips (which are commonly used as heating fuel in rural areas in North America and the EU) (82) and saw dust (used for bedding for dairy cattle and horses).

Common examples of CLLC and PAMM exposures occur in work sites such as swine- and poultry-confinement buildings (43), dairy barns, feed-preparation and grain-handling sites, and commercial grain-storage, grain-handling, and transport operations. Besides microbial concentration of agricultural dusts that predict hazard, some specific characteristics of the dust may increase its toxic effect. The practical experience of this author and many others who have worked in and around agricultural dusts has found that dust in swine barns is more inflammatory and odorous, and adheres more robustly to clothing, hair, and skin compared to dusts from other livestock species buildings (38). Swine workers have a higher prevalence of respiratory conditions (bronchitis, MMI, NAALC) relative to other livestock workers (38). The reasons for this are not fully known, but some research suggests that hog barn dust increases lymphocyte adhesion to respiratory epithelial cells, which can exacerbate the inflammatory response (83). Other variables with animal-associated dusts include the presence of ammonia (commonly present in swine and poultry barns). Ammonia has a synergistic adverse health effect when combined with livestock dust (19). (Note that compared to swine houses, ammonia concentrations are usually higher in poultry buildings, and ammonia and dust concentrations are even

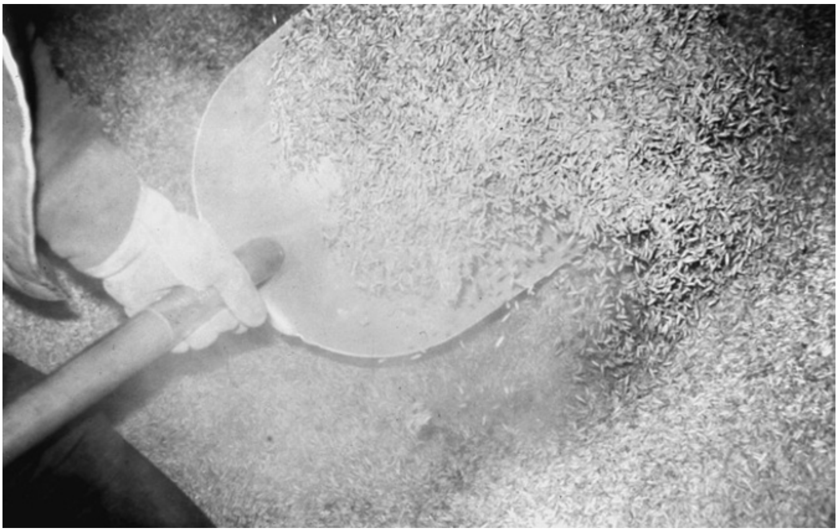


FIGURE 3.11 Shoveling or other disturbance of moldy grain can create a risk for organic dust toxic syndrome and other respiratory conditions.

FIGURE 3.12 Power washing is a common task for cleaning swine, poultry, and other livestock facilities. The process increases bioaerosol exposures, as it blasts high levels of particulates and endotoxin into the air. If power washers are operated in a building with a liquid manure pit underneath it the vibration may result in agitation of the manure, releasing hazardous concentrations of hydrogen sulfide.

higher in floor-raised poultry houses than in caged-raised houses) (13). (It is interesting to note that animal welfare advocates promote floor-raised over caged-raised layers, but the former may increase the health hazard for both birds and workers because of the associated increased ammonia and dust). The differences in the types and concentrations of exposure incidents (CLLC and PAMM) and related symptoms and diseases are summarized Tables 3.4 and 3.5.

The individual susceptibility variables that increase the risk for and severity of bronchitis, NAALC, MMI, MMS, and ODTS include cigarette smoking, co-morbidities including other respiratory or cardiovascular disease, positive atopic status, obesity, and individual genetic variance (45, 84). As the demographics of those working in livestock production has shifted from family labor to more hired workers that include foreign-born workers and women (primarily seen in North America), a higher percentage of these workers are cigarette smokers. Furthermore, they work longer hours in the buildings. These factors suggest respiratory risks will remain an issue, even with improved building design (85). Female swine workers seem to respond differently to their work environment than males. Male swine workers have a higher frequency of doctor-diagnosed atopy. Women with atopy have a lower frequency of bronchitis (85). Although the reason for this latter observation is not known, there is genetic variable sensitivity to endotoxin among workers associated with the innate immune system. About 10% of individuals have a polymorphism of Toll-like receptors (TLR4) on their white blood cells, rendering them less sensitive to endotoxin (45, 86). This provides them with partial protection from bronchitis, MMI, MMS, NAALC, and ODTS. An additional individual variable is that exposure to agricultural dusts at an early age provides lifetime protection from atopic disease to an estimated 10% of the exposed population (hygiene hypothesis).

3.3.5 Clinical Aspects of Agricultural Dust-related Respiratory Diseases

Diagnosing agricultural dust-related respiratory diseases depends largely on the ability of the healthcare provider to ascertain a complete and accurate occupational history. This depends on the provider's understanding of agricultural processes that result in hazardous exposures. The following description is intended to assist the professional in understanding occupational history variables with a focus on chronic compared to acute conditions. Chronic bronchitis, MMI, and NAALC will be discussed first, followed by the acute conditions of ODTS and FL.

Diagnosing occupational bronchitis, MMI, and NAALC secondary to agricultural dust exposures can be challenging as there are no specific clinical tests to determine the exposure source. Assuming dust exposure is an important element of the history, an effort should be made to determine if it is CLLC or PAMM exposure (see Tables 3.4 and 3.5). Questions address the timing of symptom onset: When do symptoms generally occur during the work period? Do they get better with time away? Do they get worse on return to work following time off? It is important to note that many workers who have developed NAALC from agricultural dust exposures may develop asthma symptoms following non-specific exposures such as cold air or exercise. Although NAALC may develop in naïve workers within the first few hours or days of first exposure (87), more commonly it is seen in workers with more than 6 years of exposure and with exposure concentrations above 2.5 mg/m^3 for 2 or more hours per day (19, 54, 88, 89). There is a degree of adaptation or developed tolerance in many workers. Symptoms of bronchitis, MMI, and NAALC may diminish over weeks or months of exposure due to down-regulation of the immune system. However, damage to the airways could still be occurring even with diminished symptoms, leading possibly to permanent airway dysfunction in the future. Preventive steps should be taken even if symptoms diminish (6).

If a pulmonary function test (PFT) is conducted, this author (KJD) has observed some unique characteristics of the northern European extracted farm population that should be considered. In this farm population, baseline forced expiratory flows (FEF_{25-75}) are commonly quite low (e.g., 60% of predicted) even in asymptomatic individuals. This suggests that small airway obstruction is common among this population, which may lead to future clinically significant symptoms. For large airways function we have seen through experience that farmers commonly have higher baseline volumes and flows compared to standard industrial comparison populations. This is probably because of some genetic variation, the heavy work they do, and the healthy worker effect. The pulmonary function of farmers with mild lung impairments might show 100% or more of predicted value compared to the industrial-based comparison group. However, that same pulmonary function might be 70% or 80% of predicted if the farmer patient were compared to a northern European farmer comparison group (which does not exist). Therefore, one might not detect low-level lung disease in farmers with baseline testing only. Cross-work shift testing is ideal as each person serves as their own control. A 10–20% drop in FEV_1 and FEF_{25-75} over a work shift is common among swine and poultry workers. Furthermore, we have shown that work shift decrements are predictive of future baseline declines and air trapping (90, 91). These findings, along with an accompanying rise in peripheral blood white cell count (mainly an acute neutrophil response) and an increased sensitivity to methacholine challenge (92), suggest an inflammatory pathologic process is ongoing. These clinical observations coupled with a concordant occupational history are relevant to diagnosis of occupational agricultural dust exposure association with bronchitis, MMI, and NAALC in farm patients.

Treating bronchitis, NAALC, and MMI first requires elimination or reduction in exposure. This may include relocation to a different (less exposed) task, engineering control of the source of dust, and use of a personal protective respirator. (Controlling exposure is also a principle of prevention and will be discussed later in this chapter.) Smoking cessation is extremely important to reduce the risk and exacerbation of disease. Medical surveillance is recommended with assessment of symptoms and pulmonary function on an annual or biannual basis for those exposed with prior symptoms.

Medical treatment includes anti-inflammatories (mainly steroidal) and also bronchodilators for NAALC. Treatment with these drugs (93) should not continue indefinitely (to reduce possible side effects) and they should be used in conjunction with a program to reduce exposures.

Diagnosing acute episodes of ODTS and FL is based on occupational histories and clinical findings. Distinguishing ODTS from FL is challenging as patients may have a similar occupational history, symptoms, and clinical findings. Although the treatment and prevention of ODTS and FL are similar, it is important to differentiate them, as FL (with continued exposures) can lead to a progressive end-stage debilitating interstitial fibrosis.

Diagnosis of ODTS is characterized by a history of PAMM exposure followed in 4–6 hours by an acute onset of an influenza-like illness with several or all of the following symptoms: headache, chest tightness, cough, fever, muscle aches and pain, fatigue, and a general feeling of malaise. Symptoms may last for 24–72 hours depending on the extent of exposure and individual variation. Although these acute symptoms can be identical to FL, an important fact to note is that most PAMM exposures associated with these symptoms are in fact ODTS (49). An additional fact noted by this author (KJD) in consulting on numerous cases, is that exposure significantly in excess of usual exposure limits is also an important key point in the history. For example, we have found that swine workers experiencing CLLC exposures (and related symptoms and conditions) may also experience ODTS episodes associated with the periodic task of moving and sorting pigs for market. The usual concentration of dust exposure may be elevated up to five times higher than their everyday exposures, as movement and herding of the pigs results in increased aerosolization of settled dust in the building (94). ODTS may occur during any season, but often it is associated with late summer, fall (cleaning grain bins in preparation for fall harvest), and fall through early spring (opening and unloading silos). If several people are exposed to the same PAMM exposure all of them may get sick, mimicking a more generic toxicity exposure such as an insecticide or a toxic gas. However, there will likely be variability of severity of illness among those exposed. Many people will know what they have and what exposure caused it as they will have had previous episodes. Clinical data may show heightened breath sounds on auscultation, a high neutrophilic white count, obstruction on PFT, but usually a normal PO_2 and normal chest x-ray. ODTS often does not occur as the only condition, as a percentage of ODTS cases progress or develop simultaneously with FL.

Diagnosing FL is also challenging. Exposures and symptoms are variable; no single symptom is diagnostic. Also, the disease can present in acute, sub-acute, and chronic forms. Acute FL should be suspected in a farmer with a PAMM exposure and concomitant delayed acute influenza-like illness similar to ODTS. Symptoms and objective clinical findings are usually more severe compared to ODTS. FL often includes pneumonitis with or without active interstitial lung disease. In most circumstances, the following combination of factors is necessary for a tentative diagnosis of acute FL disease:

1. The patient presents with a history of PAMM exposure to decayed plant agricultural dusts followed by a 4–6 hour delayed but abrupt onset of influenza-like symptoms.
2. The illness includes a characteristic cluster of symptoms including cough, fever, malaise, chest tightness, headache, fatigue, dyspnea, and basal crepitate rales, which last for 48–72 hours with slow recovery.
3. A chest radiograph reveals bilateral, ground glass, or micronodular lung infiltrates in the lower two-thirds of the peripheral lung field (see Figure 3.13).
4. Pulmonary function tests of acutely ill patients include decreased lung volumes with a restrictive pattern, small airways obstruction, and decreased carbon monoxide diffusing capacity.
5. Patients may have a low PO_2 and be cyanotic.
6. Broncheoalveolar lavage in the first few hours of onset may reveal predominately neutrophils, but will change to a mononuclear cell field with a predominance of lymphocytes several hours following onset. The lymphocytosis is characterized by a high T-cell to B-cell ratio (as compared to peripheral blood) (59). Also notable is the decrease in T4 to T8 cell ratios (note such increased numbers of suppressor cells are the opposite of the finding in sarcoidosis).
7. Supporting (not diagnostic) evidence includes positive serology to any of a panel of 15 or so fungal or thermophilic actinomycetes antigens included in a "farmer's lung panel" (note that the offending antigen may not be in the panel).

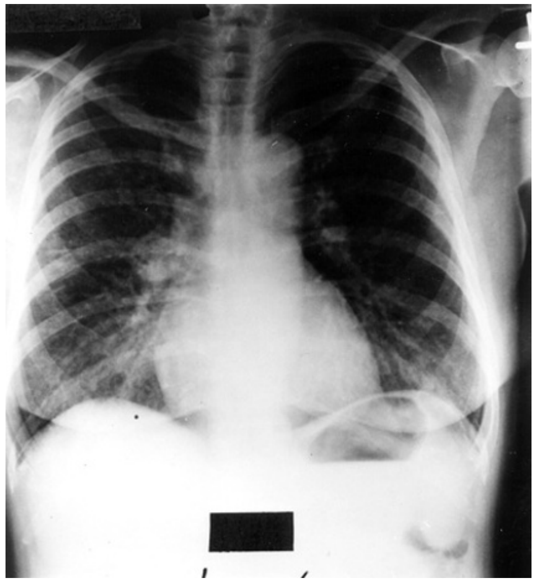


FIGURE 3.13 This lung-field radiograph shows a micronodular infiltrate in the lower lung field, commonly seen in acute cases of farmer's lung.

Sub-acute and chronic cases of FL do not have acute influenza-like symptoms and are difficult to diagnose. They may begin with acute FL, then progress slowly with continuous low-level exposure over months or years in an insidious manner, presenting in the latter stages with increasing symptoms of fatigue, progressive dyspnea, and cyanosis (subacute), and progress to the chronic form noted by exertional dyspnea, cough, fatigue, and weight loss (66). These cases show a spectrum of abnormalities, including lymphocytosis in bronchoalveolar lavage (BAL) fluids, pneumonitis, fibrosis, and hyperexpansion or honeycombing of lungs (on lung biopsy) (67).

The following are clinical details to assist diagnosis. Although most FL patients are serologically positive, at least 10% of the healthy farm population possesses FL antibodies. (Care must be taken to use an appropriate battery of FL antigens.) Although clinical test results vary among cases, pulmonary function is likely to show a restrictive pattern. Chest radiograph may show nodular thickening of the alveolar interstitium. High-resolution computerized tomography will more readily demonstrate the latter lesions (95) and typically will show well-defined patches of hyperinflated tissue (mosaic pattern) suggestive of small airway obstruction.

Lung biopsy is not normally required or advised, but may be useful in an exceptional case when a specific diagnosis is needed (e.g., for worker's compensation) or with a difficult differential diagnosis. Lung biopsy in acute FL reveals a characteristic mononuclear cell infiltrate or granulomatous interstitial pneumonitis, possibly with giant cells (see Figure 3.14). Gross thickening of the alveolar capillary membranes results from mononuclear infiltration into interstitial tissues, resulting in obliteration of the alveoli. Mononuclear cells often form non-caseating granulomata that may occlude bronchioles. Multinucleated Langerhan's giant cells and foreign body type cells that may be bi-refringent or non-refringent are common in areas of inflammation. Spores of potential causative molds or bacteria usually are not recognized in tissues. Biopsies in subacute cases will reveal a progression of interstitial fibrosis and perhaps diminished mononuclear cell infiltrate or granulomas. Bronchoprovocation by FL antigens has been used as a definitive diagnostic test, but can involve significant risk of exacerbating the disease in the patient and is not recommended.

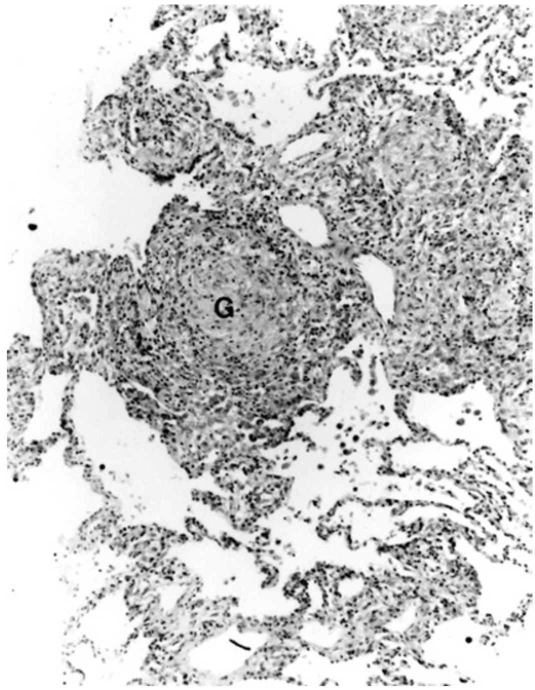


FIGURE 3.14 This biopsy of a patient with acute farmer's lung shows the characteristic mononuclear cell infiltrate. The letter G indicates a forming granuloma. Multinucleated giant cells may also be seen.

A number of features differentiate acute FL and ODTS. These are summarized on Table 3.7 and discussed below (48, 52, 96). FL occurs in only a small subset of any exposed population. Although predisposing factors must exist, these have not yet been defined. ODTS, in contrast, can affect a high percentage of exposed individuals following PAMM exposures. Thus, cases are often clustered, with all individuals in certain PAMM exposures affected simultaneously.

A number of laboratory tests can help to distinguish FL from ODTS. Chest radiographs of FL patients characteristically reveal a finely nodular density in the lower lung fields, while chest radiographs of ODTS patients characteristically are clear (although occasionally may have a mild infiltrate). Blood gas measurements often show decreased PO_2 for FL, but are usually normal for ODTS. While PFT for ODTS patients may reveal an obstructive pattern, PFT in FL patients shows marked restriction, often with reductions of both FEV_1 and FVC, often yielding a normal FEV_1/FVC ratio, with decreased compliance and diffusing capacity. BAL in FL typically yields fluids with a predominance in lymphocytes, while in ODTS, BAL fluids are typically dominated by neutrophils ODTS (52).

Table 3.6 Symptoms and conditions resulting from two types of exposure conditions to agricultural dusts

Symptoms	Conditions
PAMM exposures	
(Delayed response 2–6 hours after exposure)	ODTS – toxic alveolitis
Cough	and/or
Chest tightness	hypersensitivity pneumonitis
Malaise	
Headache	
Myalgia	
Arthralgia	
Fever	
CLLC exposures	
Cough: intermittent, associated with exposure	Acute bronchitis
Phlegm production: intermittent, associated with work exposure	
Cough and phlegm production: occurring more than 3 weeks out of the year, for longer than 2 years	Chronic bronchitis
Chest tightness: wheezing on exposure	NALC
Sore throat	MMI
Nasal irritation	
Eye irritation	
Stuffy nose	Chronic sinusitis
Difficult nasal breathing	(one manifestation of MMI)
Complaints of being "plugged up" or "persistent cold"	

PAMM, periodic, acute, massive and moldy; ODTS, organic dust toxic syndrome; CLLC, chronic lower level concentration; NALC, non-allergic asthma-like condition; MMI, mucous membrane irritation

Table 3.7 Epidemiologic and clinical differentiations of organic dust toxic syndrome and farmer's lung

Organic dust toxic syndrome	Farmer's lung
Often "mini" epidemics: all those exposed to an acute episodic massive exposure affected	Not every person exposed will be affected
Acute symptoms, delayed response to exposure (2–6 hours)	Acute symptoms, delayed response to exposure (2–6 hours)
Cough, chest tightness, malaise, headache, myalgia, arthralgia, fever	Cough, chest tightness, malaise, headache, myalgia, arthralgia, fever
Lasting 24–72 hours	Lasting 24–72 hours
	Hypersensitivity pneumonitis typically has more severe acute symptoms than ODTS
Elevated WBC, with left shift	Elevated WBC, mononuclear cells may be relatively elevated
Usually normal chest film	Usually finely nodular infiltrate more evident in lower lobes and mediastinum
Pulmonary function shows obstruction	Pulmonary function shows restriction
PO_2 usually normal	PO_2 below normal values
BAL: elevated white cells with neutrophil predominant	BAL: elevated white cells, mononuclear cells may predominate
Biopsy: acute inflammation of alveolitis, bronchitis	Biopsy: more chronic inflammation of alveoli, with mononuclear cells, possible granulomas and/or giant cells

ODTS, organic dust toxic syndrome; WBC, white blood count.

Differentiating sub-acute and chronic FL from depression, chronic bronchitis, sarcoidosis, and other chronic interstitial lung disease may be challenging. As mentioned several times previously, an accurate and detailed occupational history is perhaps the most important differential tool, bolstered by the clinical findings mentioned above. However, chronic FL can be misdiagnosed as depression, chronic bronchitis, or any chronic interstitial lung disease. Pulmonary sarcoidosis may prove an especially difficult differential because of the histopathologic and other similarities to FL. A high T/B cell, and low T4/T8 ratio may help to characterize the specific condition. A review article by James (97) provides a summary of T-cell lymphocyte characteristics of various granulomatous diseases. A slight increase in lymphocytes in a BAL sample may be found in asymptomatic farmers and thus is not diagnostic by itself. Acute FL can be misdiagnosed as ODTS (FL may often occur simultaneously with ODTS), influenza, a bad cold, infectious pneumonia, or atopic asthma. Differentiation of FL from most cases of asthma can be based on the presence of wheezing and the absence of rales in asthma, and chest x-ray changes (infiltrate in lower lung fields) in FL.

Differentiating FL and ODTS from silo gas (oxides of nitrogen poisoning) and metal fume fever, as with other conditions, mainly relies on a sound and accurate occupational history. (Note the latter two conditions are covered later in this chapter.) Because acute FL and ODTS may result from exposure within a silo, either may be confused as silo filler's disease resulting from exposure to nitrogen oxides (see Section 3.5) (55). Dyspnea, which is often present for several weeks after acute silo gas exposure, may be confused with FL. However, silo gas exposure occurs within the first 2 weeks of silo filling (which occurs mainly in late summer or early fall), while acute illness from dust exposure during silo unloading occurs at least 1 or 2 months after it has been filled (commonly in late fall through early spring). The primary physical finding with silo gas exposure is pulmonary edema, not generalized, febrile influenza-like symptoms as in FL or ODTS.

Exposure to welding fumes may also create symptoms similar to ODTS (see Section 3.2). Welding, particularly with galvanized metal (which contains zinc), produces zinc aerosols that can create a syndrome (metal fume fever) with symptoms similar to ODTS (24).

Treatment of FL and ODTS are very similar. Since both acute ODTS and acute FL are self-limiting, with symptoms resolving in 2–5 days in mild cases, affected farmers with mild cases may not seek medical care. However, when medical treatment is sought the treatment is the same for both conditions, being primarily supportive and symptomatic (96). As the patient may be hypoxic with a respiratory alkalosis, supportive therapy includes oxygen via nasal cannula and re-hydration with a balanced electrolyte solution. Non-steroidal anti-inflammatories and/or a burst and taper of corticosteroids may diminish the acute symptoms and shorten the duration of illness (although there are no objective data to back this practice). Bronchodilators may be used if bronchoconstriction is a predominant symptom. Desensitization is not effective. Antibiotics and antihistamines are not indicated.

As mentioned previously, the primary importance of a proper diagnosis of FL is to help the patient prevent future (even small concentrations) exposure, which can lead to silent progressive disease and permanent impairment.

Typical exposure dust concentrations in agriculture resulting in respiratory diseases are usually higher than the recommended or regulated concentrations. For CLLC exposures, common dust concentrations in confined swine and poultry buildings are between 5 and 10 mg/m^3. Dust in grain-handling facilities and feed-preparation areas is similar. A small number of dose-response studies are available for agricultural dusts, but only for cotton dust, grain dust, and swine and poultry confinement exposures. These dose-response data apply to CLLC exposures. Decreased pulmonary function has been demonstrated in those exposed to cotton dust concentrations in excess of 1 mg/m^3 of dust. Grain dust studies have led to the Occupational Health and Safety Association (OSHA) legal permissible

Table 3.8 Comparison of OSHA and ACGIH TLVs to recommended exposure limits to toxic dusts and gases based on current research (88, 98, 99)

Toxic substance	Current research recommendations for CAFOs	Typical findings in CAFOs	ACGIH	OSHA
Total dust (mg/m^3)	2.5	3–6	4	15
Respirable dust (mg/m^3)	0.23	0.5–1.5	–	–
Ammonia (ppm)	7	5–15	25	25
Hydrogen sulfide (ppm)	–	0.5–5	10	10
Carbon dioxide (ppm)	1500	1000–4000	5000	5000
Endotoxin (EU)	100 EU	50–1000 EU	–	–

exposure limit (PEL) of 10 mg/m^3 of total dust (higher than the 4 mg/m^3 recommended by NIOSH, the American Conference of Governmental Industrial Hygienists, and most other industrialized countries). Duplicated dose-response studies indicate that dust exposure in confined swine and poultry facilities should be no higher than 2.5 mg/m^3, with endotoxin limited at 100 EU/m^3 and microbes less than 10^4 organisms/m3 (98, 99). Numerous studies suggest that dusts in both swine- and poultry-confined work environments are more biologically active than grain dust, and therefore logic suggests the limits should be lower. Dust levels in livestock buildings commonly reach 5–10 mg/m^3, endotoxin in livestock buildings commonly measures over 1000 EU/m^3, and microbes 10^5 organisms/m^3. Table 3.8 lists the relative legal and recommended maximum occupational exposure concentrations of dusts and gases (88, 98, 99).

PAMM exposures in other settings, such as a disturbance of spoiled plant material, can produce microbe concentrations well over 10^9 organisms/m^3. For example, loosening bales of hay in a confined space, such as in a barn, has produced concentrations as high as 10^9 organisms/m^3 of thermophilic microbes. A person doing light work in this setting may retain 7.5×10^5 spores/minute in the lungs. Concentrations of 4×10^9 viable spores/m^3 have been documented in silo openings (81). Endotoxin is found to reach levels in silos of 88–873 endotoxin units of activity per milligram of dust during unloading of silos (81). Respirable histamine levels as high as 10 nmol/m^3 have been recorded after chopping bedding (100).

To summarize, current US OSHA (as well as other countries') PEL standards for agricultural dust exposures (see Table 3.8; 88, 98, 99) are inadequate. Available research suggests that agricultural dusts (in addition to grain and cotton dust) are not "nuisance" dusts and need to have PELs that reflect the actual hazard that has been documented (e.g., in swine- and poultry-confinement housing). Additional dose-response studies are important to help set exposure limits. Consequently, it is apparent that farmers commonly are exposed to harmful concentrations of agricultural dusts, and prevention interventions need to target a lower exposure to agricultural dusts in many different exposure settings.

3.4 Confined Animal Feeding Operations and Respiratory Disease Hazards

3.4.1 Introduction

CAFOs are agricultural work places with potential respiratory hazards similar to other work sites with agricultural dust exposures. The primary type of exposure is of the CLLC type and there are secondary occasional PAMM exposures. The occasional PAMM exposures occur in three primary tasks: (1) moving and sorting market hogs, (2) load out of broilers, layers, and turkeys, and input of new layers in cages, and (3) rototilling (reconditioning) the litter in floor-raised poultry. Additional to dust exposures, there are hazardous gas exposures from decomposing animal wastes

Table 3.9 Potentially hazardous agents in dusts from livestock buildings (11,79)

Feed particles[a]
Swine proteins (urine, dander, serum)
Swine feces[b]
Mold
Pollen
Grain mites, insect parts
Mineral ash
Gram-negative bacteria
Microbial by-products
Endotoxin
(1→3)-β-D-glucan
Microbial proteases
Mycotoxins
Histamine
Ammonia adsorbed to particles
Infectious agents
Plant parts and by-products
Tannins
Plicatic acid

[a] Grain dust, antibiotics, growth promotants.
[b] Gut, microbial flora, gut epithelium, undigested feed.

(ammonia and hydrogen sulfide) that have an additive or synergistic chronic health effect (ammonia) with the dust, and occasional acute hazardous hydrogen sulfide. This section will discuss the health hazards and prevention measures for CAFO workers. Table 3.9 lists hazardous dust and gases commonly found in livestock buildings (11, 79).

The US Environmental Protection Agency defines a CAFO as a facility that concentrates livestock or poultry production in enclosed areas where grass or other plants will not grow, and is a potential surface water pollutant (i.e., run-off can lead to a receiving stream). The term CAFO has been given a negative image by some special interest groups and certain components of the general public. Producers and others prefer to use the less-encumbered term (intensive livestock housing) to try to promote an informed rational approach to the subject, reducing the tendency for an emotional response. This should be kept in mind when health or safety professionals communicate with producers. However, in this chapter the term CAFO is used, based solely on the EPA definition.

CAFOs began with poultry production in the late 1950s. Swine CAFOs began to appear in the 1980s, and to a lesser extent for sheep, beef cattle, dairy cattle, and veal calves (101, 102). CAFOs may be open feed lots (more common with beef cattle) or totally enclosed buildings (more common with poultry and swine). They are production systems that include equipment for ventilation, heating, feed preparation and delivery, and disposal of animal wastes (80).

3.4.2 What Toxic Dusts and Gases are found in Confinement Houses?

CAFO dust is a complex mixture of potentially hazardous agents that are generated primarily from the animals (hair, dander, dried feces) and feed (see Table 3.9) (11, 101, 103). Dust particles in CAFOs contain approximately 25% protein and range in size from less than 2 μ to 50 μ in diameter (11, 104). One-third of the particles are within the inhalable size range (less than 10 μ in diameter) (11, 103). Fecal material particles constitute the majority of small (≤10 μ) particles and consist of high concentrations of gut-flora bacteria and exfoliated gut epithelium. This component of the dust constitutes a burden to lower airways. The larger particles are mainly of feed grain origin and primarily impact the upper airways. Additional components of CAFO dust mix include animal dander, broken bits of hair, bacteria, endotoxin, pollen grains, insect parts, and fungal spores (11, 79). CAFO dusts differ from grain dusts from other sources in that they present a chronic exposure to higher concentrations of endotoxin and (1→3)β-D-glucan. The dust also absorbs ammonia (NH_3) and possibly other toxic or irritating gases, adding to the potential hazards of the inhaled particles (54, 101, 105, 106). A recent study has shown that the mixed exposure to dust and ammonia in CAFOs has a synergistic toxic effect on the airways, as measured by cross-shift pulmonary function decline in workers. CAFO dust combined with ammonia results in two to four times (synergistic effect) the extent of cross-shift decline compared to a single exposure of dust or ammonia (19).

Gases generated inside the buildings arise from decomposition of animal urine and feces (ammonia, hydrogen sulfide, and methane are among the 160 gases that have been identified; 34, 101, 105, 107–109). Ammonia (NH_3) and hydrogen sulfide (H_2S) are the two gases that present a known respiratory hazard for workers. Methane is not a respiratory hazard, but is a fire and explosive hazard in CAFOs. Fossil-fuel-burning heaters and high-pressure washers powered by internal combustion engines emit carbon dioxide (CO_2) and carbon monoxide (CO), and the animals' respiration emits CO_2. CO_2 is not an acute hazard for workers, but CO may present a risk to the unborn fetus of a pregnant worker (101).

In swine and some beef and dairy operations, animal wastes are handled in liquid form in one of two ways: it is dropped through a slatted floor into a deep (6–8 feet) pit beneath the house where it remains until the manure slurry is pumped out to be distributed on fields as a crop nutrient (usually twice a year) or it is frequently removed from shallow pits (2–4 feet) under the building through any of several mechanisms to a solid storage structure or earthen lagoon outside the building. Poultry wastes are handled as a solid. In caged-layer operations the manure is stored under the building for some months until it is mechanically removed for land application as a plant nutrient. Broilers (chickens for meat) and turkeys are raised on the floor on a base material such as saw dust, which is compacted with the avian feces to form a solid material called litter. The source of NH_3 inside CAFOs is decomposition of urine and feces on the floor of the building (40%) and the manure storage under the building. The H_2S is the end product of the microbial degradation of sulfur-containing amino acids within animal feces stored anaerobically in liquid manure form (swine and cattle facilities, not poultry). Animal waste stored in liquid form under the building will continually emit low concentrations of H_2S that may emit ambient concentrations of 1–5 ppm (lower than OSHA limits of 10 ppm) into the work environment. However, when the liquid manure is agitated in any way, for example before or during pump out, lethal concentrations may be rapidly emitted.

The mixture and concentrations of dusts and gases inside CAFOs vary depending on numerous factors, including management practices, ventilation and other engineering controls, the age, number, and type of animals in the building, and the design and management of the feeding and waste-handling systems. Dust and gas concentrations and composition vary over time relative to the season of the year and the age of the animals. This section focuses on swine and poultry CAFOs as these operations have been extensively studied and are those most commonly reported as potential health risks for workers

3.4.3 Who is Exposed to CAFO Dusts and Gases, and When?

Worker tasks in CAFOs include feed preparation, feeding animals, cleaning the buildings, sorting and moving animals from one pen or building to another, performing routine vaccinations and treatments, breeding sows, tending to birthing sows, and "processing" piglets. The latter involves umbilical cord stump sanitation, iron administration, identification (e.g., ear clipping or tagging), tail docking, canine teeth clipping, and castration. (Note there are differences in these procedures among producers and in different countries.) Women commonly work in these facilities, particularly in the farrowing operations. Farm family children may often be exposed because they may be helping out or may be accompanying parents due to lack of convenient childcare options. Larger operations often employ immigrant farm workers in CAFOs. Veterinarians who provide services for these farm operations are exposed. Additionally, larger corporate-style farms employ service technicians who work in these facilities in maintenance or animal health.

Dust and gas concentrations increase in winter when the houses are tightly closed and ventilation rates are reduced to conserve heat (110). Dust concentrations increase when animals are being moved, handled, and fed, or when buildings are being cleaned by high-pressure spray washing or sweeping (94, 103). Ventilation systems are designed to control only heat and humidity in the building and often will not reduce dust or gas levels adequately to insure a healthy environment for humans or animals, especially in cold weather. Should the ventilation fail in cold weather, CO_2 from animal respiration and manure pits, combined with CO_2 and CO from heaters, can rise to asphyxiating or toxic levels in a matter of hours. In warm seasons, the greater risk to animals from ventilation failure is heat stress from high temperatures and humidity. Although massive animal losses have been attributed to these latter situations, they do not create an acute human health threat as workers can leave the building in a safe time.

Hydrogen sulfide (H_2S) may pose an acute hazard when the liquid manure slurry is agitated, an operation commonly performed to suspend solids so that pits can be emptied by pumping (36, 105, 111). However, agitation may occur in many ways, such as draining the pits by gravity flow (an optional design in some buildings) or wash water running into the pits from above. During agitation, H_2S can be released rapidly and increase from the usual ambient levels of less than 5 ppm to lethal levels of over 500 ppm within seconds (105, 109). Generally, the greater the agitation, the more rapidly H_2S is released. Animals and workers have died or become seriously ill in swine CAFOs when H_2S levels have risen from agitated manure in pits under the building. Several workers have died when entering a pit during or soon after the emptying process to repair pumping equipment or clean out solids (105). Those attempting to rescue these workers also have died. Workers may be exposed to high H_2S levels when they enter the pit to retrieve animals or tools that have fallen in, or to repair ventilation systems or cracks in the cement. Hydrogen sulfide exposure is most hazardous when the manure pits are located beneath the houses. However, an acutely toxic environment may result from outside storage facilities if gases backflow into a building due to inadequate gas traps or other design fault, or if a worker enters a separate confined-space storage facility. Generally, outside storage facilities are much safer. However, a case on a dairy farm in Pennsylvania has been reported where two young boys were overcome (but survived) when playing near an outside storage pit during the pump-out procedure. Recycled waste wall board (dry wall) has been used for bedding in some dairy operations. Dry wall contains calcium sulfate, which is thought to contribute to extra H_2S emissions. Dry wall was used in the case mentioned above.

Swine CAFOs in North America are concentrated in North Carolina in the east, and most states of the Midwest, including Oklahoma, Texas, Colorado, and Utah. Swine CAFOs are also found in the mid-east and prairie provinces of Canada, northern European countries, Australia, and Brazil. Poultry CAFOs (which include turkey, broiler, and egg production) are concentrated in the east-central, southeast, Midwest, and far west of the US. Poultry confinements are also found in Europe, Australia, and Brazil. Other types of CAFOs (beef, dairy, veal) are not nearly as common as swine and poultry CAFOs, and are located in regions where principle feedstuffs (corn, soybeans, and wheat) are grown.

Although respiratory exposures are extremely common among CAFO workers, there are several other occupational hazards that should be considered, including zoonotic infections, traumatic injuries, needle sticks, and loud noise. Infectious agent hazards involving the respiratory tract include, but are not limited to, swine influenza, methicillin-resistant *Staphylococcus aureus*, ornithosis, and Q fever (112). These diseases are covered in detail in Section 3.7. CAFO workers are subject to injuries from animals, pinch points in gates and pens, cuts and needle sticks. Furthermore, high noise levels in these facilities can lead to noise-induced hearing loss. All of these hazards are discussed in subsequent chapters.

3.4.4 How Commonly Does Excessive Exposure Occur?

In the United States, an estimated 700,000 people work in livestock and poultry confinement operations (113). This number includes owner-operators, hired farm workers, spouses, children, veterinarians, and service technicians. Included in the hired farm workers in the United States are minority populations: Hispanic, Asian, and Bosnian, among others.

The largest group of CAFO-exposed workers with the most frequent and severe health problems is swine CAFO workers (113–115). Here, typical dust concentrations are 2–6 mg/m^3 (11). Buildings may have dust levels of 10–15 mg/m^3 during cold weather or when moving or sorting the pigs. Concentrations in this range are high enough to create an unclear view across a 50-foot room. Concentrations of dust, endotoxin, H_2S, CO_2, and CO may exceed safe levels. Furthermore, research has shown that safe dust and gas concentrations in CAFOs are considerably lower than established regulatory (OSHA) concentrations. Table 3.8 compares recommended maximum exposure concentrations from current research to levels set by OSHA and ACGIH. The more toxic nature of swine dust relative to other dusts is thought to be because of the high degree of its biological activity (high concentrations of endotoxin and glucans), its apparent ability to increase lymphocyte adhesion to respiratory epithelial cells (swine dust) and therefore its general inflammatory nature and the additive and synergistic actions of the mixed dust and gas exposures. Nearly 60% of swine confinement workers who have worked for six or more years experience one or more respiratory symptom (50, 114, 116, 117). The prevalence of respiratory symptoms among workers in non-confinement swine workers is generally less than half of that reported by swine confinement workers (113).

3.4.5 Respiratory Effects of Inhaling Confinement House Dusts and Gases

The worker health effects of CAFO exposure were first described by Donham in 1977 (110). Since that time, numerous studies by many different authors in various countries around the world have been published on the health of CAFO workers. Even with improvements in the engineering of CAFO buildings over the subsequent 40 years, veterinarians as well as others still commonly experience the common complex of CLLC agricultural dust respiratory conditions (bronchitis, MMI, MMS, NAALC; 118–121). An individual's specific response depends on similar risk factors as described for disease mechanisms in the previous section on agricultural dusts (80, 114, 122–126).

The acute symptoms experienced by swine and poultry CAFO workers are listed in Table 3.10 (40, 87, 99, 102). Additionally, CAFO workers may experience delayed and chronic respiratory conditions (88, 107, 127–132).

CAFO workers (especially swine workers) commonly complain of a "persistent cold," with symptoms of stuffy nose, headache, and "popping" ears (88). These patients typically have chronic noninfectious sinusitis (a common component of MMI symptoms) produced by long-term inhalation of inflammatory aerosols within CAFOs.

Chronic lower airway effects manifest as chronic bronchitis with or without obstruction, and are experienced by 25% of all swine CAFO workers. This is the most commonly defined health problem of this occupational group, and is suffered two to three times more frequently compared to farmers who work in conventional swine housing units or in agricultural operations other than swine or poultry production (113). Symptoms are similar to bronchitis from other CLLC exposures but perhaps more common and severe. Symptoms include chronic cough, with excess production of phlegm and sometimes chronic wheezing and chest tightness. Smokers experience a greater prevalence and severity of

Table 3.10 Acute symptoms of swine confinement workers (40, 87, 102, 107, 115)

Symptom	Prevalence (%)
Cough	67
Sputum or phlegm	56
Scratchy throat	54
Runny nose	45
Burning or watering eyes	39
Headaches	37
Tightness of chest	36
Shortness of breath	30
Wheezing	27
Muscle aches and pains	25

chronic bronchitis than do non-smokers. Most workers removed from the confinement house environment become asymptomatic (in the absence of smoking) within a few months, but bronchitic symptoms can persist for years in some workers.

Although irreversible airways obstruction has not been a common finding in confinement house workers, there is objective evidence that long-term lung damage may occur (63, 133). Pulmonary function studies show evidence of air trapping in the lung s (63)suggestive of impending COPD and risk for emphysema. Lavage studies of bronchial fluids and sputum studies show a persistent leukocytosis, with inflammatory and epithelial cells (134, 135). Baseline pulmonary function studies (FVC, FEV_1) of healthy confinement workers usually do not differ significantly from those of workers in conventional swine buildings (10, 114). However, flow rates at 25–75% of lung volume ($FEF_{25–75}$) are significantly lower. Furthermore, work shift declines in FEV_1 and flow rate values are seen in most confinement house workers following a 2–4 hour exposure (136). In addition, the severity of chronic bronchitis symptoms increases in workers with a longer history of confinement house work (112, 113). Work shift decrements in volumes and flow rates are predictive of future declines in baseline flow rates and lung volumes (63, 133). A prospective study of a cohort of swine CAFO workers revealed a decline in PFT flow rates over time with increasing evidence of obstruction (125). These findings lend further suggestion that COPD may occur among these workers in future years (63). Although end-stage lung disease in CAFO workers has not been systematically studied, the authors are aware of many anecdotal case studies where workers have quit because of health reasons. One study of owner-operators revealed a dropout rate of 10% over a 6-year period for respiratory health reasons (112). Another study of swine producers revealed a high drop out of swine producers who developed PFT-documented airway obstruction (137). Experimental animal studies have shown that long-term CAFO exposures create a risk for pneumonia, pleuritis, and bronchial epithelial inflammation and necrosis (33, 80).

Relative to the work-exposure time and development of symptoms, there are some important points that should be communicated to workers and managers. As described above, cross-sectional studies have shown that chronic respiratory conditions on average are recognized after 6 years of 2 or more hours per day of work in CAFOs. However, as livestock production has become more specialized, workers may spend 8 or more hours per day working in CAFOs, therefore chronic symptoms may occur in less time. However, the experience of this author (KJD) bolstered by surveillance of new workers (87) indicates that 10–20% of those who have not previously worked with swine experience acute symptoms within the first few days of work. These symptoms may include cough, chest tightness, and malaise; symptoms of mild ODTS. This response is likely due to the individual's variant genetic polymorphism regarding the endotoxin response, as previously described. If symptoms persist in these workers, even with appropriate efforts at exposure reduction, then it may be advisable for them to leave that employment. On the other hand, there is an accommodation phenomenon in that the symptoms of some workers may dissipate with time, which is thought to be the result of down-regulation of the innate immune system (87).

Although dust exposure is the most common hazardous exposure in CAFOs, the most dramatic acute response results from exposure to H_2S. At moderately high concentrations (100–400 ppm), the irritating properties of H_2S produce rhinitis, cough, dyspnea, tracheobronchitis, and possibly pulmonary edema. At higher concentrations (400–1500 ppm), H_2S will cause sudden collapse, respiratory paralysis, pulmonary edema, and death. An acutely exposed person (500–1000 ppm) or a chronically exposed person (50–200 ppm) may have a delayed response of acute respiratory distress (pulmonary edema) within the next 24–48 hours. Such exposed persons should be medically monitored closely for up to 48 hours. Additional to its irritant qualities,

H_2S is a general cellular toxin that works by disrupting the cellular metabolic system and has a predilection for the central nervous system. At least 25 deaths of confinement workers in the US have been reported from this exposure through 2005 (36, 101). Often multiple deaths occur during exposure events, as would-be rescuers become victims. Autopsy reports of victims have reported aspiration of the liquid manure (111). However, this is probably not the cause of death, but may be a sequelae of the H_2S intoxication.

3.4.6 Diagnosis

As described previously, a detailed occupational history (see Tables 3.10 and 3.11) is of primary importance to achieving a diagnosis of an agricultural dust-related illness. Patients' responses to confinement dusts are variable, and one or more condition may occur simultaneously (e.g., chronic bronchitis, occupational asthma, and sinusitis). A new worker may initially react with flu-like symptoms, which may reside within a week or two. Veteran workers' chronic symptoms of bronchitis, MMI, MMS, and NAALC are most likely related to their work exposure if:

1. they have been working in the building for more than 2 hours per day for 6 years, or 3 years full-time
2. the patient's symptoms subside while away from work for a couple of days or more
3. the symptoms exacerbate on return to work from a few days off on the first day, and diminish over a week
4. the patient complains of a continuous head cold that won't go away
5. the patient complains of lasting fatigue in combination with the symptoms
6. the patient thinks they are allergic to the dust (but are negative atopic status)
7. the patient complains that the building environment seems poorly ventilated and very dusty with an ammonia smell
8. the environmental assessment of the work place is conducted and dust is found at greater than 2.5 mg/m^3, and ammonia greater than 7 ppm.

For patients with occasional acute ODTS symptoms beginning 4–6 hours following a task, a positive occupational history might include the following:

1. They have been moving and sorting animals, catching and loading poultry, or rototilling litter in a poultry building.
2. They have been power washing the building inside.
3. They have been using a leaf blower to blow dust off the poultry cages or pig pens.
4. If they are a dairy farm worker, they have been using a bale shredder to blow straw bedding into cattle-loafing stalls.

Patient management should include a medical assessment for safe use of respirators (free of cardiopulmonary conditions, no history of claustrophobia, proper selection and fit). A personal and family medical history should include questions on allergies, asthma, heart conditions, and hobbies or personal habits (such as smoking) that might complicate the work exposure. Have environmental assessments been conducted? A work air-quality environment assessment would be helpful, and maximum concentrations should be under the current research recommendations given in Table 3.8. PFTs may be useful. Lowered volume and flow rates (FEV_1 and FEF) over the work period of 5–30% are common in symptomatic workers in CAFOs. Less commonly, decreases of 5% or more in volumes (FVC) over the work period may be seen. However, baseline PFT values may be normal. A decreased tolerance to methacholine challenge is common. Dermal prick tests for suspected feed or swine allergens are usually negative.

Table 3.11 summarizes the primary respiratory conditions associated with swine confinement dusts and gases. Conditions provoked within other types (animal species) of confinement buildings may be similar, but typically less severe and less common.

Table 3.11 Occupational respiratory conditions associated with swine livestock confinement diagnosis, treatment. and control (19, 20, 115)

	Symptoms/history	Work exposure	Diagnostic aids	Treatment/control	Prognosis
Bronchitis	• Cough, with sputum production, possibly tightness of chest • Very frequently seen among swine confinement workers; somewhat less often in poultry workers • Smoking associated with increased frequency and more severe symptoms • Symptoms continuing for 2 or more years classified as chronic bronchitis • Reduced symptoms may be seen in new workers in a few weeks (accommodation)	• Usually occurs in those who work in swine confinement for 2 or more hours per day • More frequent and severe for those who have worked 6 or more years in confinement • Generally occurs in buildings with poor environment: dusty (appears hazy and dust accumulates on horizontal surfaces), poor ventilation, often older buildings (built before 1985) • Nursery buildings and those with manure pits under slatted floors may be biggest offenders • Usually worst during cold weather	• Symptoms and history usually sufficient for diagnosis • PFT may show decreased flow rates • Skin tests or other immunological tests not indicated	• Protection from environment most important action • Medications usually not indicated • Bronchodilators and anti-inflammatories may provide temporary relief of symptoms but should not be used long term • Improved ventilation crucial • Employ management procedures to limit dust generation (i.e., frequent cleaning) • Install dust and gas control technology • Establish a respirator program • Abstain from smoking	• Most improve if environmental exposure is controlled through engineering, management, or use of respirator • Cessation of smoking crucial • Temporary removal from the environment or use of a respiratory may help until other measures can be taken • Progressive obstructive disease occurs • Usually not necessary to quit working
Non-allergenic asthma-like condition	• Chest tightness, mild dyspnea, some obstruction during breathing • Often accompanied by bronchitis • Very common in exposed workers • History similar to bronchitis, but often with a non-productive cough • Reduced symptoms may be seen in new workers in a few weeks (accommodation)	• Follows a work exposure (usually at least a 2-hour exposure) • Identical to bronchitis (above) • May develop extrinsic asthmatic symptoms, e.g. wheeze with exposure to cold air or exercise	• PFT following a work shift shows decreased flow rates, primarily FEV_1 and FEV_{25-75} • Respiratory challenge with methacholine or histamine shows decreased PFT flow rates	• Identical to bronchitis (above)	• Identical to bronchitis (above)

(*Continued*)

Table 3.11 (Continued)

	Symptoms/history	Work exposure	Diagnostic aids	Treatment/control	Prognosis
Allergic occupational asthma	• Wheezing within minutes (immediate asthma) or for up to 24 hours (delayed asthma) following exposure • Only seen in small percentage of workers (less than 5%)	• Among atopics or those who already have asthma from another source, often occurs with first exposure • With other workers, a period of sensitization is required, which may vary from a few months to several years • Extent of exposure not as important (environment may be relatively clean, and a person may spend a very small amount of time in the building)	• Same as asthma from any other source: obstructive air-flow patterns following exposure; skin test often positive to one or more of feed grains, hog dander, hog hair, various molds, dusts; associated with atopic status and increased airways reactivity • Reversible with bronchodilators	• Medication and treatment same as for any asthmatic • Attempts to control exposures by environmental control and respirators may or may not be helpful • Desensitization usually not applicable because of multiple antigens and irritant gases	• Same as for any asthmatic • Depending on degree of sensitivity, may be almost impossible to protect these people from their environment • This may be one condition for which patient must quit working in confinement house • Increased airway reactivity and asthma may continue past employment
Organic dust toxic syndrome	• Fever, muscle aches, chest tightness, cough, malaise • Symptoms develop 4–6 hours after exposure • Self-limited symptoms usually resolve in 24–72 hours • Recurrent episodes common • Seen in 25–35% of the swine farming population	• Usually associated with work in a totally enclosed building • Usually occurs following working in situations involving heavy or high dust exposure or concentrations (e.g., 4–6 hours of very dusty work such as handling or sorting hogs, loading crates of poultry, power-washing building interior)	• Elevated white blood count, usually neutrophilia • PFT will show decreased FEV_1 and diminished flow rates • pO_2 may be decreased • Bronchoalveolar lavage usually shows polymorphonuclear cell response • X-ray may show scattered patchy infiltrates • Lung biopsy may show inflammatory infiltrates	• Symptomatic treatment in acute stages may include oxygen and IV fluids to correct acid-base in balance and dehydration • Steroids and/or non-steroidal anti-inflammatory may be used to control fever and myalgia • Most cases do not seek medical attention; often confused with influenza or farmer's lung	• Usual recovery period is 3–4 days, but patient may feel tired and have shortness of breath for several weeks • Subsequent attacks may occur in future following heavy exposure

H_2S intoxication	• Sudden and immediate onset of nausea, dizziness, possibly sudden collapse, respiratory distress, apnea • May lead to sudden death or patient may recover if removed from environment, often with dyspnea, hemoptysis, and pulmonary edema, following intensive exposure • Acute respiratory distress may be seen 24–48 hours following high exposure concentrations	• Almost always occurs with agitation of a liquid manure pit while emptying it • Respiratory effects will occur within seconds of encountering high concentration of H_2S	• If patient survives: x-ray often shows pulmonary edema; possibly presence of sulfhemoglobin and sulfide in blood • If deceased: autopsy shows pulmonary edema, froth in trachea, possibly greenish tinge to viscera; blood contains sulfide and sulfhemoglobin	• Avoidance • Remove exposed person from environment (without exposing others) and resuscitate • May have to ventilate • Seek medical care, watch for and control pulmonary edema	• If patient survives initial exposure, will probably recover, usually with minimal loss of lung function • Recovery period may be from days to 2–3 years, depending on severity of exposure
MMI and sinusitis	• Conjunctivitis, rhinitis, pharyngitis • Stuffy nose, constant cold, headache, ears popping	• See bronchitis and NAALC (above)	• Symptoms and history sufficient	• See bronchitis and NAALC (above)	• Good, depending on environmental control and appropriate respirator use

PFT, pulmonary function test; MMI, mucous membrane irritation; NAALC, non-allergic asthma-like condition.

3.4.7 Treatment

Medications may alleviate the symptoms but not cure chronic respiratory conditions of CAFO workers. Only elimination of exposure can lead to cure. Acute symptoms are medically treatable (ODTS, asthma, pulmonary edema from H_2S intoxication). Bronchitis and NAALC may respond temporarily to enteral or inhalant-administered bronchodilators and/or corticosteroids. Details of these treatments, specific control measures, and the prognosis for these illnesses are listed in Table 3.11.

Medical treatment and cure must be accompanied by reducing exposures to dust and gas by management and engineering controls, appropriate use (selection and fitting) of respirators, and/or temporary removal from the work site. In order to reduce dusts and gases, a patient may need to contact an extension agent or consult a veterinarian or agricultural engineer who has knowledge of environmental control or knowledge for referral to such personnel. Monitoring air quality in these buildings is essential to ensure a healthy work environment. Minimum assessment includes ammonia and total dust (mass not just particle counts) twice yearly; at least once in cold weather conditions. Contaminant concentration should be below those levels listed in Table 3.8.

Healthcare providers should direct CAFO workers who smoke to a smoking cessation program. Healthcare providers must be cognizant of the patient's emotional wellness in addition to their physical problems. Recommendations to leave farming are rarely necessary and should only be given once the cause and prognosis of illness have been determined and other avenues of controlling harmful exposures have been fully explored. Guidelines for healthcare providers dealing with CAFO workers include: (1) if the patient has severe symptoms, a 2–3 week "vacation" from the work environment with PFT before and at the end of this time might be indicated, (2) reducing work periods to 2 hours or less per day may help, (3) fit and instruct the patient on wearing an appropriate respirator, (4) apply a temporary course (2–3 weeks) of inhaled steroid and/or bronchodilators, (5) make contacts for arrangement and assessment of the work environment and controls as indicated for dust to achieve concentrations below 2.5 mg/m^3 of dust and 7 ppm of NH_3, and (6) monitor the patient's symptoms and pulmonary function at least annually.

Farmers are becoming increasingly concerned about confinement-associated respiratory conditions. A healthcare provider can explain potential long-term respiratory conditions but also instill confidence regarding maintenance of the farmer's health status so that they can continue with their livestock operation. Annual monitoring of the patient's respiratory status may be reassuring to many patients and may encourage behavior changes in the patient to institute environmental control measures and comply with proper selection and use of respirators.

3.5 Oxides of Nitrogen ("Silo Gas")

3.5.1 Introduction

Oxides of nitrogen (NO_x or silo gas) are produced during the ensilage process by bacterial action on nitrates stored in the plant material. The main occupational health hazards are associated with work inside non-airtight tower silos (Figure 3.5). NO_x may also be produced in other storage facilities, such as silage pits and plastic agricultural bags. These, however, have minimal occupational hazard for NO_x exposure as they are handled outdoors, not in an enclosed space. NO_x gases are strong irritants. If inhaled, they can cause injury to the respiratory system (silo filler's disease), including bronchial irritation, pulmonary edema and bronchiolitis obliterans (delayed), or sudden death. If the exposed individual survives the acute episode, he or she may develop diffuse pulmonary fibrosis. Workers may be exposed when they enter a confined space where the gas collects, such as when entering a silo, the silo chute, or an adjacent feed room where the silo chute opens. The formation of NO_x gases occurs during the first 10 days following filling of the silo. Details of silo gas formation are given below.

3.5.2 Oxides of Nitrogen on the Farm

Silage commonly constitutes a major portion of the feed ration for ruminant livestock, including beef and dairy cattle. Alfalfa silage may also be fed to sheep. Silage is chopped green plant material, which may include whole corn plant, sorghum, alfalfa, oats, and grass among others, that is stored in a manner allowing anaerobic fermentation to occur. The fermentation process results in the formation of short-chain fatty acids, which lowers the pH of the plant material to the point that inhibits unwanted microbial growth, thus preserving the fodder.

Oxides of nitrogen are produced (138, 139) through microbial oxidation of nitrogen compounds in green chopped plant material. Four oxides of nitrogen (collectively referred to as NO_x) are found in silo gas: nitric oxide (NO), nitrogen dioxide (NO_2), nitrogen tetroxide (N_2O_4), and nitrous acid (HNO_2). Of these compounds, NO_2 and N_2O_4 are the primary health hazards due to their strong irritant properties (139). Concentrations of NO_x reach a maximum in 1–3 days following storage of the chopped plant material, after which production continues at a decreasing rate for 1–20 weeks (140). Both NO_x and carbon dioxide are produced simultaneously. Both gases are heavier than air and may lie at or near the silage surface and in depressions in the silage, where they displace oxygen, or flow down the silo chute through doors left open at the silage level, like water flowing downhill. NO_x may concentrate at the base of a silo, in an adjoining feed room, or within the chute (see Figure 3.15) (140, 141).

Higher NO_x production is associated with certain crop management and weather conditions (e.g., corn silage, heavy nitrogen fertilization of crops, stressed plants in drought or rain prior to harvesting, damage to leaves or roots, cloudy weather, and harvesting after a frost) (138–140).

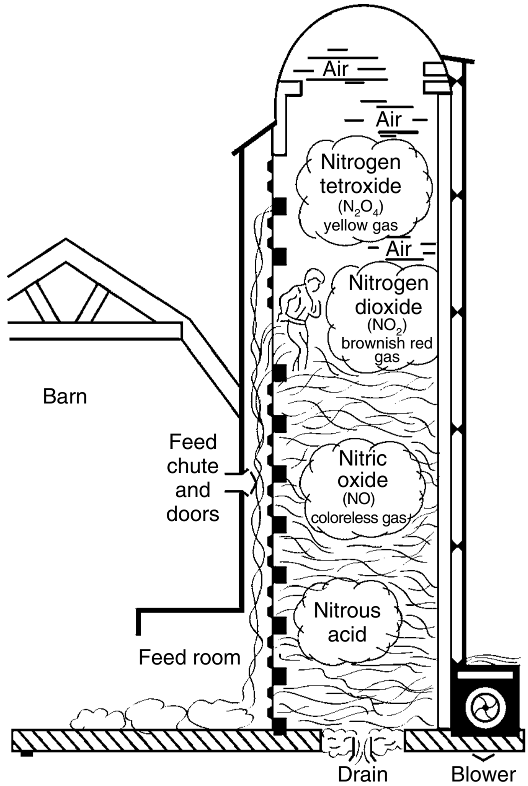


FIGURE 3.15 The formation of nitrogen oxides in a non-airtight silo shortly after it is filled. (Source: United States National Library of Medicine, National Institutes of Health, http://www.nlm.nih.gov/.)

3.5.3 When are Farmers Exposed to NO_x?

Expect exposure to NO_x to occur around time of silage harvest (typically late summer or early fall). (Haylage and oatlage may be harvested in summer, corn silage in late summer or early autumn.) Typically, a worker climbs the ladder in the chute and enters the silo to level silage to enhance storage capacity, and to "cap" the silage by putting a plastic sheet over the material before adding an extra layer of 6–12 inches of silage on top of the plastic. This is done to stop oxygen entering the silage, enhancing the anaerobic fermentation process. Additionally, workers may enter a silo to feed silage out to animals, to prepare a silo unloading machine for use, or to check on the level of silage. All of these tasks are potentially fatal when attempted soon after filling or when a silo has not been ventilated adequately.

Because lower concentrations of NO_x are not highly irritating farmers may work in atmospheres with low to moderate NO_x concentrations for hours without detecting danger. However, gases at these levels can be causing injury to the lungs and airways without the exposed person knowing. The high carbon dioxide and low oxygen atmosphere in the environment induces deep breathing, which speeds penetration of NO_x into the lungs, where the gas causes damage. When NO_x concentrations are high, a worker may become too weak to get out of the silo without assistance. The danger is increased when movement of a worker releases gases trapped in the silage, or when a worker enters or falls into a cavity in the silage. Gases concentrated in adjacent buildings or at the base of the silo may be inhaled by bystanders, children at play, or livestock.

3.5.4 How is NO_x Detected?

Nitrogen dioxide can be detected by its bleach-like odor and yellow to reddish-brown color, which may be seen as a cloud, or by red-brown stains on nearby objects (the silage surface, silo wall, base of the chute, or other structures). Other oxides of nitrogen may not be observable, but can still be harmful. Dead birds or insects may lie at the base of the chute or near the silo.

3.5.5 How Common are Farmer Exposures to NO_x?

Medically-diagnosed cases are not common and represent only a small percentage of actual cases. A study in New York State estimated an annual incidence rate of 5/100,000 (142). An unpublished survey in the late 1960s revealed that 4.2% of Wisconsin farmers had developed symptoms of NO_x inhalation when working in or near recently filled silos (138, 143). The severity of the hazard rests partially in the high case fatality rate. One case review reported a fatality rate of 29% (138).

3.5.6 Respiratory Effects of Oxides of Nitrogen

Reactions to NO_X depend on the concentration, length of exposure, and specific type of NO_x. Methemoglobinemia may result from NO_2 inhalation (40% of cases in one review) as the gas is converted to nitrite in the lungs and absorbed into the blood (139). However, the primary health effect is direct tissue damage from nitric acid formation in the airways and lung tissue. Relatively mild exposure to NO_x produces ocular irritation and transient respiratory tract symptoms manifest as cough, possibly with dyspnea, fatigue, nausea, cyanosis, vomiting, vertigo, or somnolence, and lasting for up to 2 weeks. Mild symptoms may not force workers to leave the silo, thus increasing their probability of a latent severe reaction. Chest films, PFTs, and blood gases may be normal in mild exposures, with complete recovery. High concentrations of NO_x induce immediate distress, resulting in collapse and death within minutes. Death may be due to airway spasm or laryngospasm, reflex respiratory arrest, or simple asphyxiation due to low ambient oxygen concentrations (138, 140, 144). Pathogenesis includes acid damage to the peripheral (primarily the lower) airways, bronchioles, and alveoli, resulting in exudation and thickening of alveolar walls with lymphocytic cellular infiltrates. People who survive may experience one or both of two possible delayed respiratory responses: (1) pulmonary edema (normally within 48 hours following exposure) and (2) bronchiolitis obliterans (within days to weeks). At the time of exposure patients may have minimal symptoms. However, it is possible a slowly evolving and progressive inflammation of the lungs may result in massive, possibly fatal, pulmonary edema from 6 to 24 hours later. In a small percentage of cases, recovery from this first phase of illness may appear to be complete, only to be followed 2–4 weeks later by a relapse characterized by bronchiolitis obliterans (a fibrocellular blockage of the small airways). Such a relapse may be fatal or result in a slow recovery over a period of weeks or months with a varying degrees of diffuse permanent pulmonary fibrosis and small airways obstruction (145).

3.5.7 Diagnosis

Patients in the acute stages of silo filler's disease may present with moderate to severe respiratory distress, hypotension, and hemoconcentration. Coughing up thin, watery sputum (edema fluid) is a common clinical sign associated with a high concentration of NO_x exposure. Leukocytosis, methemoglobinemia, and metabolic acidosis may also be present (138–140, 144). PFTs show a reduced vital capacity, increased airways resistance, and impaired CO_2 diffusion.

Because the initial illness may be mild, patients may present to a healthcare provider for the first time during a relapse 2–6 weeks after exposure to NO_x. At this time cough, tachypnea, dyspnea, fever, tachycardia, cyanosis, or other symptoms of respiratory distress are likely due to bronchiolitis obliterans. Small, discrete nodules resembling military TB, with or without confluence, will be evident on the chest radiograph.

Silo filler's disease may be confused with a number of illnesses, including hypersensitivity pneumonitis or ODTS (see Section 3.2). However, the exposure circumstances for the latter two conditions are entirely different. Military TB may be ruled out by a negative sputum smear for acid-fast bacillus. A detailed medical and occupational history is crucial for correct diagnosis. Prompt treatment of patients with acute symptoms is vital to prevent possible death and to lessen the probability of relapse.

3.5.8 Treatment

Any symptomatic patient who has been exposed to NO_x should be monitored closely by a healthcare provider for 48 hours because of the possibility for sudden development of acute pulmonary edema and acute respiratory distress (138, 140, 145). Ready access to emergency care should be accessible if symptoms of respiratory distress develop. Exposed persons (especially if they have symptoms of pulmonary distress or edema) should be placed on steroids (20–120 mg prednisone/day, tapered over time) for 6–8 weeks to decrease the probability of latent bronchiolitis obliterans (139, 144, 146). In addition, those presenting for the first time with bronchiolitis obliterans should receive steroid treatment. Patients may require intensive supportive therapy, including oxygen, bronchodilators, and assisted ventilation. Blood should be checked for methemoglobinemia (nitrate toxicity) and treated with methylene blue if indicated (138, 140). Antibiotics may be required to treat secondary respiratory infections. A course of inhaled sympathomimetics (e.g., albuterol) and anticholinergics (e.g., ipratropium bromide) may be helpful if symptoms of reactive airways develop.

3.5.9 Prevention of Silo Filler's Disease

Farmers must thoroughly understand the hazards associated with recently filled silos. Once filled, no one should enter the silo for at least 10 days. If entry is imperative during filling, the blower (silo filler) should be run for 30 minutes prior to entering the silo and kept running while anyone is inside. All silo doors down to the level of the silage should be opened, and all roof sections should be in place to assure proper ventilation. Doors between the silo room and barn should be kept closed. Children and animals should be kept away from the silo and adjacent feed room during filling and for 2 weeks afterward. Before being entered for the first time, the filler door should be opened from the ground (not from within the chute) with a rope. Passive detector tubes (also called colorimetric tubes) can be used to assess the concentrations of NO_X. These tubes should be placed at the bottom of the silo chute. Detailed procedures for measuring toxic gases are given in Chapter 15.

Because of small silo door openings and the deadly nature of NO_x, rescue of people inside a silo is extremely difficult and hazardous. Unless testing has been done to assure the absence of toxic levels of NO_x, safe entrance into the silo within 2 weeks of filling can only be accomplished safely with self-contained breathing apparatus.

The hazard of NO_x exposure is substantially reduced (but not eliminated) with storage in oxygen-limited tower silos, bunkers, or agricultural bags. Although silo gas may form in oxygen-limited tower silos, they are bottom unloaded and there is little reason to enter them. Bunkers and agricultural bags are kept outdoors and do not present a confined space, so if oxides of nitrogen form they present a low risk of exposure to workers.

3.6 Applied Agricultural Chemicals

Contact with certain pesticides and the chemical fertilizer anhydrous ammonia can have adverse respiratory affects on exposed agricultural workers. The pulmonary effects of pesticides will only be briefly reviewed here (see Table 3.12) as they are covered in more depth in Chapter 6. Certain fumigants, cholinesterase-inhibiting insecticides, and the herbicide paraquat can threaten life through their acute effects on the respiratory tract. Fumigants, commonly used in grain storage facilities, agricultural commodity storage and transport, and as a soil sterility treatment, can cause laryngeal edema, bronchospasm, and/or pulmonary edema. Cholinesterase-inhibiting insecticides can not only cause systemic poisoning, but also respiratory depression, bronchoconstriction, and bronchorrhea. Paraquat, a broad-spectrum herbicide, when ingested can lead to a delayed fatal malignant proliferation of connective tissue (fibrosis) in the lungs. The respiratory health effects of these chemicals are summarized in Table 3.12 (31).

Anhydrous ammonia is a common nitrogen source fertilizer used in North America as well as other places in the world. The primary crop for its use is corn. Injected into soil as a gas it may escape the container and application equipment exposing workers in the vicinity, causing skin or eye burns, and injury to the respiratory tract. Stored in liquid form under very high pressure, it is cold (–33°C). It also is very alkaline and has an extraordinary affinity for water. Anhydrous ammonia can cause severe damage from alkali burns, freezing, and desiccation to any tissue it touches. Most injuries are to the skin and eyes. If sprayed into the eyes, it will penetrate the cornea and deeper structures, often leading to full or partial blindness.

When anhydrous ammonia is inhaled (because of its hydroscopic nature), the ammonia dissolves in the mucous fluids of upper airways and becomes a severe irritant that may induce laryngospasm. Tissue damage from light to moderate exposure usually is limited to the upper airways. However, massive exposure resulting in inhalation deep into the lungs produces severe inflammation at all levels of the respiratory tract. Pulmonary edema and/or bronchiectasis may follow, either acutely or within 48 hours. A large ammonia release in a confined space could produce fatal results or severe disabling airway disease. Chronic sequelae of massive ammonia exposure may result in chronic bronchitis, obstructive pulmonary disease, bronchial hyperactivity, or bronchiolitis obliterans.

Many farm service and supply companies are located in small rural communities and they often have anhydrous storage and sales facilities. Farmers typically purchase the anhydrous ammonia from the local dealers in 1000 gallon (3785 liter) wheeled “nurse” tanks. They transport the tank to fields where it is pulled behind a tractor and the anhydrous ammonia injected into the soil with an applicator. Farmers may be exposed when an applicator hose breaks or a safety valve malfunctions.

Rural communities may also be exposed to anhydrous ammonia not just in on-farm occupational exposures. Several cases of unintended massive release of the chemical have occurred at farm service and supply companies due to damaged or malfunctioning storage or filling equipment. Furthermore, anhydrous ammonia is used as a refrigerant in large cooling facilities, for example in meat- and poultry-processing plants. Many of these plants are located in small towns in rural

Table 3.12 Respiratory effects of fumigants, cholinesterase inhibitors, and paraquat

Pesticide type	Representative commercial products	Use	Possible effects on the respiratory tract
Fumigants	Halocarbons: methyl bromide vikane chloropicrin carbon tetrachloride chloroform sulfur and phosphorus phosphine carbon disulfide sulfur dioxide oxides and aldehydes ethylene oxide acrolein	Used to kill insects, microorganisms, weeds, rodents, in grain, agriculture, industry, homes	Irritation Laryngeal edema Bronchospasm Pulmonary edema Respiratory depression
Cholinesterase inhibitors (organophosphates and carbamates)	Parathion (Alleron®, Paramar®, Phoskil®), phorate (Agrimet®, Thimet®), fonofos (Dyfonate®); aldicarb (Temik®), carbofuran (Furadan®)	Insecticides with widespread agricultural, industrial, and home use	Bronchoconstriction Bronchorrhea Pulmonary edema Respiratory depression and death (due to inactivation of acetylcholinesterase)
Paraquat	Paraquat (Crisquat, Esgram; mixtures: Weedol®, Gramonol®, Pathclear®, Gramoxone®)	Herbicide, defoliant, widely used in agriculture and elsewhere	Upper respiratory tract irritation Following ingestion, pulmonary fibrosis leading to death

areas. Refrigerant leaks from these systems have resulted in occupational injuries and deaths among plant employees as well as community exposures.

3.6.1 Prevention of Agricultural Chemical-induced Respiratory Problems

Prevention of poisonings and injuries depends on safe usage and storage practices, following approved application techniques, following safety and personal protective equipment (PPE) recommendations on the package label of the product, monitoring the health status of frequently exposed workers, compliance with governmental regulations, following package label safety instructions, and intelligent use (proper selection, fitting, and maintenance) of PPE (147, 148). General pesticide protection methods are covered in Chapter 6. This chapter will deal only with protection from fumigants.

Avoidance is the only effective technique for preventing fumigant poisonings. Fumigants intended for use inside structures must not be released until there are assurances the structures have been vacated; guards and warning signs should be posted around treated buildings. Slow-release pellets and more efficiently enclosed application systems assist in this practice. Farmers can avoid fumigants by eliminating the need for their use through storing good-quality, dry grain in clean, rodent- and insect-proof storage areas, which are monitored and aerated when necessary. If fumigation of farm-stored grain or structures becomes necessary, it is advisable to hire a professional fumigator.

As fumigants are so highly penetrable, self-contained breathing apparatus should be considered if it becomes necessary to enter the structure. Note that some fumigants may penetrate the rubber seal of the apparatus around the face. The precise recommendations on the package label should be followed.

Prevention of exposure to anhydrous ammonia requires routine inspection and maintenance of storage, transport, and application equipment and proper PPE use (149). Any defects in hoses or valves should be immediately repaired. Hoses and valves should be routinely replaced at 5-year intervals, regardless of whether or not they appear safe.

PPE should include routine use of non-ventilated chemical safety goggles, cuffed neoprene or rubber gloves, and long-sleeved shirt, pants and boots. In the case of eye or skin exposure, the victim must continuously flush affected areas with water for several minutes. By law (US) a 5-gallon (20-liter) tank of water must be stored on the nurse tank for emergency purposes. The operator should carry a bottle of water in his or her pocket for immediate access.

3.7 Zoonotic Infections Causing Respiratory Disease

About 25 of the over 250 known zoonotic infectious diseases (infections common to animals and man) are considered to be a significant occupational hazard to agricultural workers in western industrialized countries. Of these, approximately eight may affect the respiratory tract, including bovine TB, histoplasmosis, hydatidosis, Newcastle disease, ornithosis, Q fever, swine and avian influenza, methicillin-resistant *Staphylococcus aureus* (MRSA) and tularemia.

These zoonotic diseases can be transmitted directly to humans from live animals, their carcasses or byproducts (wool, bone, hides), or indirectly through the environment where certain of these organisms survive for extended periods. Humans as well as animals may serve as reservoirs for three of these infections (tuberculosis, influenza, and MRSA), which may be transmitted from humans to animals and back again from animals to humans. High-risk groups for these infections include farmers and ranchers, farm workers, veterinarians, slaughterhouse workers, animal transporters, and those who process animal products. These eight zoonoses are covered in more detail along with other zoonoses in Chapter 13 (see Tables 13.1, 13.2, and 13.3). This author (KJD) recommends the following prevention practices where history suggests an infectious zoonotic disease hazard exists. For some infections (e.g., histoplasmosis, ornithosis, fever) blood should be drawn and serum frozen for possible future serological testing if a febrile illness is presented. (A rise in serologic titer from baseline would enhance a rapid diagnosis of some zoonotic infections that are often difficult to diagnose.) Potential workers in dairy farms (especially those from countries with high TB rates) should be tested for TB prior to employment, as human TB can be transmitted to cattle and then back to other workers. New workers in swine farms should be tested for MRSA by nasopharyngeal swabs (culture or PCR) prior to work, as they may transmit MRSA to swine. Swine and poultry workers should be immunized yearly for current influenza strains to assist in prevention of influenza transmission between people and pigs or poultry.

3.8 General Preventive Measures for Agricultural Respiratory Illnesses

Preventive recommendations for specific exposures were briefly discussed in Sections 3.2–3.7 of this chapter. The following section provides a general comprehensive programmatic approach to preventing agricultural respiratory conditions, with emphasis on agricultural dust hazard prevention.

3.8.1 General Strategies for Prevention of Agricultural Dust-induced Illnesses

Prevention of excessive exposure to agricultural dusts is advisable for all farmers, and imperative for farmers sensitized to components of agricultural dust that cause allergic asthma or FL. Prevention should take a multi-faceted approach, based on the principles of the multiple modal (Iowa model) of prevention, as described in Chapter 15. This generic paradigm is a "total worker health" approach for prevention and includes the following:

1. medical monitoring and control of basic health parameters (e.g., BMI, cholesterol, blood pressure, smoking cessation) and occupational-induced deficits (e.g., hearing, pulmonary function)
2. environmental control, including emission control (keeping dust from emitting in the working environment)
3. removing or diluting dust in the air
4. modifying work processes to decrease exposure by assigning or choosing jobs that decrease exposure for sensitive individuals
5. protecting the individual with PPE (e.g., a respirator)
6. educating the workers on occupational health and safety practices.

These factors are listed in order from highest to lowest effectiveness, although economic and operational aspects may affect this order. Preventing generation of the dust at its source, through engineering and management interventions, has high priority, then removal or dilution if dust reaches the worker's breathing zone (e.g. ventilation). If acceptable exposures cannot be attained by these means, PPE should be considered. Case studies have shown that some dairy farmers with a history of FL have successfully managed their illness by wearing a respirator regularly and delegating tasks with potential high exposure to bioaersols to other workers (146). Other farmers with predisposing conditions have undertaken more dramatic steps, including eliminating major sources of dust by installing airtight silos, bunker silos, or agricultural bag technologies (in place of conventional non-airtight tower silos), mechanizing cattle-feeding systems, and installing more effective ventilation systems in the barn. Newer hay-processing and storage systems are now available that reduce microbial growth and allow material handling mechanically outdoors rather than in barn-confined spaces. Robotic milkers and barn cleaners are now available which also reduce dust exposure for dairy workers. Although very expensive, this equipment allows sensitized farmers to stay working on the farm.

3.8.2 Emission Control

As health hazards of agricultural dusts increase with the concentration of microbial content, preventing microbial growth in feedstuffs is an important prevention strategy. Capping silage with a plastic sheet held in place by rocks or a heavy chain (rather than additional plant material) reduces the mold and dust in the top layers of silage. Grain and hay should be dried to less than 15% and 20% moisture content, respectively, before storage. Commercial hygrometers are available to measure the moisture content of grain and hay to take the guesswork out of determining the optimum time and conditions for storage. Hay and silage additives are available that purport to reduce microbial contamination as well as improving feed quality. However, there are many instances when microbial growth cannot be prevented. For prevention of aerosolization of microbe-laden silage when silo caps are removed, a minimal-cost option is to wet down the top layer of silage prior to unloading the first layer of material. The silo-loading blower may be run to force air into the silo to help dilute contaminants once the dust or silo gas is generated. Respiratory PPE must be considered an important adjunct in prevention when engineering and management methods are not completely successful. (Chapter 15 provides guidelines for the selection and fitting of respirators.)

Additional controls on the farm now include machinery improvements such as combines or tractor cabs with air-filtration systems. In newer grain elevators conveyor belts and augers are totally enclosed, and the grain is often misted with a vegetable oil as it goes into storage. Dust collectors (e.g., cyclone separators and bag houses with shaker filters) and effective ventilation systems have greatly reduced dust levels in grain-handling operations and are now being researched for application in swine and poultry buildings.

Education should be a component of a comprehensive preventive program, targeting the health hazards of agricultural grain dust inhalation. Further education for prevention should also include best management practices for growing, harvesting, and storing the grain and fodder, and work practices to help ensure these feed materials are high quality with low microbial, insect, and vermin contamination. When grain dust levels are above 4 mg/m^3 (a common grain dust standard in many countries) or when workers are especially sensitive, PPE (e.g., a NIOSH-certified dust mask, see Chapter 15) should be used.

3.8.3 Work Environment Air-quality Assessment

An important component of occupational health is measuring the concentration of hazardous substances in the work environment. Commonly practiced by industrial hygienists, this is uncommon in agricultural settings, but its popularity is slowly growing in production agriculture. One needs to know what exposures exist in work environments, and what they are. Air-quality measurements should be conducted before and after remediation is attempted to determine if exposures have been reduced to safe concentrations. Air-quality assessment equipment is discussed in detail in Chapter 15.

3.8.4 Remove Dust from the Air

Properly functioning ventilation systems in animal buildings may prove beneficial, albeit costly, in reducing dust level concentrations. There are dust-filtration systems, cyclone separators, oil-misting systems, and ionization systems that can help remove dust from the air (150). Many of these systems are applied in grain elevators, but on-farm usage is not common because of the expense and extra management required.

3.8.5 Use of Respirators

There are several factors that must be considered when recommending the use of respirators:

1. Dust-filtering respirators are uncomfortable to wear, are hot, and are difficult to breathe through.

2. Respirators create difficulties in communication: it is difficult to talk and to be understood.
3. Respirators may present a medical risk to those with a cardio-respiratory ailment or those with claustrophobic tendencies.
4. Training, experience, and monitoring are necessary to ensure the worker has the correct respirator for the particular exposure, and that the respirator is worn and fitted properly.
5. Wearing a respirator may present a false sense of security (e.g., if worn in an environment for which it is not effective).
6. Respirators must be conveniently available at the exposure site or they will not be worn at all (151).

For these reasons the individual must be highly motivated to wear a respirator (152–155). Convenient supply and knowledgeable resource personnel are rare in rural areas. Although respirators have been shown to be helpful, they are not completely protective as acute pulmonary function changes and biological markers of inflammation are still present in workers who wear respirators in swine barns (156, 157). Because of all these difficulties with respirator use, they should only be considered secondary to source control and are just one component of a control program. Details of proper selection and use are given in Chapter 15.

3.8.6 Reassign Jobs to Protect Vulnerable Individuals

Workers with a history of any of the acute or chronic conditions previously described resulting from organic dust exposure should take extra precautions to prevent further dust exposure. This is especially true for those with confirmed FL or atopic asthma. Workers who have one or more of the chronic non-allergic agricultural dust conditions (bronchitis, MMI, NAALC, MMS) can usually be protected safely with the appropriate interventions mentioned above, including appropriate and regular use of a dust respirator. Those who are genetically susceptible to endotoxin may be directed to other farm tasks with less dust exposure. Currently there is no practical objective test to identify such people, therefore each person's susceptibility must be judged on exposure and symptom history. Note that this author's experience (KJD) has revealed that most workers with chronic inflammatory conditions can be kept healthy on the job if the preventive procedures recommended here are practiced. However, these workers should be medically monitored annually or bi-annually as described below.

3.8.7 Education of Owner/Operators and Workers

As will be discussed in Chapter 15, education of the owner/operators and workers alone is not very effective in long-term prevention. Although farmers may be quite knowledgeable about the causes of acute traumatic injuries on the farm, they are not very knowledgeable about the sources and causes of illnesses on the farm. Education can be incorporated as a component of a multimodal prevention program. Education must be frequent and relevant. Healthcare practitioners and veterinarians in rural areas can have an important role in health education through one-on-one education to the patient or facilitating community education programs. (Chapter 15 discusses multimodal prevention programs in more detail.)

3.8.8 Medical Monitoring

Medical monitoring of agricultural workers should be considered in two circumstances: (1) for those with one of the allergic conditions of FL disease or atopic asthma and (2) for those working in CLLC exposure situations (e.g., swine or poultry confinement systems). Monitoring of patients with confirmed FL should include annual physical examination and assessment of symptoms, including history regarding dyspnea following exposure and exertion. Annual PFT testing and chest radiographs should be considered. For assessing the degree or progression of impairment, blood gases and exercise tolerance may be useful. If modification of work behaviors and environmental control measures do not prevent the progression of symptoms and clinical signs of FL, then further protection from exposure is indicated, including industrial hygiene control and being fitted with an appropriate respirator. Rarely has this author (KJD) found it necessary to recommend quitting farming for respiratory health reasons. This author (KJD) has often consulted with farmers whose physicians have told them they must get out of farming because they are "allergic" to farm dust. On second opinion examination, these farmers are rarely atopic, but are affected by CLLC exposures resulting in inflammation-based bronchitis and NAALC. In most cases, these farmers can continue to farm if preventive measures are taken, without further endangering their health. Recommending that a farmer leave the farm should be done judiciously, as this is not a cultural, social, or economic option for most owner/operator farmers. Furthermore, studies in Wisconsin and Quebec have shown little difference in long-term outcome of respiratory health for patients who leave farming (158).

Pre-employment medical evaluations should be considered for new workers in confined livestock, poultry, and dairy operations. Any potential worker who has a history of respiratory symptoms or disease, atopy, pulmonary function abnormalities, or who smokes cigarettes should ideally be placed in a job where less exposure to dust will occur. It is advisable for these workers to have a pre-employment physical that includes assessment of respiratory symptoms and baseline pulmonary function. Furthermore, these workers should be regularly monitored for respiratory health.

3.8.9 Smoking Cessation

Because of the proven additive adverse effect of smoking and agricultural dust exposure, smoking cessation programs must be recommended for anyone in regular contact with agricultural dust. This is one of the most important prevention actions that a healthcare practitioner can recommend to his or her farm patients.

3.8.10 Prevention of Occupational Illnesses in CAFO-exposed Workers

The control of health hazards associated with CAFOs follows the same generic principles outlined in the introduction of this chapter, and discussed in detail in Chapter 15. A multi-modal prevention model for confinement house problems, based on education and industrial hygiene consultation, has demonstrated effectiveness (10). Some specific examples of management practices to reduce the sources of dusts and gases include (150): (1) delivering feed by extension spouts into covered feeders, rather than letting feed fall freely several feet from automatic delivery systems into open feeders, (2) using extra fat or oil in the feed to reduce dust, (3) sprinkling or misting the environment with vegetable-based oil, (4) regular (every 3–4 weeks) washing inside of the buildings with power sprayers (operators must use respiratory protection during this procedure), (5) using flooring that is self-cleaning (e.g., plastic-coated wire mesh), and (6) ensuring that heating units are clean, vented, and functioning properly. Details of control measures are published elsewhere (80, 97). The effectiveness of control techniques can be assessed by measuring dust and gas concentrations. The buildings should be routinely monitored to ensure air contaminants are within healthy limits. Properly designed and managed ventilation will help to reduce dust and gases inside CAFOs, but it may not reduce contaminates to recommended levels, especially in cold weather. A number of engineering techniques (e.g., the use of heat exchangers, which allow increased ventilation while capturing some "waste" heat) have been tried with varying degrees of success (102).

Respirators should be used as an adjunct to source control. Anyone working in or visiting a swine or poultry confinement house for 2 or more hours per day should be advised at a minimum to wear a NIOSH-approved two-strapped dust mask. People exposed to houses with high dust or gas concentrations or who have respiratory conditions may need to use a more efficient respirator, such as a half-mask cartridge (NH_3 cartridge with dust cap) or powered air-supplying respirator (e.g., Air Helmet). (Detailed discussion of PPE use is given in Chapter 15.)

Preventing exposure to high concentrations of H_2S from manure pits includes general safety measures such as constructing manure pits outside the confinement building, constructing openings or attaching anchor points and chains so that lids or other objects cannot fall into the pit requiring a worker to enter the pit for retrieval, and erecting safety guards and warning signs around open pits. Whenever a pit that is under a confinement house is being agitated, people must stay out of the building, ventilation of the house should be maximized, and animals should be removed or observed from outside the building.

Even when not being agitated, manure pits cannot be entered safely. If entrance is imperative, confined space entry procedures must be followed (entering person affixed with proper harness and tethered security with resources to retrieve the person). Adequate PPE protection is only assured when self-contained breathing apparatus is worn by an individual trained in its use. All operators should understand that high concentrations of H_2S cannot be smelled and that H_2S above 1000 ppm produces unconsciousness and respiratory arrest in only one to three breaths. A variety of H_2S gas alarms can give an accurate indication of hazard.

Poor air quality in the confinement house has also been shown to be associated with health problems and lowered productivity in the swine (80). Informing a swine producer of this economic fact may be the most expedient way to bring about environmental improvements that will help the workers, the animals, and the economics of the operation.

Key Points

1. Respiratory conditions, when combined with their frequency and potential disabling outcomes, are one of the most important occupational health conditions of farmers and farm workers.
2. The risk factors of hazardous respiratory exposures include:
   a. working inside livestock buildings and other agricultural structures that allow concentration of exposures (e.g., livestock and poultry confinement buildings, dairy barns, silos, manure storages structures, and grain storage structures);
   b. exposure to dust with high concentrations of microbes, cigarette smoking, atopic status, other concurrent respiratory or cardiac conditions.
3. The knowledge and ability to gain an accurate occupational exposure history is critical in establishing a potential health issue, and in diagnosis and prevention (see Table 3.13).
4. Exposure to agricultural organic dusts is a hazard that frequently results in a common syndrome or cluster of conditions regardless of the specific source of the dust. The specific condition(s) and severity vary somewhat depending on the individual's biological variation and the concentration of dust and time of exposure. Periodic acute moldy and massive (PAMM) exposures result commonly in organic dust toxic syndrome (ODTS) and or rarely farmer's lung (FL). Chronic lower-level concentrations (CLLC) may result in one and usually several of the following: bronchitis, non-allergic asthma-like condition (NAALC), mucous membrane irritation (MMI), or Monday morning syndrome (MMS). These conditions are primarily diseases of the airways, not lung tissue. These conditions are largely irritant and inflammatory, not allergic. Endotoxin is the known primary causative agent of several irritant/inflammatory agents in agricultural dust. Its origin is the cell wall of Gram-negative bacteria.
5. Gas exposures include ammonia and hydrogen sulfide in livestock confinement buildings. Ammonia is an irritant, as is hydrogen sulfide. The latter in high concentrations can be lethal and is often secondary to the agitation of liquid manure in storage structures. Anhydrous ammonia is a fertilizer injected into soil and can be extremely damaging to the respiratory system as well as skin and eyes if a farmer is exposed to high concentrations. Certain fumigant pesticides used in grain or soil can cause severe respiratory injury, with a

possible fatal outcome. Oxides of nitrogen (NO_x) are produced in freshly stored silage and present a potential respiratory hazard to those entering a non-airtight tower silo within the first 10 days of filling. It is a highly irritant gas that can cause extensive tissue destruction to the lower airways and lung tissue. Paraquat, a broad spectrum herbicide, if ingested, can cause a progressive malignant pulmonary fibrosis.

6. Prevention requires more than awareness-level education. It requires a multi-modal program approach that includes reduction in source of exposure through engineering, substitution, alteration of work practices, medical monitoring, and judicious use of properly selected and fitted respirators.
7. Diagnosis and secondary prevention of any of these agricultural respiratory conditions depends largely on an understanding of agricultural processes and exposures leading to ascertainment of an accurate and detailed occupational history (see Table 3.13) and its interpretation.

Table 3.13 Agricultural respiratory disease occupational history

Pertinent questions that suggest an agricultural-occupational relationship to one or more of the following: (1) one or more of the components of mucous membrane irritation, including sinusitis, rhinitis, pharyngitis, laryngitis, and thracheitis, (2) subacute or chronic bronchitis, (3) asthma-like condition, or (4) Monday morning syndrome.

1. Do you have regular dust exposure (>2 hours/day and >6 years)?
   a. Working with livestock inside buildings?
      i. Dairy barns
      ii. CAFOs
         1. Swine CAFO
         2. Poultry CAFO (chickens or turkeys)
   b. Working with grain handling?
      i. Moving and storing grain, such as in a grain elevator
      ii. Grinding and mixing animal feeds

Pertinent questions that suggest an agricultural-occupational relationship to one or more of the following: (1) acute bronchitis or (2) a generalized febrile condition with symptoms of organic dust toxic syndrome, hypersensitivity pneumonitis or pneumonia.

1. 2–6 hours before these symptoms began, were you involved in any of the following activities that may have resulted in a heavy exposure to an agricultural dust?
   a. Unloading a non-airtight silo (removing the moldy layers from the top of the silage)
   b. Moving or handling grain that may have been moldy
   c. Cleaning out a grain bin
   d. Breaking open/handling straw or hay bales that were spoiled
   e. Using a bale shredder to prepare animal bedding
   f. Moving, sorting, or loading swine or poultry in a confinement building
   g. Using a leaf blower to clean dust from surfaces in a swine or poultry building
   h. Using a high-pressure washer to clean in a swine or poultry building
   i. Moving or handling wood chips or sawdust that may have been spoiled
2. Have you been using a welder, and were any of the metals you were working with galvanized?
3. Have you been working in or around bird roosts (pigeons or starlings, etc.), an old poultry house, hayloft, or silo in the past 10 days?
4. Have you been working with sick poultry in a confined space or in turkey processing in the past 10 days?
5. Have you been administering aerosolized poultry vaccines (particularly Newcastle virus) in the past 10 days?

Pertinent questions that suggest an agricultural-occupational relationship to one or more of the following: difficult breathing related to pulmonary edema or laryngeal edema.

1. Have you been working with or around liquid manure storage, or moving or pumping liquid manure (within the past 48 hours)?
2. Have you been working with or around fresh (within 10 days of cutting) silage, particularly in a non-airtight silo?
3. Have you been working with or around grain or pest fumigants such as methyl bromide or phosphine in the past 48 hours?

CAFO, confined animal feeding operations.

References

1. Schenker MB, Christiani D, Cormier Y, Dimich-Ward H, Doekes G, Dosman J, et al. American Thoracic Society: Respiratory health hazards in agriculture. Am J Resp Crit Care Med. 1998;158 (158Suppl.S):S1–S76.
2. Kern J, Mustajabegovic J, Schachter E, Zuskin E, Vrcic-Keglevic M, Ebling Z, et al. Respiratory findings in farm workers. J Occup Environ Med. 2001;43(10):905–13.
3. Reynolds SJ, Nonnenmann MW, Basinas I, Davidson M, Elfman L, Gordon J, et al. Systematic review of respiratory health among dairy workers. J Agromedicine. 2013;18(3):219–43.
4. Pesticide national synthesis project. US Geological Survey; 2014 (accessed 14 June 2014). Available from: http://water.usgs.gov/nawqa/pnsp/.
5. Schenker MB. Inorganic agricultural dust exposure causes pneumoconiosis among farmworkers. Proc Am Thoracic Soc. 2010;7(2):107–10.
6. May S, Romberger DJ, Poole JA. Respiratory health effects of large animal farming environments. J Toxicol Environ Health B Crit Rev. 2012;15(8):524–41.
7. Thundiyil J, Stober J, Besbelli N, Pronczuk J. Acute pesticide poisoning: A proposed classification tool. World Health Organization; 2008 (updated 20 July 2014; accessed 14 June 2014). Available from: http://www.who.int/bulletin/volumes/86/3/07-041814/en/.
8. Treatment Manual. Washington, DC: US Department of Agriculture; 2015. p. 1–914.
9. Clark S, Rylander R, Larsson L. Airborne bacteria, endotoxin and fungi in dust in poultry and swine confinement buildings. Am Ind Hyg Assoc J. 1983;44(7): 537–41.
10. Donham K, Merchant J, Lassise D, Popendorf W, Burmeister L. Preventing respiratory disease in swine confinement workers: Intervention through applied epidemiology, education, and consultation. Am J Ind Med. 1990;18:241–62.
11. Donham K, Scallon L, Popendorf W, Treuhaft M, Roberts R. Characterization of dusts collected from swine confinement buildings. Am Ind Hyg Assoc J. 1985;46:658–61.
12. Viegas S, Faisca VM, Dias H, Clerigo A, Carolino E, Viegas C. Occupational exposure to poultry dust and effects on the respiratory system in workers. J Toxicol Environ Health A. 2013;76(4–5):230–9.
13. Kirychuk SP, Dosman JA, Reynolds SJ, Willson P, Senthilselvan A, Feddes JJ, et al. Total dust and endotoxin in poultry operations: comparison between cage and floor housing and respiratory effects in workers. J Occup Environ Med. 2006;48(7):741–8.
14. Becklake M. Grain dust and health: state of the art. In: Dosman JA, J. CD, editors. Occupational pulmonary disease, focus on grain dust and health. New York: Academic Press Inc.; 1980. p. 194–6.
15. Salvaggio JE, Taylor G, Weill H. Occupational asthma and rhinitis. In: Merchant JA, editor. Occupational Respiratory Diseases. DHHS publication no. (NIOSH)86-102. Cincinnati: US Department of Health and Human Services, Public Health Service, CDC; 1986.
16. Pont F, Gispert X, Canete C, Pinto E, Dot D, Monteis J. An epidemic of asthma caused by soybean in L'Hospitalet de Llobregat (Barcelona) [in Spanish]. Arch Bronconeumol. 1997;33(9):453–6.
17. Schenker M. Exposures and health effects from inorganic agricultural dusts. Environ Health Perspect. 2000;108(Suppl.4):661–4.
18. Donham KJ, Scallon LJ, Popendorf W, Treuhaft MW, Roberts RC. Characterization of dusts collected from swine confinement buildings. Am Ind Hyg Assoc J. 1986;47(7):404–10.
19. Donham K, Cumro D, Reynolds S. Synergistic effects of dust and ammonia on the occupational health effects of poultry production workers. J Agromedicine. 2002;8(2):57–76.
20. Donham KJ, Reynolds SJ, Whitten P, Merchant JA, Burmeister L, Popendorf WJ. Respiratory dysfunction in swine production facility workers: dose-response relationships of environmental exposures and pulmonary function. Am J Ind Med. 1995;27(3):405–18.
21. Buchan R, Rijal P, Sandfort D, Keefer T. Evaluation of airborne dust and endotoxin in corn storage and processing facilities in Colorado. Int J Occup Environ Health. 2002;15(1):57–64.
22. Dosman J, Cotton D. Occupational Pulmonary Disease, Focus on Grain Dust and Health. New York: Academic Press Inc.; 1980. 615 p.
23. Death in a Veterinarian from Avian Flu. World Health Organization; 2005 (accessed 30 January 2005). Available from: http://www.who.int/csr/don/2003_04_24/en/.
24. Zimmer A. The influence of metallurgy on the formation of welding aerosols. J Environ Monit. 2002;17:1–6.
25. Mazurek JM, Schleiff PL. Physician recognition of work-related asthma among US farm operators. Fam Med. 2010;42(6):408–13.
26. Siegel PD, Shahan TA, Sorenson WG. Analysis of environmental histamine from agricultural dust. Scand J Work Environ Health. 1992;18(Suppl.2(2)):60–2.
27. National poison data system. American Association of Poison Control Centers; 2014 (accessed 14 June 2014). Available from: http://www.aapcc.org/data-system/.
28. Radon K, Danuser B, Iversen M, Monso E, Weber C, Hartung J, et al. Air contaminants in different

European farming environments. Ann Agric Environ Med. 2002;9(1):41–8.
29. Beijer L, Thorn J, Rylander R. Effects after inhalation of (1→3)-beta-D-glucan and relation to mould exposure in the home. Mediators Inflamm. 2002; 11(3):149–53.
30. The acute work-related pesticide poisoning incidence rate. Centers for Disease Control and Prevention; 2013 (updated 18 March 2013; accessed 14 June 2014). Available from: http://www.cdc.gov/niosh/topics/pesticides/animatedmap.html.
31. Roberts J, Reigart J. Recognition and management of pesticide poisonings, 6th edition. Washington, DC: US Environmental Protection Agency; 2013.
32. Methyl bromide questions and answers. US Environmental Protection Agency; 2011 (updated 8 January 2011; accessed 14 June 2014). Available from: http://www.epa.gov/ozone/mbr/qa.html.
33. Donham K, Leininger J. The use of laboratory animals to study potential chronic lung disease in swine confinement workers. Am J Vet Res. 1984;45: 926–31.
34. Donham K, Popendorf W. Ambient levels of selected gases inside swine confinement buildings. Am Ind Hygien Assoc J. 1985;46:658–61.
35. Fennimore S, Duniway J, Martin F, Ajwa H, Westerdahl B, Goodhue R, et al. Methyl bromide alternatives evaluated for California strawberry nurseries. California Agric. 2008;62(2):62–7.
36. Beaver RL, Field WE. Summary of documented fatalities in livestock manure storage and handling facilities – 1975–2004. J Agromedicine. 2007;12(2): 3–23.
37. Donham KJ, Knapp LW, Monson R, Gustafson K. Acute toxic exposure to gases from liquid manure. J Occup Med. 1982;24(2):142–5.
38. Von Essen S, Moore G, Gibbs S, Larson KL. Respiratory issues in beef and pork production: recommendations from an expert panel. J Agromedicine. 2010;15(3):216–25.
39. Rylander R. Organic dusts and disease: a continuous research challenge. Am J Ind Med. 2004;46(4): 323–6.
40. Hoffmann HJ, Iversen M, Takai H, Sigsgaard T, Omland O, Dahl R. Exposure to work-related levels of swine dust up-regulates CD106 on human alveolar macrophages. Am J Ind Med. 2004;46(4): 378–80.
41. Donham K. Epilogue: health effects of organic dusts in the farm environment. Am J Ind Med. 1986;10: 339–40.
42. Von Essen S. Bronchitis in agricultural workers. Semin Respir Med. 14(1):60–9.
43. Guillam MT, Claude C, Dewitte JD, Michel V, Segala C. Health hazards and inhalatory exposures in poultry farming. Arch Mal Prof Env. 2007;68: 161–68.
44. Senthilselvan A, Dosman JA, Kirychuk SP, Barber EM, Rhodes CS, Zhang Y, et al. Accelerated lung function decline in swine confinement workers. Chest. 1997;111(6):1733–41.
45. Reynolds SJ, Clark ML, Koehncke N, Von Essen S, Prinz L, Keefe TJ, et al. Pulmonary function reductions among potentially susceptible subgroups of agricultural workers in Colorado and Nebraska. J Occup Environ Med. 2012;54(5):632–41.
46. Begany T. Hygiene hypothesis gains support in the United States and Europe. Respir Reviews Com (Internet). 2005;8(2) (accessed 13 December 2015). Available from: http://www.respiratoryreviews.com/jan03/rr_jan03_hygiene.html.
47. Emanual D, Marx JJ Jr, Ault B, Roberts RC, Kryda MJ, Treuhaft MW. Organic dust toxic syndrome (pulmonary mycotoxicosis) – A review of the experience in central Wisconsin. In: Dosman JA, Cockcroft DW, editors. Principles of Health and Safety in Agriculture. Boca Raton, FL: CRC Press, Inc.; 1989. p. 72–5.
48. Pratt D, May J. Feed associated respiratory illnesses in farmers. Arch Environ Health. 1984;39:43–8.
49. Forrester M. Neonicotinoid insecticide exposures reported to six poison centers in Texas. Hum Exp Toxicol. 2014;33(6):568–73.
50. Clark C, Rylander R, Larsson L. Airborne bacteria, endotoxin and fungi in dust in poultry and swine confinement buildings. Am Ind Hyg Assoc J. 1983;44:537–41.
51. Von Essen S, Robbins R, Thompson A, Rennard S. Organic dust toxic syndrome: An acute febrile reaction to organic dust exposure distinct from hypersensitivity pneumonitis. J Clin Toxicol. 1990;28(4): 389–420.
52. Von Essen S, Fryzek J, Nowzkowski B, Wampler M. Respiratory symptoms and farming practices in farmers associated with an acute febrile illness after organic dust exposure. Chest. 1999;116(5):1452–8.
53. Larsson K, Eklund A, Malmberg P, Belin L. Alternations in brochoalveolar lavage fluid but not in lung function and bronchial responsiveness in swine confinement workers. Chest. 1992;102:767–774.
54. Do Pico G. Workgroup report on diseases. Am J Ind Med. 1986;10:261–6.
55. Pladsen T. Silo emptiers' diseases. Minn Med. 1984;May:265–9.
56. Emanual D, Kryda M. Farmer's lung disease. Clin Rev Allergy. 1983;1:509–32.

57. Doekes G, Dowes J, Dowling K, Heederik D, Kullman G, Lawson R, et al. Exposures in Agricultural Populations Affecting Respiratory Health. In: American Thoracic Society: Respiratory health hazards in agriculture. Schenker M, editor. Am J Resp Crit Care Med. 1998;158(158Suppl.S):S4–S18.
58. Olenchock S, Murphy S, Mull J, Lewis D. Endotoxin and complement activation in an analysis of environmental dusts from a horse barn. Scand J Work Environ Health. 1992;18(2):58–9.
59. Pesci A, Bertorelli G, Dall'Aglio P, Neri G, Olivieri D. Evidence in bronchoalveolar lavage for third type immune reactions in hypersensitivity penumonitis. Eur Respir J. 1990;3(3):359–61.
60. Rylander R. Role of endotoxins in the pathogenesis of respiratory disorders. Eur J Respir Dis Suppl. 1987;154:136–44.
61. Jones A. Farmer's lung: an overview and prospectus. Ann Am Conf Government Ind Hygienists. 1982;2:171–9.
62. Schatz M, Patterson R. Hypersensitivity pneumonitis – general considerations. Clin Rev Allergy. 1983;1:451–67.
63. Schwartz D, Donham K, Olenchock S, Popendorf W, Van Fossen D, Burmeister L, et al. Determinants of longitudinal changes in spirometric function among swine confinement operators and farmers. Am Respir Crit Care Med. 1995;151:47–53.
64. Seaton A. The breathless farm worker. Br Med J. 1994;288:1940–1.
65. Bellanger AP, Reboux G, Botterel F, Candido C, Roussel S, Rognon B, et al. New evidence of the involvement of *Lichtheimia corymbifera* in farmer's lung disease. Med Mycol. 2010;48(7):981–7.
66. Shah R, Grammer L. Hypersensitivity pneumonitis. In: Mahmoudi M, editor. Challenging cases in pulmonology, 2nd edition. New York: Springer Verlag; 2012. p. 35–44.
67. Braun S, Do Pico G, Tsiatis A, Horvath E, Dickie H, Rankin J. Farmer's lung disease: Long-term clinical and physiologic outcome. Am Rev Respir Dis. 1979;119:185.
68. Gruchow H, Hoffmann R, Marx JJ, Emanuel D, Rimm A. Precipitating antibodies to farmer's lung antigens in a Wisconsin farming population. Am Rev Respir Dis. 1981;124:411–5.
69. Guernsey J. Respiratory disease risk relative to farmer's lung disease antibody status. In: Dosman JA, Cockcroft DW, editors. Principles of Health and Safety in Agriculture. Boca Raton, FL: CRC Press, Inc.; 1989. p. 81–4.
70. Madsen D, Klock L, Wenzel F, Robbins J, Schmidt C. The prevalence of farmer's lung in an agricultural population. Am Rev Respir Dis. 1976;113:171–4.
71. Marx J, Guernsey J, Emanuel D, Merchant J, Morgan D, Kryda M. Cohort studies of immunologic lung disease among Wisconsin dairy farmers. Am J Ind Med. 1990;18(3):263–8.
72. Notkola V, Husman K, Susitaival P, Taattola K. Morbidity and risk factors of Finnish farmers. Scand J Work Environ Health. 1992;18(2):51–4.
73. Gbaguidi-Haore H, Roussel S, Reboux G, Dalphin JC, Piarroux R. Multilevel analysis of the impact of environmental factors and agricultural practices on the concentration in hay of microorganisms responsible for farmer's lung disease. Ann Agric Environ Med. 2009;16(2):219–25.
74. Thorshauge H, Fallesen I, Ostergaard P. Farmer's lung in infants and small children. Allergy. 1989;44:152–5.
75. Kusaka H, Homma Y, Ogasawara H, Munakata M, Tanimura K, Ukita H, et al. Five-year follow-up of *Micropolyspora faeni* antibody in smoking and nonsmoking farmers. Am Rev Respir Dis. 1989;140: 695–9.
76. Warren C. Extrinsic Allergic Alveolitis: A disease commoner in non-smokers. Thorax. 1977;32(5): 567–9.
77. Blanchet M, Israel-Assayeg E, Cormier Y. Inhibitory effect of nicotine on experimental hypersensitivity pneumonitis in vivo and in vitro. Am J Respir Crit Care Med. 2004;169(8):903–9.
78. Lacey J, Lacey M. Spore concentrations in the air of farm buildings. Trans Br Mycol Soc. 1964;47:547.
79. Donham K. Hazardous agents in agricultural dusts and methods of evaluation. Am J Ind Med. 1986;10:205–20.
80. Donham K. Association of environmental contaminants with disease and productivity in swine. Am J Vet Res. 1991;52:1723–30.
81. May J, Pratt D, Stallones L, Morey P. A study of dust generated during silo opening and its physiologic effects on workers. In: Dosman JA, Cockcroft DW, editors. Principles of Health and Safety in Agriculture. Boca Raton, FL: CRC Press, Inc.; 1989. p. 76–7.
82. Organic Dust in Agriculture. General recommendations of the National Board of Occupationaal Safety and Health on organic dust in agriculture. Adopted 15 June 1994. Wageningen: Swedish National Board of Occupational Safety and Health; 1996, 21 pp (accessed 13 December 2015) Available from: http://library.wur.nl/WebQuery/clc/939066
83. Mathisen T, Von Essen S, Wyatt T, Romberger D. Hog barn dust extract augments lymphocyte adhesion to human airway epithelial cells. J Appl Physiol. 2004;96:1738–44.

84. Donham KJ. The concentration of swine production. Effects on swine health, productivity, human health, and the environment. Vet Clin North Am Food Anim Pract. 2000;16(3):559–97.
85. Dosman JA, Chenard L, Rennie DC, Senthilselvan A. Reciprocal association between atopy and respiratory symptoms in fully employed female, but not male, workers in swine operations. J Agromedicine. 2009;14(2):270–6.
86. Kline J, Doekes G, Bonlokke J, Hoffman H, Von Essen S, Zhai R. Working group report 3: Sensitivity to organic dusts – atopy and gene polymorphisms. Am J Ind Med. 2004;46:416–8.
87. Dosman J, Lawson B, Kirychuk S, Cormier Y, Biem J, Koehncke N. Occupational asthma in newly employed workers in intensive swine confinement facilities. Eur Respir J. 2004;24:698–702.
88. Donham K, Cumro D, Reynolds S, Merchant J. Dose-response relationships between occupational aerosol exposures and cross-shift declines of lung function in poultry workers: Recommendations for exposure limits. J Occup Environ Med. 2000;42(3):260–9.
89. Do Pico G. Epidemiologic basis for dose-response criteria. In: Kelly WD, editor. Agricultural Respiratory Hazards Annals of the American Conference of Governmental Industrial Hygienists. Vol. 2. Cincinatti: Governmental Industrial Hygienists; 1982. pp. 189–96.
90. Schwartz DA, Donham KJ, Olenchock SA, Popendorf WJ, Van Fossen DS, Burmeister LF, et al. Determinants of longitudinal changes in spirometric function among swine confinement operators and farmers. Am J Respir Crit Care Med. 1995;151(1): 47–53.
91. Schwartz D, Donham K, Popendorf W, Lassise D, Hunninghake G, Merchant J. Are work shift changes in lung function predictive of underlying lung disease? Am Rev Respir Dis. 1990;141:A 593.
92. Rylander R, Essle N, Donham K. Bronchial hyperreactivities among pig and dairy farmers. Am J Ind Med. 1990;17:66–9.
93. Szczyrek M, Krawczyk P, Milanowski J, Jastrzebska I, Zwolak A, Daniluk J. Chronic obstructive pulmonary disease in farmers and agricultural workers – an overview. Ann Agric Environ Med. 2011;18(2):310–3.
94. O'Shaughnessy. P P, T., Donham, K., Taylor, C., Altmaier, R., Kelly, K. Assessment of swine worker exposures to dust and endotoxin during hog load-out and power washing. Ann Occup Hyg. 2012;doi: 10.1093/annhyg/mes013.
95. Wouters I, Sigsgaard T, Gora A, Nowak D, Palmberg L, Sundblad B-M, et al. Working group report 1: Tools for the diagnosis of organic dusts-induced disease. Am J Ind Med. 2004;46:410–3.
96. Rask-Andersen A. Organic dust toxic syndrome among farmers. Br J Ind Med. 1989;46:233–8.
97. O'Sullivan A, Sheffrin S. Economics: principles in action. Upper Saddle River, NJ: Prentice Hall; 2005.
98. Reynolds S, Donham K, Whitten P, Merchant J, Burmeister L, Popendorf W. Longitudinal evaluation of dose-response relationships for environmental exposures and pulmonary function in swine production workers. Am J Ind Med. 1996;29(33–40).
99. Donham K, Reynolds S, Whitten P, Merchant J, Burmeister L, Popendorf W. Respiratory dysfunction in swine production facility workers: Dose-response relationships of environmental exposures and pulmonary function. Am J Ind Med. 1995; 27(3): 405–18,.
100. Siegel P, Shahan T, Sorenson W. Analysis of environmental histamine from agricultural dust. Scand J Work Environ Health. 1992;18(2):60–2.
101. Donham K, Gustafson K. Human occupational hazards from swine confinement. Ann Am Conf Government Ind Hygienists. 1982;2:137–42.
102. Donham K. Respiratory disease hazards to workers in livestock and poultry confinement structures. Semin Respir Infect. 1993;14(1):49–59.
103. Nilsson C. Dust investigations in pig houses. In: Hg H, editor. Proceedings of the International Society of Animal Hygiene. Hanover: University of Hanover; 1984. p. 31–7.
104. Donham K, Yeggy J, Dague R. Chemical and physical parameters of liquid manure from swine confinement facilities: Health implications for workers, swine, and environment. Agric Wastes. 1985;14: 97–113.
105. Donham K, Knapp L, Monson R, Gustafson K. Acute toxic exposure to gases from liquid manure. J Occup Med. 1982;24:142–5.
106. Sigurdarson S, O'Shaughnessy P, Watt J, Kline J. Experimental human exposure to inhaled grain dust and ammonia: Towards a model of concentrated animal feeding operations. Am J Ind Med. 2004; 46:345–8.
107. Donham K, Reynolds S, Whitten P, Merchant J, Burmeister L, Popendorf W. Respiratory dysfunction in swine production facility workers: Dose-response relationships of environmental exposures and pulmonary function. Am J Ind Med. 1995;27:405–18.
108. Donham K, Carsons T, Adrian B. Carboxyhemoglobin values in swine relative to carbon monoxide exposure: Guidelines to monitor for animal and human health hazards in swine buildings. Am J Vet Res. 1982;5:813–6.
109. Donham K, Yeggy J, Dague R. Health implications for workers and animals in swine buildings. Biol Wastes. 1988:161–73.

110. Donham K, Rubino M, Thedell T, Kammermeyer J. Potential health hazards of workers in swine confinement buildings. J Occup Med. 1977;19: 383–7.
111. Osbern L, Crapo R. Dung lung: A report of toxic exposure to liquid manure. Ann Intern Med. 1981;95:312–4.
112. Holness D, O'Blenis E, Sass-Kortsak A, Deliger C, Nethercott J. Respiratory effects and dust exposures in hog confinement farming. Am J Ind Med. 1987;11:571–80.
113. Donham K. Health effects from work in swine confinement buildings. Am J Ind Med. 1990;17: 17–25.
114. Donham K, Haglind P, Peterson Y, Rylander R, Belin L. Environmental and health studies of workers in Swedish swine buildings. Br J Ind Med. 1989;46:31–7.
115. Monso E, Riu E, Radon K, Margarolas R, Danuser B, Iversen M, et al. Chronic obstructive pulmonary disease in never-smoking animal farmers working inside confinement buildings. Am J Ind Med. 2004;46:357–62.
116. Thedell T, Mull J, Olenchock S. A brief report of Gram-negative bacterial endotoxin levels in airborne and settled dusts in animal confinement buildings. Am J Ind Med. 1980;1:3–7.
117. Donham K, Zavala D, Merchant J. Acute effects of the work environment on pulmonary functions of swine confinement workers. Am J Ind Med. 1984;5:367–76.
118. Andersen C, Von Essen S, Smith L, Spencer J, Jolie R, Donham K. Respiratory symptoms and airway obstruction in swine veterinarians; a persistent problem. Am J Ind Med. 2004;46:386–92.
119. Donham K, Zejda J. Lung dysfunction in animal confinement workers – Chairman's report to the Scientific Committee of the Third International Symposium: Issues in health, safety, and agriculture, held in Saskatoon, Saskatchewan, Canada. Pol J Occup Med Environ Health. 1992;5(3): 277–9.
120. Mustajabegovic J, Zuskin E, Schachter E, Kern J, Vrcic-Keglevic M, Vitale K, et al. Respiratory findings in livestock farm workers. J Occup Environ Med. 2001;43(6):576–84.
121. Thelin A, Tegler O, Rylander R. Lung reactions during poultry handling related to dust and bacterial endotoxin levels. Eur J Respir Dis. 1984; 65:266–91.
122. Donham KJ. Association of environmental air contaminants with disease and productivity in swine. Am J Vet Res. 1991;52(10):1723–30.
123. Donham K, Haglind P, Peterson Y, Rylander R, Belin L. Environmental and health studies of farm workers in Swedish swine confinement buildings. Br J Ind Med. 1989;46(1):31–7.
124. Prior C, Falk M, Frank A. Longitudinal changes of sensitization to farming-related antigens among young farmers. Respiration. 2001;68(1):46–50.
125. Eckert J. Epidemiology of *Echinococcus multilocularis* and *E. granulosis* in Central Europe. Parasitologia. 1997;39(4):337–44.
126. Heederik D, Brouwer R, Biersteker K, Boleij J. Relationship of airborne endotoxin and bacteria levels in pig farms with the lung function and respiratory symptoms of farmers. Int Arch Occup Environ Health. 1991;62:595–601.
127. Prior C, Falk M, Frank A. Longitudinal changes of sensitization to farming-related antigens among young farmers. Respiration. 2001;68(1):46–50.
128. Rylander R, Essle N, Donham KJ. Bronchial hyperreactivity among pig and dairy farmers. Am J Ind Med. 1990;17(1):66–9.
129. Pederson B, Iversen M, Dahl R. Bronchoalveolar lavage of pig farmers. Am J Ind Med. 1990;17: 118–9.
130. Bar-Sela S, Teichtahl H, Lutsky I. Occupational asthma in poultry workers. J Allergy Clin Immunol. 1984;73(2):271–5.
131. Reynolds SJ, Donham KJ, Whitten P, Merchant JA, Burmeister LF, Popendorf WJ. Longitudinal evaluation of dose-response relationships for environmental exposures and pulmonary function in swine production workers. Am J Ind Med. 1996;29(1): 33–40.
132. Kirychuk SP, Senthilselvan A, Dosman JA, Juorio V, Feddes JJ, Willson P, et al. Respiratory symptoms and lung function in poultry confinement workers in Western Canada. Can Respir J. 2003;10(7): 375–80.
133. Senthilselvan A, Dosman J, Kirychuk S, Barber E, Rhodes C, Zhang Y. Accelerated lung function dectline in swine confinement workers. Chest. 1997;111:1733–41.
134. Schwartz DA, Donham KJ, Olenchock SA, Popendorf WJ, Van Fossen DS, Burmeister LF, Merchant JA. Determinants of longitudinal changes in spirometric function among swine confinement operators and farmers. Am J Respir Crit Care Med. 1995;151:47–53.
135. Djuricic S, Zlatkovic M, Babic D, Gligorijevic D, Dlamenac P. Sputumcytopathological finding in pig farmers. Pathol Res Pract. 2001;197(3):145–55.
136. Donham K, Zavala D, Merchant J. Respiratory symptoms and lung function among workers in swine confinement buildings: A cross-sectional epidemiological study. Arch Environ Health. 1984;39: 96–100.

137. Chenard L, Senthilselvan A, Grover VK, Kirychuk SP, Lawson JA, Hurst TS, et al. Lung function and farm size predict healthy worker effect in swine farmers. Chest. 2007;131(1):245–54.
138. Horvath E, Do Pico G, Barbee R, Dickie H. Nitrogen dioxide-induced pulmonary disease, five new causes and a review of the literature. J Occup Med. 1978;20:103–10.
139. Fleetham J, Munt P, Tunnicliffe B. Silo-filler's disease. CMA Journal. 1978;119:482–3.
140. Douglas W, Hepper NG, Colby TV. Silo-filler's disease. Mayo Clin Proc. 1989;64:291–304.
141. Centers for Disease Control. Silo filler's disease in rural New York. Morbidity Mortality Weekly Report. 1982;31:389–91.
142. Zwemer FJ, Pratt D, May J. Silo filler's disease in New York state. Am Rev Respir Dis. 1992; 146:650–3.
143. Maurer W. Silo-filler's disease: A historical perspective and report of a case. Wis Med J. 1985;84: 13–6.
144. Epler G. Silo-filler's disease: A new perspective. Mayo Clin Proc. 1989;64:368–70.
145. Stepanek J, Capizzi S, Edell E. Case in point. Silo filler's lung. Hosp Pract. 1998;33:70.
146. Muller-Wening D, Repp H. Investigation on the protective value of breathing masks in farmer's lung using an inhalation provocation test. Chest. 1989;95:100–5.
147. Safer access to pesticides: community intervention. World Health Organization; 2006 (accessed 14 June 2014). Available from: http://www.who.int/mental_health/prevention/suicide/pesticides_safer_access.pdf.
148. Davies S. Histoplasmosis: Update 1989. Semin Respir Infect. 1990;5(2):93–104.
149. Bertolote JM, Fleischmann A, Eddleston M, Gunnell D. Deaths from pesticide poisoning: a global response. Br J Psychiatry. 2006;189:201–3.
150. Donham K. Challenges to occupational and community health and the environment in animal production. In: Aland A, Banhazi T, editors. Livestock housing: modern management to ensure optimal health and welfare of farm animals. Wageningen: Wageningen Academic; 2013. 496 p.
151. Popendorf W, Merchant JA, Leonard S, Burmeister LF, Olenchock SA. Respirator protection and acceptability among agricultural workers. App Occ Env Hygiene. 1995;10(7):595–605.
152. DDT – a brief history and status. Washington, DC: US Environmental Protection Agency; 2014 (updated 30 May 2014; accessed 14 June 2014). Available from: http://www.epa.gov/ingredients-used-pesticide-products/ddt-brief-history-and-status.
153. Greskevitch M, Kullman G, Bang KM, Mazurek JM. Respiratory disease in agricultural workers: Mortality and morbidity statistics. J Agromedicine. 2008;12(3):5–10.
154. Greskevitch M, Doney B, Groce D, Syamlal G, Bang KM. Respirator use and practices in agricultural crop production establishments. J Agromedicine. 2008;12(3):25–31.
155. National Pesticide Information Center home page; 2014 (accessed 14 June 2014). Available from: http://npic.orst.edu/index.html.
156. Dosman J, Senthilselvan A, Kirychuk S, Lemay S, Barber E, Willson P, et al. Positive human health effects of wearing a respirator in a swine barn. Chest. 2000;118:852–60.
157. Palmberg L, Larsson B-M, Sundblad B-M, Larsson K. Partial protection by respirators on airways responses following exposure in a swine house. Am J Ind Med. 2004;46:363–70.
158. Leblanc P, Belanger J, Laviolette M, Cormier Y. Relationship among antigen contact, alveolitis, and clinical status in farmer's lung disease. Arch Int Med. 1986;146(1):153–7.

CHAPTER

4

Agricultural Skin Diseases

Kelley J. Donham and Anders Thelin

Reviewer: Christopher J. Arpey

4.1 Introduction

Agricultural workers as well as other rural residents frequently come into contact with agents capable of causing skin diseases. The principal agents of skin disease in the agricultural environment are plants, insects, pesticides, sunlight, heat, and infectious agents (1). The weight of evidence in the peer-reviewed literature indicates that skin disorders are the most common occupational health concern of farmers and farm workers, but they are not the most common disabling condition. A group of European dermatologists have reviewed available surveys that have reported yearly prevalence rates of hand and arm dermatoses varying from 8% to 37% of farmers (2, 3). The Farm Family Survey study in the United States (383 males and 265 females) revealed an overall incidence of contact dermatitis of 10% in men and 14% in women (4). The available incidence surveys of occupational skin diseases among farmers are varied in quality, sensitivity, and specificity. Recognizing the need to have better, more standardized data, a group of European dermatologists developed the Nordic Occupational Skin Questionnaire (2). Use of this instrument (available in English and several other European languages) provides a clear and comparable picture of skin conditions among differing populations.

In a California study, the highest rates of occupational skin diseases were found in farm workers relative to comparison populations (5). Several surveys of North Carolina farm workers revealed a prevalence of skin conditions generally, ranging from 12% to 100% of surveyed populations, with 15% reporting hand dermatoses (6–8). Furthermore, 34% of a cohort of North Carolina farm workers reported symptoms of dermatitis at the end of the growing season (9).

Farm and rural-associated skin diseases can be classified into five major categories:

1. contact dermatitis
2. infectious dermatitis
3. arthropod-induced dermatitis
4. sun-induced skin conditions
5. skin disorders related to heat, cold, and humidity.

This chapter describes the type of conditions, diagnosis, treatment and prevention of skin diseases in each of these five categories.

Agricultural Medicine: Rural Occupational and Environmental Health, Safety, and Prevention, Second Edition.
Kelley J. Donham and Anders Thelin.

4.2 Contact Dermatitis

Contact dermatitis is by far the most common type of occupational dermatitis, especially in agricultural and rural settings. Contact dermatitis can be divided into the following categories:

1. irritant contact dermatitis
2. allergic contact dermatitis
3. photoirritant contact dermatitis
4. photoallergic contact dermatitis.

Of the different forms of contact dermatitis, irritant contact dermatitis is the most common in agricultural occupational settings, distantly followed by allergic contact dermatitis and photocontact (irritant or allergic) dermatitis.

4.3 Clinical Picture of Contact Dermatitis

Irritant contact dermatitis may be divided into two types: acute and chronic or delayed. Acute irritant contact dermatitis results from a single contact with a strong substance, causing a reaction similar to a burn. Erythema, blistering, and ulceration occur soon after contact. Most irritant contact dermatitis, however, is chronic or delayed after prolonged or repeated contacts. Erythema, increasing dryness, and thickening as well as patchy hyperkeratosis are frequent characteristics. Itching and painful fissuring are also common symptoms. There is large individual variation in the clinical picture. Contact with oil or grease may result in a pustular irritant dermatitis with acneiform (acne-like) characteristics. Repeated rubbing may result in a thickened psoriasis condition known as lichen simplex chronicus (thickening of the skin inflamed and exacerbated by chronic scratching). Polyhalogenated biphenyls, dioxin, and related chemicals may induce chloracne (a condition with multiple black-headed pimples).

Allergic contact dermatitis may appear immediately (acute) or after some time (delayed or chronic). In the acute form lesions appear within minutes or a few hours following exposure. Acute allergic contact dermatitis often begins with an erythematous (red and inflamed appearing) rash. Papule-formation and blistering is common. Itching is always a prominent symptom. Swelling and reddening may be a prominent sign. If this reaction occurs in the hands, severe swelling may impair circulation and nerve supply, creating a medical emergency. Corticosteroids and osmotic diuretics (e.g., IV mannitol) therapy may be necessary to preserve tissues and digits.

Delayed or chronic allergic contact dermatitis (more common than acute form) results from continued exposures to an allergen over days or months. Lesions may appear similar to non-allergic contact dermatitis.

Besides the hands, another common location for allergic contact dermatitis is in the periocular region (around the eyes), where airborne particulates may accumulate from burning crops or aerosolized plant material (e.g., rhus plants, i.e., poison ivy). Symptoms include redness and swelling around the eyes, and if severe, lesions may include larger areas of the face. Rhus dermatitis is covered in more detail later in this chapter.

It is often impossible to separate chronic allergic contact dermatitis from irritant contact dermatitis based only on the clinical presentation. A detailed occupational history can be very helpful in diagnosis, but a definitive diagnosis of allergic contact dermatitis must be done using patch or prick testing.

Photoirritant or photoallergic contact dermatitis results following skin contact with certain agents which when exposed to sunlight change chemical form to an irritant or allergen. The clinical appearance of these forms is similar to that of other irritant or allergenic forms of dermatitis, but has a pattern of appearance only on sun-exposed areas of the skin.

4.4 Epidemiology and Risk Factors of Contact Dermatitis

The risk factors and agents for occupational skin diseases are varied. Hand labor, which is particularly common among migrant and seasonal workers, results in close direct contact with plants, which may contain irritants or allergens, chemicals used in production, and livestock; all these create an increased risk for contact dermatitis. Reports from Finland point to cow dander, disinfectants and detergents, wet and dirty work, and rubber materials (e.g., rubber gloves and boots) as the main agents of farmers' occupational hand eczema (10). Additional risk factors include wearing wet clothes and shoes during work, wearing rain coats (for protection) when applying pesticides or harvesting tobacco, working with pesticides, sun exposure, harvesting vegetable crops without gloves, and poor (unsanitary) housing (7, 8). Atopy (biologic process of allergies) results in up to a four-fold risk of allergic contact dermatitis in farmers and agricultural workers. In one study 45% of atopic women reported hand dermatitis (10). Respiratory allergies are predictors for allergic skin conditions, for example farmers with symptoms of allergic rhinitis have a higher risk for contact dermatitis compared to those without respiratory allergy (11, 12).

4.5 Agents causing Contact Dermatitis in Agricultural Settings

4.5.1 Pesticide-induced Dermatitis

Although most contact dermatitis is of the irritant type, a few herbicides and fungicides are sensitizers that can cause allergic contact dermatitis. The most common herbicides that are sensitizers are those of the chlorinated acetanilide class, such as propachlor (tradename Ramrod, Bexton) or alachlor. The herbicide maleic hydrazide is a sensitizer used in many herbicides, among other applications. Thiram is a sulfur-based sensitizing compound used in many applications, including fungicides, miticides, bactericides, animal- and insect-repellent insecticides, rubber additives, soaps, shampoos paints, and putty. Several fungicide products are also known sensitizers. Products containing formaldehyde, beta-naphthol, guanidines, captan, captafol, and imidazole derivatives may act as sensitizers.

Insecticide-induced allergic contact dermatitis can be caused by several products, including carbaryl (a carbamate insecticide) and proparagite, a sulfur-based compound used to kill mites on orchard and a variety of other crops. Pyrethrum is a sensitizer commonly used in many household insect sprays and powders. A pyrethrum-sensitive individual may also develop sensitivities to chrysanthemums, shasta daisies, ragweed, and other members of the daisy family because they all contain oleoresins similar to pyrethrum. Furthermore, these sensitive people may also react to a number of the synthetic pyrethrums (pyrethroids) that now dominate the insecticide market. Table 4.1 provides a list of the most common skin sensitizers that may be agent of allergic contact dermatitis in farmers.

Table 4.1 Common agricultural chemicals that are skin sensitizers for agricultural workers

Insecticides	Herbicides	Fungicides	Biocicide/ fumigant	Antibiotics	Dusts and animal dander
Carbaryl (a carbamate) Thiram Pyrethrum (and pyrethrum-containing flowers, e.g. chrysanthemum, shasta daisy, ragweed, and other flowers in the daisy family) Pyrethroids (synthetic pyrethrum) Phenothiazine Proparagite (a sulfur-containing insecticide)	Thiram Chlorinated acetanilides • Propachlor (tradename Ramrod, Bexton) • Alachlor Maleic hydrazide	Thiram Captan Captafol Imidazoles Beta-naphthol Guanidines Formaldehyde	Formaldehyde	Penecillin Spectinomycin Sulfa drugs Iodine	Cattle dander Grain dust Hay dust

Although contact dermatitis is the most common type of dermatitis associated with pesticides, several more conditions have been reported as a result of chronic handling of pesticides, including urticaria (hives, short-lived multiple red raised itchy bumps on the skin), erythema multiforme (multiple red papules more permanent than hives), ashy dermatosis (diffuse bluish-gray skin plaques), parakeratosis variegata, (multiple bizarre-patterned papules), prophyria cutanea tarda (a blood disorder that results in deposits of dysfunctional blood products in the skin), chloracne (blackhead pimples), hypopigmentation (loss of skin color), and nail and hair disorders. Inorganic arsenical pesticides are known causes of skin cancers including carcinoma in situ, and basal and squamous cell carcinomas. Different preparations of these chemicals were once commonly used as insecticides, herbicides, and fungicides. However, by the 1960s inorganic pesticides had been removed from the market in most developed countries because of their toxicity. Organic arsenicals have replaced inorganic arsenicals. They are much less toxic and have not been linked to skin or other cancers (13). There are several less common occupational skin conditions of farmers that are not discussed in this chapter but are summarized in Table 4.2.

4.5.2 Other Chemicals Related to Dermatitis

Many substances besides pesticides can cause contact dermatitis, including antibiotics, vaccines, bacterins, biocides, disinfectants, petroleum-based fuels and solvents (Table 4.1). As new chemicals come into frequent use and others fall out of use, a rural healthcare provider must keep up to date with the products currently in use by their farmer

Table 4.2 Uncommon skin conditions of agricultural workers associated with pesticide contact (Spiewak 2001)

Condition	Description	Exposure
Urticaria	Elevated reddened areas, also called wheal and flare reaction	Fungicides: captan, chlorothalonil Insect repellants: diethyltoluamide
Erythema mutiforme	Concentric rings, "bulls eye" eruptions on the skin	Organophosphate insecticides: Methyl parathion, Dimethoate
Ashy dermatitis	Ashen-colored eruptions (macules) on the skin of varying size Also called erythema dyschromicum perstans	Fungicide: chlorothalonil
Parakerratosis vaiegata	Early ashy dermatoses appearance, progresses to entire skin and poikiloderma (skin atrophy with speckled like discoloration)	Undermined pesticide and fertilizer contact
Porphyria cutanea tarda	A skin photosensitivity with large blisters, scarring, excess pigmentation, skin thickening, and hair loss	Herbicides: 2,4-D and 2,4,5-T
Chloracne	Very severe and chronic acne	Herbicides: those chemicals with chlorinated polycyclic aromatics: 2,4-D, 2,4,5-T, pentachlorophenol, propanil, dichloroaniline, methazole It is probably the dioxin contaminate in the manufacture of these compounds that is harmful
Skin hypopigmentation	Light-colored areas on the skin	Carbamate insecticides: (unspecified)
Nail disorders	Yellowed, brittle, altered growth of the nails	Herbicides: paraquat, diquat, dichloronitrocresol
Hair loss		Chlorinated hydrocarbon: DDT
Skin cancer	Mainly squamous cell carcinoma	Herbicides: paraquat, arsenicals

patients and their potential health hazards. Furthermore, the rural health or safety practitioner should also maintain a knowledge base of regional work practices so that an appropriate occupational history may be obtained, facilitating diagnoses.

Some of the substances currently in use and potentially hazardous to the skin are discussed below.

Antibiotics can cause both irritant and allergic contact dermatitis. Tetracyclines are common feed additive antibiotics for swine, poultry, and cattle. Humans treated with tetracyclines are known to be more sensitive to sunlight on exposed skin. Inhalation of feed dust that contains tetracycline or the parasiticide piperazine may create sufficient systemic levels that photoirritant contact dermatitis may develop on sun-exposed skin surfaces (14).

Tars (e.g., creosote, a wood preservative used for fence posts, fence boards etc.) can cause photocontact dermatitis as well as irritant contact dermatitis.

Fertilizers contain irritant substances including nitrogen and phosphate compounds, and sometimes cobalt and nickel. Anhydrous ammonia is a nitrogen fertilizer that is stored under pressure, and is very cold, hydroscopic, and caustic. Not only is it a risk for respiratory and eye damage (see Chapter 3), it is also a common cause of severe chemical burns to the skin (15, 16).

Dairy farmers are frequently in contact with chemicals associated with rubber or synthetic rubber products (e.g., hoses to, or the lining of of, milking machinery, rubber gloves). Delayed or chronic allergy to rubber chemicals has been found among dairy farmers with eczema (17, 18). Other chemicals used on dairy farms include acids and alkali cleaning products for the milking equipment, chorine (bleach), and iodine teat dips, all of which can cause severe irritation to the skin (19, 20)

Oils and fuels are common causes of skin problems. Oil acne or oil folliculitis results from exposure to oil, especially under oil-soaked clothing. Farmers are exposed when fueling their tractors and other self-propelled equipment with gasoline or diesel fuel. Also, as farmers commonly do mechanical work on their equipment, they often are exposed to petroleum product solvents when cleaning and lubricating parts and machines. As skin conditions from these exposures occur often, farmers may not seek treatment from a health professional and therefore the frequency of these conditions is difficult to ascertain. As most workers know the sources of some of these conditions, they know that with better hygiene the conditions improve.

4.5.3 Animal-related Skin Dermatitis

Several reports from Finland indicate that sensitivity to cow dander creates a significant risk for immediate or delayed allergic contact hand dermatitis among dairy farmers (3). Eighteen per cent of women and 7% of men in a Finnish dairy farming region reported hand dermatitis within the past year (3). Risk factors included previous history of atopic dermatitis (four-fold) and respiratory atopy (two-fold). Skin tests among Finnish farmers revealed that 30% were positive for cow dander by either prick or patch testing. Other positive skin tests included animal feeds, rubber and rubber gloves, and udder ointments. A 12-year follow-up revealed 50% of the patients first diagnosed with hand dermatitis were still having problems, suggesting this is an important chronic condition that is difficult to control (10).

4.5.4 Plant-induced Contact Dermatitis

Several cultivated vegetable crops and several wild plants in rural areas and on farmland can cause irritant contact dermatitis and/or allergic contact dermatitis.

Plants Causing Allergic Contact Dermatitis

The most frequent and perhaps the most severe allergic contact dermatitis reactions are caused by wild plants growing in nature. Plants of the Anacardiaceae family, genus Toxicodendron (formerly rhus genus) are perhaps the most common of those plants causing dermatitis in rural and farm populations. These plants include poison ivy, poison oak, and poison sumac. The Toxicodendron plants shares the characteristics of bearing groups of whitish berries (21). The sap of these plants contains an oily substance, urushiol, which can cause a classic delayed allergic contact dermatitis. Urushiol, a pentadecylcatechol, is one of the most potent allergenic substances known, capable of inducing cell-mediated hypersensitivity in 70% of exposed persons (22). Contact with the sap from rhus plants (poison ivy, poison oak, and poison sumac) commonly results in an erythematous, edematous, very pruritic rash. The allergen, urushiol, absorbs into the skin in about 20 minutes. Once urushiol is absorbed into the skin, rubbing or scratching will not spread the lesions. Lesions begin to appear from 1 to 7 days following exposure. The lesions often continue to develop for several days. Vesicles may form and rupture, producing serous drainage and crusting. (Serous drainage (and scratching) does not spread the lesions.) This is not a contagious condition as there is no urushiol within the vesicles, only a serous exudate. However, scratching may lead to a secondary infection. The severity of the reaction depends both on the quantity of antigenic sap absorbed into the skin and on the individual's sensitivity. The delay of onset and decreased severity is related to slower and smaller amount of urushiol absorption in areas of skin with a thicker stratum corneum (e.g., palms, dorsal surface of hands and arms) (22).

Urushiol is located in the sap of nearly all parts of the plant, therefore dermatitis from these plants can be contracted when any part of the plant is broken, allowing sap to escape directly onto the skin. The sap from all three plant species maintains its antigenicity for months. If the sap contaminates a fomite (clothing, blanket, dog, etc.), secondary skin contact by a person with that object may result in a skin eruption. Even after the plant has died, the sap remaining in it maintains its antigenicity, therefore a person grubbing rhus plants after they have been killed with a herbicide may acquire urushiol dermatitis (23). Urushiol maintains antigenicity when rhus plants are burned therefore workers exposed to the smoke from burning rhus plants may develop a diffuse dermatitis on unprotected skin (see Figure 4.1).

Most commonly, the pattern of the skin lesions has a linear or streaked configuration. This is because as the person moves through an area with rhus plants, the broken component of the plant exudes urushiol, which is dragged across the skin in a linear pattern. A more diffuse pattern may appear when the urushiol contaminates the skin secondarily from contaminated fomite

FIGURE 4.1 Rhus allergic contact dermatitis. Left: linear pattern, sub-acute stage. Right: diffuse pattern aerosol exposure from burning brush containing poison ivy plants and wearing no shirt. (*See insert for color representation of the figure.*)

(e.g. clothing, blanket, or pet) or when exposed to the smoke of burning plant material.

Rhus plants have a varying geographic distribution. Poison ivy is by far the most geographically diverse, found in Eastern Asia, the Kurile Islands, and the Sakhalin Islands of Russia. The plant exists in the eastern two-thirds of Canada and the United States below the 44th parallel (21). It grows throughout Mexico and Guatemala, and in some of the Caribbean countries. Poison oak has a more limited distribution toward the west coast of the US. Poison sumac is primarily in the eastern third of the US and Canada from Quebec to Florida, extending west into Texas (21–23).

A much less prevalent plant-induced allergic contact dermatitis is caused by ragweed (Ambrosia species). Ragweed is much more commonly maligned as a cause of allergic rhinitis (or hay fever), caused by the protein component of the pollen. A second allergen in the pollen is an oleoresin (which contains a sesquiterpene lactone) that can cause allergic contact dermatitis from an air-borne exposure. The exposure can produce a diffuse pattern presentation of eruption similar to that caused by poison ivy smoke. It can be differentiated from photocontact dermatitis by the presence of eruptions on shaded areas of skin (as well as sun-exposed skin), such as under the chin and behind the ear lobule. The rash may be accentuated in flexural creases and at the edges of clothing. Ragweed-induced allergic contact dermatitis is present primarily in late summer and fall, often coincident with the season for those affected with allergic rhinitis. Annual recurrences in individuals are recognized, with a tendency to longer lasting episodes. Fortunately, only a small percentage of individuals exposed to ragweed oleoresin will develop allergic contact dermatitis compared to the high risk from poison ivy exposure (14).

A number of domestic food plants have been known to cause allergic contact dermatitis. Table 4.3 lists those that have been incriminated as causative agents. One example is allergic contact dermatitis that may occur in workers who pick and handle asparagus. The allergen appears to be a sulfur-containing growth inhibitor (1,2,3-trithiane-S-carboxylic acid) that is more prominent in the early growing season. The lesions typically occur on the finger tips, but may spread to the whole hand (24–27).

Bulb finger (aka tulip finger) is a chronic irritant and/or chronic allergic contact dermatitis of fingertips that develops in some harvesters, sorters, and packers of tulip, hyacinth, onion, and garlic bulbs. The irritant is thought to be a sesquiterpene lactone present in the bulbs (28). The particular allergen in tulip bulbs is called tuliposide A (29). Patch testing is available to assist in diagnosis of this condition, but there is evidence of chronic irritant contact dermatitis as a component of the condition. Fungicides used to treat bulbs may also confound or exacerbate this problem. Initially, subungual (under fingernails) tissues and fingertips become reddened, inflamed, and painful. Further handling of the bulbs causes a dry, scaly, fissured, erosive, and hyperkeratotic (calloused) dermatitis, possibly with suppuration (pus due to secondary bacterial infections) (29, 30). Figure 4.2 shows a person with bulb finger.

Plants that cause photoirritant (phototoxic) contact dermatitis include vegetables in the family Ubelliferae (carrots, celery, domestic parsnip, fennel, wild parsnip, giant hogweed) and the family Rutaceae (lemon, lime, bergamot, orange, common rue). The common class of agents in these plants is furocumarin, which is present in their juices. When the plant juice comes into contact with the skin, exposure to sunshine modifies the furocoumarin to a very irritant/toxic chemical that can cause a severe skin reaction that resembles a thermal or chemical burn. These chemicals are known as phytophotoirritants and the condition is also known as phytophototoxic contact dermatitis. Plant-induced dermatitis is most likely to affect persons who harvest, pack, and unpack for sale large quantities of cut and wet vegetables. Carrots are most commonly associated with production agricultural exposures. Two wild plant species native to Europe and Asia contain the furocoumarin that also can cause the phytotoxic dermatitis. These plants are an invasive species to North America. Wild parsnip

Table 4.3 Plants and their offending substances that can cause allergic contact dermatitis (11, 25)

Plants causing allergic contact dermatitis	Offending plant chemicals
Bulbs of tulips, hyacinths, and other flowering bulbs	Tuliposide A (allergin in tulip bulbs), sesquiterpene lactone (irritant)
Carrots	Furocoumarins
Domestic parsnip	Furocoumarins
Wild parsnip	Furocoumarins
Cow parsnip, giant hog weed (*Heracleum mantegazzianum*)	Furocoumarins
Poison ivy, poison oak, poison sumac (plants of the Anacardiaceae family)	Urushiol
Ragweed	Sesquiterpene lactone
Asparagus	1,2,3-Trithiane-s-carboxylic acid
Cucumber	Dibromodicyanobutane
Tomato	Dibromodicyanobutane
Zuchini	Dibromodicyanobutane
Potatoes	NK
Garlic	NK
Leek	NK
Mustard	NK
Kiwi fruit	NK
Mangoes	Pentadectylcatechols
Cashew nuts	Pentadectylcatechols
Pecan	NK
Olive oil	NK
Rice	NK

NK, not known.
Source: http://tigmor.com/food/library/articles/contact.htm.

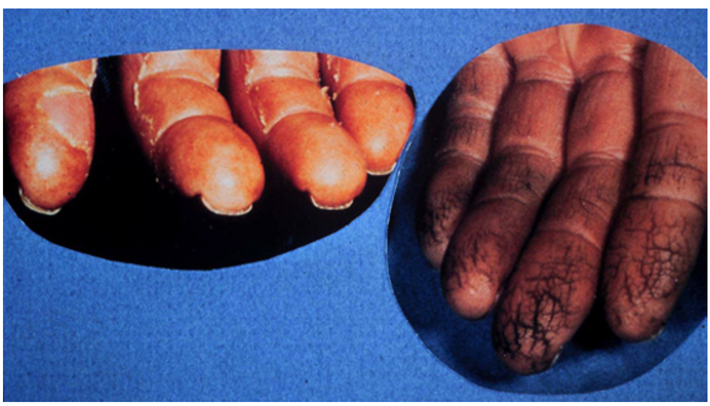


FIGURE 4.2 Bulb finger: allergic and or chronic contact dermatitis. The allergen is tulipan A and the irritant is butyrolactone. (*See insert for color representation of the figure.*)

(*Pastinaca sativa*) is an extremely common foreign invasive plant found on pasture land, road ditches, and almost anywhere that is not intensely cultivated. The second plant, *Heracleum mantegazzianum* (giant hogweed, giant cow parsnip), found in pastureland and wetland, can also cause a phototoxic reaction in combination with sunshine.

Phytophototoxic dermatitis initially presents with blisters, which then rupture, becoming erosive lesions over the course of 7–10 days. They slowly heal, leaving a hyperpigmentation that commonly has a bizarre streaked pattern that persists for months. This streaked pattern is due to the agent contacting the skin from the leafy parts of the vegetable (i.e., carrot tops), leaving an imprint of the vegetable foliage. Several less common plants have been incriminated as agents for allergic contact dermatitis. These plants along with the offending substances are summarized in Table. 4.3. Phytophototoxic dermatitis from harvesting carrots and celery is shown in Figure 4.3 and from contact with wild parsnip in Figure 4.4.

In addition to direct contact with sap from plants, occasionally airborne exposure to dust from plants can result in contact dermatitis. An example of such a case was reported in a 57-year-old female hop plantation worker (11). After 30 years' experience working with hops, she developed an eczematous allergic contact dermatitis on her hands. Additionally, she developed erythema of the neck, edema of the lids, and conjunctiva, typically beginning after 30 minutes of aerosol exposure to fresh dried hops. This second condition persisted for 48–72 hours after removal from the environment. The woman had to quit working with hops, but the allergic reaction remained, with exacerbations on use of beauty creams and herbal sedatives that contained hops (*Humulus lupulus*). Her husband continued to work with hops. The woman would have exacerbations when sleeping with her husband, as he would have small amount of hops attached to his skin or bed clothes (connubial contact). Improved hygiene and after-work showering by the husband relieved the condition for the woman.

4.5.5 Treatment of Contact Dermatitis

Topical corticosteroids are used to treat most localized forms of irritant contact dermatitis. However, caution should be used as prolonged use of the more potent topical corticosteroids may result in permanent atrophy, striae (steaks of stretch marks), and erythema of the skin. Systemic effects may also occur from absorption of steroids if administered over a wide skin area.

In addition to corticosteroids, standard principles of dermatologic therapy are advised. For acute weeping lesions, recommended treatments include soaks or compresses with physiologic saline or products with astringents and antibacterial qualities such as Burow's solution (aluminum acetate 0.14%). For dry, scaling lesions, cool

FIGURE 4.3 Phytophoto-irritant contact dermatitis may be caused by plants of the Apiaceae family, which includes celery, carrot, and parsnip among others. The juices from these plants contain a furocoumarin that becomes a toxic irritant when exposed to sunlight. (*See insert for color representation of the figure.*)

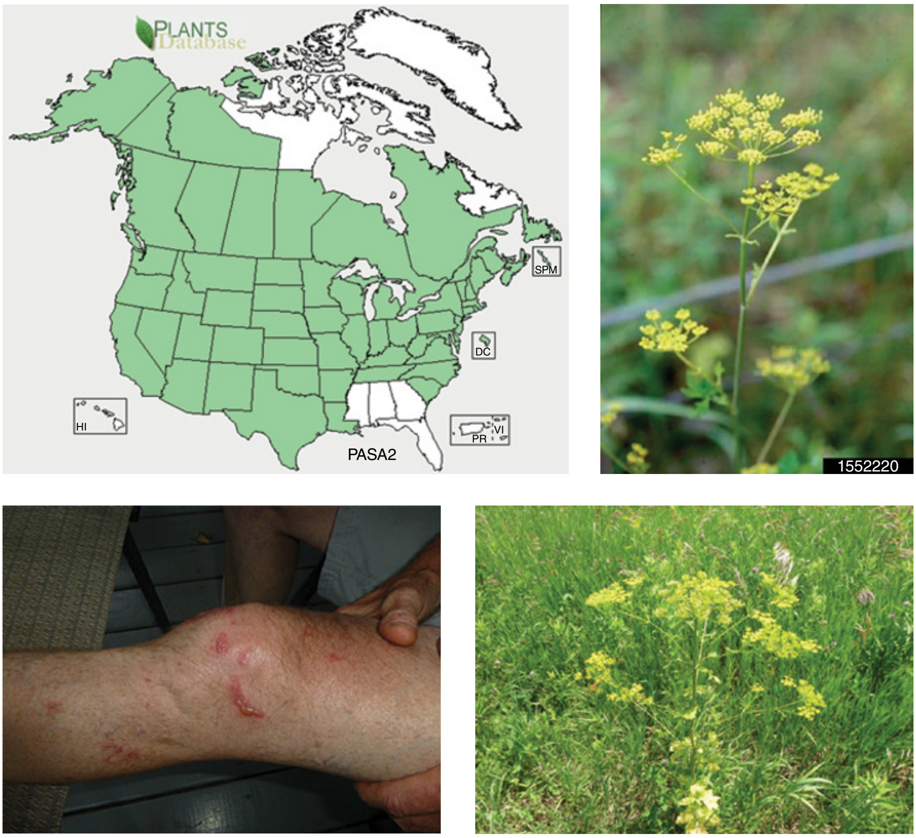


FIGURE 4.4 Wild parsnip (*Pastinaca sativa*) from the Apiaceae family is an invasive species that grows wild throughout most of North America, Canada, and northern Europe. It has a similar furocoumarin to other plants of this family and can cause a severe phytophoto-irritant contact dermatitis, as shown here on a leg. (Source: USDA, http://plants.usda.gov/core/profile?symbol=PASA2.) (*See insert for color representation of the figure.*)

baths or locally applied lotions with moisturizing properties (e.g., colloidal oatmeal) are useful. The latter is also helpful to relieve itching and to moisturize and lubricate the skin.

For widespread or severe cases systemic corticosteroids may be necessary, although the risk of side effects is higher. A 7–10 day taper of systemic corticosteroids may help prevent a "rebound flare" of dermatitis. Tapering topical potent steroids by alternating with less potent or other standard therapies may also be helpful to avoid negative outcomes of steroid use.

Mild rhus dermatitis can be treated symptomatically with compresses, calamine lotion (zinc oxide with 0.5% ferric oxide), potent topical corticosteroid preparations, and orally administered antihistamines. Severe rhus dermatitis is best managed with systemic corticosteroids. For adults, 30–80 mg of prednisone daily, in divided dosages, is appropriate initially. The dose can be reduced by 5 mg per day when vesicles are no longer forming. Antihistamines can help alleviate the itch. Compresses, colloidal baths, and calamine lotion are helpful adjuncts.

For patients in whom topical corticosteroids are contraindicated, two newer agents that are non-steroidal should be considered. Tacrolimus (Protopic® ointment) and pemecrolimus (Elidel® cream) are analogs of cyclosporine. Their mechanism of action is T-cell suppression. These products are FDA approved for this use and generally well-tolerated. However, they are much more expensive than corticosteroids, and their long-term safety and efficacy remain to be determined.

4.5.6 Prevention of Contact Dermatitis

All types of contact dermatitis can be prevented by elimination or reduction of exposure to causative agents. Specific measures include use of protective clothing, changing to clean clothes and gloves when they become contaminated, and washing exposed areas of the skin before meals and at the end of the work day. There are several ways to help prevent or minimize the skin reaction once contact with the agent has occurred. For example, in people who have had contact with the sap of rhus plants (urushiol) washing exposed skin with soap and water within 30 minutes of contact will eliminate or at least decrease the extent and severity of the subsequent dermatitis.

Nitrile protective gloves are recommended for direct handling of bulbs and other vegetables as evidence suggests some of the plant allergens can penetrate vinyl gloves (31). Agricultural workers should read and follow label directions on the package when applying pesticides, fertilizers, and other agricultural chemicals. Furthermore, barrier creams on hands and exposed skin may prevent or decrease the amount of absorption of irritant or allergenic substances. As there are different barrier creams produced for protection from different classes of substances, choosing the wrong product may lead to a false sense of security. For example, barrier creams produced for protection from urushiol contain octylphenoxypolyethoxyethanol in propylene glycol or 5% quanternium-18 bentonite (the respective trade names are Oak Ivy and Ivy Block). These products may not necessarily protect from wetness or solvents.

Poison ivy and related sensitizing plants can be eliminated by pulling the plants out by their roots (grubbing). Grubbing should be done using proper precautions such as wearing rubber (preferably nitrile) gloves and protective clothing that is washed after use. Mowing and cutting of plants should not be attempted since these actions encourage plant stem proliferation from the remaining roots. These plants also can be eliminated by the use of herbicides. The broad-spectrum herbicide glyphosate (one trade name is Roundup) works well on these plants. This chemical is applied on the leaves, absorbs into the plant, and kills the whole plant (roots and all) in a matter of days to weeks.

For patients who are extremely sensitive to urushiol or because of their job cannot avoid contact with rhus plants, hypo-sensitization is an option. There are two forms of the antigen used for hypo-sensitization, oral and subdermal injection. Hypo-sensitization provides partial protection at best. It may reduce the symptoms or protect in mild exposures. Oral hypo-sensitization may produce side effects such as pruritus ani because the rhus antigen is not inactivated in the gut and when it reaches the skin on exit of the gastrointestinal system, it can cause perianal rhus dermatitis.

Prevention of phototoxic dermatitis is two-fold. First, keep the sap of the plant from contact with skin. Second, if there is a possibility of skin contact with the sap of these plants, protect the skin from sun exposure for at least 3 days and wash exposed areas and exposed clothing with soap and water.

4.6 Infectious Dermatitis

The three most important and common infectious dermatoses of agricultural workers are zoonotic dermatophytic fungi and two zoonotic viral diseases, contagious ecthyma of sheep and goats (orf) and pseudo cowpox of cattle (milker's nodule). These dermatoses are discussed below. Other less common infectious zoonotic dermatoses include tularemia and anthrax. The latter are covered in Chapter 13.

Dermatophytic fungal infections found on the farm are caused primarily by *Trichophyton* and *Microsporum* species. By far the most common agricultural occupational animal dermatophyte infection in farmers and workers is *Trychophyton verrucosum*. Cattle are the primary host for this species. Other farm animals have their own dermatophytes (primarily *Microsporum* species) that may infect humans. These fungi can be contracted from contact with infected animals or from contaminated objects in the animal environment (e.g., feed bunks, fences etc.).

Classic dermatophytic infections in people present as red scaling lesions with a tendency for central clearing, producing a "bulls eye" type of lesion. Generations ago, people thought this lesion must be caused by a worm under the skin, thus the term "ringworm." However, animal ringworm infections of humans have many different presentations. Generally, animal ringworm infections in humans are more severe than the infection in the host animal. This is probably due to better parasite–host adaptation in the primary host. Some of the consequences of this more aggressive infection can be seen if there is an infection of the hair and skin of the scalp. Infections may extend into the follicles and cause temporary or permanent hair loss may follow. Lesions among dairy farmers may be seen on areas of the body that have close direct or indirect contact with cattle (e.g., arms and upper torso, chin, neck, and head). Lesions on the head and neck area are likely in milkers working in stanchion or tie stall barns as direct contact with the cow or the cow's head restraints is more likely as he or she attaches or removes the restraints or the milking machines from the cow.

Diagnosis of dermatophytic fungi first requires ascertainment of an accurate and detailed occupational history. Definitive diagnosis includes a skin scraping and examination with a UV light. The two main zoonotic genera (*Trychophyton* and *Microsporum*) vary in their ability to produce material that will fluoresce. Positive fluorescence has a presumptive diagnosis, but negative fluorescence is not a negative test. A more definitive test is potassium hydroxide (10–20%) preparation of crust and hair. Microscopic examination of this preparation may reveal fungal elements. To obtain a species-specific diagnosis, a culture of crust and hair from the lesion will be necessary. However, results may take 3–5 weeks for growth and laboratory identification of the organism.

Treatment of dermatophytic fungi ranges from application of topical preparations to systemic therapy, depending on the extent and depth of infection. Topical preparations may be effective if just the keratin layer of skin is infected. Effective topical preparations include iodine solutions or tolnaftate (1%) among others. The topical antifungal agents of the imidazole and allylamine classes (e.g., miconazole (Monistat®), clotrimazole (Lotrimin®), and terbinafine (Lamisil®)) may be the most efficacious pharmaceuticals. Continued topical use for 1 week after clinical symptoms resolve may help prevent relapse.

Infections of the scalp or beard usually involve the hair follicles and topical treatments are not effective. Systemic oral therapy (e.g., grisiofulvin, fluconazole, terbinafine, or itraconizole) for 4 weeks minimum is required in severe cases. Nonspecific measures to reduce inflammation, such as a burst and taper of prednisone, may be helpful for highly inflamed infections, especially those of the scalp, and may help to reduce the severity of the damage to the hair follicles and prevent permanent hair loss (32). Infections of the fingernails or toenails may require particularly long courses of oral therapy during which drug interactions and blood monitoring may be required.

Several animal viruses of the parapox group, including orf, pseudocowpox, and bovine popular stomatitis, can cause skin infections in humans. These are geographically widespread viruses found in many areas of the world. Orf (contagious ecthyma) is one of the most common animal viruses infecting humans. This virus causes a common disease of sheep and goats (contagious ecthyma) and may be transmitted to humans by direct or indirect contact to abraded skin from infected sheep or goats, usually by feeding lambs or baby goats. As the virus survives in the livestock environment for months to years, a contaminated environment (barns, stalls, fences, etc.) where sheep or goats have been kept may remain a source of infection for humans for months or years.

Following an incubation period of about a week, orf lesions typically develop on the backs of hands, fingers, or arms. They begin as one or a few red papules that enlarge to slightly umbilicated nodules, which become hemorrhagic and pustular. The center of the lesion breaks down to produce a red oozing surface with a crust. Differential diagnosis may include squamous cell carcinoma. A punch biopsy, H&E stain, and histologic examination will reveal large (pox) intracellular inclusion bodies. A clean dressing with topical antibiotics will help prevent secondary bacterial infection. Systemic responses, such as regional lymphadenopathy or a mild febrile response, may occur. Lesions of orf resolve spontaneously in about 6 weeks, often with scarring (33).

In North America, a condition called milker's nodules is caused by infection with the pseudocowpox virus, which is a common cause of cowpox in cattle. In cattle this pox virus results in ulcerated lesions on the teats and udders, primarily seen in dairy cattle. It is contagious in the herd, spread by contact with the milkers, be they milking machine or human. Human infections are contracted through direct skin contact with the teats and udders of infected cows. Like orf lesions, milker's nodules resolve spontaneously in about 6 weeks but usually do not scar (34).

In Europe, a different virus (cowpox) of the orthopox group may (rarely today) cause a skin infection in humans. This virus is the one that the English physician Edward Jenner used in 1796 to produce the first vaccine. This crude vaccine was successful in preventing smallpox, leading the way for modern application of public health immunization. Today in the UK and other European countries cats among other species may carry cowpox, and more commonly transmit the virus to humans rather than cattle.

Treatment of either orf or milker's nodules is aimed at controlling secondary bacterial infections. Topical antibiotic ointments and covering with an aseptic dressing are indicated.

4.7 Arthropod-induced Dermatitis

Because agricultural workers spend a great deal of time outdoors, they are exposed to a large variety of arthropods that bite and sting. Arthropods include wasps, bees, and ants (hymenoptera species) as well as a large variety of spiders, mites and ticks (arachnids), mosquitoes and biting flies (Diptera), and caterpillars (Lepidoptera).

Cutaneous responses to most of these arthropod bites vary considerably with the type of toxin in the particular offending arthropod's venom and biological variations among the victims (e.g., the person's degree of sensitization). Some haematophagus arthropods (blood-sucking insects such as mosquitoes, ticks, mites, etc.) inject saliva and anticoagulants as a means to facilitate taking a blood meal. Initially, some bites and stings from haematophagus insects are likely to produce little or no reaction. As a person develops sensitivity, general anaphylactic reactions may be a slight risk, but commonly local inflammatory reactions result, such as erythematous macules, papules, pruritic lesions, or blisters. Finally, after repeated exposure, sensitivity may wane. A good example of this is the often observed welts that children receive from mosquito or chigger bites. This severe reaction is rare in adults.

Other arthropods (e.g., wasps, bees, and ants) have "defensive" toxins that will produce an immediate painful sensation in the victim. Some arthropods possess systemic toxins (e.g., black widow spider and scorpions) and some inject a cytotoxic agent, causing local necrosis (e.g., brown recluse spider). The systemic or cytotoxic reaction seen with spider bites does not necessarily change with immune experience and age of the patient (35).

4.7.1 Hymenoptera Stings (Bees and Wasps)

The most common response to a sting from a hymenoptera species (wasp, bee, ant) is an immediate painful, burning sensation at the site of the sting. This is caused by toxic proteins that are largely enzymes causing local inflammation of the surrounding nerve tissue and soft tissues. One member of the *Hymenoptera* family, *Solenopsis invicta*, ommonly known as the invasive red fire ant (IRFA), is a particular problem in southern states of the US (36, 37). Unintended importation in cargo on ships coming to the port of New Orleans from Argentina in the 1930s, this prolific invasive ant species has spread over eight states from as far east as North and South Carolina and Florida westward covering a band of states ending in eastern Texas. Models based on climate and other ecologic considerations predict the fire ant range to expand north and west to include the western third of California (see Figure 4.5) (38). The fire ant is the most common hymenoptera species causing human suffering in the region. Bites from IRFA cause characteristic lesions consisting of pustules that contain a sterile milky colored fluid. These lesions may last for up to 10 days. The IRFA toxin contains a protein that is probably responsible for an allergic response as well as a cytotoxic alkaloid response causing tissue inflammation and necrosis. Most other hymenoptera stings result in mild discomfort and temporary skin lesions.

By far the most life-threatening response from hymenoptera bites or stings is a systemic allergic reaction. Although upwards of 20% of individuals may have IgE antibodies to hymenoptera toxins, only 1–3% of the population will suffer a serious allergic reaction. However, it is estimated that between 40 and 100 people die every year in the US from hymenoptera stings. The following risk factors and medical history warn of a potential life-threatening anaphylactic response: (1) the person has experienced a known previous systemic response, (2) person developed a large local response to past or current stings and/or systemic symptoms (e.g., hives, general pruritus or burning sensation, swelling of lips and tongue, wheezing, etc.). If this history is present or if any of these symptoms are seen in a person with a current sting, that person should have an on-the-scene dose of epinephrine (as available and on prior medical advice) and be taken to the nearest medical facility. Individuals with the history described above should be medically examined and if so prescribed be equipped with a medical alert tagged bracelet and carry an epinephrine auto-injection device (e.g., EpiPen) (39).

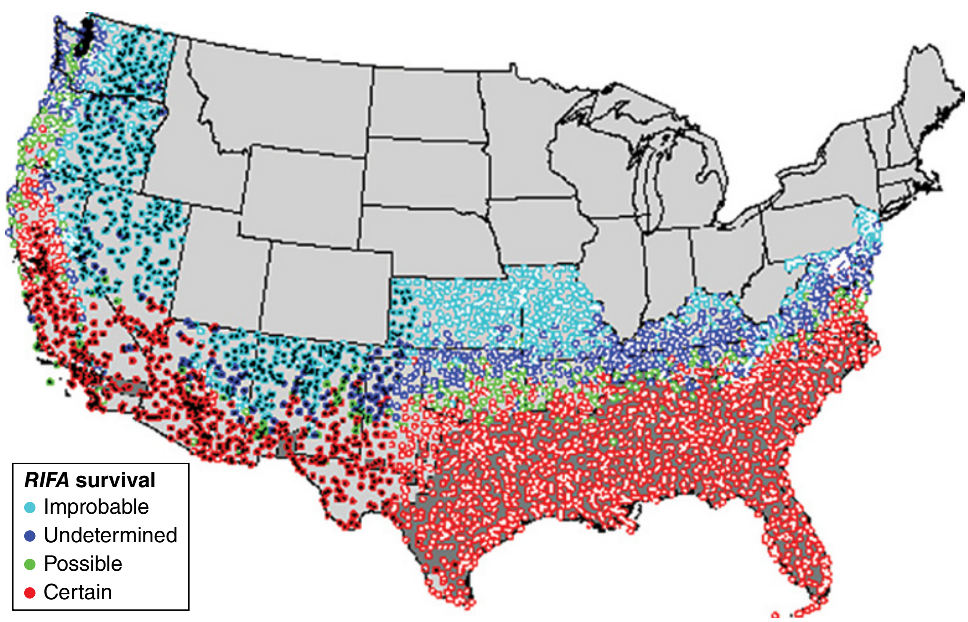


FIGURE 4.5 Potential US range expansion of the invasive fire ant based on climate and other ecologic conditions (Source: USDA, Agricultural Research Service http://www.ars.usda.gov/research/docs.htm?docid=9165. Date last modified 5.10.2006.). (*See insert for color representation of the figure.*)

4.7.2 Arachnids (Mites and Spiders)

Several species of mites cause skin problems in those living and working in rural and agricultural areas, both parasitic mites and free-living mites. Most animals have species-specific parasitic mites, including humans. These mites will complete their life cycle only on their specific host, causing pruritus, hair loss, and scaling of skin in heavy infestations (scabies). The species-specific parasitic life cycle begins with the scabies mite burrowing into the epidermis of its host, where the female lays eggs that hatch out and return to the skin surface, perpetuating the life cycle.

Scabies mites of animals such as pigs, horses, cattle, and dogs may temporarily infest people. However, these mites do not burrow into the epidermis and reproduce in humans as they do in their species-specific host parasitic relationship. They do, however, inflict bites as they feed on their temporary host. They attach by their mouth parts and inject saliva, which enzymatically digests the skin. The larvae feed on digested protein and serous exudate from the host for a few hours to days before falling off. The resulting inflammation of the skin may be accompanied by a serous exudate and an annoying pruritus. The resulting skin lesions are commonly red edematous papules. The distribution and severity of the reaction depends on the mode of exposure and the victim's degree of sensitivity. Lesions vary from normal-appearing areas of pruritus to macules, papules, petechial lesions, vesicles, and even bullae. The location of animal scabies lesions on humans is typically on the hands and forearms where they have direct contact with the infected animals.

A number of free-living mites cause skin lesions in humans. These mites complete their life cycle without an animal host. However, they do like to supplement their diet with a protein meal on occasion. Chigger bites (caused by mites of the family *Trombiculidae*) are caused by probably the most common free-living mite that humans encounter. Although not a cause of serious health consequences, these mites are frequent visitors to the skin of farm people. The larval form of this mite feeds mainly on vegetation, but requires animal protein for complete development. Other free-living mites include grain mites (*Acarus* spp.) and oak mites (*Pyometes* spp.). The former often cause lesions on the hands, typically on the webbing between the fingers, from handling grain without gloves. *Pyometes* mites have a life cycle commonly associated with oak trees, primarily pin oaks in the Midwest, but also red and black oaks. The larval forms of this mite parasitize the larvae of midge flies which live in nodules (galls) about 5 mm in size on the leaves of oak trees. When the midge matures to adult, breaking out of the gall, thousands of immature mites are released to the ground, ready to find an animal (including humans) to take on a protein meal. Similar to chiggers, these mites cause only a temporary infestation, but leave the host with a pruritic, localized, self-limiting rash. A rash from animal- or grain-associated mites commonly affects the hands and arms, where the patient has contacted the source. Chiggers and oak mites appear commonly under clothing on the torso.

4.7.3 Spiders

Three types of spiders can cause skin conditions and some may cause systemic reactions. The brown recluse spider (*Latrodectus geometricus*) is present in most of the western hemisphere. The venom of this spider is primarily an enzymatic cytotoxin. A bite from this spider will not cause immediate pain, but will cause pain in 2–6 hours. The area at the site and surrounding the bite will begin to turn purple to black in a few days and progress to local or regional areas of skin necrosis. The skin may take 3 months or more to heal, depending on the location and size of the area of necrosis, and there may be scarring.

Widow spiders are present in most areas of the western hemisphere, Europe, and some areas of Asia and Africa. Species in this group of spiders are mostly black, but can also be brown, red, or other colors. Common to this group of spiders is an hourglass figure on the ventral surfaces of their abdomen. The black widow spider (*Latrocedtus onactans*) is perhaps the most common and well-known spider of this group. Only the female will bite, injecting its combined enzymatic and neurotoxic venom, called alpha-latrotoxin. This toxin opens cation channels, resulting in excess neural stimulation at motor endplates. There may be immediate but often minor local pain from the bite, but within an hour a generalized reaction may begin with spreading pain and cholinergic symptoms of sweating, diarrhea, abdominal cramps, and dyspnea. There may also be motor function effects with cramping of large muscle groups and general weakness. Recovery usually takes several days. Death is very rare (40).

4.7.4 Scorpions

There are over 500 species of scorpions around the world, mainly in warm regions from desert to subtropical climates. All of them might sting, but most stings are no more severe than the bite of a honey bee. There are species and geographic variations in the type and potency of their toxin (41). The toxin is most commonly a neurotoxin similar to that of the widow spiders. However, there are some species that also have a cytotoxin similar to that of the brown recluse spider. Only one species (*Centroides sculpturatus*) in North America (located in the south-west) has a potent neurotoxin. Some sensitized people may have an anaphylactic reaction in response to a scorpion sting similar to that caused by hymentoptera species.

4.7.5 Lepidoptera Species (Catapillars)

Several species of caterpillar cause dermatitis and/or a systemic reaction. Among the potentially harmful of these is the puss caterpillar (*Megalopyge urens*). When touching this caterpillar its hairs may stick into the skin of the victim and release a toxin that contains high levels of histamine and the enzyme hyaluronidase, which produces immediate painful inflammatory proteolytic and hemolytic reactions.

4.7.6 Treatment of Arthropod Dermatoses

Anaphylactic Reactions

Treatment of arthropod-induced dermatoses is highly variable. Individuals with a history of severe reaction to hymenoptera stings should wear bracelets or tags warning of their sensitivity. Highly allergic people have common symptoms (generalized hives, wheezing, fainting, or shock). If stung, these people should have access to specific drugs to counteract the symptoms (ephedrine or epinephrine, diphenhydramine, and possibly corticosteroids). Acutely sensitive people should carry an epinephrine autoinjector (e.g., trade names EpiPen, Emerade, Twinject). Those prone to anaphylaxis following a sting from a bee or wasp (even if they self-inject with epinephrine) should proceed to the nearest emergency room or hospital in case of a continued or recurrent response. For prevention, those who have had a history of systemic allergic reactions should consider *Hymenoptera* sting hypo-sensitization.

Treatment of Skin Reactions from Insect Bites and Stings

Bites from free-living mites (chiggers, grain mites, oak mites) and animal scabies mites need only symptomatic treatment. These mites cannot survive on human skin for more than a few days and thus die or drop off spontaneously. However, victims are very appreciative of anti-inflammatory and anti-pruritic treatment to relieve symptoms. Over-the-counter products such as topical steroids and/or oral antihistamines may result in minor relief of the symptoms. Other more effective over-the-counter products contain camphor, phenol, and menthol. In addition, steps need to be taken to eliminate or prevent exposure. Protective clothing and gloves are useful when handling grain or animals that may have scabies. Chigger bites can generally be avoided by putting a barrier, such as a blanket, between yourself and the grass while working or picnicking. Fumigation of grain helps rid the product of vermin and mites, enhances grain quality, and decreases the health risk of grain handling as it comes out of storage.

Regarding *Hymenoptera* species stings, only the honey bee will leave its stinger in its victim (42). As the stinger will continue to pump venom for up to 30 minutes while in the skin, it is a good idea to locate it and either scrape it away with a fingernail or pull it out with forceps. Additional treatment may be appropriate when bites are numerous, when patients react severely, or when secondary infections develop. A prescription-grade (greater the 2% cortisol) topical steroid often provides good symptomatic relief. For wasp or bee stings, sprinkling papain powder (contained in many meat tenderizers and available in most grocery stores) on a wetted lesion within a few minutes of the sting is helpful in reducing the degree and length of time of the pain. The enzyme papain breaks down the protein and polypeptide secretions that act as irritants or allergens. Systemic antihistamines may reduce pruritus associated with multiple bites. Antibiotics, usually systemic, may be indicated for treating or preventing secondary infections.

Treatment of arachnid bites may require more invasive treatment. There are commercial antivenins for the widow spiders, the brown recluse, and scorpion bites or stings (43). There is wide geographical variation in scorpion species and the toxicity of their venoms. Antivenins are species and geographic specific. For best results, these should be administered within the first 4 hours of the bite. The brown recluse spider bite may require excision and debridement of the wound site, followed by a skin graft (to prevent scarring). Diaminodiphenyl sulfone (Dapsone) has been reported to decrease tissue necrosis if applied early and therefore may prevent scarring.

Arthropod-related problems can be prevented by taking the following precautions: wear light-colored, non-flowery clothing, do not wear scented preparations, avoid activities where arthropods are likely to be encountered, and keep an insecticide aerosol handy. Arthropods are best deterred by insect repellants containing diethyltoluamide (DEET, trade names include Off, Repel, Bug X30). Products with 100% DEET may be used.

4.8 Sunlight-induced Dermatoses

Both acute and chronic changes result from the sun's UV rays. With few exceptions, these problems are more common among light-skinned individuals. The sunlight-induced changes discussed below include sunburn, chronic non-cancerous lesions, precancerous lesions, and skin cancers.

4.8.1 Acute Sun-induced Skin Disorders

The most frequent reactions to sunlight are sunburn, which can be a minor self-limiting painful event for a few days, and sun poisoning, which requires medical treatment and possible hospitalization (44, 45). Sunburn is caused by exposure to UV radiation from both the UVA and UVB ranges. Mild or first-degree burns affect only the superficial layers of the skin, resulting in redness, some swelling, and pain. Second-degree burns involve deeper skin layers and blisters may form. Usually, most sunburn can be self-treated with over-the-counter medications with return to normal in 3–5 days. However, medical consultation should be sought if there is evidence of second-degree burns, with involvement of 15% or more of body area, combined with one or more of the following: fever of 101 °F (38.3 °C) or more, evidence of dehydration, pain longer than 48 hours, fainting, or nausea (44, 46).

Risk factors for sunburn include (1) fair skin color, (2) early sun season exposure (no sun acclimation), (3) working in the sun during midday (10 am to 2 pm), (4) living close to the equator, (5) working or living at high altitude, (6) working or living in ozone-depleted regions (Antarctic regions and the countries surrounding it, e.g. Australia), (7) taking any of the drugs tetracycline, St. John's wort, oral contraceptives, tranquilizers with sun exposure, and (8) lupus or other skin diseases such as psoriasis.

Besides those working directly in the sun, workers are also exposed to a substantial amount of reflected UVA and UVB radiation on water (e.g., fishermen) and in snow. Welding also provides UVA and UVB radiation that can cause skin burn. Significant UVA and UVB radiation can penetrate the windshield of a truck or tractor cab.

Treatment of first-degree or mild second-degree sunburn consists of pain and inflammation management with acetaminophen or aspirin and non-steroidal anti-inflammatory drugs (e.g., ibuprophen, naproxen). Additional treatment includes cool baths, saline or Burrow's solution, and light bandages followed by moisturizers such as aloe and topical steroidal creams. Thick petroleum-based products such as petroleum jelly and products with topical anesthetics such as benzocaine or lidocaine should be avoided. More severe burns may require IV fluid therapy for rehydration with a balanced electrolyte and systemic steroids. Advanced skincare may be required as well (46). Treatment of photocontact dermatitis is similar to that of contact dermatitis, which was discussed earlier.

4.8.2 Chronic Sun-induced Skin Disorders

Chronic exposure to sun on unprotected skin is a known risk factor for a variety of skin disorders. These disorders increase with age. As farming often results in a high level of sun exposure, farmers are at increased risk for all these sun-induced skin disorders (47, 48). The most common chronic sun-induced changes to the skin include thickening, loss of collagen, elasticity and wrinkling (photo-aging), and development of actinic keratoses (48–50). The back of the farmer's neck in Figure 4.6 shows excessive wrinkling and thickening. The collar of his shirt shaded the skin half-way down his neck, producing the area of sparing. Although this condition is mainly of cosmetic concern, it does show that extensive chronic sun exposure has occurred to the head and neck, which increases the risk for actinic keratoses and skin cancers.

Actinic keratoses, and basal cell and squamous cell carcinomas are caused by chronic long-term sun exposure. These conditions typically do not appear until a person is in their late 50s or 60s. Actinic keratoses typically appear on the nose, cheeks, ear lobes, neck, dorsal surface of the fore arms, back of the hands, and other areas that receive extensive sun exposure. They present as red to brown macules or slightly raised papules with a rough scale (see Figure 4.7). Another form of keratosis may appear on the lower lip as a light-colored scar (called actinic cheilitis). Actinic keratoses are primarily of cosmetic concern, although they are sometimes painful or pruritic. However, a percentage of them (5–10%) may develop into squamous cell or basal cell carcinomas. They may wax and wane, resolve spontaneously, or progress to skin cancer, though usually with a long latency period.

Treatment of actinic keratosis is not an emergency and may be considered elective, depending

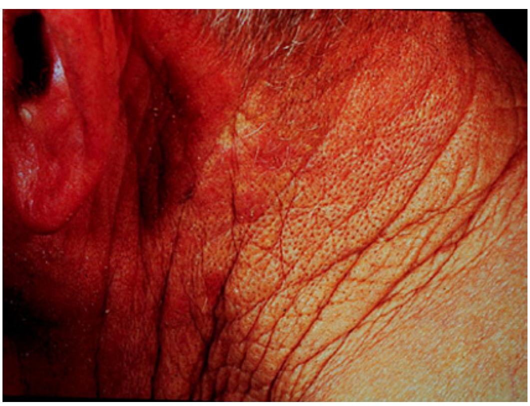


FIGURE 4.6 Compare the thickened and wrinkled skin from chronic exposure to skin protected by the shirt collar on this 65-year-old farmer. (*See insert for color representation of the figure.*)

FIGURE 4.7 Actinic kerratoses. (*See insert for color representation of the figure.*)

on the extent of the lesions, the risk factors for the particular individual, and the recommendations of a medical professional. However, several treatment methods are available, such as curettage (minor surgical removal), electrodessication, liquid nitrogen freezing, and chemical treatment (5-fluorouracil). The latter two treatments kill fast-growing cells. Imiquimod may be used to stimulate the innate immune system. In older fair-skinned patients actinic keratoses may be too numerous to treat individually therefore the dermatologist may treat the entire face with 5-fluorouracil or with tricholoacetic acid, which results in a "face peel," with the intent to slough the precancerous cells and replace them with deeper or adjacent cells without sun-damaged DNA.

FIGURE 4.8 Basal cell carcinoma. (*See insert for color representation of the figure.*)

4.8.3 Skin Cancer

Skin cancer generally has been on the rise since the 1940s and only recently (around the year 2000) has there been a leveling out of reported skin cancer cases. Currently, there are over one million cases reported annually in the United States alone.

Neoplasms are caused by light energy in the UV range (200–400 nm), with the greatest risk in the UVB radiation wavelength (290–320 nm) (51). Ozone in the stratosphere filters out a portion of the UVB radiation. However, the release of chlorofluorocarbons from human activities has decreased the ozone layer and therefore increased the amount of UV radiation potential in sunlight. Thus, we can expect a continued high prevalence of skin cancers in the future.

Farmers, like others in professions with hours of work outdoors under the sun, have a significantly high risk of acquiring skin cancer. In a study of cancer risks among farmers, it was shown that they had a higher risk of all types of skin cancers on the head or neck but a lower risk of skin cancer in other parts of the body (47, 52), demonstrating that occupation, lifestyle, and lack of protection have great impact on the risk.

It should be noted that in addition to sun exposure, chronic exposure to the formerly commonly used inorganic arsenical herbicides (not licensed by the EPA since the mid-1950s) also caused skin cancers, including carcinoma in situ (13). Data from the Agricultural Health Study (US) suggests associations of melanoma with prior contact with arsenical herbicides in addition to three insecticides, maneb, carbyryl (carbmates) and parathion (organphosphate) (53).

The most common form of skin cancer is basal cell carcinoma (Figure 4.8). These cancers arise from deeper layers of the skin (basal layer) that give rise to the superficial layers (epidermis). If untreated, basal cell carcinomas can be very destructive locally, but they rarely metastasize. The carcinomas occur in the same areas on the skin as actinic keratosis and squamous cell carcinomas.

The second most common form of skin cancer is squamous cell carcinoma (Figure 4.9). These cancers affect the most superficial layers of the skin. They are often found in similar locations to actinic keratoses (e.g., nose, checks, and ears). A small percentage of them may arise from actinic keratoses. They may appear as thickened skin or erosions. They may also appear on the lips (usually the lower lip).

Most skin cancers (with the exception of melanoma) are not highly malignant. Approximately 2 in 100 cutaneous squamous cell carcinomas metastasize. Metastasis is much more common when the lesions develop on the lips or ears. Usually the spread is to regional lymph nodes, although spread to the lung is possible.

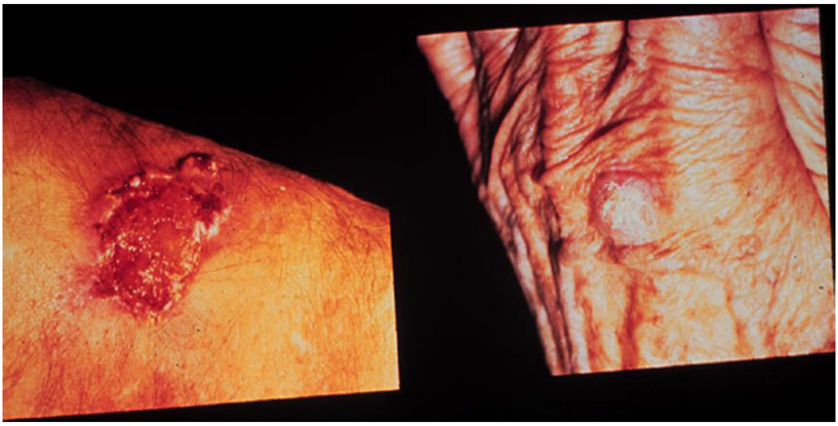


Figure 4.9 Squamous cell carcinoma: two different clinical appearances. (*See insert for color representation of the figure.*)

Basal cell carcinomas may spread locally under the superficial layers of the skin therefore their margins may not be obvious by external examination. A biopsy may be necessary to determine the margins. Although basal cell carcinomas may take several different forms in appearance, the classic basal cell carcinoma appears as a small reddened nodule with an eroded center and rolled up edges that contain small blood vessels. A classic squamous cell carcinoma is not as raised as a basal cell, and has a more exophytic (outward growth) and crusted appearance to it. It may be difficult on examination to tell whether the lesion is a basal or squamous cell carcinoma.

Melanoma skin cancers carry the highest risk of malignancy relative to other sun-exposure-related skin cancers. There are four types of melanoma, all of which carry a risk of malignancy. Increased risk is associated with certain characteristics of the melanoma, including the thickness, extent of mitotic figures on microscopic examination, and spread to regional lymph nodes. Although one specific type of melanoma (lentigo melanoma) has a similar association to chronic sun exposure as non-melanotic tumors. However, for most melanomas sun exposure risk is different to that for basal and squamous cell carcinomas (54). Whereas basal and squamous cell carcinomas are caused by long-term sun exposure, most melanomas are associated with frequent sunburn at an early age. Most melanomas do not typically occur on chronically sun-exposed areas of the skin such as the ears, nose, and cheek ridge, but on areas of the skin not highly sun exposed (e.g., back of the legs). Furthermore, melanomas are difficult to differentiate from a mole. A description of the general appearance and characteristics of sun-related skin cancers is given in Table 4.4 (55). Figure 4.10 shows the appearance of different forms of melanoma. However, the appearance of a skin lesion is rarely diagnostic. The key to confirm a diagnosis is a biopsy for histopathologic examination.

Treatment of squamous cell and basal cell carcinoma includes several options: physical removal by radiation, electrodessication, liquid nitrogen freezing, curettage (refers to surgical removal of abnormal appearing tissue using an instrument called a curette), or laser surgery. Moh's micrographic surgery for basal and squamous cells has the highest rate of cure as histologic examination of tissues is conducted concurrently with excision of tissue to assure all cancerous cells have been removed at the margins.

For more information on the epidemiology of skin cancers, see Chapter 5.

4.8.4 Prevention of Sun-induced Skin Disorders

All sun-induced skin problems can be dramatically reduced by the use of protective clothing such as a wide-brimmed hat, and by use of a

Table 4.4 Characteristics of skin cancers

Basal cell carcinoma

1. The lesion location is on a primary sun-exposed skin surface (i.e., cheek bones, nose, ears, back of hands).
2. A persistent, non-healing sore that may bleed, ooze, or crust.
3. A reddish plaque that may be irritated, itch, or hurt, and usually occurs on the cheek bones, ears, nose, or irritated area.
4. A shiny bump or nodule that is pearly or translucent and is often pink, red or white.
5. A pink growth with a slightly elevated rolled border with tiny blood vessels (telangiectasis) with an eroded center, giving a crater-like appearance.
6. A scar-like area that is white, yellow or waxy, and often has poorly defined borders.

Squamous cell carcinoma

7. The lesion location is on a primary sun-exposed skin surface (i.e., cheek bones, nose, ears, back of hands).
8. A wart-like growth that crusts and occasionally bleeds.
9. A persistent, scaly red patch with irregular borders that sometimes crust or bleed.
10. An open sore that bleeds and crusts, and persists for weeks.
11. An elevated growth with a central depression that occasionally bleeds.
12. A growth of this type may rapidly increase in size (SCF, 2001).

Melanoma (the ABCDs and differentiation from common moles)

13. The lesion may be located on almost any part of the body.
14. "A" is for asymmetry: one side of the tumor does not match the other side. Moles are round and symmetrical.
15. "B" is for border: the borders of early melanomas are usually irregular. Moles have smooth and regular borders.
16. "C" is for color: varied shades of brown, tan, or black, and in later stages red, blue, and white colors may be present. Moles may be differentiated in that they usually are a single shade of brown.
17. "D" is for diameter: Melanomas are usually larger than ¼ inch (7 mm) in diameter (the size of a pencil eraser). Moles usually are smaller.

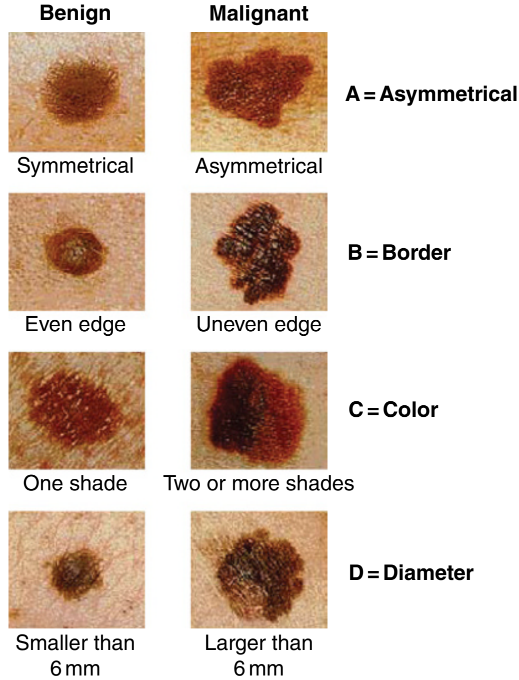


FIGURE 4.10 The ABCDs of melanoma aid in the presumptive differentiation of a mole (nevus) from a melanoma. (Source: http://www.cancer.gov/types/skin/moles-fact-sheet#q9.). (*See insert for color representation of the figure.*)

broad-spectrum sunscreen cream of at least SPF 15. A broad spectrum sunscreen provides both UVA and UVB protection. These days no sunscreen is allowed by the FDA to be labeled as all-day or waterproof protection. Sunscreen is best applied 30 minutes before sun exposure, again 30 minutes after sun exposure, and every 2 hours following. Sun blocker or sun barriers such as zinc oxide or titanium dioxide are other options. If appropriately applied, they block all sun radiation. Blockers have been recommended by some for very young children; as with sunscreens (those containing PABA), there is a low risk of photoallergy. For farmers, the practical experience of this author (KJD) has found that farmers will more likely carry and use sunscreens in pump sprayers compared to creams. Some clothing now is SPF-rated, but most clothing covering the skin provides adequate protection. A broad-brimmed hat is a very important protective piece of clothing. Baseball style hats are more common among farmers, but well-styled western or Australian-styled hats are becoming more acceptable and should be encouraged. Staying or working in a shaded area from noon until two o'clock daylight saving time is highly recommended when possible (43, 45).

4.9 Skin Disorders Related to Heat, Cold, and Humidity

4.9.1 Heat-induced Dermatoses

Hot, moist environments can cause a series of conditions resulting from obstruction of the sweat ducts. Lack of evaporation due to hot, humid environments and areas of the skin not well ventilated enhances skin damage and bacteria growth. Staphylococcal infections have been incriminated in this situation due to blockage and rupture of the sweat ducts and release of sweat within the skin (56–58). If the blockage is near the opening of the duct, sweat leaks into the superficial skin layer (stratum cornium). This produces small clear vesicles and is termed miliaria crystallina (sudamina). Typically, there are no accompanying symptoms with this condition. If the duct ruptures in the deeper layers of the epidermis, the condition miliaria rubra develops (prickly heat). Inflammation of tissues surrounding the ruptured duct results in a rash, characterized by uniform small red papules or vesicular papules, which are regularly spaced. The regular spacing pattern may result because the lesions are located near hair follicles. However, close observation will reveal that they lie between hair follicles. Miliaria is commonly found in areas where moisture may collect, such as body fold areas and under the arms. Also, it occurs at sites of pressure and areas of friction such as the belt line (59, 60). Symptoms of miliaria rubrae include stinging, often reported as a feeling of being pricked with pins and needles. An intense pruritus (itching) may develop. Miliaria rubrae is by far the most common condition of this series. If the duct ruptures at the junction of the epidermis and the lower skin layer (dermis), a condition called miliaria profunda develops, which is characterized by 1–3 mm papules without pain of itching. Sweat ducts in this condition may be rendered functionless, and this could lead to greater future risk of heat stress or compensatory sweating on unaffected areas of the skin.

Treatment of miliaria rubrae depends on removal of the patient from the hot, humid environment. Topical application of water-based (not oil-based) steroid preparations is often helpful, as is a topical water-based or powder-based antibiotic. Application of the astringent calamine lotion may help reduce itching. Anhydrous lanolin may help to retard or prevent further sweat duct damage (56).

Prevention of miliaria involves avoiding sustained heat and humidity by commonsense measures such as wearing cool, well-ventilated clothing, and using fans and air-conditioners to keep one's workplace (if possible) and home cool. Regular bathing and application of talc or similar body powders at the beginning of the work day will help absorb moisture and reduce friction and the risk or severity of miliaria rubra.

Excessive sweating may cause intertrigo, which is an erythematous eruption in body folds with maceration and risk for secondary bacterial and candidal (yeast) infection, especially among the obese. Barrier creams such as zinc oxide and the topical antifungals are often helpful either separately or when combined. Careful drying after bathing or sweating is an important adjunctive approach, and powders should be avoided as they can become paste-like with moisture and cause additional irritation.

4.9.2 Cold-related Skin Disorders

Chilblains (perniosis) is a mild form of cold injury. Distal areas of the body, like fingers, toes, nose and ears, are especially affected. The lesions are swollen with bullae, ulcerations, and reddish-blue discolorations. Treatment is symptomatic.

In frostbite there is an impairment of circulation. Superficial frostbite only affects the superficial layers of the skin. In more severe cases deeper layers are affected, with risk of gangrene. The consequences of a deep frostbite cannot be evaluated immediately. Several weeks have to pass to accurately estimate the tissue loss. Even minor frostbites may result in a long-term hypersensitivity to cold, including Raynaud-like reactions, paresthesias, and hyperhiderosis. For more information on heat- and cold-related conditions see Chapter 9.

Key Points

1. Irritant contact dermatitis is by far the most common skin condition among agricultural workers. Some of the common agents include gasoline and other petrochemicals and solvents, and certain pesticides and herbicides.
2. Allergic contact dermatitis is less common, but may be more clinically severe. There are immediate (which can be a medical emergency if the hands are involved) and delayed forms. Rhus plants (poison ivy, oak, and sumac) contain urushiol, the highly allergenic agent in these plants that causes a common sub-acute allergic contact dermatitis in rural and farm populations.
3. The juice from several vegetable plants (e.g., carrots, celery) and wild invasive plants (e.g., wild parsnip, hog weed) contains a furocumarin that can contaminate skin, and with exposure to sunlight can cause a phytophototoxic (irritant) dermatitis.
4. Zoonotic agents causing skin infections include the pox viruses orf (sheep and goats) and milker's nodules (cattle), and the fungal agent *Trychophyton verrucosum* (cattle).
5. Arthropods causing skin conditions include mites, ants, wasps, bees, and spiders. Mites of animals or free-living species cause only a temporary irritant contact dermatitis, most commonly found on the hands and forearms. Fire ants in the southern US can cause painful pustules. Bee and wasp stings cause a painful but temporary skin condition at the site of the sting. The main problem is for those who are allergic and may have a life-threatening anaphylactic response to a sting.
6. Sun exposure is the most important exposure for agricultural skin conditions because of the combination of the observed high prevalence in farmers and workers, and the potential disabling outcomes. Actinic keratoses are benign lesions, but a small percentage may result in a squamous cell carcinoma or basal cell carconoma. Squamous cell and basal cell carcinomas are the most common chronic sun-induced cancers, but they rarely become aggressively malignant. Basal cell carcinomas can be a problem if they invade important structures such as a tear duct. They may also spread under the skin in a wider area than observable. Melanomas are not as common as the basal cell carcinomas but certain types can be aggressively malignant and life-threatening. Causative sun-exposure history is related to frequent sunburn at an early age.
7. The key to prevention of skin problems is to prevent exposures to agents that are harmful to the skin. Rubber, or preferably nitrile gloves, should be worn when handling any potentially irritant or allergenic chemicals, plants, or livestock with obvious pox, fungal, or mite infections. Professional veterinary diagnosis, treatment, and prevention of diseases of animals are important in prevention of zoonotic skin infections. Sun protection is important from an early age, including protective clothing and hats, proper use of sunscreen, and avoidance, if possible, of working in the sun during midday hours.

References

1. Burke W. Skin diseases in farmers. In: Langley R, McLymore R, Meggs W, Roberson G, editors. Safety and health in agriculture, forestry, and fisheries. Rockville, MD: Government Institutes, Inc.; 1997. p. 322–52.
2. Susitaival P, Flyvholm MA, Meding B, Kanerva L, Lindberg M, Svensson A, et al. Nordic Occupational Skin Questionnaire (NOSQ-2002): a new tool for surveying occupational skin diseases and exposure. Contact Dermatitis. 2003;49(2):70–6.
3. Susitaival P, Husman L, Hersmanheimo M, Notkola V, Husman K. Prevalence of hand dermatoses among Finnish farmers. Scand J Work Environ Health. 1994;20:206–12.

4. Park H, Sprince N, Whitten P, Burmeister L, Zwerling C. Farm-related dermatoses in Iowa male farmers and wives of farmers: a cross-sectional analysis of the Iowa Farm Family Health and Hazard Surveillance Project. J Occ Environmental Medicine. 2001;43(4):364–9.
5. Mathias C. Occupational dermatoses. J Am Acad Dematol. 1988;19(6):1107–14.
6. Feldman SR, Vallejos QM, Quandt SA, Fleischer AB, Jr., Schulz MR, Verma A, et al. Health care utilization among migrant Latino farmworkers: the case of skin disease. J Rural Health. 2009;25(1):98–103.
7. Vallejos QM, Schulz MR, Quandt SA, Feldman SR, Galvan L, Verma A, et al. Self report of skin problems among farmworkers in North Carolina. Am J Ind Med. 2008;51(3):204–12.
8. Irby CE, Yentzer BA, Vallejos QM, Arcury TA, Quandt SA, Feldman SR. The prevalence and possible causes of contact dermatitis in farmworkers. Int J Dermatol. 2009;48(11):1166–70.
9. Arcury T, Quandt S, Mellen B. An exploratory analysis of occupational skin diseases among Latino migrant and seasonal farm workers in North Carolina. J Agric Saf Health. 2003;9(3):221–32.
10. Susitaival P, Hannuksela M. The 12-year prognosis of hand dermatosis in 896 Finnish farmers. Contact Dermatitis. 1995;32:233–7.
11. Spiewak R, Gora A, Dutkiewicz J. Work-related skin symptoms and type I allergy among eastern-Polish farmers growing hops and other crops. Ann Agric Environ Med. 2001;8(1):51–6.
12. Spiewak R, Dutkeiwicz J. Atopy, allergic diseases, and work-related exposures among students of agricultural schools: first results of the Lublin study. Ann Agric Environ Med. 2002;9:249–52.
13. Spiewak R. Pesticides as a cause of occupational skin diseases in farmers. Ann Agric Environ Med. 2001(a);8(1):1–5.
14. Belsito D. Allergic Contact Dermatitis. In: Freedberg I, Eissen A, Wolff K, Austen K, Goldsmith L, Katz S, editors. Fitzpatrick's Dermatology in General Medicine, Vol. 1. 6th edition. New York: McGraw-Hill; 2003. p. 1164–9.
15. Amshel CE, Fealk MH, Phillips BJ, Caruso DM. Anhydrous ammonia burns case report and review of the literature. Burns. 2000;26(5):493–7.
16. Sykes R, Mani, M. Hiebert, J. Chemical burns: retrospective review. J Burn Care Rehabil. 1986;7(4):343–7.
17. Telintum J, Nater J. Contact allergy caused by nirtofurazone (furacine) and nifurprazine (carofur). Hautarzt. 1974;8:403–6.
18. Nurse D. Dermatitis Danger in Dairy Farmers. Med J Aust. 1978;1:223.
19. International Hazard Data Sheet on Occupation. International Labor Organization (updated 16 November 2000; accessed 12 December 2015). Available from: http://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---safework/documents/publication/wcms_193145.pdf.
20. Francesa U, Keown J, Endres M, Mondak C, Garcia A. Safety risk areas at the dairy farm. Publication Number FS950.2008. South Dakota State University Extension (accessed 6 December 2015). Available from: http://www.sdstate.edu/news/publications/database/pub-details2.cfm?customel_datapageid_858688=884150&taxonomy=dairy%20science&searchStr=.
21. Canadian Poisonous Plant Informantion System. Canadian Biodiversity Information Facility, Government of Canada (updated 6 June 2005; accessed 6 December 2015). Available from http://www.cbif.gc.ca/eng/species-bank/canadian-poisonous-plants-information-system/all-plants-common-name/poison-sumac/?id=1370403267173.
22. Mitich LW. Poison-ivy/poison-oak/poison-sumac – the virulent weeds. Weed Technol. 1995;(9):653–6.
23. Poison Ivy, Oak and Sumac. American Academy of Dermatology; 2005 (accessed 6 December 2015). Available from: https://www.aad.org/dermatology-a-to-z/diseases-and-treatments/m---p/poison-ivy.
24. Ricker J, Ruzicka T, Neumann NJ, Homey B. Protein contact dermatits to asparagus. J Allergy Clin Immunol. 2004; 113(2):354–5.
25. Hausen B, Wolf C. 1,2,3-Trithiane-5-carboxylic acid, a first contact allergen from *Asparagus officinalis* (Liliaceae). Am J Contact Dermatitis. 1996;7(1):41–6.
26. Tulip. DermNet NZ; 2015 (updated 28 December 2013; accessed 6 December 2015). Available from: http://www.dermnetnz.org/dermatitis/plants/tulip.html.
27. Rademaker M. Occupational contact dermatitis among New Zealand farmers. Australia J Dermatol. 1998;39:164–7
28. White G, Cox N. Diseases of the skin: A Color Atlas and Text. 2nd edition. Mosby; St. Louis; 2005.
29. Gette MT, Marks JE, Jr. Tulip fingers. Arch Dermatol. 1990;126(2):203–5.
30. Mijnssen GA. Pathogenesis and causative agent of "tulip finger." Br J Dermatol. 1969;81(10):737–45.
31. Marks J. Allergic contact dermatitis to Alstroemeria. Arch Dermatol. 1988;124(6):914–6.
32. Rippon JW. Medical Mycology. Philadelphia: W.B. Saunders; 1974.
33. Leavell UW Jr, McNamara MJ, Muelling R, Talbert WM, Rucker RC, Dalton AJ. Orf. Report of 19 human cases with clinical and pathological observations. J Am Med Assoc. 1968;204:657–64.

34. Nomland R, McKee A. Milker's nodules: Report of ten cases. Arch Dermatol. 1952;65:663–71.
35. Harves R, Millikan L. Concepts of therapy and pathophysiology in artrhopod bites and stings. Int J Dermatol 1975;14:543–62,621–34.
36. Gilbert L, Patrock R. Phorid flies for the biological suppression of imported fire ants in Texas: Region-specific challenges, recent advances and future prospects. Southwestern Entomologist. 2002;25:7–17.
37. Lemmons, C. Fighting Fire with Fire: Invasion and Biocontrol of the Red Imported Fire Ant. 2004 (accessed 6 December 2015). Miami (Ohio) University. Avaialble from: http://jrscience.wcp.miamioh.edu/fieldcourses04/PapersMarineEcologyArticles/FightingFirewithFire.Inva.html.
38. Potential United States Range Expansion of the Invasive Fire Ant. Agricultural Research Service, US Department of Agriculture (last modified 10 May 2006; accessed 7 December 2015). Available at: http://www.ars.usda.gov/research/docs.htm?docid=9165.
39. McLean J. Management of Insect Sting Reactions. Modern Treatment. 1968;5:814–24.
40. Prongay R, Kelsberg G, Safranek S. Clinical inquiry: which treatments relieve painful muscle spasms from a black widow spider bite? J Fam Pract. 2012;61 (11):694–5.
41. Corona M, Valdez-Cruz N, Merino E, Zurita M, Possani L. Genes and peptides from the scorpion *Centruroides sulpturatus*. Toxicon. 2001;39(12): 1893–8.
42. Graber M. Stingers can continue for inject venom for 20 minutes. EMS Update. Emergency Medical Services Learning Resources Center. 2002;23(2):1–2.
43. Allen R, Norris R. Delayed use of widow spider antivenin. Ann Emerg Med. 1995;26(3):393–4.
44. Travelers' Health: Sun Exposure. Center for Disease Control, Public Health Service (updated 21 April 2013; accessed 6 December 2015). Available from: http://wwwnc.cdc.gov/travel/page/sun-exposure.
45. Sams WJ. Sun-induced aging. Clinical and laboratory observations in man. Dermatol Clin. 1986; 4(3):509–16.
46. Sunburn. National Institute of Health, National Library of Medicine, Medline Plus (updated 15 May 2013; accessed 6 December 2015). Available from: https://www.nlm.nih.gov/medlineplus/ency/article/003227.htm.
47. Schmalwieser AW, Cabaj A, Schauberger G, Rohn H, Maier B, Maier H. Facial solar UV exposure of Austrian farmers during occupation. Photochem Photobiol. 2010;86(6):1404–13.
48. Sartorelli P, Romeo R, Paolucci V, Puzzo V, Di Simplicio F, Barabesi L. Skin photoaging in farmers occupationally exposed to ultraviolet radiation. Med Lav. 2013;104(1):24–9.
49. Howell J. The sunlight factor in aging and skin cancer. Arch Dermatol. 1960;82:865–9.
50. Willis I. Sunlight and skin. J Am Med Assoc. 1971;217:1088–93.
51. Kripke M, Ananthaswamy H. Carcinogenesis: Ultraviolet radiation. In: Freedberg I, Eissen A, Wolff K, Austen K, Goldsmith L, Katz S, editors. Fitzpatrick's Dermatology in General Medicine, Vol. 1. 6th edition. New York: McGraw-Hill; 2003. p. 371.
52. Wiklund K, Dich J, Holm L, Eklund G. Risk of cancer in pesticide applicators in Swedish agriculture. Br J Ind Med. 1989;46(11):809–14.
53. Dennis LK, Lynch CF, Sandler DP, Alavanja MC. Pesticide use and cutaneous melanoma in pesticide applicators in the agricultural heath study. Environ Health Perspect. 2010;118(6):812–7.
54. Desmond R. Epidemiology of malignant melanoma. The Surgical Clinics of North America. 2003;83 (1):1–29.
55. What You Need to Know About Melanoma and other Skin Cancers. NIH Publication Number 19-7625. US Department of Health and Human Services, National Cancer Institute (revised June 2010; accessed 6 December 2010). Available from: http://www.cancer.gov/publications/patient-education/skin.pdf.
56. Heat Rash. Rochester, Minnesota: Mayo Clinic; 2012 (accessed 6 May 2014). Available from: http://www.mayoclinic.org/diseases-conditions/heat-rash/basics/treatment/con-20033908.
57. Sehgal V. Text Book of Clinical Dermatology. 4th edition. New Delhi: Jaypee Brothers; 2004. 301 pp.
58. Lyons R, Levine R, Auld D. Miliaria Rubra: A manifestation of staphylococcal disease. Arch Dermatol. 1962;86(3):282–6.
59. Lobitz R. Miliaria. Arch Environ Health. 1965; 11:460.
60. Holtz E, Kingman A. Pathogenesis of miliaria rubra: role of resident microflora. Br J Dermatol. 1978;99: 117–37.

Chapter

5

Cancer in Agricultural Populations

Kelley J. Donham

Reviewer: Charles F. Lynch

5.1 Introduction

A 68-year-old dairy farmer in Eastern Iowa (United States) had been complaining of back pain and difficulty urinating for at least 2 years. At the continued insistence of his wife, he made an appointment with a physician (the first time he had been to a doctor in 15 years). A digital rectal exam revealed an enlarged and somewhat irregular prostate. A follow-up prostate-specific antigen blood test was elevated. He was referred to a urologist, the nearest one being over 120 km away, which required overnight travel. It took several days for him to organize someone to feed and milk the cows in his absence. A biopsy revealed prostate cancer, which had spread beyond the capsule. Additional tests showed the cancer had spread to several pelvic lymph nodes and also to the vertebrae of the backbone. He was given the choice of chemotherapy and radiation, castration, or estrogen therapy. The first three choices would mean having to leave the farm and not being able to take care of his dairy operation. The last option would allow him to maintain his farm with perhaps a lesser potential for the best possible long-term outcome. He was concerned that he could not afford to pay for the more expensive treatment. He discussed the options with his family physician. Given all the information and his perceived limitations, he chose the estrogen therapy, and stayed at home to tend his cows as long as he could. The farmer was able to work for about 8 months longer, until he got too sick. He died at his home under the care of a rural visiting nurse, a year after the diagnosis.

His physician expressed regret that he had not come in sooner, for the cancer may have been arrested before it spread. The farmer's wife expressed concern that there may be a cancer epidemic, as she knows at least four other people that live within a 2-mile radius that have cancer. She wanted to know if the pesticides they have used all these years may have been the cause. The physician could not answer her questions.

This case (based on a real case, a farm neighbor and friend of this author (KJD)) is illustrative of the common cultural, psychosocial, and health care accessibility considerations of cancer in rural and agricultural populations compared to urban populations. Healthcare access in rural areas is generally distant, which creates challenges for screening and other clinical preventive services access. Furthermore, work and care of livestock and the farming operation generally takes precedence over care of self. However, when rural women have cancer, they may be less likely to be

Agricultural Medicine: Rural Occupational and Environmental Health, Safety, and Prevention, Second Edition.
Kelley J. Donham and Anders Thelin.

concerned about the farm, and feel isolated, not supported or understood by their spouse. Rural people are conflicted about the chemicals they work with in that they cannot make a living without them, yet fear they may cause cancer or other health problems. The fear is exacerbated when several cancer cases are detected in their neighborhood. However, investigation of these "clusters" does not often find a cancer rate beyond that expected. Healthcare providers and other scientists have not yet been able to provide conclusive facts about cause–effect for exposure to chemicals in their environment, increasing their concern. This case is an example of the socioeconomic aspects of cancer in the farm population. These factors are critical to implementation of diagnosis, treatment, and prevention in this population. Following a discussion of the epidemiology, risk factors, causation, and prevention associated with agricultural cancers, the final paragraphs will return to these "social medicine" and prevention factors, which are so critical for health and safety professionals to understand and practice to decrease the burden of cancer in their farm patients/clients.

The case example above indicates the broad emotional context incorporated in the term "cancer," which tends to deviate from a rational approach to this disease, often creating a focus on cure rather than prevention and loss of a broad health and safety perspective of these diseases relative to other diseases. Furthermore, there has been a greater focus on pesticides relative to other causes of cancer. This chapter aims to help the reader obtain a broad understanding of cancer and prevention in the context of agricultural environmental exposures generally. It should be noted that ascribing cause-effect of exposures to cancer is very challenging and can be confusing. The authors will attempt to facilitate understanding of the vast amount of literature on this subject. It should be noted that cancer has been one of the areas in agricultural medicine that has garnered a major portion of research and prevention resources. The World Health Organization's International Agency on Research in Cancer (IRAC) reviews and assimilates data from around the world to enhance the generalization of data on epidemiology, agents, mechanisms, and prevention. In the United States the Environmental Protection Agency (EPA), the National Institutes of Cancer and Environmental Health Sciences, and the National Institute for Occupational Safety and Health collaborate in the research into and prevention of cancer. Most industrialized countries have similar agencies and resources addressing the topic. Determining the cause-effect of agents in disease often requires concordance among several lines of scientific discovery, including epidemiologic studies (with control of variables and biases), accurate exposure studies, and evidence of a plausible biologic mechanism. Reviewing these three critical areas of evidence, the authors hope to provide a functional understanding of cancer as an occupational disease in agriculture.

5.1.1 Epidemiology of Cancer in Farm Populations

There have been well over 300 articles published on the epidemiology of cancers in farm populations in the past 20 years. However, there are several limitations of these epidemiologic studies that should be recognized. Designing definitive cancer epidemiologic studies is challenging due to the nature of chronic diseases and the lack of availability of reliable exposure data and comprehensive population data. Most available studies are descriptive and ecologic in nature in that they are not well controlled, without quantitative exposure variables, and not prospective in design. Most studies are mortality studies (fatal cases). There is little data on cancer morbidity, that is, counts that include cancer survivors, those living with cancer or treatable cancers where people may die of co-morbidities rather than the cancer itself. More morbidity data are therefore needed to determine the overall cancer burden on the farm population. To identify risk factors, accurate quantitative exposure data are required that may be applied to more detailed analyses such as prospective, case-control, and logistic regression studies. Also, there is abundant information that often multiple agents and co-factors (e.g., genetic and lifestyle factors) coalesce, resulting in cancer. Designing and conducting epidemiologic studies to control for these numerous variables is challenging, and few such studies are available at this time. However, there have been notable studies in the United States within the past two decades that have been designed to address these deficiencies (1, 2). The Agricultural Health Study (AHS) (2–6) is the most comprehensive study of cancer in farm populations that has been accomplished to date. The AHS is a prospective cohort study that in 1993 began to collect associated exposure data. The study team enrolled 89,658 people in Iowa and North Carolina who took the US EPA training and examination to obtain the certificate required to acquire and apply restricted-use pesticides. The cohort consisted of 52,395 applicators (farmers), 32,347 of their spouses, and 4916 commercial applicators (most are farmers). Future plans for the AHS include continued data collection and follow-up for health outcomes for the foreseeable future (expected to continue to at least 2018). Table 5.1 depicts the leading causes of fatalities in the AHS cohort over the 14-year period from 1993 to 2007 (3, 4). Non-cancer illnesses (e.g., heart disease and diabetes among others) accounted for 56.2% of the fatalities. Unintentional injuries of all types and sources accounted for 10.2% of the fatalities. The remaining 33.6% of fatalities were caused by cancer. A comparative estimate of fatalities in the general population suggest the AHS cohort is relatively lower in non-cancer illness, lower in unintentional injuries by 8%, and lower in cancer deaths by about 10% (7).

The leading cancer deaths in the AHS cohort are from lung cancer (25.4% of cancer deaths, 8.5% of all deaths) and intestinal

Table 5.1 Cancer and other leading causes of mortality in the Agricultural Health Study 1993–2007

Cause of mortality	*n*	All cancer fatalities (%)	All fatalities (%)
Injuries	496		10.2
Illness (non-cancer)	2,743		56.2
Cancer total	1,641		33.6
Cancer type			
Lung	417	25.4	8.5
Intestinal	190	11.6	3.8
All lymphatic and hematopoietic	238	14.5	4.9
Leukemia	91	5.6	1.9
Non-Hodgkin's lymphoma	90	5.5	1.8
Multiple myeloma	52	3.2	1.1
Hodgkin's lymphoma	5	0.3	0.1
Prostate	171	10.4	3.5
Pancreas	103	6.3	2.1
Kidney	71	4.3	1.5
Brain	59	3.6	1.2
Liver and gall bladder	50	3.1	1.0
Urinary bladder	35	2.1	0.7
Stomach	26	1.6	0.5
All other cancers	281	17.1	5.8

Pesticide applicators: n = 57,310.
Fatalities: n = 4880.

Table 5.2 Cancers with decreased mortality and incidence ratios in the Agricultural Health Study relative to the general population (1993–2007)

Cancer type	Cancer fatalities (n) in 57,310 member cohort	SIR	SMR
All cancers	1626	0.85[a]	0.61[a]
Lung	417	0.48[a]	0.43[a]
Urinary Bladder	35	0.59[a]	0.55[a]
Liver and gall bladder	50	0.73	0.70[a]
Oral (buccal, pharynx)	16	0.56[a]	0.34[a]
Esophagus	48	0.64[a]	0.51[a]
Intestine	158	0.87[a]	0.75[a]
Rectum	32		0.69[a]
Pancreas	103	0.72[a]	0.75[a]
Prostate	171	1.19[a]	0.81[a]
Brain	59	0.78	0.76[a]
All lymphatic and hemopotetic	238	0.98	0.88[a]

SIR, standard incidence ratio (number of cases compared to that expected for the general population).
SMR, standard mortality ratio (number of fatalities compared to that expected for the general population).
[a] $p \leq 0.05$.

cancer (11.6% of all cancer deaths, 3.8% of all deaths). Cancers of the blood and lymphatic system are the third most common cancer causes of death (14.5%) followed by prostate (10.4%), pancreas (6.3%), kidney (4.3%), and brain (3.6%). However, there are significant differences in the rates of these cancers and other cancers compared to the general population. The overall cancer mortality among farmers has been shown to be lower than comparison populations in many studies in the United States and other developed agricultural countries. The AHS findings from the United States help to quantitatively define these differences, as shown in Table 5.2 (3, 4).

The overall standardized mortality ratio (SMR) in the AHS cohort for cancer fatalities is 0.61 and the standard incidence ratio is 0.85 (2, 6) (this means that cancer fatalities are 39% less common compared to the general population, and cancer occurrences (including cancer survivors and those living with cancer) are 15% less common). The overall cancer burden among farmers is lower primarily because the most common fatal cancer (lung cancer) is reduced, lowering the overall cancer mortality rate.

Table 5.2 lists the cancers for which the farm population is at lower risk (3, 4).

However, there are certain cancers for which the farm population has increased risks (Table 5.3; 3, 4). Similar cancer patterns as described above exist in farm populations in other industrialized (1, 6, 8–12) countries. Data from the AHS indicate that the lowered lung cancer mortality in farmers explains 60% of the overall lowered cancer deaths relative to comparison populations (1, 4). Although lung cancer is lower, it still is the number one cause of cancer deaths in the farm population, accounting for over 25% of the total cancer deaths (4, 6), which suggests that prevention must target lung cancer as well as other cancers. There are several less common cancers that also cause lower mortality in the farm population, including urinary bladder, liver, oral, esophagus, intestinal, rectum, pancreas, brain, prostate and

Table 5.3 Cancers of increased incidence and mortality ratios in the Agricultural Health Study (1993–2007)

Cancer type	SIR	SMR
Lip	1.30	Not reported
Ovary	2.45[a]	1.61
Multiple myeloma	1.20	1.01
Eye	Not reported	1.98
Thyroid	0.98	1.53
Prostate	1.19[a]	0.81[a]

SIR, standard incidence ratio (number of cases compared to that expected for the general population).
SMR, standard mortality ratio (number of fatalities compared to that expected for the general population).
[a] $p \leq 0.05$.

blood and lymph tissue. The incidence of these cancers generally tracks the mortality ratio, except for prostate cancer where the incidence (but not mortality) is higher compared to the general population (3, 4, 8, 9). This suggests that either prostate cancers are less malignant in farmers or they receive more effective curative care. It is unlikely that the difference is due to the latter; the case history in the introduction is an example of the general late arrival to diagnosis and treatment of farmers.

Although farmers may experience decreased overall cancer mortality due to lung and several other cancers, there are several cancers for which they suffer excess morbidity and mortality. The specific cancer risk rates vary to some degree between studies. However, the combined results of these studies corroborate the increased risk for the following cancers: (1) leukemia, (2) non-Hodgkin lymphoma, (3) Hodgkin lymphoma, (4) multiple myeloma, (5) skin cancers (including squamous cell carcinomas (SCCs) and basal cell carcinomas (BCCs), lip cancer, and melanoma), (6) soft tissue sarcoma, (7) prostate cancer, (8) testicular cancer, (9) brain cancer, and (10) stomach cancer (3, 4, 8–11). Although these findings are quite consistent among studies in industrialized countries, these cancers (with the exception of prostate cancer) are not common cancers. Furthermore, the relative risks of these cancers are generally not great, ranging from 20 to 200% above comparison populations, with risk rates generally near the lower limit of this range. Table 5.3 depicts those cancers of increased morbidity (incidence) and mortality in the AHS (3, 4). These data indicate statistically increased incidence (SMR 2.45) and mortality (SMR 1.61) for ovarian cancer, and increased incidence of prostate cancer (SMR 1.19), but not increased mortality (0.81). Increased incidence and/or mortality (but not statistically significant) were seen for lip, multiple myeloma, eye, and thyroid cancer.

There are some minor differences in the cancer statistics in the AHS compared to other studies (2, 3). For example, in the AHS there was no increased incidence found for some cancers although other studies revealed increased rates for Hodgkin lymphoma, non-Hodgkin lymphoma, leukemia, brain cancer, and lip cancer. AHS results revealed in women an increase in ovarian cancer (not generally seen in other studies). There was an interesting comparison of the applicator (farmer) group to the commercial pesticide applicators in this study. The latter had almost identical cancer rates and patterns to the general population, but their average age was younger, and tobacco and alcohol use were similar to the general population, but higher than the farm cohort (1, 2, 5, 6, 9, 12–14).

The less common cancers (not counting lung and intestine) in the farm population (AHS applicators) accounted for 63% of the total cancer deaths. The implications of this are relevant to prevention in that a focus on these less common cancers is important in addition to lung and colon cancer in order to have a potential impact on the overall cancer burden of the farming population.

There are apparent lifestyle and other cancer-protective factors in the agricultural populations that mask the magnitude of the burden of cancer to famers (relative to comparisons to general populations). Waggoner compared cancer

Table 5.4 Causes of cancer deaths relative to all causes of death in the Agricultural Health Study

Type	rSMR
All cancers	1.20[a]
Eye	3.69[a]
Ovary	3.00[a]
Thyroid	2.85[a]
Multiple myeloma	1.89[a]
Kidney	1.62[a]
Leukemia	1.59[a]
Non-Hodgkin's lymphoma	1.57[a]
Prostate	1.53[a]
Melanoma	1.42[a]
Brain	1.42[a]
Intestine	1.41[a]
Pancreas	1.40[a]
Lung	0.78[a]

rSMR, relative standardized mortality ratio.
[a] $p \geq 0.05$.

mortality to all causes of death in the AHS cohort (4). Table 5.4 lists computed relative standard mortality ratios (rSMR) comparing the observed cancer fatalities to all causes of fatalities in the AHS cohort (4). This gives a picture of the relative burden of cancer compared to other causes of death. It can be seen that many of the cancers that were not statistically significant compared to the general population, and were in fact relatively more significant causes of death within the AHS cohort. The overall rSMR for all cancers is 20% higher within the farming cohort, led by ovarian, thyroid, eye, multiple myeloma, kidney, leukemia, non-Hodgkin lymphoma, and prostate cancers. These data provide additional insight as to which cancers to include in education and prevention efforts.

5.1.2 Trends

As there has been tracking of cancers in some populations for over 30 years, some trends have been noted. Since the 1970s, data from the Iowa cancer registry and the AHS in rural and agricultural populations has evidenced a decreasing trend in stomach cancer, with relative rates dropping from 1.14 to 1 in the 1990s and a slight downward trend with leukemia. There has been an increase noted over this time in cancer of the prostate, large intestine, pancreas, non-Hodgkin lymphoma, and multiple myeloma (1). There are some similarities to cancer trend patterns in the general population, as noted by some evidence of increased rates in prostate, all skin cancers, non-Hodgkin lymphoma, multiple myeloma, and brain cancer. It is interesting to note that the trend in the farm population appears to parallel to some degree the trend in the general population. It would therefore appear that there are some shared risk factors of the farm and general populations. Some of the trends have an obvious explanation, for example Milham (14) reported an increase in lung cancer in the 1970s–1990s in Washington state orchard workers. This excess was related to the use of inorganic arsenical pesticides. However, these have not been used since the 1950s, and that risk factor and the excessive lung cancers in that sub-population have now diminished. Similar changes in the use of other chemicals may be responsible for the observed trends. For example, many organochlorine and organophosphate insecticides (of which several have shown associations with certain cancers) have been banned or severely restricted in usage, replaced by less toxic products (e.g., pyrethroids and neonicotinoids). Matching surveillance trends with current chemical usage patterns may reveal important associations. Monitoring trends in cancer incidence is very important to assist scientists as to the direction of research and preventive practice. Blair and colleagues (15) have made an important argument for prospective cohort studies as these are the best way to monitor trends as well as occupational risk factors for cancers.

5.1.3 Mechanisms of Causation: Protective Factors and Risk Factors

As mentioned above, understanding the causation of cancer involves analysis of the relationships of exposures and outcomes, protective factors, and risk factors.

The protective factors reported in several studies have cited some lifestyle habits among farmers that appear to retard cancer. Cigarette smoking has long been known to be a strong risk factor for cancers of the lung, head and neck, stomach, pancreas, colo-rectal, kidney, bladder, acute myeloid leukemia, uterus, cervix, and ovary (16). Long-term cigarette smokers (compared to never smokers) have over 25 times the risk of acquiring lung cancer and five times the risk of acquiring one or more of the other smoking-related cancers (17). As for farmers, lower smoking rate has been cited numerous times as a major protective behavior. Farmers in most developed agricultural communities smoke significantly less than the general population. For example, in the Iowa AHS cohort, 11.3% were current smokers at time of enrollment (1993–1997) (3) compared to 20.5% of the 2014 US general male population. Other surveys of smoking prevalence among farmers range from 50% less to nearly 66% less. Several authors use this difference to explain the relative decrease in smoking-related cancers (6, 8, 11, 18, 19).

An additional lifestyle protective factor is the decreased use of alcohol relative to the general population (6). It has been shown that the combination of smoking and alcohol is a risk factor for head and neck and esophageal cancer (16). Several other authors have also identified a decreased use of alcohol among farmers associated with a decrease in overall cancer rates (1, 11, 20). Others propose that increased physical activity among the farming population is also protective for cancer, especially for colon cancer. Other cancers have also shown a decrease relative to exercise including lung, mouth and throat, liver, pancreas, bladder, and kidney (6).

Others have suggested that the dietary habits of farmers are protective of cancer. Increased consumption of fresh fruits and vegetables and higher fiber diets contribute to cancer protection. Farmers generally have a higher caloric intake, but their body mass index is quite similar when compared to the general population. A recent study revealed that farmers have lower cholesterol, blood pressure, and resting heart rate relative to the general population (21). These data suggest that farmers are more physically fit due to greater amounts of exercise/work, compensating for higher caloric intake. Farmers receive a higher percentage of calories from protein, and proportionally a higher percentage of that protein comes from red meats (suggesting they have less caloric intake from monosaccharide carbohydrates in their diet). Although they have a lower intake of vegetables, they have a higher intake of fruits. Their fiber intake is slightly higher. Although exercise and diet appear protective, obesity rates (greater than BMI of 30) appear to be similar to those of the general population (22). Several studies suggest an association of obesity as young adults is a risk factor for two agricultural-associated cancers: multiple myeloma and bowel cancer (23, 24).

One interesting hypothesis for an alternative or additional protective factor for cancer in the farm population is exposure to endotoxin. As discussed in Chapter 3, endotoxin is a component of the cell membrane of Gram-negative bacteria and is found in high concentrations of most agricultural dusts. Endotoxin is a strong inflammatory substance. When inhaled, endotoxin can cause respiratory and generalized symptoms. Mastrangelo (25) conducted a comparison study of cancer outcomes in dairy farmers, comparing their outcomes to cancer outcomes in crop farmers and orchardists. They found that overall lung cancer in dairy farmers was reduced relative to the comparison groups. Furthermore, there was a greater decrease in lung cancer as the length of time in dairy farming increased and the amount of land associated with the dairy farms increased. The authors interpreted these exposure measures as surrogates for increasing endotoxin exposure, and thus protective for lung cancer. They hypothesized that endotoxin exposure increased tumor necrosis factor from the stimulated alveolar macrophages, retarding the development of lung cancer cells. Lange (26) supports this hypothesis, noting that endotoxin is an immunomodulator, which not only stimulates production of tumor necrosis factor but activates lymphocytes and prevents cancer by that mechanism, especially lung cancer.

5.1.4 Mechanisms of Cancer Causation

It must be noted that cancer is not just one disease, but many diseases. Each cancer type has its own biology, which means there may be several mechanisms and risk factors. Several general hypotheses of cancer causation exist, including immunotoxicity (certain chemicals disturb the normal ability of the innate immune system to detect and attack cancer cells), genotoxicity (damage to the DNA of normal cells, turning them to cancer cells) (6), chronic inflammation, oxidative stress, and chromosomal aberrations (27). One type of chromosomal aberration is shortening of telomere length. Telomeres are nucleotide chains at the end of chromosomes that prevent chromosomal dysfunction during cell division. Although telomeres shorten with each cell division, cancer agents may enhance the normal (aging) shortening of telomeres, leading to cancer (27).

Even with some understanding of the general biological mechanisms of cancer causation (as previously mentioned), establishing specific occupational causation and risk factors is a difficult job. Information to establishing causation in populations requires numerous repeated and controlled epidemiologic studies, quantitative exposure assessment, biological plausibility, and biological in vitro and or in vivo studies. Although numerous studies have been performed, occupational cancer causation in the farming population remains only partially defined. The following pages will review some of the essential epidemiological research associated with cancer in agricultural populations.

5.1.5 Known and Potential Cancer Agents in Farming Populations

Well over 300 papers have been published in the past decade that have found associations with cancer to a diverse array of chemicals and other agents. However, associations are not necessarily cause-effect, which adds to the complexity of interpreting the available data relative to recommending preventive measures.

The primary class of potential farm-related agents investigated has been pesticides. However, there are many other potential agents (besides pesticides) used in agriculture that present confounding complications in epidemiologic studies (28). There is a need to evaluate the plethora of available data in a meta-analysis process to determine the weight of evidence for causation, as has been done for certain cancers by individual investigators. In a broader approach to this task the International Agency for Research on Cancer (IARC) of the World Health Organization, an inter-disciplinary organization, has brought together skills in epidemiology, laboratory sciences, and biostatistics to identify in a comprehensive way the causes and prevention of cancer. IARC publishes reference materials, including a broad analysis of available research, via a strict protocol to identify potential cancer agents and classify them according to weight of evidence relative to causation. The results are relatively conservative as it takes significant evidence from several fields of research to classify specific agents as cause-effect for cancer. Table 5.5 lists possible agents (selected from the larger general IARC list as substances with potential occupational exposures to farmers) (28). Only eight substances with possible occupational exposures to farmers are listed in Group 1 (human carcinogens):

1. *Ultraviolet radiation* (sun and arc welding): It is clear that chronic sun exposure is related to non-melanotic (BCCs, SCCs, and lip) skin cancers. There is evidence that chronic sun exposure may also be a risk factor for melanomas in some regions (such as in Sweden) (9) or with a particular type of melanoma (lentigo) (16). However, most melanomas generally appear to be associated with frequent sunburn at an early age (16).
2. *Aflatoxin*: Aflatoxin is a mycotoxin produced by the fungus *Aspergillus flavus*, known to be carcinogenic to the liver in animal studies. Exposure potential is primarily from ingestion of moldy grain. Occupational exposure could come from inhalation of dusts from moldy grain. There are numerous mycotoxins produced by various

Table 5.5 International Agency for Research on Cancer (IARC): classification of cancer agents that may be found in a farming environment

Carcinogens to humans (IARC Group 1)	Comment	Probably carcinogenic to humans (IARC Group 2A)	Comment	Possibly carcinogenic to humans (IARC Group 2B)	Comment
Aflatoxin	Possibly found in spoiled grain or hay	Captafol	Fungicide banned in 1987	Chlorphenoxy herbicides	Dioxin-tainted products are the concern
Inorganic arsenic pesticides	Banned since 1950s	Creosote	Wood preservative often used for wooden fence posts		2,4,5-T banned in 1985
Diesel exhaust	Most modern farm tractors and harvesters are powered by diesel		Found in nitrogen fertilizers and livestock waste		2,4-D still used, with below toxic dioxin levels
Formaldehyde	Used occasionally as a foot bath to prevent foot rot in cattle and sheep or as a fumigant	Nitrate	May be ingested in contaminated well water	Fungal mycotoxins Fumonsin, T-2 toxin	May be found in spoiled grain or animal feed
		Non-arsenical insecticides (not further specified)	May include spraying of cholinesterase or chlorinated hydrocarbons		
Helicobacter pylori	A zoonotic bacterium common in pigs may cause stomach cancer			Gasoline	Used for Farm Machinery Fuel
				Iron dextran	Used for iron supplement in baby pigs
		Glyphosate (trade name Roundup)	A herbicide extensively used on GMO corn, soybeans, and cotton (internationally)		
Schistosoma haematobium	A protozoan parasite found in Asian rice paddies			*Shistosoma japonicum*	A protozoan parasite found in Asian rice paddies
Dioxin	Former contaminant of the herbicides 2,4,5-T and 2,4-D (2,4,5-T now banned)		Animal studies suggest carcinogenesis, but no human cancer association risks found so far	Welding fumes	
				Captan	Fungicide
				Maleic hydrazine	Herbicide
				Methyl iodide	Soil sterilant
				Methyl parathion	Oganophosphate
				Permethrin	Insecticide
				Thiram	Fungicide
				Ziram	Carbamate fungicide

The following agents have been regulated to severe restricted use or banned (date) by the US EPA, EU, and other major agencies:
Group 1 agents: inorganic arsenic herbicides, pesticides (banned c. 1955).
Group 2A agents: captafol, a fungicide (banned 1987).
Group 2B agents: herbicides 2,4,5-T (banned 1985), trifluralin (banned in EU 2007); insecticides mirex (banned 1976), toxaphene (banned 1990), aldicarb (banned 2010), aldrin (banned 1970), dieldrin (banned 1987), endrin (banned 1980), methyl bromide (banned 2000), parathion (banned in 50 countries); fungicides maneb (banned in EU 2009), zineb (banned in EU 1997).
Data from the International Agency for Research on Cancer (IRAC), 2014, http://monographs.iarc.fr/ENG/Classification/.

mold species. A plausible carcinogenic mechanism is that mycotoxins may alter the immune system, allowing cancer cells to persist (29), but inhalation exposure and associated cancer has not been shown.

3. *Inorganic arsenical pesticides*: Inorganic arsenical pesticides and herbicides are known causes of lung cancer and skin cancer (16). However, these chemicals have been banned since the 1950s, and so that occupational risk has been removed from the farming population (14).
4. *Diesel exhaust fumes*: Diesel exhaust fumes contain polycyclic aromatic compounds which affect the immune system by decreasing IgG and IgA antibody production. Diesel exhaust fume exposures have been associated with lung cancer. Exposures in farming can occur while operating most modern tractors and harvesters as they are commonly powered by diesel engines.
5. *Formaldehyde*: Formaldehyde is occasionally used as a footbath for herd treatment and prevention of foot and hoof infections, primarily for dairy cattle and sheep, but also occasionally for goats and pigs. A container with 5% formalin and perhaps other biocides is placed an area where the animals have to regularly walk through it. The use is to prevent or control infections of the hoofs, interdigital space, and feet. The primary condition of cattle and sheep is called foot rot, caused by different bacterial agents. Another foot disease of dairy cattle is hairy heel wart. An additional (but less common) farm usage of formaldehyde is as a fumigant in swine or poultry buildings.
6. *Helicobacter pylori*: Farmers can be exposed to *Helicobacter pylori*, a bacterial agent known as the cause of stomach ulcers and possible stomach cancer in humans. Pigs also harbor this agent, which is thought to be a zoonotic agent.
7. *Schistosoma haematobium*: *Schistosoma haematobium* is a protozoan parasite found in Africa and the Middle East that can infect farmers and fishermen through water contact. Chronic infection has been associated with bladder cancer.
8. *Dioxin*: Dioxin has been noted as a cause of several types of cancers in humans. Dioxin was found to be a manufacturing contaminant of the phenoxyacetic acid herbicides 2,4-D and 2,4,5-T, which are commonly used broad-leaf herbicides. Use of these herbicides has shown associations with soft tissue sarcoma and non-Hodgkin lymphoma. The data on this subject are not consistent, but the herbicide 2,4,5-T has been banned. The manufacture of 2,4-D has been improved to reduce dioxin contamination to sub-toxic concentrations.

IARC Group 2A (less evidence of carcinogenicity) includes four probable agents that could have occupational exposures for farmers. *Captafol* is a now-banned fungicide. *Creosote* is a distillation product of wood or coal tar, used as wood preservative among other things. Farmers can be exposed by handling treated wooden fence posts or animal topical medicines that contain creosote. Experimental animals exposed to creosote have developed skin cancer. *Nitrates* are common contaminants of surface and shallow water wells (which may be drinking-water sources in farming areas) due to run-off contamination from fertilizers or animal wastes. Atrazine (a corn herbicide) may be an accompanying contaminant. Atrazine and nitrate may combine in the acid medium of the stomach to produce nitrosamines, which are known carcinogens (18). Some *non-arsenical pesticides* are also listed in Group 2A. Although most of those chemicals have been either banned or severely restricted in usage, the organophosphate insecticides malathion and diazion, as well as the herbicide glyphosate, remain in use. These exposures will be discussed in more detail below. IARC also lists 13 substances in the Group 2B (possible carcinogens) that may have farm exposures. Table 5.5 lists these possible agents and how farmers might be exposed.

5.1.6 Animal Exposures as Possible Cancer Hazards

Animal contact has been associated with a variety of hematopoietic cancers in farm populations. These associations have been seen with cattle, chickens, cats, and pigs (11). The first three of these species have well-described tumor viruses, and several studies have led to hypotheses that these animal tumor viruses may infect humans, causing cancer. Associations with cattle tumor viruses have been studied most extensively. The most common cancer in cattle is bovine lymphosarcoma (BLS), which is caused by a virus very similar in genetic sequence to the human type 2 leukemia and HIV viruses. Ecologic associations of human leukemia (particularly acute lymphocytic leukemia) have been seen with dairy farming (20). The incidence of leukemia has been shown to be higher in areas of high dairy cattle density, and with increased prevalence of diagnosed BLS in the cattle population (30, 31). The incidence of BLS virus infection in dairy herds is quite high, with about 30% of the herds infected in some regions (compared to about 1% of beef herds). However, only a small percentage of infected cattle develop BLS in their lifetime. (It should be noted that beef and dairy cattle are usually killed well before their natural life span, so it is not known how many of these infected animals might have developed BLS if allowed to live longer). It is also clear that the BLS virus is shed in the milk of infected cattle, even in infected animals that are clinically normal (32). Furthermore, it is common practice that dairy farm families drink unpasteurized milk from their herds (32). Experimental infections of non-human primates with BLS-virus have provided evidence that they become infected (antibody titer rise over time) and have shown an altered neutrophil to lymphocyte ratio. Although no cancer was documented in these animals over the course of the study, one of the chimpanzees developed leprosy. This was the first case of leprosy diagnosed in any non-human animal other than armadillos (33). The authors of this study hypothesized that this virus damaged the cellular immune system of the affected chimpanzee, allowing a latent form of leprosy to manifest clinically. A new hypothesis was therefore developed that these animal tumor viruses (at least BLS virus) may indirectly be a risk factor by damaging the cellular immune system. This hypothesis has not yet been tested.

5.1.7 Pesticides as Potential Carcinogens

Pesticides have been a research focus as potential carcinogens for several decades. As of January 2015, over 213 peer-reviewed publications have arisen from the AHS alone. Many of these publications have described various pesticide exposures associated with an increased risk of certain cancers for farmers. Table 5.6 lists the associations that have been described in the AHS along with other potential cancer association abstracted from studies other than the AHS, and from several other countries (13, 34, 35).

Organophosphate insecticides have shown up in many studies as associated with leukemia, non-Hodgkin lymphoma, soft tissue sarcoma, and pancreatic cancer. Chlorinated hydrocarbon insecticides are thought to be endocrine disrupters and thus related to genitourinary tumors. It should be noted that most organochlorine insecticides have been banned or severely restricted in their licensed usage since the 1970s because of their persistence in the environment. Also, many organophosphate insecticides have been banned or severely restricted because of their acute toxicity and in some cases chronic toxicity. Organochlorines, organophosphates, and carbamate insecticides have been replaced in many instances by two less toxic classes of insecticides, pyrethroids, and neoticotinoids. To date, very few papers have been published reporting associations of these latter chemicals with cancer. The following paragraphs provide some details of associations of potential agents (mainly pesticides) with specific cancer types.

5.1.8 Details of Epidemiology and Agricultural Risk Factors for Specific Cancer Types

Cancers of the Lymphatic and Hematopoietic Systems

An excess of hematopoietic cancers in the farm population is has been shown consistently

Table 5.6 Substances suggestive of associations with human carcinogenicity

Cancer site	Pesticides (type/class)	Other exposures
Prostate	Aldrin (I/OC)[a,b]	Endocrine disruptors (e.g., dioxine)
	Butylate (H/C)	Diet: high fat, low fruit and vegetables
	Chlordecone (I/OC)[a]	Family history of prostate cancer
	DDT (I/OC)[a,b]	Family history plus fonofos exposure
	Fonofos (I/OP)	
	Lindane (I/OC)[b]	
	Malathion (I/OP)[b]	
	Simazine (H)[b]	
	Terbufos (I/OP)[b]	
	Methyl bromide (I, fumigant)	
	Permethrin/pyrethrum (I)	
	Mirex	
	Toxaphene	
	Parathion	
	DDT	
Lung	Chlorpyrifos (I/OP)	Smoking tobacco
	Diazinon (I/OP)[b]	Diesel exhaust
	Dieldrin (I/OC)[a,b]	
	Acetochlor (H)	
Pancreas	DDT (I/OC)[a,b]	
Colon	Aldicarb (I/C)[a,b]	Diet: low fiber
	Dicamba (H)	Raising poultry
	EPTC (H)	
	Imazethapyr (H)	
	Trifluralin (H)[a]	
	Acetochlor (H)	
Rectum	Chlordane (/OC)[a,b]	Diet: low fiber
	Chlorpyrifos (I/OP)	
	Pendimethalin (H)	
	Dieldrin (I/OC)[a,b]	
	Acetochlor (H)	
Multiple myeloma		Raising sheep
Leukemia	DDT (I/OC)[a,b]	Livestock exposures,
	Diazinon (I/OP)[b]	Animal tumor viruses (cattle, cats, chickens)
	Terbufos (I/OP)[b]	
Bladder	Imazethapyr (H)	
Skin melanoma	Carbaryl (I/C)[b]	Frequent sunburn at an early age
	Maneb/Mancozeb (F/C)[b]	Chronic sun exposure for lentigo melanoma
	Parathion (I/OP)[a,b]	
Basal cell and squamous cell sarcoma		Chronic sun exposure
NHL	Toxaphene (I/OC)[a,b]	Livestock exposures; raising poultry; animal tumor viruses (cattle, cats, chickens)
	Chlordane (I/OC)[b]	
	Lindane (IOC)[b]	
	2,4-D and 2,4,5-T (H)	
Soft tissue sarcoma	2,4-D and 2,4,5-T (H)	
Testicular		Fertilizer and pesticide application by male parent
Brain	Insecticides (OC)	*Toxoplasma gondii* infection
Stomach		Ingested nitrates

I, insecticide; H, herbicide; F, fungicide; C, carbamate; OC, organochloride; OP, organophosphate.

[a] Substances banned or severely restricted by the US EPA.

[b] Substances banned or severely restricted by the EU.

among epidemiologic studies across countries with developed agricultural systems. Leukemia, Hodgkin lymphoma, non-Hodgkin lymphoma, and multiple myeloma are typically elevated in most studies. Elevated rates for these specific cancers have been relatively consistent over many years of investigations, with no evidence of a trend upwards or downwards (8). Recent research has been refined as different degrees of pesticide associations have been shown with different subtypes of non-Hodgkin lymphoma (36, 37). Furthermore, an association has been identified between pesticide exposure to presence of a precursor to multiple myeloma (monoclonal gammopathy of undetermined significance) (38). Although results are mixed, several studies have shown that hematopoietic cancers are more common among livestock producers relative to grain or other types of farming (39–41). This has created the hypothesis that the real risk is from chemicals used in livestock production or from animal tumor viruses. However, there appears to be a variance in risk factors between specific cancers of the hematopoietic system. For example, bovine lymphosarcoma virus seems to be more related to acute lymphocytic leukemia, while other studies have shown associations of benzene exposure (a component of gasoline, regulated to 1% or less in the United States and the EU) to myeloid leukemia (31, 42).

Skin and Lip Cancer

Basal Cell Carcinoma (BCCs), followed by Squamous Cell Carcinoma (SCCs) are the most common types of skin cancer. These skin cancers rarely metastasize, rarely cause death, and therefore are rarely reported in cancer mortality epidemiologic studies. It is very clear that long-term chronic sun exposure is the most important risk factor for these skin cancers. They are usually not seen until the sixth decade of life. They occur on highly sun-exposed skin (tips of the ears, nose, cheeks, and back of hands). People with fair skin complexions are at increased risk. Actinic keratosis (AK), also called solar keratosis, are non-cancerous skin lesions also associated with long-term sun exposure (43). They appear as brown scaly patches on sun-exposed skin in the same locations and with the same risk factors as SCCs and BCCs. They appear histologically as lesions of excess keratin cells that retain nuclei (parakeratosis). Although AK are mainly initially of cosmetic concern, they are considered a precancerous lesion mainly for SCC and less so for BCC. The risk for AK proceeding to SCC or BCC is controversial in the literature. Cohen reviewed available data indicating that progression of AK to SCC within 1 year is less than 1% and increases up to 10% in 10 years (43). Progression to BCC is significantly of lower risk. Further details of skin cancers are given in Chapter 4.

SCCs that appear on the lips have a slightly higher probability of metastasizing compared to other locations. Many studies show lip cancer mortality higher in farm populations. Risk factors proposed for lip cancer additional to chronic sun exposure include viral infections, immune deficiencies, and actinic chelitis (the latter is a form of AK that appears mainly on the lower lip) (44).

Several studies have shown that melanoma incidence and mortality rates are increasing in the farm population (9, 16). As previously mentioned, the relationship between sun exposure and melanoma is not as clear as with non-melanotic skin cancers, but sun exposure does appear to be a risk factor.

Prostate Cancer

Prostate cancer in farmers has been extensively studied in recent years. At least two meta-analyses have been conducted (45, 46), plus two large morbidity studies of farmers and pesticide applicators (47–50). Risk factors have focused on pesticide exposures and hereditary influences (50). Possible mechanisms include disturbances of cellular metabolism and hormonal mediation.

Some research evidence suggests an association with the fumigant methyl bromide (12, 47). Methyl bromide has been used to fumigate grain or other produce and to “sterilize” soil for ground crops. In reality only a small percentage of farmers would be exposed to this material today, as it was phased out for most agricultural uses in the United States and most industrialized countries in 2005 as it has some adverse environmental impacts (ozone depletion).

One of the proposed cellular mechanisms includes activation of the protein tyrosine kinase, which is thought to enhance prostate cancer (50). Another metabolic disturbance at the cellular level (which has a hereditary factor) is interaction of certain cholinesterase-inhibiting insecticides and a genetically altered pathway of vitamin D synthesis (51). Vitamin D is a proposed anti-carcinogen because it promotes normal cell division.

Another theory of prostate cancer causation is hormonal mediation. Estrogen is known to be protective for prostate cancer, therefore theoretically anything inhibiting estrogen may increase risk. Dioxin is an estrogen inhibitor and dioxins are found in older formulations of 2,4-D and 2,4,5-T herbicides (2,4,5-T has now been banned and the dioxin content of 2,4-D is strictly regulated). Dioxins bio-accumulate in fat stores and as farmers are known to have higher amounts of animal fats in their diets they may have higher body burdens of dioxin. Grain dust exposure may also slightly increase risk and this may be due to dioxins within grain dust from contamination with previous herbicide applications (52). Other chemicals also mimic steroidal hormones, including mirex, toxaphene, and parathion. Metabolites of DDT alter the metabolism of steroids via the mixed oxidative enzyme system. Other potential dietary risks include increased fat, and decreased fruit and vegetable consumption. (Note toxaphene and parathion have been banned for several years.)

Specific exposures associated with prostate cancer suggested in other studies include certain insecticides in the following classes: organophosphates (malathion, fonofos, turbufos), organochlorines (aldrin, dieldrin), and pyrethroids (specifically permethrin) (49). (Note that turbofos, aldrin, and dieldrin have been either banned or severely restricted in registered usage.)

Hereditary factors appear important in the development of prostate cancer, as a positive family history of prostate cancer is a major risk factor. Alavanja and co-workers (12, 47) have shown an interaction between positive family history and exposure to several pesticides (primarily with the organophosphate fonofos). Research reported by Koutros and co-workers provided evidence of a heritable risk factor involving polymorphism of certain genes in combination with exposure to aldrin or malathion, resulting in increased prostate cancer risk (50). Although not consistent, these proposed risk factors appear to increase with age relative to comparison populations (53).

In summary, prostate cancer appears to be related to multiple risk factors in the farming environment. The fumigant methyl bromide and a variety of other pesticide exposures in the cholinesterase, chlorinated hydrocarbon, and parathyroid classes appear to interact with genetic and hereditary susceptibility factors. High-fat diets seem to play a role as well.

Testicular Cancer

There has been an increase in testicular cancer in the past two decades in the general population (54). Generally studies have shown a relative increase in testicular cancer in agricultural populations compared with other occupations (10). A general hypothesis relates risks to early life exposures. To investigate this hypothesis in the farm population, a cohort study of parents and their farm exposures was carried out relative to testicular cancer in their sons. Those exposed to fertilizers compared to non-exposed (relative risk, RR) were found to have an RR factor of 2.4, which rose to 4.2 in non-seminoma tumors. This relative risk is quite large compared to most farm-related cancers, but this is only one study. A likely untested hypothesis based on this one study would be that the exposure to the fathers resulted in DNA damage to the sperm cells inherited by the sons, which increased the risk for testicular cancer. More studies are needed to confirm the association and test a derived hypothesis.

Brain Cancer

Khuder and co-workers (55) conducted a meta-analysis of 33 epidemiologic studies of brain cancer in farmers. They found an overall RR of 1.3, with a confidence interval (CI) of 1.09–1.56. A greater risk was reported in studies within the central regions of the United States. Relatively little research data are available for risk factors and mechanisms of brain cancer in farmers. However, Thirugnanam and colleagues (56) hypothesized that a risk of brain cancer may be related to infection with *Toxoplasma gondii*. This single-cell intracellular protozoan parasite has a predilection for nervous tissue and infection of brain cells results in some genotoxic or immunotoxic mechanisms effect, resulting in formation of the tumor. An alternate hypothesized mechanism of brain cancer causation is possible chronic carcinogenic effects of organochlorine and/or organophosphate insecticides on nervous tissue (8). A summary of exposures and reported risk factors is given in Table 5.6.

5.1.9 Cancer in Special Agricultural Populations

Although most cancer research among farming population has been conducted among principal operators (which are predominantly white males), more recent research has been conducted to provide some insight into cancer risks for women, children, and migrant seasonal workers in agriculture.

Cancer in Farm Women

Generally the research is fairly positive regarding farm women's cancer experience. Overall, similar to farm men, farm women experience less cancer, as reported risk rates are 8–40% lower than in comparison populations (4, 11, 19, 57). The main cancer risk deficits are for lung, breast, cervical, and ovarian cancer (19, 20, 57, 58). However, recent reports from the AHS show an increased risk for ovarian cancer in female pesticide applicators (3, 4), but this was not seen in other female farmers or in the spousal population of farmers (6). The overall decrease is likely related to lower cigarette smoking. Within the population of female farmers there have been reported associations of organochlorine insecticides and triazine herbicide (e.g. atrazine) exposure to breast cancer and ovarian cancer (8). There is little further evidence for other occupational or environmental exposure risks for cancer in farm women, with the exception of one study which suggests about a 50% increase in risk for non-Hodgkin lymphoma (57). This suggests that women may experience similar exposure risks as men, and further research is warranted.

Cancer in Farm Children

Cancer is rare in children and this makes it difficult to identify a large enough cohort with agricultural exposure information to obtain reliable risk estimates. Future research with the International Coalition of Prospective Agricultural Health Studies consortium (AGRICOH) may provide sufficient numbers for statistical confidence (59). (AGRICOH is an international consortium that aims to join data sets to achieve more robust studies with rare cancers and small populations.) However, some research evidence suggests that farm children may be at increased risk for certain cancers, including Ewing's bone sarcoma, Wilm's sarcoma (30, 60), Hodgkin lymphoma, leukemia, and brain, testicular, and eye cancers (30, 61). Several studies have suggested increased cancer risks for young children associated with their fathers' exposure to work in horticulture, poultry production, or with pesticides (30). Brain cancer in children has been associated with pig farming and pesticides (30, 62). Leukemia has been associated with pesticide exposure (62) and in one study with a specific pesticide used in orchards, propargite (61). Kidney cancer has also been associated with pesticides (62). An extensive Australian study of parental exposures and risk of Ewing's sarcoma in children revealed that farm residency of parents was a possible significant risk factor. However, this study did not identify specific agents. A review of childhood cancers from the AHS revealed slight increases in children for all lymphomas (SIR 2.18, 95% CI 1.36–4.10) and non-Hodgkin lymphoma (1.98, 95% CI 1.05–3.76) (60). There was a small risk associated with these cancers for the children of fathers who did not use gloves when handling pesticides.

To summarize, at present there are indications for small risk factors for certain cancers in children (30, 54, 61–66). Pesticides are the most common exposure source cited, but animal and presumptive animal tumor viruses may also be possible sources. The mechanisms include some form of genotoxic damage to the germ cells of the parents, or congenital damage to the fetus. This hypothesis has arisen from studies of associated parental exposures and childhood cancers. However, there could also be associations of environmental or occupational exposures in later-age onset of tumors.

Cancer in Hispanic Farm Workers

There are little data available regarding cancer patterns among Hispanic farm workers. These cancer patterns do not mirror those for farm owners/operators, as lung and prostate cancers seem to be much more important. The available literature is reviewed and summarized in Chapter 2.

Cancer in Selected Farming Subpopulations

Cancer has been studied in a few agricultural subpopulations, revealing cancer risks and patterns common to the general agricultural community. Sugarcane production workers in Puerto Rico have a high risk of oral cancer. The relative risk is 4.4 compared with other populations (67). There have been no particular risk factors identified for the high risk of oral cancer in this subpopulation, but it is probably related to personal behaviors, such as tobacco or other substance use, perhaps in combination with other occupational exposures.

A French research paper noted an increasing bladder cancer gradient from the north to the south of France. As vineyard production is greater in the south of France compared to the north, a hypothesis was investigated that vineyards and pesticide exposure were an explanation for the observed gradient. An epidemiological study showed a slightly elevated association of bladder cancer to vineyard production and pesticide use, with a standardized mortality ratio of 1.14 (CI 1.07–1.22). A stated hypothesis was that the vineyard workers had higher pesticide exposure, leading to the observed increased bladder cancer. Although bladder cancer incidence is generally low in the agricultural population, researchers in the United States have shown an association of bladder cancer and proximal bowel cancer with exposure to the herbicide imazethapyr, a heterocyclic amine used in clover and alfalfa, among other tolerant crops (68). Additional research is warranted to further define these relationships.

5.1.10 Social Medicine Aspects of Cancers in Farmers

Briefly addressed in the introduction to this chapter, rural and agricultural populations have a number of social and psychological concerns that healthcare providers should take into consideration when caring for them. Cancer is a frightening word to most people. In fact, 25% of the Anglo farmers and 50% of Latinos consider cancer to be the same as a death sentence (69, 70). There has been much publicity about the adverse health effects of cancer, which weighs on peoples' minds. A Wisconsin study (71) revealed three major themes farmer have concerning pesticide exposure: (1) Do pesticides cause cancer? (2) What other health risks are related to pesticides? (3) Can I sustain the farm with adverse health consequences, or can I farm without pesticides?

Once cancer is diagnosed in a farm family, there are several relationship issues that occur. There are relationship problems that occur between spouses, friends and other family members. A major problem is that women living with cancer do not feel spousal support and understanding of their feelings. Furthermore, there are feelings of loneliness and avoidance by friends and family. These latter problems are worse in women than men. On the other hand, men afflicted with cancer are concerned about their jobs and how they will keep the farm going and support the family (69, 70).

Although overall cancer rates are lower in the farming population generally, cultural, physical, and economic barriers to healthcare services create complications in diagnosing, treating, and preventing cancer in rural and agricultural populations. These complications are:

1. general difficulties with healthcare accessibility in rural areas
2. cultural issues of the farming population, who generally tend not to use medical services unless they are very sick
3. a tendency of avoidance or procrastination for seeking medical care because of fear of a possible diagnosis of cancer
4. cultural and practical considerations that mean farm work and taking care of animals takes precedence over personal health care
5. farm population is an older population so naturally there is more cancer of certain types, creating a concern in the rural population that there are “epidemics” of cancer
6. concern that pesticides may cause cancer, but a need to use pesticides to maintain livelihood
7. little information available for prevention
8. limited options for home-based or outpatient treatment.

Health professionals should consider all the factors mentioned above in the face of a cancer diagnosis in a farm family member. These issues should be discussed with the families and solutions considered. As mental and social healthcare professionals are in short supply in many rural and farm areas, the healthcare provider can seek non-profit organizations or support groups to help these families cope. Agricultural extension services or private non-profit organizations like churches and Agriwellness (www.agriwellness.org) aim to give social and psychological support for the victims of farm injuries or serious illnesses.

5.1.11 Prevention of Cancer in Farm Populations

There is a higher level of prevention of pesticide health hazards than for any other category of occupational hazard. In the United States several federal agencies have special programs of research and prevention for possible pesticide health risks, for example the EPA, USDA, OSHA, NIOSH, NCI, and NIEHS. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), promulgated in 1944 and upgraded in 1972, and has introduced significant pesticide safety practices. The EPA and USDA require and oversee the testing and registration of all pesticides for human and animal health and environmental protection. States must also register pesticides, and their registration requirements may be more strict that the federal requirements. The primary prevention is that any chemical that is to be marketed must have manufacturer proof that it is safe. Surveillance activities review the performance of these products following release, and registration is withdrawn if signs of health or environmental problems appear. (Further details of these regulatory preventive programs are given in Chapter 6). Similar programs exist in most developed countries. There is also a good deal of international cooperation to enhance research, share information, and establish policy through prominent governmental and non-governmental organizations activities such as IARC, AGRICOH (59), and the Stockholm Conference on Persistent Organic Pollutants.

From an individual and clinical practice perspective, the basic methods for prevention of cancer are similar to other preventive strategies in occupational health. These methods include deployment and enforcement of existing regulations, identification and removal of the hazard, substitution of safer products or processes, lifestyle and dietary interventions, proper use of PPE, early detection, and education.

The available information on the risk factors for specific agricultural pesticides that may have associations to cancer is not very detailed. Most of the pesticides that have shown some association to cancer have been banned or limited in their legal usage, as newer and less toxic insecticides (e.g., pyrethroids and neoticotinoids) have taken over the market. However, exposure to all pesticides should be limited, sun exposure to bare skin limited, drinking water must be free of nitrates and atrazine, and exposure to animal tumor viruses minimized. As regulations for worker protection are relatively minimal in agriculture, self/family/employers must self-regulate prevention. Best practise prevention is effected with multimodal methods (discussed in detail in Chapter 15). One thing to recognize is that lung, colon, and prostate cancers have high rates of mortality. Even though lung cancer is not an agricultural risk, establishing lung cancer prevention provides an opportunity for large gains in cancer mortality reduction. As tobacco smoking is a well-known risk factor, prevention in farming communities should include smoking cessation programs. Dietary factors recommended by the American Cancer Society should be emphasized for prevention of breast, colon and prostate cancer. Dietary improvement (as with the general population) remains an area that could help reduce risks. The exercise protective factor advantage among farmers is probably waning as increased mechanization reduces the exercise associated with manual labor. Furthermore, as manual labor requirements are reduced, barriers to exercise include cultural norms that have not included "recreational" and preventive exercise. Rural residents, particularly farmers, lack the available time and facilities for recreational exercise. Lack of exercise may emerge as a risk factor in future years. These authors agree that an important emerging area for preventive intervention is to address the cultural, time, and facilities barriers to recreational and preventive exercise.

Regarding cancer screenings, standard recommendation such as that of the American Cancer Society should be followed (16). For example, women aged 45–54 should have annual breast exams. Women 55 and older should have breast exams every other year. For men, prostate specific antigen (PSA) screening is now not generally recommended by some organizations and physicians because it often leads to unnecessary surgery. Consultation with a physician, including family history considerations, should be considered before PSA testing.

Barriers to cancer screening among the farm population include the cultural practice of this population to use health services mainly for treatment of acute illnesses. Additional barriers identified for cancer screening for the farm population include (1) cost, (2) lack of time off from work, (3) long distance to providers, and (4) self-reliant behaviors (72, 73). Thus, the rural healthcare professional must make a special effort to help increase the degree of current cancer screening in agricultural patients, which should include visual skin cancer screening. Skin cancer prevention is based on preventing sun exposure. One survey of over 1000 farmers and spouses indicated that although nearly 90% of the population knew the long-term consequences of sun exposure, only 40% of men and 65% of women adequately protected their skin from the sun. That survey also revealed that the use of sun protection was directly related to income and education. Few of those surveyed ever had a specific skin examination. Clearly medical practitioners need to encourage routine skin examinations and the routine use of sun protection in their farm patients. Table 5.7 lists key strategies for cancer prevention in farming populations (73–76).

5.2 Summary

Farm populations in the United States and most industrialized countries have a lower overall relative risk for cancer fatalities compared to general populations. The primary reason for this is that farmers have lower rates of the most common fatal cancers, that is, lung and bowel. This difference mainly arises because farm populations generally have lower rates of cigarette smoking, increased exercise, and healthier diets. The farm population also has lower rates for other cancers in addition to lung and bowel, mainly those that are smoking-related (urinary bladder, esophagus, and tongue).

Table 5.7 Common sense approach to cancer prevention in agricultural populations

General lifestyle actions (these references should be reviewed occasionally, as they may change with newer information)	General screening (these are generalized recommendations and the reader is referred to the references for details and updates as they change with newer information)	General environment and agricultural specific preventive actions
1. Refrain from smoking and use of other tobacco-related products. 2. Maintain weight below BMI 30 and preferably 25 or lower without being underweight. 3. Maintain regular physically activity for at least 30 minutes every day. Limit sedentary habits. 4. Avoid sugary drinks and other foods with high simple sugar content and high-energy dense foods. 5. Eat more of a variety of vegetables, fruits, whole grains and legumes such as beans. 6. Limit consumption of red meats (such as beef, pork, and lamb) and avoid processed meats. 7. If consumed at all, limit alcoholic drinks to two for men and one for women a day. 8. Limit consumption of salty foods and foods processed with salt (sodium). 9. Don't use supplements to protect against cancer. 10. It is best for mothers to breastfeed exclusively for up to 6 months and then add other liquids and foods.	1. Yearly mammogram for women over 40–54, and every other year over 55. 2. Pap test every 3 years for women beginning aged 21–29. 3. Pap and HPV testing every 5 years for women aged 30–65. 4. Colonoscopy every 10 years or sigmoidoscopy every 5 years for men and women aged 50 and above. 5. Annual fecal occult blood, fecal immunochemistry, or stool DNA. If positive follow with colonoscopy. 6. Prostate screening should be based on discussion with your provider, as PSA test benefit is in question. For Afro-Americans with family history of prostate cancer, screening may be considered at age 45.	1. Practice regular protection from sun exposure using sun screens and protective clothing, and avoidance of sun (if possible) during midday. 2. Regularly test drinking water for nitrates (at least annually, in the spring). If greater than 10 mg/L, seek and eliminate possible sources of contamination, remediation, and alternative sources. 3. Avoid possible unnecessary exposure to animal tumor viruses (e.g., do not drink unpasteurized milk). 4. Substitute less toxic chemicals for those with some evidence of human cancer associations (e.g., substitute pyrethroid or neonicotinoid insecticides for organophosphate insecticides). 5. Use enclosed systems for handling and applying pesticides if at all possible. 6. Hire professional certified applicators to apply plant protection products. 7. Review package label instructions on use of agricultural chemicals. Use the PPE specified on the label. 8. Learn and stock (in protected but convenient) PPE for specific uses on the particular farm. Learn how to properly fit and wear the appropriate PPE. 9. Assess the radon level in your basement and call a certified radon remediation technician if greater than 4 picocuries per liter of air.

Breast, liver, and kidney cancer rates are also lower than expected. The farm population is at increased risk, however, for several cancers, including hematopoietic cancers (leukemia, non-Hodgkin lymphoma, multiple myeloma), skin, soft tissue sarcoma, prostate, testicular, stomach, and brain.

Risk factors for agricultural cancers are generally associations and not proven cause-effect. Most research on cancer risk factors has focused on pesticides. The AHS (the largest and longest prospective study to date) has focused on pesticides as well as other potential cancer agents. Associations between several cancers have been seen with one or more specific insecticides, herbicides, fungicides, and fumigants. However, none can be considered cause-effect at this stage. Numerous additional risk associations have been shown, including diesel exhaust, mycotoxins, nitrate- and atrazine-contaminated drinking water, and animal tumor viruses. The only current risk exposure association that shows cause-effect is UV energy exposure (sun exposure).

Some of the rural and agricultural population's cultural, psychosocial, economic, and geographical characteristics can create barriers to clinical screening and health care. These factors create extra challenges for farmers, family members and farm workers who face cancer, and for healthcare providers. Prevention strategies must include management of lifestyle factors, including smoking cessation, increased fiber and fruit in diets, obesity management, and increased regular exercise. Federal and local pesticide and chemical control regulations must be maintained and enforced. Sun protection, drinking water testing, and minimizing pesticide contact are all important factors in prevention.

Key Points

1. The farm population has a 39% lower cancer mortality rate than the general population.
2. Lower lung cancer rates explain about 60% of the cancer sparing.
3. Cancer patterns in farming populations are similar in most industrialized countries.
4. Prevention must include several elements of the rural community that could involve healthcare providers, veterinarians, local public health services, agricultural extension services, pesticide educators, and farm organizations.

References

1. Cerhan JR, Cantor KP, Williamson K, Lynch CF, Torner JC, Burmeister LF. Cancer mortality among Iowa farmers: recent results, time trends, and lifestyle factors (United States). Cancer Causes & Control. 1998;9(3):311–9.
2. Alavanja MC, Sandler DP, Lynch CF, Knott C, Lubin JH, Tarone R, et al. Cancer incidence in the agricultural health study. Scand J Work Environ Health. 2005;31(Suppl.1):39–45;discussion 5–7.
3. Koutros S, Lubin JH, Sandler DP, Hoppin JA, Lynch CF, Knott C, Blair A, Freeman LE. An update of cancer incidence in the Agricultural Health Study. J Occup Environ Med. 2010;52(11):1098–105.
4. Waggoner JK, Henneberger PK, Umbach DM, Blair A, Alavanja MC, Kamel F, et al. Mortality in the Agricultural Health Study, 1993–2007. Am J Epidemiol. 2011;1 (173):71–83.
5. Blair A, Freeman LB. Epidemiologic studies in agricultural populations: observations and future directions. J Agromedicine. 2009;14(2):125–31.
6. Blair A, Sandler DP, Tarone R, Lubin J, Thomas K, Hoppin JA, et al. Mortality among participants in the Agricultural Health Study. Ann Epidemiol. 2005;15(4):279–85.
7. Kochanek K, Xu J, Murphy S, Minino A, Kung H-C. National Vital Statistics report. Deaths: Final Data for 2009. Atlanta: US Center for Disease Control and Prevention, Division of Vital Statistics; 2011.
8. Blair A, Zahm SH. Agricultural exposures and cancer. Environ Health Persp. 1995;103(Suppl.8):205–8.
9. Wiklund K, Dich J. Cancer risks among male farmers in Sweden. Eur J Cancer Prev. 1995;4(1):81–90.
10. Faroy-Menciere B, Deschamps F. Relationships between occupational exposure and cancer of the testis. Ann Med Interne. 2002;153(2):89–96.
11. Pukkala E, Notkola V. Cancer incidence among Finnish farmers, 1979–1993. Cancer Causes Control. 1997;8(1):25–33.
12. Alavanja1 MCR, Samanic C, Dosemeci M, Lublin J, Tarone, R, Lynch C, et al. Use of agricultural pesticides and prostate cancer risk in the Agricultural Health Study cohort. Am. J. Epidemiol. 2003;157(9): 800–814.
13. Alavanja MC, Ross MK, Bonner MR. Increased cancer burden among pesticide applicators and others due to pesticide exposure. Cancer J Clin. 2013;63(2): 120–42.
14. Milham S. Cancer among farmers: A meta-analysis. Ann Epidemiol. 1999;9:71.
15. Blair A, Thomas K, Alavanja MCR, Beane Freeman L, Hoppin JA, Kamel F, et al. Investing in prospective cohorts for etiologic study of occupational exposures. Am J Ind Med. 2015; 58(2):113–22.
16. Tobacco-Related Fact Sheet. Atlanta: American Cancer Society; 2014 (updated 21 February 2014; accessed 21 February 2016). Available from: http://www.cancer.org/cancer/cancercauses/tobaccocancer/tobacco-related-cancer-fact-sheet.
17. Shiels MS, Gibson T, Sampson J, Albanes D, Andreotti G, Beane Freeman L., et al. Cigarette smoking prior to first cancer and risk of second smoking-associated cancers among survivors of bladder, kidney, head and neck, and stage 1 lung cancers. J Clin Oncol. 2014; 32(35):3989-95. Epub 10 November 2014.
18. Kirkhorn SR, Schenker MB. Current health effects of agricultural work: respiratory disease, cancer, reproductive effects, musculoskeletal injuries, and pesticide-related illnesses. J Agric Saf Health. 2002; 8(2):199–214.
19. Kristensen P, Andersen A, Irgens LM. Hormone-dependent cancer and adverse reproductive outcomes

in farmers' families – effects of climatic conditions favoring fungal growth in grain. Scand J Work Environ Health. 2000;26(4):331–7.
20. Kristensen P, Andersen A, Irgens LM, Laake P, Bye AS. Incidence and risk factors of cancer among men and women in Norwegian agriculture. Scand J Work Environ Health. 1996;22(1):14–26.
21. Meppelink SM. Certified safe farm injuries as they pertain to chronic disease. M.Sc. thesis. Ann Arbor: University of Iowa; 2014.
22. Kirkhorn S, Greenlee R, Reeser J. The epidemiology of agricultural-related osteoarthritis and its impact occupational disability. Wis Med J. 2003;102(7): 38–44.
23. Gibson TM, Park Y, Robien K, Shiels MS, Black A, Sampson JN, et al. Body mass index and risk of second obesity-associated cancers after colorectal cancer: a pooled analysis of prospective cohort studies. J Clin Oncol. 2014;32(35):4004–11.
24. Teras LR, Kitahara CM, Birmann BM, Hartge PA, Wang SS, Robien K, et al. Body size and multiple myeloma mortality: a pooled analysis of 20 prospective studies. Br J Hematol. 2014;166(5):667–76.
25. Mastrangelo G, Marzia V, Marcer G. Reduced lung cancer mortality in dairy farmers: Is endotoxin exposure the key factor? Am J Ind Med. 1996;30(5):601–9.
26. Lange JH. Reduced cancer rates in agricultural workers: a benefit of environmental and occupational endotoxin exposure. Medical Hypotheses. 2000;55 (5):383–5.
27. Hou L, Baccarelli AA, Savage S, Hoppin JA, Sandler DP, Barker J, et al. Lifetime pesticide use and telomere shortening among male pesticide applicators in the Agricultural Health Study. Environ Health Persp. 2013;121(8):919–24.
28. Coble J, Engel L, Elci OC, Dosemeci M, Lynch CF, Alavanja M. Prevalence of exposure to solvents, metals, grain dust, and other hazards among farmers in the Agricultural Health Study. J Expo Anal Environ Epidemiol. 2002;12(6):418–26.
29. Guyton KZ, Loomis D, Grosse Y, Ghissassi F, Bengrahim-Tallaa L, Guha N, et al. Carcinogenicity of tetrachlorvinphos, parathion, malathion, diazinon, and glyphosate. www.thelancet.com/oncology. Published online 20 March 2015. DOI: 10.1016/ S1470-2045(15)70134-8.
30. Kristensen P, Andersen A, Irgens LM, Bye AS, Sundheim L. Cancer in offspring of parents engaged in agricultural activities in Norway: incidence and risk factors in the farm environment. Int J Cancer. 1996;65(1):39–50.
31. Donham KJ, Berg JW, Sawin RS. Epidemiologic relationships of the bovine population and human leukemia in Iowa. Am J Epidemiol. 1980;112(1):80–92.
32. Rubino MJ, Donham KJ. Inactivation of bovine leukemia virus-infected lymphocytes in milk. Am J Vet Res. 1984;45(8):1553–6.
33. Donham KJ, Leininger JR. Spontaneous leprosy-like disease in a chimpanzee. J Infect Diseases. 1977;136 (1):132–6.
34. Schottenfeld D, Fraumenti Jr J. (eds). Cancer Epidemiology and Prevention. 3rd edition. New York: Oxford University Press; 2006.
35. Alavanja MCR, Bonner MR. Pesticide exposure and cancer risk: a review. J Toxicol Environ Health, Part B: Crit Rev. 2012;15(4):283–63.
36. Alavanja MC, Hofmann JN, Lynch CF, Hines CJ, Barry KH, Barker J, et al. Non-hodgkin lymphoma risk and insecticide,fungicide and fumigant use in the Agricultural Health Study. PLoS One. 2014;9(10):e109332.
37. Morton LM, Cozen W, Linet MS, Chatterjee N, Davis S, Severson RK, et al. Etiologic heterogeneity among non-Hodgkin lymphoma subtyp. Blood Cells. 2008;112(13):5150–516.
38. Landgren O, Hoppin JA, Beane Freeman LE, Cerhan JR, Katzmann JA, Rajkumar SV, Alavanja MC. Pesticide exposure and risk of monoclonal gammopathy of undetermined significance in the Agricultural Health Study. Blood Cells. 2009;113(25):6386–91.
39. Pahwa P, McDuffie HH, Dosman JA, Robson D, McLaughlin JR, Spinelli JJ, et al. Exposure to animals and selected risk factors among Canadian farm residents with Hodgkin's disease, multiple myeloma, or soft tissue sarcoma. J Occup Environ Med. 2003;45(8):857–68.
40. Amadori D, Nanni O, Falcini F, Saragoni A, Tison V, Callea A, et al. Chronic lymphocytic leukaemias and non-Hodgkin's lymphomas by histological type in farming-animal breeding workers: a population case-control study based on job titles. Occup Environ Med. 1995;52(6):374–9.
41. Beane Freeman LE, Koutros S, Blair A, Ward MH, Alavanja M, Hoppin JA. Poultry and livestock exposure and cancer risk among farmers in the Agricultural Health Study. Cancer Causes & Control. 2012;23(5): 663–70.
42. Sperati A, Rapiti E, Settimi L, Quercia A, Terenzoni B, Forastiere F. Mortality among male licensed pesticide users and their wives. Am J Ind Med. 1999;36 (1):142–6.
43. Cohen JL. Actinic keratosis treatment as a key component of preventive strategies for nonmelanoma skin cancer. J Clin Aesthetic Dermatol. 2010;3(6): 39–44.
44. Khuder SA. Etiologic clues to lip cancer from epidemiologic studies on farmers. Scand J Work Environ Health. 1999;25(2):125–30.

45. Keller-Byrne JE, Khuder SA, Schaub EA. Meta-analyses of prostate cancer and farming. Am J Ind Med. 1997;31(5):580–6.
46. Van der Gulden JW, Vogelzang PF. Farmers at risk for prostate cancer. Br J Urol. 1996;77(1):6–14.
47. Lewis-Mikhae A, Bueno-Cavanillas A, Guiron TO, Olmedo-Reuena R, Delgaldo-Rodriquez M, Jimenez-Moleon JJ. Occupatioanl esposure to pesticides and prostate cancer: a systematic review and meta-analysis. Occup Environ Med. 2014. DOI:10.1146/oemed-2014-102692.
48. Dich J, Wiklund K. Prostate cancer in pesticide applicators in Swedish agriculture. The Prostate. 1998;34(2):100–12.
49. Koutros S, Lubin JH, Heltshe SL, Andreotti G, Barry KH, DellaValle CT, et al. Risk of total and aggressive prostate cancer and pesticide use in the Agricultural Health Study. Am J Epidemiol. 2013; 177(1):59–74.
50. Koutros S, Berndt SI, Barry KH, Andreotti G, Hoppin JA, Sandler DP, et al. Genetic susceptibility Loci, pesticide exposure and prostate cancer risk. PLoS One. 2013;8(4):e58195.
51. Karami S, Koutros S, Barry KH, Moore LE, Han S, Hoppin JA, et al. Pesticide exposure and inherited variants in vitamin D pathway genes in relation to prostate cancer. Cancer Epidemiol Biomarkers Prev. 2013;9(1):557–66.
52. Van der Gulden JW. Farmers at risk for prostate cancer. Br J Urol. 1996;77(1):6–14.
53. Parker AS, Cerhan JR, Putnam SD, Cantor KP, Lynch CF. A cohort study of farming and risk of prostate cancer in Iowa. Epidemiology. 1999;10(4):452–5.
54. Kristensen P, Andersen A, Irgens LM, Bye AS, Vagstad N. Testicular cancer and parental use of fertilizers in agriculture. Cancer Epidemiol Biomarkers Prevention. 1996;5(1):3–9.
55. Khuder SA, Mutgi AB, Schaub EA. Meta-analyses of brain cancer and farming. Am J Ind Med. 1998;34(3):252–60.
56. Thirugnanam S, Rout N, Gnanasekar M. Possible role of *Toxoplasma gondii* in brain cancer through modulation of host microRNAs. Infect Agents Cancer. 2013;8(8):(online publication).
57. Folsom AR, Zhang S, Sellers TA, Zheng W, Kushi LH, Cerhan JR. Cancer incidence among women living on farms: findings from the Iowa Women's Health Study. J Occup Environ Med. 1996;38(11): 1171–6.
58. Settimi L, Comba P, Carrieri P, Boffelta P, Magnani C, Terracini B, et al. Cancer risk among female agricultural workers: A multi-center case-control study. Am J Ind Med. 1999;36(1):135–41.
59. Leon ME, Douwes J, Hoppin JA, Kromhout H, Lebailly P, Nordby KC, et al. AGRICOH: a consortium of agricultural cohorts. Int J Environ Res Public Health. 2011;8(5):1341–5.
60. Valery PC, McWhirter W, Sleigh A, Williams G, Bain C. Farm exposures, parental occupation, and risk of Ewing's sarcoma in Australia: a national case-control study. Cancer Causes & Control. 2002;13(3): 263–70.
61. Gunier RB, Harnly ME, Reynolds P, Hertz A, Von Behren J. Agricultural pesticide use in California: pesticide prioritization, use densities, and population distributions for a childhood cancer study. Environ Health Persp. 2001;109(10):1071–8.
62. Fear NT, Roman E, Reeves G, Pannett B. Childhood cancer and paternal employment in agriculture: the role of pesticides. Br J Cancer. 1998;77(5):825–9.
63. Flower KB, Hoppin JA, Lynch CF, Blair A, Knott C, Shore DL, et al. Cancer risk and parental pesticide application in children of Agricultural Health Study participants. Environ Health Persp. 2004;112(5): 631–5.
64. Reynolds P, Von Behren J, Gunier RB, Goldberg DE, Hertz A, Harnly ME. Childhood cancer and agricultural pesticide use: an ecologic study in California. Environ Health Persp. 2002;110(3):319–24.
65. Vinson F, Merhi M, Baldi I, Raynal H, Gamet-Payrastre L. Exposure to pesticides and risk of childhood cancer: a meta-analysis of recent epidemiological studies. Occup Environ Med. 2011;68(9):694–702.
66. Weichenthal S, Moase C, Chan P. A review of pesticide exposure and cancer incidence in the Agricultural Health Study cohort. Environ Health Persp. 2010; 118(8):1117–25.
67. Coble JB, Brown LM, Hayes RB, Huang WY, Winn DM, Gridley G, et al. Sugarcane farming, occupational solvent exposures, and the risk of oral cancer in Puerto Rico. J Occup Environ Med. 2003;45(8): 869–74.
68. Koutros S, Ma X, Lee WJ, Hoppin JA, Christensen CH, Andreotti G, et al. Heterocyclic aromatic amine pesticide use and human cancer risk: results from the US Agricultural Health Study. Int J Cancer. 2009;124(5):1206–12.
69. Burman ME, Weinert C. Concerns of rural men and women experiencing cancer. Oncol Nurs Forum. 1997;24(9):1593–600.
70. Burman ME, Weinert C. Rural dwellers' cancer fears and perceptions of cancer treatment. Public Health Nurs. 1997;14(5):272–9.
71. Perry M, Bloom F. Perceptions of pesticide-associated cancer risks among farmers: a qualitative assessment. Human Organization. 1998;57(3):342–9.

72. Muldoon JT, Schootman M, Morton RF. Utilization of cancer early detection services among farm and rural nonfarm adults in Iowa. J Rural Health. 1996;12(4Suppl.):321–31.
73. Reding DJ, Lappe KA, Krueger M, Kolehouse BL, Steneil D, Leer RA. Cancer screening and prevention in rural Wisconsin: the Greater Marshfield Experience. Wis Med J. 1997;96(8):32–7.
74. Reduce your Cancer Risk. American Institute for Cancer Research; 2015 (accessed 17 December 2015). Available from: http://www.aicr.org/reduce-your-cancer-risk/.
75. American Cancer Society Guidelines for the Early Detection of Cancer. American Cancer Society; 2015 (accessed 17 December 2015). Available from: http://www.cancer.org/healthy/findcancerearly/cancerscreeningguidelines/american-cancer-society-guidelines-for-the-early-detection-of-cancer.
76. Known and probable human carcinogens. American Cancer Society; 2015 (accessed 17 December 2015). Available from: http://www.cancer.org/cancer/cancercauses/othercarcinogens/generalinformationaboutcarcinogens/known-and-probable-human-carcinogens.

Chapter

6

Health Effects of Agricultural Pesticides

Kelley J. Donham

Reviewer: Diane Rohlman

6.1 Introduction

It was a sunny and windy day in June when farmer (C.B.) was spraying the insecticide carbofuran (trade name Furadan, a carbamate) on his soy bean fields to control aphids in central Iowa (United States) (see Figure 6.1). He had been working since 7:00am. Near noon, he began to feel tired, so he went to the house for lunch. During lunch, he had a sudden urge for a bowel movement. He went to the bathroom with a severe case of diarrhea. While in the bathroom, he became extremely weak and lost his vision. His wife found him in the bathroom in a near-comatose state. She was able to get him into the car, and with great foresight she took along the package label of the chemical he had been applying to his fields. The emergency room physician examined C.B., then called the state poison control center and read the information about the specific ingredients on the product label. Determining that C.B. had been applying a carbamate insecticide, the physician treated him with an IV drip of atropine over the course of 8 hours. C.B. began to improve and over the next three days made an uneventful recovery.

An alert and resourceful wife combined with access to knowledgeable emergency medicine personnel and a quality poison control center allowed C.B. to survive a life-threatening poisoning to farm again.

Acute occupational pesticide poisonings are uncommon events in agriculture in industrialized countries in current times. Development of safer pesticides, formulations, engineering designs, work practices, governmental oversight, and applicator education among other trends are responsible for a significant reduction in the risk of acute occupational poisonings. However, acute poisonings can still occur, and they can be life threatening if there is extensive exposure. C.B. had splashed some of the concentrate on his hands while mixing and loading the product, and was caught in the pesticide drift due to the wind while he was applying the chemicals.

Although acute pesticide toxicity is a relatively low risk today compared to acute injuries and other agricultural health hazards, it remains one of a farmer's highest occupational health hazard concerns (1). This author (KJD) believes this concern results from the large amount of cautionary information on the subject based on historical experiences that comes from the media, governmental, and non-governmental organizations. Most of the evidence of acute and chronic exposure relates to organophosphate (OP) and

Agricultural Medicine: Rural Occupational and Environmental Health, Safety, and Prevention, Second Edition.
Kelley J. Donham and Anders Thelin.

Figure 6.1 Spray application of insecticides to row crops. Applicators are much better protected inside a tractor with a cab, especially if the windows are shut and the cabin filtration system is properly functioning. (Source: Frederico Rostango/Shutterstock.com.)

organocholorine (CL) insecticides, many of which have been either banned or severely restricted in their use for nearly two decades. There is uncertainty among scientists and health professionals about the chronic health hazards that pesticides may cause. As health and safety professionals, we cannot provide absolute answers to clients/patients who pose health questions related to long-term exposure to pesticides(2). A recent review of the health effects of pesticides by McCauley and colleagues summarized pesticide chronic health effects as follows: "Although a number of health conditions have been associated with pesticide exposure, clear linkages have not yet been made between exposure and health effects except in the case of acute pesticide exposure" (3).

This chapter provides an overview of the types of pesticides used today in production agriculture, how they are used, their acute toxicity and hypothesized chronic toxicity, and methods to treat and prevent poisonings. Furthermore, we attempt to provide health and safety professionals with better tools for an evidence-based anticipation, recognition, treatment, prevention, and accurate risk communication to their agricultural patients/clients about this group of chemicals (4).

6.2 Definition of Pesticides

The term "pesticide" combines the root words *pest* (an annoyance or scourge) and *cide* (from the Latin for killer or act of killing). Today, pesticide is a generic term that applies to thousands of different products used to kill undesirable insects, plants, fungi, vermin, or microbes that are economically, socially, or healthfully detrimental to us (pests) (5).

For the purpose of this chapter we will cover those classes of products primarily used in agriculture, including insecticides, herbicides, fungicides, and fumigants. Fumigants have a broad range of lethality to life forms and will be discussed as a special class of pesticides.

6.3 History and Risk Communication

The large-scale use of insecticides began in the mid-1940s with the industrial manufacturing of dicholor-diphenyl-tricholorethane (DDT) (6). This chemical was extremely effective in killing and controlling insects because it persisted in the environment (one application lasted for several weeks). DDT belongs to the organochlorine (OCL) class of chemicals which includes numerous subsequently developed chemicals. OCLs led to many advances in human disease prevention throughout the world by the control of insects that cause malaria, arthropod-borne encephalitis, and yellow fever among many other insect-vector diseases. Additionally, OCLs were found to have important agricultural value to combat arthropods that attack crops, such as corn root worm, cotton boll weevil, and lice and mites that infest livestock. The publicity and interest garnered by the success of OCLs on the part of many public and private research organizations, pharmaceutical and chemical companies, and the agricultural industry drove continued new product development and production of the vast array of new pesticide products that have come onto the market since the success of DDT (7, 8). Use of these products increased with their associated economic success, without a great deal of public or governmental attention.

However, all that began to change with the book *Silent Spring* written by Rachel Carson in 1962 (9). Carson was a science editor for the US Fish and Wildlife Service. She predicted a new world when spring would come without the melodies of songbirds because of their demise from pesticide toxicity (a "silent spring"). This book led to the global environmental movement of more recent times(10). This author believes the environmental movement has had many positive effects relevant to the use of pesticides and many other environmental pollutants, but it has also added an emotional and disproportional approach rather than a science-based risk approach to hazard communication and mitigation of occupational hazards across the broad range of agriculture health and safety hazards. As mentioned previously, and discussed in more detail later in this chapter, pesticides are responsible for a small percentage of acute illnesses and fatalities relative to acute injuries and the numerous other health and safety hazards discussed in this book.

To enhance an informed rational approach to risk communication on this subject, this author (KJD) recommends using more specific terms such as insecticide or organophosphate insecticide (as appropriate) rather than the word pesticide. The word pesticide invokes a perception of a serious acute, chronic health and environmental hazard to much of the public and scientific world. Pesticides include an extremely broad group of chemicals. Over 1000 active pesticide ingredients are incorporated into over 16,000 formulations of specific products. Only a small percentage of these products are acutely toxic, mainly in the insecticide class. Using primary classification terminology may convey a more accurate risk assessment, for example, when dealing with products that kill weeds the term "herbicide" (mostly very low acute or chronic human health risk) is used. Agriculturalists often utilize the term "plant protection products" to help avoid the general negativity associated with "pesticides". The term "insecticides" should be used to refer to chemicals that kill insects (generally more toxic than herbicides).

Numerous pesticide control policies and control programs have been instituted to help promote pesticide safety. The US Federal Insecticide, Fungicide, and Rodenticide (FIFRA) Act was promulgated originally in 1947. Since the publication of *Silent Spring*, more extensive pesticide control programs have come into existence in most industrialized countries. In the United States the Environmental Protection Agency (EPA) was created in 1970. One of the EPA's mandates was to enforce and manage FIFRA. Since 1970 the EPA has implemented numerous upgrades of the Act (11) to reflect current knowledge and practices. All pesticides must be registered with the US EPA before they can be sold in the United States. For manufacturers to gain registration of a pesticide, the EPA requires substantial testing (using guidelines set by the

National Research Council) to ensure beyond a reasonable doubt that it meets safety standards that protect human health, animal health, and the environment (7, 12). Most industrialized countries have similar protective regulations on the usage of pesticides, but this is not necessarily true in less-developed countries, where such regulations may not be present or oversight and enforcement may be inadequate.

Registration is just one of many governmental and private preventive programs aimed at facilitating pesticide safety (prevention will be discussed in detail in a later section of this chapter). An aim of this chapter is to help inform the history and practices already in place that have helped to create the degree of safety in existence in recent times in the United States and other developed countries in the use of pesticides. However, appropriate caution remains warranted when applying pesticides and when providing science-based information to patients or clients about the health risks of pesticides. As pesticides include a diverse group of chemicals that have great variability in toxicity and regional usage (13–16), we aim to provide information that will help the reader discern the relative degree of risk of the various classes and specific chemicals used in their region so that informed and appropriate responses to exposures may be rendered. A good resource to help the professional assess the risk of specific products is the website of the National Pesticide Information Center, where active ingredients can be searched by product name (13).

6.4 Pesticides: Classes, Subclasses, and Relative Toxicity

The basic classification of pesticides was described in the introduction to this chapter. This section provides more detail on classification to help interpret the health risks of the various products. Several of the chemicals in the fumigant class are highly toxic to humans, as are several of the rodenticides. Biocides are of relatively low toxicity. (Rodenticides and biocides will not be discussed here as they are not specific to occupational exposures in agriculture.) Within each of these major classes of pesticides there are several subclasses, each with different chemical structures, toxic mechanisms, and variance in toxicity to humans. Table 6.1 (17) provides a basic outline of the subclasses of pesticides.

Table 6.1 Classes and subclasses of pesticides (17)

I. **Insecticides** (kill/control insects) listed in order of most common usage and example of currently used chemical in the class
   A. Pyrethroids (PRs), e.g. permethrin
   B. Neonicotinoids (NNs), e.g. imidacloprid
   C. Cholinesterase-inhibiting compounds
      1. Organophosphates (OPs), e.g. malathion
      2. N-methyl carbamates (CBs), e.g. carbofuran (Furidan)
   D. Organochlorines, e.g. DDT, Dicofol
   E. Biological insecticides, e.g. *Bacillus thuringiensis*
   F. Plant-incorporated protectants, e.g. Bt corn

II. **Herbicides** (among at least 19 classes of herbicides, only those classes that are listed here have an important role in agricultural production)
   A. Chlorphenoxy herbicides, e.g. 2,4-D
   B. Pentachlorophenol and dinitrophenolic herbicides, e.g. Dinocap
   C. Paraquat and diquat, e.g. Graoxone
   D. Phosphonates, e.g. glyphosate (Roundup)
   E. Acetamids, e.g. metolachlor (Dual)
   F. Anelids, e.g. Alachlor (Lasso)
   G. Benzadiathiazinone, e.g. pronamide (Rapier)
   H. Carbamates and thiocarbamates, e.g. EPTC (Eradicane)
   I. Chloropyridinyl, e.g. thriclopyr (Garlon)
   J. Dinitroaminobenzine
   K. Triazines, e.g. atrazine (Atranex)
   L. Urea derivatives, e.g. chlorimuron ethyl (Classic)

III. **Fungicides**
   A. Substituted benzenes, e.g. chlorothalonil (Bravo)
   B. Strobilurins, e.g. Dyna-shield
   C. Thiocarbamates, e.g. Thiram (Thiram 75)
   D. Ethylene and bis-ditiocarbamates, e.g. Maneb
   E. Thiophthalimides, e.g. Captan
   F. Triazoles, e.g. triadimefon (Bayleton)
   G. Copper compounds, e.g. copper sulfate
   H. Organomercury compounds, e.g. proprionate
   I. Organotin compounds, e.g. fentin acetate (Batasan)
   J. Cadmium compounds, e.g. cadmium chloride (Caddy)

IV. **Fumigants** (among at least five classes of Fumigants only those classes that are listed here have an important role in agricultural production)
   A. Halocarbons, e.g. methyl chloride
   B. Oxides and aldehydes, e.g. formaldehyde
   C. Sulfur compounds, e.g. sulfur dioxide
   D. Phosphorus compounds, e.g. phosphine gas

Acute health risks of toxic products are determined in large part by the calculated dose at which 50% of experimentally dosed animals (usually rats) die (LD_{50}). The LD_{50} values of pesticides range widely between and within each class of pesticide. The EPA (17), EU, and WHO (18, 19) all have toxicity classification systems to designate the relative risk of exposures to specific chemicals. These systems are generally similar and are based on the global harmonizing system, which aims to keep such systems compatible between countries. The EPA uses a system of four categories based mainly on acute toxicity:

1. Category I (highly toxic): The package label is required to have the skull and cross bones icon, and to include the phrase "danger-poison".
2. Category II (moderately toxic): Warning required. Usually ingestion of the product is required for acute toxicity.
3. Category III (slightly toxic).
4. Category IV (practically non-toxic)

The toxicity classification of individual chemicals can be found in EPA and WHO resources (18, 19). The following describes the general toxicity category of the various groups of pesticides, from high to low toxicity.

1. Fumigants
   a. Most fumigants are Category I, highly toxic.
2. Rodenticides
   a. Most rodenticides are Category I.
   b. Agricultural occupational exposure with rodenticides is uncommon.
3. Insecticides
   a. Organophosphates
      i. Several have been assigned Category I, but most of these have either been banned or severely restricted in usage.
      ii. Most remaining registered organophosphates are Category II.
   b. Carbamates
      i. Most carbamates with remaining registrations are Category II.
   c. Organochlorines
      i. As of 2015, this author (KJD) could find no organochlorines registered in the United States.
      ii. Most previously registered products were Category II or Category III.
   d. Pyrethroids
      i. Most products are Category III.
   e. Neonicotinoids
      i. Most products are Category III.
   f. Ryanoids
      i. Ryanodine, the one commercial insecticide in this class, is a synthetic derivative of a natural compound found in the South American plant *Ryania speciosa*. This class has not achieved much usage in agriculture at present, and is toxicity category III.
   g. Bio-pesticides (natural products derived from living entities)
      i. *Bacillus therigiensis*, oil of the neem tree among many others, Category IV.
      ii. Plant-incorporated protectants (genetically modified plants, e.g. Bt corn, Roundup ready soybeans), Category IV.
   h. Herbicides
      i. Most herbicides are Category III.
   i. Fungicides
      i. Most fungicides are Category III.

The vast majority of applied pesticides are herbicides (over 60% of product sold globally (Figure 6.2) and 80% in the United States (Figure 6.3)), which are of relatively low acute toxicity to mammals, including humans (20–22). The majority of insecticides used today are the low acute toxicity pyrethroids and neonicotinoids compared to the more toxic organophophates and carbamates of the past. Figure 6.4 displays types of applied insecticide usage in Iowa, which is representative of a large row-crop grain-producing region.

6.5 How Farmers, Agricultural Workers, and Agriculture-associated Workers are Exposed to Pesticides

The predominant way workers are occupationally exposed to insecticides and herbicides is by skin contact and absorption (see Figure 6.5). The

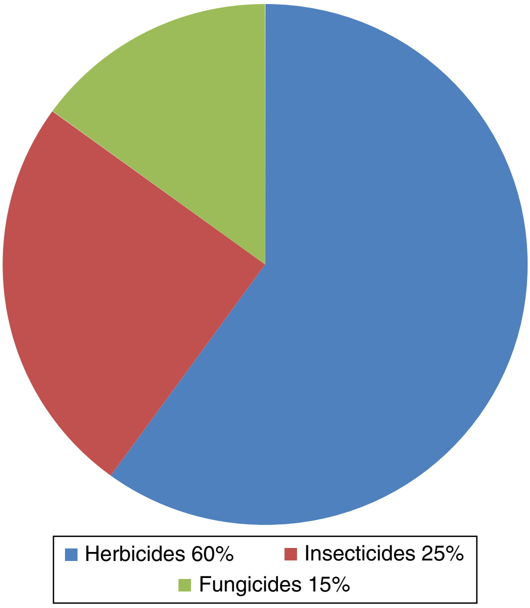


FIGURE 6.2 Herbicides dominate the type of pesticide used worldwide. These chemicals are used to control weeds and are generally of relatively low toxicity to humans and other animals compared to insecticides. (Source: Children's Health and Environment. WHO; 2008. Available from http://www.who.int/ceh/capacity/Pesticides.pdf.)

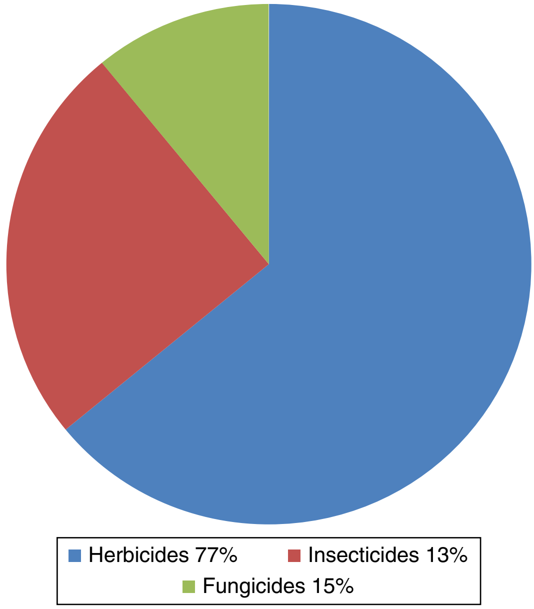


FIGURE 6.3 US pesticide usage by type (percentage of total product sold in 2007). (Source: Pesticide Industry Sales and Usage 2006–2007 Market Estimates: Usage. Washington, DC: US Environmental Protection Agency; 2013. Available from http://www.epa.gov/opp00001/pestsales/07pestsales/usage2007_table3_4.htm.)

chemical structure of insecticides is such that they readily penetrate the chitin exoskeleton of insects, which is chemically similar to skin. Although protective clothing may reduce contact with skin, should it become contaminated with insecticide it will provide a continued source of exposure until it is removed and carefully washed. Absorption of insecticides through skin is enhanced when covered with clothing or other materials, indicating the importance of preventing initial skin contact and basic hygiene (21). Ingestion and inhalation are less important occupational exposure mechanisms in the agricultural setting, but ingestion is the exposure route for most serious acute non-occupational poisonings. As the newer classes of insecticides (e.g., pyrethroids and neonicotinoids) and herbicides are of relatively low toxicity, illness from skin absorption is uncommon. It usually requires a relatively high dose that may be taken by ingestion to induce acute toxicity. The greatest risk for poisoning through ingestion is from ingestion by children or suicide attempts. Other less common consumption methods for insecticides or herbicides include ingestion of contaminated food products and eating in unsanitary conditions where insecticides are handled and where hand-washing is not practiced prior to eating or smoking. Another mechanism of ingestion exposure includes storing pesticides in unmarked or emptied food containers (e.g., soft drink bottles) and using old pesticide containers for drinking water containers. Inhalation is probably the least common mechanism of exposure except for fumigant exposure (which is discussed later in this chapter) and combustion of pesticides or pesticide containers. As particles in most formulations (including powders, microcapsules, and sprays) are larger than respirable size (22) most of the inhaled pesticide (except fumigants) will be trapped in the trachea, where it is elevated back into the pharynx by the mucociliary apparatus and swallowed. Fumigants and those rare formulations that include mists or fumes are the most likely source of respiratory exposure.

Several occupations besides farmers or farm workers have pesticide exposure risk, including those working in chemical manufacture, warehouses, transportation, formulation, sales, and commercial and private applicators. Those working in formulation plants and application (the latter conduct mixing and loading tasks) handle concentrates, which can result in especially high-risk exposure tasks (23) (Figure 6.6). Livestock producers also have significant exposures (primarily dermal) when applying parasiticides to animals (24). The workers applying the insecticides may have additional risks of exposure beyond mixing and loading. These exposures may occur from leaking application equipment, spray drift, and the maintenance and cleaning of equipment. It must be noted (especially on smaller farms) that farm owners/operators or workers may perform (and thereby have opportunities for exposure) several of the tasks described above, including mixing and loading, applying, and harvesting. Reeves and Schafer (25) estimated that 51% of occupational poisoning cases in California are caused by insecticide drift and 25% from exposure to insecticide residues on plant foliage. Workers who load and clean crop-dusting airplanes also have a high risk of exposure as the contaminated wash water often splashes on them. Furthermore, the "flagger" on the ground who marks where the next pass of the airplane

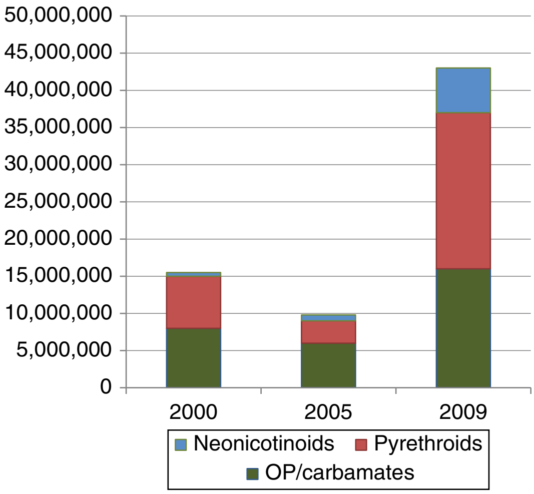


FIGURE 6.4 Type of insecticides applied (in pounds) in Iowa. There has been a significant reduction in the use of more toxic insecticides (carbamates and organophosphates (OPs)) and an increase in the use of much less toxic chemicals (pyrethroids, neonicotinoids, and rayanoids). (Source: Iowa Department of Agriculture and Land Stewardship.)

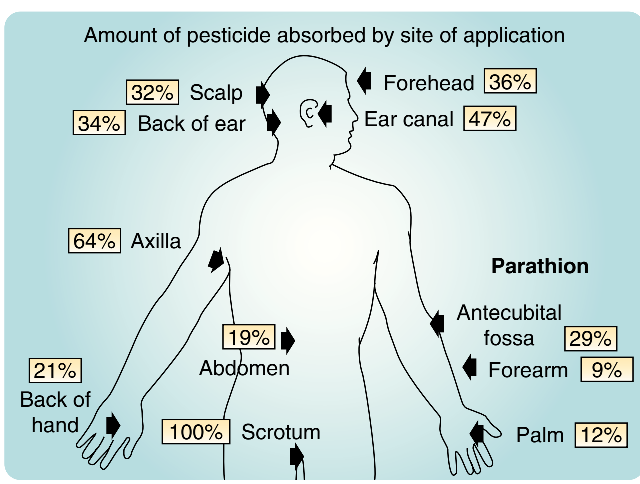


FIGURE 6.5 The most common systemic exposure to pesticide is through skin contact. Skin absorption of organophosphate pesticides is especially efficient in areas of thin skin with high blood supply, such as the head, axilla, and groin.

Figure 6.6 Mixing and loading insecticides prior to application have the potential for worker exposure as the chemicals put into the tank are concentrated. The minimum protection during this application should be unlined rubber or nitrile gloves.

should be is also at risk of exposure (Figure 6.7). (GPS navigation systems are rapidly replacing the need for flaggers.) Farm workers who pick fruits and vegetables that have been sprayed are at risk because of contact with insecticide on the foliage (Figure 6.8). Regulations intended to reduce this exposure include a time delay (re-entry interval) before workers can go into a treated field. EPA and state regulations require that notices be posted to advise people to keep out of these fields, orchards, and vineyards until the particular product has been broken down by sun, heat, and other natural processes.

In many areas the farm service and supply firms have incorporated pesticide application in their services. These firms are taking over an increasing share of application of what the individual famer has previously done. They have large expensive equipment that covers fields rapidly and monitors application with advanced technology, freeing the individual operator of the expense and regulatory requirements of pesticide use. This service also offers increased safety to the producer and worker as it separates them from potential exposure and the work is accomplished by more experienced and knowledgeable people with licensed commercial pesticide certification (commercial applicator certification requires an examination). Licensed applicators have a lower risk of exposure events than other workers (26).

Other occupationally exposed people include grain elevator workers involved in grain fumigation, and fire fighters and bystanders in situations where pesticides are burning. The latter are at risk from exposure to volatilized insecticides or toxic products of the burned chemicals.

The risk of exposure to handlers, retailers, or consumers of food products treated with insecticides is low. Most industrialized countries have special agencies (e.g., the USDA and FDA in the United States) that test agricultural products for pesticide content. Although the main concern is surface contamination of food, there are a few insecticides that are water soluble (e.g., aldicarb (carbamate), acephate (organphosphate), imidacloprid, and dinotefuran (neonicotinoids)) and may be absorbed in the water and incorporated into the plant vasculature (xylum and phloem). A few cases of poisoning have been reported where consumers have eaten fruit or vegetable crops

Figure 6.7 In crop-dusting applications there is a risk of insecticide exposure for the pilot, those who mix and load the plane, those who clean up the plane, and the "flagger" on the ground who marks the way for the pilot (GPS navigation is replacing the need for a flagger). Others on the ground who live or work in the area are subject to spray drift exposure. Knowledge of what chemicals are being applied will help the health and safety professional to determine the level of risk. (Source: Action Sports Photography/Shutterstock.com.)

Figure 6.8 Pruning or harvesting grapes or other fruit or orchard crops presents a possible exposure risk to workers from pesticides that may remain on the foliage if insufficient time is not allowed for the chemical to degrade. (Source: Richard Thornburg/Schutterstock.com.)

(e.g., cucumbers and water melons) treated with the insecticide aldicarb (27). This problem is mainly a concern with plants raised in an area with a high water table, creating an environment where the aldicarb could be taken up by the plant with the water. The EPA has now banned aldicarb with effect for all registrations by 2018.

6.6 The Risk of Pesticide Poisonings

As mentioned above, fatal occupational pesticide poisonings in agriculture are rare today in industrialized countries. However, exposures resulting in minor illnesses are more frequent than fatal poisonings. The available information on the incidence and prevalence of pesticide poisonings are only estimates (similar to most occupational or public health illness reporting) because people mildly poisoned (especially agricultural people) rarely/seldom seek medical attention unless they are seriously ill. In addition, medical care personnel may find it difficult to recognize pesticide poisoning as symptoms may be vague and mimic other conditions. In most states or countries there is no requirement for reporting pesticide poisonings. For example, in the United States reporting is required for medically treated or disabling illnesses or injuries only in a business with at least 11 employees. Foreign-born farm workers, particularly those un-documented or those who have language barriers, are reluctant to seek medical attention for fear of being fired or discovered by authorities. Furthermore, they may fear financial, social, or cultural embarrassment by the medical care system. For all these reasons, the actual number of documented cases is under-reported. On the other hand, estimates by some advocacy groups may overestimate the actual number of poisonings. The available estimates reported here arise from multiple sources, including emergency room and hospital records, poison control centers, workers' compensation records, and special surveys conducted by the US Center for Disease Control and Prevention (CDC) through the Sentinel Event Notification System for Occupational Risk (SENSOR) (28).

For poisoning (all types) the National Poison Data System reports over 5500 confirmed events annually (29). The CDC SENSOR program reports about 67 agricultural occupational illnesses per year (8, 28) (mostly mild), an estimated 1.2% of all poisonings (8, 28). Most of the reported poisonings from pesticides are non-occupational and often involve children who gain access to potentially hazardous products that have not been adequately secured (8, 28). About 17% of pesticide poisonings in the United States are suicides. In developing countries, suicide by insecticides or the herbicide paraquat is a much greater problem than in more developed countries (30, 31).

The CDC SENSOR program is an active surveillance system that collects data from 11 states (Arizona, California, Florida, Iowa, Louisiana, Michigan, New Mexico, New York, Oregon, Texas, and Washington) (16, 28). These states include those with an intensive production agricultural industry and states where a large number of farm workers are employed. The SENSOR report for the 8-year period from 1998 to 2006 tallied a total of three agricultural occupational pesticide fatalities, and 532 non-fatal illnesses (28) (estimated fatality rate = 0.063/100,000, estimated illness rate = 1.4/100,000). (Note that 98.8% of the illnesses had low or moderate health consequences.) In comparison, National Institute for Occupational Safety and Health (NIOSH), Census of Fatal Occupational Injuries (CFOI) reported 479 total (all causes) occupational fatalities in the agricultural sector in 2013 (32) and 53,982 lost-time work illnesses and injuries in 2012 (33) (respective rates 22.2 fatalities/100,000 and 1,120 injuries/100,000) (33). (These estimates assume an exposed population base of 4.8 million, as reported by the US Department of Agriculture for 2007 (34).)

Although the data presented above are for the United States, similar rates would be expected for most industrialized countries. However, the picture for less-developed countries is quite different. Developing countries have many more acute poisonings because of higher exposures (often with individual hand-operated applicator equipment such as backpack sprayers), less awareness, fewer control practices (including lack of PPE), lack of medical and diagnostic services, and less controlled regulations. The Food and Agricultural Organization of the WHO has published (in 2001) detailed guidelines for the protection of farmers and workers applying insecticides in less-developed countries (35). However, it is apparent that such recommendations often do not penetrate to the intended users. This author (KJD) has observed small farmers in a West African country purchasing toxic insecticides in unlabeled zip-lock bags at local markets. Furthermore, this author has observed farmers being highly exposed (with no PPE) applying the organochlorine endosulfan (one of the more toxic OCLs) with a hand-carried rotary atomizer applicator held above the head to apply the chemical to the foliage of cotton plants. The worker was being heavily exposed to the insecticide during the application. (Personal exposure was being monitored during this process and the calculated levels of exposures were below the level of acute toxicity (36).) Endosulfan is banned in most developed countries and under consideration of being banned in many less-developed countries. It is difficult to obtain accurate, sensitive, and specific data for exposures and outcomes in most developing countries. The incidence rates of pesticide poisonings reported by various developing countries vary from 18/100,000 to 180/100,000 (37). Additionally, there is no effective and common reporting classification tool for countries to use for consistent and accurate reporting. Such an instrument has been proposed to WHO. WHO has also provided resources for training health professionals in less-developed countries about pesticide use and exposure prevention (20).

A major concern of the international community is the high prevalence of suicide by insecticides or the herbicide paraquat in less-developed countries (estimated 877,000 deaths annually) (30, 38). The bulk of these occur in South-East Asia and the less-developed countries of the Western Pacific. This topic has been addressed by WHO through conferences and a specific intervention program of pesticide suicide prevention (38).

6.7 Insecticides: Usage, Acute Toxicity Mechanisms, Diagnosis, and Treatment

Seven classes of insecticides are discussed here: (1) organochlorines (OCLs), (2) organophosphates (OPs), (3) carbamates (CBs), (4) pyrethroids (PYs), (5) neonicotinoids (NNs), (6) ryanoids, and (7) bio-pesticides (including plant-incorporated protectants, PIPs). Classes 6 and 7 will be discussed only briefly as they present little if any occupational health hazard. These pesticides are discussed by the relevant classes seen above, according to their historical development and usage, and in order of relative occupational exposure health risk (from highest to lowest). As alluded to above, the LD_{50} toxicity varies by as much as 1000-fold among the various insecticides used in agriculture (17, 39). Potential harm also varies relative to their persistence in the environment among other toxicological features, for example toxicity varies relative to the physical and chemical properties of their formulation, for example:

1. *Volatility*: Products formulated as aerosols, gases, or fine dusts are of higher volatility and are generally a greater health hazard relative to granular or slow-release microcapsules.
2. *Multiple active ingredients*: It is common for more than one active ingredient to be incorporated within a single commercial product, creating possible additive or synergistic health effects and thus difficulty in determining the principle toxic product to treat.
3. *Inactive ingredients*: Carriers or solvents within compounds may cause skin irritation or other health conditions independent of the active ingredient.
4. *Chemical stability*: Some insecticides, particularly those in the OCL class, may take days to weeks before they degrade to non-toxic status following application. Entry into fields or premises where these products have been applied may result in a toxic exposure if entry occurs prior to this time.

There is constant change in the product development of insecticides used in crop and livestock production. Furthermore, the usage of products varies geographically among different states, regions, and countries based on types of crops, climate, economy, and regulations. The informed health and safety professional must keep up to date on the chemicals used on specific crops and livestock in their region, how they are applied, and when they are used. This information may be obtained from the agricultural extension service, regional/area agricultural chemical service dealers, regional/state departments of agriculture, regional/state environmental protection agencies, and regional livestock veterinarians. Table 6.2 is an example of notes a health or safety professional could develop to guide them in pesticide risk anticipation for their own region. The regional crops and usage of insecticides are recorded along with the health risks and serve as a quick reference to help assess risk should an event occur. Knowing the class and specific products used is essential to understanding the risk. Organochlorines are of relatively low acute toxicity to humans, but were largely replaced by the higher acutely toxic organophosphates and carbamates in the 1970s. Organophosphates and carbamates were largely replaced by pyrethroids and neonicotinoids in the 1990s (relatively low acute toxicity to humans) (17, 39). All classes of insecticide affect the nervous system of insects. Organochlorines, neonicotinoids, and pyrethroids function by interfering with the conduction of a nerve impulse along the membrane of a nerve cell (dendrite). Organophosphates and carbamates function by interfering with the transmission of a nerve impulse across the synapse between two nerve cells. Compared to insects, mammals have different biochemical mechanisms of nerve conduction along axonal membranes, rendering them less sensitive to pyrethroids and neonicotinoids. Mammals also possess enzymes that readily break down these insecticides. As the nervous system physiologies of insects and mammals (including humans) differ, pyrethroids, neonicotinoids,

Table 6.2 Example of a risk assessment tool for pesticide exposures usage on a specific crop and region (corn, zea mays), Midwest United States

Insect control (insecticide use)

Soil grubs

Insecticide usage

- Neonicotinoid insecticide most common
- Applied as a seed coating that comes with the commercial seed
- Season of use: spring (planting time)
- Operator health risk: minimal unless extensive ingestion

Root worm and cut worm

Insecticide usage

- Most often a genetically modified plant crop containing the *Bacillus theringiensis* toxin (Bt corn)
  - Operator health hazard: no occupational health risk known
- A pyrethroid most often used, if not a Bt product or additional insecticide
  - Season: generally at planting or early growing stage (May–June)
  - Health risk: skin irritation. acute systemic symptoms only if large quantities ingested
- A carbamate or organophosphate may uncommonly be used as a spray (late May–June), acute health risk if heavy skin contact or ingestion

Weed control (herbicide use)

Chemicals used

- Glylphosate
  - Glyphosate (Roundup) may be applied on "Roundup ready" corn or soybeans (about 75% of corn planted in the United States and 90% of soybeans)
    - Applied as a spray
    - Season: usually two applications, first early in growing (May) and second in mid to late June
    - Health risk: low risk, acute hazard very rare unless large quantity ingested
  - Trizaine herbicide (e.g., atrazine): applied prior to planting or early growing season as a pre-emergent (kills weeds before they emerge from the ground, May–June)
    - Often applied as a spray in combination with glyphosate
- Health risk: very low risk, acute hazard very rare unless large quantity ingested

Fungus control (fungicide use)

- Chemicals used: strobilurin class fungicide most common
- Applied as a foliar (spray boom or airplane application)
- Season applied: usuallyJuly and August
- Human health risk: usually low acute toxicity risk

and organochlorines are relatively safe (some 2000 times less acutely toxic to humans compared to their toxicity to insects). Organophosphates and carbamates have a relatively similar toxic mechanism for insects and mammals, and represent a greater risk of acute toxicity to humans than the other insecticide classes. However, organophosphates and carbamates are a minor component of the insecticide arsenal used today by farmers in both developed and less-developed countries. For all markets in the United States OPs fell from 57% in 1980 to 35% in recent years of all insecticides used, the difference made up by increased use of GMO crops, neoticotinoids and pyrethroids, which make up the bulk of the remaining 65% (40, 41). Table 6.3 lists commonly used insecticides as of 2015. It can be seen that 65% of these products are low or low-moderate acutely toxic, and these are mainly either pyrethroids or neonicotinoids. Twenty-three per cent are considered of high toxicity; they are either organophosphates or carbamates.

The remainder of this chapter will discuss in more detail each class of insecticide, describing its usage, acute toxic mechanisms, acute symptoms, diagnosis, treatment, and prevention.

Table 6.3 Relative insecticide toxicity of some commonly used insecticides (as of 2015)

Insecticide	Chemical class[a]	Risk level[b]
Lannate (methomyl)	CB	H
Bidrin (dicrotophos)	OP	H
Methyl parathion	OP	H
Counter (terbufos)	OP	H
Curacron (profenofos)	OP	H
Dicofol M Temik (aldicarb)	CB	H
Vydate (oxamyl)	CB	H
Dimethoate	OP	M–H
Larvin (thiodicarb)	CB	M
Lorsban (chlorpyrifos)	OP	M
Comite (propargite)	O	M
Ammo (cypermethrin)	PY	L–M
Asana XL (esfenvalerate)	PY	L–M
Baythroid XL (β-cyfluthrin)	PY	L–M
Karate (λ-cyhalothrin)	PY	L–M
Brigade (bifenthrin)	PY	L–M
Mustang Max (Z-cypermethrin)	PY	L–M
Orthene (acephate)	OP	L–M
Delta Gold (deltamethrin)	PY	L–M
Denim (emamectin benzoate)	O	L–M
Intrepid (methoxyfenozide)	O	L
Intruder (acetamiprid)	NN	L
Belt SC (flubendiamide)	O	L
Blackhawk, Tracer (spinosad)	O	L
Malathion	OP	L
Centric or Cruiser (thiamethoxam)	NN	L
Prevathon (chlorantraniliprole)	O	L
Admire Pro (imidacloprid)	NN	L
Sevin (carbaryl) L	CB	L
Diamond (novaluron)	O	L
Steward (indoxacarb)	O	L

[a] CB, carbamate; OP, organophosphate; O, other or unclassified; PY, pyrethroid; NN, neonicotinoid.
[b] L, low; M, moderate; H, high.

6.7.1 Organochlorines

OCLs were used primarily for row crops, fruit and vegetable production, control of ectoparasites on livestock, and vector control in public health applications. Increased livestock and poultry production resulted from the control of lice and mange mites in many species. Lindane was the active ingredient in products used in the United States and many other countries for lice and mite control in the hair of adults and children. Control of mosquitoes has resulted in a decline in malaria in many regions of the world. However, malaria and other insect vector-borne diseases have now returned as an important disease in many tropical countries as the use of OCLs has diminished (6). Malaria accounts for an estimated 880,000 fatalities yearly, mainly in Sub-Sahara Africa, South America and the Middle East (42).

The toxic mechanism of OCLs is disruption of nerve impulse transmission along a nerve fiber (axon or dendrite). A nerve impulse is created following a stimulus that results in an exchange of sodium for potassium across the nerve cell membrane, facilitated by a biochemical sodium pump. The exchange of ions results in a wave-like shift of polarity traveling along the nerve axon, innervating the end organ or tissues (muscle), or connecting other parts of the

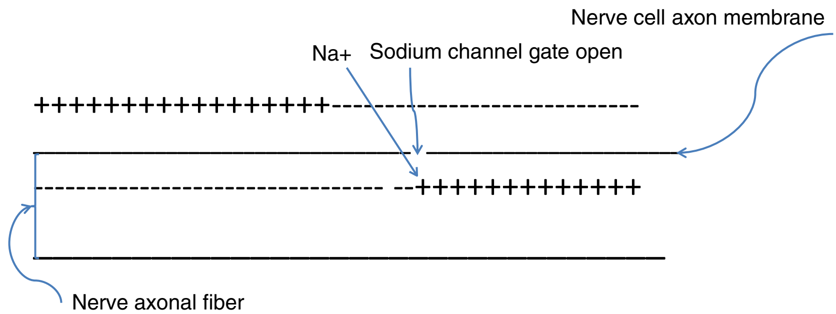


Figure 6.9 This figure represents nerve impulse transmission along a nerve fiber. Transmission occurs by an exchange of polarity across the nerve membrane by exchange of sodium (positive ion) outside the nerve membrane for potassium (negative ion) inside the membrane activated by a "sodium pump". The toxic mechanism of action of organochlorine (OCL), pyrethroid (PY), and ryanoid (RY) insecticides is that of "sodium pump modulation". OCLs and PYs "open" the sodium channel, and RYs "close" the channel, resulting in toxic over or under nerve transmission in insects.

brain. OCLs are sodium channel modulators (SCM) and "open" the sodium channel, increasing nerve transmission (4). Figure 6.9 illustrates the mechanism for OCL toxicity. Pyrethroid and ryanoid insecticides are also SCMs but the Ryanoids close rather than open the channel. Fortunately, insects are much more susceptible to OCLs, Pyrethroids, and Ryanoids than mammals. This is shown by the fact that cattle, sheep or swine producers who used OCLs on their stock were often soaked with the chemicals along with the animals they were treating, yet rarely developed acute toxic symptoms. As OPs replace the OCLs in the 1960s and 1970s, this author (KJD) observed that many producers handled OPs as they had handled OCLs (not very carefully) and were poisoned because OPs are more acutely toxic.

Organochlorines are stored in the fat tissues of animals and thus bio-accumulate in food webs, resulting in species at the higher end of the food chain having the highest exposures and the highest levels of OCLs in their fat stores. Substantial research affirmed the initial findings regarding bioaccumulation of OCLs in many animal species (including humans) and documented the negative effects on reproduction, especially in large carnivorous birds (e.g., raptors such as the bald eagle). This resulted in legislation in the 1970s that severely limited the use of OCLs in many applications around the world in the 1970s. The WHO-sponsored Stockholm Convention on Persistent Organic Pollutants (43) recommended a ban on all OCLs, with some recommendations for guarded use of DDT in malarial prone areas. At the time of writing, this author (KJD) could find no EPA registration for usage of any OCL in the United States.

6.7.2 Symptoms, Diagnosis, and Treatment of Acute OCL Poisoning

As OCLs are not in general use today, the main hazard is from OCL pesticides that have not been correctly disposed of and have remained in chemical stores on farms and other places. Improper usage and children getting into unsecured chemical stores are the most likely exposures. Acute toxicity from OCLs usually results from extensive exposures either through a drenching with concentrate or ingestion of large quantities of the product. The primary symptoms involve the central nervous system. Low exposure symptoms or initial symptoms of higher exposures include headache, dizziness, vomiting, incoordination, tremors, and confusion. Additional symptoms may include hyperesthesia (increased skin sensitivity) or paresthesia (feeling of tingling of the skin) of the face or extremities. Advanced cases may involve tonic (contraction of extensor muscle) and colonic (rapid shift of contractions and relaxation) seizures, possibly progressing to coma with respiratory and cardiac depression (17).

6.7.3 Diagnostic Aids for OCL Exposures

Liquid-gas chromatography to identify OCLs in the blood provides the most objective evidence of poisoning. However, as specific blood concentrations relative to toxicity are not known, clinical judgment has to be used regarding the significance of blood concentrations. Clinical judgment includes a related occupational history and symptoms. Analysis for specific urinary metabolites may be helpful. As OCLs are hepatotoxic and induce liver enzymes, one would expect to see elevated transaminases (enzymes produced by the liver) in blood serum tests (17, 39).

6.7.4 General Principles of Pesticide-poisoning Treatment

The basic principles for treatment of acute poisonings (17, 39) can be applied to most of the insecticides and herbicides discussed in this chapter. Although there may be variations in the treatment based on the condition of the patient and the particular exposure that require careful clinical judgment, the basic principles include the following practices.

1. *Skin decontamination*: If a dermal exposure is evident or strongly suspected, remove the clothes and wash the body and hair with soap and water to prevent further pesticide absorption.
2. *Eye decontamination*: If eye exposure is evident, remove contact lenses if present, and flush the eyes with copious amount of saline or clean water.
3. *Support respiratory function and airway protection*: Remove fluids from airways with a large suction device. Administer oxygen if clinical need is apparent, and intubate if airway protection and/or ventilation is needed.
4. *Gastrointestinal decontamination*
   a. *Gastric lavage* should be used with clinical judgment to avoid negative consequences, principally aspiration. Lavage may be useful if a potentially life-threatening dose has been ingested and if done within 60 minutes of ingestion.
   b. *Inducing emesis (vomiting)*: Syrup of ipecac has been historically recommended to empty the stomach of poison, but current recommendations are on a case-by-case basis and are guided by recommendations from a poison control center or physician. Consideration for use may include information that a serious toxicity is possible, and if emergency medical treatment is more than an hour away.
   c. *Activated charcoal* (general antidote) is an effective absorbent for many ingested poisons, if given orally in slurry within 60 minutes of ingestion. Caution should be used to prevent aspiration. The airway should be cleared of any debris and a swallowing reflex should be noted. Otherwise an endotracheal tube should be inserted to protect the airway.
   d. *Catharsis* (emptying of intestines and colon) is not generally recommended for gastrointestinal (GI) tract decontamination.
5. *Seizure management* may be necessary as some insecticide poisonings may result in seizures. Benzodiazepines (e.g., lorazepam) are among the first line of seizure control medications to consider.

Good clinical judgment must be used to determine which, if any, of these procedures should be used. All suspected pesticide exposures cannot be treated in the same way. Instead, one must determine if the particular chemical and amount ingested is potentially toxic enough to warrant the risk of aspiration pneumonia and patient discomfort. Furthermore, emesis and/or lavage are likely only of benefit within the first 60 minutes

Table 6.4 General principles for treatment of pesticide exposures (17, 44)

Objective of treatment	Actions
Skin decontamination	Remove clothing, completely wash and shampoo the patient (attendants should use protective gloves and aprons if highly toxic chemicals like OPs or CBs are suspected)
Eye decontamination	Remove contact lenses if present Continually flush eyes for 15 minutes, preferably with sterile balanced saline or clean water
Airway protection	Clear airway, intubate if ventilatory support needed, administer O_2 as necessary (Note: If carbamate or organophosphate poisoning, assure tissue oxygenation prior to administration of atropine. If paraquat poisoning, O_2 is not indicated.)
Gastrointestinal tract clearing	Caution to assure lavage may be helpful balanced against risk of aspiration or other harm Lavage if less than 60 minutes from ingestion, and only if relatively large amounts ingested Contraindicated with ingestion of hydrocarbons or caustics Use oralgastric tube, saline infusion and aspiration Intubate if unconscious or airway not protected Contraindications for lavage: (1) unprotected airway, (2) low level of consciousness not intubated, (3) ingestion of drugs that may cause rapid unconsciousness and not intubated, (4) ingestion of corrosive, acid, or alkali substances, (5) ingestion of hydrocarbons, (6) risk of bleeding from intubation
Administer adsorbents (activated charcoal)	Give within 60 minutes of ingestion Keep giving even if patient vomits May have to give antiemetic or administer with an oralgastric or nasogastric tube Intubate if unprotected airway May repeat in 2–4 hours Dosage: adolescents and adults 25–100 g; infants and children to 12 years of age 0.5–1.0 g/kg administered orally as slurry, or by nasogastric tube, or gastric tube May repeat dosage after 2–4 hours (but not with atonic gut)
Induce vomiting	Use ipecac guardedly if a time delay beyond 1 hour is anticipated before definitive treatment at a medical care facility Rarely recommended for home or pre-hospital use because of risk of respiratory exposure Effective in 30 minutes Use only in alert, conscious people and within 60 minutes of ingestion Do not use if there is aspiration risk or ingestion of hydrocarbons or corrosives
Induce catharsis (emptying of the intestinal tract)	Generally cathartics are relatively not indicated for management of poisoning incidents They are absolutely contraindicated if there is any signs of bowel stasis, e.g. obstruction, recent surgery, or ingestion of diquat or paraquat (the latter may cause bowel stasis) Sorbitol is the drug of choice, often contained with activated charcoal Dosage: adults 1–2 g/kg, 1–2 mL/kg of 70% sorbitol; children 1.5–2.3 mL/kg up to 50 g Sorbitol is not likely needed in poisoning with OPs, CBs, arsenicals, or sulfur, as these are cathartics
Control of seizures	Lorazipam: adults 2–4 mg IV over 2–5 minutes, repeat as necessary to a maximum 8 mg over 12 hours; children over 12 years same dosage as adults, with maximum of 4 mg; children under 12 years 0.05–0.10 mg/kg over 2–5 minutes, repeat if necessary at 10–15 minute intervals to a maximum dose of 4 mg Diazepam: adults 5–10 mg IV repeated every 5–10 minutes to a maximum of 30 mg; children 0.2–0.5 mg/kg IV repeated every 5 minutes to a maximum of 10 mg or if under 5 years to a maximum of 5 mg Phenobarbital: all ages 15–20 mg/kg IV, followed by 5 mg/kg at 15–30 minute intervals to a maximum of 30 mg/kg

following ingestion. Table 6.4 summarizes the general principles discussed above (17, 44). The toxic mechanisms, clinical presentation, diagnosis, and treatments are described below for different classes of pesticides, but the general principles above and in Table 6.4 should be considered before specific treatment.

Excellent references for specific treatment including dosage of medication include Robert and Reigarts (17) and Eddleston (44).

6.7.5 Specific Treatment of OCL Poisoning

Treatment of OCL poisoning should first follow the general principles noted in Table 6.4. If seizures are present, management should first follow prevention of physical injury during the event. Management of seizures medically is first with IV diazepam or lorazepam, and if necessary phenobarbital. Specific recommended dosages for children and adults are given in Table 6.4.

6.7.6 Cholinesterase-inhibiting Insecticides (Organophosphates and Carbamates)

Three primary characteristics differentiate OPs from OCLs: (1) OPs degrade relatively rapidly in the environment, (2) OPs do not bio-accumulate along food chains, and (3) OPs are more acutely toxic to mammalian species, including humans. One positive outcome of the shift from OCLs to OPs is the reappearance of many birds of prey (raptors), such as eagles and hawks, whose numbers had diminished over the previous three decades.

OP and CB insecticides are neurotoxins by a different mechanism than OCLs. Normally, when a nerve impulse reaches the end of a nerve fiber (axon), there are vesicles in the end organ of the nerve that release acetylcholine (ACh), which carries a chemical message across the synapse to initiate the nerve impulse in the connecting nerve. Shortly after the impulse is transmitted, a second enzyme, acetylcholine esterase (AChE), is released from the end organ. This enzyme breaks down ACh so that the nerve impulse will not continue to fire. However, OPs and CBs tie up or bind AChE by blocking receptor sites on it, effectively disabling the enzyme. The toxic result of OPs and CBs is therefore an overstimulation of the nerves that affect the autonomic nervous system (e.g., involuntary functions like heart rate, GI movement, bodily secretions, etc.) (see Figure 6.10). Insects and mammals share some of the same neurotransmitter substances, and the ACh system is critically important for both insects and mammals (4, 5, 39). However, because of important differences in the neurotransmission systems of insects and mammals, some classes of insecticides (e.g., OCLs, pyrethroids, ryanoids and neoticotinoids) present a relatively low risk for acute human poisonings while being very effective for insect control.

Although CBs and OPs have similar toxic mechanisms, the chemical linkage (CB–AChE) is relatively short lived, whereas the OP–AChE linkage is more persistent. After 5 or more hours, the OP–AChE linkage may become permanent (called aging), and new AChE must be produced by the end organ to counteract the poisoning. This toxic principle has implications for differences in the treatment of OP and CB poisonings, which are discussed below.

6.7.7 Acute Symptoms of OP and CB Toxicity

In mammals, the neurotransmitter ACh activates certain nerves that primarily control certain components of the brain, the autonomic system (digestion, heart function, etc.), and to a limited extent, skeletal muscles (motor nerves). Acute symptoms of poisoning vary with the degree of toxicity (17, 39). Mild poisonings may mimic alcohol intoxication or heat exhaustion. Symptoms may include fatigue, nausea, and vomiting. More severe symptoms can be classified by the part of the nervous system that is affected, that is, muscarinic, nicotinic, or central nervous system. Muscarinic symptoms (component of the autonomic system) appear classically as salivation, lacrimation, urination, and defecation (SLUD, or "all faucets on" signs). The two unique clinical signs related to OP poisoning that should help to differentiate it from other poisonings are myosis or pin-point pupils (some patients report periods of blindness or difficulty seeing) and bradycardia (slow heart rate). There is very little else that causes this combination of symptoms. An additional clinical sign is moist rales (breath sounds) on auscultation of the chest (because of excess mucous secretions into the airways caused by the muscarinic response). Nicotinic symptoms appear

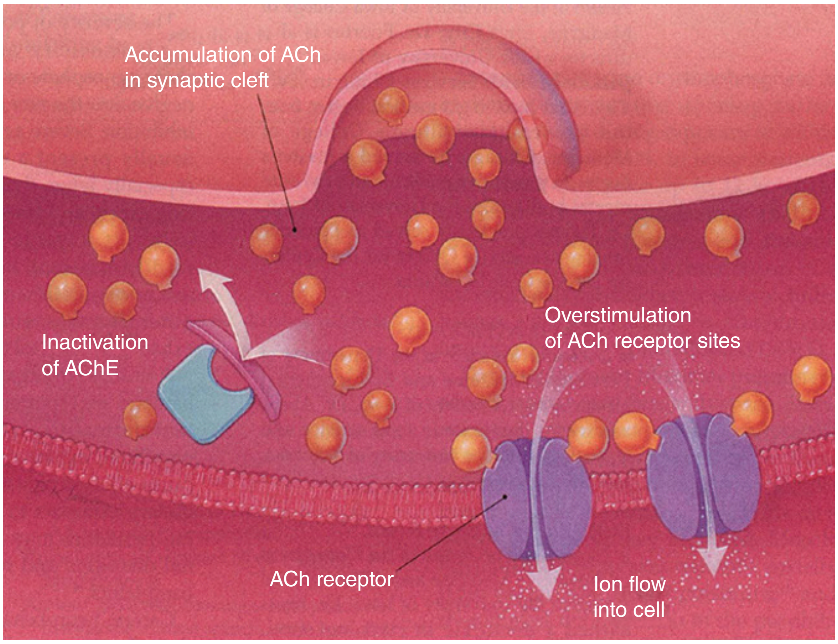


FIGURE 6.10 Normal transmission of a nerve impulse across a synapse. Acetylcholine is released from the end organ at the terminus of the nerve fiber and travels across the synapse to transmit the impulse to the next nerve fiber. The acetylcholine is rapidly broken down at the synapse by acetylcholine esterase, which stops the signal being sent.

as muscle fasciculations (twitches), often subtle, but seen in the face or extremities. It should be noted that some individuals (those with genetically reduced paraoxonase in their blood) have increased susceptibility to certain OP insecticides. Paraoxanse is an enzyme produced by the liver which helps to break down active metabolites of some OPs, for example parathion and related chemicals (45). Because many children normally have reduced paroxanase, they may be at higher risk of OP exposure.

6.7.8 Diagnostic Aids for OP and CB Poisoning

An appropriate occupational history of exposure should include details of work practices and processes. The principle diagnostic test for acute OP toxicity is the AChE test. The following principles for the use and interpretation of this test are essential for its utility in diagnosing a poisoning (17, 46). As OP and CB insecticides tie up AChE, a low AChE concentration is a positive test for poisoning (see following paragraph for interpreting low concentrations). As it is impossible to obtain and test for AChE at the nerve synapse, other sources of AChE in the body, such as blood plasma and red blood cells (RBCs), serve as surrogate sources. Plasma AChE is produced by the liver continually, and therefore in an otherwise healthy person the AChE remains depressed only for 1–2 weeks as the liver will replace that which is tied up quite rapidly. RBC AChE is depressed for much longer (4–8 weeks) as it is only replaced as new RBCs are produced by the bone marrow (Figure 6.11). This point is very important, as best practice should include testing for both RBC and plasma AChE. A positive diagnosis may be missed if serum AChE is the only test used and is conducted several (10–14) days after exposure. The serum test may be normal at that time as the liver may have replaced the tied-up AChE, but

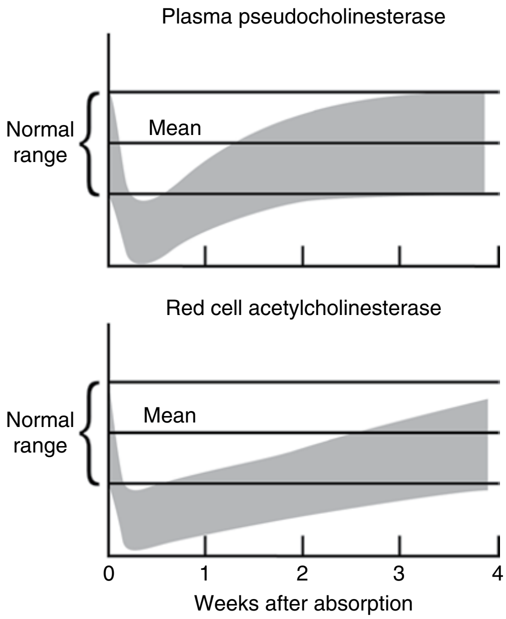


FIGURE 6.11 Organophosphates (OPs) combine with and inactivate acetylcholine esterase (AChE). Low AChE is a measure of toxicity. AChE is measured from sources in red blood cells and blood serum. Blood serum AChE returns to normal faster (1-2 weeks) compared to 4-5 weeks for red blood cell AChE. Therefore best diagnostic practices should include testing both red blood cell and serum.

the RBC AChE may still be low. Interpreting acute poisoning with a CB also has some challenges. As mentioned previously, the CB–AChE bond is short lived compared to the OP–AChE bond therefore a valid test for CB exposure must be conducted within the first few days of exposure, with either the serum or RBC AChE test.

Normal blood values of AChE vary widely between individuals therefore it is best to have individual baseline test results to compare with a second sample (coincident with exposure history) to determine if there is real depression of AChE. A 20% depression from baseline suggests a possible poisoning. A 40% depression of serum AChE or a 30% depression of RBC AChE suggests a diagnosis of acute poisoning and removal from work exposure. Without baseline values for a patient the published normal ranges provided by the manufacturer of the particular test must be used, which may not be relevant to an individual. Note that there are several different clinical chemistry tests for both plasma and RBC cholinesterase, which may provide different values. It is therefore important to make sure when comparing baseline values to exposure values that the same test is used and preferably the same laboratory to help assure reliable comparisons.

6.7.9 Treatment of OP and CB Poisoning

The treatment aim of acute OP and CB poisoning is to counteract excess ACh. The following recommendations come from Roberts and Reigert (17). Atropine, the primary antidote, blocks the effect of excess ACh on muscarinic receptors. Therapeutic dosages are to effect atropinization (e.g., pupil dilation, decreased bronchial secretions, dry mouth, tachycardia (increased heart rate), etc.). Based on the extent of poisoning, dosages may range from 1 to 3 mg IV every 5 minutes (up to 300 mg per day) until atropinization is achieved. Children under 12 should be dosed at 0.02 mg/kg, doubling the dosage every 5 minutes to effect. Dosage is by IV preferably, but intratracheal infusion may be used.

Additional to atropine, pralidoxime may be used early in combination OP poisonings (first 48 hours before aging of the OP–AChE bond). Pralidoxine can reverse the OP–ChE bond, helping to achieve atropinization more rapidly. The dosage of pralidoxine for adults and children over 12 is 2.0 g IV, given over a 30-minute period. Continued infusion should continue at 1 g per hour for 48 hours as needed, with subsequent dosage of 1 g administered over 60 minutes and repeated every hour as needed. Dosage for children under 12 is 20–50 mg/kg (in 100 mL saline) over 30 minutes (17). Pralidoxine is not indicated in CB poisonings as the CB–ChE bond is temporary.

Based on anecdotal case information and unpublished case investigations from this author's (KJD) observations in the past, workers highly exposed to OPs or CBs may take atropine for prophylaxis. They may do so on their own volition, having acquired atropine via illicit sources, for example crop dusters have been known to use atropine prophylactically (Figure 6.7). For several medical reasons prophylactic atropine is not recommenced (44). First, if the person is exposed and the atropine in the system is insufficient, clinical OP or CB toxicity may develop at a hazardous time, such as while a crop duster is flying an airplane, resulting in a risk of a serious crash. Furthermore, atropine depresses the ability of the worker to sweat, increasing the risk of hyperthermia. Eye pupil dilation can decrease visual acuity, making operation of equipment more hazardous and risking retinal damage from bright light (44). As CBs and OPs become less commonly used, this practice is likely to become much less common.

6.7.10 Pyrethrum, Pyrethrin, and Pyrethroid Insecticides

The fourth class of insecticides discussed here is pyrethrum and related products. Pyrethrins are chemical esters that make up pyrethrum, the insecticidal component found in the extract of flowers from the chrysanthemum family. These products are highly absorbed through the chitin of insects. The toxic mechanism results in a continual open access of the sodium ion channel in nerve cell membranes, causing a continual depolarization of the nerve cell and effecting paralysis of the nervous system, resulting in a rapid knockdown effect (the insect falls to the ground) (39, 47). Pyrethrins are often combined with other chemicals which hinder the capacity of the insects' enzyme systems to breakdown the pyrethins, enhancing their lethal effect. Common enhancers include piperonylbutoxide and octylbicycloheptenedicarboximide. These combined products are used in dairy barns for fly control and in over-the-counter household insecticides, but they are not used on crops as they degrade rapidly in the sun and heat.

Pyrethroids are synthetically derived chemicals similar to natural pyrethrum. They do not readily degrade with sunlight and heat and are much more potent insecticides compared to pyrethrum. Pyrethroids are now the dominant insecticide used in agricultural and commercial pest control, largely replacing OCLs, OPs, and CBs. AS mentioned above, pyrethroids are much less toxic to mammals, including humans, than to insects (more than 2000 times less toxic) (48). The reason mammals are less susceptible to pyrethroids and neonicotinoids is that they have many alternative sodium ion channel mechanisms compared to insects, and they have enzymes to rapidly break down the pyrethroid products once they enter the bloodstream (47–49). As occupational hazards these chemicals are primarily dermal and respiratory irritants and allergens. They cause contact dermatitis, both irritant and allergic types. They also cause allergic rhinitis and asthma (17, 39). These chemicals have low systemic toxicity, are rapidly degraded by the liver, and are excreted via the kidneys. Acute symptoms of pyrethroid insecticide toxicity are usually only seen with very high dosages, such as skin saturation with the concentrate or ingestion of large doses. Other related symptoms may include dizziness, salivation, headache, fatigue, vomiting, diarrhea, and irritability to sound and touch. Unusual sensations in the skin (paresthesia) noted by stinging, burning, itching, and numbness may be seen, primarily on the face, but also on the hands and arms (50). This effect is increased by sun, heat, and water. High exposures to the cyano-pyrethroid subgroup of pyrethroids may induce seizures. (Cyano-pyrethroids include flucythrinate, cypermethrin, delta permethrin, and fluvalinate.)

6.7.11 Treatment of Acute Toxicity with Pyrethroid Insecticides

As with any pesticide poisoning, the first treatment is to practice the general principles given in Table 6.4. Washing the skin with soap and water and flushing the eyes is the first response. Allergic reactions are treated with antihistamines and topical and/or systemic steroids. Asthma may be treated with beta-agonists (which dilate the muscles of the airways, i.e. albuterol pirbuterol, metaproterenol). Topical vitamin E oil preparations are effective against the paresthesia. Corn oil and petroleum jelly are less effective, and zinc oxide may increase the symptoms. Removal from the digestive tract is only warranted if a large amount has been ingested and within 1 hour following ingestion. As seen above, some of the generalized symptoms may mimic OP poisoning, but these chemicals are not cholinesterase inhibitors. Atropine administered due to a wrong diagnosis may be harmful, even fatal, to the patient (17, 39).

6.7.12 Neonicotinoid Insecticides

Humans have recognized the stimulant and addictive effects of nicotine from tobacco for hundreds of years. ACh receptor nerve cells have nicotine binding sites and nicotine exposure will cause them to activate, creating mild stimulation (the additive mechanism). In the mid-1980s and early 1990s research was conducted to investigate the use of this physiologic principle for chemicals potentially useful as insecticides. Synthetic modifications of the nicotine molecule (neonicotinoids, NNs) were developed and proved promising as effective insecticides, and yet were safe for non-target species. Insects' nerve cell binding sites are located mainly on nerve cells in their central nervous system, as compared to mammals, where they are distributed in the peripheral as well as the central nervous system. As the NN molecule binds to the receptor sites in insects, there is initial nerve stimulation. However, with continued and overstimulation, these receptor sites become desensitized and shut down, resulting in no nerve firing. Paralysis and death follow. ACh-receptor nerves in insects have a much greater affinity for nicotine binding as compared to mammals and other animal species. Thus NNs are much more lethal to the target species (insects) and relatively non-toxic to mammals (including humans), birds, and fish (41).

NNs are relatively selective to sucking and chewing insects. They are now one of the most highly used insecticide classes on the global market, capturing 25% of the world market in 2008 (41). They are used as seed protectant coatings on corn, soy beans, and many other agricultural seeds. They are also used as foliar (spray-on) insecticides on cotton, grain, legumes, potatoes, rice, and some fruits and vegetables. They are used in soil, timber, and even for flea prevention on cats and dogs. Imidacloprid is currently the major NN chemical in use today worldwide. Thiamethoxam, clothianidin, acetamiprid, and thiacloprid make up the remaining bulk of product sales.

There are few data available to create an in-depth picture of the health effects of human exposures to neonicotinoids as they have been in extensive use only since the 1990s, with few reports of human toxicity. This suggests that they are relatively non-toxic to humans. Available data suggest that skin and eye irritation is possible, but of minor concern (51). Ingestion may result in health consequences more severe than dermal or aerosol exposures. A review of human NN exposure data acquired from poison centers in Texas revealed the following (51): (1) over 90% of cases were managed at home or on-site following consultation with the poison center, (2) the bulk of the cases were reported as having no or minor to moderate health outcomes, (3) 2% of cases were referred to a healthcare facility. The following symptoms were reported: eye irritation (8%), skin irritation (7%), nausea (3%), vomiting (2%), and oral irritation (2%). The opinion of the author (48) of this review is that most exposure to these NN chemicals can be handled outside health care centers, with no or only minor health effect (52).

No specific treatment is recommended for human exposure to NNs therefore following the general principles of pesticide treatment addressed previously in this chapter is the best current recommendation.

Although NNs have comparatively benign human health effects, there have been some environmental concerns. In Europe NNs have been incriminated in the reduction in the honey bee population. "Colony collapse" syndrome is a worldwide concern (51). The possible connection of NNs to colony collapse has resulted in the EU considering NNs as restricted-use chemicals. Furthermore, other wildlife interest groups have been concerned that birds may suffer from eating seeds coated with these chemicals, and they have requested a ban on NNs. Because of these environmental concerns, the EPA has put imidacloprid on the 15-year registration review list.

6.7.13 Biological Insecticides

Biological pesticides (bio-pesticides) are "natural" substances used to control insects. These substances include microbes (e.g., *Bacillus thuringiensis*), plant products (e.g., the oil of the neem tree, *Azadirachta indica*), and naturally occurring soil substances (e.g., sulfur). Bio-pesticides also cover adding genetic materials to plants (plant-incorporated protectants, PIPs), otherwise known as genetically modified organisms (GMOs). Copping's *The Manual of Biocontrol Agents* lists and describes hundreds of bio-pesticide agents (53). Most developed countries license and control these substances. The US EPA registers them if there is proof there is no unreasonable human or environmental harm (54), the same requirements as for manufactured insecticides.

Bio-pesticides are compatible with organic food production. They are generally safer to use than manufactured products, biodegrade more rapidly, and have a more specific effect on target species. However, they may not be as effective or efficient as conventional pesticides, require close management, and are best used in an integrated pest management program.

Regarding occupational safety of these products, they are generally considered safe. Little information is available on harmful effects, including for PIPs, but use of PIPs is highly controversial. Promoted by many scientists, growers, and agribusinesses as advances in the field for producing food for the world, they are considered unsafe and/or undesirable by environmentalists and a large segment of the general public. PIPs are banned or partially banned in many countries around the world, including the EU (55). The primary concern of PIPs is food safety. The US EPA requires reasonable proof of human and environmental safety. The first PIP was registered in 1995. Since then, the EPA has registered numerous PIPs for corn, soybeans, cotton, and potatoes among various other crops. The most common PIP used in crop production today is the insertion of a gene from the bacterium *Bacillus thuringiensis* (Bt) which produces a toxin that kills insects feeding on plants containing this gene. Bt is an organism that naturally parasitizes caterpillar insects (53).

Opponents of PIPs in food products suggest that they may increase allergens, antibiotic resistance, and plant uptake of toxic heavy metals, and reduce the healthy components of plants, including phytoestrogens. However, a critical literature review by Bakshi (56) summarized that although continued research is needed, these products are generally safe. Other environmental concerns of PIPs are that they may be toxic to non-target insect species.

A major advantage of PIPs is that they result in a large reduction in the application of commercial pesticides which have known occupational and environmental health risks. The US EPA encourages further development of PIPs for the following reasons (54): (1) they are generally less harmful than conventional pesticides, (2) they are more target-specific than conventional pesticides, (3) they readily decompose, leaving no environment residue, and (4) if they are used in conjunction with integrated pest management there can be a significant decrease in the total use of conventional pesticides. However, the use of PIPs remains controversial and expansion of use globally will be cautious. The use of (non-PIP) bio-pesticides is generally favored by the public and organic growers, suggesting that their usage is likely to expand in the future.

6.7.14 Other Insecticides

Several other insecticide chemical classes exist, but they have relatively low usage. Those that are most commonly used are discussed here. *Elemental sulfur* is a very common chemical used on orchard, vine, and vegetable crops to control mites (acaraside) and fungi. It is a moderate dermal irritant, resulting in irritant contact dermatitis and irritation of the eyes and respiratory tract. Some of the sulfur on the foliage may be oxidized to sulfur oxides. These gases can increase eye and respiratory irritation for those working directly with the plant foliage. Large amounts of sulfur (e.g., 100 g) may be ingested with relatively little systemic toxicity. Although it is absorbed readily by the gut and excreted by the kidneys, there is a possibility that excess hydrogen sulfide may be formed in the gut, creating a secondary toxic exposure (17, 39). Ingested sulfur is an excellent laxative (cathartic), and may cause extended diarrhea, resulting in dehydration and electrolyte imbalance. Treatment of dermal contamination is removal of the sulfur from the skin by washing with soap and water. Eye contamination is treated by flushing the eyes with pH-balanced saline or clean water.

Propargite (a sulfur-based insecticide) is a common product used to control mites (acaricide) on citrus crops. There have been no systemic poisonings with this product, but it is a skin and eye irritant and allergen, causing allergic contact dermatitis (17, 39). Control and treatment is as described above for sulfur.

6.8 Herbicides: Usage, Acute Toxic Mechanisms, Diagnosis, and Treatment

Compared to insecticides, herbicides are generally much less toxic to humans and mammals. Plant physiology and toxicology are entirely different from those of mammals. Thus, with few exceptions, acute human poisoning events from herbicides are rare. Reported cases of human herbicide poisonings have followed unusually high exposures (e.g., unintentional or intentional ingestion of large quantities or extensive occupational exposures). An exception to this generalization is ingestion of even small amounts of the broad-spectrum herbicide paraquat. Additional generic symptoms of herbicide exposures include skin or eye irritation and irritant or allergic contact dermatitis. Chronic human toxic conditions from herbicide exposures are not causally proven to date (57).

Generally, the first treatment of herbicide poisoning should include the five principles described above (see Table 6.4). Specific treatments for individual classes of herbicides are addressed below.

The following paragraphs summarize the use, toxic principles, diagnosis, and treatment for the major classes of herbicides (17, 39, 58).

The chemical classes and mechanisms of action of herbicides are more diverse than those of insecticides. Nine primary classes of herbicides are discussed here: (1) phenolic compounds, (2) chlorophenoxy compounds, (3) arsenical compounds, (4) dipyridyl compounds, (5) organonitrogen compounds, (6) phalate compounds, (7) propenal, (8) triazine compounds, and (9) phosphonate compounds (17, 39, 58).

6.8.1 Phenolic Compounds

This group includes pentachlorophenols and dinitrophenols, products that function as preemergent herbicides and some that function as contact herbicides. These products have been used for many years in various applications, including weed and brush control along railroad rights of way and field borders, and as a fungicide, parasiticide, wood preservative, and germicide for hide preservation. Currently, there is only one registration in the United States for pentachlorophenol (pressure-treated wood preservative for utility poles). On the other hand, dinitrophenols have a wide spectrum of agricultural uses globally. Dinocap is the only currently registered dinitrophenol in the United States and is used primarily as a fungicide, acaricide (ticks and mites), and for mildew on orchard and ornamental crops. Although these compounds have caused poisonings and occasional deaths, they are not strong systemic toxins (relative to insecticides). However, they are stable compounds and may be commonly found in the blood and urine of most animal species (including humans), probably from eating contaminated foods, inhalation of the volatilized chemical or contact with wood (such as home interiors containing wood logs or wood paneling) that has been treated with phenolic compounds.

Their toxic mechanism is the uncoupling of oxidative phosphorylation in cellular respiration, preventing the intracellular energy-storing function of ADP to ATP. This results in excess energy being released as heat, rather than being stored. Hyperthermia (fever) and sweating are the principal clinical signs, and symptoms include feeling warm. Workers in hot environments (e.g., agricultural workers) are more susceptible to the effects of these compounds. Poisoned individuals working in hot environments are at special risk for heat stroke, which is the main factor that has resulted in deaths from these compounds. (Nitrophenols are more likely to cause hyperthermia than chlorophenols.) Hyperthermia (in addition to a direct cellular effect) may result in cellular necrosis of muscles, liver, kidney, and brain tissues. These chemicals are irritants and inhalation of vapors or direct contact with pentachlorophenol may cause respiratory and skin irritation. Additional symptoms of phenolic compound toxicity (additional to high body temperature) include weakness, sweating, flushed appearance, and depressed mental function. Headache, dizziness, and peripheral neuropathy may also be present. Symptoms of severe poisonings may include toxic psychosis, manic behavior, convulsions, and coma. Chronic poisoning by both nitrophenols and pentachlorophenol results in fatty liver, toxic nephrosis, and weight loss. (In the past these compounds were used as weight-loss adjuvants in humans, and to treat intestinal parasite infestations in dogs.) Nitrophenols have a characteristic bright yellow color and diagnosis may be aided by a yellow staining of the skin (direct contact) or sclera of the eye (absorption).

Laboratory confirmation requires testing the urine or blood for metabolites of this chemical group, using spectrophotometric or gas-liquid chromatographic methods. Levels in excess of 1000 ppb and compatible history, symptoms, and clinical signs are consistent with an acute poisoning.

There is no specific antidote for these chemicals. The most effective treatment has been the use of physical methods of cooling the hyperthermic patient, such as cool baths or cooling blankets. The antipyretic (reduction of fever) action of aspirin and tylenol has not been effective and may be contraindicated in acute poisoning.

6.8.2 Chlorophenoxy Compounds

These systemic herbicides have been widely used as brush and weed killers since the early 1950s (17). The primary chemicals in this class include 2,4-D and 2,4,5-T (the latter is now banned by the EPA), dichhlorprop, 4-(4-chloro-2-methylphenoxy)butanoic acid (MCPB), and dicamba. These chemicals are effective mainly on broad-leafed plants. They are used in many agricultural operations for weed and brush control. In agriculture, they may be incorporated with fertilizers to control broad-leaf weeds while fertilizing with one pass. 2,4-D and 2,4,5-T were used in equal mixtures with an orange dye as a defoliant in the Vietnam War (Agent Orange). Although many claims were filed by exposed soldiers, cause-effect data are marginal. Health problems that may have resulted from Agent Orange exposure were likely a result of dioxin, a contaminant of the manufacturing process (this problem has been largely eliminated). As these chemicals are applied as a sprayed-on emulsion, occupational exposure may occur by inhalation of droplets or direct skin contact during mixing–loading operations, application or application equipment repair, or clean up.

Chlorophenoxy compounds have low acute toxicity and acute clinical events have mainly been associated with massive exposures, such as ingestion in suicide attempts or extraordinarily high occupational exposures. They are moderate irritants to the skin and mucous membranes. Moderately to heavily exposed individuals may experience headache, dizziness, peripheral neuropathy, and airway irritation. Heavily exposed individuals (e.g., ingestion of large quantities) may result in metabolic acidosis (low blood pH) and blood electrolyte imbalance, resulting in kidney and muscle damage. Dioxins (highly toxic compounds) were a contaminant of the early manufacturing process, as the products were synthesized under too high a temperature.

(Regulations now specify no more than 0.1 ppm of dioxins in chlorphenoxy compounds.) Several cases of dioxin toxicity in manufacturing plant workers (but not agricultural workers) have been noted, including chloracne and neurological injury.

Laboratory confirmation of poisoning with chlorphenoxy herbicides requires gas-liquid chromatography of blood and/or urine. As is the case for many herbicides, chlorophenoxy compounds are excreted rapidly (within 24 hours) therefore analysis for confirmation must be accomplished soon after exposure to obtain a laboratory diagnosis. Secondary dioxin exposures are difficult to determine as levels of dioxin in today's chlorphenoxy herbicides are usually below toxic concentrations.

The general practices mentioned previously constitute initial treatment. The herbicide itself often induces catharsis (vomiting) and therefore additional cathartics are often not needed. Secondary treatment may be required in severe poisonings, including monitoring of kidney function and facilitation of kidney function as indicated (17). Key principles of treatment include IV hydration to enhance kidney output, management of electrolyte balance, and correction of blood pH.

6.8.3 Arsenicals

Arsenic compounds have been used not only as herbicides, but also as insecticides, fungicides, antibacterials, and animal anti-protozoal agents. The various forms of arsenicals include inorganic trivalent (arsenites), inorganic pentavalent (arsenates), and various types of organic (methylated) pentavalent forms (59). Of the inorganic arsenicals, trivalent forms are by far the most toxic of this group (four to ten times more toxic than pentavalent forms). The organic pentavalents are by far the least toxic. Prior to 1950, the inorganic trivalent arsenic trioxide was a commonly used herbicide, rodenticide, and insecticide. The tradename for one former commonly used product in this class was Paris Green (it contained copper, which created the green color). Paris Green was responsible for many human deaths. It is a general cellular toxin with a predilection (targeting) for the central nervous system. Chronic effects include lung and skin cancers. One may still find this chemical stored on farms or orchards, left over from years past and resulting in occasional unintended poisonings. Ingested inorganic arsenic disrupts cellular metabolism by substitution in phosphorylation reactions. Arsenic also disrupts various enzymes and co-enzymes. The trivalent inorganic arsenic is highly toxic to blood vessels, causing dilatation and increased permeability of the capillaries. Ingested arsenic first attacks the intestinal lining and blood vessels supplying the intestines (resulting in stasis and insufficient blood supply (ischemia) and causing abdominal pain and GI bleeding). It also causes necrosis of the liver, kidneys, and central nervous system. Chronic poisoning is marked by hair loss, hyper-pigmentation of the skin, and hyperkeratosis (excessive thickening of the outer layers of skin, e.g. calluses). In addition, there are relatively strong cause-effect associations of inorganic trivalent arsenicals to liver, skin, and lung cancers. Other chronic symptoms include weakness, incoordination, pain in extremities, persistent excess blood and protein in the urine, and loss of appetite and weight.

Because of their high toxicity, with many poisonings in non-target species, and associations with liver, skin, and lung cancers in humans, trivalent arsenicals have been replaced by newer, pentavalent forms, either inorganic or organic, called cacodylic acid. They are used largely as defoliants in cotton and in home use as a crab grass killer. Other forms are used as intestinal antibacterial and antiprotozoal agents in poultry and swine. The pentavalent forms are relatively safe chemicals in non-target species as they are poorly absorbed from the gut or through the skin.

Recent concerns have been expressed by scientists because of the natural presence of low-level arsenic in some drinking water and low levels found in homes and in children's play areas near agricultural areas where arsenic was applied years ago (60). The health effects of these low levels of arsenic are undetermined. Some countries (e.g., Bangladesh) have very high levels (well above the maximum recommended concentration of 50 mg/L) of arsenic in drinking water, which may give rise to cancer, neurologic disease, and a variety of other systems pathology.

Confirmation of poisoning requires measuring arsenic in the urine or blood at more than several hundred (typically over 1000) micrograms. A meal of seafood may interfere with test results, causing a temporary increase in arsenic in the urine, therefore a second measure may be indicated to confirm poisoning, recognizing, however, that arsenic is cleared very rapidly by the kidneys.

First treatment of acute poisoning must include the general principles of decontamination. Secondary treatment aims to lower the body's burden of arsenic by increased excretion through IV administration of the chelating agent dimercaprol (British anti-lewisite, BAL). This is important for acute as well as chronic poisoning.

Although there is a wide range of toxicity of the various arsenicals, it is recommended that acute exposures of any arsenical should be treated in the same manner. However, it is important to know to which specific product the patient was exposed because prognosis is highly related to the specific chemical, with pentavalent and organic forms having low toxicity compared to trivalent inorganic products.

6.8.4 Dipyridils (paraquat and diquat)

Paraquat and diquat have had widespread use in agriculture as broad-spectrum herbicides and desiccants (early and uniform maturing of crops for harvest). One important feature of these chemicals is that they adhere strongly to nearly anything they come into contact with. For example, when they are applied to the soil they adhere strongly to the soil particles and are of little environmental or personal risk thereafter. In the United States paraquat is a restricted use product (meaning there are limitations for its use and training of applicators may be required). It is not currently used in the EU. Diquat is not a restricted-use product and is widely used globally.

A primary occupational concern is the acute irritant characteristics of paraquat and diquat. If a worker is exposed to a spray of either of these chemicals, one or more of the following may occur: nosebleed, corneal opacity, yellowing and disfiguring of finger nails, dry, cracked, discolored skin, nose bleed. None of these dermal irritant effects is life threatening, but ingestion of paraquat may result in severe life-threatening complications. The immediate effects of ingestion include superficial burns of the oral and pharyngeal mucosa and GI irritation, which often causes nausea, vomiting, diarrhea, and sometimes dark-colored stools from an upper GI bleed (melena). These symptoms may be mild and distract the patient and healthcare provider from the serious consequences that follow. During the first week following ingestion there are indications of liver and kidney injury, but these are not usually fatal injuries. Also at this time there are sub-clinical lung parenchymal changes, manifested by intra-alveolar hemorrhage and edema with necrosis of alveolar pneumocytes (lung cells). Some patients may exhibit only pulmonary edema, and these usually survive with appropriate critical care management. However, 4–10 days following ingestion most patients proceed to a second stage of the disease, progressive malignant interstitial fibrosis of the lung.

If the concentrate (20% w/v) of this chemical is ingested (20–40 mg or 7.5–15 mL), life-threatening toxicity may occur. One week following ingestion there may be liver and kidney necrosis, but the principal lethal effect is to the lungs. The lethal toxic mechanism of paraquat is that it bioaccumulates in the pneumocytes (lung cells), where the free radical by-products of biotransformation may cause a malignant proliferation of fibrous connective tissue in the lungs. This reaction continues, accompanied by progressive edema and dyspnea (difficult breathing), and almost invariably ends in death of the patient in 2–3 weeks. Most cases result in death by asphyxiation. (Note that only ingestion exposures (not skin or aerosol exposure (with one known exception) are considered a risk for the malignant pulmonary reaction). Most lethal cases of paraquat poisoning have resulted from suicide attempts.

A high proportion of suicides in South Asian countries has been from paraquat ingestion, probably because of its known lethal effect and ready availability of the product.

Because any history of paraquat ingestion (especially the concentrate) should be considered an emergency, treatment should begin prior to receiving laboratory test results. As paraquat is absorbed relatively slowly from the gut, prompt recognition of the hazard and removal of the chemical from the gut has saved many lives. Immediate evacuation and lavage of the stomach should be initiated, followed by instillation of adsorbents, preferably Fuller's earth and bentonite at 100–150 g. Activated charcoal is a good substitute for the former. Adsorbents should be given to the limits of tolerance of the patient. Saline catharsis (enema) should follow.

Following emergency treatment, laboratory diagnosis of ingestion and absorption of paraquat can be accomplished by analysis of urine by chromatography or of blood by spectrophotometry, liquid chromatography or various other means. Product manufacturers and several EPA-supervised laboratories can conduct this analysis. This will help to confirm absorption and/or the success of emergency treatment, and will aid in prognosis. Once the chemical is absorbed into the bloodstream, excretion can be accelerated by diuresis with IV fluids and diuretics such as manitol and furosemide. Hemoperfusion over charcoal has been used to lower blood levels of paraquat, but it must be used within 10 hours of ingestion to be effective (17).

A conundrum in the medical treatment of paraquat poisoning is that oxygen stimulates the proliferation of fibrous connective tissue in the alveoli. Administration of supplemental oxygen is not indicated unless the arterial oxygen falls to levels that may cause cerebral anoxia. Some physicians have even practiced putting patients (early in the course of disease) in a hypoxic environment (10–12% oxygen) or nitrous oxide to retard pulmonary fibrosis. Corticosteroids with an immunosuppressant (e.g., cyclophosphamide) have been used with some evidence of benefit, along with C, E, and B vitamins.

As mentioned above, diquat has similar acute irritant effects to paraquat, but its toxic effects on the lung are much less prominent. Diquat is not as selectively concentrated in the pneumocytes and no malignant progression of pulmonary fibrosis has been recorded with diquat poisoning.

6.8.5 Organonitrogens

This group of chemicals includes most preemergent herbicides, some soil sterilants, and some contact herbicides. Generally, these are low systemic toxic chemicals. They are mainly irritants or sensitizing agents. Ingestion of these chemicals results in GI irritation, but no liver or kidney involvement. The chlorinated acetanilides (especially propachlor) are extreme skin sensitizers. Some individuals become so sensitized that complete avoidance is necessary.

Ingestion of these chemicals has resulted in irritation of the GI tract, manifested as nausea, vomiting, and diarrhea. No other systemic or organ systems toxicity has been observed.

One subgroup of organonitrogen herbicides is the carbamates. Although these herbicides are chemically similar to carbamate insecticides, they do not tie up AChE therefore individuals exposed to these chemicals should not be treated with atropine.

The first level of treatment of exposure is the five general steps of decontamination as described in Table 6.4. Ingestion of small amounts of these chemicals may warrant administration of a few ounces of activated charcoal followed by saline catharsis. Ingestion of large amounts may warrant gastric lavage, followed by administration of activated charcoal and saline catharsis. However, each case should be evaluated carefully, as these chemicals are generally of low systemic toxicity and the risk of aspiration pneumonia during lavage should be weighed in relation to the risk of toxicity.

Confirmation of absorption may be indicated in individuals with a history of ingestion, especially if symptoms occur following occupational exposure. Analytical methods to determine the urinary metabolites of many of the chemicals in this class are available.

Hypersensitivity reactions may occur. Immediate hypersensitivity may be treated with antihistamines and steroids as necessary. Delayed or chronic allergic contact dermatitis cases may be treated with topical steroids, combined with systemic steroids in severe cases. As most people develop sensitivity to these chemicals, complete avoidance by substitution of products or removal of the worker to different jobs is often necessary as PPE does not usually provide adequate protection.

6.8.6 Phtalic Acid Herbicides

These chemicals are used primarily on cotton, strawberries, beans and other vegetable crops, and weeds in turf. Dachtal (DCPA) is one example of a herbicide in this group of chemicals. These chemicals are of low systemic toxicity. Ingestion may result in blood in the urine, but no other symptoms or signs occur unless a large amount of the substance is ingested.

Similar to organonitrogens, phthalates are primarily irritants to the skin, eyes, and mucous membranes. Treatment for either dermal or ingestion exposure to these chemicals is the same as for organonitrogens. Analytical methods of identification of dacthal in blood or in urinary metabolites are available if indicated.

6.8.7 Propenal

This product is an irritant gas (similar to tear gas, in fact one specific use for this chemical is as tear gas). Propenal is the primary active ingredient in several products, for example acrolein, aqualin, and acryladehyde. These products are typically applied by bubbling the gas into water to control water weeds, for example in irrigation ditches. The chemicals are extremely strong irritants, primarily to the eyes and mucous membranes, causing tearing, runny nose, irritation of the throat and bronchi, and occasionally pulmonary edema. Asthmatics are at increased risk from exposure to these substances.

Propenal is contained in gas cylinders, and exposures have primarily been associated with accidental mishandling of equipment or equipment failure (leaky or failed valve or hose). A positive history of exposure is usually sufficient for diagnosis. Ordinarily the only treatment necessary is to remove the victim from the exposure source to fresh air for a period of time until symptoms dissipate. Asthmatics may exhibit more serious symptoms as this irritant may initiate an asthmatic attack. Treatment with bronchodilators may be necessary in conjunction with administration of oxygen with positive pressure assistance.

6.8.8 Triazines

This group of chemicals has been one of the most highly used herbicides in the past 50 years. They are used as a pre-emergent in corn (e.q., atrazine) and many small grain crops. Although triazines are found as contaminants in surface and ground waters and are suspect carcinogens, there are relatively few acute health concerns. These chemicals (especially pramitol) are potent irritants to the skin, eyes, and respiratory tract (39), but they have very low systemic toxicity.

With regard to chronic issues, atrazine has been found to be an endocrine disruptor, possibly associated with poor semen quality, as noted in some studies (61, 62). Details of the proposed chronic health effects of atrazine are discussed in a later section of this chapter.

6.8.9 Phosphonates (e.g., glyphosate)

Over the past decade, phosphonates have become the dominant broad-spectrum herbicide. They have encroached on former usages of the dipyridyls (paraquat, diquat), chlorophenoxys (2,4-D and 2,4,5-T) and triazines among other herbicides in many applications. The most common chemical in this group, glyphosate (common commercial name Roundup), is available for both home and agricultural use. Genetic engineering of plants has resulted in many crops that can tolerate these chemicals, increasing its usage tremendously in agriculture (e.g., Roundup Ready, soy beans, alfalfa, and cotton).

Its toxic mechanism in plants is inhibition of the enzyme system, which produces several amino acids, including phenylalanine, tyrosine, and tryptophan. Mammals, including humans, are not affected by these products because they do not have this enzyme system.

Similar to the triazines, phosphonates have low systemic toxicity (LD_{50} is 4300 mg/kg). However, they are moderate irritants to the skin, eyes, and upper respiratory tract. The actual symptoms may be associated with the surfactant in the product, rather than the active ingredient.

Occupational exposures in agriculture resulting in symptoms are rare. In a review of 601 cases reported to poison centers in the United States, 81% resulted in either no or only minor symptoms. Moderate to severe symptoms were seen in 5.5% of cases and 3.2% of cases were fatal. Most severe poisoning episodes resulted from ingestion of a large quantity of the product in a suicide attempt. Initial symptoms in these cases were throat and mouth pain, nausea, and vomiting. Most severe symptoms were related to the cardiovascular system (increased heart rate, dysrhythmias, and hypotension), leading to hypovolemia and low urinary output (oliguria). Respiratory effects included pulmonary edema, leading to respiratory distress. Plasma levels of glyphosate at 734 mg/mL have been associated with fatal outcomes.

First treatment as with all pesticide poisonings is application of the standard five principles of decontamination. Supportive therapy, including IV fluids (monitoring urinary output and presence of pulmonary edema), is indicated. If renal failure ensues, hemodialysis may be considered along with correction of possible hyperkalemia (high potassium levels).

A recent environmental concern of glyphosate is the emergence of resistant weeds. There is a concern that genetically modified glyphosate-resistant plants may transfer resistance to undesirable plants, thereby creating a weed control problem. Furthermore, there is a small group of international scientists who have expressed concerns about the long-term use of glyphosate. These concerns include adverse alterations in soil microbiology, reduced animal feed value of plants, and human and animal health issues. Based on limited animal studies, in 2015, the International Agency on Research on Cancer (IARC) listed glyphosate in category 2A, (probably carcinogenic to humans). These concerns are controversial, and further science-based evidence is needed to gauge their importance.

6.9 Fumigants: Usage, Acute Toxic Mechanisms and Treatment

The following paragraphs summarize the toxic principles, applications and treatment of fumigants exposures (5, 17, 39, 63). Fumigants are gases, liquids, or solids that sublime to gases and are used to control insects, rodents, and other vermin. Fumigants include several chemical classes, all with several common general physical and toxic principles. They have low molecular weight and high vapor pressure, and thus have a high capacity of diffusion and penetration into very small spaces, cracks, crevices in structures, stored grains, and soil to kill pests throughout the targeted area. The general human toxic effect of fumigants is that they are strong irritants and general cellular toxins. However, each class has additional specific toxic principles.

The classes of fumigants include: (1) naphthalene, (2) halocarbons, (3) oxides and aldehydes, (4) sulfur compounds, (5) phosphorus compounds, (6) nitrogen compounds, and (7) methyl isothiocyanate generators. Products registered for use in agriculture by the EPA include chemical representatives of only a few of the above. In agriculture, fumigants are mainly used to protect stored grains or other agricultural produce (grapes, citrus fruits, peaches, etc.) from loss due to insects or rodents. They may also be used inside livestock buildings (when empty of livestock) to control harmful bacteria, flies, rodents, and birds, and as soil sterilants to control nematodes and fungi that may be harmful to vegetable and fruit crops (63–65). Common agricultural fumigants are those used mainly as soil sterilants or structural fumigants, that is, chlorpicrin, metam sodium, methyl bromide, methyl iodide, dichloropropene, and methylisocyanate. The latter two are combined in the product Vorlex. Aluminum phosphide is commonly used to fumigate stored grain. Pellets of the product are metered into grain going into storage. When the product collects water, it hydrolyzes to phosphine gas, which is a very toxic fumigant.

Most poisoning occur when workers re-enter fumigated structures (confined space) before the structures have been adequately ventilated. Severe exposures usually occur by inhalation and, occasionally, skin contact from liquid fumigants. Extensive exposure may represent a life-threatening circumstance. In most instances, workers do not realize how severely toxic fumigants are. This is especially true among occasional users, such as farmers who attempt to treat small amounts of stored grain on their farms. Structural factors and work processes must be analyzed to determine the risk of exposure to fumigants (66).

Although injuries vary with particular chemicals, fumigants generally have one or more of the following toxic principles: (1) irritation to any exposed tissues, (2) central nervous system damage, (3) liver and kidney tissue damage, (4) tie-up of hemoglobin (oxygen-carrying capacity of blood), and (5) tie-up of general cell metabolism. These toxic principles result in six general types of injury: (1) eye, mucous membrane, and skin damage, (2) pulmonary edema, (3) seizures, (4) cardiac insufficiency (heart failure), (5) kidney failure, and (6) liver damage (67). The first two injuries are the most common exposure outcomes. The strong irritant nature of these chemicals can cause corneal desquamation (loss of surface cells over the cornea) and ulceration. Dermal effects may manifest as severe bullous (blisters) dermatitis with extensive necrosis of skin. Upper respiratory effects may include laryngeal edema and bronchospasm. Lower airways damage may result in acute or delayed (4–12 hours) pulmonary edema. Central nervous system effects may manifest as stupor, seizures, unconsciousness, or respiratory depression. Cardiac arrhythmia may result in sudden death. Kidney damage may result in acute or chronic kidney failure. Liver damage is usually reversible, but sometimes results in lethal necrosis or chronic cirrhosis.

The high capacity for fumigants to diffuse and penetrate complicates the protection of exposed workers. Systemic poisoning from fumigants can easily occur as they cross the skin barrier readily. Except for self-contained breathing apparatus (completely sealed around the face), respiratory protective devices are ineffective. Fumigants may penetrate natural rubber and neoprene. It is generally recommended that workers do not wear rubber suits or gloves while working with fumigants because severe skin injury can result if a small amount of gas or liquid enters under or through the protective material and becomes occluded, intensifying the exposure. The only effective protection against most fumigant compounds is complete avoidance.

The effects of two commonly used fumigants, methyl bromide and aluminum phosphide, are discussed here in detail. Exposure to methyl bromide has caused a significant number of acute deaths from pulmonary edema. (Methyl bromide is being phased out and replaced with methyl iodide and methyl chloride among others, which have similar health effects (68).) Prolonged or recurrent low-level exposure produces a bizarre neurological syndrome in exposed workers, apparently due to selective effects on the basal ganglia in the brain. The victims show marked incoordination, disturbed speech, cerebellar ataxia, and awkward involuntary movements of the extremities. These symptoms sometimes develop hours or even days following the last contact with methyl bromide. Manifestation persists for weeks or even months. To date, all victims of this type of poisoning have ultimately recovered normal neurological function.

Phosphine gas from hydrolyzed aluminum phosphine with low to medium exposure causes skin irritation, rash, headache, nausea, vomiting, throat irritation, chest tightness, shortness of breath, dizziness, fainting, and incoherence. High concentration exposures may result in fatal pulmonary edema and hepato-renal failure.

Although there are some generalities associated with fumigant exposures, there are also specific toxic principles for the various chemicals. Table 6.5 (17, 63, 65) lists the specific toxic principles of commonly used fumigants.

Table 6.5 Toxic principles of fumigants (17, 63, 65)

Fumigant product	Toxic principles
Acrolein	Irritating gas, used on aquatic weeds
	Eye, skin, and respiratory tract irritant
Acrylonitrile	Eye, skin, and respiratory tract irritant
	Transformed to hydrogen cyanide in the gut, resulting in cyanide poisoning
Carbon disulfide[a]	Moderate eye and respiratory tract irritant, strong skin irritant
	"Rotten egg" or "sweet" odor
	CNS toxicant, headache, nausea, delirium, paralysis, respiratory failure, death
Carbon tetrachloride[a]	Minor eye, skin, respiratory irritant
	Potent liver and kidney toxin
	Possible cardiac arrhythmias
Chloroform	Mild irritant to eyes, skin, and respiratory tract
	CNS depressant (formerly used as an anesthetic)
	Large doses may lead to cardiac arrhythmia, and liver and kidney damage
Chloropicrin[a]	Soil sterilant
	Strong irritant to eyes, skin, and respiratory tract
	Ingestion may cause gastric ulceration
Dibromochloropropane[a]	Strong irritant to eyes, skin, and respiratory tract
	Symptoms include nausea, vomiting, CNS signs
	Liver and kidney toxin
	Chronic exposure may lead to male infertility due to necrosis of seminiferous tubules
Dichloropropane/ cichloropropene[a]	Strong irritant to eyes, skin, and respiratory tract
	Possible risk of liver, kidney, and cardiac toxicity from ingestion of large quantities
Ethylene oxide/ propylene oxide	Strong irritant to eyes, skin, and respiratory tract
	May cause arrhythmias
Formaldehyde[a]	Strong irritant to eyes, skin, and respiratory tract
	Potent sensitizer, leading to allergic contact dermatitis
	Asthma-like symptoms
	Inhalation may cause acidosis
Hydrogen cyanide	See acrylonitrile above
	General cellular toxin, disrupting cytochrome oxidase system
	Predilection for the CNS
Methyl bromide[a]	Severe irritant to the eyes, skin, and especially the lower respiratory tract, causing acute or delayed (4–12 hours) pulmonary edema
	CNS toxin resulting in varying symptoms, including incoordination, tremors, slurred speech, and seizures
	Epidemiologic associations with prostate cancer
	Ozone-destroying chemical
	Scheduled for phase out in 2005 under the Montreal Protocol
Methyl iodide[a]	Soil sterilant, replacing methyl bromide
	Health effects similar to methyl bromide
Methyl chloride	Similar to methyl bromide, but less irritating and mild systemic toxicity
Naphthalene	Used as moth balls
	Mild irritant to eyes, skin, and respiratory tract
	Genetic susceptibility in some due to glucose-6-phosphate dehydrogenase deficiency, mainly in Mediterranean and African ethnicity, resulting in hemolysis and renal tubular damage
Phosphine[a]	Stored grain sterilant
	Supplied as aluminum phosphide (phostoxin) tablets.
	When exposed to air and water the active ingredient (phosphine gas) is slowly released (increases safety factor)
	Extreme irritant to eyes, skin, and respiratory tract
	Odor of dead fish
	Arrhythmias, cardiac failure, and pulmonary edema are most serious hazards
Sulfur dioxide	Severe irritant to eyes, skin, and respiratory tract
	May cause pulmonary edema or asthma-like condition

[a] Most common products used in agriculture.
CNS, central nervous system.

The first step in the treatment of fumigant poisoning is to remove the victim from the exposure to fresh air, making sure that the rescuers do not also become victims. Caution must be taken in rescuing people from where fumigants have been used, especially in confined spaces. Confined space entry procedures must be used. This means that unless it can be absolutely ensured that the environment is free of toxic exposures; rescuers should use self-contained breathing apparatus with a rescue harness and adequate power to extricate the rescuer and victim remotely.

Once a victim has been removed from the exposure, he/she must be kept quiet and in a reclined or sitting position with back rest to help prevent pulmonary edema. Respiration and cardiac function must be monitored and oxygen and/or artificial respiration administered as necessary. The basic treatment procedures are similar to those described in Table 6.4 for treatment of insecticide poisonings. One difference in treating fumigant injuries from other pesticide exposures is that skin exposure may lead to severe dermal or eye damage that will need medical attention following acute treatment. The initial basic treatment for fumigant exposures should therefore emphasize (1) extensive skin and eye flushing with water or saline to limit external tissue damage and further absorption and internal damage in addition to (2) clearing of airway and GI tract (if ingestion has occurred), and (3) cardio-pulmonary resuscitation as indicated.

If pulmonary edema is evident, immediate patient management is to limit physical activity. Intermittent positive pressure oxygen may be given, but only as needed, as excess oxygen may increase pulmonary damage from the fumigant. Oxygen saturation or PO2 should be monitored. A diuretic (e.g., furosemide) may be given to help reduce pulmonary edema fluid (17). If shock occurs, the patient should be placed on an incline with their head lower than their feet (Trendelenburg position) to help prevent blood pooling in the lower extremities.

If convulsions occur, treat as indicated in Table 6.4. It should be noted that convulsions are most likely to occur with poisonings from methyl bromide, cyanide, acrylonitrile, phosphine, or carbon disulfide. Convulsions from methyl bromide may be refractory to benzodiazepam and phenylhydantoin treatment. Barbiturates may have to be used.

Kidney and liver function should be monitored. Urine analysis with evidence of urinary casts suggests kidney tubular damage. Hemodialysis may be needed if there is significant kidney damage. The following liver function enzymes should be monitored: alkaline phosphatase, LDH, ALT, and AST.

There are certain additional characteristics and recommendations for some specific fumigants. With carbon disulfide poisoning there may be some initial severe central nervous system signs, but in most instances the patient will recover from these signs spontaneously (17). Although there is no specific antidote for carbon tetrachloride poisoning, initial hyper-baric chamber treatment with oxygen may help to limit liver damage in acute exposure. N-acetyl cysteine (mucormyst) may be administered to decrease free radical damage. It may be administered orally at 20% (1:4) in a carbonated beverage for a total of 140 mg/kg, followed by 70 mg/kg every 4 hours for 17 doses. Mucomyst may also be given via stomach tube or IV. IV glucose and vitamin infusion help to protect the liver. Hemodialysis may be necessary to sustain life if renal failure occurs.

Phosphine gas exposure has been treated with magnesium sulfate to retard the cardiac effects. The dosage given is 3 g in the first 3 hours by IV, followed by 6 g in the following 24 hours over the following 3–5 days.

Hydrogen cyanide and acrylonitrile poisoning (same toxic principle) are treated with nitrite as amyl nitrate, sodium nitrite, or sodium thiosulfate (available as Lilly cyanide kits, Eli Lilly, Indianapolis, IN). Administration is at the rate of 0.55–1 mg/kg, depending on the hemoglobin concentration.

6.10 Chronic Health Effects of Insecticides, Herbicides, and Fumigants

Hundreds of studies have been conducted aimed at discerning the chronic health effects of pesticide exposure. Numerous reports have been published in peer review literature on associations between pesticide exposures and chronic health outcomes. However, associations do not mean cause-effect. Establishing cause-effect for the chronic health effects of environmental exposures generally is very challenging for many reasons (2, 69). Determining the accurate specificity and quantity of exposures to suspected agents that may have occurred many years earlier is extremely difficult. It largely depends on the memory and accurate reporting from potentially exposed individuals. Challenges in epidemiologic studies include determining and controlling for confounding variables, co-variables, biases, and multiple causations. In addition, associations between pesticides and symptoms or health conditions are often ill-defined and subtle, adding further challenges. Bradford Hill's famous paper on environmental causation (reviewed by Lucas and McMichael) and a paper by Donham and Thorne (2, 69, 70), suggested that to determine cause-effect, most or all of following are necessary: (1) proof of exposure to the suspected agent, including exposure prior to effect, (2) a substantial dose-response effect should be seen, (3) agreement and repeatability among several studies, (4) the association should be biologically plausible (i.e., does it make sense), and (5) a probable and plausible mechanism.

Several scientists have reviewed the available research on the chronic health effects of pesticide exposures. Their opinions of the state of the science suggest that the weight of evidence requires caution and exposure prevention, but may not rise to level of cause-effect (2, 71). The quotation from a recent review of the health effects of pesticides by McCauley and colleagues summarizes chronic health effects as follows: "Although a number of health conditions have been associated with pesticide exposure, clear linkages have not yet been made between exposure and health effects except in the case of acute pesticide exposure" (3).

The deficiencies in the state of the science create complications in risk communication between the health and safety professional to their client or patient about this subject. This often results in uncertainty in the professional and the client/patient, resulting in an emotional response and fear as opposed to a rational response toward development and promotion of effective preventive measures. Given the above caveats, the suspected associations between pesticides and chronic health effects are summarized below.

Carcinogenic, mutagenic, teratogenic, and oncogenic associations have been reported and these are discussed in Chapter 5. Reproductive and urogenital disorders associated with pesticides exposures have been reported, including reduced sperm count, sterility, miscarriage, and urogenital cancers. A proposed mechanism for these outcomes has been endocrine disruption action attributed to numerous chemicals in our environment, including a few that are insecticides, herbicides, or fungicides (61). Organochlorines, organophosphate insecticides, and the herbicide atrazine have received the bulk of scrutiny as pesticide endocrine disruptors. The proposed mechanism is that these chemicals may bind to cellular androgen and/or estrogen receptors sites, mimicking hormone action (agonist effect), or block the receptor sites, resulting in a blockage of hormone action (antagonist effect). Additional actions may include interference with synthesis, transport, metabolism, and elimination of natural (normal) hormones (62). Proposed disease associations with the hormonal disruption actions have included adverse central nervous system development or developmental dysfunction in infants, children, or adults, and urogenital cancers among other outcomes (62). For example, OCL exposures have been associated with several congenital and reproductive problems, including hypospadia (a congenital altered location of the urethral opening), oral clefts, nervous system anomalies, and abnormal sperm. Additional associations of OCLs with deficits in male reproductive hormones and thyroid hormones have been reported (71).

Associations between insecticides and central and peripheral nervous system disorders have been shown. For example, fetal and child neurological development and child behavioral disorders have been associated with OCL and OP exposures (61).

Adult chronic neurological deficits associated with past acute poisonings or long-term low-level OP exposures include subtle peripheral clinical signs (e.g., visual motor speed, nerve conduction velocity, and central neurological deficits, including cognition deficits, verbal abstraction, attention and memory deficits (15), and Parkinson's disease (61, 72). Reviews by Kamel, Hoppin and associates (73), and Tanner and associates (74) suggest evidence of an association between pesticide exposures, cognitive and psychomotor dysfunction, and Parkinson's disease. However, the authors of these reviews suggest that most studies are limited by potential biases, small study populations, and insufficient exposure data.

Exposure data are often generalized to pesticides, which include hundreds of different chemicals with different toxic principles. Furthermore, many of the chemicals where associations with chronic health effects have been reported (e.g., OPs and OCLs) are in limited use today in most developed agricultural economies. Little research has been reported regarding the chronic health effects of the more common classes of insecticides used today (pyrethroids and neonicotinoids). Thus, potential chronic health associations with insecticides await further clarification.

Allergenic sensitization to pesticides can be a chronic health issue in sensitized individuals. The herbicide class anilides (e.g., alachlor, propachlor) and permethrine insecticides are the more common pesticides resulting in dermal and to a lesser extent general allergic sensitization. Dermal allergic conditions are discussed in Chapter 4. There have been some associations of organophosphates enhancing sensitization to allergens generally (75). However, the sum of these studies does not give a clear picture regarding the extent of risk and what specific insecticides may be implicated (76). Georgellis (77) suggests there are significant methodological limitations in the epidemiologic research to determine these apparent low-level risks, and new research methods are needed to determine a clearer picture of chronic health risk.

6.11 General Strategies for the Prevention of Pesticide Poisoning

The following prevention strategies are based on an analysis of risk factors, research, and practice publications (17, 19, 38, 65, 78–80). An analysis of acute toxic exposures found three consistent risk factors: (1) failure to follow labeled directions, (2) inexperienced workers, and (3) unpredictable random events (i.e., broken hose or accidental spill) (81). Dosemeci and co-workers (82) have developed an algorithm that is predictive of the extent of exposure farmers receive. They reported on six factors that are related to lowered exposures: (1) use of closed mixing systems, (2) use of tractors with enclosed cabs and charcoal air filters, (3) decreased frequency of washing application equipment, (4) increased frequency of changing gloves, (5) increased frequency of bathing and hand washing, and (6) increased frequency of changing clothes after spills.

Considering the reviews reported above, the rest of this chapter will present prevention strategies in more detail, broken down into four basic components (ordered within the generally accepted principles of health and safety prevention effectiveness): (1) engineering methods (avoidance, proper storage, handling, and security of the chemicals), (2) regulations and enforcement, (3) hygienic work practices, (4) use of PPE, (5) medical and environmental monitoring, and (6) education.

6.11.1 Avoidance, Proper Storage, and Separation

Separating people from possible contact with the pesticides is extremely important. Engineering methods to accomplish this have advanced over the past decade. For example, a system has been developed by a North American machinery manufacturer called "lock and load". This system incorporates pesticides that are sealed in containers that are attached to the applicator by the operator, who has no need to directly open or handle the pesticide, leaving the only possible exposure post application. Further development and use of these integrated systems are important to enhanced applicator protection. Additional management techniques of avoidance include secure (locked) pesticides stores outside the house and areas not accessible to children and unauthorized persons. Pesticides should not be mixed or stored in anything but their original containers. Empty containers should be rinsed three times and the rinse applied with the regular application in the field. Empty pesticide containers should never be reused and should be either disposed of according to labeled directions or returned to the seller. Mixing/loading and clean-up operations should take place at least 50 m from the house (83) in well-ventilated areas.

The use of hired commercial pesticide applicators in agriculture is a preventive management factor. Commercial applicators require certification by examination, suggesting a higher level of training compared to private applicators. In addition, commercial applicators usually use bulk containers, which eliminates exposure from handling many small containers of concentrated chemicals. They also manage the removal and clean-up of residual chemicals and equipment, eliminating farmer and farm worker exposures from these high-risk exposure-associated tasks.

Every insecticide or herbicide chemical has a certain tested degradation time after which contact with plant foliage is not hazardous. That degradation time is the Restricted Entry Interval (REI), which is printed on the product label. The Worker Protection Standard (WPS) (84) requires the employer to implement methods to keep workers out of fields and orchards for the extent of the REI. Labeling of fields indicating the REI is an important part of this mandate

6.11.2 Regulations and Enforcement

In the United States the Federal Insecticide, Fungicide, and Rodenticide Act provides the authority to regulate pesticides and is administered by the EPA. They register all pesticides for use based on the best information to assure the health and safety of humans, animals, and the environment. In addition, individual states (usually through the state departments of agriculture) also register pesticides. They may accept the EPA test results, but may also require additional testing. State requirements must be equivalent or better than the federal EPA standard. The EPA also continually monitors new information on pesticide safety and reviews all registrations every 15 years. Registrations may be revoked or amended depending on the results of the review process. The EPA also specifies what information must be on the product label relative to health and environmental protection, including proper PPE use by the applicator. Approval of the label by the EPA is a component of the registration process. The EPA also requires training and certification of product applicators that have a potential for harm to human health or the environmental (restricted-use pesticides). There are two categories of applicator: private (producers or farm managers) and commercial. Both must undertake training in the safe use of restricted-use pesticides. The examination requirements for private applicators vary among states, but commercial applicators must pass an examination in the safe use of these products to gain certification. The state departments of agriculture and extension administer this training in the United States.

The EPA also promulgated the Worker Protection Standard (84), which requires that agricultural workers receive pesticide safety training and that employers make information available on the pesticides used, provide protection for workers, provide methods to clean up an

Table 6.6 Summary of US federal regulations that affect pesticide usage

Endangered Species Act	Prohibits use of pesticides in areas that may harm endangered species Product label required to list where the product is not to be used
Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	Product label required to assure proper use of product is followed Applying product not in accordance with label is violation Pesticide uses and pesticide merchants must be registered with EPA Established class of "restricted use" pesticides (more toxic chemicals) that require special training for use
Field Sanitation Standard	Employers of more than 10 employees must provide toilets, hand-washing facilities, clean drinking water, and training about safe hygienic practices
Food Quality Protection Act	Sets standards for pesticide residues in food EPA must assess each pesticide for aggregate public exposure (food, water, etc.), determine cumulative effects, health in infants and children, and hormonal effects
Food, Agriculture, Conservation, and Trade Act (FACT)	Requires applicators to keep detailed records of specific products, use, amounts, and areas applied for all pesticides
Occupational Safety and Health Act	Requires employers to take reasonable steps to protect workers' safety and health Includes education, access to material safety data sheets of all products, and reporting of any pesticide-related illnesses
Resource Conservation and Recovery Act (RCRA)	Regulates manufacture, transportation, treatment, storage, and disposal of hazardous substances (including many pesticides)
Worker Protection Standard	EPA, registered in 1991 Requires owners and employers to provide protection to workers and pesticide handlers from potential pesticide exposure, train them, and provide mitigation in case exposure occurs

exposure, and provide first aid if there is an exposure. In addition, the US EPA sets tolerance standards for pesticides in foods under the Food Quality Protection Act of 1996. Most developed countries have similar regulations that require the safe use of pesticides to protect those applying the product and to protect the environment. Table 6.6 lists the various regulatory acts at the federal level that have jurisdiction in pesticide usage. Nine federal acts maintain regulations and best practices for occupational and environmental and public health protection of pesticides usage, and these are reviewed in detail by the Clemson University Cooperative Extension (79).

Even with these regulations, Reeves (25) found that in California 41% of pesticide poisonings were due to violations of worker safety and health laws.

6.11.3 Hygienic Work Practices

As dermal absorption is by far the highest risk for occupational exposure to pesticides, and hands are the most frequent part of the body that comes into contact with pesticides, frequent hand washing is a very important in prevention. It is especially important to wash hands before eating or smoking so as not to transfer pesticides from the hands to food or cigarettes, creating an oral route of exposure. This implies that there must be accessible hand-washing facilities at the work site for field workers. A convenient way for the individual famer to accomplish hand-washing is to carry a supply of disposable pre-moistened towelettes that contain soap. Skin barrier creams (see Chapter 4) may be helpful to retard absorption, especially as washing may reduce natural protective skin oils.

There are often emergency situations in the field where an accidental spill, mechanical malfunction, or misdirected spray may result in heavy exposure to the skin and clothing. There must be provision for rapid bathing and changing of clothes. For field workers, the employer must have protocols in place to handle these situations. This may include having a shelter with portable shower facilities and access to clean clothing on site, or readily available transportation to such facilities.

Chronic exposure may result from the build up of pesticides on the skin over several days. Therefore, daily showering or bathing and shampooing is very important. For hired field workers, housing may often be substandard and there may not be access to showering or bathing facilities at their living quarters. Managers must appreciate the importance of hygiene and provide showering/bathing/shampooing facilities as part of their worker protection programs.

During application and while working in fields where pesticide residues may still be present, wearing clean clothing daily is important to avoid skin contact with contaminated clothing (83). Nonwashable gloves and shoes should be avoided as they tend to soak up pesticides and become a constant source of exposure. Clothing and shoes that may have been contaminated should be kept out of the house and separated from the clothing of other household members. Daily washing of exposed clothes during the application season is a very important preventive procedure. Best practice recommendations include washing clothes three times separately from other clothing (85).

Eating and break places should be separate from the workplace for those working with pesticides, and these places should be kept clean and sanitary. There should also be access to handwashing facilities at these sites.

6.11.4 Personal Protective Equipment

For those working in areas of lower risk (field work, etc.), regular cotton clothing is probably sufficient. Treatment of cotton pants or shirts with commercial fluorocarbon stain-resistant or water-repellant sprays (e.g., trade names Scotch Guard or Zepfel) provides good protection (86).

For those workers involved in mixing/loading or application operations, additional PPE is necessary. The use of rubber or synthetic rubber, neoprene or better nitrile gloves is extremely important, as dermal adsorption is a relatively high risk and the hands are the most common site of exposure. These gloves should be unlined, as contamination of the lining would be a source of continuous exposure and may create a greater risk than no gloves at all. For comfort, reusable cotton gloves may be used inside the impermeable gloves, but they must be washed daily as per the procedures mentioned above. Other reusable gloves should be routinely washed inside and out to prevent contact of the contaminated glove surface with the hands (on the inside of the gloves) and other parts of the body that may be contacted by the gloves. Plastic aprons and rubber footwear additional to rubber gloves should be used in mixing and loading operations. Respirators afford little protection in most of these types of operations unless a fine powder or highly volatile chemical is used. In certain situations, such as where orchard air-blast applicators are used, respirators and a complete rubber suit along with rubber gloves are necessary. In these operations, pesticides are sprayed with powerful high-pressure fans into the foliage. The sprayer is attached to a wagon (the pesticide reservoir) that is pulled through the field by a tractor. Operators without a protective cab, or who otherwise have exposure to this blast, are highly exposed primarily via the dermal route and secondarily by the respiratory route, and therefore these workers need extensive protection.

It is a common observation by this author that workers are either under-protected or overprotected. The hazard of under-protection is obvious. The hazard of over-protection leading to heat stress is a high risk in hot climates, especially for elderly, non-acclimated workers, or workers with co-morbidities such as cardiorespiratory embarrassment. Achieving the right level of protection requires an understanding and analysis of the exposure risks, including the toxicity and formulation of the specific product, mixing/loading and application processes, degree of training and compliance of workers, and climate. There is not a single specific formula for proper worker protection. Understanding and integrating all of the information mentioned above and following the label directions and material safety data sheet (MSDS) will help to ensure the protection of those applying the product.

6.11.5 Medical Monitoring

Workers exposed to insecticides may be monitored in several ways. Perhaps the most common way (and one that has been included in some regulatory practices) is monitoring of AChE (medical monitoring) for OP and CB exposed workers (17, 87). As there are no federal requirements, states can choose and design their own programs. California and Washington require medical monitoring (88). Thirty states require reporting of pesticide poisoning and 11 of those states require action on those cases (28). Note, however, that the medical monitoring procedures described below may not be effective for CBs (without OP exposure) as CBs have only a temporary blockage of AChE and such monitoring may not detect exposure unless it is within 24 or 48 hours. AChE testing estimates indirectly the levels at nerve synapses by measuring the surrogate AChE produced by the liver and found in the blood plasma (plasma AChE), and/or that found in red blood cells (RBC AChE).

Procedures for Monitoring AChE

Keifer and Sheridan have prepared a flow chart for clinicians that provides convenient and comprehensible guidelines for medical monitoring (90). The following paragraphs summarize those recommendations. As mentioned earlier, OPs and CBs cause a lowering of the blood AChE. Monitoring of this blood parameter can help to prevent acute toxicities. Such monitoring is recommended if workers have been exposed to OP restricted-use insecticides for at least 30 hours on 30 consecutive days. There are various methods of measuring AChE in the blood. As AChE levels are highly variable among individuals, it is important to obtain a pre-exposure baseline level for follow-up comparisons. (Workers must not have had any OP exposure for at least 30 days prior to testing to assure a valid baseline measurement.) A second (not required) baseline test will help to assure the validity of the test. If a second baseline test is taken, the mean of the two tests should be used as the baseline value.

Best practice prescribes that both plasma AChE and RBC AChE should be assessed using the same laboratory procedures and by the same laboratory to best assure comparable results. If only one test is conducted, the plasma AChE test is recommended.

The following principles should be employed in the AChE monitoring of workers:

1. Take a sample at least 2 weeks before start of application or other exposure.
2. Record the baseline measure in a secure manner that can be matched to the person and subsequent measures.
3. Conduct both serum and RBC cholinesterase levels.
4. Conduct follow-up tests at midseason and at the end of the application season.

If the AChE levels fall to 40% of the baseline serum level and 30% of the baseline RBC level, the worker should be removed from exposure until the levels return to their baselines. A greater than 40% drop from baseline warrants immediate medical attention (46, 88).

Exposure Monitoring

Monitoring of exposure is usually conducted as a research technique, rather than as a preventive procedure. A common practice has been to have workers wear cotton gloves and/or have cotton patches taped on standardized locations on the body and clothing. Following work exposure, the gloves are removed and taken to a laboratory where they are extracted with solvents and analyzed for pesticide content and concentration. This procedure provides a relative measure of dermal exposure. Another method is the use of fluorescent tracers in the pesticide. Following contact with the pesticide, a worker is exposed to a UV light and the degree of fluorescence is related to the total amount of exposure. This is a qualitative test, but recent research has involved the measure of fluorescence based on a computer integration of fluorescence from several angles and body locations (so called VITAE method). These fluorescent methods have proven to be a great teaching device for workers to see how much of the body becomes exposed during work with pesticides, but has not proven sufficiently quantitative for health monitoring (24).

Table 6.7 General quick references on types and usage of pesticides (94–97)

1. Roberts J, Reigart J (2013) Office of Pesticide Programs, US Environmental Protection Agency
   www.epa.gov/pesticiee-worker-safety
   Clinical overview of types of pesticides, diagnosis, and treatment
2. Pesticides: topical and chemical fact sheets
   www.epa.gov/pesticieds/fact sheets/chemicals
   Search on individual pesticides by name to find the class of insecticide, how it is used, the specific toxicity, and prevention
3. Extoxnet – Extension Technology Network, Pesticide Information Profiles
   www.extoxnet.orst.edu/pips/dinocap
   Search on individual pesticides by name to find the class of insecticide, how it is used, the specific toxicity, and prevention
4. Registration and review of pesticides, Environmental Protection Agency
   www.epa.gov/oppsrrd/registration_review
   Search and find the registration requirements under the Federal Insecticide, Fungicide, and Rodenticide Act
   Regular reviews are scheduled for the safety of pesticide products. Reviews of products may also occur before the regular review interval if new information and research on safety is suggestive of a health or environmental risk.
5. Pesticide National Synthesis Project, US Geological Survey
   water.usgs.gov/nawqa/pnsp/usage/maps/
   An interactive map indicates where certain pesticides are used and on what crops
   Active ingredients can be searched by product name (11) http://pims.psur.cornell.edu/

Many pesticide breakdown products are excreted in the urine. Spot tests using these procedures have shown promise as a field monitoring method (91). Relative to AChE testing, urinary metabolite tests are more specific to the particular insecticide exposure and more quantitative. However, to assess quantitation of exposure the urine sample must be standardized by measuring its creatinine concentration.

6.11.6 Training

A proper understanding on the part of owners/operators, managers, and workers of the toxicity of the chemicals and method of protection is extremely important. Most industrial countries have programs to train applicators, for example the US EPA requires all applicators of restricted-use pesticides to take pesticide applicator training. However, other factors in addition to training are needed to create effective prevention (92) as little correlation has been shown between training and PPE use (93).

6.12 Summary

From the broad array of chemicals available, only selected pesticides of particular importance to agricultural workers have been covered in this chapter. Further details can be found in the references listed below and in the websites listed in Table 6.7 (94–97). Many toxic syndromes are complex and are not easy to recognize via symptoms and clinical signs alone. The most important element in diagnosis is an awareness of the potential hazard presented by these chemicals and the appropriate history for exposure potentials. The alert health professional will not fail to inquire into the possibility of toxic exposure when confronted with complex patterns of clinical disease in those exposed to agricultural pesticides.

Pesticides are a broad group of chemicals that includes over 1000 active substances and 16,000 formulations developed to kill insects (insecticides), weeds (herbicides), or fungi (fungicides). Regulations instituted under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947 has resulted in the progressive development of products that are safer for humans, animals, and the environment. Administered by the US EPA (since 1972) FIFRA has been amended several times (the last in 2012) to govern the safe use of pesticides.

As agricultural practices and pesticides vary tremendously, the health or safety professional should find out what pesticides are used in their community, on what crops, and how and when they are applied in order to assess health risk and ascertain an accurate occupational history.

Key Points

1. The agricultural use of commercial pesticides began in the mid-1940s with the organochlorine DDT. Because of its environmental persistence and bio-accumulation in food chains, and encouraged by the international environmental movement (10), DDT and other organochlorines have either been banned or severely restricted in their legal usage. The diminished use of organochlorines (OCLs) has had positive environmental effects, most notably the resurgence of feral carnivorous birds (raptors) because of the removal of the softening effect OCLs have on their egg shells. The restriction of OCLs has also reduced the hypothesized negative association of endocrine disruption of OCLs on humans and animals. However, as DDT and other OCLs were very effective in controlling arthropods, vector-borne diseases which have now increased, especially malaria in Sub-Saharan Africa, Asia, and the Middle East. For example, in South Africa, malaria deaths increased from 4117 in 1995 (before the DDT ban)to 64,622 in 2000 (43). Now 15 countries in Sub-Sahara Africa and the Middle East and six other countries have resumed using DDT or have reserved the right to begin using DDT. A panel of scientists studying the issue have recommended that DDT be re-instituted with caution, pending no other effective vector-control methods available, using only the minimal effective dose (43).
2. With diminishing use of OCLs, organophosphates (OPs) and carbamates (CBs) came on the market in the 1960s. They are less environmentally persistent, but are more acutely toxic to humans, animals, and the environment. Many of these chemicals were therefore banned or severely restricted from use in the 1980s.
3. Two new classes of insecticides came on the market in the 1990s, pyrethroids and neonicotinoids, which are much less toxic to humans, animals, and the environment, and now make up the bulk of insecticides used. They are much lower in acute toxicity to humans, less persistent, and have few known environmental effects (with the exception of an association of neonicotinoids with the colony collapse condition of honey bees).
4. In general, the most to least acutely human toxic pesticide classes are (1) fumigants (they are generally lethal to all life forms), (2) organophosphate insecticides, (3) herbicides, (4) fungicides, and (5) biocides. In terms of usage (tonnage of product sold), the order from most to least used is (1) herbicides (over 60% of applied pesticides), (2) insecticides, (3) fungicides, (4) biocides, and (5) fumigants.
5. The acute toxicity of the insecticides varies greatly according to the specific class and also within classes. The relative acute human toxicity of insecticides classes from most to least toxic is (1) organophosphates, (2) carbamates, (3) organochlorines, (4) pyrethroids, and (5) neonicotinoids. Table 6.3 lists commonly used insecticides (in 2015), their relative acute toxicity, and their chemical class.
6. Regarding acute toxic mechanisms, all four classes of insecticides effect transmission of nerve impulses. OCLs, pyrethroids, and rayanoids all have similar mechanisms in that they disrupt ion exchange across nerve cell membranes and thus disrupt the normal polarization and depolarization, resulting in dysfunctional nerve impulses. OCLs and CBs affect excess nerve impulse transmission from one nerve cell to another at the level of the synapse. They block the enzyme that breaks down the transmitter substance ACh, which results in excess or continued firing of that nerve impulse.
7. Regarding acute illnesses, the CDC (SENSOR) reported an average of 0.4 annual fatal agricultural occupational pesticide fatalities and 67 non-fatal pesticide illnesses in the 8-year

period from 1998 to 2006 (28) (estimated fatality rate = 0.063/100,000, estimated illness rate = 1.4/100,000). In comparison, NIOSH reported a total of 479 total occupational fatalities in the agricultural sector in 2013 (32) and 53,982 injuries and illnesses in 2012 (respective rates 22.2 fatalities/100,000 and 1,120 injuries/100,000) (33).

8. OCLs, CBs, and OPs are hypothesized as having chronic toxicity as numerous published research articles have shown associations to cognitive, central, and peripheral neurological deficits, certain cancers, and developmental conditions. However, "clear linkages have not yet been made between exposure and health effects, except in the case of acute pesticide exposure" (3).
9. The word "pesticide" is often perceived by the general public as referring to a chemical that is acutely and chronically toxic to humans, animals, and the environment disproportionately to other causes of occupational morbidly and mortality. A small percentage of pesticides in use today out of the 16,000 registered formulations are very toxic or damaging to the environment. Insecticides form the major class of pesticides that contains most of the chemicals that are potentially hazardous. Using the term "pesticide" may communicate an unintended negative perception based on fear, distracting from a more science-based term for balanced communication. In order to avoid this concern, rather than pesticide, specific appropriate terms such as insecticide or herbicide, or even the class of chemical (e.g. pyrethroids or organophosphates), should be used to avoid generalized negative implications. The agricultural industry has adopted the term "plant protection products" to help deflect negative implications and improve accurate communication.
10. The generic principles of treatment of acute exposure to pesticides are:
    a. External decontamination (remove exposed clothing and wash skin and hair)
    b. Internal decontamination (administration of universal antidote, e.g. activated charcoal, diatomaceous earth).
    c. Induced emesis and catharsis recommended only in certain circumstances.
    d. Seizure control may be required with benzodiazepine drugs (e.g., diazepam) or barbiturates if refractory to the former.
11. The principal antidote for OP and CB poisoning is atropine. For OP poisoning pralidoxime chloride (2 PAM) in addition to atropine may be helpful if given within the first 48 hours of exposure. There are no other specific antidotes for other plant protection products.
12. Five basic components or goals of pesticide exposure prevention in a large farming operation include but are not limited to the following:
    a. Avoidance, proper storage, and separation through the following principles:
        i. Separation of worker from the hazardous chemicals through selection of the least toxic chemicals to do the job, proper training, storage, and security of chemicals.
        ii. Use of engineering methods (mechanical equipment that separates worker from chemical).
        iii. Use of commercial/professional applicators.
    b. Ensure regulations are followed and enforced.
    c. Farm owner/operators, managers must read and understand the package label and make sure employees understand and follow those recommendations.
    d. Implement and maintain hygienic work practices.
    e. Proper selection and use of PPE.
    f. Training of producers, commercial applicators, employers, workers, and health professionals on the safe use of plant protection products.

References

1. Thu K, Donham K, Yoder D, Ogilvie L. The farm family perception of occupational health: A multi-state survey of knowledge, attitudes, behaviors, and ideas. Am J Ind Med. 1990;18(4):427–31.
2. Lucas RM, McMichael AJ. Association or causation: evaluating links between "environment and disease". Bull World Health Organ. 2005;83(10): 792–5.
3. McCauley LA, Anger WK, Keifer M, Langley R, Robson MG, Rohlman D. Studying health outcomes in farmworker populations exposed to pesticides. Environ Health Perspect. 2006;114(6):953–60.
4. Mutel C, Donham K. Medical practices in rural communities. New York: Springer-Verlag; 1983.
5. Morgan D. Rural health series: toxicology of fungicides, rodenticides, and fumigants. Washington, D.C.: National Library of Medicine; 1978.
6. DDT – a brief history and status. US Environmental Protection Agency; 2014 (updated 30 May 2014; accessed 14 June 2014). Available from: http://www.epa.gov/pesticides/factsheets/chemicals/ddt-brief-history-status.htm.
7. Pesticides: registration review. US Environmental Protection Agency; 2012 (updated 6 December 2012; accessed 14 June 2014). Available from: http://www.epa.gov/oppsrrd1/registration_review/.
8. The acute work-related pesticide poisoning incidence rate. Centers for Disease Control and Prevention; 2013 (updated 18 March 2013; accessed 14 June 2014). Available from: http://www.cdc.gov/niosh/topics/pesticides/animatedmap.html.
9. Carson R. Silent Spring. Boston: Houghton Mifflin; 1962.
10. Griswold E. How Silent Spring Egnited the Environmental Movement. New York Times Sunday Magazine. 2012;Sep 23.
11. Agriculture: About EPA's National Agricultural Center. US Environmental Protection Agency; 2015 (updated 5 December 2015; accessed 21 December 2015). Available from: http://www.epa.gov/agriculture/agriculture-about-epas-national-agriculture-center.
12. Regulating biopesticides. US Environmental Protection Agency; 2014 (updated 12 March 2014; accessed 14 June 2014). Available from: http://www.epa.gov/oppbppd1/biopesticides/.
13. National Pesticide Information Center home page; 2014 (accessed 14 June 2014). Available from: http://npic.orst.edu/index.html.
14. Pesticide illness and injury surveillance. Centers for Disease Control and Prevention; 2014 (accessed 14 June 2014). Available from: http://www.cdc.gov/niosh/topics/pesticides/.
15. Farahat T, Abdelrasoul G, Amr M, Shebl M, Farahat F, Anger W. Neurobehavioral effects among workers occupationally exposed to organophosphorous pesticides. Occup Environ Med. 2003;60: 279–86.
16. Calvert G, Plate D, Das R. Acute occupational pesticide-related illnesses in the US, 1998–1999: Surveillance findings from SENSOR – Pesticides Program. Am J Ind Med. 2004;45:14–23.
17. Roberts J, Reigart J. Recognition and management of pesticide poisonings. 6th edition. Washington, DC: US Environmental Protection Agency; 2013.
18. Regulating Pesticides. US Environmental Protection Agency; 2014 (updated 4 February 2014; accessed 18 January 2015). Available from: http://www.epa.gov/pesticides/regulating/labels/pest-label-training/module2/page2.html.
19. The WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification. Geneva: World Health Organization; 2009.
20. Pesticides: Training for the health sector. Children's Health and the Environment. Geneva: World Health Organization; 2008 (accessed 12 December 2015). Available from: http://www.who.int/ceh/capacity/Pesticides.pdf.
21. Pesticide Industry Sales and Usage 2006 and 2007. Washington, DC: US Environmental Protection Agency (accessed 21 December 2015). Available from:http://www.epa.gov/pesticides/pesticides-industry-sales-and-usage-2006-and-2007-market-estimates.
22. Morgan D, Donham K, Mutel C, Cain C. Pesticide poisonings and injuries: where, when, and how. Iowa City, IA: Institute of Agricultural Medicine and Rural Health, Department of Occupational and Environmental Health, University of Iowa; 1978.
23. Hines C, Deddens J, Tucker S, Hornung R. Distributions and determinants of pre-emergent herbicide exposures among custom applicators. Ann Occup Hyg. 2001;45(3):227–39.
24. Stewart P, Fears T, Nicholson HF, Kross BC, Ogilvie LK, Zahm SH, et al. Exposure received from application of animal insecticides. Am Ind Hyg Assoc J. 1999;60(2):208–12.
25. Reeves M, Schafer KS. Greater risks, fewer rights: US farmworkers and pesticides. Int J Occup Environ Health. 2003;9(1):30–9.
26. Alavanja MC, Sandler DP, McDonnell CJ, Mage DT, Kross BC, Rowland AS, et al. Characteristics of persons who self-reported a high pesticide exposure event in the Agricultural Health Study. Environ Res. 1999;80(2Pt1):180–6.

27. Baron RL. A carbamate insecticide: a case study of aldicarb. Environ Health Perspect. 1994; 102(Suppl.11):23–7.
28. Pesticide Illness and Injury Surveillance. SENSOR – Pesticides Program (11 September 2013). Atlanta: Centers for Disease Control and Prevention; 2013 (accessed 1 June 2014). Available from: http://www.cdc.gov/niosh/topics/pesticides/overview.html.
29. National poison data system. American Association of Poison Control Centers; 2014 (accessed 14 June 2014). Available from: http://www.aapcc.org/data-system/.
30. Bertolote JM, Fleischmann A, Eddleston M, Gunnell D. Deaths from pesticide poisoning: a global response. Br J Psychiatry. 2006;189:201–3.
31. Pickett W, King WD, Lees RE, Bienefeld M, Morrison HI, Brison RJ. Suicide mortality and pesticide use among Canadian farmers. Am J Ind Med. 1998;34(4):364–72.
32. Census of Fatal Occupational Injuries (CFOI) – Current and Revised Data. US Department of Labor; 2014 (updated 11 September 2014; accessed 14 January 2015). Available from: http://www.bls.gov/iif/oshcfoi1.htm.
33. Agricultural Safety: Occupational Injury Surveillance of Production Agriculture (OISPA) Survey Atlanta. Centers for Disease Control and Prevention; 2014 (updated 25 June 2014; accessed 15 January 2015). Available from: http://www.cdc.gov/niosh/topics/aginjury/oispa/injtables.html.
34. Census of Agriculture. Washington, DC: US Department of Agriculture; 2007 (updated 5 October 2015; accessed 21 December 2105). Available from: http://www.agcensus.usda.gov/Publications/2007/.
35. Guidelines on organization and operation of training schemes and certification procedures for operators of pesticide application equipment. Rome: World Health Organization; 2001.
36. Kuye R, Donham K, Marquez S, Sanderson W, Fuortes L, Rautiainen R, et al. Pesticide handling and exposures among cotton farmers in The Gambia. J Agromedicine. 2007;12(3):37.
37. Thundiyil J, Stober J, Besbelli N, Pronczuk J. Acute pesticide poisoning: a proposed classification tool. Bull W H H. 2008;86(3):161-240 (accessed 21 December 2015). Available from: http://www.who.int/bulletin/volumes/86/3/07-041814/en/.
38. Safer access to pesticides: community intervention. World Health Organization; 2006 (cited 14 June 2014). Available from: http://www.who.int/mental_health/prevention/suicide/pesticides_safer_access.pdf.
39. Reigart J, Roberts J. Recognition and management of pesticide poisonings. 5th edition. Washington, DC: Office of Pesticide Progams, US Environmental Protection Agency; 1999. p. 87–9, 68–9.
40. Pesticide Industry Sales and Usage 2006–2007. Pesticide Market Estimates: Usage. Washington, DC: US Environmental Protection Agency; 2013 (updated 19 July 2103; accessed 12 January 2015). Available from: http://www.epa.gov/opp00001/pestsales/07pestsales/usage2007_3.htm#3_8.
41. Tomizawa M, Casida JE. Neonicotinoid insecticide toxicology: mechanisms of selective action. Annu Rev Pharmacol Toxicol. 2005;45:247–68.
42. Cone M. Should DDT be used to combate Malaria? Sci Am. 2009;May 4.
43. Stockholm Convention. Committee on Persistent Organic Pollutants. Geneva: World Health Organization; 2008 (updated 2008; accessed 19 January 2015). Available from: http://chm.pops.int/default.aspx.
44. Eddleston M, Buckley N, Dawson A. Management of acute organophosphorus pesticide poisoning. Lancet. 2008;371(9612):597–607.
45. Lee B, London L, Paulauskis J, Myers J, Christiani D. Association between human paraoxonase gene polymorphism and chronic symptoms in pesticide-exposed workers. J Occup Environ Med. 2003;45(2):118–22.
46. Wilson B. Cholinesterases. In: Krieger R, editor. Handbook of Pesticide Toxicology. 2. San Diego: Academic Press; 2001. p. 967–85.
47. Soderlund DM, Clark JM, Sheets LP, Mullin LS, Piccirillo VJ, Sargent D, et al. Mechanisms of pyrethroid neurotoxicity: implications for cumulative risk assessment. Toxicology. 2002;171(1):3–59.
48. Bradberry SM, Cage SA, Proudfoot AT, Vale JA. Poisoning due to pyrethroids. Toxicol Rev. 2005;24(2):93–106.
49. Koshlukova S, Reed N, Pfeifer K, Gee J. Risks to humans from dietary exposures to the neonicotinoid insecticde. Imidacloprid: California Environmental Protection Agency; 2008 (accessed 14 June 2014). Available from: http://www.cdpr.ca.gov/docs/medtox/pubs/imidacloprid_2008.pdf.
50. Li Y, Zhang C, Yin Y, Cui F, Cai J, Chen Z, et al. Neurological effects of pesticide use among farmers in China. Int J Environ Res Public Health. 2014;11(4):3995–4006.
51. Fishel F. Pesticide toxicity profile: neonicotinoid pesticides. University of Florida Extension; 2013 (accessed 14 June 2014). Available from: http://edis.ifas.ufl.edu/pi117.
52. Forrester M. Neonicotinoid insecticide exposures reported to six poison centers in Texas. Hum Exp Toxicol. 2014;33(6):568–73.

53. Copping L. The Manual of Biocontrol Agents. 4th edition. Farnham: Ashgate; 2009.
54. Biopesticides. US Environmental Protection Agency; 2013 (updated 8 April 2013; accessed 14 June 2014). Available from: http://www.epa.gov/oecaagct/tbio.html.
55. Pollack M, Shaffer G. Biotechnology policy: between national feats and global disciplines. Policy-making in the European Union. 6th edition. Oxford: Oxford University Press; 2010.
56. Bakshi A. Potential adverse health effects of genetically modified crops. J Toxicol Environ Health B Crit Rev. 2003;6(3):211–25.
57. Swan SH, Kruse RL, Liu F, Barr DB, Drobnis EZ, Redmon JB, et al. Semen quality in relation to biomarkers of pesticide exposure. Environ Health Perspect. 2003;111(12):1478–84.
58. Morgan D. Rural health series: toxicology of commonly used herbicides. Iowa City, IA: Institute for Agricultural Medicine and Rural Health, University of Iowa; 1979.
59. Peterson M, Talcott P. Small animal toxicology. Philadelphia: W.B. Saunders Co.; 2001. p. 420–8.
60. Wolz S, Fenske R, Simcox N, Palcisko G, Kissel J. Residential arsenic and lead levels in an agricultural community with a history of lead and arsenate use. Environ Res. 2003;93(3):293–300.
61. Endocrine disruptors. National Institute of Environmental Health Sciences; 2014 (updated 13 June 2014; accessed 26 June 2014). Available from: http://www.niehs.nih.gov/health/topics/agents/endocrine/.
62. Mnif W, Hassine AI, Bouaziz A, Bartegi A, Thomas O, Roig B. Effect of endocrine disruptor pesticides: a review. Int J Environ Res Public Health. 2011;8(6):2265–303.
63. Worf G. Selecting and using chemical fumigants and soil sterilants for ornamental disease control. University of Wisconsin Extension; 1990 (accessed 14 June 2014). Available from: http://www.learningstore.uwex.edu/assets/pdfs/A2612.pdf.
64. Private stored grain fumigation. Training manual for the private pesticide applicator certificaton fumication endorsement. University of Minnesota Extension Service; 2001 (accessed 21 December 2015). Available at: http://www.extension.umn.edu/agriculture/pesticide-safety/pat/pfum/manual.pdf.
65. Bond E. Manual of fumigation for insect control. FAO Plant production and protection report 54. Rome: Food and Agriculture Organization of the World Health Organization; 1984 (accessed 21 December 2015). Available at: http://www.fao.org/docrep/x5042e/x5042e00.htm.
66. Reed C. Influence of environmental, structural, and behavioral factors on the presence of phosphine in worker areas during fumigations in grain elevators. J Agric Saf Health. 2001;7(1):21–34.
67. Morgan D, Donham KJ, Mutel CF, Cain C. Pesticide poisonings and injuries: Where, when, and how. Iowa City, IA: Institute of Agricultural Medicine and Rural Health, Department of Occupational and Environmental Health, University of Iowa; 1978.
68. Fennimore S, Duniway J, Martin F, Ajwa H, Westerdahl B, Goodhue R, et al. Methyl bromide alternatives evaluated for California strawberry nurseries. California Agric. 2008;62(2):62–7.
69. Donham KJ, Thorne PS. Agents in organic dust: criteria for a causal relationship. Am J Ind Med. 1994;25(1):33–9.
70. Georgellis A, Kolmodin-Hedman B, Kouretas D. Can traditional epidemiology detect cancer risks caused by occupational exposure to pesticides? J Exp Clin Cancer Res. 1999;18(2):159–66.
71. Garry VF, Holland SE, Erickson LL, Burroughs BL. Male reproductive hormones and thyroid function in pesticide applicators in the Red River Valley of Minnesota. J Toxicol Environ Health A. 2003;66(11):965–86.
72. Garcia AM, Fletcher T, Benavides FG, Orts E. Parental agricultural work and selected congenital malformations. Am J Epidemiol. 1999;149(1):64–74.
73. Kamel F, Hoppin JA. Association of pesticide exposure with neurologic dysfunction and disease. Environ Health Perspect. 2004;112(9):950–8.
74. Tanner CM, Kamel F, Ross GW, Hoppin JA, Goldman SM, Korell M, et al. Rotenone, paraquat, and Parkinson's disease. Environ Health Perspect. 2011;119(6):866–72.
75. Hoppin JA, Umbach DM, London SJ, Henneberger PK, Kullman GJ, Coble J, et al. Pesticide use and adult-onset asthma among male farmers in the Agricultural Health Study. Eur Respir J. 2009;34(6):1296–303.
76. Garcia AM, Benavides FG, Fletcher T, Orts E. Paternal exposure to pesticides and congenital malformations. Scand J Work Environ Health. 1998;24(6):473–80.
77. Georgellis A, Kolmodin-Hedman B, Kouretas D. Can traditional epidemiology detect cancer risks caused by occupational exposure to pesticides? J Exp Clin Cancer Res. 1999;18(2):159–66.
78. Council on Scientific Affairs. Educational and informational strategies to reduce pesticide risks. Prev Med. 1997;26(2):191–200.
79. Pesticides – Related laws and regulations. Clemson University, Alabama Clemson Cooperative Extension; 2014 (accessed 2 July 2014). Available from: http://

www.clemson.edu/extension/pest_ed/safety_ed_prog/laws_regs.html.
80. Perry MJ, Marbella A, Layde PM. Association of pesticide safety knowledge with beliefs and intentions among farm pesticide applicators. J Occup Environ Med. 2000;42(2):187–93.
81. Mage DT, Alavanja MC, Sandler DP, McDonnell CJ, Kross B, Rowland A, et al. A model for predicting the frequency of high pesticide exposure events in the Agricultural Health Study. Environ Res. 2000;83(1):67–71.
82. Dosemeci M, Alavanja MC, Rowland AS, Mage D, Zahm SH, Rothman N, et al. A quantitative approach for estimating exposure to pesticides in the Agricultural Health Study. Ann Occup Hyg. 2002;46(2):245–60.
83. Gladen BC, Sandler DP, Zahm SH, Kamel F, Rowland AS, Alavanja MC. Exposure opportunities of families of farmer pesticide applicators. Am J Ind Med. 1998;34(6):581–7.
84. Pesticide worker safety: Agricultural Worker Protection Standard (WPS). Washington, DC: US Environmental Protection Agency; 2014 (updated 3 November 2015; accessed 21 December 2015). Available from: http://www.epa.gov/pesticide-worker-safety/agricultural-worker-protection-standard-wps.
85. Phillips TA, Belden JB, Stroud M, Coats JR. Evaluation of a cold-water hand-washing regimen in removing carbaryl residues from contaminated fabrics. Bull Environ Contam Toxicol. 2003;71(1):6–10.
86. Branson D, Sweeney, M. Pesticide personal protective clothing. Rev Environ Contam Toxicol. 1991;122:81–109.
87. Bolognesi C. Genotoxicity of pesticides: a review of human biomonitoring studies. Mutat Res. 2003;543(3):251–72.
88. Furman J. Cholinesterase monitoring for agricultural pesticide handlers guidelines for health care providers. Washington, DC: Washington State Department of Labor and Industries; 2006 (accessed 21 December 2015). Available from: http://depts.washington.edu/opchild/pdf/ProvidersGuidelines.pdf.
89. Requiring Clinical Diagnostic Tools and Biomonitoring of Exposures to Pesticides. Washington, DC: American Public Health Association; 2010 (updated 2014; accessed 21 December 2015). Available from: http://www.apha.org/policies-and-advocacy/public-health-policy-statements/policy-database/2014/07/21/09/17/requiring-clinical-diagnostic-tools-and-biomonitoring-of-exposures-to-pesticides.
90. Keiffer M, Sheridan C. Cholinesterase monitoring protocols for healthcare providers. Washington, DC: Occupational Safety and Health Administration; 2013 (accessed 21 December 2015). Available from: https://www.osha.gov/dte/grant_materials/fy11/sh-22284-11/CholinesteraseHealthcareProviders.pdf.
91. Castorina R, Bradman A, McKone T, Barr D, Harnly M, Eskenazi B. Cumulative organophosphate pesticide exposure and risk assessment among pregnant women living in an agricultural community: A case study from the CHAMACOS cohort. Environ Health Perspect. 2003;111(13):1640–8.
92. Perry M, Marbella A, Layde P. Association of pesticide safety knowledge with beliefs and intentions among farm pesticide applicators. J Occup Environ Med. 2000;42(2):187–93.
93. Mandel J, Carr W, Hillmer T, Leonard P, Halberg J, Sanderson W, et al. Factors associated with safe use of agricultural pesticides in Minnesota. J Rural Health. 1996;12(4Suppl.):301–10.
94. Pesticides: Pesticide registration manual. Environmental Protection Agency; 2015 (updated 18 December 2105; accessed 22 December 2015). Available from: http://www.epa.gov/pesticides.
95. Extoxnet, the Extension toxicology network. A joint effort of University of California-Davis, Oregon State University, Michigan State University, Cornell University, and the University of Idaho (accessed 21 December 2015). Available from: http://extoxnet.orst.edu/.
96. Pesticide National Synthesis Project, National Water-Quality Assessment Program. Virginia: US Geological Survey. (updated 5 January 2016) accessed 21 February 2016). Available from: http://water.usgs.gov/nawqa/pnsp/stats/.
97. Product ingredient and manufacturer system. Ithaca, New York: Cornell University Extension; 2012 (updated 16 December 2105; accessed 21 December 2015). Available from: http://pims.psur.cornell.edu/.

CHAPTER

7

General Environmental Hazards in Agriculture Communities

Kelley J. Donham and Anders Thelin

Reviewer: David Osterberg

7.1 Introduction

The natural environment is often cited as one of the major advantages of rural over urban life, and many a migrant to the city has yearned for the sight of green fields, the smell of fresh-cut hay, the smell of a clear running brook, or simply a deep breath of clear country air. … By and large, rural residents have been little more beneficent in their relation with nature than the denizens of our concrete and asphalt jungles. Indeed, profligate waste, and destructiveness have marked the exploitation of our land and other natural resources since the earliest white settlements in America. T. Ford, 1978 (1).

Mr. Ford's pessimistic quote from nearly four decades ago might still be considered fresh and relevant by environmentalists but controversial by agriculturalists. The debate goes on and progress (both political and environmental) is measured incrementally. Since the end of our hunter-gatherer societies and the beginning of our agricultural societies, there has been a trade-off between the process and progress of producing food, fiber, and energy for society, the health of the natural environment, human health, and the welfare of livestock and poultry. Furthermore, the advent of the industrial revolution (c. 1780–1830) charted a path of increasing intensification of agricultural and non-agricultural industry that has increasingly stressed the natural environment. Such industrial development has not only challenged the urban environment, but also our rural environments as urban discharges and emissions have reached rural residential streams and air. As our industrialized nations' economies have grown strong and the basic necessities of life have been met, the timing was right to support a rising environmental consciousness during the late 1960s and 1970s. In 1970, the US Congress established the Clean Air Act to protect the public's health from air pollution. In 1972, the US Congress enacted the Clean Water Act to restore and maintain the chemical, physical, and biological integrity of the nation's water supplies. During this decade, most industrialized nations developed similar regulations and standards for air and water quality.

However, water and air pollution grow as global concerns. In the 1980s, research emerged indicating that rural environmental problems may be as great as or even greater than some urban environmental problems (2). Furthermore,

Agricultural Medicine: Rural Occupational and Environmental Health, Safety, and Prevention, Second Edition.
Kelley J. Donham and Anders Thelin.

during this time more people left the farm, and city people moved out to the country for a lifestyle change, as farming became more concentrated into larger and more intensive operations. These changes contributed to a progressively evolving dichotomy between the farm and non-farm cultures relative to awareness and concern for water, air and soil contamination from agricultural operations. Furthermore, research provided evidence for agriculture as a source of pollution associated with degrading water quality for drinking, recreation, and natural ecosystem health (3). A broad cross-section of citizens has become concerned about these issues; some of these individuals have complained of perceived health consequences from these exposures. Lack of a scientific basis for many of these concerns obscures specific cause-effect diagnoses and increases the rift between the agricultural, rural non-agricultural, and urban communities. A large portion of the production agricultural community feels threatened that their industry has been negatively portrayed based mainly on misdirected opinion. They fear the resulting excessive regulation will unnecessarily economically burden their operations, adding additional stress to their already stressful lives. Rural health and safety professionals must be aware of this stress and balance their attitudes and interactions in this arena with the social and scientific basis of these issues as they relate to clients and patients. The risk of not doing so is to risk losing trust and therefore effectiveness in health and safety service.

This chapter provides a science-based overview of the major rural environmental pollutants and their sources with a focus on those pollutants that have a known direct or indirect effect on human health, and those that have attracted public concern. The aim of this chapter is to create awareness to enable rural health and safety professionals to better anticipate and evaluate potential environmental health risks while participating in informed public debate. Furthermore, this chapter will provide information regarding the nature and prevention of resulting health effects in patients, clients, and communities. Issues primarily related to ecosystem health and sustainability are beyond the scope of this chapter. Sources of water, air, and solid waste contamination will be followed by what is known about the health effects of these substances.

7.2 Water Quality

7.2.1 Introduction

Water quality for human use depends on the presence or absence of certain natural elements as well as the presence or absence of substances added from human activities. Water pollution is by far the most important general environmental concern in rural areas. The consequences of water pollution include stress on natural ecosystems, depredated quality of water for recreational purposes, and adverse health effects from drinking contaminated water. The US Environmental Protection Agency (EPA) and others (3–6) reported that up to 40% of surface bodies of water are impaired for certain uses (e.g., recreation or drinking water). Agriculture and municipalities are the main sources of pollutants. To be more quantitative, agriculture is considered to be the source of pollution for 60% of all river miles and 50% of all lake acreages. Howarth (5) reported that on average 26% of the nitrogen applied to the land for crop fertilization ends up in our surface and ground water systems. (The amount of nitrogen runoff varies from 3% to 80% depending on the model applied, regional soil types, and land use). Surveys in the Midwest and Eastern sectors of the United States revealed that 12–46% of shallow water wells, that is, less than 50 m deep (a primary source of drinking water for rural populations), are contaminated with nitrates in excess of the EPA limits of 10 mg/L (7, 8). Although nitrogen may be the most common contaminant, and perhaps the most serious direct threat to human health, there are additional water contaminants from urban lawns, gardens, streets, golf courses, municipal waste treatment facilities, and industries (e.g., salt, oil, pesticides, phosphorus, mercury, and polychlorinated biphenyls,). Additional agricultural source water contaminants include animal waste, phosphorus, heavy metals, antibiotics, antibiotic-resistant genetic material, infectious agents, veterinary pharmaceutical residues, and trace elements from animal feeds (e.g., copper zinc, and selenium) (7).

Given adequate time, natural systems have the capacity to mitigate pollutants if the system is not overloaded. However, the time to degrade contaminants has been short-circuited in many areas as millions of acres have been tiled, streams straightened, drainage ditches dug, drainage wells drilled and wetlands drained. These practices have tremendously expanded crop productivity by rapidly removing surface waters and decreasing subsoil moisture, which provides a healthier environment for small grains and allows fieldwork to proceed when soil moisture would otherwise be too high. Removal of excess subsurface moisture is important for plant health to increase the availability of oxygen to the plant's roots for respiration, to mitigate toxic products in the soil, and to enhance healthful soil microbiology (8). However, along with these positive production factors, negative environmental issues associated with agricultural drainage include the following (2, 8–10):

1. Increased nitrogen runoff into receiving streams and percolation into ground waters.
2. Removal of wetlands which serve to break down water pollutants before they percolate back to the ground water (recharge).
3. Increases the speed, volume, and force of water removed from the land through increases in the force and volume of water, thereby reducing possibilities for recharge and increasing potential erosion.

Additional to the agricultural component challenging water quality, millions of acres of earth have been put under concrete for parking lots and roads, creating additional rapid runoff without opportunity for recharge. Figure 7.1 demonstrates the effects of increased drainage speed (8, 10). It should be noted that to help counter

FIGURE 7.1 Row crop cultivation that has exposed bare soil to wind and rain, combined with practices to speed drainage, has created difficulties to manage soil erosion. However, land management practices in the last three decades have slowed the problem. (Source: Medical Practice in Rural Communities, Chapter 3, Figure 3.5, page 48, book authors: Cornelia F. Mutel, Kelley J. Donham, Rural Health and Agricultural Medicine Training Program, Department of Preventive Medicine and Environmental Health, College of Medicine, The University of Iowa, Iowa City, Iowa 52242, U.S.A., © Springer-Verlag New York Inc., 1983. Image reprinted with kind permission of Springer Science and Business Media.)

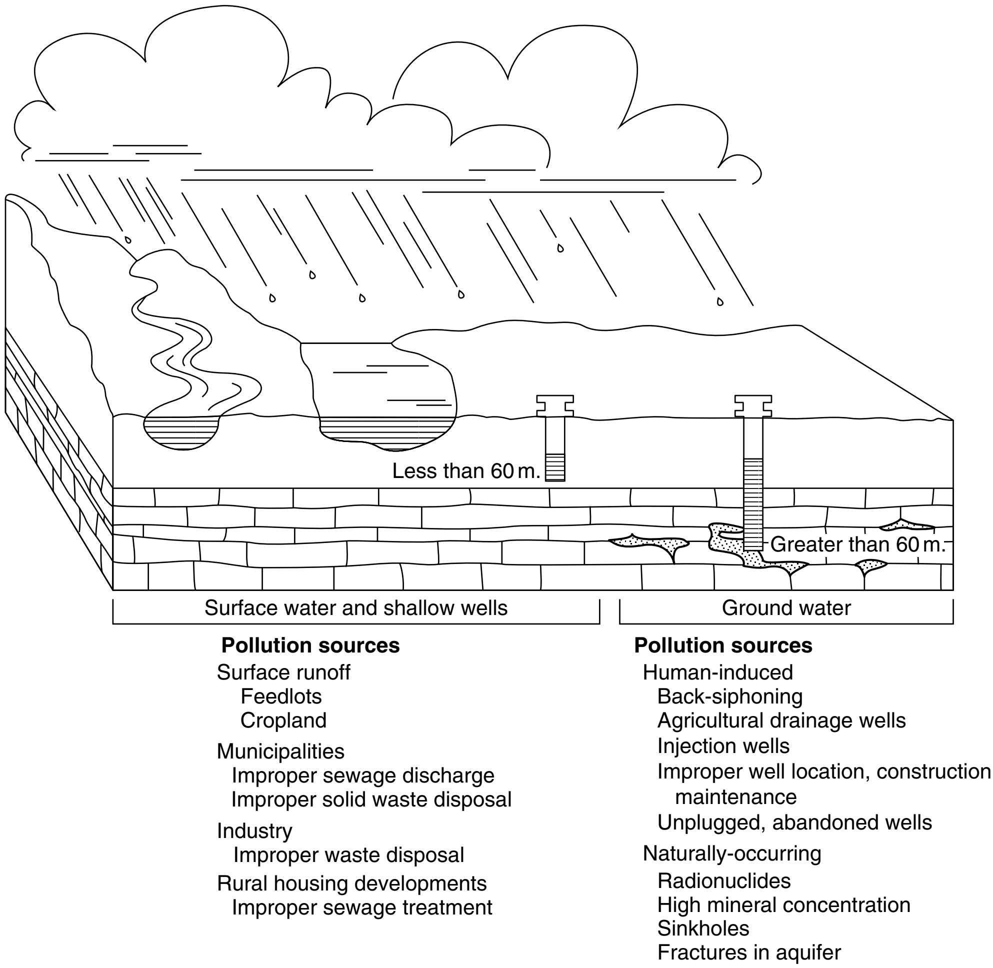


FIGURE 7.2 Surface waters and shallow wells experience the same sources of pollution. Ground water may contain harmful substances from natural sources as well as from human actions. (Source: Medical Practice in Rural Communities, Chapter 3, Figure 3.1, page 44, book authors: Cornelia F. Mutel, Kelley J. Donham, Rural Health and Agricultural Medicine Training Program, Department of Preventive Medicine and Environmental Health, College of Medicine, The University of Iowa, Iowa City, Iowa 52242, U.S.A., © Springer-Verlag New York Inc., 1983. Image reprinted with kind permission of Springer Science and Business Media.)

this problem there have been recent government programs to slow water runoff on our agricultural and urban landscapes, such as building ponds, retaining and building new wetlands, building deep-rooted plant filter strips along streams, and retiring highly erodible cropland amongst others (11). Figure 7.2 demonstrates how runoff not only creates a risk for surface water quality, but also ground water accessible by shallow (less than 50 m) water wells.

The 1987 Water Quality Act (amendments to the 1972 Clean Water Act) in the United States (3) set specific water quality standards. Most developed countries have similar standards. The result has been an important improvement in point source pollutants (mainly industrial sources). (A point source pollution is from a specific observable source, such as a factory, whereas a non-point source is diffuse, over large land areas, without an individual specific observable source.)

However, it has only been in the past two decades that regulations (3, 11, 12) have been promulgated relevant to non-point source pollutants, which have included agricultural sources. These newer regulations are attempting to address issues of agricultural contamination. In addition to regional concerns, agricultural air emissions from industrialized as well as developing countries find their way to distant surface waters as acid rain, pesticides in rainfall, and of course climate change (13–15).

Most rural and farm residents' drinking water supplies are not regulated. Nearly 50% of the global population lacks ready access to monitored and sufficiently treated drinking water (2, 3). Health and safety professionals in rural areas should be aware of potentially harmful pollutants or natural substances in water supplies in their practice areas in order to advise their patients'/clients' communities on preventive actions.

The direct contributions of water pollution to human health are difficult to quantify and vary among different geographical and demographic regions. Although acute health concerns are occasionally reported, chronic health problems are often multi-factorial and it can be difficult to attach cause-effect to poor water quality.

7.3 Substance Sources and Health Effects of Water Pollution from Agricultural Operations

7.3.1 Animal Wastes and Inorganic Fertilizers

A major source of water contaminants is the unused products of fertilizers for crops, which come from both organic (e.g., animal manure) and inorganic (e.g., anhydrous ammonia and mined potash among others) substances. Livestock manure contains nitrogen compounds, phosphorus, antibiotics, microbes, antibiotic-resistant genetic material, and veterinary pharmaceuticals (14–18). Inorganic fertilizers are important sources of nitrate, phosphorus, chloride, calcium, and magnesium contamination. Nitrates and phosphorous are the "footprint" of agricultural water pollution, as they are present in the highest concentrations in runoff waters and are the substances of greatest health and environmental concern (6). (As the term "animal manure" connotes an environmentally harmful substance to the urban population, the agricultural community in the United States often uses the term "plant nutrients" to counteract this negative image.) Typically, manure is directly applied to land, primarily for the nitrogen it contains as a plant nutrient. Nitrogen not taken up by plants is converted to nitrates in the soil, which have the potential to leave the land and become water or air pollutants. A more detailed discussion of the fate and pathway of nitrate is given below.

7.3.2 Nitrates: Sources and Environmental Fate

Because nitrogen is a fundamental element of life, recycling of nitrogen is a fundamental ecologic principle (17–22). Nitrogen in the soil is "fixed" by bacteria into nitrate or ammonia, which can be taken up by plants as a food source.

Plants fed to animals are digested and the nitrogen is incorporated into animal proteins. The nitrogen is then recycled to the air and soil as animal waste is applied to soil. The process of nitrification and denitrification by bacteria in our soils and waters converts this nitrogen to ammonia (NH_3), nitrate (NO_3), and other oxidized forms (primarily nitrous (N_2O) and nitric oxide (NO)), and finally to nitrogen gas (N_2) and back to the atmosphere (14). However, when nitrogen is added to fields faster than plants can utilize it, one of the major breakdown products, nitrate (NO_3), accumulates. Nitrate is highly soluble and susceptible to runoff into rivers and lakes, and finally into the oceans or ground waters.

The nitrogen cycle is out of balance in a large component of agriculture, in both industrialized and some developing countries. Nitrogen pollution not only contaminates water, but also air in the form of nitrous oxide (N_2O), an important greenhouse gas (23). Although industries and auto exhausts are significant N_2O sources, agriculture contributes 80% of the human-generated N_2O (from land application of fertilizers (75%) and breakdown of animal manure (5%)) (13). The quantity of applied fertilizer has been increasing over the past few decades. For example, 50% of all fertilizer ever applied to crops has been applied since 1984. The primary problem is that some of the applied nitrogen (estimated mean of 26%) never reaches plant tissues (14, 24). The remainder escapes by runoff or volatilization to overburden the nitrogen cycle. This problem has increased as our agricultural systems have evolved from small diversified low-input operations through the 1950s to larger more intensive monoculture operations which require larger amounts of fertilizers (22, 24).

7.3.3 Nitrates: Health Effects

Ingested nitrates (NO_2) are readily reduced to nitrites (NO_3) by commensal bacteria in the mouth and gastrointestinal (GI) track (25). Although the primary risk of high concentration of ingested nitrates is from contaminated well water, fresh green vegetables also contain low concentrations of the substance (25). Nitrites are readily absorbed into the blood and complex with hemoglobin to produce methemoglobinemia (MetHb), which renders the red blood cells incapable of carrying sufficient oxygen to the body tissues (26). Infants (especially those under 6 months) are much more susceptible than adults to MetHb than adults because their gut flora enhances the conversion of ingested nitrate to the more toxic nitrite, fetal hemoglobin is more readily oxidized to MetHb, and infants lack the enzyme to convert MetHb back to normal hemoglobin (27). The typical history of a poisoning is one of an infant who has been fed formula remixed with water (e.g., water from a shallow well) containing high levels of nitrates. White-skin infants may present with a blue-gray color of the skin (thus the common name "blue baby"). In dark-skin infants look for bluish color of the nasal or oral mucosa, lips, or nail beds. These infants may present with an irritable or lethargic disposition, depending on the degree of toxicity (28). The infant's condition may progress rapidly to coma and death if not recognized and treated readily. The treatment for MetHb is IV methylene blue at 1–2 mg/kg in a 1% solution. A clinical response should be seen in 20 minutes. Repeated doses (if necessary) should not go beyond 7 mg/kg and be given over at least a 4-hour period.

Other causes of MetHb include a congenital metabolic problem (usually benign and managed with daily doses of ascorbic acid) and local anesthetics of the lidocaine family (29). GI infections and inflammation may increase the production of nitric oxide, which can be reduced to nitrite in the gut, causing low-level MetHb (30). An additional source of MetHb is exposure to silo gas (nitrogen oxides, see Chapter 3). Those exposed to silo gas should be assessed and treated if necessary for MetHb, in addition to the respiratory insult from the irritant nitrogen oxide gases. Occupational and environmental history leading to a diagnosis of MetHb includes primarily ingestion of high nitrate water, but should not leave out the other potential sources mentioned above.

A simple bedside test for MetHb is to take a drop of venous blood and expose it to room air (or, better, pure oxygen). MetHb (and sulfhemoglobin, another condition that can occur on a farm, associated with hydrogen sulfide poisoning, see Chapter 3) will not return from dark blue to red (31). A second simple test is to combine a few drops of the patient's blood with potassium cyanide. If the dark color of the blood is caused by MetHb, it will readily turn from blue to red. This test will also distinguish MetHb from sulfhemoglobin, as the latter will not change color with potassium cyanide. The preferred laboratory test is co-oximetry, which measures spectrophotometrically at four wavelengths and can differentiate MetHb from sulfhemoglobinemia.

The US EPA guideline for nitrate in drinking water is 10 mg/L. Two of the recently reported cases of blue baby investigated in the United States revealed water concentrations of 22.9 and 27.4 mg/L (28).

Additional suspected perinatal risks from nitrate consumption by mothers include suppressed intrauterine growth, prematurity, and spontaneous abortion. Laboratory animal studies and case studies of eight spontaneous abortions in four women in Indiana suggest there is a risk of abortion with nitrate-contaminated well water (32). Confirming the health risks of excess nitrate for pregnant women requires further study (33).

Another suspected risk for nitrate ingestion is an increased risk for stomach cancers and perhaps other cancers (25, 33) (see Chapter 5). The concern is associated with the formation of N-nitroso carcinogens by the reaction of nitrates with amino acids and or N-alkyl-amines (such as the herbicide atrazine). Van Leeuwen (34) has shown in Ontario that atrazine and nitrate in the water are associated with excess stomach cancer. Several studies have shown that the farming population is at increased risk for stomach cancer (see Chapter 5). There is greater total intake of nitrates in the EU (50–140 mg/day) than in the United States (40–100 mg/day) (26). The WHO and the EU have set maximum acceptable daily limits of ingested nitrate at 3.7 mg/kg/day (259 mg/day for a 70 kg person). The US EPA recommended limit is 1.6 mg/kg/day (112 mg/day for a 70 kg person) (26). Therefore, people who drink 2 liters of water per day containing 10 mg/L of nitrate-nitrogen (45 mg/L nitrate) consume 90 mg of nitrate per day (close to the US EPA maximum recommended consumption). Surveys in the United States have shown that 12–46% of wells tested have nitrates greater than 10 mg/L (depending on the land use and geology of the region) (6). The highest levels are found in irrigated areas with sandy or porous soils. Wells of less than 60 m (200 feet) in depth are more susceptible to contamination. Water is not the only source of ingested nitrates, as vegetables heavily fertilized with nitrogen may also contribute to the total dietary burden (26).

Specific mechanisms and dose-response are not fully known for nitrate toxicity. However, the weight of evidence clearly indicates that both acute and chronic health effects of ingested nitrates are possible, and therefore limits on ingestion of nitrates are warranted.

Although the focus of concern about nitrates in water and health has been on adverse health effects, recent research has revealed a positive health role for nitrates and nitrites in vascular health and immune function (25). The key is balance; some nitrates are healthful, but an excess can be harmful.

7.3.4 Phosphorus: Sources and Fate

Second to nitrate, phosphorus (P) is the most ubiquitous agricultural environmental pollutant. As with nitrate its main sources are inorganic crop fertilizers and animal manures (35, 36). When manure is applied in amounts sufficient to meet the nitrogen needs of the plants, P is in excess of plant needs and consequently builds up in soils (37). The excess P may reduce water filtration capacity (water is retained in the soil at higher concentrations) and degrade soil fertility because of nutrient imbalances. To illustrate how serious degraded soil fertility can become, one million acres of the Netherlands (a country with concentrated livestock production and small land mass) is degraded because of excess P from excessive animal manure applications (38). Furthermore, P attaches to soil particles and may leave the farm as runoff with eroded soil to contaminate surface waters.

7.3.5 Phosphorus: Health Effects

Phosphorus at levels that may be found in drinking water is not directly toxic to humans or animals, but it contributes along with nitrogen to eutrophication (increased nutrients leading to aquatic plant growth and oxygen depletion) of the surface fresh waters and salt water estuaries that may result secondarily in adverse human and animal health conditions (39). The increased oxygen demand caused by algal blooms can result in fish kills, decreased aquatic diversity, decreased quality of water for recreation, and undesirable odors and tastes in drinking water. The additional results of this contamination include creating an environment for high growth of several algae and dinoflagellates species which can produce toxins that cause adverse human and animal health effects. Examples include brown and red algal blooms (brown or red tide; 35, 40–42), cyanobacteria, and the protest dinoflagellate *Pfiesteria piscicida* (43). The red and brown algae are saltwater estuary species and may produce toxins that are consumed by and concentrated in shellfish or certain predator fish that may cause mild peripheral neurologic symptoms in people if ingested, or skin irritation or asthmatic symptoms with water or aerosol contact (40–42). Sea mammals or fish may also be affected by the toxins in these algae. Blue-green algae (cyanobacteria) blooms can exist in either fresh or brackish waters. There are many species of cyanobacteria, and blooms have been reported from 40 countries. They can create toxins, and contact or ingestion of this water can be harmful to both humans and animals. Drinking water highly contaminated with cyanobacteria and the various toxins they produce can cause death (rarely), but also sub-lethal pathology to the liver, nervous system, and other organ systems (41). Swimming or other recreational exposure can result in GI, skin, mouth, eye, or ear irritation (42).

Eutrophication of rivers and estuaries on the east coast of the United States has been speculated as being the source of an overgrowth of the dinoflagellate *Pfiesteria piscicida*. Toxins produced from this organism are incriminated in fish kills as well as certain health conditions in people exposed to water overgrown with the organism. Symptoms include skin irritation, short-term memory loss, confusion, and cognitive impairment (43). Many of these symptoms appear to be temporary.

7.3.6 Soil Particles

Soil erosion is a major source of particulate contamination of surface water sources worldwide (1). Each year in the United States an estimated 4 billion tons of soil runs into rivers, streams, and lakes (44). This area of loss is equal to 12 million acres (4.7 million ha), 15 cm deep, which is approximately the same size of land area on which corn is grown in the state of Iowa (the number one corn-producing state in the United States). Particles in drinking or recreational waters alone do not necessarily pose a health risk, but they do produce aesthetic problems such as poor taste, turbidity, and odors. Particles also are a signal of additional potential contaminants, such as nitrates, microbial organisms, herbicides, and insecticides. Soil that becomes airborne (particulates) may cause health hazards, which are discussed in the section on air contamination later in this chapter.

7.3.7 Trace Elements

Sodium (Na), potassium (K), copper (Cu), and zinc (Zn) are found in animal manure. They are additives to animal feeds, often at concentrations higher than the animal is capable of assimilating, and thus passed on in the manure. Although there is little scientific evidence of toxic health hazards to humans, there are concerns with degradation of soil fertility and toxicity to grazing animals. Soils with long-term applications of animal manure may contain excess Cu and Zn, which are toxic to some plants and to animals grazing on these soils. Cu and Zn are not highly water soluble, are not removed to any great degree by plants, and therefore tend to accumulate in soils. This degrades the productivity of the soils and leads to possible Cu toxicity to sheep primarily and secondarily to cattle, as they graze close to the ground, ingesting soil along with plant material (45–47).

7.3.8 Infectious Microbes in Water

Microbial contamination of ground and surface waters can occur from livestock operations (21). Organisms that have been associated with animal waste that have human health implications include *Helicobacter pylori* (48) (an agent that can cause gastric ulcers), *Campylobacter, Salmonella, Cryptosporidium* (which all cause GI disturbances), and *Listeria* (which causes GI and numerous other conditions; 21, 49–54). Although there may be hundreds of species of organisms found in swine waste, most animal waste pathogens do not survive long in slurry or land application because they are not well suited to survive desiccation, sunlight, low pH, competition with other microbes, high osmosity, and high ammonia concentrations (55, 56). For example, *Salmonella* and *Leptospira* species were found to survive for only 3 days in swine waste (57) or 19 days (*Salmonella*) in poultry manure (21, 58).

7.3.9 Health Effects of Infectious Microbes in Water

Although there have been documented cases of animal-origin bacterial and parasitic GI illnesses and other water-borne illnesses (e.g., leptospirosis, salmonellosis, *E. coli*, giardia, and cryptosporidiosis (from animal-to-water-to-person)) (54, 59), it has been difficult to characterize or quantify the overall health risk of these exposures (60). Well waters may become contaminated if the wellhead is not properly sealed or the casing is not intact. Furthermore, well contamination is a greater risk during times of flooding or heavy runoff. The following information suggests sources of infectious agents in water present potential hazards. Fecal bacterial species growing in lagoons of confined animal feeding operations (CAFOs) have been found in surface and ground water in the vicinity of CAFOs (61). An example of a non-point contamination of a municipal water supply outbreak includes an outbreak in Milwaukee in 1993 involving an estimated 400,000 people who contracted *Cryptosporidium parvum* infection from drinking city water (53, 62). One hundred deaths were attributed to this outbreak, mainly in elderly or those immunocompromised. Although the source was never confirmed, the early speculation was that the infectious agent originated in runoff from cattle pastures and contaminated city water supply reservoirs (53). *C. parvum* is present worldwide. Ninety-four animal species are susceptible, with eight different cryptosporidia species, *C. parvum* being the most common in livestock and humans. Feral birds may serve as environmental disseminators of this organism. There are no data at present on CAFOs as sources of human infection with *C. parvum* (53). Young ruminants are especially susceptible to this infection and shed the organism in their feces. The filtering component of the water-treatment plant of most cities is not capable of removing this organism, and it is resistant to the usual municipal water treatments such as chlorination. UV light or ozination are more effective alternatives (63).

The typical human *C. parvum* infection persists for 4–7 days with typical GI symptoms of stomach cramps or pain, dehydration, nausea, vomiting, fever, and weight loss. Treatment in humans is to address the dehydration caused by the diarrhea. Nitrazoxanide a recommended antiparasitic drug. Rehydration may be necessary, given either orally or, in severe cases, intravenously (49).

7.3.10 Veterinary Pharmaceuticals

Small quantities of antibiotics, paraciticides, and growth enhancers (or their by-products) pass in the urine and feces of animals and find their way into soils and water sources through manure application (7, 18, 64, 65). The fate, transport, and impact of veterinary pharmaceuticals in the environment were recently discussed in a review article (66). It is apparent that veterinary pharmaceuticals are a potential health concern, but secondary in importance to nitrogen and microbial pathogens.

7.3.11 Health Hazards of Veterinary Pharmaceuticals in Surface Drinking Waters

Of the various pharmaceuticals that may enter surface waters, perhaps the primary agents of health concern are antibiotics and their possible influence on emerging antibiotic-resistant organisms (this subject is discussed in detail in Chapter 11).

Field studies in the vicinity of poultry and swine confinement facilities have revealed the presence of antibiotics in a variety of water sources, including animal waste lagoons, monitoring wells, field tiles, streams, and rivers. Antibiotics of the following classes were found at a concentration of around 100 μg/L of water: tetracyclines, sulfa, beta-lactams (e.g., penicillin), macrolids (e.g., erythromycin), and fluroquinalones (e.g., enterofloxacin) (18). A potential hazard is present (but low risk) in the consumption of antibiotics and antibiotic-resistant organisms in well or surface waters (18, 64, 66, 67). The health significance of the consumption of these substances at low concentrations is uncertain.

7.3.12 Pesticides

Rain may wash insecticides, herbicides, and fungicides from plants or soil into bodies of surface water and shallow wells (68–79). Organochlorine insecticides and some herbicides persist in the environment, and these are most likely to contaminate rural water. However, organchlorine insecticides have largely been replaced by the less persistent organophosphates, carbamates, and pyrethroids, and are less likely to contaminate water supplies. Certain herbicides (e.g., atrazine and glyphosate), the chlorinated phenoxyacetic acid products (2,4-D), and fungicides (e.g., hexachlorobenzene and pentachlorophenol) are also of concern (50).

7.3.13 Health Effects of Pesticides in Water

Occasional cases of acute pesticide poisoning occur from drinking water, when a spilled pesticide enters an unprotected water well (unsealed, uncased, or broken-cased) or back-siphoning from a mixing-loading operation. During mixing and loading operations the pesticide concentrate is placed in a tank and diluted to specifications by adding water from a hose connected to a hydrant. Should the hydrant be turned off, with the hose under the liquid surface, the contents of the tank will siphon back down the hose into the well (unless there is a check valve in the hydrant) (Figure 7.3). Organophosphate or carbamate insecticides are most likely to cause acute poisonings from back siphoning cases.

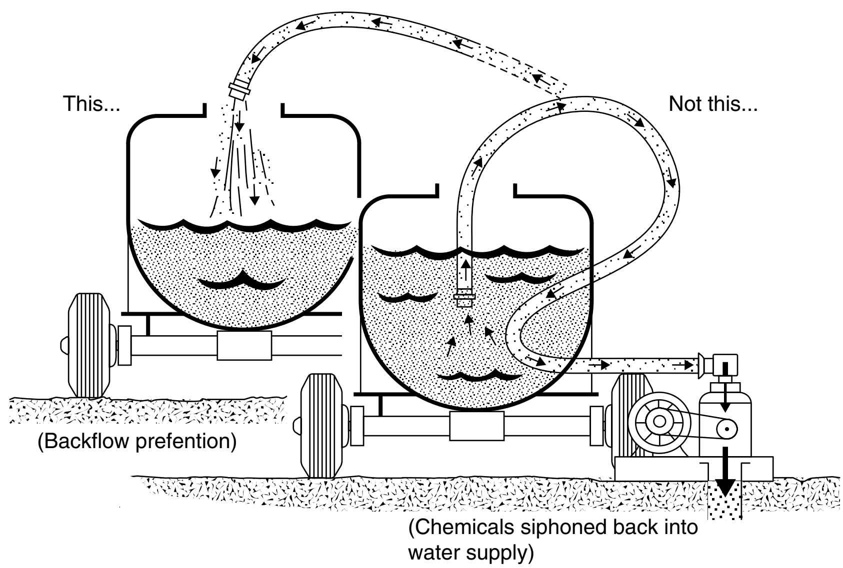


FIGURE 7.3 Back-siphoning of agricultural chemicals into wells occurs when a hose filling a mixing/application tank is connected to a hydrant that does not have a check valve. (Source: Medical Practice in Rural Communities, Chapter 3, Figure 3.3, page 45, book authors: Cornelia F. Mutel, Kelley J. Donham, Rural Health and Agricultural Medicine Training Program, Department of Preventive Medicine and Environmental Health, College of Medicine, The University of Iowa, Iowa City, Iowa 52242, U.S.A., © Springer-Verlag New York Inc., 1983. Image reprinted with kind permission of Springer Science and Business Media.)

The quality and quantity of data are adequate to support associations of pesticide-contaminated water and chronic health consequences, but not to the extent of cause-effect.

Possible adverse chronic health concerns associations with pesticides include cancers of various types and neurologic disorders (reviewed in detail in Chapters 5 and 6).

7.3.14 Water Pollutants from Urban Sources

Improperly treated municipal sewage may pollute surface water supplies with infectious agents and nitrates. Furthermore, urban municipalities and industries usually locate their waste disposal sites in rural areas. If these sites (sanitary landfill or toxic waste facilities) are not properly engineered and managed, nitrates, infectious agents, and other potential toxic substances may leach into shallow aquifers or run off into surrounding streams, thereby contaminating local or distant downstream water supplies. Despite governmental regulations, these incidents happen sporadically in rural areas of industrialized countries (51, 71, 72). The overall health effects on the rural population are not known (72).

7.3.15 Possible Health Effects of Chlorine in Drinking Water

Most municipalities chlorinate their drinking water to kill infectious agents. Additional sources of chlorine include inorganic fertilizers, rural homes, animal feeding operations (AFOs) that have chlorinated water systems, and rural water supply systems. Chlorination of drinking water supplies presents a dilemma in environmental health practice. Chlorine is a very effective disinfectant, but there are disinfection by-products that may be harmful (i.e., trihalomethane compounds) and are formed as the chlorine combines with organic molecules in the water (73–75). Trihalomethanes are carcinogens in laboratory animals. Epidemiologic studies have revealed an association between the presence of these substances in drinking water and increased bladder, colon, and rectal cancers, as well as reproductive problems in women (73–75). There is growing concern for a health hazard for rural (or urban) populations if their surface water source is downstream from or in the vicinity of a community, rural housing, or agricultural operation that discharges chlorinated water.

The US EPA has set a limit of 80 ppb trihalomethanes in drinking water (73). As there are few studies that have looked for these substances in rural water supplies, the extent of the potential hazard is not known. Suffice it to say that with the current limited extent of knowledge of this subject, the benefits of chlorination far exceed the risks.

7.3.16 Water Pollutants from Rural Industrial Sources

Many urban and rural industries intermittently discharge (unintentionally and possibly intentionally) improperly treated waste products into streams or lakes or improperly dispose of waste chemicals in the ground, resulting in groundwater contamination (75, 76). For example, packing plants and rendering plants that do not have adequate waste treatment facilities may contaminate surface water supplies with nitrates, infectious agents, and complex organic materials.

Methylmercury, another example of a rural industrial water pollutant, is found in many industrialized countries, including areas of the north central and northeastern United States and eastern Canada. Mercury was formerly used in paper pulp mills as a fungicide. It is also a contaminant of coal-fired power plants. Mercury is transformed by micro flora in the environment into the neurotoxin methylmercury, which accumulates in fish and other aquatic life, endangering people who eat fish. The adverse health effects of methylmercury (77) are a global concern highlighted by the classic case of chronic community poisoning which occurred among Japanese people who consumed seafood from the contaminated waters of Minimata Bay. Northern Canadian first-nation people in Quebec and Ontario are at risk because they acquire much of their food (protein) from fish in methylmercury-contaminated lakes. Mercury (like most heavy metals) is neurotoxic. The primary adverse effect is the abnormal neurological development of the unborn fetus and young children, which manifests itself in deficient cognitive, vision, and fine motor skills. Associations have also been reported of chronic methylmercury exposure with various cancers. Studies remain in progress to investigate the full extent of this problem (47).

7.3.17 Ground Water Pollution from Drainage Wells and Other Non-agricultural Industries

Agricultural drainage wells were mentioned in the introduction to this chapter as one of the methods to get water off the land quickly to enhance crop production. Such new wells are illegal today, but those remaining (to be phased out in the future) carry surface contaminants directly to ground waters which may also have connection to the aquafers that serve as the source of drinking water for area residents (78, 79) (see Figure 7.4).

Other industries use drainage wells (also called injection wells) as a means of disposal of unwanted materials or to enhance production. Petroleum companies and many other chemical companies have used injection wells to dispose of a variety of wastes. Waste material is forced under pressure into a well deep into the ground, below the aquifers from which drinking water normally is drawn. However, if there is a mechanical failure or a geophysical connection between the two levels, the injected material may contaminate a drinking water aquifer. Petroleum companies also frequently inject saltwater into oil wells to increase their yield of oil or to dispose of excess saltwater (often a by-product of oil wells) from active wells to nearby inactive wells. Most injection wells are in the Texas and Kansas oil fields and in the upper Midwestern industrial belt. Specific health hazards depend on the particular contaminants, but actual risks have not been defined (80).

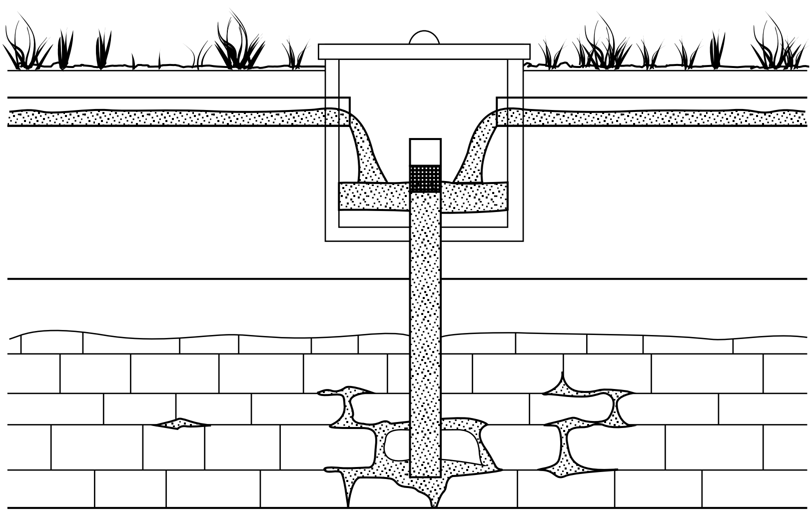


FIGURE 7.4 Drainage wells are designed to remove excess surface waters to ground waters. This expedient method of water removal risks polluting ground water sources with agricultural chemicals, nitrates, and infectious agents among other surface substances so drainage wells are slowly being phased out in most countries. (Source: Medical Practice in Rural Communities, Chapter 3, Figure 3.2, page 45, book authors: Cornelia F. Mutel, Kelley J. Donham, Rural Health and Agricultural Medicine Training Program, Department of Preventive Medicine and Environmental Health, College of Medicine, The University of Iowa, Iowa City, Iowa 52242, U.S.A., © Springer-Verlag New York Inc., 1983. Image reprinted with kind permission of Springer Science and Business Media.)

A variety of other industrial chemicals may be accidentally spilled or discharged into rural water supplies. Examples include a spill of carbon tetrachloride that contaminated water for miles downstream in the Ohio River, and a train wreck that spilled 13,000 liters of phenol, contaminating rural wells for miles around the accident scene (72). Not only are production agriculture operations potential contaminate emitters (81, 82), but agricultural industries may also be sources of contaminants. A veterinary pharmaceutical company in a small Midwest town had a landfill containing orthonitroanaline that leached into the adjacent river, jeopardizing water quality for several miles downstream. Underground leaking petrochemical tanks and pipelines have also contaminated groundwater in rural areas (71, 80).

7.3.18 Water Pollutants from Inappropriate Land Management

Water contamination commonly results from inappropriate land use and from lack of pollution controls. Examples include rural subdivisions with too high a density of septic tanks or poorly functioning leach fields. Strip mines often result in excessive erosion and acid leakage into water sources. Water seeping through abandoned deep-shaft mines may pick up hazardous minerals or particulates, and working mines may deposit wastes directly into lakes or onto land where run-off can carry contaminants into surface waters. In Minnesota, taconite mining companies dumped their tailings in Lake Superior for many years, contaminating the lake with asbestos. Many rural as well as urban residents obtain their water from that lake (83).

Impending problems in areas west of the Mississippi River (particularly the Platte and Colorado River basins) include increased levels of mineral salts in soil and groundwater, cross-aquifer contamination, and a decline in local water tables. All these problems have resulted from intensive irrigation of arid lands that have been brought into agricultural production (46, 83). Excessive salinity of water has a laxative effect on people drinking this water because of its sodium and magnesium salts. Furthermore, some people who drink this water may have difficulty controlling hypertension and hypocalcaemia secondary to pregnancy because of its sodium salts (46). Moreover, as the salinity (and therefore osmosity) of soils increases, additional irrigation water is required to make water available to the plants, creating an environmental conundrum.

7.3.19 Water Pollutants from Natural Sources

Several natural substances may contaminate rural well water supplies. Fluoride, for example, is a natural material found in many different ground waters. It has the positive benefit of prevention of dental caries. Safe but dental-effective concentrations are in the range 0.5–1.2 mg/L, with optimal concentrations of 0.7 mg/L (97). Many municipalities in developed countries add fluoride to drinking water to achieve optimal concentrations for the proven public health benefit. However, some aquifers naturally contain high concentrations of fluoride, which can result in adverse health conditions. Excess fluoride can cause a brown-colored mottling of teeth in children at concentrations over 1.5 mg/L. At higher concentrations (i.e., 10 mg/L), fluoride may result in abnormal bone formation (skeletal fluorosis) (84). Several countries have areas with excess fluoride in their water, including Africa, China, Middle Eastern countries, India, Sri Lanka and the United States (85). Over 8 million people in 44 states of the United States are exposed to high concentrations of fluoride in their drinking water, including certain areas of Arizona, Colorado, Illinois, Iowa, New Mexico, Ohio, Oklahoma, South Dakota, and Texas (46, 86).

Arsenic (Ar) is a heavy metal that has been used in insecticides, herbicides, and the treatment of intestinal parasite in animals (see Chapter 6). It occurs naturally in certain ground water aquifers around the world as a natural result of filtration of water through rock formations that contain high concentrations of this element. Chronic exposure to Ar in drinking water can increase the risk for skin, bladder, kidney, and lung cancers, diabetes, anemia, various skin conditions, and developmental, immunologic, circulatory, and neurological conditions (87–89). In many areas around the world Ar in the water is a health hazard. Globally, Ar is of concern in Argentina, Chile, Bangladesh, China, and India (88). In rural areas of Taiwan, Ar has been associated with a condition called black foot, which is a circulatory impairment to the soft tissues of the foot resulting in gangrene (90). Ar is a concern in some ground waters in parts of Mexico, Texas, the upper Midwest, and the New England States (91). The US EPA sets maximum concentration limits (MCL) of Ar in water of 10 μm/L (10 ppb), the same as that recommended by the WHO. Mitigation options include: (1) finding and drilling into alternative aquifers with safe Ar concentrations, (2) use of microbiological safe surface waters, and (3) use of captured rain water (90).

7.3.20 Health Effects of Hard Water

Many rural well waters contain excessive quantities of calcium and magnesium salts (hard water). This "problem" actually may have a positive health effect. Some epidemiologic studies have suggested a protective association between water hardness and cardiovascular disease, stroke, stomach cancer, eclampsia, and bone density (16). However, other studies have linked hard water to certain adverse health conditions.

Many rural residents with hard water buy and install water softeners. It may be prudent to install a water-softening system for hot water only. Most water softeners in use are ion-exchange systems, which exchange magnesium and calcium with sodium, resulting in extra sodium in the water. People who must restrict sodium intake for control of cardiovascular disease may want to use a different softening system (e.g., reverse osmosis) (46, 86).

Radionuclides are often common natural components of drinking water. Associated health hazards with natural radionuclides are an increasing concern worldwide (92). The normal background radiation exposure for humans in the United States is about 100 millirems/year. A small portion of this radiation (estimated at 0.24 millirems/year on average) comes from water that contains naturally occurring radionuclides (46). Many radionuclides may be present in water, including ^{222}Rn, ^{226}Ra, ^{228}Ra, ^{40}K, and ^{90}Sr. The largest contributor of adverse health consequences is radon (^{222}Rn) (93), which is a decay product of ^{238}U. Radon is a gas that escapes from rocks and finds its way to ground waters and to surface waters. Radon is found at much higher concentrations in ground water. In surface waters, it diffuses rapidly to the air. Certain areas of the world have high concentration of radon in the water. Some epidemiologic studies suggest that populations in these areas have slightly higher rates of certain cancers. The US EPA estimates that radon in water causes 168 fatal cancers per year. Eleven per cent of these are stomach cancers and 89% are lung cancers from inhaled radon gas which escapes from the water (46, 93). The most prominent health risk is inhalation of radon gas that is concentrated in basements of homes or in underground mines, creating an occupational hazard. Radon gas is thought to be the second biggest (next to tobacco cigarette smoking) cause of lung cancer in the world, accounting for 3–14% of all lung cancers (92). The EPA estimates 20,000 lung cancer deaths annually in the United States are caused by radon (93). For health reasons, radon concentration should be below 11,000 Bq m^3 (becquerels per cubic meter) or 324 pCi/L (picocurries per liter) (92, 94). For those using a private well, mitigation may necessitate drilling a new well in a different aquifer.

Sulfates are often a natural component of many rural water wells, causing off-odors and bad taste. At high concentrations (e.g., 600 mg/L), sulfates can cause diarrhea (95). It is estimated that 3% of US public water supplies have sulfate levels above 300 mg/L (96, 97). There is no regulated maximum concentration of sulfate in drinking water, but the US EPA has recommended a maximum level of 250 mg/L based on aesthetic odor and taste quality (96). Sulfates are removed from water by reverse osmosis systems, but not ion-exchange systems. In the latter, sodium sulfate is the product that can come through in the water-softening process, which may have some cathartic effect, but no other known adverse health effect (96).

Individuals can develop a tolerance to sulfate over time, enabling them to drink water at higher concentrations without the cathartic effect. Individuals who are dehydrated and the elderly may be more susceptible to high sulfates, especially when working in hot environments (95, 98). A secondary potential health hazard of high sulfates is that if water for livestock contains high concentrations of sulfates (e.g., above 250 mg/L) there is a higher risk of acute toxic concentrations of hydrogen sulfide in liquid manure stored in anaerobic storage systems (99) (see Chapter 3).

In summary, rural water pollution and rural drinking water quality is a major general environmental concern in rural and agricultural settings. Nitrate contamination followed by phosphorus contamination top the list of pollutants of concern. However, there are many other human (urban and agricultural) and natural sources of water contamination that may pose health risks to rural residents. Table 7.1 summarizes the various sources of water contamination, whether ground or surface waters are affected, the health hazards, and control and prevention.

7.4 Prevention of the Adverse Health Effects of Water Pollution

The following steps are first-order practices to help prevent adverse health effects from contaminated drinking water.

1. Regularly test drinking water supplies, preferably annually in spring (or rainy season). As a minimum test for nitrates and coliform bacteria. Test also for natural substances (e.g., fluoride, arsenic, etc.) if residing in an area where these are possibly present. Testing can be done through most local health departments.
2. Inspect the well (or have a professional sanitarian or well driller make the inspection) for damage to the well cap or casing and for hazardous location of potential pollution sources in the area of the well head.
3. Fill in and cap non-functioning wells as they present a hazard for ground water contamination. The local health department or a professional well driller can help with this.
4. Ensure there are operating check valves in outdoor hydrants to prevent back-siphoning of contaminates into the well.

For primary prevention of water contamination there is adequate scientific and technical information available to control water pollution from agriculture and urban sources. However, developing effective policy, regulations, and enforcement that will curb pollution without creating an economic liability is difficult. Difficulties include the large number and geographic dispersion of agricultural operations, and striking a balanced political–economic approach to regulations. However, voluntary changes in production practices can have important environmental benefits. Minimal or no tillage practices in row crop production leaves plant material on top of the ground, dramatically decreasing soil erosion and thus water pollution. Cover crops planted following harvest are effective for incorporating nutrients remaining in the soil and preventing runoff. Time-released nitrogen fertilizer products are available to maximize plant incorporation. Special diets and new corn varieties have been developed for animals, leading to less P in the manure. The US Department of Agriculture (USDA) sponsors programs to build or preserve wetlands (100) and riparian buffers and vegetation filter strips that decrease runoff into streams. One researcher advocates the use of polyacrylamide addition to soils, which acts to stabilize soils so that they hold on to fertilizers, preventing runoff (101). Wood chip bio-filters installed into field tile drainage systems show potential for removing nitrates in water prior to discharge into receiving streams (102). A policy in the United States to help manage water pollution from agriculture in many states is a special tax on pesticides and fertilizers. The policy has shown some benefit in pollution control (103). Precision agriculture technologies use global positioning systems to

Table 7.1 Rural water pollution: sources, health effects, and prevention

		Water source			
Substance	Pollution source	Surface	Ground	Potential health hazard	Prevention
Nitrates	Runoff into surface waters and seepage into ground water from heavily fertilized cropland, livestock feedlots, or earthen manure storage structures	X	X	Infant methemoglobinemia (blue baby)	Test drinking water annually for nitrates Use bottled water for infant formula or breastfeed during first year of infant's life
	Wells improperly constructed, maintained, or located		X	Biologic conversion to nitrosamines (suspected carcinogens)	Educate and encourage farmers to establish runoff control measures
	Septic tanks, cesspools	X			Install a deep well
	Improperly treated sewage discharged from municipalities or industries	X			Zoning laws to control rural development
Pesticides	Runoff from agricultural fields	X	X	Acute poisonings Suspected effects: carcinogenic aplastic anemia peripheral neuropathy hypertension elevated cholesterol	Monitoring and enforcing point source pollutants Proper location and construction of wells Have wells tested for specific pesticides applied on adjacent fields
	Spillage	X	X		
	Back-siphoning into well		X		
Infectious agents *Salmonella* *E. coli* *Campylobacter* *F. tularensis* *Giardia* *Entamoeba* *Viruses* *Helminths* *Cryptosporidia* *Helicobacter pylori*	Human sources: septic tanks cesspools improperly treated sewage sludge from sewage dumped in landfills Animal sources: domestic animals (runoff from feedlots or from fields where manure has been applied) wildlife (runoff or defecation directly into streams)	X X X X	X X X X	enteritis gastroenteritis hepatitis A tularemia giardiasis echinococcosis gastric ulcers	Zoning laws and public health laws to prevent high-density rural development Ensure proper construction of septic systems (permit system) Ensure proper location and construction of wells Ensure proper location and maintenance of feedlots to prevent runoff Boil or chemically treat water from streams or lakes for drinking when on camping or hiking trips

Methylmercury	Fossil fuel power plants Pulp mills Chloralkali plants	X X		Mercury contamination of fish, hazardous to people eating certain fish from contaminated water Nervous system disorders	Prevent discharge into streams and lakes
Mineral salts	Irrigation		X	Mainly aesthetic problems of poor taste Possible diarrhea complicates control of hypertension and hypocalcemia secondary to pregnancy	Zoning laws to limit irrigation in marginal areas Magnesium salts may have a positive heart health factor Best not to use sodium ion exchange water softener for these
Fluorine	Added to municipal water supplies Natural geologic formations	NA X	NA X	Low levels: prevention of dental caries High levels: mottling of teeth, skeletal fluorosis	Test water if newborn in family, use alternative water source if too high level
Calcium and magnesium (water hardness)	Natural geologic formations	X	X	Aesthetic (taste) and property damage, scale in pipes May reduce the risk of cardiovascular disease People on reduced sodium diets should not drink water from sodium ion-exchange water softeners	Home sodium ion-exchange water softener on hot water source only (not for drinking water as extra sodium in may complicate control of hypertension or other certain cardiac problems)
Radiation	Natural geologic formations		X	Uncertain, possibly increased risk for bone cancer and lung cancer	Home cation exchange or reverse osmosis water softener Drill well to different aquifer (usually shallow wells are radiation free) Use treated surface water
Sulfates	Natural geologic formations		X	Bad taste, diarrhea	Drill well to different aquifer Install special water treatment process (i.e., aeration or chill) Use treated surface water

(*Continued*)

Table 7.1 (continued)

		Water source			
Substance	Pollution source	Surface	Ground	Potential health hazard	Prevention
Particulates	Soil erosion from agricultural cropland or surface mining	X		Direct health effects unknown, but may carry pesticides, microbes, nitrates Signals runoff problem Aesthetic effects: objectionable odor, turbidity, odors	Promote soil conservation practices, such as conservation tillage and terracing
Hazardous chemical wastes	Industrial waste disposal sites that are improperly located, constructed, or maintained Industrial injection wells	X	X X	Variable depending on specific substance	Monitor old dump sites Provide properly located, engineered, and maintained hazardous waste disposal sites Contact local environmental authority if hazardous waste site suspected
Trihalomethane compounds	Chlorination of municipal water supplies, rural water supplies, fertilizers, home/farm chlorination systems	X		Reduced risk for waterborne infections Suspected carcinogens	Test wells Limit is < 80 ppb of trihalomethane Choose a non-halogen disinfectant or refilter water to remove organic materials prior to chlorine addition

manage the amount of fertilizer and pesticides applied to cropland according to specific localized needs. These systems have the potential to reduce excess farm chemical application that may end up as water contamination. However, evaluation of the effectiveness of these processes is challenging (104–106). Multiple interventions focusing on watershed regions seem to be effective (107). An important problem for the institution of voluntary controls is that in the Corn Belt region of the United States over 50% of the land farmed is rented or leased. Most renters are interested in least cost production, and long-term land conservation practices are not to their short-term economic advantage. Advanced policy development to manage this concern is needed.

7.5 Air Quality in Rural Agricultural Environments

7.5.1 Introduction

Human health hazards from rural and agricultural air pollution are of minor concern compared to water pollution. Numerous sources of air pollutants originate in the rural environment, but pollutants may also be blown in from urban areas. There are acute exposures that can be traced directly to air pollution (such as eye burns from direct exposure to anhydrous ammonia or poisonings from pesticide drift) but are rarely reported. Most health problems are more chronic and less severe. Exposures may complicate existing conditions in an additive or synergistic manner. For example, in rural areas, as in urban, any one of the low-level pollutants (such as ozone, nitrogen oxides, or particulates) may have inconsequential health effects, but each may precipitate severe health problems in people who have concurrent respiratory or cardiovascular conditions, who smoke, or who are exposed to other industrial or agricultural air pollutants. Table 7.2 summarizes the major air pollutants in rural and agricultural settings.

7.5.2 Air Pollution from Livestock and Crop Operations

The most common air pollution problems include odors from livestock operations, dust from tilled fields, particulates from burning crop residues, pesticides from aerial application, and anhydrous ammonia leakage from storage containers (1). Gasses, particulates, and bioaerosols may be emitted from livestock operations and fertilizers applied to cropland. Local concerns as well as the regional and global consequences of these emissions are discussed in this section.

7.5.3 Fate of Emissions and Atmospheric Effects

Residents in rural areas near livestock farms may have health concerns relative to odors, hydrogen sulfide, and ammonia (108). Environmentalists and climate scientists have regional and global concerns relative to ammonia, methane, and carbon dioxide that may be emitted from these operations (109, 110). Western Europe, particularly the Netherlands, has taken the lead in researching the global impact from ammonia, methane, and carbon dioxide emitted from livestock operations. About 50% of the total emitted ammonia comes from land application of manure, and about 40% from stored liquid manure (e.g., lagoons). Once in the atmosphere, ammonia gases can be transported downwind and then deposited into surface waters and on soils as ammonia or as other oxidized nitrogen compounds. Luebs and co-workers found that 8.5 kg/ha/week of ammonia was deposited within 1 km, and ¼ kg/ha/week 8 km downwind of a large concentrated dairy facility (111).

In addition to the nitrogen from water pollution, deposition of excess ammonia nitrogen from the air causes increased risk for eutrophication of ponds, lakes, and streams in the region. It can also bring excess nutrients to natural areas, causing overgrowth by undesirable plant species and nitrate leaching through soil (112). Ammonia in the atmosphere may also react with acids already in the air, such as hydrochloric, sulfuric, and

Table 7.2 Rural air pollution: sources, health effects, and prevention

Pollutant	Source	Health effect	Control/prevention
Odors	Agriculture: livestock production	Rural neighbors may experience somatic symptoms from odors and stress, including respiratory symptoms and nausea They fear they may not be able to use their home space as they like, and fear loss of property value	Good management practices and use of many available source control measures Zoning laws to separate agricultural operations from residences or place limits on concentration of animals in a region Promulgation and enforcement of odor source regulations (where they exist) Nuisance law suits
Particles, fugitive dust	Agriculture: tilled fields Surface mining Unpaved roads Mining fracking sands	Difficult to measure a direct health hazard An additive irritant to other air pollutants, especially in individuals with respiratory or cardiovascular disease	Promote soil conservation practices, such as conservation (minimum) tillage Installation and preservation of windbreaks Oil or calcium chloride on gravel roads
Other suspended particulates	Agriculture: burning of crop residue Forestry: managed forest burning Rural manufacturing Rural energy production Mining Burning in open dumps	Similar to fugitive dust, but mainly localized in southeastern United States Occurs sporadically during certain times of the year Similar to fugitive dust Similar to fugitive dust	None recommended at present time Enforcement of guidelines from state and federal environmental offices Eliminate open dumps Public education
Pesticides	Aerial spraying to control insects or fungi that damage agricultural crops or forests	No health hazard recognized for area residents	Education of applicators Regulations to assure proper pesticide is applied in the proper amounts Education of agricultural businesses
Anhydrous ammonia	Accidental leakage from storage tanks in towns Leakage from soil fertilizer applications Leakage from refrigeration units Animal and poultry urine and manure degradation	Chemical burns to eyes and skin Chemical pneumonitis and pulmonary edema At low levels, respiratory tract inflammation, synergistic with particulate exposure	Periodic checks for proper functioning of storage tanks and transfer equipment Periodic checks for proper function and maintenance of application equipment Management of source control from livestock and poultry operations
Nitrogen oxides	Rural manufacturing Rural fossil fuel energy plants Rural motor vehicles Drift from urban centers Ensilage processing of forage crops Oxidation of ammonia from livestock and poultry manure	Irritant to eyes and respiratory tract	Support current regulations and their environment

Sulfur oxides	Rural coal-fired energy plants Drift from urban centers Oxidation of sulfur compounds from animal manure degradation	Irritant to eyes and respiratory tract	Support current regulations and their environment
Carbon dioxide	Rural industry Rural fossil fuel energy plants Drift from urban centers	Unknown	Support current regulations and their environment
Hydrocarbons	Rural industry and manufacturing	Unknown	Support current regulations and their environment
Radioactivity	Nuclear energy plants	Unknown	Support current regulations concerning nuclear plants
Carbon monoxide	Automobiles and trucks Drift from urban areas	Unknown at levels found in the rural environment Possibly enhances arteriosclerosis Possibly decreases birth weight and retards development in newborn	See below
Ozone	Photochemical oxidation of combustion products	Irritation to eyes and respiratory tract Prolonged exposure may lead to chronic bronchitis or obstructive lung disease People with concurrent heart or lung disease are at greatest risk	Reduce reliance on automobiles for transportation Enforce regulations to decrease emissions from internal combustion engines
Acid rain	Conversion of nitrous and sulfur oxides to sulfuric and nitric acids, which are washed to the ground by precipitation	Direct human health effects not fully evaluated Quality of surface water decreased	Enforcement of regulations for emissions from industries, cars and trucks

nitrous acids. This results in ammonium aerosols, which are then transported downwind and can return to earth with precipitation. Apsimon and Kruse-Plass (20) have reported that ammonium nitrates are more strongly acidifying to soils and water than strong acids. As in nitrate water pollution, denitrification and nitrification of ammonia produces nitrous oxide (N_2O), which contributes to greenhouse gases and ozone depletion (13, 23). Approximately 1–2% of total N loss from land-applied manure is lost as N_2O (113). Denitrification also produces nitric oxide (NO), which can contribute to acid rain (14, 114, 115).

Methane is a greenhouse gas that contributes to global warming (116). Methane is 20 times stronger on a molecular basis as a greenhouse gas than carbon dioxide (13). It is 58 times stronger on a mass basis because of its relatively greater ability to absorb long wavelengths of light energy (117). Total world yearly methane emissions are 354 million metric tons. The United States emits 27 million metric tons and livestock (wastes and ruminant eructation) accounts for 9% of this total (116). Intensive confinement systems with anaerobic storage of manure along with large surface area lagoons increase the amount of methane emissions. Globally, agriculture is the primary source of methane emission (109, 118).

7.5.4 Particulate Air Contaminants in Rural Areas

Fugitive dust from tilled fields and emitted particles from burning of crop residues or forest land are two of the major sources of airborne particulate hazards in agricultural communities (44). For example, fugitive dust in the San Joaquin Valley of California often results in violations of air particulate standards of 50 μg per cubic meter (state standards can be more strict that federal standards) and the EPA ambient air quality standards of 150 μg particulates per cubic meter (119). The specific health hazards of these two pollutants are not certain, but when added to other respiratory insults they may cause overt symptoms in predisposed individuals (e.g., asthmatics). Agricultural tillage (especially mold board plowing, which removes surface plant material) methods expose soils to drying winds which can pull hundreds of tons of topsoil into the atmosphere. These particulates may have regional as well as global affects. Minimum and no-tillage practices and windbreaks decrease wind erosion.

Residues of crops and forest land are burned as a regular agricultural practice in some areas of the world, creating air contamination with suspended particles. In Georgia, for example, nearly 600,000 acres of agricultural land and over 500,000 acres of forest land are burned off annually (120), producing more than 26,000 metric tons of suspended particulates. Some farming practices in several countries in South America (e.g., Brazil, Argentina, Parguay) have resulted in the burning of large areas of indigenous forests to allow expansion of crop production. Indonesia has surpassed Brazil in deforestation for the purposes of paper pulp production, palm oil plantations, mining, and wood for construction. During 2000-2012, 47,000 ha per year, totaling 6 million ha, were deforested in Indonesia (121). Other regions of East Asia are burning forests to plant rubber trees to supply the demand for tires for globalized automobile sales. This practice produces very significant particulate pollution in a wide area around these regions.

Other fine air particulates (particulate matter 2.5 microns and below (PM 2.5)) may form from ammonia reacting with oxides of nitrogen and sulfur, which can be deposited in deep portions of the lungs, increasing morbidity and mortality, especially when combined with smoking cigarettes and co-morbidities (19, 122).

7.5.5 Odors

Odors may be a concern in many different agricultural enterprises. Most concern in recent years has been in community members who live in the vicinity of large concentrated animal feeding operations. Odors and odorants are primarily a nuisance concern, but also may cause unpleasant somatic physiologic responses (122–125). Odors and their health consequences are discussed in detail later in this chapter.

7.5.6 Microbes

Microbes may be emitted into the local air environment from a variety of crop and livestock operations. Air downwind from open feed lots or confined animal feeding facilitates contains higher particulate and microbial content than air in comparison to background concentration (126–129). Furthermore, antibiotic-resistant organisms, including methicillin resistant *Staphylococcus aureus* (MRSA), have been isolated both inside and downwind from swine facilities (126, 128). Areas downwind from fields that are irrigated (especially with spray booms) with effluent from animal manure storage or anaerobic treatment lagoons have microbe concentrations that are 10^3 to 10^5 times higher in comparison to rural areas lacking these structures (127). Air sampling indicates that the vast majority of these organisms in the air are not viable. It is difficult to find cases where an illness from an infection has been acquired from aerosolized organisms in the vicinity of agricultural operations. This evidence suggests infection from aerosolized agricultural dusts is a relatively low risk compared to health risks from the inflammatory substances endotoxin and glucans, which are components of the dust along with microbes (129).

7.5.7 Endotoxin and Glucans

Many microbes contain toxins (e.g., endotoxin, glucans) which are potent inflammatory substances (these toxins and sources are described in Chapter 3). These substances may cause asthma-like symptoms, bronchitis, mucus membrane irritation, and organic dust toxic syndrome (a systemic influenza-like illness, see Chapter 3) (128). Thu and Donham (108) have shown that residents in the vicinity of CAFOs experience respiratory symptoms similar to workers inside these facilities (see Chapter 3). However, there is some evidence that exposure to endotoxin is ubiquitous in agriculture, and particularly exposure early in life may protect from atopic asthma later in life (see Chapters 2 and 3) (129, 130).

7.5.8 Antibiotics

Antibiotics are present in aerosolized dust inside and outside in the exhaust air of livestock buildings (131–133). Streptomycin and other antibiotics are sprayed on apple and pear trees to prevent the bacterial organism *Erwinia amylovora*, which causes fire bilght (133). Obviously, there is ample opportunity for antibiotics to contaminate the air in the vicinity of certain livestock and orchard operations. However, this situation has had little study to determine the extent of human exposure and health risks (see Chapter 12).

7.5.9 Air Pollution from Agricultural Chemicals

During adverse weather conditions or when spraying residential neighborhoods, herbicides and insecticides may contaminate the air. Pesticides attach to soil particulates or volatilize into the atmosphere, where they are transported regionally and globally. Pesticides may be found in many places around the world in air and rain, even in remote areas (134). Around 1-50% of applied pesticides may enter the atmosphere (135). Air pollution from agricultural pesticides presents nominal acute health hazards, but certain occupational hazards may exist for the applicators and agricultural workers who mix and load chemicals and maintain application equipment (see Chapter 6) (136).

Agricultural service and supply businesses commonly store large quantities of anhydrous ammonia fertilizer. Occasionally, large clouds of this irritant chemical escape when a tank or valve leaks (Figure 7.5). Area residents and workers may receive severe burns when the chemical contacts their eyes and skin. If they inhale ammonia, they may die of acute chemical pneumonitis and pulmonary edema (see Chapter 3). Rural physicians and emergency medical personnel should be aware of the first-aid treatment for anhydrous ammonia exposure: flushing affected areas with copious amounts of water and administering oxygen if necessary (137, 138). In the case of large ammonia leaks, the cloud may be washed from the air by spraying it with water from a fire control hose.

FIGURE 7.5 Anhydrous ammonia is an important fertilizer in many areas of the world. Excess nitrogen can run off with soil erosion, escape into the air, and be a source of chemical damage to the eyes and respiratory tract of applicators. (Note that this farmer is operating a tractor without a rollover protective structure. Injury from a possible overturn of this tractor is a much greater immediate risk to life than the anhydrous ammonia he is applying.) (Source: Medical Practice in Rural Communities, Chapter 3, Figure 3.4, page 46, book authors: Cornelia F. Mutel, Kelley J. Donham, Rural Health and Agricultural Medicine Training Program, Department of Preventive Medicine and Environmental Health, College of Medicine, The University of Iowa, Iowa City, Iowa 52242, U.S.A., © Springer-Verlag New York Inc., 1983. Image reprinted with kind permission of Springer Science and Business Media.)

7.5.10 Rural Industry

Expansion of rural manufacturing, mining, and/or processing has increased industrial contributions to rural air pollution as well as water pollution. Moreover, the increasing demands for energy have resulted in construction of new coal-fired power plants in rural areas, where they are less costly to build and where air pollution control standards are more easily met. As a result, air pollution from particulates, carbon dioxide, nitrogen oxides, sulfur oxides, hydrocarbons, and mercury are increasing (1). Like other rural pollutants, these substances have not been demonstrated to be the direct cause of any particular health problems but are assumed to have an additive effect with other pollutants.

Fossil fuels have been the main source of energy for the world since the industrial revolution. However, since the late 1990s, easily extractable fossil fuels have become scarce. The process of hydraulic fracturing of shale (fracking), which began in 1949, has increased in many rural areas of the world since 2000, creating a new boom in energy extraction in rural areas. However, it has also brought environmental concerns. Fracking involves injection of water and various proprietary chemicals at high pressure into oil and gas wells to fracture rock formations, followed by injection of sand to keep fractures porous, allowing trapped gas and oil to be harvested. Although fracking has increased the availability of fossil fuels for energy usage, it has presented new environmental hazards to both water and air quality, and increased seismic activity in many rural areas (139). Hazards include ground water contamination from the injection of the variety of chemicals associated with fracking water and disposal of waste water in drainage wells. Surface water contamination is also a hazard with flow back of the injection fluids and waste water to the surface. The process uses extensive amounts of water, creating potential water shortages in some areas. Risks to air quality include emission of various volatile organic compounds, methane, nitrogen oxides, and carbon dioxide (from flared excess methane). Particulate air contamination is a potential hazard as fractured silica may be aerosolized from sand extraction processes, and truck and train traffic transporting fracking sand to the injection sites.

In addition to fracking operations, dust from surface mining processes and from roads heavily traveled by trucks transporting coal and ore and general traffic on rural gravel roads is a concern in some rural areas (1). However, the direct acute environmental health problems of dust from sand extraction and mining are difficult to document.

Reported health symptoms of residents in fracking locales have been anecdotal and not substantiated with cause-effect data. Symptoms have included headaches, nosebleeds, disorientation, fainting, fear of cancer, and psychosocial stress from the unknown (140). Hazards of increased seismic activity (earthquakes) have been reported, but appear of minor risk relative to ground water contamination.

Some countries have banned fracking. Others (e.g., the EU and North American countries) are in the process of assessing hazards and considering regulations.

Wind turbine farms, although they do not create air pollutants, are discussed briefly here as they are increasingly present in the rural landscape and there have been some suggestions of minor health hazards. Wind turbines have greatly increased in number since 2000. Although this energy source is thought to be "green," the increasing health complaints of citizens living in rural areas with wind farms suggest this relatively new source of energy is not without some concerns. Reported symptoms include stress, sleep disturbance, headache, anxiety, depression, and cognitive dysfunction. Suspect exposures associated with these symptoms include noise (audible and infrasound), ground current, and shadow flicker (141). Other environmentalists are concerned that wind farms result in the death of many birds because they fly into the spinning blades of the turbines.

Since the 1980s concern has been expressed by environmental scientists about the potential effects of high-voltage electrical fields that surround high-power transmission lines. Currently in the United States, between a quarter and half a million miles of high-voltage lines (765 kV or greater) cross the rural countryside between wind farms, new generating plants and urban centers (142). Environmental scientists have found ecologic relationships between high-voltage electrical fields and increased rates of infant mortality, fetal malformation, and abnormal behavior in test animals (142). This information is not strong or consistent therefore the implications for human health are uncertain.

7.5.11 Control

Gaseous nitrogen and methane emissions are perhaps the two most important substances to control because of their regional and global effects. Control of air pollution from nitrogenous products in agricultural operations involves enforcing regulations and providing incentives for producers not to apply more nitrogen to the soil than the crops can utilize in a season (do not over burden the natural nitrogen cycle). This requires a combination of best management practices (i.e., soil testing and calculation of plant needs) and application of the appropriate amounts to the appropriate soils (precision farming) (115). Regulations, monitoring, and enforcement are also needed to assure best management practices. Furthermore, soil preparation and nitrogen application methods must be conducted in a manner that prevents escape of nitrogen into surface water or nitrogen products escaping into the air. These methods include incorporating manure into the soil and covering manure storage structures to prevent off-gassing into the air. Methane capture from anaerobic digestion of manure and utilizing this as an energy source has important potential for control of this greenhouse gas. However, the costs and management challenges of this practice have prevented wide-scale application.

A summary of rural air pollutants, sources, health effects, and prevention is given in Table 7.2.

7.6 Solid Waste Concerns in Rural Agricultural Areas

The primary problem of solid wastes in rural areas is their contribution to the contamination of groundwater. Secondary problems include contamination of surface water, attraction of filth-laden insects and rodents, pollution of air by odors, and pollution by particulates from open burning (71, 143). Socioeconomic and demographic trends have increased the problems of rural solid wastes during the past three decades. The more humans intensely use the land, the greater the quantity of solid waste. The rural industries of agriculture, mining, and manufacturing all produce solid wastes. In addition, solid wastes are contributed from people living in rural residential areas as they encroach on the rural landscape. Hazardous wastes are also transported from urban areas to rural landfills (144).

Safe disposal of chemical containers poses a solid waste problem. They may be used unsafely for unintended purposes (such as water containers) or thrown into an open ditch in an outlying area of the farm (see Figures 7.6 and 7.7). Direct contact with or consumption of residual chemicals may cause human or animal illness directly, or these chemicals may contaminate surface or ground water. The empty containers should

Figure 7.6 Empty agricultural chemical containers should be rinsed three times and returned to the retailer or otherwise disposed of in an approved manner. These empty containers could be a source of poisoning if residual contents leaked out or if they were used for another purpose, exposing humans or animals. (Source: Medical Practice in Rural Communities, Chapter 3, Figure 3.6, page 56, book authors: Cornelia F. Mutel, Kelley J. Donham, Rural Health and Agricultural Medicine Training Program, Department of Preventive Medicine and Environmental Health, College of Medicine, The University of Iowa, Iowa City, Iowa 52242, U.S.A., © Springer-Verlag New York Inc., 1983. Image reprinted with kind permission of Springer Science and Business Media.)

FIGURE 7.7 Empty agricultural chemical containers disposed of improperly could lead to water or soil pollution. (Source: Medical Practice in Rural Communities, Chapter 3, Figure 3.8, page 58, book authors: Cornelia F. Mutel, Kelley J. Donham, Rural Health and Agricultural Medicine Training Program, Department of Preventive Medicine and Environmental Health, College of Medicine, The University of Iowa, Iowa City, Iowa 52242, U.S.A., © Springer-Verlag New York Inc., 1983. Image reprinted with kind permission of Springer Science and Business Media.)

then be returned to the seller. Empty pesticide containers should be rinsed three times and the rinse water should be applied to the soil or crop as specified for the intended use of the specific chemical.

Sanitary disposal of dead animals is a concern. Whereas rendering plants, which used to be common in rural areas, would arrange collection of dead animals from farms, this service is now rare and costly. Also, when fire, weather, or another disaster results in a large number of animal deaths, it is difficult to manage such a large disposal of carcasses. For example, in the summer of 2015 over 60 million chickens and turkeys were killed and disposed of as a result of an outbreak of a high-pathology strain of avian influenza in Iowa and Nebraska. The disposal process burdened the local and regional landfills.

Rural manufacturing, mining, and energy production facilities increase the need for special facilities to store potentially hazardous wastes. Urban manufacturing and energy production also create solid waste problems in rural areas. Less populated rural areas are chosen as disposal sites for hazardous chemical and radioactive wastes. Often, local officials and area residents may not be aware of the potential hazards, allowing the construction of improperly located or constructed hazardous waste disposal facilitates (71). One survey found 34 of 50 industrial waste sites caused local groundwater contamination (144). As more people have moved to rural areas, and as farm dwellers have become less self-sufficient, use of consumer items and resulting packaging wastes have increased.

Generalizing about the types of human health problems caused by solid waste pollution is difficult because these problems depend on specific circumstances and the type and quantity of substances to which humans are exposed.

Most rural areas need more and better waste storage, collection, and disposal systems. Some rural solid waste systems have been developed, such as regional collection boxes or weekly collection at mail boxes. These systems help to deter rural residents from maintaining open dumps on their own acreages. New mechanisms are needed to ensure proper disposal of pesticide containers. The use of returnable containers and large bulk containers are two promising practices (144). Zoning laws could ensure adequate sewage treatment capacity in rural areas. New techniques could provide safe methods for recycling animal wastes and regulations could govern the proper disposal of industrial radioactive wastes.

7.7 Animal Feeding Operations

7.7.1 Introduction

The proliferation of animal feeding operations (AFOs) has increased the intensity, concentration, specialization, and consolidation of livestock operations in agriculture in industrialized countries over the past four decades. The US EPA defines an AFO as a facility that confines livestock or poultry for at least 45 days in a 12-month period, and in a closed structure or open lot where vegetation or crops will not grow. CAFOs are AFOs that are larger than specified sizes and are a potential point source for water pollution. CAFOs therefore require regulation (145). In regard to water, air, and solid waste pollution, CAFOs have many of the same concerns as described above for other agricultural operations. However, CAFOs raise special concerns because of the high concentration of animals on a small land area and the associated increased levels of feed, manure (usually handled in liquid form), dead animals, flies, emitted gases, particulates, odors, odorants, and infectious diseases. Environmentalists express concern that the large volume of manure in CAFOs may not be able to be recycled without pollution, that local and regional air and water quality suffers, that community health hazards are created, and that depressed quality of life and lower property values are experienced by those living in the vicinity of CAFOs. These concerns have been raised from the early 1980s and continue today (146). Numerous regional, national, and international conferences have been held, and reviews and reports published on the subject since 1994 (110, 147–151).

This section concentrates on the current state of science-based information on the occupational and community health consequences of large-scale livestock operations. Physical health as well as the social and economic concerns of individuals and communities are considered. A broad definition of health is used here as defined by the WHO, which states that health is "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity" (86). One reason why large-scale livestock production has raised concern is that it has diverged from family farming and developed like other industries in management, structure, and concentration. The magnitude of the problem is highlighted by the following facts relative to the United States:

- Nationwide, there is 130 times more animal waste produced annually than human waste.
- Animal waste is generally not treated before it is returned to the environment (152).

In the following pages the scientific literature is reviewed relative to the environmental impacts of air and water emissions on community.

7.7.2 Air Quality Concerns from CAFOs

Merkel *et al.* (153) published the first assessment of emitted gases from stored livestock liquid manure, listing nearly 200 emitted compounds (173). Most of these substances are emitted at very low concentrations (e.g., 1 ppb) and the health risks at these concentrations are not known. However, ammonia and hydrogen sulfide are emitted at higher concentrations and are the most important emittants of concern as direct human health hazards. Methane and carbon dioxide are also emitted at relatively high concentrations. Although methane may present a fire and explosive hazard inside livestock buildings, along with carbon dioxide it is mainly important as a greenhouse gas and is relatively unimportant as an inhaled toxic human health hazard.

The primary source of gaseous compounds is the microbial degradation of the manure. Ammonia is released from manure and urine from either an aerobic or anaerobic process. Other fixed compounds and trace compounds come primarily from the anaerobic decomposition of manure in liquid storage systems. The emitted compounds can be grouped into the following classes of chemicals: mercaptans, sulfides, disulfides, amines, organic acids, phenols, alcohols, ketones, indole, skatole, carbonyls, esters, and nitrogen heterocycles (154, 155).

In addition to gases, particulate substances are emitted from livestock feeding operations. A large quantity of organic dust is generated from feed sources and the animals (pigs, poultry, or cattle) themselves, which produce dust containing hair, dander, feathers, and dried feces (156, 157). This dust contains many bioactive substances, including endotoxin and glucans (inflammatory substances) (127, 156). It also has a bioaerosol component. Many Gram-negative and Gram-positive bacteria, fungi, and molds have been identified as components of this dust (156, 158, 159). These organisms contribute to the organisms emitted to the air from the building (159). The vast majority of organisms identified in the air are saprophytic and very few pathogens are identified. They are combined with dust that becomes a part of the total aerosolized particulates. About 50% of the particulate mass is less than 10 μm, but a much smaller fraction is less than 5 μm. Hence, the dusts mainly impact the airways, not the lung parenchyma per se.

7.7.3 Odors and Odorants

Most of the public concern about CAFOs has been about odor. An odor is an unpleasant sensation in the presence of an odorous substance (odorant). The odorant may or may not have additional harmful toxic physical effects. Ritter (160) identified the classes of compounds from animal manure. The primary odorant classes of chemicals are mercaptans and sulfides. The fixed gases ammonia and hydrogen sulfide are the odorants produced in the highest concentrations. Riskowski *et al.* (161) described an odor phenomenon associated with livestock (mixed gas) environments where ammonia and hydrogen sulfide odors are detectable at much lower odor threshold concentration levels than previously published. It is likely that in this mixed environment other less concentrated chemicals and particles interact to enhance the detection of these odorants.

Researchers have looked at the fixed gases (e.g., ammonia and hydrogen sulfide) as potential surrogates for emissions and odors. However, the results of several researchers have shown that there is a poor correlation between ammonia and hydrogen sulfide and odor strength (162, 163).

The particulate emissions interact synergistically with gases to cause important occupational health hazards (see Chapter 3). Although a good deal is known about the health effects of dust and gases on workers inside buildings, little is known about the health effects on those living in the neighborhood of CAFOs. Goodrich *et al.* (164) have shown (relative to background) a high level of viable organisms downwind of manure sprinklers, as well as inside beef and turkey facilities. Pickrell (165) has shown swine barn environments to have significantly higher particle and microbe concentrations compared to other livestock environments. He has also shown that the concentrations inside CAFOs are 10^3–10^6 times higher compared to outside (159). Very little is known about the hazardous concentrations of odorants in outdoor air around CAFOs. We do know there are serious worker health problems caused by hydrogen sulfide (H_2S) and ammonia (NH_3) inside CAFOs, but it is difficult to infer health risks outside these buildings based on worker health studies. Available data (166, 167) suggest ammonia and hydrogen sulfide are on the order of 10^3 times higher inside buildings compared to outside.

Odors from livestock facilities can be considered a nuisance, which is often how courts treat them. However, growing evidence suggests that odors may cause physical illness. Symptoms reported by people living in the vicinity of swine CAFOs and associated odors include nausea, vomiting, headache, shallow breathing, coughing, sleep disorders, upset stomach, appetite depression, irritated eyes, nose and throat, and mood disturbances including agitation, annoyance, and depression (122, 123, 168). Ackerman (169) reported that odors can result in strong emotional and physical symptoms, particularly after repeated exposures. Schiffman *et al.* (125) studied the profile of mood states (POMS) of 44 people living near large animal facilities. Compared to controls she found that people living near the facilities were more angry, confused, tense, depressed, and fatigued. In order to determine acceptable odor levels relative to distance from the source, Walsh and others (170) surveyed people living in a 5-km area surrounding a large cattle feed lot. An odor panel found acceptable odor levels at the 5-km radius (170). The results of more recent research suggest that physical health problems may also be caused by long-term inflammation, secondary to inhaled dust and gases (165, 170).

7.7.4 Physical Health

The occupational health of workers in CAFOs is well documented, as described in Chapter 3. However, the occupational exposures have little relationship to the health concerns of those living in the vicinity of these structures, as the exposure concentrations are several orders of magnitude lower in the community compared to inside the facilities. However, when considering the health hazards of residents living in the vicinity of CAFOs, one has to look beyond direct toxic explanations, especially when considering air emissions. The issue of residential exposure to CAFOs is similar to other environmental cases (e.g., Three Mile Island, Love Canal etc.) where residents' health complaints cannot be explained by measured concentrations of hazardous substances and standard toxicological mechanisms (171, 172, 173). For example, Reynolds reported H_2S levels in the vicinity of CAFOs at well under the threshold limit value (TLV) for occupational health set at 10 ppm (81). Levels of ammonia in the vicinity of swine CAFOs were generally less than 1 ppm, but these residents reported a high prevalence of respiratory symptoms compared to controls.

Possible reasons for this observation include the fact that residents live in the area for more than 8 hours per day. Also, there may be vulnerable populations who react at much lower levels than occupational limits. For example, several states have limits for hydrogen sulfide at 20–50 ppb, three orders of magnitudes below the occupational exposure limit and most federal agency limits for environmental exposure.

Results from studies of the physical health concerns of residents near CAFOS have been reported (108, 123, 125, 174). Additional studies have reported objective data suggesting that high blood pressure and low pulmonary functions are associated with living in the vicinity of a CAFO (123, 124, 175).

7.7.5 Behavioral and Social Health

Wilson (2002) has reported on a concern for social justice, in that CAFOs have been built in many areas of low socio-economic status populations, where the community members do not have the social or economic capital to question their construction. Schiffman *et al.* (125) reported excessive mood alterations in CAFO neighbors. Similar studies have investigated in other environmental settings, including community concerns around paper pulp mills, hazardous waste sites, refineries, and solid waste disposal sites (125). Although most of these studies have not documented objective findings of toxic physical insult to humans, a few studies have reported subtle findings such as increased concentrations of urinary catecholamine. Additionally, most of these studies have not shown evidence of known toxic levels of substances in the environment.

7.7.6 Extra-toxic Mechanisms

In addition to the literature regarding direct toxic effects, there is also literature on extra-toxic effects of low-level emissions (176). This literature has focused on explaining the symptoms of community members who may be exposed to waste sites, sewage treatment plants, and other large population-based community exposures, where assessment of toxic substances cannot show a cause-effect. Medical research and regulatory agencies have difficulty dealing with situations that lack the objective findings of an adverse health effect, measured toxic substances at known toxic concentrations, or an obvious dose-response relationship. These community exposures are more complex as they mix the physical, mental, emotional, economic, and social environments. "Genetic memory" and other very basic limbic-level self-preservation mechanisms may be involved. The following sections will review some of the literature that helps to explain the reality of adverse health symptoms in community environmental concerns where there is an absence of objective toxicological data.

7.7.7 The Somatasization of Adverse Odors

There are two cranial nerves involved in innervating the nasal mucosa: the first cranial nerve (olfactory nerve) and the fifth cranial nerve (trigeminus) (176). The olfactory nerve is primarily responsible for odor detection. The trigeminus nerve has many branches, some that carry sensory information from the nasal, oral and sinus mucosa. This provides additional information to the brain on odor sensation, such as irritation or pungency, which triggers protective responses, including decreased respiratory rate, rhinitis, tearing, cough, gag reflex, and bronchoconstriction. These are all warning indicators that something associated with the odor may be harmful and our genetic-based "instinctive protective" mechanisms are telling us to make physiologic changes to meet the impending insult or to get out of the area (176, 177). It therefore makes sense that odors can result in symptoms of mucosal irritation, nausea, mood disorders, and general adverse physical and mental feelings (176, 177).

Along with these physiological responses to low-level irritants and odors, there are behavioral interactions that may explain the health symptoms of illness associated with odors. Five possible mechanisms may account for extra-toxic odor-related symptoms (176).

Innate Odor Aversions

As a basic protective mechanism, our body wants to avoid certain odors that may signify potential harm. For example, odors in "putrefaction" gas (e.g., H_2S, mercaptans, and other sulfur containing chemicals) are common substances which stimulate physiologic effects at lower than toxic levels. These gases may be associated with spoiled food, but are also associated with animal manure, as are many of the odors associated with these innate odor responses.

Pheromone Phenomena

Pheromones stimulate physiologic responses, especially around sexual reproduction. These are mostly overt for insects, but many mammals, including humans, respond to them. Some odors might destroy normal positive pheromone responses, resulting in impaired sexual function, as reported by Schiffman *et al.* (176, 177) for people living in the vicinity of CAFOs.

Exacerbation of Underlying Conditions

Previous research has shown that workers with underlying conditions (asthma, atopy, bronchitis, heart conditions) are more susceptible to the CAFO environment than others (178). Furthermore, it is now evident that individuals genetically differ in their susceptibility to endotoxins. Research by Meggs *et al.* (179, 180) also lends strength to the theory that underlying conditions may amplify exposures.

Aversive Conditioning

Some people previously exposed to high levels of odorous gases, causing toxic effects, may respond physiologically to less than toxic levels (slight odor) of a substance in future exposures. This author (KJD) has observed this condition in several cases of CAFO workers who experience symptoms and anxiety when smelling CAFO odors following a severe CAFO gas exposure episode. This conditioned stimulus is probably an innate protective mechanism. This can also happen with lower level exposures over a long period of time (acquired odor intolerance) (179, 180).

Stress-induced Illness

Odor-related stress-induced illness has been discussed as one cause of "environmental stress syndrome". This phenomenon has been seen following non-odor disaster sites such as Three Mile Island (177). Studies have revealed increased urinary catecholamines in affected individuals. They also have a feeling of depression, helplessness, and a high degree of environmental worry which is exacerbated by detection of the offending odor. Community members may be excessively worried that their property values are falling because of the odor source in their neighborhood. Odors can act as a cue for these individuals, stimulating adverse physiologic risks relative to an associated exposure. Long-term stress can be associated with muscle tension and headaches, coronary artery disease and peptic ulcers.

7.8 Global Climate Change: Effects on Agricultural Production and the Environment

This chapter has discussed current general environmental issues in rural and agricultural environments. Future results of agricultural environmental exposures will be likely controlled both negatively and positively by global climate change. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) reported that human activity is likely a principle cause of increased carbon dioxide (CO_2), nitrous oxide N_2O, and methane (CH_4) (greenhouse gases) levels in the environment, and these are the principal drivers of climate change (109). The Fifth IPPC Report affirmed that human activity was a cause of increased greenhouse gas emissions (181). Pond and colleagues (118) indicated that agriculture is responsible for the major component of atmospheric CH_4 and N_2O (13). Although the effects of greenhouse gases are global, they affect production agriculture regionally in different ways, with droughts in some areas and exceptionally hard rains in others. Heavy rains exacerbate the agricultural practices that have increased the runoff of nitrogen, phosphorus, and other chemicals into receiving streams and ground waters in certain areas (e.g., the upper US Midwest Corn Belt). Heavy rains also increase the risk of soil erosion. In other areas (e.g., Australia, the western United States, and Sub-Sahara Africa), drought has challenged both crop and livestock production, resulting in high levels of economic risk, followed by emotional stress in farmers.

In the shadow of climate change, variable predictions are presented for production of the world's three main food calorie sources (rice, wheat, and corn) (118). Crops in some areas may benefit due to increased warmth, moisture, and the fertilizing effect of increased atmospheric CO_2. Europe and areas of North America above the 40th parallel may see substantial increases in corn production. South America and Africa may realize a 30% reduction in cereal grain production. South Asia may see a 10% reduction in rice production.

All of these outcomes and predictions are in flux at this time, but it is expected that the future will not have the same climate as today. Many climate scientists feel that preparation for managing the potential negative consequences of climate change on the sustainability of agriculture lags behind the climate change predicted in various models.

Key Points

1. Pollution of surface and shallow ground waters with nitrates and phosphorus from crop fertilization and urban sources is the most important environmental concern relative to agriculture. Known related health hazards of nitrate contamination of drinking water include methemoglobinemia, which affects primarily newborns, resulting in a blue tinge to the skin of a white-skinned baby (blue baby condition) as a result of oxygen-deprived red blood cells. Fetuses and infants up to 6 months are at a higher risk than adults of this condition. Excess nitrates in water have also been associated with (not cause-effect) stomach cancer. Secondary prevention of the adverse health effects of nitrates and phosphorus water contamination includes the following:
   a. Regular testing of drinking water supplies, preferably annually in spring (or rainy season). As a minimum test for nitrates and coliform bacteria.
   b. Inspect the well (or have a professional sanitarian or well driller) for damage to the well cap or hazardous location of potential pollution sources in the area of the well head.
   c. Fill in and cap non-functioning wells as they present a hazard for ground water contamination. The local health department or a professional well driller can help with this.
   d. Ensure there are functioning check valves in outdoor hydrants to prevent back-siphoning of contaminates into the well.
2. Pollution of rivers, lakes, and brackish waters with excess phosphorus and nitrogen causes eutrophication, which enhances hazardous algal or dinoflagellate blooms. Toxins from brown and red algae may cause skin and gastrointestinal irritation from water contact and neurological symptoms from ingestion of shellfish harvested from areas of these blooms. Cyanobacteria and *Pfisteria* contamination cause skin irritation and peripheral neurologic symptoms from water contact. Consumption of water contaminated with cyanobacteria toxins can cause severe neurologic, liver, and gastrointestinal symptoms. Primary prevention includes management of efficient nitrogen and phosphorus fertilizer use, incorporating livestock manure into the soil, and management of water and soil run-off from farm land to receiving streams by application of various techniques that may include restoring wet lands, buffer strips, cover crops, and bio-filters in field tile drainage systems among many other practices.
3. Fluoride, arsenic, calcium and magnesium salts, and radon are natural substances found in certain regional (mainly ground) waters. Fluoride prevents dental caries at low levels, but excessive levels may cause staining and mottling of teeth, and weakening of bones (fluorosis). Arsenic in excess in water causes many health problems, including skin, neurological, and cancer problems. Hardness (especially magnesium) has benefits for cardiovascular health. Radon consumed in water is a minor risk for stomach cancer, but if inhaled as an off-gas from water in houses is an important risk for lung cancer.
4. Agricultural burning, soil tillage, rural soft surface roads, and agricultural operations are the main sources of air particulate pollution.
5. The primary hazardous gases emitted from livestock CAFOs into the surrounding environment are odors, ammonia, hydrogen sulfide, and the greenhouse gases carbon dioxide and methane. Particulate emissions include dust particles, microbes, endotoxin, and glucans. The health hazards for workers present in these buildings is well documented. Although several studies have suggested that residents living in the vicinity of a CAFO report a variety of general flu-like symptoms and behavioral health symptoms, objective evidence of cause-effect physical harm is minimal. The stress of neighboring residents is well documented, as is loss of property value.

6. Extra toxic mechanisms may explain the physical symptoms experienced by those exposed to perceived environmental exposures, where measured concentrations of contaminants are not sufficient to explain cause-effect. Extra toxic mechanisms include physiologic responses to odors and a combination of economic, social, and psychological stressors.
7. Nitrogenous gases and methane emissions from agricultural operations are of some concern, both regionally and globally, as they can add to soil acidification, gaseous particulates, and greenhouse gases. Models of global climate change predict drought in some areas and more heavy, intense rain in others. This would mean crop failures in some areas, as well as heavy runoff, soil erosions, and fertilizer water contamination. Northern areas may see benefits to corn production, while parts of Europe and Asia will see a significant drop in grain production.
8. Although fracking and wind turbines bring new energy sources online, the former presents air particulate hazards, surface and ground water pollution and seismic activity. In some areas there has been mild concern from those residing near wind turbines. Flu-like symptoms and psycho-social symptoms are thought to be secondary to audible and sub-audible noise and flicker response. Extra toxic mechanisms may also explain these symptoms.

References

1. Ford TR. Contemporary rural America: Persistence and change. In: Ford TR, editor. Rural USA: Persistence and Change. Ames, IA: Iowa State University Press; 1978. p. 4–5.
2. Nonpoint source pollution: the nation's largest water quality problem. US Environmental Protection Agency; 2012 (updated 22 August 2012; accessed 19 July 2014). Available from: http://water.epa.gov/polwaste/nps/outreach/point1.cfm.
3. The Quality of our Nation's Waters. A summary of the national water quality inventory. 1998 Report to Congress. Washington, DC: US Environmental Protection Agency; 2000. EPA 841-S00-001.
4. Dungan RS. Board-invited Review: Fate and transport of bioaerosols associated with livestock operations and manures. J Anim Sci. 2010;88(11):3693–706.
5. Howarth R, Boyer W, Pabich J, Galloway N. Nitrogen use in the United States from 1961–2000 and potential future trends. Ambio. 2002;31(2):88–96.
6. Hamilton P, Helsel D. Effects of agriculture on ground-water quality in five regions of the United States. Ground Water. 1995;33(2):217–26.
7. Boxall A, Fogg L, Blackwell P, Kay P, Pemberton E, Croxford A. Veterinary medicines in the environment. Rev Environ Contam Toxicol. 2004;180:1–91.
8. Drainage. US Environmental Protection Agency; 2012 (updated 27 June 2012; accessed 19 July 2014). Available from: http://www.epa.gov/oecaagct/ag101/cropdrainage.html.
9. Hutchinson GL, Viets FG, Jr. Nitrogen enrichment of surface water by absorption of ammonia volatilized from cattle feedlots. Science. 1969; 166(3904):514–5.
10. Wu J, Babcock B. Metamodeling potential nitrate water pollution in Central United States. J Environ Qual. 1999;28(6):1916–8.
11. Centner T. Animal feeding operations: encouraging sustainable nutrient usage rather than restraining and proscribing activities. Land Use Policy. 2000; 17(3):233–40.
12. Matisziw T, Hipple JD. Spatial clustering and state/county legislation: The case of hog production in Missouri. Regional Studies. 2001;35(8):719–30.
13. Overview of greenhouse gases. US Environmental Protection Agency; 2014 (updated 15 April 2014; accessed 21 July 2014). Available from: http://www.epa.gov/climatechange/ghgemissions/gases.html.
14. Follett R, Delgado J. Nitrogen fate and transport in agricultural systems. J Soil Water Conserv. 2002; 57(6):402–8.
15. Ham J. Seepage losses from animal waste lagoons: A summary of a four-year investigation in Kansas. Trans ASAE. 2002;45(4):983–92.
16. Sengupta P. Potential health impacts of hard water. Int J Prev Med. 2013;4(8):866–75.
17. Hooda PS, Edwards AC, Anderson HA, Miller A. A review of water quality concerns in livestock farming areas. Sci Total Environ. 2000;250:143–167.

18. Campagnolo ER, Johnson KR, Karpati A, Rubin CS, Kolpin DW, Meyer MT, et al. Antimicrobial residues in animal waste and water resources proximal to large-scale swine and poultry feeding operations. Sci Total Environ. 2002;299(1–3):89–95.
19. Anderson N, Strader R, Davidson C. Airborne reduced nitrogen: ammonia emissions from agriculture and other sources. Environ Int. 2003; 29(2–3):277–86.
20. ApSimon HM, Kruse-Plass M. The role of ammonia as an atmospheric pollutant. In: Nielsen VC, Voorburg JH, L'Hermite PL, editors. Odour and ammonia emissions from livestock farming. Barking: Elsevier Science Publishers; 1991. p. 17–20.
21. Bitton G, Harvey RW. Transport of pathogens through soils and aquifers. In: Mitchell R, editor. Environmental Microbiology. New York: Wiley-Liss; 1992. p. 103–24.
22. David MB, Drinkwater LE, McIsaac GF. Sources of nitrate yields in the Mississippi River Basin. J Environ Qual. 2010;39(5):1657–67.
23. Nitrous oxide emissions: US Environmental Protection Agency; 2014 (updated 17 April 2014; accessed 19 July 2014). Available from: http://epa.gov/climatechange/ghgemissions/gases/n2o.html.
24. Novotny V. Diffuse pollution from agriculture. Water Sci Technol. 1999;39(3):1–13.
25. Hord NG, Tang Y, Bryan NS. Food sources of nitrates and nitrites: the physiologic context for potential health benefits. Am J Clin Nutr. 2009;90(1):1–10.
26. Mensinga T, Speigers G, Meulenbelt J. Health implications of environmental nitrogenous compounds. Toxicol Rev. 2003;22(1):41–51.
27. Nitrate/Nitrite Toxicity: Who is at Most Risk of Adverse Health Effects from Overexposure to Nitrates and Nitrites? Atlanta: Agency for Toxic Substances and Disease Registry, US Public Health Service, CDC; 2015 (updated 6 January 2014; accessed 24 January 2015). Available from: http://www.atsdr.cdc.gov/csem/csem.asp?csem=28&po=7.
28. Knobeloch L, Salna B, Hogan A, Postle J, Anderson H. Blue babies and nitrate-contaminated well water. Environ Health Persp. 2000;108(7):675–8.
29. Martin DG, Watson CE, Gold MB, Woodard CL Jr, Baskin SI. Topical anesthetic-induced methemoglobinemia and sulfhemoglobinemia in macaques: a comparison of benzocaine and lidocaine. J Appl Toxicol. 1995;15(3):153–8.
30. Avery A. Infantile methemoglobinemia: reexamining the role of drinking water nitrates.[see comment]. Environ Health Persp. 1999;107(7):583–6.
31. Schoffstall J, Bouchard M, Schick P. Methemoglobinemia. eMedicine; 2002 (updated 22 May 2002; accessed 6 December 2004). Available from: www.emedicine.com/med/topic1466.htm.
32. Spontaneous abortions possibly related to ingestion of nitrate-contaminated well water – LaGrange County, Indiana, 1991–1994. Morbity Mortality Weekly Report. 1996;45(26):569–72.
33. Levallois P, Phaneuf D. Nitrate contamination of drinking-water – An evaluation of health risks. Can J Public Health/Revue Canadienne De Sante Publique. 1994;85(3):192–6.
34. Van Leeuwen J, Waltner-Toews D, Abernathy T, Smit B, Shoukri M. Associations between stomach cancer incidence and drinking water contamination with atrazine and nitrate in Ontario (Canada) agroecosystems, 1987–1991. Int J Epidemiol. 1999;28(5):836–40.
35. Carpenter S, Caraco N, Correll D, Howarth R, Sharpley A, Smith V. Nonpoint pollution of surface waters with phosphorus and nitrogen. Ecolog Applic. 1998;8(3):559–68.
36. Cooperband LR, Good LW. Biogenic phosphate minerals in manure: implications for phosphorus loss to surface waters. Environ Sci Technol. 2002; 36(23):5075–82.
37. Lory J. Managing manure phosphorus to protect wate quality. University of Missouri Extension; 1999 (accessed 19 July 2014). Available from: http://extension.missouri.edu/p/G9182.
38. Vos C, Zonneveld J. Patterns and processess in a landscape under stress: The study area. In Vos C, Opdam P, editors. Landscape Ecology of a Stressed Environment. London: Chapman and Hall; 1993.
39. Jawson S, Wright R, Smith L, editors. Animal Feeding Operations and Ground Water: Issues, Impacts, and Solutions – a Conference for the Future, November 4–5, 1998. St. Louis: US Department of Agriculture's National Program on Manure and Byproduct Utilization; 1998.
40. Harmful Algal Blooms (HABs). Atlanta: Health Studies Branch, Center for Disese Control and Prevention; 2015 (updated 24 July 2012; accessed 24 January 2015). Available from: http://www.cdc.gov/nceh/hsb/hab/.
41. Geoffrey A, Codd G, Morrison L, Metcalf J. Cyanobacterial toxins: risk management for health protection. Toxicol Appl Pharmacol. 2005; 203(3):264–72.
42. Pilotto L, Douglas R, Burch M, Cameron S, Beers M, Rouch G. Health effects of exposure to cyanobacteria (blue–green algae) during recreational water–related activities. Aust N Z J Public Health. 1997;21(6):562–6.
43. What you should know about pfiesteria. Maryland Department of Natural Resources; 2014 (accessed 19

July 2014). Available from: http://www.dnr.state.md.us/bay/cblife/algae/dino/pfiesteria/facts.html.
44. Miller T. Living in the Environment: Concepts, Problems, Alternatives. Belmont, CA: Wadsworth; 1975. p. 108–28.
45. Drinking Water and Health. Washington, DC: National Academy of Sciences; 1977.
46. Chanlett E. Environmental Protection. 2nd edition. New York: McGraw-Hill; 1979. p. 33,81–5.
47. Fawell J, Nieuwenhuijsen J. Contaminants in drinking water environmental pollution and health.Br Med Bull. 2003;68(1):199–208.
48. Lee A., Fox J, Hazell S. Pathogenicity of *Helicobacter pylori*: A perspective. Infect Immun. 1993;61:1601–10.
49. Parasites – Cryptosporidum. Center for Disease Control and Prevention; 2013 (updated 21 October 2013; accessed 21 July 2014). Available from: http://www.cdc.gov/parasites/crypto/.
50. Craun GF, McCabe LJ. Review of the causes of waterborne-disease outbreaks. J Am Waterworks Assoc. 1973;65:74–83.
51. Drinking Water and Health. Washington, DC: National Academy of Sciences; 2003. p. 2, 40–46, 57–99, 270–275, 369–400, 410–414, 781–804.
52. Sischo WM, Atwill ER, Lanyon LE, George J. Cryptosporidia on dairy farms and the role these farms may have in contaminating surface water supplies in the northeastern United States. Prev Vet Med. 2000;43(4):253–67.
53. Fayer R. Cryptosporidium: a water-borne zoonotic parasite. Vet Parasitol. 2004;126(1–2):37–56.
54. Fone D, Barker R. Associations between human and farm animal infections with *Salmonella typhimurium* DT 104 in Herefordshire. Commun Dis Rep CDR Rev. 1994;4(11):R136–R140.
55. Donham K, Yeggy J, Dauge R. Production rates of toxic gases from liquid manure: Health implications for workers and animals in swine buildings. Biological Wastes. 1988;24:161–73.
56. Donham KJ, Dauge R. Chemical and physical parameters of liquid manure from swine confinement facilities: Health implications for workers, swine, and the environment. Agricultural Wastes. 1985;14:97–113.
57. Will L, Diesch S, editors. Leptospires in animal waste treatment – animal health problem? Proceedings of the 76th Annual Meeting of the US Animal Health Association, St. Joseph Missouri; 1972. pp 138–149.
58. Berkowitz J, Kraft D, Finstein M. Persistence of salmonellae in poultry excreta. J Environ Qual. 1974; 3:158–61.
59. Fuortes L, Nettleman M. Leptospirosis: A consequence of the Iowa flood. Iowa Med. 1994; 84:449–50.
60. Moore A. Surveillance for waterborne disease outbreaks – United States, 1991–1992. Morbid Mortal Weekly Report, Surveillance Summaries. 1993; 42(SS–5):1–22.
61. Krapac IG, Dey WS, Smyth CA, Roy WR. Impacts of bacteria, metals, and nutrients on groundwater at two hog confinement facilities. Conference Proceedings of Animal Feeding Operations and Groundwater: Issues, Impacts, and Solutions: A Conference for the Future. St Louis: National Groundwater Association; 1998. p. 29–50.
62. America's Animal Factories. National Resources Defense Council; 1998. p. 1–7 (accessed 26 April 1999). Available from: http://www.nrdc.org/nrdcpro/nrdcpro/factor/exec.html.
63. Robens J. Research needs to prevent ground water contamination from animal feeding operations. Conference Proceedings of Animal Feeding Operations and Groundwater: Issues, Impacts, and Solutions: A Conference for the Future. St Louis: National Groundwater Association; 1998. p. 1–7.
64. Martinez JL. Environmental pollution by antibiotics and by antibiotic resistance determinants. Environ Pollut. 2009;157(11):2893–902.
65. Pimentel D. Green revolution agriculture and chemical hazards. Sci Total Environ. 1996;188(Suppl.1): S86–98.
66. Bennish M. Animals, Humans, and Antibiotics: Implications of the Veterinary Use of Antibiotics on Human Health. Adv Pediatr Infect. 1999; 14:269–90.
67. Gibbs SG, Green CF, Tarwater PM, Mota LC, Mena KD, Scarpino PV. Isolation of antibiotic-resistant bacteria from the air plume downwind of a swine confined or concentrated animal feeding operation. Environ Health Perspect. 2006;114(7):1032–7.
68. Ahmad T, Rafatullah M, Ghazali A, Sulaiman O, Hashim R, Ahmad A. Removal of pesticides from water and wastewater by different adsorbents: a review. J Environ Sci Health. Part C Environ Carcinog Ecotoxicol Rev. 2010;28(4):231–71.
69. Borggaard OK, Gimsing AL. Fate of glyphosate in soil and the possibility of leaching to ground and surface waters: a review. Pest Manag Sci. 2008; 64(4):441–56.
70. Castillo M, Torstensson L, Stenstrom J. Biobeds for environmental protection from pesticide use – a review. J Agric Food Chem. 2008;56(15):6206–19.
71. Harris G, Garlock C, LeSeur L. Groundwater pollution from industrial waste disposal. A case study. J Environ Health. 1982;44:1073–84.
72. Delfino J. Contamination of potable groundwater supplies in rural areas. In: Pojasek R, editor. Drinking

Water Quality Enhancement Through Source Protection. Ann Arbor, MI: Ann Arbor Scientific Publications; 1977.
73. Lantagne D. Trihalomethane formation in rural household water filtration systems in Haiti. Submitted to the Department of Civil and Environmental Engineering in partial fulfillment of the requirements for the degree of Master of Engineering in Civil and Environmental Engineering, Massachussetts Institute of Technology, Boston; 2001.
74. Bull RJ. Health effects of drinking water disinfectants and disinfectant by-products. Environ Sci Technol. 1982;16(10):554A–9A.
75. Metzler DF. Health implications of organics in groundwater. Am J Public Health. 1982;72(12): 1323–4.
76. Ground Water Protection. US Environmental Protection Agency, Office of Drinking Water; 1980 (accessed 29 December 2015). Available from: http://catalog.hathitrust.org/Record/003143394.
77. Mercury. Washington, DC: US Enviornmental Protection Agency; 2014 (updated 29 December 2014; accessed 25 January 2015). Available from: http://www.epa.gov/mercury/effects.htm.
78. Class V UIC study fact sheet: Agricultural drainage wells. Washington, DC: US Environmental Protection Agency; 2014 (accessed 19 July 2014). Available from: http://water.epa.gov/type/groundwater/uic/class5/upload/study_uic-class5_classvstudy_fs_agriculturaldrainage.pdf.
79. Agricultural drainage well closure. Iowa Department of Agriculture and Land Stewardship, Water Resources Bureau (accessed 29 December 2015). Available from: http://www.iowaagriculture.gov/waterResources/agDrainageWellClosure.asp.
80. Rabinowitz PM, Ilya B, Slizovskiy IB, Lamers V, Trufan SJ, Holford TR. Proximity to natural gas wells and reported health status: Results of a household survey in Washington County, Pennsylvania. Environ Health Perspect. 2015;123(1):DOI:10.1289/ehp.1307732.
81. Reynolds S, Donham, KJ, Stookesberry, J, Thorne, PS, Subramanian, P, Thu, K, Whitten, P. Air quailty assessment in the vicinity of swine production facilities. J Agromedicine. 1997;4:37–45.
82. Lamka K, Le Chavallier M, Seidler R. Bacterial contamination of drinking water supplies in a modern rural neighborhood. Appl Environ Microbiol. 1980;39:734–8.
83. McKee W. Environmental Problems in Medicine. Springfield, IL: CC Thomas; 1974. p. 273, 314–24,628–9.
84. A systematic review of the efficacy and safety of fluoridation. Part A: A review of methodology and results. Australian Government National Health and Medical Research Council; 2007.
85. Water sanitation health. World Health Organization; 2014 (accessed 19 July 2014). Available from: http://www.who.int/water_sanitation_health/en/.
86. Health Hazards of the Human Environment. Geneva: World Health Organization; 1972.
87. Arsenic in drinking water. US Environmental Protection Agency; 2013 (updated 17 September 2013; accessed 19 July 2014). Available from: http://water.epa.gov/lawsregs/rulesregs/sdwa/arsenic/index.cfm.
88. Arsenic. World Health Organization; 2014 (accessed 19 July 2014). Available from: http://www.who.int/ipcs/assessment/public_health/arsenic/en/.
89. Proposed Revision to Arsenic Drinking Water Standard. US Environmental Protection Agency; 2000 (updated May 2000; accessed 7 December 2004). Available from: http://www.epa.gov/safewater/ars/proposalfs.html.
90. Water Sanitation and Health. World Health Organization; 2004 (accessed 7 December 2004). Available from: http://www.who.int/water_sanitation_health/dwq/arsenic/en/.
91. National Analysis of Trace Elements – Arsenic in Ground Water of the US. US Geological Survey; 2004 (updated 17 November 2004). Available from: http://webserver.cr.usgs.gov/trace/pubs/geo_v46n11/fig1.html.
92. WHO handbook on indoor radon: a public health perspective. Geneva: World Health Organization; 2009.
93. Risk assessment of radon in drinking water. Washington, DC: National Research Council; 1999.
94. Proposed radon in drinking water regulation. US Environmental Protection Agency; 2014 (updated 30 June 2014; accessed 19 July 2014). Available from: http://water.epa.gov/lawsregs/rulesregs/sdwa/radon/regulations.cfm.
95. Heizer WD, Sandler RS, Seal E, Jr., Murray SC, Busby MG, Schliebe BG, et al. Intestinal effects of sulfate in drinking water on normal human subjects. Dig Dis Sci. 1997;42(5):1055–61.
96. Sulfate in drinking water. US Environmental Protection Agency; 2012 (updated 8 March 2012; accessed 19 July 2014). Available from: http://water.epa.gov/drink/contaminants/unregulated/sulfate.cfm.
97. Community Water Fluoridation. Centers for Disease Control and Prevention Atlanta, Georgia, Last updated July 28, 2015 (accessed February 21, 2016). Available from: http://www.cdc.gov/fluoridation/facqs/.
98. Sulfate in drinking-water: background document for development of WHO guidelines for drinking-water quality. Geneva: World Health Organization; 2004.

99. Donham KJ. Community and occupational health concerns in pork production: a review. J Anim Sci. 2010;88:E102–E111.
100. Knight R, Payne V, Borer R, Clarke R, Pries J. Constructed wetlands for livestock wastewater management. Ecolog Eng. 2000;15(1–2):41–55.
101. Entry J, Sojka R, Watwood M, Ross C. Polyacrylamide preperations for protection of water quality threatened by agricultural runoff contaminants. Environ Pollution. 2002;120(2):191–200.
102. Christianson L, Helmers, M. Woodchip Bioreactors for Nitrate in Agricultural Drainage. Ames, IA: Iowa State University Extension Engineering; 2011 (accessed 29 December 2015). Available from: http://lib.dr.iastate.edu/extension_ag_pubs/85.
103. Archer D, Shogren J. Risk-indexed Herbicide Taxes to Reduce Ground and Surface Water Pollution: An Integrated Ecological Economics Evaluation. Ecolog Economics. 2001;38:227–50.
104. Topp E, Scott A, Lapen DR, Lyautey E, Duriez P. Livestock waste treatment systems for reducing environmental exposure to hazardous enteric pathogens: some considerations. Bioresource Technol. 2009;100(22):5395–8.
105. Meals DW, Dressing SA, Davenport TE. Lag time in water quality response to best management practices: a review. J Environ Qual. 2010;39(1):85–96.
106. Tomer MD, Locke MA. The challenge of documenting water quality benefits of conservation practices: a review of USDA–ARS's conservation effects assessment project watershed studies. Water Sci Technol. 2011;64(1):300–10.
107. Zhu Y, Balke KD. Groundwater protection: what can we learn from Germany? J Zhejiang Univ Sci B. 2008;9(3):227–31.
108. Thu K, Donham K, Ziegenhorn R. A control study of the physical and mental health of residents living near a large-scale swine operation. J Agric Saf Health. 1997;3:13–26.
109. Climate Change 2007: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Intergovernmental Panel on Climate Change, Fourth Assessment Report. Geneva: The World Health Organization, World Meteorological Organization, United Nations Environmental Programs; 2007 (accessed 29 December 2015). Available from: http://www.meteotrentino.it/clima/pdf/rapporti_meteo/IPCC_Impacts_Adaptation_and_Vulnerability.pdf.
110. Donham K. The concentration of swine production. Effects on swine health, productivity, human health, and the environment. Vet Clinics N Am: Food Animal Practice. 2000;16(3):559–97.
111. Luebs R, Davis K, Laag A. Enrichment of the atmosphere with nitrogen compounds volatilized from a large dairy area. J Environ Qual. 1973;2(1):137–41.
112. Voorburg J. Achievements of the odour group. In: Nielsen V, Voorburg JH, L'Hermite P, editors. Odour and Ammonia Emissions from Livestock Farming. Barking: Elsevier Science Publishers; 1991. p. 212–3.
113. Whalen S, Phillips R, Fischer E. Nitrous oxide emission from an agricultural field fertilized with liquid lagoonal swine effluent. Global Biogeochem Cycles. 2000;14(2):545–58.
114. Petersen S. Nitrous oxide emissions from manure and inorganic fertilizers applied to spring barley. J Environ Qual. 1999;28(5):1610.
115. Robertson GP, Vitousek PM. Nitrogen in Agriculture: Balancing the Cost of an Essential Resource. Annu Rev Environ Resour. 2009; 34(1):97–125.
116. Sharpe R, Harper L, Byers F. Methane emissions from swine lagoons in Southeastern US. Agric Ecosys Environ. 2002;90(1):17–24.
117. Third Communication from the Euoropean Community under the UN Framework Convention on Climate Change. Report SEC(2001) 2053. Brussels: Commission of European Communities; 2001 (accessed 29 December 2015). Available from: http://www.meteotrentino.it/clima/pdf/rapporti_meteo/IPCC.
118. Izaurralde RC. Global climate change and agriculture. In: Pond W, Nichols B, Brown D, editors. Adequate food for all: culture, science, and technology of food in the 21st century. Boca Raton, FL: CRC Press; 2009.
119. Clausnitzer H, Singer M. Respirable-dust production from agricultural operations in the Sacremento Valley, California. J Environ Qual. 1996;25:877–84.
120. Ward D, Elliot E. Georgia rural air quality: Effect of agricultural and forestry burning. J Air Pollut Control Assoc. 1976;26:216–20.
121. Harbell E. Deforestation in Indonesia is double the government's official rate. Scientific American; 2014 (updated 30 June 2014; accessed 21 July 2014). Available from: http://www.scientificamerican.com/article/deforestation-in-indonesia-is-double-the-government-s-official-rate/?&WT.mc_id=SA_DD_20140630.
122. Schinasi L, Horton RA, Guidry VT, Wing S, Marshall SW, Morland KB. Air pollution, lung function, and physical symptoms in communities near concentrated Swine feeding operations. Epidemiology. 2011;22(2):208–15.

123. Wing S, Horton RA, Rose KM. Air pollution from industrial swine operations and blood pressure of neighboring residents. Environ Health Perspect. 2013;121(1):92–6.
124. Wing S, Wolf S. Intensive livestock operations, health, and quality of life among eastern North Carolina residents. Environ Health Perspect. 2000;108(3):233–8.
125. Schiffman S, Miller E, Suggs M, Graham B. The effect of environmental odors emanating from commercial swine operations on the mood of nearby residents. Brain Res Bull. 1995;37:369–75.
126. Gibbs SG, Green CF, Tarwater PM, Scarpino PV. Airborne antibiotic resistant and nonresistant bacteria and fungi recovered from two swine herd confined animal feeding operations. J Occup Environ Hyg. 2004;1(11):699–706.
127. Thorne PS, Ansley AC, Perry SS. Concentrations of bioaerosols, odors, and hydrogen sulfide inside and downwind from two types of swine livestock operations. J Occup Environ Hyg. 2009;6(4):211–20.
128. Ferguson DD, Smith TC, Hanson BM, Wardyn SE, Donham K. Detection of airborne methicillin-resistant *Staphylococcus aureus* inside and downwind of a swine building, and in animal feed: Potential occupational, animal health, and environmental implications. J Agromedicine. 2015.
129. Rylander R. Symptoms and mechanisms – inflammation of the lung. Am J Ind Med. 1994; 25:19–34.
130. Roy CJ, Thorne PS. Exposure to particulates, microorganisms, beta(1–3)-glucans, and endotoxins during soybean harvesting. Am Ind Hyg Assoc J. 2003;64(4):487–95.
131. Hamscher G, Pawelzick H, Sczesny S, Nau H, Hartung J. Antibiotics in dust originating from a pig-fattening farm: A new source of health hazard for farmers? Environ Health Persp. 2003;11(13).
132. Zahn J, Anhalt J, Boyd E. Evidence for transfer of tylosin and tylosin-resistant bacteria in air from swine production facilities using sub-therapeutic concentrations of tylan in feed. J Animal Sci. 2001;79:189.
133. Khachatourians G. Agricultural use of antibiotics and the evolution and transfer of antibiotic-resistant bacteria. Can Med Assoc J. 1998;159(9): 1129–36.
134. Van Duke H. Atmospheric dispersion of current-use pesticides: A review of evidence from monitoring studies. Water Air Soil Pollution. 1999;115:21–70.
135. VandenBerg F, Kubiak R, Benjay W, Majewski M, Yates S, Reeves G, et al. Emission of pesticides into the air. Water Air Soil Pollution. 1999;115(1–4): 195–218.
136. Guide to Health and Hygiene in Agricultural Work. Geneva: International Labour Organization; 1979.
137. Helmers S, Top F, Knapp L. Ammonia injuries in agriculture. J Iowa Med Soc. 1971;May:271–80.
138. Working Safely with Anhydrous Ammonia. Cincinatti. National Technological Information Service, National Technical Reports Library, US Department of Commerce; 1979. pp. 4–13 (accessed 29 December 2015). Available from: https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB80184427.xhtml.
139. Hitzman M. Induced seismicity potential in energy technologies. Washigton, DC: National Research Council of the National Academies, National Academy Press; 2013 (accessed 29 December 2015). Available from: http://www.nap.edu/read/13355/chapter/1.
140. Tucker C. Health concerns of "fracking" drawing increased attention: EPA conducting studies on health effects. The Nation's Health. 2012; 42(2):1–14.
141. Jeffery RD, Krogh C, Horner B. Adverse health effects of industrial wind turbines. Can Fam Physician. 2013;59(5):473–5.
142. Aldrich TE, Easterly CE. Electrical Fields and Public Health. Environ Health Persp. 1987; 75:159–171.
143. Solid Waste Facts: SW-694. Washington, DC: US Environmental Protection Agency; 1980. p. 1–8.
144. Decision Makers Guide in Solid Waste Management: SW-500. 2nd edition. Washington, DC: US Environmental Protection Agency; 1976. p. 5, 60–63, 70, 109.
145. Concentrated animal feeding operations (CAFOs): Definitions. Commonwealth of Massachusets, Office of Energy and Environmental Affairs; 2015 (accessed 29 December 2015). Available from: http://www.mass.gov/eea/agencies/agr/about/divisions/concentrated-animal-feeding-ops-definitions-generic.html.
146. Thu K, Durrenberger P, editors. Pigs, Profits, and Rural Communities. Albany: State University of New York; 1998.
147. Hribar MA. Understanding concentrated animal feeding operations and their impact on communities. Bowling Green: National Association of Local Boards of Health; 2010 (accessed 29 December 2015). Available from: http://www.cdc.gov/nceh/ehs/docs/understanding_cafos_nalboh.pdf.
148. Thorne PS. Environmental health impacts of concentrated animal feeding operations: anticipating hazards--searching for solutions. Environ Health Perspect. 2007;115(2):296–7.

149. Thu K, editor. Understanding the impacts of large-scale swine production, Proceedings from an Interdisciplinary Scientific Workshop, Des Moines, Iowa, June 29–30, 1995. Iowa City, IA: University of Iowa Printing Service; 1996. p. 71-96.
150. Antimicrobial resistance and human health [press release]. Pennsylvania: The Pew Charitable Trusts; 2008.
151. Merchant J, Ross R, Hodne C. Iowa Concentrated Animal Feeding Operations Air Quality Study. Iowa City, IA: University of Iowa and Iowa State University; 2002.
152. Report to the State of Iowa Department of Public Health on the Investigation of the Chemical and Microbial Constituents of Ground and Surface Water Proximal to Large-Scale Swine Operations. Atlanta: National Center for Environmental Health, Centers for Disease Control and Prevention; 1998 (accessed 29 December 2015). Available from: http://www.sraproject.org/wp-content/uploads/2007/12/investigationofthechemicalandmicrobialconstituentsofground.pdf.
153. Merkel J, Hazen T, Miner J. Identification of gases in a confinement swine building atmosphere. Trans Am Soc Agric Engrs. 1969;12:310–5.
154. O'Neill D, Phillips VR. A review of the control of odor nuisance from livestock buildings. J Agric Eng Res. 1992;53.
155. Donham KJ. The concentration of swine production. Effects on swine health, productivity, human health, and the environment. Vet Clin North Am Food Anim Pract. 2000;16(3):559–97.
156. Donham KJ, Scallon LJ, Popendorf W, Treuhaft MW, Roberts RC. Characterization of dusts collected from swine confinement buildings. Am Ind Hyg Assoc J. 1986;47(7):404–10.
157. Donham KJ, Wing S, Osterberg D, Flora JL, Hodne C, Thu KM, et al. Community health and socioeconomic issues surrounding concentrated animal feeding operations. Environ Health Perspect. 2007;115(2):317–20.
158. Thorne P, Keikhaefer M, Donham K. Comparison of bioaerosol sampling methods in barns housing swine. Appl Environ Microbiol. 1992;58:2543–51.
159. Kiekhaefer MS, Donham KJ, Whitten P, Thorne PS. Cross seasonal studies of airborne microbial populations and environment in swine buildings: implications for worker and animal health. Ann Agric Environ Med. 1995;2:37–44.
160. Ritter W, Chirnside A. Impact of land use on ground-water quality in southern Delaware. Ground Water. 1984;22:38–47.
161. Riskowski G. Methods for evaluating odor from swine manure. Appl Engng Agric. 1991;7:248–53.
162. Popendorf W, Donham K. Agricultural Hygiene. Patty's Industrial Hygiene, Vol. 4. In: Vern Rose and Barbara Cohrssen, editors. Boston: Wiley; 2010.
163. Smith R, Kelly J. A comparison of two methods for estimating odour emissions from area sources. In Proceedings of the International Conference on Air Pollution from Agricultural Operations, Kansas City, February 7–9, 1996. Ames: Midwest Plan Service. pp 263–9.
164. Goodrich P. Airborne health hazards generated while treating and land disposing waste. In: American Society of Agricultural and Biological Engineers. Publication PROC-275. St Joseph, MI: ASAE; April 21–24 1975. pp 7–10.
165. Pickrell J. Hazards in confinement housing – gases and dusts in confined animal houses for swine, poultry, horses, and humans. Vet Human Toxicol. 1991;33:32–9.
166. Reynolds S, Donham K, Whitten P, Merchant JA, Burmeister LF, Popendorf WJ. Longitudinal evaluation of dose-response relationships for environmental exposures and pulmonary function in swine production workers. Am J Ind Med. 1996;29:33–40.
167. Overcash M, Humenik F, Miner J. Livestock Wastes Management, Vols I & II. Boca Raton, FL: CRC Press; 1983. p. 1–11(vol I),165–73(vol II).
168. Donham KJ. Community and occupational health concerns in pork production: a review. J Anim Sci. 2010;88(13Suppl.):E102–11.
169. Ackerman D. Smell. A natural history of the senses. London: Chapmans; 1990. p. 5–59.
170. Walsh P, Lunney C, Casey K. Odour impact survey. Milestone Report No. 18, Meat Research Corporation Project No. DAQ-079. Toowomba, Qld: Department of Primary Industries, Beef Industry Group; 1995.
171. Donham K, Reynolds S, Whitten P, Merchant J, Burmeister L, Popendorf W. Respiratory dysfunction in swine production facility workers: Dose-response relationships of environmental exposures and pulmonary function. Am J Ind Med. 1995;27(3):405–18.
172. Davidson L, Fleming R, Baum A. Chronic stress, catecholamines, and sleep disturbance at Three Mile Island. J Human Stress. 1987;13:75–83.
173. Jacobson L. No correlation between hydrogen sulfide and odor. Pork News - Environmental Issue, Minnesota Pork Journal. 1997;Nov–Dec.
174. Kilburn K. Exposure to reduced sulfur gases impairs neurobehavioral function. Southern Med J. 1997;90:997–1006.
175. Schinasi L, Wing S, Augustino KL, Ramsey KM, Nobles DL, Richardson DB, et al. A case control study of environmental and occupational exposures

associated with methicillin resistant *Staphylococcus aureus* nasal carriage in patients admitted to a rural tertiary care hospital in a high density swine region. Environ Health. 2014;13(1):54.
176. Shusterman D. Critical review: the health significance of environmental odor pollution. Arch Environ Health. 1992;47(1):76–87.
177. Shusterman D, Balmes J, Cone J. Behavioral sensitization to irritants/odorants after acute overexposures. J Occup Environ Med. 1988;30:565–7.
178. Rylander R. Organic dust and disease: A continuous research challenge. Am J Ind Med. 2004;46:323–6.
179. Meggs W, Elshick T, Metzger W. Nasal pathology and ultrastructure in patients with chronic airway inflammation (RADS and RUDS) following an irritant exposure. Clin Toxicol. 1996; 34:383–96.
180. Meggs W. Hypothesis for induction and propagation of chemical sensitivity based on biopsy studies. Environ Health Persp. 1997;105:473–8.
181. Climate Change 2014: Synthesis Report. Geneva: World Health Organization, United Nations Environmental Programme, Intergovernmental Panel on Climate Change; 2014.

CHAPTER

8

Musculoskeletal Disorders

Anders Thelin and Kelley J. Donham

Reviewer: Steven R. Kirkhorn

8.1 Introduction

While agricultural workers engage in physical activities that enhance the risk of musculoskeletal injuries, even in the general population low back pain is a common disorder. More than 80% of the population in Western industrialized countries experience back problems. In most cases the pain will not be fully evaluated, and no diagnosis will be made. Musculoskeletal symptoms from the neck, shoulder, and the extremities may be nearly as common as back pain, and agricultural workers are certainly at risk. This chapter will review the common occupational-related musculoskeletal conditions of farmers. Many of these conditions are common to others who engage in long-term hard physical labor. However, this chapter will focus on the specific risks and conditions common to agricultural work, as well as the treatment and prevention of these conditions.

8.1.1 Definitions

Musculoskeletal injuries include diseases of the bone, joints, and structures around the joints, (tendons, ligaments, and muscles). Secondary nerve involvement is also included in musculoskeletal disorders.

The following are common musculoskeletal conditions:

Acute injury and delayed effects of acute injury
- Fractures and dislocations
- Sprains (injury of a ligament that has been partially or completely torn)
- Strains (muscle, tendon, or ligament pushed or pulled to its maximal limit)

Inflammation
- Tendonitis (inflammation of a tendon)
- Tenosynovitis (inflammation of a tendon sheet)
- Enthesitis (inflammation of a tendinous insertion)
- Bursitis (inflammation of a bursa)
- Myositis (inflammation of a muscle, which may be primary (e.g., polymyositis) or secondary to mechanical injuries)

Arthritis
- Post-traumatic arthritis (after acute trauma)
- Infectious arthritis (due to direct infection of a joint)
- Reactive arthritis (inflammation of a joint due to an immunologic process or reaction, e.g. rheumatic arthritis)
- Osteoarthritis (sometimes also called arthrosis; a degenerative process in joint cartilage of partly unknown causes)

Agricultural Medicine: Rural Occupational and Environmental Health, Safety, and Prevention, Second Edition.
Kelley J. Donham and Anders Thelin.

Repetitive strain injuries
Cumulative trauma disorders or overuse syndrome (1). Can also be related to static work.

In this chapter trauma and acute injuries will not be covered. Rheumatic disorders will be briefly discussed as they relate to work situations.

Musculoskeletal injuries exhibit a number of characteristic symptoms: pain, tenderness, stiffness, edema, and disuse. Pain is an early symptom, and nociceptive and neurological pain are probably most common. However, chronic pain conditions related to psychological and psychosocial factors are increasing.

8.1.2 Work-related Disorders

Determining a cause-effect association between work exposure and musculoskeletal injuries is often difficult both for the patient and the healthcare provider. However, treatment, prevention, and worker's compensation claims are dependent on the association between work and injury.

Given the difficulties in diagnosis management, prognosis, and insurance or employer liability, the potential confounding dimensions must be considered. For current or chronic degenerative musculoskeletal disorders, the effect of work activity or sports activity may be primary or secondary, positive or negative, relative to the injury. Musculoskeletal disorders may have a complex etiology with multiple risk factors like age, gender, and obesity. Moreover, a number of risk factors may be found in farm work.

8.1.3 Epidemiology

Specialization has been one of the megatrends in production agriculture over the past three decades (see Chapter 1). Today, many farmers engage in routine and repetitive tasks for long periods, rather than constantly moving from one task to another as was past practice. Thus the ergonomic design of the work environment is of greater importance today. The risk for static and/or repetitive work is significant in many modern farming operations. Typical disorders and potentially related activities are listed in Table 8.1.

A number of reports over the years have indicated a significant risk of low back pain among farmers (2–6). However, because of the research methodology, most of these studies have been unable to ascribe causality. Further research and longitudinal studies are needed for a better understanding of work-related low back pain among farmers (7).

A fairly significant relationship between hip join osteoarthritis and farm work has been reported in a number of studies over the last 25 years (8–11). Although the occupational association is clear, the specific causes of this problem are not known (12).

Tendonitis of the shoulders, epicondylitis, pronator syndrome, and especially carpal tunnel syndrome are common disorders related to physical work among farmers (13, 14). Female dairy farmers may be at special risk of these conditions (15).

While farming may or may not have a causal relationship to many of the disorders described in this chapter, many patients with these complaints will consult occupational health physicians and rural doctors, and will raise questions regarding farm tasks and possible relation to their injury, the consequences of further similar work, and compensation. Knowledge of the work of farmers is important to enable healthcare providers to answer their patients' questions and recommend specific treatment, prevention, and rehabilitation of their farmer patients.

8.2 Chronic Pain Conditions

Several factors affect the perception of pain, as described by Waddell in the Glasgow illness model 1984 (16). Waddell's model describes how physical problems transcend into distress, illness, and sick leave. His concept of illness behavior describes how pain and other symptoms may be related to hope of compensation in terms of moving to another job, financial gain, or sympathy. The neurologist Henry Miller (17) coined the term "accident neurosis" to

Table 8.1 Musculoskeletal disorders associated with physical factors

Disorder	Causal relationship	Typical activity
Cervical degenerative disk disease	No	Ceiling work, fork-lift truck driving
Neck pain	No	Ceiling work, fork-lift truck driving, load carrying in hand or on shoulder, assembling work
Whiplash injury	Yes	Trauma, especially traffic accident
Spinal degenerative disk disease	No	High work load, bending, twisting, difficult working positions, manual material handling, whole-body vibration
Spinal stenosis	No	Standing and walking
Spondylolysis and spondylolisthesis	No	High work load, bending, twisting, difficult working positions, manual material handling, whole-body vibration
Ankylosing spondylitis	No	Inactivity
Low back pain	Possible	High work load, bending, twisting, difficult working positions, manual material handling, whole-body vibration
Coccygodynia	No	Sitting, trauma
Impingement syndrome	Yes	Working with elevated arms, especially with vibrating tools, repetitive and static work with arms in abduction
Shoulder tendinitis	Yes	Working with elevated arms, especially with vibrating tools, repetitive and static work with arms in abduction
Shoulder dislocations	No	Trauma
Thoracic outlet syndrome	No	Overhead activities, fork-lift truck driving, material handling
Frozen shoulder	No	All kinds of movements in the shoulder
Osteoarthritis of the acromioclavicular joint	Probably not	Manual material handling, lifting material, transporting material on the shoulder
Cervicobrachial syndrome	No	Fork-lift truck driving, load carrying in hand or on shoulder, assembling work, manual material handling, work with chainsaw
Epicondylitis	Possible	Turing screws, hammering, assembling parts
Olecranon bursitis	Yes	Trauma, repetitive or continuous pressure
Flexor pronator syndrome	Yes	Manual material handling, milking
De Quervain's tenosynovitis	Yes	Manual material handling, sawing, forceful hand wringing
Ulnar cubaital tunnel syndrome	Yes	Resting forearm on hard surface or sharp edge
Stenosing tenosynovitis	Possible	Manual material handling
Scaphoid fractures and non-union of the scaphoid	Yes	Trauma
Carpal tunnel syndrome	Possible	Manual material handling, vibrating tools, working with hand-held tools and equipment
Dupuytren's contracture	No	Working with hand-held tools and equipment
Ganglion	Possible	Repetitive manual material handling
Herbeden–Bochards osteoarthritis	No	Manual material handling
Osteoarthritis of the first carpometacarpal joint	Possible	Trauma, screwing, vibration
Trochanteritis	Possible	Trauma, repetitive kneeling
Osteonecrosis of the femoral head	No	Walking, running
Osteoarthritis of the hip	Yes	Unspecific farm work
Knee ligament injuries	Yes	Trauma
Bursitis of the knee	Yes	Kneeling, trauma
Chondromalacia patellae	Possible	Running, high physical activity, walking, climbing stairs
Injuries of the meniscus	Yes	Trauma
Baker's cyst	No	Walking, kneeling
Osteoarthritis of the knee	Probably not	Walking, running, kneeling, climbing stairs and ladders, working on rough ground

(*Continued*)

Table 8.1 (Continued)

Disorder	Causal relationship	Typical activity
Periosteitis	Yes	Training running
Ankle sprains	Yes	Trauma
Avulsion fractures of the fifth metatarsal	Yes	Walking, running
Plantar fasciitis	No	Standing, walking, running
Morton's neuroma	No	Dorsiflexion of toe
Hallux valgus	No	Walking, running
Pes planus	No	Walking, standing
Rheumatoid arthritis	No	No
Psoriasis	No	No
Crohn's disease	No	No
Salmonella	Possible	Infection from animals
Shigella	Possible	Infection from animals
Yersinia	Possible	Infection from animals
Other immunologic factors	Possible	Contact with material and/or animals

describe a category of patients with chronic pain related to litigation processes.

Other psychosocial issues may predispose to chronic pain, including depression, childhood deprivation, family difficulties, and personality disorders (18). The point is that the health professional may be challenged to determine work-related injuries in the absence of objective signs of physical injury or disease. Psychosocial conditions may be important etiologic factors of chronic pain or effect modifiers, or may have no relationship (19–21).

Psychosocial conditions may act as an important etiologic factor (22, 23), but mostly the impacts of psychosocial conditions are regarded as effect-modifying factors (24–26) (Figure 8.1).

Several studies have reviewed the association of psychosocial factors with low back problems, neck problems, and shoulder problems (19, 27). Such factors are demand/control imbalance, job content, social support, job dissatisfaction, shift work/overtime, and stress in the work environment. Evidence for association between low job satisfaction and back and neck pain has been reported (20, 28, 29). Complex psychosocial factors may be relevant for back and neck problems (30). The economic burden, particularly indirect costs, of chronic pain is very high (31).

Because development of chronic pain is not well understood (32), a number of models have been presented to describe how this kind of chronic pain develops and persists (33). One of these models is the concept of myofascial pain. This syndrome is described as a regional muscle pain disorder characterized by localized muscular tenderness and pain. So-called trigger points are pathognomonic. A trigger point is a hyperirritable spot, painful on pressure. Tenderness and referred pain are common as well (34). Fibromyalgia may be described as a more generalized myofascial pain syndrome, accompanied by fatigue and sleep disturbance (35–39). Alternative models have been presented of how chronic pain emerges and how repeated pain signals may be transformed into persisting hyperexcitability (40–42). Pain research has demonstrated (the gate control theory) that nociceptive receptors (peripheral, cutaneous receptors) are inhibited by central mechanisms activating other receptors. Fast nociceptive sensory information transmitted to the brain relies on interplay between the inputs from nociceptive and non-nociceptive primary fibers, both normally under strong inhibitory control in the spinal cords dorsal horn. Two amino acids, GABA and glycine, serve pivotal roles in this process. Disturbance of these descending inhibitory signals may play an important role in chronic pain syndromes (43–45).

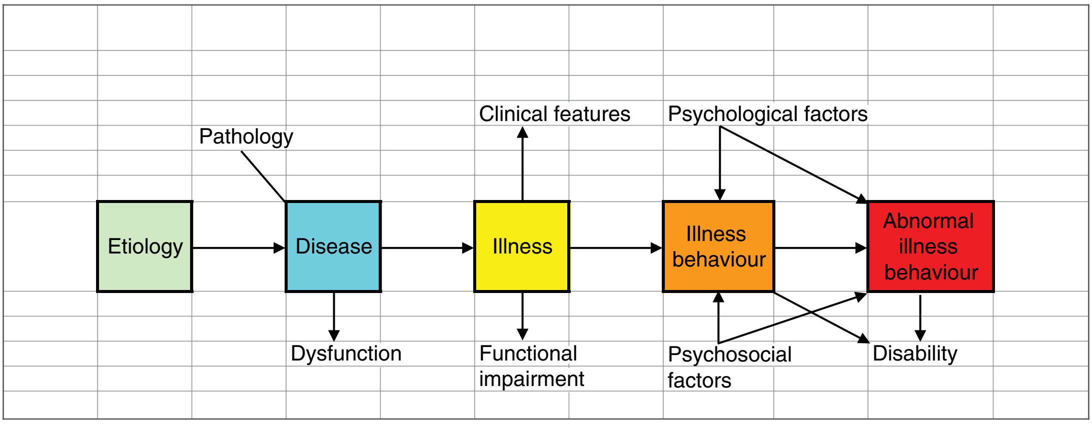


FIGURE 8.1 Psychosocial factors and illness behavior.

8.3 Injuries of the Neck

Neck pain is second only to low back pain as a common musculoskeletal disorder and is frequently reported among workers. Although neck pain may be related to cervical degenerative disease or whiplash injury, years of research on chronic neck pain plus advanced radiological methods have provided little understanding for most chronic neck pain. Perhaps a more psychological approach, focusing not only on the pain but also on counselling and general physical conditioning, may be helpful (46).

8.3.1 Cervical Degenerative Disk Disease

The cause of cervical degenerative disk disease is unknown. It is common in both men and women, with a rising prevalence in advancing age. Middle-age people may have subclinical degenerative changes. Degenerative changes are most common at C5–6. Frequently more than one disk is affected. Disk protrusion can affect the nerve roots and thus account for radiculopathy, resulting in pain and other symptoms, radiating into the arms. Increasing levels of spinal degeneration are related to increasing chronicity of patient complaints (47).

The first symptom of disk disease is pain with the neck flexed or extended for long periods. Sometimes the symptoms are first noticed after trauma. Work histories such as working with forklifts, tractor driving, or computer work are common (48). A typical problematic farm work practice is looking back over the shoulder while driving a tractor with equipment at the rear (Figure 8.2). Chronic neck pain may reflect a state of instability in the cervical spine and the symptoms may be related to a number of conditions (49). As with other chronic musculoskeletal problems psychological and psychosocial factors may be related to onset, severity, and chronicity of symptoms (28, 50, 51).

Neck pain or high interscapular pain related to movements is the most frequently reported symptom, but pain during the night also is common. Patients often make efforts to find a good pillow. Physical examination is often negative. Some restrictions of neck flexion or rotation may be noticed. Localized tenderness is a non-specific finding. Only in severe cases will there be findings such as a reflex change or local sensory/tactile change.

If the symptoms from the neck are combined with other observations such as weight loss, fever, intravenous drug use, or history of urinary tract infection, other serious conditions of the spine must be considered. In case of trauma, a spinal fracture should be suspected. Arthritis

FIGURE 8.2 Looking back over the shoulder while driving a tractor may be problematic in cases of neck disorder.

(rheumatoid or ankylosing spondylitis) can also cause neck symptoms. C-reactive protein (CRP) and erythrocyte sedimentation rate are useful tests to differentiate traumatic or degenerative disease from a systemic condition.

Standard plain-film x-ray is indicated in chronic cases and when serious underlying conditions are suspected. Narrowed disk space is a common finding together with degenerative changes such as osteophytes of the surrounding vertebrae. Magnetic resonance imaging (MRI) is not indicated unless there is a suspicion of serious spinal pathology.

In cases with no x-ray findings, other potential diseases include neck tension syndrome, whiplash injury, tumors, and entrapment problems of the brachial plexus. Neuropathy related to diabetes or other metabolic abnormalities may also affect the nerve function of the upper extremities.

Patients with neck problems should avoid prolonged sitting with the neck in a fixed position or working with the head in extreme positions. Driving may be difficult, especially tractor driving on rough ground. Early intervention with a physical therapist is often recommended. Active therapy, including specified exercises and cervical traction, may be helpful. Heat, massage, and ultrasound may reduce pain and stiffness. A soft cervical collar supports the head and gives some rest for the neck muscles. It may be helpful initially but is of no help or may have a negative effect with longer term use. Nonsteroidal anti-inflammatory drugs (NSAID) reduce pain and stiffness. Oral corticosteroids muscle relaxants and sedatives are not usually warranted. In rare instances, painkillers might be essential.

Modification of the job sometimes must be encouraged, including ergonomic changes to the workstation and changes of work routines and job rotation. Psychosocial difficulties must be considered as well.

Patients with neck problems who develop neurological deficits may need more aggressive therapeutic efforts. Those who have upper extremity radiculopathy and do not respond to conservative therapy should be transferred to specialists for further evaluation.

8.3.2 Neck Tension Syndrome

Neck pain that persists without any objective findings is sometimes labelled tension myalgia, chronic neck disease, neck-shoulder syndrome, or neck-tension syndrome. Some authors report that tension conditions of the neck results from static sustained muscle contraction (52). The symptoms are said to be frequent among secretaries, computer operators, and small-part assemblers as well as among those who carry loads in the hands or on the shoulders. They might also be seen after repeated or sustained overhead work. Other researchers (53) conclude that psychosocial conditions may be as important as occupational physical stress in relation to neck pain (7, 19, 30, 47, 54). Involvement of physiotherapists as well as psychotherapists in a program to train the patient to handle his or her situation may be indicated.

8.3.3 Whiplash Injury

A sudden jerk to the neck may result in a complex injury. Typically whiplash trauma is an acceleration–deceleration loading of the cervical spine, usually generated by a rear-end car collision. Other types of car crash and injuries related to diving and fall-trauma may result in a neck distortion, giving the same type of injury. Whiplash injuries are common and usually the damage is insignificant, but occasionally it can be more severe. Usually, symptoms decline and disappear within a short time, but sometimes pains and various manifestations – such as vertigo, numbness, vision disturbances, difficulty concentrating, and memory impairment – may linger. These symptoms are labelled whiplash-associated disorders (WAD). After many years of research, there is still controversy about whether WAD complications are related to physical changes, biopsychological reactions, or merely to insurance claims questions (55–59).

The Quebec task force analyzed more than 10,000 publications concerning whiplash and whiplash-related disorders (60). Objective signs of injury such as fractures, ligament strains, disk fragmentation, and bleeding were reported after studies on animals and post-mortem studies (61, 62). The Quebec classification with five grades is widely accepted (63–67) (Table 8.2).

Table 8.2 The Quebec classification of whiplash injuries

Grade	Clinical presentation
0	No functional manifestations or physical signs
1	Neck pain with no physical signs
2	Neck pain, rage-of motion limitation, and tender point
3	Neck pain and neurologic impairment
4	Neck pain and fracture or dislocation

The percentage of exposed people reporting WADs varies among countries (68–70). Studies in Australia, New Zealand, and Saskatchewan, Canada, indicate that the insurance system has a considerable effect on the number of WADs (71–73).

Psychosocial considerations are less questioned in patients with grade 3 and 4 symptoms on the Quebec classification system. These patients should be carefully evaluated at a trauma clinic. Those with lower grade symptoms might be followed as outpatients. It is important that the patient resumes working as soon as possible, at least part-time. Some patients may need support to tackle post-traumatic stress reactions (74, 75). WADs are problematic when assessing litigation claims. The problem is not restricted to road traffic accidents but is also related to different types of accidents in working life.

8.4 Injuries of the Spine

The annual incidence of low back pain episodes is reported to be about 50% of working age adults (76). More than10% seek medical care for their back condition (77). The cost of back conditions is substantial and includes the costs of medical treatment, lost productivity, disability, work absence, and disability pensions (78). Low back

Figure 8.3 Tractor-driving is associated with whole-body vibration and prolonged sitting.

problems are defined as acute or subacute for the first few weeks and chronic if they persist for more than 3 months (79, 80). Most patients with low back pain recover spontaneously within a week or a month. However, most people suffer recurrent episodes of low back pain (2, 50, 81).

Risk factors for low back injury include heavy lifting, bending and lifting, bad work positions, whole-body vibration, and prolonged sitting in fixed position. Several research studies of farmers have reported high rates of low back pain (82, 83). Tractor driving has been identified as a major factor (3, 84) as well as whole-body vibration and prolonged sitting (85–87) Figure 8.3.

Most of the studies reporting a relationship between farming and low back pain have been based on cross-sectional studies. Furthermore, few studies have included any results on physical diagnosis (e.g., degenerative disk, etc.). More definitive prospective studies and case-control studies are lacking (88). Part-time farmers have been reported to have more problems than full-time farmers (89). Physical factors as well as psychological factors have been demonstrated as risks, but explain fewer than half of the cases of low back problems (90). Despite frequent symptoms of low back pain, farmers do not often seek medical care and are generally not away from their work for very long (90).

8.4.1 Spinal Degenerative Disk Disease

Intervertebral disk degeneration is a normal aging process. However, hereditary factors are important in degenerative changes in the spine. Some differences between men and women have also been demonstrated (91). Females experience a greater number of joints affected compared to men, while men have more lumbar spine degeneration. Sciatic symptoms are more prevalent among men than women of the same age (92). Men experience symptoms at a younger age, but between 35 and 54 years of age there is almost no gender difference. The highest prevalence is reported for the middle-aged groups (93).

A common belief is that disk degeneration and disk hernia (with or without sciatic symptoms) emerge because of heavy work, heavy lifting, or turning or twisting at the waist. However, research on workers in traditionally heavy jobs shows that they have fewer back problems and less sick leave due to sciatica than a comparison population. Numerous studies have failed to show a relation between mechanical stress on the back and degenerative disk changes (94).

During the last two decades, use of MRI and statistical regression methods have expanded knowledge of these conditions. No specific risk for heavy lifting work was apparent compared to people with jobs involving sitting for long periods (95, 96). Other studies have found only a weak relationship between disk degeneration and occupation. Almost half of the general population of middle age and beyond have MRI-objective disk changes (97). One-third of individuals without symptoms have disk changes, and 50% of those with symptoms have normal MRIs (97–99). In a study of twins, hereditary factors, not occupation, were related to disk problems (100). Experimental studies have not indicated a relationship between whole-body vibration or disk compression and degeneration (101, 102).

Based on the available research, it appears that disk degeneration is mainly dependent upon hereditary factors. However, sitting for long periods appears to be a greater risk factor than heavy work. This may be related to the fact that there is less space around the nerve roots when sitting. A fixed position may also promote swelling if there is an ongoing inflammation, and prolonged sitting may promote a weaker muscle capacity. In any case disk degeneration in relation to work is difficult to define. Smoking, obesity, and general health status are also related to the risk for sciatica (103).

Sciatic pain, weakness, and numbness are mostly caused by pressure on the nerve roots exiting the spinal cord or a bulging or herniated disk with an associated inflammation. The onset of symptoms may be sudden or gradual. Pain is associated with movement of the back. Forward bending may be very difficult. Pain is usually located in the lumbar region but may extend to the buttock and is usually not well defined. Patients with typical nerve root symptoms avoid sitting and prefer standing or walking. The degree of sciatic pain or radiculopathy is proportional to the level of root pressure. Pain location is as follows:

L4: Pain below the knee in the medial part of the leg
L5: Pain in the lateral calf and dorsal part of the foot and/or in the great toe
S1: Pain in the posterior calf and lateral border of the foot

In the case of nerve root pressure, the straight leg-raising test (Lasègue's sign) is generally positive. The smaller the angle associated with pain, the more positive the test. Compression of the S1 root causes absent or decreased ankle reflex and involvement of the L4 root causes absent or decreased knee reflex, while there is no loss of reflex with the L5 nerve root. Skin sensation may be affected as follows:

L4: Decreased sensation in the medial part of the leg and foot
L5: Decreased sensation in the dorsal part of the foot and the great toe
S1: Decreased sensation in lateral border of the foot and/or the three lateral toes

Muscle force may be decreased so that the patient has difficulty rising back on the heels (L4) or onto the toes (S1). The ability to dorsiflex the great toe (L5 supplying the extensor hallicus longus) may also be weak. Sometimes the patient reports hyperesthesia.

Plain-film x-ray views are usually obtained with the patient standing. Scans or MRI should be obtained in case of insecurity concerning diagnosis, prior to surgery. In other cases more advanced diagnostic measurements can wait (Figure 8.4).

The physician examining a patient with back pain must differentiate other causes that may be related to the pathologic process involving the abdomen, kidneys, or pelvis. Bone infection, ankylosing spondylitis, and tumors can be differentiated with bone scans, x-ray, and MRI exams respectively (Figure 8.5).

Figure 8.4 MRI of lower back showing degenerative changes: deformed vertebral bodies. (Source: Department of Radiology, Central Hospital, Wexiö, Sweden.)

Figure 8.5 MRI of lower back showing disk herniation with nerve root pressure. (Source: Department of Radiology, Central Hospital, Wexiö, Sweden.)

The great majority of patients with disk degenerative disorder with low back pain with or without radiculopathy will resolve without any treatment. Bed rest should be avoided (104). If possible the patient should work and perform daily living activities. The prognosis is better if the patient is physically active (105, 106). Patients should have instructions to adjust their work according to their ability. In some cases a lumbosacral corset may be helpful but it should not be used for long periods. Anti-inflammatory drugs such as non-steroidal anti-inflammatories may be prescribed.

Exercise should be implemented as soon as possible. Patients presenting recurrent problems or delayed recovery may be referred to a physiotherapist. In some places it is possible to join a "back school." Such schools have specially designed exercise schemes and personnel who can teach the patient about prevention (103). Job activity should be designed to minimize prolonged sitting or standing and to avoid sitting while leaning forward and rotating.

Patients with strong or persistent pain as well as patients with significant nerve root engagement may be candidates for surgery. Surgery is performed to relieve nerve root pressure. Alternatively, a corticosteroid injection may be helpful in providing relief of radicular symptoms in some cases. The long-term prognosis is not better for patients who have had surgery. Thus it is necessary to reflect carefully on the patient's situation before a decision favoring surgery. A corticosteroid injection may be helpful in providing relief of radicular symptoms and can be considered as an adjunct in balanced non-operative management.

8.4.2 Spinal Stenosis

Spinal stenosis is mostly the result of progressive degenerative disease (107). Deformation of the facet joints as well as deformation of other structures may encroach on the spinal canal as well as the neruoforamina. Spinal stenosis may also be a late complication to disk surgery hernia or congenital conditions.

Spinal stenosis is a common cause of leg pain, especially among the elderly. As individuals with spinal stenosis have problems with standing and walking, sitting may be preferable. The pain in the lower extremity is variable between and within patients over time. Patients should be observed walking, and reflexes of the lower extremity should be examined at each visit.

Plain-film x-rays may show a number of degenerative changes: degenerative low disks with associated osteophytic changes and scoliotic changes. A CT scan or MRI may show the impingement of the nerve roots. Most patients with spinal stenosis are older and have other degenerative disorders, such as disturbed circulation of the legs from arteriosclerosis (intermittent claudication), which may present symptoms similar to spinal stenosis. If spinal stenosis is suspected, referral to an orthopedic specialist is recommended for evaluation and treatment (108).

8.4.3 Spondylolysis and Spondylolisthesis

Spondylolysis is a defect in the continuity of the superior and inferior articular processes of the neural arch of a vertebra, almost always the fifth lumbar vertebra. The bone of the articular process is replaced by fibrous tissue usually as the result of a congenital defect or trauma such as an improperly healed stress fracture. Spondylosis may cause instability and displacement of a vertebra or spondylolisthesis. Spondylolisthesis may also result from osteoarthritis or malformation of the articular processes (109) (Figure 8.6).

These conditions cause variable symptoms unless there is significant displacement (110, 111). On examination there may be a visible or palpable "step" above the sacral crest. Plain-film x-ray demonstrates the defect on lateral views and there may be secondary degenerative changes. Most patients do not need any treatment and they should continue to be physically active. Individuals with symptoms may be helped with conservative measures similar to patients with degenerative disk disease. Surgery is justified only when disability is severe (112).

The available literature suggests it is not necessary to exclude workers with spondylolisthesis from moderate physical work (113–116). Studies indicate that the prognosis for young people with sponylolysis is good (117).

FIGURE 8.6 Plain-film x-ray showing spondylolisthesis. (Source: Department of Radiology, Central Hospital, Wexiö, Sweden.)

8.4.4 Ankylosing Spondylitis

Ankylosing spondylitis (Bechterew's disease) is a chronic and often disabling disease. It is strongly related to constitutional factors. It is often necessary to intervene with patients with ankylosing spondylitis to facilitate their working life.

Approximately 1% of the white population have ankylosing spondylitis. The frequency is lower in Japan and among African black populations. The variation is strictly related to the variation of the HLA-B27 gene. Almost 90% of patients with ankylosing spondylitis have this gene and 10–20% of those who are HLA-B27-positive will develop the disease. While ankylosing spondylitis has primarily been recognized in men, recently women have also been found to be susceptible (118). Physicians and radiologists may miss diagnose in mild disease; females usually have a milder disease (119, 120).

The following five manifestations suggest a diagnosis of ankylosing spondylitis (121):

1. Occurrence of symptoms in patients younger than 40.
2. Insidious unset of back discomfort.

3. Persistence of back pain for more than 3 months.
4. Morning stiffness.
5. Improvement of back pain after exercise.

The physical examination may reveal a reduced mobility in both anterior and lateral planes, and a loss of the normal lumbar lordosis. Lateral x-ray views of the lumbar spine show that the normal concavity of the vertebral bodies is lost and a squared form has developed. Severe degenerative bony changes progress over most portions of the spinal column (122).

Other organs may become involved with amyloidosis, including the eye, lung, and cardiovascular system. It is not possible to make any accurate prognosis for an individual patient. Treatment must focus on good spinal posture and exercise. Anti-inflammatory medication (NSAID) may be helpful. If this does not relieve symptoms, anti-tumor necrosis factor (TNF) alpha drugs may be begun. These drugs often have a very good effect on symptoms and physical capacity. Daily physical activity and work activity should be encouraged, but risk of fractures should be advised in severe cases. The combination of a more fragile skeleton and difficulties with motion must be considered a significant risk for farmers who handle animals or are exposed to other kinds of physical stress.

8.4.5 Coccygodynia

Coccygodynia is persistent pain in the region of the coccyx (tailbone). Usually there is no evident pathology. A local injury such as a direct fall onto the coccyx or a blow to the area is typically reported. The injury in most cases is probably a strain or sprain in one coccygeal joint. Pain is worse when sitting. There is localized tenderness. Plain films are typically normal. Infections or tumors should be ruled out. Treatment is usually not required. A small pillow to sit on may be helpful as well as anti-inflammatory drugs. In most cases the condition will resolve spontaneously over time.

8.4.6 Low Back Pain

Low back pain is an imprecise term sometimes used to describe any kind of low back condition. Some patients with low back pain have objective findings such as x-ray findings or relevant clinical observations. Other patients have pain without objective manifestations (123, 124). Most back pain in early course is non-specific. Pain may be generated by nociceptors in most of the anatomic structures of the lower back. Studies indicate that a nociceptive stimulus may start a muscle contraction in different spinal muscles (125–127). The contraction may be for the purpose of stabilizing the painful segment and may be facilitated by higher centers in the brain or spinal cord, which may continue the contraction even after the initial nociceptive stimulus has healed (128). This biomechanical loading may be acute, repeated, and prolonged, leading to the low back pain. The scientific medical understanding of most low back pain is still limited, despite modern technology. For details see biomechanical textbooks and reviews (94, 129–132). Patients with low back pain and without any objective signs of disease may need the same support and training as patients with a degenerative disk disease (see above).

8.5 Injuries of the Shoulder

The shoulder is the most movable mechanical system in the body. Three joints, the glenohumoral, the acromioclavicular, and the sternoclavicular, and more than 20 muscles integrate as a complex unit that creates stability and force in a wide range of motion.

Shoulder pain is a very common symptom often related to occupational activity (133–135). Shoulder pain affects the ability to work in a wide variety of jobs ranging from heavy manual jobs (e.g., farming and construction) to low physical demand jobs (e.g., computer terminal jobs). Repetitive motion, fixed static work, prolonged sitting, poor posture, excessive force, and vibrations are the mechanical stresses related to shoulder disorders (136–138). Psychosocial conditions (as with other chronic musculoskeletal conditions) are strongly related to shoulder pain and disability (19, 139–142).

Occupational groups working with the arms elevated (e.g., welders at shipyards, painters, and construction workers) have significant risks for shoulder pain, especially if they use vibrating tools (143, 144). As with other musculoskeletal diseases, work exposure in relation to clinical findings is difficult to evaluate.

Regarding farmers, studies in Finland indicate a higher risk of osteoarthritis of the glenohumoral joint relative to a comparison population (135, 145). Other studies have revealed that farmers report a significant association between difficult working positions and shoulder pain. However, farmers overall report a low risk of neck and shoulder problems (90).

8.5.1 Impingement Syndrome or Shoulder Tendonitis

Impingement syndrome (146) has previously been referred to as rotator cuff syndrome, supraspinatus tendonitis, or shoulder tendonitis. The supraspinatus tendon is perhaps the prominent structure for impingement as it passes beneath the acromion process of the scapula. Individual factors such as the anatomic space, age, and intensity of localized inflammation are related to the risk and the magnitude of symptoms. The bursa between acromion and humerus may be affected, resulting in a bursitis. In chronic cases, especially among older people, the tendon may rupture, resulting in a rotator cuff rupture. Supraspinatus tendonitis will produce a "painful arc," described as pain when abducting from 45 to 90 (variation 60–120) degrees. Repeated or maintained abduction with pressure on the acromion process is also painful. Pain relief with release of pressure is a positive impingement sign (147). Pain is felt in the anterolateral aspect of the upper arm, sometimes radiating distally and/or to the base of the neck (148). Lying on the affected side provokes pain.

The clinical evaluation will note a minor weakness as a result of pain inhibition on resisted abduction. The impingement sign is usually positive when the impingement is caused by a localized inflammation or injured supraspinatus tendon. Palpation may confirm the site of a rotator cuff lesion, revealing tenderness, or a defect when the supraspinatus tendon is completely torn at its insertion to the greater tuberosity of humerus. With chronic disease the inferior aspect of acromion may be deformed with osteophytic formations, resulting in further encroachment of the subacromial space.

Plain-film x-rays may show sclerotic changes of the acromion, greater tuberosity of humerus, or osteoarthritis of the acromioclavicular joint. Ectopic calcification is a common finding. Osteoarthritis of the glenohumoral joint is not very common. Rupture of the cuff will be demonstrated by MRI (149, 150) (Figure 8.7).

Patients with less severe symptoms may be referred to physiotherapy, including ultrasound, heat, and/or pendulum exercise (151). NSAIDs are useful. A local injection of corticosteroids in combination with anesthetics into the subacromial space is a rapid way to resolve pain. Patients who do not respond or who respond only temporarily may be candidates for surgery. This is generally performed by arthroscopy to restore the subacromial space. Cuff disruption can be identified and sometimes repaired by arthroscopic surgery (152).

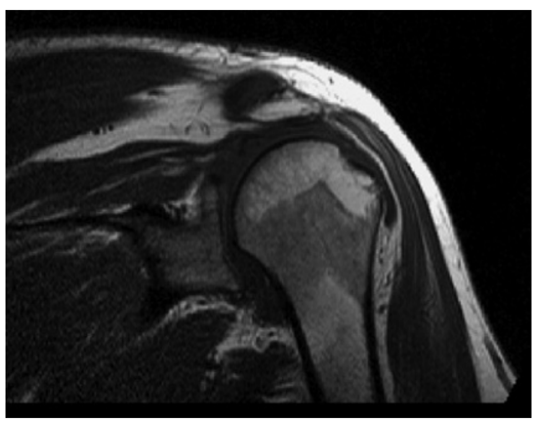


FIGURE 8.7 MRI of the shoulder showing rotator cuff rupture. (Source: Department of Radiology, Central Hospital, Wexiö, Sweden.)

The long-term outcome of rotator cuff tendonitis is unfortunately not always positive (153, 154). The level of degeneration and psychosocial factors is a good predictor of outcome. Reduction in extreme stress, like some sports, leads to more rapid healing (155–157).

8.5.2 Shoulder Dislocations

The shoulder joint is anatomically unstable as the surface area of the glenoid fossa is only 20% of the humeral head, and the stability therefore depends on the surrounding tissues. Recurrent anterior subluxation usually occurs in patients who have had an acute full luxation previously (158). Luxations are usually related to contact sports like football and rugby, but are also seen among swimmers. Farming confrontations with cattle, for example, may pose a risk for shoulder luxation. Patients with recurrent dislocations are well aware of the situation and can re-establish the normal position of the humerus on their own. In other cases the situation is not clear and the symptoms may be more diffuse.

Instability associated with some loss of range of rotation can be demonstrated by applying pressure to the head of the humerus with the patient's arm in abduction, which may result in pain and a noticeable laxity of the joint. Plain-film x-rays are often normal. MRI and examination under anaesthesia may be necessary to demonstrate the instability of the joint (159–162). Conservative treatment consists of muscle strengthening and exercises of flexibility. In cases of recurrent subluxation surgery may be indicated.

8.5.3 Thoracic Outlet Syndrome

Thoracic outlet syndrome (TOS) is a compression of neurovascular structures as they pass out from the chest and neck under the clavicle to the axilla. Normally the passage is spacious even in case of extreme movements. Most patients with TOS probably have an abnormal anatomy. This may be due to a previous injury to the clavicle, a hypertrophic anterior scalene muscle, or an extra cervical rib (or a fragment of a rib). The incidence of TOS is not well known (135, 163). TOS is probably not strictly a work-related disorder but may be aggravated in jobs where heavy loads are carried with extended arms (164, 165). Some patients have pain from the shoulder radiating down to the forearm and the hand, and have difficulties with overhead work. Numbness, tingling, and weakness are also reported and may be related to insufficient circulation (vascular TOS).

X-rays should be obtained to evaluate anatomic abnormalities. Electrodiagnostic testing may be performed to evaluate involvement at the brachial plexus (166, 167). Treatment is usually conservative and should focus on postural strength training and education to teach the patient to avoid movements that result in putting pressure on the thoracic inlet region. General physical fitness and reduction of obesity should be encouraged. Rarely will patients require surgery.

8.5.4 Frozen Shoulder

Frozen shoulder (adhesive capsulitis) is a condition with restricted active and passive movement in the shoulder. A diffuse inflammatory process is the apparent direct cause of immobility (168). Frozen shoulder (which may or may not start following trauma) is a process of gradually increasing pain and immobility of the glenohumeral joint. Most patients spontaneously recover. Physicians frequently and incorrectly use frozen shoulder as a generic term for a variety shoulder problems.

Rehabilitation of patients with frozen shoulder is often a problem in occupational medicine. Many frozen shoulder patients with manual tasks will have significant difficulty in performing their occupational work. However, the long-term prognosis is good as most patients recover within a 2-year period (169).

8.5.5 Osteoarthritis of the Acromioclavicular Joint

Osteoarthritis or arthrosis of the acromioclavicular (AC) joint is a disease of the cartilage. The cartilage is degenerated, and the joint is deformed with osteophytes at the joint margins. Although studies of AC in relation to work exposures are variable, heavy physical work, especially work with vibrating tools or in conjunction with contact sports, appears to be a risk factor (170–172). Osteoarthritis is frequently reported but often not related to any major functional impairment. Most patients with AC joint osteoarthritis probably have no pain and no other indication of a joint disease. Some degree of osteoarthritis is often regarded as a normal age degeneration phenomenon (173). Pain is localized to the joint area and aggravated particularly by overhead use of the limb. Plain-film x-rays show narrowing of the cartilage space and osteophytes. Treatment is often not indicated. NSAID and/or a local injection of corticosteroids may be helpful. In severe cases surgery is justified (174).

8.5.6 Cervicobrachial Syndrome

Cervicobrachial pain syndrome is a non-specific term used for pain in the shoulder and neck. Localized inflammation of the muscles (myositis or myalgia) or myofaschial sheets may be the cause.

Repetitive work strain, bad working positions, especially working with elevated arms, and static work such as computer terminal work have been associated with cervicobrachial syndrome (136, 138, 175–180).

The treatment of patients with non-specific symptoms is problematic. Job-rotation and other arrangements at the workplace combined with physiotherapy are recommended. Psychosocial factors must be examined, and the way the work routine is organized is strongly related to the risk of this kind of shoulder symptoms (181).

8.6 Injuries of the Elbow, Wrist and Hand

All common work-related hand and arm problems can be seen among farmers. Some studies indicate a risk for forearm problems among milkers (182, 183). Vibration is related to a variety of symptoms from the hands and arms in different occupations among farmers (184, 185) and lumberjacks (186, 187).

8.6.1 Epicondylitis

Epicondylitis is the result of inflammation of a tendon at its insertion (enthesis) onto bone at an epicondyle. Lateral and medial humoral epicondylitis are prevalent enthesopathies. Lateral epicondylitis (also called tennis elbow) is much more common than medial epicondylitis and affects more than 1% of the population (188, 189). Pain radiates to the proximal forearm, and weakness of grip is a common complaint. Most patients have no symptoms at rest. The typical finding at examination is localized tenderness over the lateral humeral epicondyle. Dorsiflexion of the wrist against resistance is painful. In more severe cases there is a soft tissue swelling overlying the epicondyle.

The prevalence of lateral epicondylitis has been studied in a number of cross-sectional studies indicating significant risks related to repetitive and manual work (190–194). Other studies do not support this finding (195, 196). No studies of the prevalence of epicondylitis among farmers are known.

The lesion usually heals untreated if harmful activity is eliminated. Physiotherapeutic measures are often helpful, especially stretching (197). NSAID may be helpful and in more established cases a localized steroid injection is effective. Repeated injections may be problematic and the effectiveness may decline. In chronic cases surgery may be recommended. To prevent further problems a brace for the forearm is useful to alter the leverage on the forearm muscles. It should be used only during activities (198). The long-term prognosis is good over the course of 2–3 years (193).

Medial epicondylitis is a similar condition but is much less prevalent. It is also called golfer's elbow but mostly occurs in people who have never played golf. Pain is experienced over the medial elbow and may radiate distally. Wrist movements are painful. Symptoms are mostly not as severe as experienced in lateral epicondylitis. Management is similar to that outlined for lateral epicondylitis.

8.6.2 Olecranon Bursitis

Olecranon bursitis presents as a localized swelling over the olecranon process of the elbow. It is a common condition and can result from trauma.

The trauma may be direct or repeated following recurrent friction and pressure. Penetration of the bursa may result in an infection. Some patients do not manifest symptoms other than the swelling; others have pain and localized tenderness. Two common generalized conditions, gout and rheumatoid arthritis, may be associated with olecranon bursitis.

Signs of increased warmth suggest infection. After infection has been ruled out, a corticosteroid injection into the bursa usually is beneficial. A protective pad to avoid re-injury may be recommended to those involved in activities that irritate the bursa.

8.6.3 Flexor Pronator Syndrome

The median nerve may be subject to entrapment in the cubital tunnel (199) and because of hypertrophy of the pronator teres muscle in the forearm (Figure 8.8) (200). This syndrome has been related to playing musical instruments (201). It is also found among female cow milkers who report frequent problems from the forearms (183). Sensory and motor manifestations may arise, but usually the symptoms are mild with some weakness and/or diffuse pain. The sensory disturbances may be similar to carpal tunnel syndrome. Local infiltration of steroids or anaesthetics may be used. In chronic or refractory cases surgical exploration might be indicated.

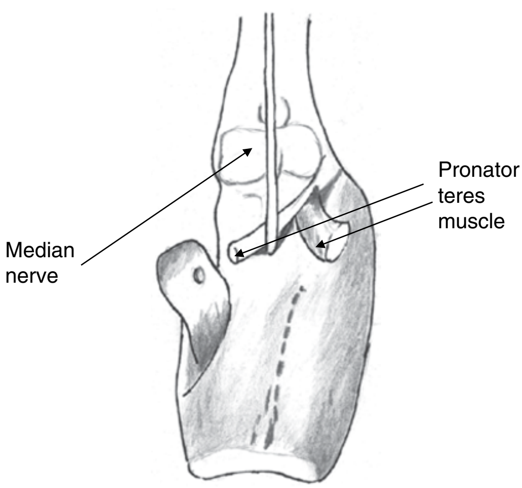


FIGURE 8.8 Compression of the median nerve during its passage through the pronator teres muscle.

8.6.4 De Quervain´s Tenosynovitis

Two of the tendons to the thumb, the abductor pollicis longus and the extensor pollicis brevis, pass in a common synovial sheath in a bony groove across the styloid process of the radius. At this point a stenosing tendosynovitis sometimes appears, related to repeated or heavy friction. De Quervain described the condition in the 19th century. The typical patient is a middle-aged female or a young mother with a child (202). Women milking cows and working with gardening might be at risk. Instant or repeated use of the thumb may start an inflammation of the tendon sheath resulting in a thickening and constriction of the two tendons.

Pain is associated with a pinch grip and may radiate proximally and distally. Pain is easily demonstrated at resisted contraction and on stretching. A *positive Finkelstein's test* is a reliable sign (flexion of the thumb across the palm in combination with ulnar deviation of the hand at the wrist generates pain.) Swelling and crepitus over the affected area are sometimes noted. X-ray will differentiate de Quervain's tenosynovitis must be separated from osteoarthritis of the first carpometacarpal joint.

Some patients do not need any special therapy, and rest from aggravating movements will benefit the patient. Anti-inflammatory drugs may be prescribed. Corticosteroid injection is helpful in most cases. Surgery is indicated only in those patients who have recurrent symptoms.

De Quervain's tenosynovitis should not be confused with intersection syndrome, which is a painful condition that affects the radial side of the forearm close to the wrist due to inflammation of the muscle bellies of the abductor pollicis longus and extensor pollicis brevis as they cross over the extensor carpi radialis longus and the extensor carpi radialis brevis. The mechanism of intersection syndrome injury is usually repetitive resisted extension, as with rowing, weight lifting, or gardening. Rest is the best treatment, supported with a wrist brace for some days.

8.6.5 Ulnar Nerve Entrapment or Compression

The most common site of ulnar nerve compression is behind the elbow where the nerve passes behind the medial epicondyle (199, 203). An additional location of entrapment can result from repeated pressure on the palm of the hand, which can cause a compression of the ulnar nerve at the wrist. The latter is reported in bicycle riders after gripping the handlebars for long periods, and in workers frequently using a hammer. In addition, the nerve might be compressed at Guyon's canal. Symptoms are mainly sensory with pain, numbness, and paresthesiae. Diagnosis might be confirmed by nerve conductivity tests. Resting the elbow or hand is the first step in management. An injection of corticosteroids might be given, and in severe cases surgery is indicated.

8.6.6 Trigger Finger

Stenosing tenosynovitis of the fingers or the thumb occurs as a result of nodule formation within a flexor tendon. Movement is restricted although the nodule usually is small. The finger is often locked and to unlock the finger the patient may extend it passively. A sudden snapping or "triggering" may be felt. As this occurs repeatedly, the tenosynovitis progresses so that the movements will be even more difficult. The formation of the nodule may be a complication to a simple tenosynovitis related to frequent grasping of hard objects. Tenosynovitis and nodule formation may also be related to rheumatoid arthritis and to diabetes (204, 205). Often surgery to incise the thickened tendon sheath is needed. Sometimes an injection of corticosteroids at the site of the lesion provides some relief.

8.6.7 Fractures and Nonunion of the Scaphoid

A young person falling on his or her outstretched hands may suffer a fracture of the scaphoid. The same type of trauma in the elderly probably will generate a Colle's fracture. X-rays must be conducted carefully. If the radiography is negative, the wrist should be immobilized for a week and repeat x-rays obtained. In case of a fracture, immobilization is needed for 4 months. A nonunion may generate symptoms long after the original injury. Surgical treatment is often necessary to deal with non-unions.

8.6.8 Carpal Tunnel Syndrome

Carpal tunnel syndrome (CTS) is a common disorder. The finger flexor tendons, the radial artery, and the median nerve pass through the carpal tunnel, which is a fibroosseous channel, bounded by the carpal bones and the transverse carpal ligament (Figure 8.9). The median nerve innervates the muscles of thumb opposition and is sensory to the first three fingers and half the fourth (Figure 8.10).

CTS is produced by entrapment of the nerve as it passes through the tunnel. CTS was first described in 1947 by Brain and others (206), and further described by Phalen and others (207, 208). The associations between CTS and pregnancy, rheumatoid arthritis, myxoedema, gout and diabetes have been known for some time (209). The apparent common anatomic feature to the various etiologic factors of CTS is the (inflammation related) thickening of the sheath surrounding the flexor tendons. Anatomic abnormalities and conditions after traumatic injuries such as Colle's fracture have also resulted in median neuropathy (210, 211). A significant relation between CTS and obesity has furthermore been demonstrated (suggesting the reason for the recent increase in CTS) (212, 213).

Numerous studies have demonstrated a strong relation of CTS to work (214, 215). Repetitive work, especially in combination with vibration, has been associated with CTS (216–221). Other studies have revealed continuous and powerful gripping to be an etiologic factor (222, 223). As with other musculoskeletal injuries, psychological and psychosocial factors may affect complaints of CTS (213), especially since worker's compensation is a frequent question regarding

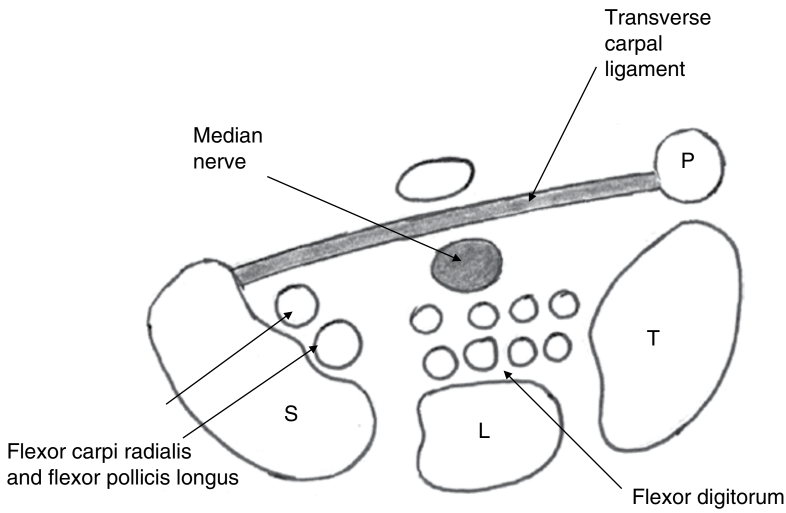


FIGURE 8.9 The carpal tunnel. S, scaphoideum; L, lunatum; T, triquetrum; P, piriformis.

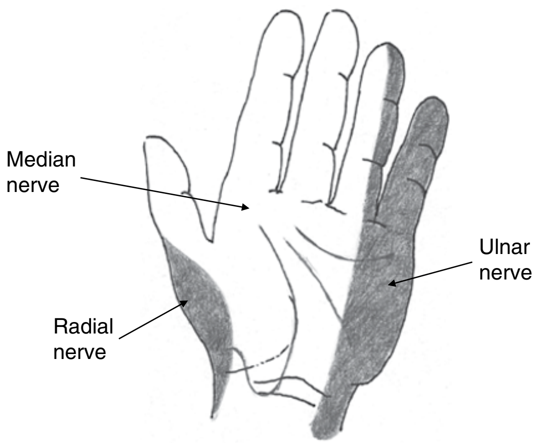


FIGURE 8.10 The sensory distribution of the median nerve.

CTS. Repetitive keyboard use is probably the most reported precipitating factor in litigation cases but the evidence for that kind of exposure as a causal factor is weak (224).

In farming relevant risk factors for CTS include being a middle-age female. Cow milking appears to be a risk for CTS (13) as is professional sheep shearing (14). Generally the patient suffers from pain and paresthesia in the region innervated by the median nerve (Figure 8.10). Pain is usually more severe at night. It may radiate up the arm and commonly disturbs sleep in early mornings. Most patients report the need to shake or move their hands or arms to make the pain and numbness abate. The diagnosis should never be delayed until signs of motor dysfunction appear.

Phalen's sign may be positive (hyperflexion of the wrists for a short period provokes paresthesias or dysesthesias in the median distribution). Tinel's sign (tapping over the area of entrapment provokes paresthesias) may also be positive. Durkan's or the closed fist test (applying a defined pressure direct over the carpal tunnel) (225) is considered to have the best combination of sensitivity and specificity of the three office-based tests (226). The definitive diagnose of CTS is based on of slowing of the nerve conduction velocity across the carpal tunnel. Prompt relief after injection of a steroid into the carpal tunnel may be used as a diagnostic tool. Signs of disturbed motor function are late symptoms (227).

If underlying medical conditions such as obesity, diabetes, or rheumatoid arthritis are identified these should be properly treated. Reduction of provocative work activities may require movement to another job or work modifications. In the early stages this may be the only measure necessary.

Injection of a steroid gives relief for only a limited period. Many patients are referred for surgery.

8.6.9 Dupuytren's Contracture

Dupuytren's contracture is a fibrous proliferation in the palmar fascia of the hand and sometimes the plantar fascia of the foot. The proliferation results in a progressive thickening and contracture. The skin becomes hypertrophic (228). The affected fingers develop a flexion deformity and cannot be extended. The etiology is unknown, but a number of conditions such as epilepsy and chronic alcoholism are associated with Dupuytren's contracture (229). Some observations indicate that multiple minor traumatic injuries may be etiologically associated with development of this condition (230, 231). Genetic factors are probably the paramount factors in this condition. Surgery is the only therapy.

8.6.10 Ganglion

A ganglion cyst is a fluid-filled swelling expanding from a joint or a tendon sheath. These cysts are commonly found at the dorsal part of the wrist, but sometimes also on the volar aspect of the wrist or around the ankle. They are more common among young women. Ganglions are mostly painless and may be easily observed as they protrude over the dorsum of the hand. Sometimes ganglions are not visible and they may also be painful in these cases. Many ganglions disappear without any special measure. They may be punctured and the fluid aspirated, or viscous fluid may be displaced by firm manual pressure. In chronic cases surgery to remove the sac may be required. Physical and repetitive work has been related to the genesis of ganglions and their progress (164, 232).

8.6.11 Herbeden–Bochards Osteoarthritis

Osteoarthritis of the finger joints is a very common problem among elderly women. The English physician William Heberden first described it in the 18th century. The degenerative process often starts in the distal inter-phalangeal joints but may progress to most of the small joints of the hand. The condition is usually believed to be a hereditary form of osteoarthritis, and it is much more common among females. In most cases no treatment is required, and only in extreme cases is work capacity reduced.

8.6.12 Osteoarthritis of the First Carpometacarpal Joint

Osteoarthritis of the first carpometacarpal joint (CMC I) is a very common disorder. The cause is unknown in most cases and very often the osteoarthritis is asymptomatic. Some patients, however, have pain when using the thumb and differential diagnosis may include de Quervain's disease. A relation to exposure in farming has been reported. Older farmers often relate injuring their thumbs on the tractor steering wheel before improved steering mechanisms for tractors were introduced in the late 1940s. The direct mechanical link between the tractor wheels and the steering wheel in old tractors sometimes made the steering wheel rotate quickly and unpredictably with great force when the tractor hit a bump. The driver could catch his thumb on the wheel, causing injury. It is possible that this common "historical" trauma may be related to later problems of osteoarthritis of the thumbs.

Plain-film x-rays will demonstrate the diagnosis. An orthosis to immobilize the thumb may be helpful. NSAID may also be helpful. A few patients have more recurrent difficulties and more pain. They may be candidates for surgery, mostly an arthroplasty.

8.7 Injuries of the Hip

8.7.1 Trochanteritis

The greater trochanter of the femur is the site of powerful muscles (gluteus medius and gluteus minimus). A bursa is located between the two muscles, and a second bursa is located between the gluteus medius and the tensor fascia lata (Figure 8.11). Inflammatory reactions such as

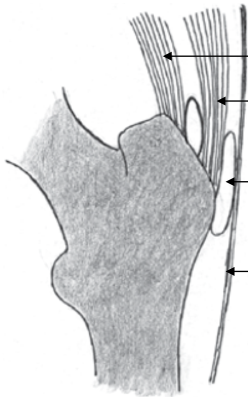


FIGURE 8.11 The trochanteric bursa.

bursitis and tendonitis and/or enthesopathy are common soft tissue lesions in this region and it is often difficult to distinguish between the different locations (bursa, tendon, tendon insertion). Often there is a combination of inflamed structures. Pain and tenderness are located to the lateral aspect of the trochanteric area, and in more severe cases the pain may radiate distally. The problems may follow a direct trauma (233), but more commonly there is a gradual onset. Trochanteritis is related to sporting activities (e.g., football or rugby) but it is also reported in the middle-aged and elderly, often overweight females (234).

Tenderness is characteristically localized over the trochanter and is palpated with the patient lying on the unaffected side. Pain may be reproduced by resisted contraction of the muscles. Arthritis of the hip joint is excluded by radiography. Physiotherapy in combination with NSAID may be helpful, and the patient should rest from activities that produce pain. An injection of a corticosteroid in combination with local anesthetic may also help the patient.

8.7.2 Osteoarthritis of the Hip

Osteoarthritis of the hip can result from several factors, including (1) congenital hip disease, (2) Legg–Perthes disease, (3) slipped upper femoral epiphysis, and (4) trauma with fracture engaging the femoral head or the acetabulum. A relatively large number of studies have demonstrated a relationship between osteoarthritis of the hip and farming (8–10, 235, 236). A comparison of colon roentgenograms and urograms on farmers to an urbanized population demonstrated a ten-fold overrepresentation of osteoarthritis among the farmers (11). The high risk of osteoarthritis of the hip among farmers has been proposed to be associated with tractor driving (237). However, another study demonstrated a significant risk of osteoarthritis associated with animal contacts (dairy farming and swine production) with no special risk to tractor drivers (12). In some rural areas, osteoarthritis of the hip is such a common disorder that most farmers know one or more fellow farmers with the disease. Osteoarthritis of the hip in relation to other occupations has been investigated (9, 238), but farming has shown the highest consistency in results.

Osteoarthritis of the hip as well as the knee is also related to obesity and negatively related to osteoporosis (239). Smoking is also negatively associated with osteoarthritis (8, 240). Osteoarthritis is a disease of the articular cartilage. The cartilage surface degenerates with fibrillation, fissures, and a general loss of cartilage. A low-grade inflammatory reaction occurs (241, 242) and as the disease progress the subchondral bone is affected and osteophytic changes appear at the margin of the cartilage. In severe cases the cartilage has disappeared, bone attrition is established, and the bone structure degenerates. The disorder may be one-sided at first but often the other hip joint is affected later.

Pain is first noticed in the groin and anteriomedial part of the thigh. The onset is insidious. The correlation between the radiological changes and the degree of pain is not consistent. Most patients first notice problems after they have been walking on rough ground, in snow, or during some unaccustomed activity. Later the patients may have pain not only during activity but also at rest and during the night. Initially the patient observes only slight restriction of movement, but this progresses and bending at the

FIGURE 8.12 Plain-film x-ray of the pelvis and hip joints showing osteoarthritis of the left hip joint. (Source: Department of Radiology, Central Hospital, Wexiö, Sweden.)

waist becomes difficult, especially in the morning. Patients may have problems putting on socks or tying shoelaces. Tolerable walking distance is reduced, and the patient develops a limp. The rate of impairment is variable. Some patients pass from first symptoms to surgery in a 2-year period while others just have small problems for decades. In severe cases the range of motion is restricted in all directions and often there is a reduction of leg length. A plain-film x-ray gives the diagnosis (Figure 8.12).

In early cases the patient may be helped by NSAID therapy. Physiotherapy and systematic exercise reduce the functional problems and prepare the patient for a more rapid recovery when surgery is performed (243). If the patient is obese, weight loss is desirable. In severe cases a total hip replacement operation is the standard procedure.

After hip replacement surgery, most patients rapidly recover. Their pain is gone and the range of motion in most cases is dramatically restored. Farmers are anxious to return to full-time work following surgery. This may be problematic and most orthopedists recommend that the patient takes a low-risk, physically light job to avoid problems with the prosthesis.

8.8 Injuries of the Knee, Ankle, and Foot

8.8.1 Knee Ligament Injuries

Ligament sprains and strains are common soft tissue injuries prevalent in athletic workers. Farmers active in handling cattle or pigs are at risk of these injuries. Knee injuries are also frequently reported in dairy farmers who work daily directly with 600–700-kg livestock. Accurate diagnosis of knee ligament sprains is difficult. MRI and arthroscopy may be essential tools.

Long-term difficulties may be related to untreated ligament injuries (244). Rupture of the cruciate ligaments may not be properly diagnosed. Defects may result in a feeling of instability, pain, and a secondary development of osteoarthritis. Patients with knee instability usually report a previous trauma, but not always. Patients with chronic knee problems related to ligament injuries should be referred to orthopedic surgeons and specialists in sports medicine.

8.8.2 Bursitis of the Knee

Working on the knees (e.g., milking cows, repairing machinery, cleaning etc.) or a direct blow can produce a prepatellar bursitis. The prepatellar bursa as well as the infrapatellar bursa is exposed to pressure in many types of jobs. Localized swelling with no warmth is noted in the front of the patella. The treatment is usually symptomatic. Aspiration may be done but often the bursa refills quickly.

8.8.3 Chondromalacia Patellae

A softening, fibrillation, and roughening of the under-surface of the patellar articular cartilage is called chondromalacia. The pathological changes differ from those of osteoarthritis (245). Chondromalacia is generally not a progressive disorder.

Chondromalacia patients report pain as a deep-seated ache in the retropatellar area. Sitting for a prolonged time in cars, planes, or tractors with the knee flexed is problematic. The patient may have to get up and walk around for a while. Stiffness and a sensation of instability of the knee are frequently reported. Exercises to strengthen the quadriceps are essential therapy. Stretching may also be helpful and activities that can provoke pain should be avoided. NSAIDs may be given. The long-term prognosis is good. Other forms of retropatellar dysfunction may need to be differentiated by use of MRI or other diagnostic procedures (246, 247).

8.8.4 Injuries of the Meniscus

Tears of the meniscus are a common injury among males between 20 and 30 years of age. Tears may occur in any type of sports, most commonly contact sports. Farmers handling cattle (especially dairy farmers) are at risk, as well as those in occupations with prolonged squatting or kneeling, and the elderly (degenerative changes). Frequently patients with defective meniscus do not remember any specific trauma related to their injury. Symptoms of meniscal injuries of may arise long after the initial trauma.

A history of the knee "locking up" is characteristic. This indicates that a fragment of the meniscus is trapped between the condyles of the femur and tibia, preventing further motion. Some patients report painful "clicks" when they walk or a "snapping" sensation. Swelling in the knee is often present and the patient commonly has a feeling of instability of the knee. Quadriceps atrophy is a common finding. MRI or arthroscopy confirms the diagnosis. Most patients are effectively helped by arthroscopic surgery. Injuries of the meniscus and/or excision of the meniscus predispose to later development of osteoarthritis (248, 249) therefore early surgical repair may reduce osteoarthritis in the affected joints in later years.

8.8.5 Baker's Cyst

Baker's cyst (popliteal cyst) in the popliteal fossa communicates with the synovial cavity of the knee. Inflammation of the knee, which generates excess synovial fluid, may therefore result in swelling of the popliteal fossa. The patient reports a feeling of tension in the back of the knee and sometimes pain. Examination and treatment of this condition should focus on the knee joint.

8.8.6 Osteoarthritis of the Knee

Farmers appear to be at elevated risk of degenerative osteoarthritis of the knee (9, 250) although results have not been reproduced in all studies (251, 252).

Osteoarthritis of the knee is a prevalent disorder among the elderly. As farmers are often elderly, they often have osteoarthritis-related knee symptoms. The condition is more common among women and there is a strong relation to obesity (249, 253). Previous injuries such as tears of the meniscus, ligament sprains, and knee instability may all contribute to future osteoarthritis of the knee. The process may start in any of the cartilage areas and eventually expand to all of these compartments. Medial tibiofemoral osteoarthritis is the most common form (Figure 8.13).

FIGURE 8.13 Plain-film x-ray of the left (sin) knee showing osteoarthritis of the knee. (Source: Department of Radiology, Central Hospital, Wexiö, Sweden.)

Many occupations have an increased risk of osteoarthritis of the knee, including mining, dock work, and shipyard work (254–256). Work that requires squatting, sitting, or kneeling has been related to osteoarthritis of the knee (257–259).

Osteoarthritis of the knee has pathology similar to osteoarthritis in other major joints. In severe cases of knee osteoarthritis a varus (or valgus) deformity may develop. A disparity in leg length may follow and the patient may acquire a limp. The disorder may be in one leg first, but often the other knee joint is affected later. As the degenerative process progresses, the knee starts to deform. Excess synovial fluid resulting in swelling and crepitus is a common finding. Movement of the joint is restricted.

Plain-film x-ray is useful for diagnosis, but it should be carried out while standing so as not to miss the narrowing of the cartilage space. In early cases, tears of the meniscus, chondromalacia, or loose pieces of the cartilage in the joint space may be included in a differential diagnosis.

Physical therapy and activity are important to maintain the quadriceps muscle capacity and the stability of the joint (260). Weight loss is necessary if the patient is overweight. Anti-inflammatory drugs may be used as well as localized steroid injections. A brace for the knee may be used temporarily. Several surgical interventions are often very successful. In cases with a significant and dominating medial tibiofemoral osteoarthritis, a wedge osteotomy may help the patient for many years. In other cases a unilateral or total knee replacement arthroplasty is the best option.

8.8.7 Ankle Sprains

Ankle sprains and malleolar fractures are common in farming after slipping on icy or muddy ground or during a struggle with cattle or horses. The ankle is supported by a large number of ligaments connecting the tibia and fibula with the talus and calcaneus. The ligament most often injured is the anterior talofibular ligament, but often several of the ligaments are sprained. A sprain is often combined with a malleolar fracture. Plain-film x-rays can rule out a fracture (but it may take several views and an experienced reader to identify an ankle fracture). Pain may vary from minimal to severely limiting walking. Local swelling and tenderness are found at the site of ligament damage. If not properly treated, ankle fractures and complicated ligament injuries may result in the development of osteoarthritis and other disabling conditions.

8.9 General Disorders, Infections, and Reactive Arthritis

Rheumatoid diseases are alterations of the immune system for which the complete etiologies are not fully known. Exposure to certain microbes, hereditary factors, certain occupational activities, and certain organic dust exposures are possible risk factors related to rheumatoid arthritis (261, 262). No studies have been found indicating any association between farming and rheumatoid diseases. Rheumatoid arthritis – and in some instances possibly psoriasis – is a chronic disabling disease.

8.9.1 Inflammatory Bowel Diseases

Ulcerative colitis and Crohn's disease are both chronic inflammatory bowel diseases that sometimes are accompanied by arthritic symptoms (263). A special relationship between Crohn's disease and ankylosing spondylitis has been described (264). It has also been shown that Crohn's disease is more common among people engaged in sedentary work (265, 266) and less prevalent among farmers (267). The predicted mortality risk for farmers is 30% below that for comparison populations.

8.9.2 Reactive Arthritis

Reactive arthritis is classically seen following infection with enteric pathogens such as Salmonella, Shigella, Campylobacter, or Yersinia. Other pathogens may also sometimes generate arthritic symptoms (268, 269). The etiologic mechanisms may be related to those previously discussed for ankylosing spondylitis (270). Many of these infectious agents may be found in a farming environment. Most concerns are a veterinary responsibility but all these infections may also be a zoonotic risk (271, 272).

In children younger than 10 years, post-infective arthritis may be more severe than the enteric infection (273). Symptoms of arthritis may arise a few days to a month after the onset of gastrointestinal symptoms. Often the symptoms persist for months. Joint abnormalities are reported more often in Scandinavian countries than in the United States (274, 275). Arthritic complications are more common and more severe among individuals who have the HLA-B27 histocompatability type. Patients with autoimmune abnormalities and arthritis symptoms should be screened for serologic or cultural evidence for a Yersinia infection (276).

Direct septic infections caused by Yersinia and Salmonella are occasional causes of spondylitis and focal osteomyelitis (277). Salmonella osteomyelitis may involve any part of the skeleton but most commonly affects the long bones, the chondrosternal junctions, and the spine. Persons with sickle cell disease or prosthesis are at special risk (278).

8.10 Prevention of Musculoskeletal Disorders

The prevention of agricultural musculoskeletal disorders associated with agricultural work is challenging at best due to the variety of the work, the variable nature of the commodity handled, and the work environment. However, the principles of ergonomic assessment can be applied to agricultural tasks to reduce ergonomic risk factors. Assistance by occupational health and safety specialists, agricultural health and safety research centers, or university Extension in assessing equipment and work practices can be helpful in preventing musculoskeletal disorders. The National Institute of Occupational Safety and Health (NIOSH) has published *Simple Solutions for Agriculture: Ergonomics for Farm Worker* (http://www.cdc.gov/niosh/docs/2001-111), which highlights various modified tools such as lifting stands, carts, pallet systems, and manure scraper systems for nurseries, animal production, and vegetable and berry production. Ongoing research into other ergonomic designs include hand grips for nursery tools, pneumatic shears for pruning fruit trees, back support for ground crop harvesting, weeding tools, tub size for grape harvest, carts to move cattle feed bags, and support belts for fruit-picking buckets to name just a few (279). Other important interventions include rest breaks and position changes in repetitive work such as fruit and berry harvesting, and cultivating and meat packing.

8.11 Summary

Knowledge of the work of farmers is important to enable healthcare providers to understand and help their patients with physical work-related problems. Musculoskeletal disorders and pain are the most common reasons for doctor visits among farmers. The symptoms are often related to specific tasks. The risk for static and/or repetitive work is significant in many modern farming operations and more common along with increasing specialization.

A large number of reports over the years have indicated a risk of low back pain among farmers often related to tractor driving (2–6). However, most of these studies have been unable to ascribe causality. Further research and longitudinal studies are needed for a better understanding of work-related low back pain among farmers.

Psychosocial issues (depression, family difficulties, and economic problems) may predispose to chronic pain. The point is that the health professional may be challenged to determine work-related injuries in the absence of objective signs of physical injury or disease. Psychosocial conditions may be important etiologic factors of chronic pain or effect modifiers.

Intervertebral disk degeneration is common. A common belief is that disk degeneration and disk hernia (with or without sciatic symptoms) emerge because of heavy work, heavy lifting, or turning or twisting at the waist. However, research involving workers in traditionally heavy jobs shows that they have fewer back problems and less sick leave due to sciatica than a comparison population. Numerous studies have failed to show a relation between mechanical stress on the back and degenerative disk changes. Other studies have found only a weak relation between disk degeneration and occupation. Almost half of the general population of middle age and beyond have MRI-objective disk changes. One-third of individuals without symptoms have disk changes, and 50% of those with symptoms have normal MRIs.

A relatively large number of studies have demonstrated a relationship between osteoarthritis of the hip and farming (2 to 10 times increased risk among farmers). The etiologic mechanisms are not known, but has been proposed to be associated with tractor driving. However, one study demonstrated a significant risk of osteoarthritis associated with animal contacts (dairy farming and swine production) with no special risk to tractor drivers. In some rural areas, osteoarthritis of the hip is such a common disorder that most farmers know one or more fellow farmers with the disease. Osteoarthritis of the knee may also be a common disorder among farmers. Osteoarthritis of the hip and knee as well as degenerative back disorders may all be related to chronic inflammatory processes. These processes may be due to exposures in farming other than physical load.

Key Points

1. Musculoskeletal symptoms and disorders are the most common reasons for physician visits among farmers.
2. Psychosocial conditions like loneliness, poor profitability, and economic problems can have a strong connection with various pain conditions.
3. Chronic back pain is common in all occupational groups, including farmers, but heavy physical labor has little correlation with the presence of various spinal disorders.
4. Chronic hip problems are common among farmers and are likely to have a relationship with any type of occupational exposure.
5. Recent research suggests that inflammatory processes related to contaminated dust or infectious agents from animals may have a causal relationship with back and joint problems.

References

1. Cassvan AW, Weiss L, Weiss JM, Rook JL, Mullens SU. Cumulative Trauma Disorders. Boston: Butterworth-Heinemann; 1997.
2. Magora A. Investigation of the relation between low back pain and occupation. 6. Medical history and symptoms. Scand J Rehabil Med. 1974;6(2):81–8.
3. Rosegger RR, Rosegger S. Health effects of tractor driving. J Agric Eng Res. 1960;5:241–275.
4. Penttinen J. Back Pain and Sciatica in Finnish Farmers [monograph]. Helsinki: The Research Institute for Social Security; 1987.
5. Holmberg S, Stiernström EL, Thelin A, Svärdsudd K. Musculoskeletal symptoms among farmers and non-farmers: a population-based study. Int J Occup Environ Health. 2002;8(4):339–45.
6. Holmberg S, Thelin A, Stiernström EL, Svärdsudd K. Psychosocial factors and low back pain, consultations, and sick leave among farmers and rural referents: a population-based study. J Occup Environ Med. 2004;46(9):993–8.
7. McLean SM, May S, Klaber-Moffett J, Sharp DM, Gardiner E. Risk factors for the onset of non-specific neck pain: a systematic review. J Epidemiol Community Health. 2010;64(7):565–72.
8. Thelin A, Jansson B, Jacobsson B, Ström H. Coxarthrosis and farm work: a case-referent study. Am J Ind Med. 1997;32(5):497–501.
9. Vingård E, Alfredsson L, Goldie I, Hogstedt C. Occupation and osteoarthrosis of the hip and knee: a register-based cohort study. Int J Epidemiol. 1991;20(4):1025–31.
10. Croft P, Cooper C, Wickham C, Coggon D. Osteoarthritis of the hip and occupational activity. Scand J Work Environ Health. 1992;18(1):59–63.
11. Axmacher B, Lindberg H. Coxarthrosis in farmers. Clin Orthop. 1993(287):82–6.
12. Thelin A, Vingård E, Holmberg S. Osteoarthritis of the hip joint and farm work. Am J Ind Med. 2004;45(2):202–9.

13. Stål M, Hansson GA, Moritz U. Wrist positions and movements as possible risk factors during machine milking. Appl Ergon. 1999;30(6):527–33.
14. Monsell FP, Tillman RM. Shearer's wrist: the carpal tunnel syndrome as an occupational disease in professional sheep shearers. Br J Ind Med. 1992; 49(8):594–5.
15. Stål M, Hagert CG, Moritz U. Upper extremity nerve involvement in Swedish female machine milkers. Am J Ind Med. 1998;33(6):551–9.
16. Waddell G. Volvo award in clinical sciences. A new clinical model for the treatment of low-back pain. Spine. 1987;12(7):632–44.
17. Miller H. Accident neurosis. Br Med J 1961; 5230:919–25.
18. Snelgrove S, Liossi C. Living with chronic low back pain: a metasynthesis of qualitative research. Chronic Illn. 2013;9(4):283–301.
19. Linton SJ. A review of psychological risk factors in back and neck pain. Spine. 2000;25(9):1148–56.
20. Bigos SJ, Battie MC, Spengler DM, Fisher LD, Fordyce WE, Hansson TH, et al. A prospective study of work perceptions and psychosocial factors affecting the report of back injury. Spine. 1991;16(1):1–6.
21. Palmer KT, Walker-Bone K, Griffin MJ, Syddall H, Pannett B, Coggon D, et al. Prevalence and occupational associations of neck pain in the British population. Scand J Work Environ Health. 2001;27(1): 49–56.
22. Linton SJB, Buer N, Vlayen J, Hellsing A. Are fear-avoidance beliefs related to a new episode of back pain? Psychol Health. 1999;14:1051–1059.
23. Mannion AF, Dolan P, Adams MA. Psychological questionnaires: do "abnormal" scores precede or follow first-time low back pain? Spine. 1996; 21(22):2603–11.
24. Dworkin RH. Compensation in chronic pain patients: cause or consequence? Pain. 1990; 43(3):387–8.
25. Cherkin DC, Deyo RA, Street JH, Barlow W. Predicting poor outcomes for back pain seen in primary care using patients' own criteria. Spine. 1996;21(24):2900–7.
26. Jonsson E, Nachemson, A. Ont i ryggen. Ont i nacken. Stockholm: SBU; 2000.
27. Theorell T, Harms-Ringdahl K, Ahlberg-Hulten G, Westin B. Psychosocial job factors and symptoms from the locomotor system – a multicausal analysis. Scand J Rehabil Med. 1991;23(3):165–73.
28. Bongers PM, de Winter CR, Kompier MA, Hildebrandt VH. Psychosocial factors at work and musculoskeletal disease. Scand J Work Environ Health. 1993;19(5):297–312.
29. Hemingway H, Shipley MJ, Stansfeld S, Marmot M. Sickness absence from back pain, psychosocial work characteristics and employment grade among office workers. Scand J Work Environ Health. 1997; 23(2):121–9.
30. Croft PR, Lewis M, Papageorgiou AC, Thomas E, Jayson MI, Macfarlane GJ, et al. Risk factors for neck pain: a longitudinal study in the general population. Pain. 2001;93(3):317–25.
31. Schaefer C, Sadosky A, Mann R, Daniel S, Parsons B, Tuchman M, et al. Pain severity and the economic burden of neuropathic pain in the United States: BEAT Neuropathic Pain Observational Study. Clinicoecon Outcomes Res. 2014;6:483–96.
32. Freund B, Schwartz M. Post-traumatic myofascial pain of the head and neck. Curr Pain Headache Rep. 2002;6(5):361–9.
33. Fransen M, Woodward M, Norton R, Coggan C, Dawe M, Sheridan N. Risk factors associated with the transition from acute to chronic occupational back pain. Spine. 2002;27(1):92–8.
34. Travell JGS, Simons DG. Myofascial pain and dysfunction. In: The Trigger Point Manual. Baltimore: Williams & Wilkins; 1983.
35. Reiffenberger DH, Amundson LH. Fibromyalgia syndrome: a review. Am Fam Physician. 1996;53(5): 1698–712.
36. Quintner JL, Cohen ML. Referred pain of peripheral nerve origin: an alternative to the "myofascial pain" construct. Clin J Pain. 1994;10(3):243–51.
37. Wolfe F, Simons DG, Fricton J, Bennett RM, Goldenberg DL, Gerwin R, et al. The fibromyalgia and myofascial pain syndromes: a preliminary study of tender points and trigger points in persons with fibromyalgia, myofascial pain syndrome and no disease. J Rheumatol. 1992;19(6):944–51.
38. Hubbard DR, Berkoff GM. Myofascial trigger points show spontaneous needle EMG activity. Spine. 1993;18(13):1803–7.
39. Hanock J. Comments on Barnsley et al. Pain. 1995;61:487–495.
40. Boureau F, Delorme T, Doubrere JF. [Mechanisms of myofascial pain]. Rev Neurol (Paris). 2000;156(Supp l.4):4S10–4.
41. Hong CZ. New trends in myofascial pain syndrome. Zhonghua Yi Xue Za Zhi (Taipei). 2002;65(11): 501–12.
42. Bjurström MF, Giron SE, Griffis CA. Cerebrospinal fluid cytokines and neurotrophic factors in human chronic pain populations: A comprehensive review. Pain Pract. 2014.
43. Yunus MB. Towards a model of pathophysiology of fibromyalgia: aberrant central pain mechanisms

with peripheral modulation. J Rheumatol. 1992; 19(6):846–50.
44. Guo D, Hu J. Spinal presynaptic inhibition in pain control. Neuroscience. 2014; Dec 26:283.95.
45. Zeilhofer HU, Wildner H, Yevenes GE. Fast synaptic inhibition in spinal sensory processing and pain control. Physiol Rev. 2012;92(1):193–235.
46. Ferrari R, Russell AS. Regional musculoskeletal conditions: neck pain. Best Pract Res Clin Rheumatol. 2003;17(1):57–70.
47. Marchiori DM, Henderson CN. A cross-sectional study correlating cervical radiographic degenerative findings to pain and disability. Spine. 1996; 21(23):2747–51.
48. Skov T, Borg V, Orhede E. Psychosocial and physical risk factors for musculoskeletal disorders of the neck, shoulders, and lower back in salespeople. Occup Environ Med. 1996;53(5):351–6.
49. Steilen D, Hauser R, Woldin B, Sawyer S. Chronic neck pain: making the connection between capsular ligament laxity and cervical instability. Open Orthop J. 2014;8:326–45.
50. Bigos SJ, Battie MC, Fisher LD, Hansson TH, Spengler DM, Nachemson AL. A prospective evaluation of preemployment screening methods for acute industrial back pain. Spine. 1992;17(8):922–6.
51. Riihimäki H, Tola S, Videman T, Hänninen K. Low-back pain and occupation. A cross-sectional questionnaire study of men in machine operating, dynamic physical work, and sedentary work. Spine. 1989; 14(2):204–9.
52. Weiss LD. Occupation-Related Cumulative Trauma Disorders. In: Cassvan AW, Weiss, LD, Weiss JM, Rook JL, Mullens SU, editors. Cumulative Trauma Disorders. Newton: Butterworth-Heinemann; 1997.
53. Palmer KT, Cooper C, Walker-Bone K, Syddall H, Coggon D. Use of keyboards and symptoms in the neck and arm: evidence from a national survey. Occup Med (Lond). 2001;51(6):392–5.
54. Holte KA, Vasseljen O, Westgaard RH. Exploring perceived tension as a response to psychosocial work stress. Scand J Work Environ Health 2003;29(2): 124–33.
55. Benoist M, Rouaud JP. Whiplash: myth or reality? Joint Bone Spine. 2002;69(4):358–62.
56. Kwan O, Friel J. A review and methodologic critique of the literature supporting 'chronic whiplash injury'. Part II. Reviews, editorials, and letters. Med Sci Monit. 2003;9(9):RA230–6.
57. Ferrari R. Re: Whiplash disorders – a review. Injury. 2003;34(10):803–5; author reply 805–6.
58. Lovell ME, Galasko CS. Whiplash disorders – a review. Injury .2002;33(2):97–101.
59. Williams M, Williamson E, Gates S, Lamb S, Cooke M. A systematic literature review of physical prognostic factors for the development of Late Whiplash Syndrome. Spine. 2007;32(25):E764–80.
60. Quebec Task Force. Quebec Task Force report on whiplash associated disorders. Section 4. Best evidence synthesis. Spine. 1995;85:24–33.
61. Taylor JR, Twomey LT. Acute injuries to cervical joints. An autopsy study of neck sprain. Spine. 1993;18(9):1115–22.
62. Rauschning W, McAfee PC, Jonsson H, Jr. Pathoanatomical and surgical findings in cervical spinal injuries. J Spinal Disord. 1989;2(4):213–22.
63. Atlas SJ, Deyo RA, Patrick DL, Convery K, Keller RB, Singer DE. The Quebec Task Force classification for spinal disorders and the severity, treatment, and outcomes of sciatica and lumbar spinal stenosis. Spine. 1996;21(24):2885–92.
64. Ferrari R. The Whiplash Encyclopedia: The facts and myths of whiplash. Gaitersburg: Aspen Publishers; 1999.
65. Pearce JM. A critical appraisal of the chronic whiplash syndrome. J Neurol Neurosurg Psychiatry. 1999;66:273–276.
66. Barnsley L, Lord S, Bogduk N. Whiplash injury. Pain 1994;58(3):283–307.
67. Pennie B, Agambar L. Patterns of injury and recovery in whiplash. Injury. 1991;22(1):57–9.
68. Schrader H, Obelieniene D, Bovim G, Surkiene D, Mickeviciene D, Miseviciene I, et al. Natural evolution of late whiplash syndrome outside the medicolegal context. Lancet. 1996;347(9010):1207–11.
69. Partheni M, Miliaras G, Constantoyannis C, Papadakis N. Whiplash injury. J Rheumatol. 1999;26(5):1206–7; author reply 1208–10.
70. Giebel GD, Bonk AD, Edelmann M, Huser R. Whiplash injury. J Rheumatol. 1999;26(5):1207–8; author reply 1208–10.
71. Mills H, Horne G. Whiplash – manmade disease? N Z Med J. 1986;99(802):373–4.
72. Awerbuch MS. Whiplash in Australia: illness or injury? Med J Aust. 1992;157(3):193–6.
73. Cassidy JD, Carroll LJ, Cote P, Lemstra M, Berglund A, Nygren A. Effect of eliminating compensation for pain and suffering on the outcome of insurance claims for whiplash injury. N Engl J Med. 2000;342(16):1179–86.
74. Nijs J, Van Oosterwijck J, De Hertogh W. Rehabilitation of chronic whiplash: treatment of cervical dysfunctions or chronic pain syndrome? Clin Rheumatol. 2009;28(3):243–51.
75. Carroll LJ, Hogg-Johnson S, Cote P, van der Velde G, Holm LW, Carragee EJ, et al. Course and prognostic

factors for neck pain in workers: results of the Bone and Joint Decade 2000–2010 Task Force on Neck Pain and its Associated Disorders. Spine. 2008; 33(4Suppl.):S93–100.
76. Leboeuf-Yde C, Klougart N, Lauritzen T. How common is low back pain in the Nordic population? Data from a recent study on a middle-aged general Danish population and four surveys previously conducted in the Nordic countries. Spine. 1996;21(13):1518–25; discussion 1525–6.
77. Picavet HS, Struijs JN, Westert GP. Utilization of health resources due to low back pain: survey and registered data compared. Spine. 2008;33(4):436–44.
78. Osborne A, Blake C, Meredith D, McNamara J, Phelan J, Cunningham C. The lived experience of low back pain among Irish farmers: case studies. J Agromedicine. 2014;19(2):181–90.
79. Deyo RA. Measuring the functional status of patients with low back pain. Arch Phys Med Rehabil. 1988;69(12):1044–53.
80. Hansson TH. Ländryggsbesvär och arbete. Stockholm: Arbetsmiljöfonden; 1989.
81. Walker-Bone K, Palmer KT. Musculoskeletal disorders in farmers and farm workers. Occup Med (Lond). 2002;52(8):441–50.
82. Osborne A, Blake C, Fullen BM, Meredith D, Phelan J, McNamara J, Cunninghem C. Prevalence of musculoskeletal disorders among farmers: A systematic review. Am J Ind Med. 2012;55(2): 143–158.
83. Fethke NB, Merlino LA, Gerr F, Schall MC, Jr., Branch CA. Musculoskeletal pain among Midwest farmers and associations with agricultural activities. Am J Ind Med. 2014.
84. Schultze K-JP, J. Berufsbedingte Wirbelsäulenschäden bei Traktoristen und Landwirten. Beit Orthoped u Traumatol. 1979;26:356–362.
85. Wickstrom G. Effect of work on degenerative back disease. A review. Scand J Work Environ Health. 1978;4(Suppl.1):1–12.
86. Boshuizen HC, Bongers PM, Hulshof CT. Self-reported back pain in tractor drivers exposed to whole-body vibration. Int Arch Occup Environ Health. 1990;62(2):109–15.
87. Boshuizen HC, Hulshof CT, Bongers PM. Long-term sick leave and disability pensioning due to back disorders of tractor drivers exposed to whole-body vibration. Int Arch Occup Environ Health. 1990; 62(2):117–22.
88. Lings S, Leboeuf-Yde C. Whole-body vibration and low back pain: a systematic, critical review of the epidemiological literature 1992–1999. Int Arch Occup Environ Health. 2000;73(5):290–7.
89. Park H, Sprince NL, Whitten PS, Burmeister LF, Zwerling C. Risk factors for back pain among male farmers: analysis of Iowa Farm Family Health and Hazard Surveillance Study. Am J Ind Med. 2001; 40(6):646–54.
90. Holmberg S, Thelin A, Stiernström E, Svärdsudd K. The impact of physical work exposure on musculoskeletal symptoms among farmers and rural non-farmers. Ann Agric Environ Med. 2003;10(2):179–84.
91. Kellgren JH, Lawrence JS. Osteo-arthrosis and disk degeneration in an urban population. Ann Rheum Dis. 1958;17(4):388–97.
92. Hirsch C, Ingelmark BE, Miller M. The anatomical basis for low back pain. Studies on the presence of sensory nerve endings in ligamentous, capsular and intervertebral disc structures in the human lumbar spine. Acta Orthop Scand. 1963;33:1–17.
93. Krämer J. Biomechanische Veränderungen im lumbalen Bewegungssegment. Die Wirbelsälue in Forschung und Praxis. Stuttgart: Hippokrates Verlag; 1973.
94. Farfan HF. A reorientation in the surgical approach to degenerative lumbar intervertebral joint disease. Orthop Clin North Am. 1977;8(1):9–21.
95. Videman T, Nurminen M, Troup JD. 1990 Volvo Award in clinical sciences. Lumbar spinal pathology in cadaveric material in relation to history of back pain, occupation, and physical loading. Spine. 1990;15(8):728–40.
96. Evans W, Jobe W, Seibert C. A cross-sectional prevalence study of lumbar disc degeneration in a working population. Spine. 1989;14(1):60–4.
97. Modic MT, Herfkens RJ. Intervertebral disk: normal age-related changes in MR signal intensity. Radiology. 1990;177(2):332–3; discussion 333–4.
98. Savage RA, Whitehouse GH, Roberts N. The relationship between the magnetic resonance imaging appearance of the lumbar spine and low back pain, age and occupation in males. Eur Spine J. 1997;6(2):106–14.
99. Boos N, Rieder R, Schade V, Spratt KF, Semmer N, Aebi M. 1995 Volvo Award in clinical sciences. The diagnostic accuracy of magnetic resonance imaging, work perception, and psychosocial factors in identifying symptomatic disc herniations. Spine. 1995; 20(24):2613–25.
100. Battie MC, Haynor DR, Fisher LD, Gill K, Gibbons LE, Videman T. Similarities in degenerative findings on magnetic resonance images of the lumbar spines of identical twins. J Bone Joint Surg Am. 1995;77(11):1662–70.
101. Videman T, Simonen R, Usenius J, Osterman K, Batti M. The long-term effects of rally driving on spinal pathology. Clin Biomech. 2000;15(2):83–6.

102. Hutton WC, Ganey TM, Elmer WA, Kozlowska E, Ugbo JL, Doh ES, et al. Does long-term compressive loading on the intervertebral disc cause degeneration? Spine. 2000;25(23):2993–3004.
103. Cook CE, Taylor J, Wright A, Milosavljevic S, Goode A, Whitford M. Risk factors for first time incidence sciatica: a systematic review. Physiother Res Int. 2014;19(2):65–78.
104. Wilkinson MJB. Does 48 hours' bed rest influence the outcome of acute low back pain? Brit J Gen Pract. 1995;45:481–484.
105. Deyo RA, Diehl AK, Rosenthal M. How many days of bed rest for acute low back pain? A randomized clinical trial. N Engl J Med. 1986;315(17):1064–70.
106. Coomes EN. A comparison between epidural anaesthesia and bed rest in sciatica. Br Med J. 1961;5218:20–4.
107. Lee JY, Whang PG, Lee JY, Phillips FM, Patel AA. Lumbar spinal stenosis. Instr Course Lect. 2013; 62:383–96.
108. Kobayashi S. Pathophysiology, diagnosis and treatment of intermittent claudication in patients with lumbar canal stenosis. World J Orthop. 2014; 5(2):134–45.
109. Sakai T, Sairyo K, Suzue N, Kosaka H, Yasui N. Incidence and etiology of lumbar spondylolysis: review of the literature. J Orthop Sci. 2010; 15(3):281–8.
110. Levin DB. The painful back. In: McCarty DJ, editor. Arthritis and Allied Conditions: A textbook of rheumatology. 11th edition. Philadelphia: Lea & Febiger; 1989.
111. Lipson SJ. Low back pain. In: Kelley WN, Harris ED Jr, Ruddy S, Sledge CB editors. Textbook of Rheumatology. 3rd edition. Philadelphia: WB Saunders; 1989.
112. Kwon BK, Albert TJ. Adult low-grade acquired spondylolytic spondylolisthesis: evaluation and management. Spine (Phila Pa 1976), 2005;30(6Suppl.): S35–41.
113. Postacchini F. The evolution of spondylolysis into spondylolisthesis during adult age. Ital J Orthop Traumatol. 1989;15(2):210–6.
114. Matsunaga S, Sakou T, Morizono Y, Masuda A, Demirtas AM. Natural history of degenerative spondylolisthesis. Pathogenesis and natural course of the slippage. Spine. 1990;15(11):1204–10.
115. Osterman K, Schlenzka D, Poussa M, Seitsalo S, Virta L. Isthmic spondylolisthesis in symptomatic and asymptomatic subjects, epidemiology, and natural history with special reference to disk abnormality and mode of treatment. Clin Orthop. 1993(297):65–70.
116. Floman Y. Progression of lumbosacral isthmic spondylolisthesis in adults. Spine. 2000;25(3):342–7.
117. Muschik M, Hahnel H, Robinson PN, Perka C, Muschik C. Competitive sports and the progression of spondylolisthesis. J Pediatr Orthop. 1996; 16(3):364–9.
118. Russell ML. Ankylosing spondylitis: the case of the underestimated femal. J Rheumatol. 1985;1985:1.
119. Marks SH, Barnett M, Calin A. Ankylosing spondylitis in women and men: a case-control study. J Rheumatol. 1983;10:624.
120. Gran JT, Husby G, Hordvik M. Spinal ankylosing spondylitis: a variant form of ankylosing spondylitis or a distinct disease entity? Ann Rheum Dis. 1985;44(6):368–71.
121. Calin A, Porta J, Fries JF, Schurman DJ. Clinical history as a screening test for ankylosing spondylitis. J Am Med Soc. 1977;237(24):2613–4.
122. Murray GC, Persellin RH. Cervical fracture complicating ankylosing spondylitis: a report of eight cases and review of the literature. Am J Med. 1981;70(5):1033–41.
123. Borenstein DG. Chronic low back pain. Rheum Dis Clin North Am. 1996;22(3):439–56.
124. Shelerud RA. Epidemiology of occupational low back pain. Clin Occup Environ Med. 2006; 5(3):501–28, v.
125. Indahl A, Kaigle A, Reikeras O, Holm S. Electromyographic response of the porcine multifidus musculature after nerve stimulation. Spine. 1995; 20(24):2652–8.
126. Kaigle AM, Wessberg P, Hansson TH. Muscular and kinematic behavior of the lumbar spine during flexion-extension. J Spinal Disord. 1998; 11(2):163–74.
127. Solomonow M, Zhou BH, Harris M, Lu Y, Baratta RV. The ligamento-muscular stabilizing system of the spine. Spine. 1998;23(23):2552–62.
128. Dahl JB, Erichsen CJ, Fuglsang-Frederiksen A, Kehlet H. Pain sensation and nociceptive reflex excitability in surgical patients and human volunteers. Br J Anaesth. 1992;69(2):117–21.
129. Frymoyer J, Gordon S. New perspectives on low back pain. Airlie, VA: American Academy of Ortohpaedic Surgeons; 1988;.
130. Chaffin D, Andersson G. Occupational Biomechanics. New York: Wiley; 1991.
131. Wiesel S, Weinstein J, Herkowitz H, Dvorák J, Bell G. The lumbar spine. Philadelphia: WB Saunders; 1996.
132. Mayer T, Gatchel R, Polatin P. Occupational musculosceletal disorders. Function, outcomes and evidence. Philadelphia: PRIDE Research Foundation Scientific Publications; 2000.

133. Tola S, Riihimäki H, Videman T, Viikari-Juntura E, Hänninen K. Neck and shoulder symptoms among men in machine operating, dynamic physical work and sedentary work. Scand J Work Environ Health. 1988;14(5):299–305.
134. Frost P, Andersen JH. Shoulder impingement syndrome in relation to shoulder intensive work. Occup Environ Med. 1999;56(7):494–8.
135. Hagberg M, Wegman DH. Prevalence rates and odds ratios of shoulder-neck diseases in different occupational groups. Br J Ind Med. 1987;44(9):602–10.
136. Buckle PW, Devereux JJ. The nature of work-related neck and upper limb musculoskeletal disorders. Appl Ergon. 2002;33(3):207–17.
137. Mani L, Gerr F. Work-related upper extremity musculoskeletal disorders. Prim Care. 2000;27(4): 845–64.
138. O'Neil BA, Forsythe ME, Stanish WD. Chronic occupational repetitive strain injury. Can Fam Physician. 2001;47:311–6.
139. Bergenudd H, Lindgärde F, Nilsson B, Petersson CJ. Shoulder pain in middle age. A study of prevalence and relation to occupational work load and psychosocial factors. Clin Orthop. 1988(231): 234–8.
140. Johansson JA, Rubenowitz S. Risk indicators in the psychosocial and physical work environment for work-related neck, shoulder and low back symptoms: a study among blue- and white-collar workers in eight companies. Scand J Rehabil Med. 1994;26(3):131–42.
141. Dyrehag LE, Widerström-Noga EG, Carlsson SG, Kåberger K, Hedner N, Mannheimer C, et al. Relations between self-rated musculoskeletal symptoms and signs and psychological distress in chronic neck and shoulder pain. Scand J Rehabil Med. 1998;30(4):235–42.
142. Andersen JH, Kaergaard A, Mikkelsen S, Jensen UF, Frost P, Bonde JP, et al. Risk factors in the onset of neck/shoulder pain in a prospective study of workers in industrial and service companies. Occup Environ Med. 2003;60(9):649–54.
143. Herberts P, Kadefors R, Andersson G, Petersen I. Shoulder pain in industry: an epidemiological study on welders. Acta Orthop Scand. 1981;52(3): 299–306.
144. Stenlund B, Goldie I, Hagberg M, Hogstedt C. Shoulder tendinitis and its relation to heavy manual work and exposure to vibration. Scand J Work Environ Health. 1993;19(1):43–9.
145. Katevuo K, Aitasalo K, Lehtinen R, Pietila J. Skeletal changes in dentists and farmers in Finland. Community Dent Oral Epidemiol. 1985; 13(1):23–5.
146. Koester MC, George MS, Kuhn JE. Shoulder impingement syndrome. Am J Med. 2005;118(5): 452–5.
147. Fongemie AE, Buss DD, Rolnick SJ. Management of shoulder impingement syndrome and rotator cuff tears. Am Fam Physician. 1998;57(4):667–74, 680–2.
148. Gorski JM, Schwartz LH. Shoulder impingement presenting as neck pain. J Bone Joint Surg Am. 2003;85–A(4):635–8.
149. Rossi F. Shoulder impingement syndromes. Eur J Radiol. 1998;27(Suppl.1):S42–48.
150. Stevenson JH, Trojian T. Evaluation of shoulder pain. J Family Practice. 2002;51(7).
151. Ludewig PM, Borstad JD. Effects of a home exercise programme on shoulder pain and functional status in construction workers. Occup Environ Med. 2003;60(11):841–9.
152. Escamilla RF, Hooks TR, Wilk KE. Optimal management of shoulder impingement syndrome. Open Access J Sports Med. 2014;5:13–24.
153. Chard MD, Sattelle LM, Hazelman BL. The long-term outcome of rotator cuff tendinitis – a review study. Br J Rheumatol. 1988;27:385–9.
154. Brox JI, Staff PH, Ljunggren AE, Brevik JI. Arthroscopic surgery compared with supervised exercises in patients with rotator cuff disease (stage II impingement syndrome). Br Med J. 1993;307(6909):899–903.
155. Hutson MA. Sports Injuries: Recognition and Management. 2nd edition. Oxford: Oxford University Press; 1996.
156. Anderson NH, Søjbjerg JO, Johannsen HV, Sneppen O. Self-training versus physiotherapist-supervised rehabilitation of the shoulder in patients treated with arthroscopic subacromial decompression: a clinical randomized study. J Shoulder Elbow Surg. 1999;8(2):99–101.
157. Brox JI, Gjengedal E, Uppheim G, Bohmer AS, Brevik JI, Ljunggren AE, et al. Arthroscopic surgery versus supervised exercises in patients with rotator cuff disease (stage II impingement syndrome): a prospective, randomized, controlled study in 125 patients with a 2 1/2-year follow-up. J Shoulder Elbow Surg. 1999;8(2):102–11.
158. Goss TP. Anterior glenohumeral instability. Orthopedics. 1988;11(1):87–95.
159. Cofield RH, Irving JF. Evaluation and classification of shoulder instability. With special reference to examination under anesthesia. Clin Orthop. 1987(223):32–43.

160. Horsfield D, Stutley J. The unstable shoulder – a problem solved. Radiography. 1988;54(614):74–6.
161. Kieft GJ, Bloem JL, Rozing PM, Obermann WR. MR imaging of recurrent anterior dislocation of the shoulder: comparison with CT arthrography. Am J Roentgenol. 1988;150(5):1083–7.
162. Adolfsson L, Lysholm J. Arthroscopy and stability testing for anterior shoulder instability. Arthroscopy. 1989;5(4):315–20.
163. Cuetter AC, Bartoszek DM. The thoracic outlet syndrome: controversies, overdiagnosis, overtreatment, and recommendations for management. Muscle Nerve. 1989;12(5):410–9.
164. Kroemer KH. Avoiding cumulative trauma disorders in shops and offices. Am Ind Hyg Assoc J. 1992;53(9):596–604.
165. Guidotti TL. Occupational repetitive strain injury. Am Fam Physician. 1992;45(2):585–92.
166. Poole GV, Thomae KR. Thoracic outlet syndrome reconsidered. Am Surg. 1996;62(4):287–91.
167. Lindgren KA. TOS (thoracic outlet syndrome) – a challenge to conservative treatment. Nord Med. 1997;112(8):283–287.
168. Kessel L, Bayley I, Young A. The upper limb: the frozen shoulder. Br J Hosp Med. 1981;25(4):334, 336–7, 339.
169. Harris G, Bou-Haidar P, Harris C. Adhesive capsulitis: review of imaging and treatment. J Med Imaging Radiat Oncol. 2013;57(6):633–43.
170. Stenlund B. Shoulder tendinitis and osteoarthrosis of the acromioclavicular joint and their relation to sports. Br J Sports Med. 1993;27(2):125–30.
171. Stenlund B, Goldie I, Hagberg M, Hogstedt C, Marions O. Radiographic osteoarthrosis in the acromioclavicular joint resulting from manual work or exposure to vibration. Br J Ind Med. 1992; 49(8):588–93.
172. Worcester JN, Jr., Green DP. Osteoarthritis of the acromioclavicular joint. Clin Orthop. 1968 ;58:69–73.
173. Petersson CJ. Degeneration of the acromioclavicular joint. A morphological study. Acta Orthop Scand. 1983;54(3):434–8.
174. Menge TJ, Boykin RE, Bushnell BD, Byram IR. Acromioclavicular osteoarthritis: a common cause of shoulder pain. South Med J. 2014; 107(5):324–9.
175. Fernström E, Ericson MO. Computer mouse or trackpoint – effects on muscular load and operator experience. Appl Ergon. 1997;28(5–6):347–54.
176. Punnett L, Bergquist U. Visual display unit work and upper extremity musculoskeletal disorders. A review of epidemiological findings. Ergonomic Expert Committee document no. 1. ISBN 91-7045-436-1. Solna: Arbetslivsinstitutet; 1997.
177. Jonsson B. The static load component in muscle work. Eur J Appl Physiol. 1988;57:305–310.
178. Backman AL. Health survey of professional drivers. Scand J Work Environ Health. 1983;9(1):30–5.
179. Kilbom Å. Disorders of the cervicobrachial region among femal workers in the electronics industry. Int J Indust Ergonomics. 1986;1:37–47.
180. Krapac L, Krmpotic A, Pavicevic L, Domljan Z. Cervicobrachial syndrome – work and disability. Arh Hig Rada Toksikol. 1992;43(3):255–62.
181. Kvarnström S. Occurrence of musculoskeletal, disorders in a manufacturing industry with special attention to occupational shoulder disorders. Scand J Rehabil Med Suppl. 1983;8:1–114.
182. Stål M, Moritz U, Gustafsson B, Johnsson B. Milking is a high-risk job for young females. Scand J Rehabil Med. 1996;28(2):95–104.
183. Stål M, Moritz U, Johnsson B, Pinzke S. The natural course of musculoskeletal symptoms and clinical findings in upper extremities of female milkers. Int J Occup Environ Health. 1997;3(3):190–197.
184. Thelin A. Work and health among farmers. A study of 191 farmers in Kronoberg County. Sweden. Scand J Soc Med Suppl. 1981;22:1–126.
185. Raffi GB, Lodi V, Malenchini G, Missere M, Naldi M, Tabanelli S, et al. Cumulative trauma disorders of the upper limbs in workers on an agricultural farm. Arh Hig Rada Toksikol. 1996;47(1):19–23.
186. Färkkilä M, Aatola S, Starck J, Korhonen O, Pyykkö I. Hand-grip force in lumberjacks: two-year follow-up. Int Arch Occup Environ Health. 1986;58(3):203–8.
187. Pyykko I, Sairanen E, Korhonen O, Farkkila M, Hyvarinen J. A decrease in the prevalence and severity of vibration-induced white fingers among lumberjacks in Finland. Scand J Work Environ Health. 1978;4(3):246–54.
188. Kivi P. The aetiology and conservative treatment of humeral epicondylitis. Scand J Rehabil Med. 1982;15:37–41.
189. Major HP. Lawn-tennis elbow. Br Med J. 1883;ii:557.
190. Roto P, Kivi P. Prevalence of epicondylitis and tenosynovitis among meatcutters. Scand J Work Environ Health. 1984;10(3):203–5.
191. Punnett L, Robins JM, Wegman DH, Keyserling WM. Soft tissue disorders in the upper limbs of female garment workers. Scand J Work Environ Health. 1985;11(6):417–25.
192. Ohlsson K, Attewell RG, Pålsson B, Karlsson B, Balogh I, Johnsson B, et al. Repetitive industrial work and neck and upper limb disorders in females. Am J Ind Med. 1995;27(5):731–47.

193. Haahr JP, Andersen JH. Prognostic factors in lateral epicondylitis: a randomized trial with one-year follow-up in 266 new cases treated with minimal occupational intervention or the usual approach in general practice. Rheumatology. 2003;42(10):1216–25.
194. Walker-Bone K, Palmer KT, Reading I, Coggon D, Cooper C. Occupation and epicondylitis: a population-based study. Rheumatology. 2012;51(2): 305–10.
195. McCormack RR, Jr., Inman RD, Wells A, Berntsen C, Imbus HR. Prevalence of tendinitis and related disorders of the upper extremity in a manufacturing workforce. J Rheumatology. 1990;17(7):958–64.
196. Chiang HC, Ko YC, Chen SS, Yu HS, Wu TN, Chang PY. Prevalence of shoulder and upper-limb disorders among workers in the fish-processing industry. Scand J Work Environ Health. 1993;19(2):126–31.
197. Sölveborn SA. Radial epicondylalgia ('tennis elbow'): treatment with stretching or forearm band. A prospective study with long-term follow-up including range-of-motion measurements. Scand J Med Sci Sports. 1997;7(4):229–37.
198. Brummel J, Baker CL, 3rd, Hopkins R, Baker CL, Jr. Epicondylitis: lateral. Sports Med Arthrosc. 2014;22(3):e1–6.
199. Assmus H, Antoniadis G, Bischoff C, Hoffmann R, Martini AK, Preissler P, et al. Cubital tunnel syndrome – a review and management guidelines. Cent Eur Neurosurg. 2011;72(2):90–8.
200. Kopell HP, Thompson WAL. Peripheral Entrapment Neuropathies. Baltimore: Williams & Williams; 1963.
201. Bejjani FJ, Kaye GM, Benham M. Musculoskeletal and neuromuscular conditions of instrumental musicians. Arch Phys Med Rehabil. 1996; 77(4):406–13.
202. Harvey FJ, Harvey PM, Horsley MW. De Quervain's disease: surgical or nonsurgical treatment. J Hand Surg [Am]. 1990;15(1):83–7.
203. Stewart JD. The variable clinical manifestations of ulnar neuropathies at the elbow. J Neurol Neurosurg Psychiatry. 1987;50(3):252–8.
204. Saldana MJ. Trigger digits: diagnosis and treatment. J Am Acad Orthop Surg. 2001;9(4):246–52.
205. Chammas M, Bousquet P, Renard E, Poirier JL, Jaffiol C, Allieu Y. Dupuytren's disease, carpal tunnel syndrome, trigger finger, and diabetes mellitus. J Hand Surg [Am]. 1995;20(1):109–14.
206. Brain WR, Wright AD, Wilkinson M. Spontaneous compression of both median nerves in the carpal tunnel: six cases treated surgically. Lancet. 1947; 1:277–282.
207. Phalen GS, McCormack LJ, Gazale WJ. Giant-cell tumor of tendon sheath (benign synovioma) in the hand. Evaluation of 56 cases. Clin Orthop. 1959; 15:140–51.
208. Phalen GS. The carpal-tunnel syndrome. Seventeen years' experience in diagnosis and treatment of six hundred fifty-four hands. J Bone Joint Surg Am. 1966;48(2):211–28.
209. Dorwart BB. Carpal tunnel syndrome: a review. Semin Arthritis Rheum. 1984;14(2):134–40.
210. Dekel S, Papaioannou T, Rushworth G, Coates R. Idiopathic carpal tunnel syndrome caused by carpal stenosis. Br Med J. 1980;280(6227):1297–9.
211. Browne EZ, Jr., Snyder CC. Carpal tunnel syndrome caused by hand injuries. Plast Reconstr Surg. 1975; 56(1):41–3.
212. Werner RA, Franzblau A, Albers JW, Armstrong TJ. Influence of body mass index and work activity on the prevalence of median mononeuropathy at the wrist. Occup Environ Med. 1997;54(4):268–71.
213. Leclerc A, Franchi P, Cristofari MF, Delemotte B, Mereau P, Teyssier-Cotte C, et al. Carpal tunnel syndrome and work organisation in repetitive work: a cross sectional study in France. Study Group on Repetitive Work. Occup Environ Med. 1998; 55(3):180–7.
214. Hagberg M, Morgenstern H, Kelsh M. Impact of occupations and job tasks on the prevalence of carpal tunnel syndrome. Scand J Work Environ Health. 1992;18(6):337–45.
215. Rossignol M, Stock S, Patry L, Armstrong B. Carpal tunnel syndrome: what is attributable to work? The Montreal study. Occup Environ Med. 1997; 54(7):519–23.
216. Feldman RG, Travers PH, Chirico-Post J, Keyserling WM. Risk assessment in electronic assembly workers: carpal tunnel syndrome. J Hand Surg [Am]. 1987;12(5Pt2):849–55.
217. Wieslander G, Norbäck D, Gothe CJ, Juhlin L. Carpal tunnel syndrome (CTS) and exposure to vibration, repetitive wrist movements, and heavy manual work: a case-referent study. Br J Ind Med. 1989;46(1):43–7.
218. Lundborg G, Sollerman C, Strömberg T, Pyykkö I, Rosen B. A new principle for assessing vibrotactile sense in vibration-induced neuropathy. Scand J Work Environ Health. 1987;13(4):375–9.
219. Tanaka S, Wild DK, Cameron LL, Freund E. Association of occupational and non-occupational risk factors with the prevalence of self-reported carpal tunnel syndrome in a national survey of the working population. Am J Ind Med. 1997; 32(5):550–6.

220. Bovenzi M. Hand-arm vibration syndrome and dose-response relation for vibration induced white finger among quarry drillers and stonecarvers. Italian Study Group on Physical Hazards in the Stone Industry. Occup Environ Med. 1994;51(9):603–11.
221. Barcenilla A, March LM, Chen JS, Sambrook PN. Carpal tunnel syndrome and its relationship to occupation: a meta-analysis. Rheumatology. 2012;51(2):250–61.
222. Silverstein BA, Fine LJ, Armstrong TJ. Occupational factors and carpal tunnel syndrome. Am J Ind Med. 1987;11(3):343–58.
223. Stetson DS, Silverstein BA, Keyserling WM, Wolfe RA, Albers JW. Median sensory distal amplitude and latency: comparisons between nonexposed managerial/professional employees and industrial workers. Am J Ind Med. 1993;24(2):175–89.
224. Nordström DL, Vierkant RA, DeStefano F, Layde PM. Risk factors for carpal tunnel syndrome in a general population. Occup Environ Med. 1997;54(10):734–40.
225. Durkan JA. The carpal-compression test. An instrumented device for diagnosing carpal tunnel syndrome. Orthop Rev. 1994;23(6):522–5.
226. Slater RR, Jr. Carpal tunnel syndrome: current concepts. J South Orthop Assoc. 1999;8(3):203–13.
227. Ghasemi-Rad M, Nosair E, Vegh A, Mohammadi A, Akkad A, Lesha E, et al. A handy review of carpal tunnel syndrome: From anatomy to diagnosis and treatment. World J Radiol. 2014;6(6):284–300.
228. Hill NA. Dupuytren's contracture. J Bone and Joint Surgery. 1985;67:1439–1443.
229. Noble J, Arafa M, Royle SG, McGeorge G, Crank S. The association between alcohol, hepatic pathology and Dupuytren's disease. J Hand Surg [Br]. 1992;17(1):71–4.
230. Mikkelsen OA. Dupuytren's disease – the influence of occupation and previous hand injuries. Hand. 1978;10(1):1–8.
231. Nemetschek T, Meinel A, Nematschek-Gansler H, Reill P, Riedl H. [Aetiology of dupuytren's contracture (author's transl)]. Virchows Arch A Pathol Anat Histol. 1976;372(1):57–74.
232. Barton NJ, Hooper G, Noble J, Steel WM. Occupational causes of disorders in the upper limb. Br Med J. 1992;304(6822):309–11.
233. Haller CC, Coleman PA, Estes NC, Grisolia A. Traumatic trochanteric bursitis. Kans Med. 1989;90(1):17–8, 22.
234. Little H. Trochanteric buritis: a common cause of pelvic girdel pain. Can Med Assoc J. 1979;120: 456–458.
235. Thelin A. Osteoarthritis of the hip joint. A common disorder among farmers. Läkartidningen. 1985;82:3994–3999.
236. Andersen S, Thygesen LC, Davidsen M, Helweg-Larsen K. Cumulative years in occupation and the risk of hip or knee osteoarthritis in men and women: a register-based follow-up study. Occup Environ Med. 2012;69(5):325–30.
237. Torén A, Oberg K, Lembke B, Enlund K, Rask-Andersen A. Tractor-driving hours and their relation to self-reported low-back and hip symptoms. Appl Ergon. 2002;33(2):139–46.
238. Maetzel A, Makela M, Hawker G, Bombardier C. Osteoarthritis of the hip and knee and mechanical occupational exposure – a systematic overview of the evidence. J Rheumatol. 1997;24(8):1599–607.
239. Felson DT, Anderson JJ, Naimark A, Walker AM, Meenan RF. Obesity and knee osteoarthritis. The Framingham Study. Ann Intern Med. 1988;109(1):18–24.
240. Felson DT, Anderson JJ, Naimark A, Hannan MT, Kannel WB, Meenan RF. Does smoking protect against osteoarthritis? Arthritis Rheum. 1989; 32(2):166–72.
241. Wang X, Hunter D, Xu J, Ding C. Metabolic triggered inflammation in osteoarthritis. Osteoarthritis Cartilage. 2014.
242. Sokolove J, Lepus CM. Role of inflammation in the pathogenesis of osteoarthritis: latest findings and interpretations. Ther Adv Musculoskelet Dis. 2013;5(2):77–94.
243. Klassbo M, Larsson G, Harms-Ringdahl K. Promising outcome of a hip school for patients with hip dysfunction. Arthritis Rheum. 2003; 49(3):321–7.
244. Simonet WT, Sim FH. Symposium on sports medicine: Part I. Current concepts in the treatment of ligamentous instability of the knee. Mayo Clin Proc. 1984;59(2):67–76.
245. Bentley G, Dowd G. Current concepts of etiology and treatment of chondromalacia patellae. Clin Orthop. 1984(189):209–28.
246. Merchant AC. Classification of patellofemoral disorders. Arthroscopy. 1988;4(4):235–40.
247. Reid DC. Sports Injury Assessment and Rehabilitation. Edinburgh: Churchill Livingstone; 1992.
248. Graf B, Docter T, Clancy W, Jr. Arthroscopic meniscal repair. Clin Sports Med. 1987;6(3): 525–36.
249. Holmberg S, Thelin A, Thelin N. Knee osteoarthritis and body mass index: a population-based case-control study. Scand J Rheumatol. 2005; 34(1):59–64.

250. Sandmark H, Hogstedt C, Vingård E. Primary osteoarthrosis of the knee in men and women as a result of lifelong physical load from work. Scand J Work Environ Health. 2000;26(1):20–5.
251. Sahlström A, Montgomery F. Risk analysis of occupational factors influencing the development of arthrosis of the knee. Eur J Epidemiol. 1997; 13(6):675–9.
252. Holmberg S, Thelin A, Thelin N. Is there an increased risk of knee osteoarthritis among farmers? A population-based case-control study. Int Arch Occup Environ Health. 2004;77(5):345–50.
253. Felson DT, Chaisson CE. Understanding the relationship between body weight and osteoarthritis. Baillieres Clin Rheumatol. 1997;11(4):671–81.
254. Kellgren JH, Lawrence JS. Rheumatism in miners. II. X-ray study. Br J Ind Med. 1952;9(3):197–207.
255. Partridge RE, Duthie JJ. Rheumatism in dockers and civil servants. A comparison of heavy manual and sedentary workers. Ann Rheum Dis. 1968; 27(6):559–68.
256. Lindberg H, Montgomery F. Heavy labor and the occurrence of gonarthrosis. Clin Orthop. 1987(214):235–6.
257. Felson DT, Hannan MT, Naimark A, Berkeley J, Gordon G, Wilson PW, et al. Occupational physical demands, knee bending, and knee osteoarthritis: results from the Framingham Study. J Rheumatol. 1991;18(10):1587–92.
258. Cooper C, McAlindon T, Coggon D, Egger P, Dieppe P. Occupational activity and osteoarthritis of the knee. Ann Rheum Dis. 1994;53(2):90–3.
259. Coggon D, Croft P, Kellingray S, Barrett D, McLaren M, Cooper C. Occupational physical activities and osteoarthritis of the knee. Arthritis Rheum. 2000;43(7):1443–9.
260. Bischoff HA, Roos EM. Effectiveness and safety of strengthening, aerobic, and coordination exercises for patients with osteoarthritis. Curr Opin Rheumatol. 2003;15(2):141–4.
261. Fingeroth JD, Weis JJ, Tedder TF, Strominger JL, Biro PA, Fearon DT. Epstein-Barr virus receptor of human B lymphocytes is the C3d receptor CR2. Proc Natl Acad Sci U S A. 1984;81(14):4510–4.
262. Klockars M, Koskela RS, Järvinen E, Kolari PJ, Rossi A. Silica exposure and rheumatoid arthritis: a follow up study of granite workers 1940–81. Br Med J (Clin Res Ed). 1987;294(6578):997–1000.
263. Holden W, Orchard T, Wordsworth P. Enteropathic arthritis. Rheum Dis Clin North Am. 2003;29(3): 513–30, viii.
264. Breban M, Said-Nahal R, Hugot JP, Miceli-Richard C. Familial and genetic aspects of spondyloarthropathy. Rheum Dis Clin North Am. 2003;29(3):575–94.
265. Boggild H, Tuchsen F, Orhede E. Occupation, employment status and chronic inflammatory bowel disease in Denmark. Int J Epidemiol. 1996;25(3):630–7.
266. Sonnenberg A. Occupational distribution of inflammatory bowel disease among German employees. Gut. 1990;31(9):1037–40.
267. Cucino C, Sonnenberg A. Occupational mortality from inflammatory bowel disease in the United States 1991–1996. Am J Gastroenterol. 2001;96(4):1101–5.
268. Hill Gaston JSL, M.S. Arthritis associated with enteric infection. Best Pract Res Clin Rheumatol. 2003;17(2):219–239.
269. Söderlin MK, Kautiainen H, Puolakkainen M, Hedman K, Söderlund-Venermo M, Skogh T, et al. Infections preceding early arthritis in southern Sweden: a prospective population-based study. J Rheumatol. 2003;30(3):459–64.
270. Yu D, Kuipers JG. Role of bacteria and HLA-B27 in the pathogenesis of reactive arthritis. Rheum Dis Clin North Am. 2003;29(1):21–36, v–vi.
271. Cover TL, Aber RC. Yersinia enterocolitica. N Engl J Med. 1989;321(1):16–24.
272. Seuri M, Granfors K. Antibodies against Yersinia among farmers and slaughterhouse workers. Scand J Work Environ Health. 1992;18(2):128–32.
273. Bottone EJ. Yersinia enterocolitica: a panoramic view of a charismatic microorganism. CRC Crit Rev Microbiol. 1977;5(2):211–41.
274. Winblad S. Arthritis associated with Yersinia enterocolitica infections. Scand J Infect Dis. 1975;7(3):191–5.
275. Vantrappen G, Ponette E, Geboes K, Bertrand P. Yersinia enteritis and enterocolitis: gastroenterological aspects. Gastroenterology. 1977;72(2):220–7.
276. Laitinen O, Leirisalo M, Skylv G. Relation between HLA-B27 and clinical features in patients with yersinia arthritis. Arthritis Rheum. 1977;20(5): 1121–4.
277. Mahlfeld K, Franke J, Grasshoff H. [Spondylitis due to Salmonella typhimurium]. Unfallchirurg. 2003;106(4):334–8.
278. Rubin MM, Sanfilippo RJ, Sadoff RS. Vertebral osteomyelitis secondary to an oral infection. J Oral Maxillofac Surg. 1991;49(8):897–900.
279. Kirkhorn SR, Earle-Richardson G, Banks RJ. Ergonomic risks and musculoskeletal disorders in production agriculture: recommendations for effective research to practice. J Agromedicine. 2010;15(3):281–99.

CHAPTER

9

Physical Factors

Anders Thelin and Kelley J. Donham

Reviewer: Jeffrey Levin

Noise and Hearing Loss

9.1 Introduction

Traditionally, safety programs have focused on protection of the fingers, feet, arms, and lungs, with protection for the ears a much lower priority. Hearing has been called the "forgotten sense."

Occupational hearing loss can be caused not only by continuous exposure to noise but also by head injuries, explosions, thermal injuries such as slag burns, or exposure to ototoxic substances. Long-lasting exposure to noise in excess of 85 decibels (dB) is by far the most common reason for occupational hearing loss.

Awareness of work-related hearing loss among farmers emerged along with the implementation of new agricultural technologies. The hearing damage caused by high-intensity and/or steady noise is sometimes called a second-order consequence of technology. Farmers and lumberjacks used to work with tractors, harvesters, chainsaws, and other engines without any protection (Figure 9.1). In private workshops, they have long been exposed to high-intensity impulse sounds without any prevention equipment or knowledge of the risks. Fans, dryers, and mills also generate hazardous noise. Even work with animals, especially manual feeding of pigs, may be related to excessive noise exposure.

Non-occupational activities like driving cars, motorbikes, and lawnmowers can also contribute to excessive noise exposure, along with sound from radios or other personal listening devices with the volume raised so they can be heard over the noise from a tractor engine, noise that may last through long workdays. Finally, farmers hunt and shoot more than people in the general population, and impulse sounds from gunshots represent a significant risk factor for both temporary and permanent hearing loss.

Very few studies (1) of individual noise exposure (dosimetry) in farming and forestry have been reported. It is difficult to map noise exposure in a farm where the work environment in terms of noise is diverse and constantly changing. The best method is to describe typical jobs and the related noise burden. One study of Swedish farmers revealed that 90% had some degree of impaired hearing and of those 14% had sufficiently extensive hearing loss to qualify as a hearing impairment (2). Other studies have substantiated that hearing loss is common among farmers (3, 4). Later studies (1, 5, 6) indicate that the situation may be improving because of improved machinery design. However, in most

Agricultural Medicine: Rural Occupational and Environmental Health, Safety, and Prevention, Second Edition.
Kelley J. Donham and Anders Thelin.

FIGURE 9.1 Farmers and loggers have an occupational history of work with tractors, harvesters, chainsaws, grain dryers fans, manual feeding of pigs, among other excessive noise sources. They commonly work without protection, as seen in this photograph of a farmer operating an old tractor without a protective cab and without hearing protection.

countries there still are no broadly deployed hearing protection programs for farmers.

9.2 Noise, Definitions, and Measurements

Sound is waves or alternating sequences of compression and rarefaction of particles within an elastic medium such as air. Noise is unwanted sound. Sound level or intensity may be measured as sound pressure level (L_p) and expressed in decibel units. Sound pressure level is a measure of the effective pressure of a sound relative to a reference value. By definition, 0 dB is the faintest sound the average normal hearing young adult can detect. The decibel scale is a logarithmic scale, which means that adding or subtracting sound levels cannot be done using absolute levels. If, for example, you add two equal noise sources with respective measures of 80 dB, the sum in dB is *not* 160. The following formula should be used to determine the actual dB sound pressure:

$$L_{ptot} = 10 \lg \sum 10^{Lpn/10}$$

Inserting 80 dB in the formula for the sum of the sound pressure levels yields:

$$L_{ptot} = 10 \lg \left[10^{80/10} + 10^{80/10} \right]$$
$$L_{ptot} \approx 83 \text{ dB}$$

where Lptot is the total sound pressure, lg is the log and Lpn is the Lp for every unit (i.e. all individual sound pressures one wants to sum) included (n). Thus, adding two equal sources of noise raises the sound pressure level by 3 dB. If one of the sources is much stronger than the other (more than 10 dB) the above formula demonstrates that the weaker one may be neglected. In prevention practice the stronger source should always be removed first.

The terms "sound level" or "noise level" are used when measuring with a sound level meter. The noise meter detects primarily sound with respect to the wavelength the ear detects most easily (2000–5000 Hz). An A-filter is used to block most noise outside of this range. The sound level is given in dB(A) with respect to the intensity perceived by the ear. The human ear can detect to a limited degree sound in the frequency interval 20–20,000 Hz. Lower frequencies are infrasound and higher are ultrasound. Ultra- and infrasound may affect human beings in other ways than affecting the ear. The frequency of the sound resulting from speech is primarily between 500 and 3000 Hz (but may include sounds as low as 125 Hz and as high as 8000 Hz). The sound level or intensity of speech is 20–60 dB(A). Noise at the level of 120 dB is unpleasant and 140 dB is painful. A chainsaw generates approximately 110 dB and a tractor between 80 and 100 dB outside and much lower inside a modern cab. There are large variations in noise relative to the age and quality of maintenance of the tractor.

To estimate the risk of hearing damage it is necessary to measure sound level, exposure time, and noise frequency. Noise with more high-frequency sounds may be more deleterious than low-frequency noise. The importance of assessing high-impulse sounds should be emphasized (7). The first-generation sound meters had no capacity to track impulse sounds, but modern sound meters have the capacity to catch very short impulse sounds. A dosimeter is a type of sound meter, often worn by an individual worker, which continually measures the sound level in a work environment and integrates the total exposure over time, giving a time-weighted average (TWA) of noise exposure over the work period. The work period is typically an 8-hour work day during a 40-hour work week. This type of assessment is the usual way to determine if a worker is being exposed to harmful levels of noise.

9.3 How Noise Affects the Auditory System

Chronic noise exposure gradually impairs the hearing. A noise-induced hearing loss (NIHL) (with appropriate work history) should be considered when the hearing threshold is reduced 25 dB or more at one or more tonal frequencies within the hearing range. In other words, if an individual is presented with a pure tone at a given hearing frequency that requires 25 dB or more of intensity to be perceived (the threshold is exceeded), then that is presumed to represent a hearing loss at that tone. NIHL generally progress insidiously; an individual may not realize he or she has an NIHL until perception of speech is affected.

Exposure to loud noise for a short period of time produces a temporary hearing loss (a temporary threshold shift, or TTS). A TTS can last for several hours or a day and might be experienced as ringing in the ears (tinnitus) and difficult hearing. Chronic noise exposure (months to years) may generate a permanent threshold shift (PTS) from which there is no recovery. As a TTS may mimic a PTS, an audiometric test should not be performed within a 24-hour period after significant noise exposure.

NIHL pathology results from trauma to the sensory cells of the cochlea. The sensory epithelium of the cochlea consists of one inner row of stereociliated hair cells and three outer rows of stereociliated hair cells. The outer hair cells function like an amplifier to help increase the nerve impulse from the inner hair cells. The hair cells (particularly the outer hair cells) become distorted or even disrupted due to oxygen radicals generated from the high level of metabolic activity in these cells, resulting in degeneration and eventually apoptosis and cell death. Normal hair cells generate nerve impulses to cochlear nerve fibres, which transmit the sensation of sound to the brain. Additional noise damage may result in degeneration of cochlear nerve fibres. Individual susceptibility to noise is variable due to genetic differences. Some individuals are able to tolerate high noise levels for long periods of time. Others can rapidly lose hearing in the same environment. Furthermore, for anatomic reasons related to their positioning in the cochlea, this loss is first typified among hair cells (and connected nerve fibres) that transmit tones in the high-frequency hearing range before the speech frequencies are usually affected. Thus the goal should be to reduce noise to below 85 dB, the lower the better.

The inner ear is partially protected by the activity of the middle ear muscles (stapedius and tensor tympani). Continual noise is dampened as these muscles relax with loud noise, reducing the impulse energy transmitted to the hair cells. Impulse sounds like gunshots penetrate to the cochlea before the normally protective acoustic reflexes have had time to react. Impulse noise exceeding 140 dB may cause immediate and irreversible hearing loss.

Exposure to hazardous noise tends to have its maximum effect in the high-frequency regions of the cochlea. NIHL is usually most severe around 4000–6000 Hz. As the damage from noise continues over time a broader range of frequencies is affected. Prolonged exposure to sounds louder than 85 dB is generally regarded as potentially injurious (85 dB average over 8 hours, referred to as the action level, is the "legal" maximum exposure as regulated by the Occupational Safety and Health Administration (OSHA) in the United States and this level is similar in most industrialized countries). The 85 dB level is, however, arbitrary and consideration in setting that level was influenced by economic factors (i.e., further noise reduction might be too expensive). The 85 dB level is obviously not a safe level for everybody.

9.4 Symptoms and Disablement

With regard to symptoms and disability, the first sign of NIHL is usually a slight difficulty in comprehending (not just hearing) speech at a dinner party or a meeting where many people are talking at the same time or there is competing background noise. People with NIHL hear vowel sounds better than voiceless consonants. As noise affects high frequencies more than low NIHL patients have more difficulty understanding people with higher pitched voices (e.g., women and children).

The first loss of hearing capacity frequently develops around 4000–6000 Hz and is often not realized by the individual. Over time the loss expands to a wider range of frequencies. The majority of human speech is largely within the range of 500 to 3000 Hz. A significant loss of capacity in this area leads to a communicating disablement. Later in life this is often combined with a presbyacusis (common age-related loss of hearing capacity), leading to even greater difficulties in perception. Because of this combination the progress unfortunately often proceeds even if the exposure to noise is reduced or dismissed.

A number of other diseases and conditions may also affect hearing and must be ruled out in evaluating hearing impairment. Presbycusis affects mainly higher frequencies, with the most significant loss in the highest area. Hereditary hearing impairment is a common condition and may have very different character. Otosclerosis is regarded as a form of hereditary hearing loss. Sudden deafness or sudden sensorineural hearing loss is a momentary mostly one-sided hearing loss of unknown aetiology. The character of the loss may be very different, as well as the prognosis. Ménière's disease, tumours, some metabolic disorders like diabetes mellitus, and certain medications may also affect the hearing capacity, as well as, of course, infections.

People who have been active in hunting and shooting often have more impairment on the left side as the source of the noise is lateralized in individuals who trigger with their right hand. Otherwise, the hearing loss in NIHL mostly is bilateral and symmetric.

For the future, new technology such as neural stem cell and embryonic stem cell transplantation may in coming years open up the possibility of the repair of cochlea hair cells (8). At present, however, no medical or surgical treatment is available to heal the effects of NIHL. The focus therefore must be on prevention and those with an established impairment must take steps to reduce their exposure (see below). Hearing amplification may be helpful, but must be carefully fitted and optimized. Sometimes hearing aids can be of selective use, for example at a lecture or in a group, but may be of no benefit in a standard work situation (driving tractors or working with a chainsaw). The capacity to hear warning sounds in traffic or a work situation may be reduced (9). Warning sounds in tractors or feeding systems or other technical systems in farming may be complemented with warning lights.

In many countries occupational hearing loss is compensated. However, the differentiation between NIHL and presbyacusis is a problem and the regulations and rules differ. Efforts have been made to standardize the normal loss of hearing over time and calculate the burden due to occupational noise exposure (10). Another complicating factor is the difficulty in estimating the pre-employment hearing loss.

9.5 Tinnitus

Tinnitus is a common complication for persons with NIHL. Tinnitus is perceived by a patient as a ringing, buzzing, or chirping sound. However, this sound cannot be measured (11, 12). Only a minority of those with tinnitus have major daily problems. Some of these patients also have psychological or psychiatric problems, which may result from or be a primary cause of these sounds (13, 14).

Damage to the stereociliated hair cells, regardless of cause, may not only generate a loss of hearing signals but also generate the disturbing buzzing. However, a large number of other (non-cochlea-related) causes of tinnitus have been reported (trauma, multiple sclerosis, some drugs) and the mechanisms are not fully understood (11). Tinnitus in the absence of hearing loss is probably not related to noise exposure. Some patients with tinnitus may need medical assistance. Those with depression and/or other forms of psychological problems may benefit from treatment. Psychological counselling and changes in lifestyle in combination with cognitive therapy and support may help the patient to control and minimize the difficulties.

Selective sound sensitivity is another reaction to heavy noise exposure (15) often related to stress and fatigue in the workplace.

9.6 Hearing Loss due to Trauma or Toxins

A blunt head injury may cause a traumatic hearing loss by a fracture of the temporal bone with a cochlear injury. Explosions, burns, and a piece of welder's slag may generate forces or penetrate the ear canal and damage the anatomic structures. It is easy to separate a conductive hearing loss from a sensorineural one by using a tuning fork (512 Hz). Traumatic membrane perforations usually heal spontaneously. If not, grafting the tympanic membrane is possible. Reconstruction of the ossicular chain is also possible.

Some chemical substances are ototoxic and may injure the cochlea. The majority of these substances are components of drugs (aminoglycoside antibiotics, loop diuretics, antineoplastic agents, and even salicylate drugs such as aspirin in higher does for prolonged periods of time). A combination of these kinds of drugs with noise exposure may be potentially hazardous. Patients under medication thus should be even more cautious with respect to noise exposure.

Hearing loss may also result from exposure to ototoxic substances in the workplace. Some heavy metals have ototoxic potentials as well as some other substances. Organophosphate insecticides in the farm work environment may have an ototoxic effect (16, 17). A combination of pesticides and noise thus may be hazardous. More research is needed in this area.

9.7 Audiometry

Pure tone audiometry is the standard method used by occupational health professionals to screen hearing and analyse hearing losses for a possible relationship with workplace noise. In this kind of audiometry the sensitivity to pure tones is measured at 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz for air conduction. Where there are differential diagnostic questions or other special questions a bone conduction audiometry might also be performed. The normal range of hearing is 0–20 dB at each frequency. The results are presented graphically in Figures 9.2 to 9.6.

Hearing detection threshold losses at a given pure tone frequency are generally considered to be mild in the range 25–40 dB, moderate at 40–70 dB, severe at 70–90 dB, and profound above 90 dB. It should be noted that NIHL is characterized by relatively little hearing loss at 8000 Hz due to anatomic positioning of these hair cells on the cochlear membrane and the physical forces of noise at high exposure levels. The resultant hearing loss "notch," as seen in

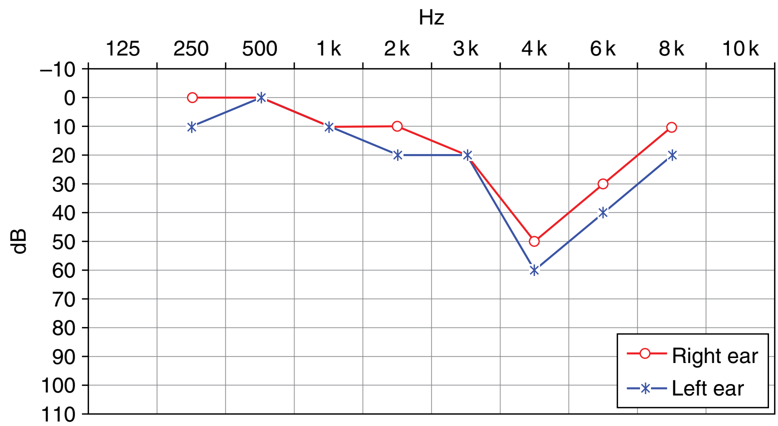


FIGURE 9.2 Typical audiogram of mild noise-induced hearing loss.

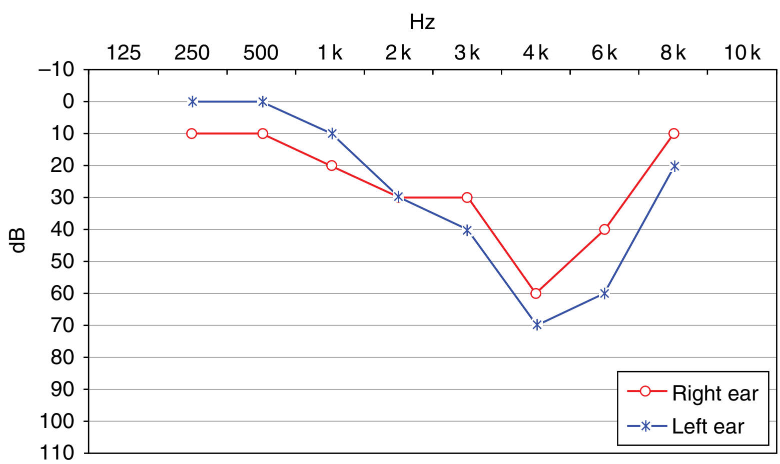


FIGURE 9.3 Typical audiogram of moderate noise-induced hearing loss reveal.

Figures 9.2 to 9.4, at 4 kHz is characteristic. This same notch is absent in presbyacusis (Figure 9.5). In the case of non-organic loss, the threshold pattern may not be restricted to higher frequencies (Figure 9.6) as typically seen with noise-induced, sensorineural loss and/or presbyacusis (Figures 9.2 to 9.5). It should be re-emphasized that NIHL is typically bilateral and symmetrical.

A pure tone audiometry may also be performed as a Bekesy audiometry. This is a self-administrated audiometry in which the patient responds to signals by pressing and releasing a button. This method is frequently used in occupational health practice, but is generally regarded less reliable than standard audiometry administered by an audiologist. Bekesy audiometry may be combined with a computer-supported analysis of the audiogram. Special programs to classify hearing losses have been developed (18).

More in-depth audiometric and hearing tests, for example speech audiometry, speech discrimination tests, and optoacoustic emission audiometry as well as tympanometry, are generally not conducted in occupational health practice.

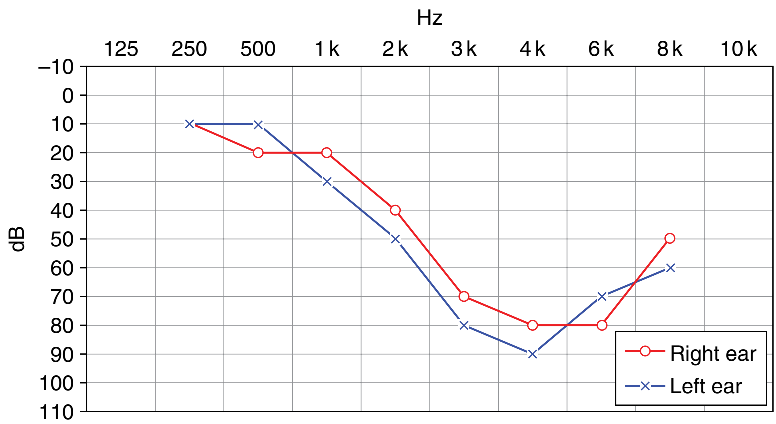


FIGURE 9.4 Typical audiogram of severe noise-induced hearing loss.

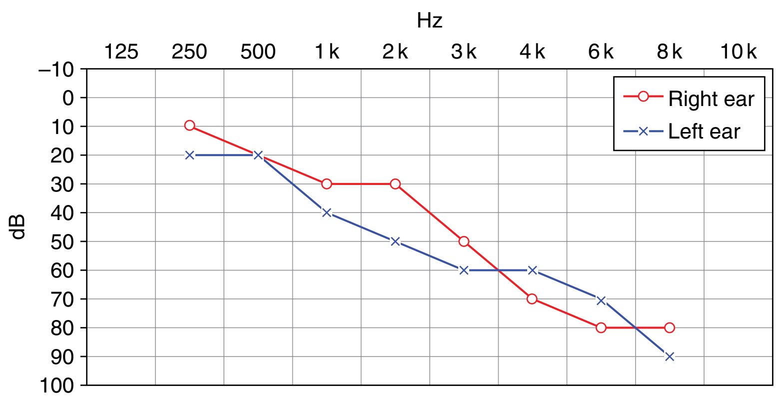


FIGURE 9.5 In hearing loss associated with aging (presbyacusis) the 4 kHz notch is usually absent.

Patients needing more testing should be referred to higher-level care facilities such departments of audiology.

All audiometric tests should be performed with the patient placed in a sound-insulated test booth that meets standards for reduction of ambient noise otherwise the results cannot be regarded as standardized and reliable.

9.8 Other Effects of Noise

Noise exposure may also have effects other than hearing loss (19–22), for example noise has been related to increases in diastolic blood pressure (22, 23). Noise may act as a stressor, affecting job performance and increasing injury risk due to interference with perception of speech and auditory signals (9, 24, 25).

9.9 Prevention

NIHL is preventable. Most Western industrialized countries have incorporated within their occupational health and safety laws regulations for noise exposure limits and prescribed controls to prevent NIHL. Generally, exposure above 85 dB(A) over an 8-hour working day is

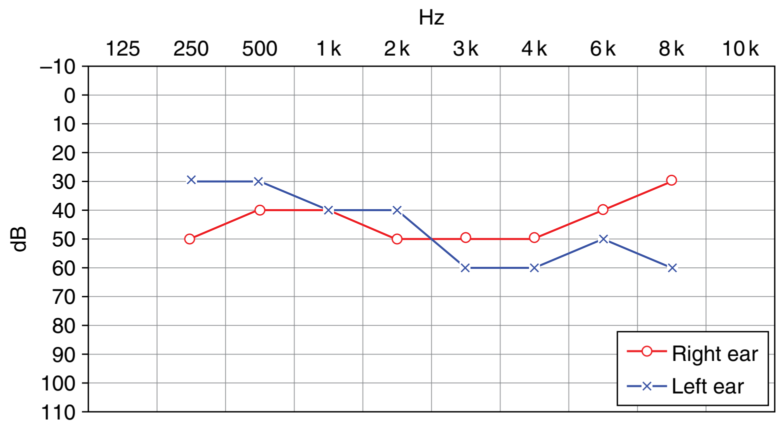


FIGURE 9.6 In other cases of hearing loss (toxicity or developmental), the threshold pattern may not be restricted to higher frequencies, as typically seen with sensorineural loss (noise-induced and/or presbyacusis).

not permitted, for example in the United States OSHA laws require that remediation must take place if 8-hour exposure is at 85dB or above. Remediation might focus on measures to reduce average exposure to significantly lower levels. If the exposures are 90 dB or above, the workplace can be penalized by OSHA authorities and a hearing conservation program (HCP) may be required. HCPs are similar among most industrialized countries and very prescriptive control measures must be implemented. These general control measures are discussed below. Complying and maintaining these programmatic steps is important in attaining effective sustained prevention of NIHL.

9.9.1 Definition of Noise Emissions

A successful HCP (one that complies with the specifications of most countries' occupational health and safety regulations) includes documented accurate assessment of noise exposure levels (26, 27). Noise must be monitored with properly calibrated personal noise dosimeters that define exposure in terms of personal TWA dose, which includes the defined range of frequencies exposed, intensity, and type (28). The individual must wear this instrument through the work day as it collects, stores, and provides the TWA exposure in relation to the prescribed parameters mentioned above and relative to the noise standard (e.g., 85 dB, etc.). Changes in work practices and equipment to reduce noise will require repeated monitoring to document that prescribed reductions have occurred. This is difficult to do in a farming environment as the workplace is so varied that it is difficult to develop a noise map that is relevant for more than a few days or for an individual task on a given farm.

Those working with noise reduction in farming must therefore rely on information on typical emissions from different types of equipment, confinement systems, and other defined modules of farm work, and estimate total exposures and identify priority areas for reduction (26–28). However, there is a large degree of variability among machine-related tasks on different farms (e.g., the noise exposure from a type of machine and task depends on the make, model, and condition of that machine and how the operator interacts with the machine). Quantitating noise exposure by time and task therefore provides very rough estimates in most farming environments. This is an area requiring further research to enable more accurate estimates of noise exposure on farms to be obtained.

9.9.2 Engineering Controls

Tractors, harvesters, mills, fans, compressors, and other types of equipment used in farming are common noise sources. The most effective way to reduce noise is for machinery manufacturers to include noise abatement engineering in the design of new equipment. However, manufacturers of farm equipment have not historically had noise reduction as a high priority in the development of new equipment. Proper maintenance of the equipment is also necessary to minimize noise emission. Worn machinery with defects tends to generate more noise. To manage noise emission, an ambitious program (27) for the maintenance of equipment will not only save money, but also help the farmer to reduce the noise exposure.

9.9.3 Enclose the Noise Source

The noise source may be separated from the user or vice versa. Modern tractor cabs mostly have a good internal acoustic environment relative to older tractors or tractors with no cabs. However, how good the environment is depends on the windows and doors of the cab being kept closed, and properly functioning door and window seals. Fans, dryers, compressors, and mills may all be enclosed. If enclosure is not possible other techniques can be recommended, such as installing absorbents in the ceiling and walls to reduce echo.

9.9.4 Administrative Controls

Alternative work practices can reduce exposure to excessive noise (29, 30). For example, work can be planned so that noise sources such as fans and dryers may be switched off when the worker is in the building. Feeding of animals (especially breeding female pigs on limited feed) can produce noise in excess of 90 dB at feeding time. Feeding processes should be designed such that the actions of the worker do not initiate a conditioned response to vocalize with cues to feeding, and thus expose the worker to excess noise. Often this can be done with an automated feeding system, activated when workers are not in the building and in such a way that animal activity is not stimulated too much. Alternative work methods might be introduced to replace the noisier methods (29, 31). Reduced exposure time for a given employee is also an important administrative control principle as prolonged exposure to high noise levels is a fundamental cause of NIHL.

9.9.5 Worker Education

Farmers, lumberjacks, and employees in farming and forestry must understand the harmful effects of noise. This is a prerequisite for a successful HCP. Education programs might be necessary to help the individuals deal with existing noise hazards and protect themselves (30). An occupational safety and health program with recurrent audiometric tests provides opportunities for personal training based on information on the individual's hearing capacity and how this applies to the work environment (32).

9.9.6 Hearing Protection Devices

Often noise cannot be avoided because of cost and technology limitations. Workers can use hearing protection devices to reduce personal noise exposure and hearing impairment. Devices are available in a variety of types and qualities. Earplugs or "aurals" may be premolded, formable, or custom molded. Earmuffs or "circumaurals" have a better protective effect, especially for high-frequency noise. In special situations a combination of plugs and muffs may be indicated. Each type of device has advantages and disadvantages, and when worn properly should offer a measureable level of noise reduction (referred to as the noise reduction rating). The user may need support and encouragement to ensure a habit of protection. The selection of appropriate, effective, and acceptable hearing protection is vital for compliance and usage (32). Additional details on personal protective equipment are given in Chapter 15.

Vibration and Injuries Related to Vibration

9.10 Introduction

Maurice Raynaud first described the white finger phenomenon in his thesis in 1862 (33). These intermittent blanching episodes of the fingers and hands are now referred to as primary Raynaud's disease. Fifty years later a number of reports demonstrated certain occupational exposures could induce "white fingers" or vascular spasm of the fingers. The occupational exposures noted were the use of hand-held vibratory tools (secondary Raynaud's) (34, 35). More recent understanding of the effects of vibration on human tissues has changed from a focus on vibration-induced white finger disease to a broader view of the pathophysiology of vascular, neurological, and musculoskeletal conditions that include the hands and arms: hand–arm vibration syndrome (HAVS) (36). This has been recommended as a collective term for the different effects of vibration energy transmitted by the hands and upper extremities (37).

The primary cause of HAVS is mechanical energy (although co-factors may be involved) from an oscillating source, which transmits vibration energy to body tissues (38). The frequency of vibration causing damage can be from 5 to 2000 Hz, with the most severe exposure in the 50–200 Hz range. Most structures have their own natural vibration frequency (resonance), including the human body (generally 50 Hz and lower). Resonance (resulting in amplification of that energy) results when vibration of a compatible frequency is transmitted to another object with the same natural frequency. Vibration energy sources that have been associated with HAVS in farmers include mechanical tools (e.g., chain saws, grinders, pneumatic wrenches, and drills) and self-propelled machines of all types (e.g., steering wheels of tractors, combines, and all-terrain vehicles). Vibrations from the handlebars of snowmobiles used in ranching or reindeer herding are transmitted to the hands and arms (39). HAVS is a well-documented occupational condition among forest workers (40, 41) as well as farmers (2, 42).

In addition to HAVS, a number of health problems have been attributed to whole-body vibrations, including musculoskeletal, neurologic, and circulatory system disorders (43, 44). Those affected include farmers and forestry workers who drive tractors, harvesters, trucks, and other machines in which the operator is in a seated positon.

9.11 Hand–arm Vibration Syndrome

9.11.1 Vibration White Finger

Secondary Raynaud's syndrome, also called vibratory white finger (VWF), is one of the components of HAVS. The typical clinical picture of primary or secondary Raynaud's diesase consists of episodes of patchy, sharply delineated blanching of the skin, mostly in those parts of the fingers that have been most strongly exposed (37). Spasm of the digital arteries elicited by exposure to cooling of the hand or the whole body or a feeling of discomfort in a cold or chilly environment results in reduced blood flow. The fingers turn white and a decreased manipulative dexterity follows. Redness, some swelling, light pain, and paresthesias occur with the return of blood circulation as a consequence of reactive hyperthermia (Figure 9.7). Taylor and Pelmear developed a classification system for cold-induced peripheral vascular and sensorineural symptoms (45). This was later modified (Table 9.1) (46). Severe symptoms are unusual. Progression to fingertip gangrene is possible, but very uncommon (47).

The specific pathophysiology of VWF is still obscure. Mechanisms such as centrally mediated increased vasoconstrictor tone, local hypersensitivity to cold, occlusive vascular disease, local nerve injury, increased viscosity of the blood, and low blood pressure have been discussed (37, 48). Patients with advanced symptoms of VWF have an increased basal vascular tone in the finger arteries but no narrowing of the vascular lumen

FIGURE 9.7 The intermittent blanching episodes of the fingers and hands are referred to as primary Raynaud's disease (a hereditary or developmental condition). This condition, also called "white fingers," is caused by a spasm of blood vessels supplying the hand. It may also be caused or exacerbated by occupational long-term use of hand-held vibratory tools ("vibration white fingers") and it is triggered by cold weather conditions. (*See insert for color representation of the figure.*)

Table 9.1 The Stockholm Workshop scale: classification of cold-induced Raynaud's disease in the hand–arm vibration syndrome (46)

Stage	Grade	Description
0		No attacks
1	Mild	Occasional attacks affecting only the tip of one or more fingers
2	Moderate	Occasional attacks affecting distal and middle (rarely also proximal) phalanges of one or more fingers
3	Severe	Frequent attacks affecting all phalanges of most fingers
4	Very severe	As in stage 3 with tropic skin changes in the finger tips

The staging is made separately for each hand.

(49). It is possible that vibration causes an imbalance between alpha-1 and alpha-2 adrenergic receptors, with a significant impact on the reactions resulting in a localized spasm (50). Hereditary factors as well as biochemical conditions and previous traumatic injuries as well as stress disorders may contribute to the development of VWF (51).

9.11.2 Diffusely Distributed Neuropathy

The diffusely distributed neuropathy observed in some vibration-exposed people predominantly affects large nerve fibers with sensory damage related to the resonance frequencies of vibrating tools (52). Disturbed blood circulation has also been discussed (53) as an etiologic factor.

9.11.3 Pain in Hand and Arm

Vibration may contribute to an excessive strain of joints or structures around the joints, resulting in pain and restriction of movements. Vibration as an etiologic or contributing factor in osteoarthritis in the wrist (54, 55) as well as in the shoulder region has also been discussed (56, 57). However, wrist pain may be related to strain of joints and tendons more than to vibration exposure or associated with a possible osteoarthritis. Vacuolisation in the small bones of the hands and the forearms has also been reported (but not confirmed by epidemiologic data), indicating the negative effects of vibration injury (58–61).

9.11.4 Carpal Tunnel Syndrome

The symptoms of carpal tunnel syndrome (CTS) (see Chapter 8 musculoskeletal disorders) are caused by compression of the median nerve as it passes through the carpal tunnel of the wrist. Most people with CTS have not been exposed to vibration. However, tool vibration may require a stronger grip on the tool handle, which may cause a greater load on the wrist. Static work during wrist flexion may also be a major factor contributing to the development of CTS in workers with handheld tools (62, 63).

9.11.5 Other Effects of Vibration

Some studies indicate that vibration may have a more general negative effect on muscular strength (64, 65). A hearing deficit has been reported that is not ascribed to noise exposure but is related to localized vibration (66). The mechanisms of these effects are largely unknown (67, 68).

Other symptoms related to hand–arm vibration include vibration-induced, diffusely distributed neuropathy (to be distinguished from the polyneuropathy of other origin). It is reported as numbness and a small reduction in tactile sense. An increased risk of Dupuytren's contracture is also reported (69).

9.11.6 Diagnosis and Prevention of HAVS

Obtaining an informed and accurate history and clinical picture are of primary importance in diagnosing vibration-induced injury. A cold provocation test sometimes demonstrates the symptoms. Measuring the presence of vasospasm by recording finger systolic blood pressure in response to cold is another method (70, 71). However, there is a controversy regarding the diagnostic value of these tests (72). Neurological disturbances may be demonstrated with methods for assessing vibration and temperature thresholds (52, 73–76). CTS is verified by electro diagnostic methods. Plain-film x-ray may demonstrate changes in joints and skeletal structure.

Differentiation of vibration-induced "white finger" includes consideration of the epidemiology of the condition. Primary Raynaud's phenomenon is a common condition, especially among females (it affects 6% of the general middle-aged female population, perhaps higher (13% in Sweden) (77)). Other causes of VWF include trauma of the fingers or hands, frostbite, occlusive vascular disease (which may be related to smoking), connective tissue disorders, drug intoxication, exposure to vinyl chloride monomer, and several neurological disorders. To judge the causality of an occupational vibration injury necessitates a positive history of exposure (e.g., daily or weekly exposure of several hours, over several years of work) and characteristic vibration (e.g., vibration from causes such as hand-held tools and machinery operation in the range of 50–200 Hz (38)).

The spasm of the digital arteries and the white finger usually disappears in minutes or within an hour. Warming of the hands or the whole body may facilitate this. Swinging the hands or placing them in warm water may reduce the intensity of an attack. Nifedipine, a calcium antagonist, has been used to prevent attacks, but has not been very effective. In severe cases thymoxamine, stanozolol, or prostaglandin E may be useful, but they are not used very often and the effectiveness has been questioned. Surgical sympathectomy has been tried but has not had positive outcomes and may aggravate symptoms. Biofeedback has been suggested, but results have not been confirmed to date. The diffusely distributed neuropathy and wrist pain have no special treatment. In the case of CTS surgery is a common practice.

Different steps may be taken to reduce or remove the risk of vibration-induced injuries. Tools and other equipment should be designed in such a way that the risk of injuries is low. The redesign of the traditional chainsaw in the 1970s is a good example of how a risk can be reduced. In the early 1970s more than 30% of lumberjacks had problems with VWF and other HAVS-related symptoms. Within a decade the risk of HAVS from using a chainsaw had almost gone (41, 78). Proper and continuous maintenance of tractors, other machines, and tools diminishes the risk of damage by vibration exposure. The period of exposure should be shortened if other methods to reduce or avoid exposure are impractical. Special gloves to keep the hands warm and absorb some of the vibration energy may be useful in some cases (79). Furthermore, keeping core temperature high in cold working environments by appropriate warm clothing is also helpful in preventing episodes of symptoms. More complete and individualized worker training regarding HAVS may help in the prevention and management of the condition in those with symptoms.

9.12 Whole-body Vibration

Exposure to whole-body vibrations may result in adverse symptoms involving the musculoskeletal, neurologic and circulatory systems, women's urogenital system, and the spinal column. The human low back has a resonance frequency of 3–5 Hz, which is a predominant frequency in many vehicles (80, 81). The design of the driver's seat as well as the driver's position affect the transmission of vibrations to the human low back (78, 79).

Research to date has not consistently demonstrated a significant vibration-induced injury to the low back demonstrated as low back pain or sciatica (80, 81). A large number of cross-sectional studies indicate a relationship between whole-body vibration in combination with sitting and/or awkward postures (tractor driving or bus driving for example) and low back pain/sciatica but very few longitudinal or experimental studies are indicative (82, 83). Difficulties with standardization of exposure data and "soft" or imprecise outcome data impede the research (84). Most reviews and meta-analysis, however, indicate that exposure to whole-body vibration increases the risk of low back pain and sciatica (85).

Other studies indicate that whole-body vibration probably can contribute to disorders of female reproductive organs such as menstrual disturbances, abortions, and stillbirths. Animal experiments suggest whole-body vibration may have harmful effects on the fetus (43).

A kind of "vibration sickness" has been reported by exposed workers, characterized by diffuse symptoms such as gastrointestinal disturbances, nausea, decreased visual acuity, and muscular pain and balance disorders (86). These reports have not been consistent (43).

The International Organization for Standardization (ISO) has established guidelines for whole-body vibration exposure (91). Despite positive epidemiologic information in the face of inconsistent objective clinical information of the causative adverse effects of whole-body vibration, it seems wise to make efforts to reduce exposure in terms of better tractors, better seats and shorter working time driving tractors and other vehicles (87).

9.13 Disorders due to Heat and Cold

Stress from physical work for farmers in hot or cold weather is unfortunately often taken for granted. The adverse effects on health and work performance of excess heat and cold temperatures are not always recognized. Although there are studies regarding heat and cold stress in occupational activity, such studies are limited in a farming context (88). Heat illness does occur among employed farm workers in the warm climates of the Americas and Africa (89, 90) and may also be a reality among farmers in temperate climates. Most research on the physiology of work in hot and cold environments is from the military and space industries, but this information can be applied to work in agriculture.

9.14 Human Thermal Balance

The human body continually works to adapt to its physical surroundings. The following factors interplay to create the thermal balance necessary for health comfort and optimal physiologic and biochemical function: surrounding air temperature, radiant energy, humidity, wind velocity, isolation, and the vapor resistance of clothing and physical activity. Human thermal balance may be described by the following equation (91):

$$M - W = R + C + K + E + H_{res}$$

where M is the total metabolic effect generated by the body, W is the mechanical effect, R is radiation, C is convection, K is conduction, E is evaporation, and H_{res} is heat transportation by respiration. This equation describes an equilibrium process to keep the body at a constant temperature. For short periods the thermal balance may be disrupted. For example, heavy work may raise body temperature by 0.5–1.0°C. In case of imbalance the equation becomes:

$$S = M - W - R - C - K - E - H_{res}$$

where S is the heat effect stored or lost. If heat production is larger than heat export the body temperature will rise. If heat export is larger than heat production the temperature will fall. The main ways of export are via skin and through radiation, convection, and evaporation. The interrelation of these depends on the microclimate.

The body converts muscle energy to mechanical work. However, the major component of cellular energy is transformed to heat. Generally, metabolic processes and physical activity generate enough heat to maintain the thermal balance. To compare the energy produced between different people, the energy production rate can be expressed in relation to the body surface. The average produced effect at rest is approximately 58 W/m^2 skin surface.

Convection, radiation, and evaporation are the three main ways of heat transfer from (or to) the human body. For convective heat transfer dry-bulb temperature and wind velocity are variable factors. The hotter the air the less heat is exported. If the air temperature exceeds skin temperature, the heat flow is reversed and the surrounding air heats the body.

The objects surrounding the worker dictate radiant heat transfer. Heat is exported from the body to surrounding objects with a temperature below +35°C. Around 60–70% of body heat loss is by radiation to surrounding objects. Like convection, radiation depends on the amount of the body surface area that is in contact with the surroundings.

Evaporation is the most efficient method of heat export. Evaporation is affected by humidity, wind velocity, and temperature. Internal physiological factors (circulation, rate of sweat secretion, sweat secretion thresholds) also affect evaporative cooling. A non-acclimatized person may come under heat stress much earlier than a well-adapted person. The wet-bulb temperature is a good indicator of humidity, air temperature, and wind speed relative to evaporation conditions. A wet-bulb temperature of +24°C or more impedes a non-acclimatized person. A temperature of +33°C can be regarded as the maximum safe work temperature for an acclimatized person.

The ability to sweat and the capacity to export heat by sweat are a prerequisites for work in a hot environment. The capability to sweat varies among people and can be developed by acclimatization and physical conditioning. A non-acclimatized person may perspire 600 g of water and salts per hour during work. A well-trained and acclimatized person can produce 1000 g per hour. Loose-fitting clothing that wicks, low humidity, and high wind velocity all promote the cooling effect.

Sweat consists of water and salts. Unless loss of water and salts is compensated for, work capacity is quickly reduced. A loss of 1–1.5 liters for a normal-sized person impedes capacity and endurance. Acclimatization to hot microclimate requires work in a hot surrounding for a few hours daily for a period of 7–9 days. The acclimatization is lost in a period of weeks if not maintained.

Adaptation to work in a cold surrounding is not as difficult as adapting to heat. A well-trained person acclimatized to work in a cold environment tolerates larger variations in local temperature before feeling uncomfortable. There is no evidence for the general concept that the body increases metabolism to compensate for low temperature (92).

Cooling of some part of the body results in reduced sweat production, and a localized heating in the same area generates a general increase in sweat production. The forehead is a strategic area for this effect. Physical work generates a natural adaptation to work in cold surroundings. However, heavy physical work does not exclude the risk of cold injuries to the face and extremities when working in very cold and windy weather.

9.15 Disorders due to Heat

Heat stress is described by several specific increasingly serious stages of heat-related illnesses along a continuum. Heat cramps, heat exhaustion, heat syncope, and heat stroke are listed in increasing seriousness of heat illnesses. Heat stroke is the most dangerous heat reaction, but the former conditions are more common, less serious, and may occur in any order prior to heat stroke. Skin disorders and infertility are other reactions related to heat exposure.

Some health conditions, especially conditions with reduced sweat production capacity or reduced evaporation capacity, impede the ability to work (or stay) in a very hot climate. Such conditions include obesity, some cardiac diseases, use of alcohol, and medications that inhibit sweating, such as atropine. (The latter may be used by insecticide applicators as a prophylactic.) Antidepressants, diuretics, and beta blockers may also increase risk. Conditions that may increase heat illness include those causing reduced cutaneous blood flow or dehydration, use of drugs or exposure to chemicals that increase metabolism (e.g., amphetamines and the insecticide/fungicide dinitrophenol), certain cancers, and infections. Older people do not acclimatize as well as younger people and women generate more heat performing the same tasks as men.

9.15.1 Heat Cramps

A large consumption of water without salts in hot weather may lead to heat cramps. Low levels of sodium alter muscle reactions, resulting in weakness, slow muscle contractions, or even severe muscle spasms. Dizziness, malaise, and vomiting may be associated symptoms.

Normally the food and body reserve of salt is sufficient to compensate for losses when working in a hot environment. Drinking water (up to 1 liter per hour) is the most important preventive measure when working in hot weather. Water is also the first choice of treatment for heat cramps. Salt tablets or a mild salt solution (1 teaspoon or 6 g per liter of water) may be given, consumed over 60 minutes or so. However, a better remedy is to provide one of the balanced salts solutions marketed as sports drinks. Patients with heat cramps should be moved to a cool location. A few days of rest before a return to work is recommended.

9.15.2 Heat Exhaustion

Heat exhaustion is a more serious condition than cramps. Prolonged exposure to heat in combination with inadequate intake of water and salt can cause heat exhaustion, which is characterized by cardiovascular changes, fatigue, and a feeling of being exhausted. Thirst, headache, and weakness are common symptoms. The temperature exceeds 38°C, the skin is moist, and the pulse rate is increased. Loss of water and salt causes a blood electrolyte imbalance. A progression to heat syncope or stroke is a risk and is indicated by an increase in temperature and decreased sweating along with possible confusion. Early recognition of these signs as indications of progression to a more serious condition, including heat stroke, should prompt rapid intervention measures.

After a loss of approximately 1.5% of body weight (~1 liter of sweat) the tolerance to heat is reduced, the pulse rate increases, and the risk of a rapid increase in body temperature is obvious. Cardiovascular failure is possible if the loss of water and salt is not compensated for and the mental capacity is reduced, leading to impaired judgement and increased risk of traumatic injuries.

The risk of heat exhaustion is controlled by continuous fluid replacement. Unfortunately, thirst is not an adequate indicator of the dimension of water loss and as a symptom of heat illness lags behind the onset of dehydration. Thirst is reduced even with a small intake of water. More water and salts than indicated by the thirst must be consumed.

9.15.3 Heat Syncope

Heat syncope is caused by disturbed blood distribution. Excessive circulating blood volume aggregates in the largest body organ (the skin) because of cutaneous vasodilatation. The result is a reduction in systolic blood pressure and hypoperfusion of the body's other organs, including cerebral hypotension, with sudden unconsciousness. Long periods of standing in combination with strenuous work in hot environments predispose to heat syncope. The patient should be positioned in a recumbent position and moved to a cooler place. Recovery is usually quick without any further symptoms if preventive measures are rapidly and appropriately applied. Persons who are not acclimatized have a greater risk. Other pre-existing medical conditions should be monitored.

9.15.4 Heat Stroke

Heat stroke is characterized by high body temperature, a lost or strongly reduced sweating capacity, disturbed mental activity (often manifest as confusion), coma, and/or convulsions (93, 94). Blood pressure goes down and the skin is hot and dry. The core temperature usually exceeds 41°C. Life-threatening disturbance of electrolyte balance, disturbance of blood-clotting factors (thrombocytopenia, fibrinolysis, and consumptive coagulopathy) (95), and rhabdomyolysis may result in cardiac shock and permanent damage to the liver and kidneys.

The classic form appears among those known to have a reduced capacity to adjust to high temperatures. Exertional heat stroke results from heavy work in a hot environment, especially among those who are not acclimatized.

On-scene emergency treatment includes immediate rapid reduction in body temperature by spraying or immersing the body in cool water while waiting for transportation to a hospital. This action should be ongoing until the body temperature has declined to 39°C. Emergency room or in-hospital treatment should include continuous observation and monitoring of the patient for hypovolemic, cardiogenic shock, and reduced kidney function. The capacity to treat complications of kidney failure and cardiac shock should be on hand while administering fluid and electrolyte replacement, and monitoring kidney function and urine output (96).

9.15.5 Skin Disorders Related to Heat

Intertrigio is common among obese people. The skin in body folds, the groin, and the axilla become erythematous and macerated. Good hygiene is necessary (daily bathing with soap). To avoid further problems, weight reduction is highly recommended.

Heat rash (miliaria) is caused by inflammation and obstruction of the sweat glands and causes sweat retention. Symptoms vary but the usual appearance is multiple small red inflamed papules with erythema where clothing fits tightly or in areas that do not dry easily, such as under arms and at the belt line (see Chapter 4 for details of this condition).

Heat urticaria is a condition with elevated (swollen) plaques stimulated by heat. It can be localized or generalized. Antihistamines may help. Corticosteroids are not recommended. The condition is self-limiting and will dissipate in 24–48 hours, but may leave the patient with a temporary pruritus at the site of the lesion.

Additional details of heat-related skin disorders are seen in Chapter 4 (agricultural dermatoses).

9.15.6 Nephrolithiasis and Hot Environment

Some studies indicate that a chronic dehydration increases the risk of kidney stone disease (97). Chronic dehydration is mostly seen among workers with low water intake in a hot environment. One study indicated an almost fourfold risk for kidney stones in a group of workers in a glass plant in comparison with a control working group (98). Uric acid stones are most likely and adequate fluid intake is recommended to avoid problems.

9.15.7 Infertility

Work in a hot environment for long periods is a well-known risk factor for male infertility (99). Working in a hot environment over time contributes to loss of semen quality (100, 101). A hot environment has also been suggested as a risk for cancer of the testis (102).

9.16 Disorders Related to Cold

9.16.1 Systemic Hypothermia

If the body's core temperature is reduced to below 35°C systemic hypothermia will occur with a cascading group of symptoms. Shivering starts or is more intensive. Working capacity is reduced as a result of deteriorating muscle capacity and reduced absorption of oxygen. Physical exhaustion gradually increases. As the body temperature declines further, confusion and apathy will be begin along with possible hallucinations. Shivering declines and stops due to hypoglycaemia. A paradoxical feeling of hotness may arise and may be characterized by undressing, which obviously aggravates the condition.

Below a body temperature of 33°C, muscle function is even more limited and the cardiac activity is affected due to slowed repolarization. Consciousness is reduced and below 30°C the individual is generally not communicable. The pupils are dilated and breathing is weak. Cardiac activity is hard to detect and the risk of cardiac arrest or ventricular fibrillation is evident. Death may follow.

In all cases of hypothermia the first action should be to avoid more cooling. If the person is conscious and alert, physical activity may be stimulated to assist personal heat production. If the person is wet he or she must be transported to a dry environment and wet clothing should be changed. If the patient is unconscious emergency transportation to hospital is urgent. It may be dangerous to start warming an unconscious person in the field because of the risk of cardiac fibrillation. Unconscious patients with body temperatures as low as 28°C generally recover completely without any permanent disability if complications can be managed.

The circumstances under which a person with hypothermia is found must be analyzed. Pre-existing medical conditions, problems with alcohol or drug abuse, depression, and possible suicidal action as well as dementia must be considered. In other cases the situation is generally related to unintended circumstances (falling in cold water) or unusual and unexpected weather conditions.

9.16.2 Localized Hypothermia

Localized tissue damage may develop in exposed parts of the body, such as the nose, ears, fingers, and feet, if body temperature is reduced below 15°C due to cooling, humidity, or immobilization. This is related to localized ischemia and the development of small superficial thrombosis. Actual freezing of the tissues may also occur, resulting in significant damage.

The degree of a localized cold injury is related to the speed of cooling, depth, and surface area affected. In case of superficial damage, only the epidermis and dermis are affected. The skin is white and without circulation but is not adherent to underlying structures. Warming rapidly restores normal conditions. Firm skin adherent to underlying structures characterizes deep damage. Rewarming should be performed as soon as possible. This can be done using warm water (40–42°C). Higher water temperatures risk superficial heat damage because the skin has temporarily lost sensitivity.

Prolonged local cold exposure sufficient to damage blood vessels and permanently disrupt blood supply to local areas is called *frostbite*. There are variable amounts of tissue necrosis with frostbite, which can be mild or extensive with significant loss of skin, digits, or even appendages. In cases of severe frostbite hospitalization is recommended. Profound tissue damage may develop and the period of healing may be long and complicated, with ulceration and gangrene.

Chilblains or pernio is a superficial skin lesion due to inflammation and related to a temporary exposure to cold. Prolonged exposure may lead to chronic pernio or "blue toes." The acral parts of the toes may be erythematous and edematous with small ulcerating lesions.

Immersion foot is an extensive frostbite involving the whole foot. It is characterized by a long course with chronic complications. After prolonged cold exposure, the foot is cold to the touch, swollen, and cyanotic, or waxy white. Some days later hyperaemia occurs and the foot turns red, hot, more swollen, and painful. Localized hemorrhage and lymphangitis appear and in some cases thrombophlebitis and gangrene may follow. A month later intense paresthesias sometimes occur. Chronic localized cold sensitivity and hyperhidrosis may be present for many years with immersion foot, as well as with other localized cold injuries.

Cold urticarial is characterized by superficial and/or angioedematous reaction after cold contact. Cold urticarial may be genetic, but acquired idiopathic cold urticarial is more common. Therapy is often difficult. There is a risk that this kind of urticaria may develop to an anaphylactic reaction at a further exposure. Patients should be warned against swimming in cold water and other dangerous cold exposures.

9.17 Climate and Physical and Mental Capability

Acclimatization and individual physical differences in tolerance to extreme temperatures are important variables in worker productivity that may include impaired social relations or organizational problems (103, 104). Ambient temperatures of 30°C and above have been shown to reduce mental and physical performance in workplaces (105). The decrease in performance is apparently due mainly to discomfort rather than excess physiologic strain. The effective temperature (ET) scale is recommended to evaluate climate effects in workplaces. Wind velocity has great impact on the performance. Studies (106) indicate the following:

- 5% drop in performance at 29°C (ET)
- 10% drop in performance at 30°C (ET)
- 17% drop in performance at 31°C (ET)
- 30% drop in performance at 32°C (ET).

The comfort zone for light work with low air velocity, acceptable clothing, and no radiant heat is given by three parameters: dry-bulb temperature, wet-bulb temperature, and water vapor pressure.

9.18 Prevention of Injuries Related to Heat and Cold

Agriculture is a highly diversified work context with respect to climate and comfort. Settings vary from tropical zones to ranching in areas with very cold winters, such as central Canada or reindeer production in the Scandinavian countries. In industries like farming and forestry it is difficult to control heat exposure and cold exposure with engineering measures. However, in extreme climate situations, worker acclimatization is the first priority. Adequate water should be supplied, and workers should be fit and not hindered by medical problems or medications that might complicate temperature exposures.

Traditionally farmers have developed strategies to adjust working methods and appropriate clothing to the local conditions. Introducing new techniques may change the prerequisites. Tractor cabs, for example, may provide protection against dust exposure, but without air conditioning the local in-cab climate may be very hot. If adaptions are not made to accommodate working in cold or hot environments, work quality and quantity are generally reduced. However, few studies are available to quantify these effects in agricultural contexts (104).

The US National Weather Service has developed guidelines (Figure 9.8) to predict exposure risks according to high temperature and humidity (107). The cooling effect of low temperature depends on wind velocity; the wind chill index combines these two factors.

Risk zones and related heat disorders.

Heat index

Relative humidity %									
100	22	27	33	42					
90	22	26	31	39	50				
80	22	26	30	36	45	58			
70	21	25	30	34	41	51	62		
60	21	24	28	32	38	46	56	65	
50	21	24	27	31	36	42	49	57	66
40	20	23	26	30	34	39	44	51	59
30	20	23	26	29	32	36	40	45	51
20	19	22	25	28	31	34	37	41	45
10	18	21	24	27	30	30	35	38	41
0	18	21	23	26	28	31	33	35	38
Air temperature °C	21	24	27	30	32	35	38	41	44

Heat index	Heat disorders possible with prolonged exposure and/or physical activity
27°C–31°C	Fatigue
32°C–40°C	Sunstroke, heat cramps and heat exhaustion
41°C–54°C	Sunstroke, heat cramps or heat exhaustion likely, and heat stroke possible
55°C or higher	Heatstroke/sunstroke highly likely

NOTE: Direct sunshine increases the heat index by up to 9°C

FIGURE 9.8 The physiologic effect of heat on the body depends largely on the combination of temperature and humidity. The US National Weather Service has developed guidelines to predict exposure risks according to high temperature and humidity.

9.19 Summary

A number of studies over the years have substantiated that hearing loss is common among farmers. Later studies indicate that the situation may be improving. However, in most countries there still are no broadly deployed hearing protection programs for farmers. It is difficult to map noise exposure in a farm where the work environment in terms of noise is diverse and constantly changing, thus very few studies of individual exposure (dosimetry) in farming and forestry have been reported.

Exposure to loud noise for a short period of time produces temporary hearing loss (temporary threshold shift, or TTS). A TTS can last for several hours or a day and might be experienced as ringing in the ears (tinnitus) and difficult hearing. Chronic noise exposure (months to years) may generate a permanent threshold shift (PTS) from which there is no recovery. Very loud noise can instantaneously cause permanent hearing impairment.

A simple pure tone audiometry demonstrates hearing damage nature and extent with major hearing loss at 400 MHz, which is often characteristic of noise damage. Some people with noise injury also have problems with tinnitus and hyperacusis.

Noise-induced hearing loss (NIHL) is preventable. Most Western industrialized countries have regulations for noise exposure limits and prescribed controls to prevent NIHL. Generally, exposure above 85 dB(A) over an 8-hour working day is not permitted. A hearing conservation program may be required.

Prevention begins with the mapping of noise and its character. Improved technology and work organization often leads to lower noise levels.

Workers can be separated from noise sources. Training and information lowers individual exposure levels and personal protective equipment should be available.

Hand-held vibrating tools transfer energy to the hands and arms. Prolonged exposure causes damage to blood vessels, nerves, and other structures in the hands and forearms: hand–arm vibration syndrome (HAVS). Vibration white finger (a component of HAVS) is an injury that has been known for more than 100 years. It is still not known how and why mechanical energy from vibrations induce nerve damage and alter control of blood vessel tone. Hereditary factors are likely to have great significance as well as the vibration intensity and exposure time.

Farmers and foresters who drive tractors and forestry machines are also exposed to whole-body vibrations that may cause different types of damage. The effects of whole-body vibration are not well known, but low back pain and general malaise are common associated symptoms.

Occupational injuries related to heat and cold may at first glance appear to be a minor problem. In fact, people in tropical and subtropical areas die every year because of heatstroke. Farmers are an exposed group and knowledge about risks and prevention is important.

Convection, radiation, and evaporation are the three main ways of heat transfer from (or to) the human body. If the air temperature exceeds skin temperature, the heat flow is reversed and the surrounding air heats the body. Evaporation is the most efficient method of heat export. Evaporation is affected by humidity, wind velocity, and temperature. Internal physiological factors also affect evaporative cooling. The non-acclimatized person may come under heat stress much earlier than a well-adapted person. A temperature of +33°C can be regarded as the maximum safe work temperature for an acclimatized person.

The ability to sweat and the capacity to export heat by sweat are prerequisites for work in a hot environment. The ability to sweat varies among people and can be developed by acclimatization and physical conditioning. A non-acclimatized person may perspire 600 g of water per hour during work. A well-trained and acclimatized person can produce 1000 g per hour.

Four different conditions caused by heat can be identified: heat cramps (related to low levels of sodium), heat exhaustion (related to inadequate intake of water and salt), heat syncope (caused by disturbed blood supply), and heat stroke. Heat stroke is an emergency characterized by a core body temperature above 41°C and widespread disruption of electrolyte balance and coagulability.

Industrial injuries related to cold can easily be prevented. Traditionally farmers have developed strategies to adjust working methods and clothing to the local conditions.

Key Points

1. Hearing loss is a common occurrence among farmers. Better prevention has reduced the risks over the years.
2. Noise levels above 85 dB over an 8-hour working day should be avoided. The risk level of 85 dB is arbitrary. Risk of hearing damage may also occur at lower noise levels.
3. Noise damage can be prevented. Technical improvements in machinery and better working practices as well as training skills and personal protective equipment reduce the risks.
4. Working with hand-held vibrating tools involves the risk of vibration injury. Hand–arm vibration syndrome (HAVS) includes vibration white finger (VWF), polyneuropathy, and other damage to local structures. Hereditary factors are related to the risk of injury.
5. The ability to tolerate high temperature varies among people and can be developed by acclimatization and physical conditioning.
6. Heat stroke is an emergency. Work-related deaths are reported annually in tropical and subtropical regions.

References

1. McBride DI, Firth HM, Herbison GP. Noise exposure and hearing loss in agriculture: a survey of farmers and farm workers in the Southland region of New Zealand. J Occup Environ Med. 2003;45(12):1281–8.
2. Thelin A. Work and health among farmers. A study of 191 farmers in Kronoberg County. Sweden. Scand J Soc Med Suppl. 1981;22:1–126.
3. Blatherwick FJ. Tractor noise – a farm hazard. Alberta Med Bull. 1969;34:21–28.
4. Tomlinson RW. A tractor noise limit according to predicted driver hearing loss. Bedford: National Institute of Agricultural Engineers; 1970.
5. Marvel ME, Pratt DS, Marvel LH, Regan M, May JJ. Occupational hearing loss in New York dairy farmers. Am J Ind Med. 1991;20(4):517–31.
6. Depczynski J, Challinor K, Fragar L. Changes in the hearing status and noise injury prevention practices of Australian farmers from 1994 to 2008. J Agromedicine. 2011;16(2):127–42.
7. Bruel PV. Do we measure damaging noise correctly? Bruel & Kjaer Tech Rev. 1976;1:3.
8. Li H, Liu H, Heller S. Pluripotent stem cells from the adult mouse inner ear. Nat Med. 2003;9(10):1293–9.
9. Choi SW, Peek-Asa C, Sprince NL, Rautiainen RH, Donham KJ, Flamme GA., et al. Hearing loss as a risk factor for agricultural injuries. Am J Ind Med. 2005;48(4):293–301.
10. ISO-1000: Acoustics: Determination of Occupational Noise Exposure and Estimation of Noise Induced Hearing Impairment. Switzerland: International Organization for Standardization; 1990.
11. Andersson G, Lyttkens L, Larsen HC. Distinguishing levels of tinnitus distress. Clin Otolaryngol. 1999;24(5):404–10.
12. Axelsson A, Ringdahl A. Tinnitus – a study of its prevalence and characteristics. Br J Audiol. 1989;23(1):53–62.
13. Holgers KM, Erlandsson SI, Barrenas ML. Predictive factors for the severity of tinnitus. Audiology. 2000;39(5):284–91.
14. Zoger S, Svedlund J, Holgers KM. Psychiatric disorders in tinnitus patients without severe hearing impairment: 24 month follow-up of patients at an audiological clinic. Audiology. 2001;40(3):133–40.
15. Hetrick WP, Erickson MA, Smith DA. Phenomenological dimensions of sensory gating. Schizophr Bull. 2012;38(1):178–91.
16. Ernest K, Thomas M, Paulose M, Rupa V, Gnanamuthu C. Delayed effects of exposure to organophosphorus compounds. Indian J Med Res. 1995;101:81–4.
17. Teixeira CF, Augusto LG, Morata TC. [Hearing health of workers exposed to noise and insecticides]. Rev Saude Publica. 2003;37(4):417–23.
18. Klockhoff I, Drettner B, Svedberg A. Computerized classification of the results of screening audiometry in groups of persons exposed to noise. Audiology. 1974;13(4):326–34.
19. De Joy DM. The nonauditory effects of noise: review and perspectives for research. J Auditory Res. 1984;24:123–150.
20. Rehm S, Gros E, Jansen G. Effects of noise on health and well-being. Stress Med. 1985;1:183–191.
21. Abel SM. The extra-auditory effects of noise and annoyance: an overview of research. J Otolaryng. 1990;(Suppl.1):1–13.
22. Sloan RP. Cardiovascular effects of noise. In: Fay TH, editor. Noise and Health. New York: New York Academy of Medicine; 1991.
23. Yousefi Rizi HA, Hassanzadeh A. Noise exposure as a risk factor of cardiovascular diseases in workers. J Educ Health Promot. 2013;31(2):14.
24. Jones D. Recent advances in the study of human performance in noise. Environ Int. 1990;16: 447–458.
25. Smith AP. A review of the effects of noise on human performance. Scand J Psychol. 1989;30:185–206.
26. Franklin RC, Depczynski J, Challinor K, Williams W, Fragar LJ. Factors affecting farm noise during common agricultural activities. J Agric Saf Health. 2006;12(2):117–25.
27. Depczynski J, Franklin RC, Challinor K, Williams W, Fragar LJ. Farm noise emissions during common agricultural activities. J Agric Saf Health. 2005;11(3): 325–34.
28. Solecki L. Characteristics of annual exposure to noise among private farmers on family farms of mixed-production profile. Ann Agric Environ Med. 2006;13(1):113–8.
29. Ehlers JJ, Graydon PS. Noise-induced hearing loss in agriculture: creating partnerships to overcome barriers and educate the community on prevention. Noise Health. 2011;13(51):142–6.
30. Lower T, Fragar L, Depcynzksi J, Challinor K, Mills J, Williams W. Improving hearing health for farming families. Rural Remote Health. 2010;10(1):1350.
31. Lower TE, Fragar L, Depcynzksi J, Fuller J, Challinor K, Williams W. Social network analysis for farmers' hearing services in a rural community. Aust J Prim Health. 2010;16(1):47–51.
32. Voaklander DC, Franklin RC, Challinor K, Depczynski J, Fragar LJ. Hearing screening program impact on noise reduction strategies. J Agric Saf Health. 2009;15(2):119–27.

33. Raynaud M. De l'asphyxie locale et de la gangrène symétrique des éxtremités. Paris: L. Leclerc, Libraire-Éditeur; 1862.
34. Loriga G. Il lavoro con i martelli pneumatici. Boll Inspett Lavoro. 1911;2:35–60.
35. Hamilton AA. A study of spastic anemia in hands of stonecutters. Bull US Bureau of Labor Statistics No 236. Ind Accidents and Hygiene Series. 1918;19:53–66.
36. Stockholm workshop '86. Symptomatology and diagnostic methods in the hand–arm vibration syndrome. Scand J Work Environ Health. 1986;13:4.
37. Gemne G. Pathophysiology and pathogenensis of disorders in workers using hand-held vibrating tools. In: Pelmear P, Taylor W, Wassermann D, editors. Hand–arm vibration. A comprehensive guide for occupational health professionals. New York: Van Nostrand Reinhold; 1992.
38. Gemne G. Diagnostics of hand–arm system disorders in workers who use vibrating tools. Occup Environ Med 1997;54(2):90–5.
39. Anttonen H, Virokannas H. Hand–arm vibration in snowmobile drivers. Arctic Med Res. 1994;53 (Suppl.3):19–23.
40. Taylor W, Pelmear PL, Pearson J. Raynaud's phenomenon in forestry chain saw operators. In: Taylor W, editor. The Vibration Syndrome. London and New York: Academic Press; 1974.
41. Pyykkö I, Korhonen O, Färkkilä M, Starck J, Aatola S, Jantti V. Vibration syndrome among Finnish forest workers, a follow-up from 1972 to 1983. Scand J Work Environ Health. 1986;12(4Spe cNo):307–12.
42. Peplonska B, Szeszenia-Dabrowska N. Occupational diseases in Poland, 2001. Int J Occup Med Environ Health. 2002;15(4):337–45.
43. Seidel H. Selected health risks caused by long-term, whole-body vibration. Am J Ind Med. 1993;23(4): 589–604.
44. Seidel H, Heide R. Long-term effects of whole-body vibration: a critical survey of the literature. Int Arch Occup Environ Health. 1986;58:1–26.
45. Taylor W, Pelmear PL. Vibration white finger in industry. London: Academic Press; 1975.
46. Gemne G, Pyykkö I, Taylor W, Pelmear P. The Stockholm workshop scale for the classification of cold-induced Raynaud's phenomenon in the hand–arm vibration syndrome (revision of the Taylor–Pelemar scale). Scand J Work Environ Health. 1987;13:275–278.
47. Thulesius O. Vibration-induced white fingers. Läkartidningen. 1976;73:2269–2270.
48. Ekenvall L. Vibration syndrome. Clinical and pathogenic aspects (thesis). Stockholm: Karolinska Institutet; 1987.
49. Ekenvall L, Lindblad LE, Bevegard S, Etzell BM. High vascular tone but no obliterative lesions in vibration white fingers. Am J Ind Med. 1987;12(1): 47–54.
50. Ekenvall L, Lindblad LE. Is vibration white finger a primary sympathetic nerve injury? Br J Ind Med. 1986;43:702–706.
51. Gerhardsson L, Hagberg M. Work ability in vibration-exposed workers. Occup Med (Lond). 2014;64(8):629–34.
52. Rolke R, Rolke S, Vogt T, Birklein F, Geber C, Treede RD, et al. Hand–arm vibration syndrome: clinical characteristics, conventional electrophysiology and quantitative sensory testing. Clin Neurophysiol. 2013;124(8):1680–8.
53. Bovenzi M, Apostoli P, Alessandro G, Vanoni, O. Changes over a workshift in aesthesiometric and vibrotactile perception thresholds of workers exposed to intermittent hand transmitted vibration from impact wrenches. Occup Environ Med. 1997;54:577–587.
54. Bovenzi M, Fiorito A, Volpe C. Bone and joint disorders in the upper extremities of chipping and grinding operators. Int Arch Occup Environ Health. 1987;59(2):189–98.
55. Fam AG, Kolin A. Unusual metacarpophalangeal osteoarthritis in a jackhammer operator. Arthritis Rheum. 1986;29(10):1284–8.
56. Stenlund B, Goldie I, Marions O. Diminished space in the acromioclavicular joint in forced arm adduction as a radiographic sign of degeneration and osteoarthrosis. Skeletal Radiol. 1992;21(8):529–33.
57. Stenlund B, Goldie I, Hagberg M, Hogstedt C. Shoulder tendinitis and its relation to heavy manual work and exposure to vibration. Scand J Work Environ Health. 1993;19(1):43–9.
58. Kumlin T, Wiikeri M, Sumari, P. Radiological changes in carpal and metacarpal bones and phalanges caused by chain saw vibration. Br J Ind Med. 1973;30:71–73.
59. Karjalainen P, Alhava EM, Valtola J. Thenar muscle blood flow and bone mineral in the forearms of lumberjacks. Br J Ind Med. 1975;32:11–15.
60. Kivekas J, Riihimäki H, Husman K, Hänninen K, Harkonen H, Kuusela T, et al. Seven-year follow-up of white-finger symptoms and radiographic wrist findings in lumberjacks and referents. Scand J Work Environ Health. 1994;20(2):101–6.
61. Gemne G, Saraste H. Bone and joint pathology in workers using hand-held vibrating tools. Scand J Work Envrion Health. 1987;13(4Special Issue):290–300.
62. Hagberg M, Morgenstern H, Kelsh M. Impact of occupations and job tasks on the prevalence of carpal tunnel syndrome. Scand J Work Environ Health. 1992;18(6):337–45.

63. Silverstein BA, Fine LJ, Armstrong TJ. Occupational factors and carpal tunnel syndrome. Am J Ind Med. 1987;11(3):343–58.
64. Färkkilä M, Aatola S, Starck J, Korhonen O, Pyykkö I. Hand-grip force in lumberjacks: two year follow-up. Arch Occup Environ Health. 1986;58: 203–208.
65. Necking LE, Dahlin LB, Fridén J, Lundborg G, Lundström R, Thörnell LE. Vibration-induced muscle injury. An experimental model and preliminary findings. J Hand Surg [Br]. 1992;17:270–274.
66. Pettersson H, Burstrom L, Nilsson T. Raynaud's phenomenon among men and women with noise-induced hearing loss in relation to vibration exposure. Noise Health. 2014;16(69):89–94.
67. Pyykkö I, Starck J, Färkkilä M, Hoikkala M, Korhonen O, Nurminen M. Hand–arm vibration in the aetiology of hearing loss in lumberjacks. Br J Ind Med. 1981;38:281–289.
68. Iki M, Kurumatani N, Hirata K, Moriyama T, Satoh M, Arai T. Association between vibration-induced white finger and hearing loss in forestry workers. Scand J Work Environ Health. 1986;12(4Spec. No.):365–70.
69. Palmer KT, D'Angelo S, Syddall H, Griffin MJ, Cooper C, Coggon D. Dupuytren's contracture and occupational exposure to hand-transmitted vibration. Occup Environ Med. 2014;71(4):241–5.
70. Pyykko I, Farkkila M, Korhonen O, Starck J, Jantti V. Cold provocation tests in the evaluation of vibration-induced white finger. Scand J Work Environ Health. 1986;12(4Spec.No.):254–8.
71. Poole K, Elms J, Mason HJ. The diagnostic value of finger systolic blood pressure and cold-provocation testing for the vascular component of hand–arm vibration syndrome in health surveillance. Occup Med (Lond). 2004;54(8):520–7.
72. Harada N, Mahbub MH. Diagnosis of vascular injuries caused by hand–transmitted vibration. Int Arch Occup Environ Health. 2008;81(5):507–18.
73. Ekenvall L, Nilsson BY, Gustavsson P. Temperature and vibration thresholds in vibration syndrome. Br J Ind Med. 1986;43(12):825–9.
74. Lundborg G, Sollerman C, Strömberg T, Pyykkö I, Rosen B. A new principle for assessing vibrotactile sense in vibration-induced neuropathy. Scand J Work Environ Health. 1987;13(4):375–9.
75. Lundström R, Strömberg T, Lundborg G. Vibrotactile perception threshold measurements for diagnosis of sensory neuropathy. Description of a reference population. Int Arch Occup Environ Health. 1992;64(3):201–7.
76. Lindsell CJ, Griffin MJ. Normative data for vascular and neurological tests of the hand–arm vibration syndrome. Int Arch Occup Environ Health. 2002;75(1–2):43–54.
77. Leppert J, Aberg H, Ringqvist I, Sorensson S. Raynaud's phenomenon in a female population: prevalence and association with other conditions. Angiology. 1987;38(12):871–7.
78. Pope MH, Broman H, Hansson T. The dynamic response of a subject seated on various cushions. Ergonomics. 1989;32(10):1155–1166.
79. Magnusson M, Pope MH, Rostedt M, Hansson T. The effect of backrest inclination on the transmission of vertical vibrations through the lumbar spine. Clin Biomech. 1993;8:5–12.
80. Lings S, Leboeuf-Yde C. Whole-body vibration and low back pain: a systematic, critical review of the epidemiological literature 1992–1999. Int Arch Occup Environ Health. 2000;73(5):290–7.
81. Bovenzi M, Hulshof CT. An updated review of epidemiologic studies on the relationship between exposure to whole-body vibration and low back pain (1986–1997). Int Arch Occup Environ Health. 1999;72(6):351–65.
82. Lis AM, Black KM, Korn H, Nordin M. Association between sitting and occupational LBP. Eur Spine J. 2007;16(2):283–98.
83. Bible JE, Choemprayong S, O'Neill KR, Devin CJ, Spengler DM. Whole-body vibration: is there a causal relationship to specific imaging findings of the spine? Spine. 2012;37(21): E1348–55.
84. Tiemessen IJ, Hulshof CT, Frings-Dresen MH. Low back pain in drivers exposed to whole body vibration: analysis of a dose-response pattern. Occup Environ Med. 2008;65(10):667–75.
85. Burström L, Nilsson T, Wahlström J. Whole-body vibration and the risk of low back pain and sciatica: a systematic review and meta-analysis. Int Arch Occup Environ Health. 2014;88(4):403–18
86. Wertheim AH. Working in a moving environment. Ergonomics. 1998;41(12):1845–58.
87. Nelson CM, Brereton PF. The European vibration directive. Ind Health. 2005;43(3):472–9.
88. Xiang J, Bi P, Pisaniello D, Hansen A. Health impacts of workplace heat exposure: an epidemiological review. Ind Health. 2014;52(2):91–101.
89. Crowe J, Wesseling C, Solano BR, Umana MP, Ramirez AR, Kjellstrom T, et al. Heat exposure in sugarcane harvesters in Costa Rica. Am J Ind Med. 2013;56(10):1157–64.
90. Mirabelli MC, Richardson DB. Heat-related fatalities in North Carolina. Am J Public Health. 2005;95(4):635–7.
91. Gagge AP, Nishi Y. Heat exchange between human skin surface and thermal environment. In: Lee DKH,

editor. Handbook of Physiology. Bethesda: American Physiological Society; 1977.
92. Burton AC, Edholm OG. Man in a Cold Environment. New York: Hafner; 1969.
93. Shibolet S, Coll R, Gilat T, Sohar E. Heatstroke: its clinical picture and mechanism in 36 cases. Q J Med. 1967;36(144):525–48.
94. Yeo TP. Heat stroke: a comprehensive review. AACN Clin Issues. 2004;15(2):280–93.
95. O'Donnell TF, Jr. Acute heat stroke. Epidemiologic, biochemical, renal, and coagulation studies. J Am Med Asssoc. 1975;234(8):824–8.
96. Glazer JL. Management of heat stroke and heat exhaustion. Am Fam Physician. 2005;71:2133.
97. Embon OM, Rose GA, Rosenbaum T. Chronic dehydration stone disease. Br J Urol. 1990;66(4): 357–62.
98. Borghi L, Meschi T, Amato F, Novarini A, Romanelli A, Cigala F. Hot occupation and nephrolithiasis. J Urol. 1993;150(6):1757–60.
99. Lahdetie J. Occupation- and exposure-related studies on human sperm. J Occup Environ Med. 1995;37(8):922–30.
100. Auger J, Kunstmann JM, Czyglik F, Jouannet P. Decline in semen quality among fertile men in Paris during the past 20 years. N Engl J Med. 1995;332(5):281–5.
101. Bonde JP, Giwercman A, Ernst E. Identifying environmental risk to male reproductive function by occupational sperm studies: logistics and design options. Occup Environ Med. 1996;53(8):511–9.
102. Haughey BP, Graham S, Brasure J, Zielezny M, Sufrin G, Burnett WS. The epidemiology of testicular cancer in upstate New York. Am J Epidemiol. 1989;130(1):25–36.
103. Enander A. Performance and sensory aspects of work in cold environments: a review. Ergonomics. 1984;27(4):365–78.
104. Jokl MV. The effect of the environment on human performance. Appl Ergonomics. 1982;13(4): 269–280.
105. Caplan AL, J. An experimental investigation of the effects of high temperature on the efficiency of workers in deep mines. Bull Inst Min Metall (London). 1946;480:1.
106. Zenz C. Occupational Medicine. Chicago: Year Book Medical Publishers, Inc.; 1975.
107. Bross MH, Nash BT, Carlton FB Jr. Practical Therapeutics – Heat Emergencies. Am Fam Physician. 1994;50:389.

Chapter
10

Psychosocial Conditions in Agriculture

Anders Thelin and Kelley J. Donham

Reviewers: Michael Rosmann and Brandi Janssen

10.1 Introduction and Background

Occupational stress is a common health problem and stress is related to a number of physical and mental disorders. Stress may also have more subtle manifestations, affecting organization and productivity.

Farmers are by tradition subject to a number stressors like difficult weather conditions, machinery break down, and sick animals. Recent years have added a number of new stressors, which sometimes are out of the control of the individual farmer. The economic situation for many farmers has been tighter despite an increase in efficiency (1). The adaptation of new technology in dairy farming needs continuous online information and backup capacity day and night (2). Draughts, flooding, and outbursts of zoonosis are dramatic crises that, if not managed, may lead to periodic depression, hopelessness, and suicide (3).

Comparative studies of the general mental health in urban and rural settings in industrialized countries reveal similar patterns (4), with a possible exception for depressive disorders and suicides. In rural areas, however, people may have considerable greater inaccessibility to medical service, which may affect the outcome (5, 6).

Most research on stress and psychosocial conditions in farming involves cross-sectional or observational studies with low ability to identify causal associations. Thus, hard facts concerning occupational stress in farming associated with mental health problems are lacking. The picture is also complicated by observations indicating that not all employment stress is problematic. Recent observations indicate that psychological work demands related to sufficient control over the work situation may be favorable (7). Longitudinal studies with relevant referents are needed for a better understanding of the work environment and mental health in a farming context.

The understanding of a healthy work environment in terms of psychosocial conditions is a growing section of occupational medicine. Tools to monitor and control stress in the workforce are available but so far not conformed to farming workplaces.

10.1.1 From Peasant to Entrepreneur

The social life of farmers has traditionally been structured by cultural traditions, marriage and extended family relations, and interdependence in work and daily living (neighboring). In many areas of the world, farming villages are still

Agricultural Medicine: Rural Occupational and Environmental Health, Safety, and Prevention, Second Edition.
Kelley J. Donham and Anders Thelin.

important social structures, providing the framework for rural populations. In industrialized Western countries the conditions in rural areas have slowly changed over a period of more than 100 years. Farming as a way of living has been increasingly isolated to the individual, relatively independent from the former social structure (8, 9). Neighbors and the rest of the family are mostly integrated into their personal activities. Although farming is still an important form of production in most countries, farming is more and more industrialized and the farmer today is a specialist, no longer doing everything from building the family home to slaughtering and food preparation. In some areas corporate farms and farming companies today are new actors in farm business. This is related to the fact that modern farming is a very capital-intensive business. It is hard to start farming without a large inheritance or assistance from family.

Basic changes in the way of living and working have a strong impact on the psychological work environment (Figures 10.1 and 10.2). These changes create new sources of stress, and the coping mechanisms imbedded in the former social structures are diminished. These new sources of stress are added to the traditional stressors and affect the work environment as well as family relations.

10.1.2 Farming in a Changing World

From the 1960s it has been discussed if modern living with rapid turnover of goods and services as well as intensive competition might affect people's health. Thomas Holmes and Richard Rahe developed the Social Readjustment Scale to estimate the individual's psychological stress (10). They found that rapid social changes in people's life were related to cardiovascular diseases.

These findings in human beings have also been identified in studies of other animals as disturbing social structures (e.g., moving non-human primates from one established group to another) related to arteriosclerosis and cardiac infarction (11, 12). From an evolutionary perspective these observations indicate that human beings might

FIGURE 10.1 Traditional farming engaged many people.

FIGURE 10.2 Modern farming often is one man's business.

be prone to new health risks in situations with rapidly developing new social structures.

The effects of different environmental factors like noise, pollutions, pesticides, and crowding are relatively well known. The impact of different psychosocial conditions is not so well elucidated. However, the science of how psychological factors generate physical health problems has grown during the last decades. Today it is accepted that chronic stress can exacerbate many general public health problems, such as cardiovascular diseases, diabetes, obesity, and depression (13, 14).

In recent years an increasing number of conflicting interests have confronted farmers as a group and often also individual farmers (15). Inspections on farms regarding food safety and animal welfare may be very frustrating. Activities from environmentalist groups are sometimes very threatening, especially after reports on destroyed machinery and even arsons (16, 17). The dependence of governmental subsidizing may also be disturbing as it is often related to considerable paperwork, changing regulations, and controls.

10.2 Stress and Stress-related Health Disorders

10.2.1 Sources of Stress

An ideal model for understanding of how occupational and environmental stress develops does not exist. There is no general instrument to help differentiate stressful from non-stressful situations and no tool to explain why certain situations or events produce stress in some individuals but not in others (18). However, a number of social and occupational stress-related conditions relevant in a farming context may be observed.

Diseases

Illness and or fear of illness are potential stressors. The conceptualization of health defects may generate anxiety and fear of losing control. Diseases in the family may be a stressor of the same magnitude as a personally perceived illness. Destructive feedback mechanisms may be established since stress may generate physical symptoms which cause more anxiety, fear, and stress. Caring for an ill or disabled family member is a heavy burden and stressor for many persons.

Family

A supportive family and good family relations can buffer stress. On the other hand, conflicts in the family negatively affect all members in the family (19–21). Dissolving family relationships (in most cases) is extremely stressful for all involved, including the children (22, 23).

In farming communities the context and the prerequisites for family life have changed over time. The extent of change varies in different countries. The social conditions are naturally very different in a village community like rural Switzerland in comparison to a modern one-person farm operation in Britain or the United States. In the latter case the farmer is mostly alone while his spouse has another job several kilometers away. In certain rural areas, for example northern rural Sweden, there is a deficit of women as they leave the rural setting to seek other employment. Opportunities to establish a family are disturbed in these areas. The percentage of farmers living alone is larger than among other professionals, at least in some areas (24).

The image of a farmer as a strong independent operator of big machines and manager of large herds has limitations. He/she may be a lonesome person without another person to relate to all day long. If he/she has a spouse, when that spouse comes home they have experiences and contacts to talk about with others unattached to the farm, further isolating the farming partner. Sometimes members of the previous farming generation, such as the parents of the farmer, are living close by and are still involved in the farming operation. Intergenerational issues in family farming can be an extreme stressor. The generations may differ in how the farm should be managed. The operation of the farm, or the farm property, or the estate, in the old way, may no longer be realistic. Difficulties adjusting to changes in social position in intergenerational farms may cause controversy among all family members involved (8).

Traditional gender roles in farmers have been in transition over the past few decades. Traditionally women on farms had several roles and expectations. These multiple roles may be a source of conflicts and stress, especially when the family includes children (25, 26). Changes in gender roles have resulted in more equity and in many countries women have major or primary roles as principle or co-principle operators of the farm, but they still also have the most responsibility for children and household (27). Women on farms with children often have a job outside the farm. These women still feel a responsibility, obligation, or pressure to assist in farming and may be strongly stressed by these conflicting roles (28).

Economy

Most farmers are entrepreneurs. To start and run a modern farm in Western industrialized countries a large capital investment is a prerequisite. The economic resources of farmers are very unequal. Some have a large family capital in terms of a farm they have inherited. Others have a significant property with money from other sources. However, a large number of farmers permanently have marginal cash resources (29). They have to work longer and harder than the average wage earner and they are heavily economically exposed to changes in market prices and the effects of weather on the outcome of their investment. Most farmers live with a constant worry about their economic survival, creating stress (30). Occurrences like a salmonella outbreak or a major change in farm politics may result in an economic or mental breakdown (29).

Relation to Governmental Authorities and Neighbors

In recent years farmers around the world have been criticized for polluting the environment with toxic chemicals and for inhumane treatment of animals in the types of housing used and husbandry practices (17). New laws and updated regulations concerning animal welfare have been introduced in many countries recently (31, 32). Activist groups are working in many areas, sometimes with very aggressive methods and an agenda of changing farming to ensure animals are no longer regarded as property (33).

Many people living in cities have lost the contact with the land that their parents and grandparents had, and do not understand rural agricultural conditions and values. Sometimes farmers are exposed in the media as ruthless profit makers. In many countries a repressive legislation has been introduced and farmers have to open their farms to different types of inspections and controls. These actions may be a result of a notice from a distressed neighbor or just a person passing by. For example, this author (AT) observed a Swedish farmer was reported to authorities 30 times by casual by-passers for possible violations of environmental or animal welfare concerns, resulting in inspections by authorities. In some countries, as in Sweden, the farmer has to pay for some inspections. These conditions are usually present in industrialized countries, but they have generally led to a cultural gap between the farming community and the rest of society that is noted by a mutual lack of understanding, mistrust, and more of an adversarial than cooperative relationship.

The changing legal and political framework within which farmers are required to operate is a source of stress to many farmers. More than half of British farmers were concerned about the amount of record keeping and paperwork required and many had difficulties understanding and completing the forms. Several farmers were anxious about incurring penalties for mistakes in completing forms or failing to comply with obscure regulations (3, 29). Some farmers have a feeling of inferiority, of being a burden to the rest of society. Different types of subsidies increase this feeling of inferiority. Farming in general has lost status relative to other professions. However, the farming population is generally more highly educated than the general population in many areas of industrialized countries (34). Farmers are proud and independent people, but often feel unappreciated (35).

Psychosocial Workplace Factors

Loneliness and social isolation are of concern in modern life on farms, particularly in sparsely populated areas and areas where it is difficult to attract spouses and social institutions are waning. However, several studies indicate that most farmers have well-functioning social networks as the art and practice of "neighboring" (social interaction, mutual caring, and cooperative work) is still alive in many agricultural areas (29, 36). Community social isolation is mostly not a stressor in farming. Residents of urban areas may be more isolated and lonely than farming populations.

Bad weather or machinery break down in time of harvesting or sick animals entail temporary stress. On the other hand, nice weather and healthy animals may alleviate stress. These normal variations in the life of a farmer probably have no impact on the long-term outcome of their mental health. Solving problems may contribute to the feeling of control and thus act as a positive health factor. However, climate change and stress related to drought, fires, and flooding are a real concern in an increasing number of countries (37, 38).

Increasing technology in farming is usually accompanied by different monitoring systems. Robotic milking systems (39), for example, require continuous surveillance and recording, with information and alarms transmitted to the farmer's cellphone day and night. Personality factors may predispose how the individual deals with this kind of continuous monitoring (40). Some individuals with obsessive personality traits may have difficulty adapting to this new work situation (41).

Farming still requires long hours of hard work. Seventy per cent of British farmers worked over 10 hours a day and 20% over 15 hours (29). Dairy farmers had the longest working days. Many Swedish farmers do not have vacations and some do not have a single day away from the job during a full year (42). The lack of opportunities for relaxation and sleep deprivation contribute to stress. However, little is known about the health effects of long working days and short vacations among farmers.

Most family farmers do not have employees. They do not have to realize any role conflicts (except possibly for family relations), and they have no problems with career development, organizational changes, and many other stressors prevalent in industrial or business enterprises. Large farm operations, however, often employ several workers. Some of these are well educated. Others do not have any education or training and do not even speak the language. The farmer, the leader of this kind of organization, needs understanding and skills to be a responsible manager (2). The transformation from traditional farmer to an employer may be a long and stressful learning process (18).

Physical Workplace Factors

Environmental pollution, noise, heat, cold, vibration, chemical exposure, and work injuries are physical factors in the workplace or living environment of farmers that may induce stress. Gaseous odors or particulate emissions from livestock operations may induce physical stress (43, 44). This stress has been measured in the neighbors of large confined animal-feeding operations (45). Many of the neighbors are farmers. This situation creates neighbor conflict and can create severe stressors in some farm communities (46).

As reviewed in Chapter 9 many agricultural operations are very noisy. Noise has been a documented stressor in other settings, such as in those living near airports (47). A recent report shows that people exposed to long-term aircraft noise may develop different metabolic changes, with weight gain (increasing waist circumference) and pre-diabetes probably occurring via stress-induced mechanisms (see below) (48).

Although many male farmers are not concerned about injury risks, many women are highly concerned about potential injury to their family members, which certainly adds to the risk load. In fact some women are sufficiently concerned that they would advise their children to seek employment outside of agriculture (49).

10.3 Stress Physiology

The Hungarian–Canadian researcher Hans Seyle is the father of the modern concept of stress. His first paper "A syndrome produced by diverse nocuous agents" appeared in 1936 (50). Seyle noted that a number of different environmental factors could generate the same physical reactions among different individuals. He started to use the term "stress" to refer to the response that the individual makes to environmental insults. He used the word "stressor" as a term for the stimulus causing stress. During his career he developed a model for how the body defends itself in stressful situations and he emphasized that stress is a general physical reaction caused by a number of environmental factors or stressors.

Stress as a general physical reaction or a syndrome became known as the *general adaptation syndrome* (GAS). It is divided into three stages. The first is the *alarm reaction* characterized by general mobilization through activation of the sympathetic nervous system. The body's systems are activated to maximize strength and prepare them for a fight-or-flight response.

The alarm reaction successively passes on to the second phase of GAS, which is called the *resistance stage*. The objective physical symptoms disappear and the organism adapts to the stressor. The length of this stage depends on the severity of the stressor and the body's adaptive capacity. Although the person gives the outward appearance of normality the body's physical reactions are not normal. This condition is also called *allostasis*. Seyle believed that these reactions in the long run could generate a number of diseases, which he called diseases of adaptation.

The capacity to resist stress is individual and has limitations. Sooner or later the ability to resist will expire and the persistent stress will generate end-stage effects. This final stage is called the *exhaustion stage*. Seyle thought that exhaustion frequently resulted in depression and sometimes even death.

It was obvious to Seyle that stress reactions in some situations were valuable. The capacity to mobilize extra resources when an individual is in difficulty is an important adaptive evolutionary mechanism. This good kind of stress was termed "eustress" while the opposite was called "distress". Distress results in diseases.

Seyle's concept of stress was criticized from different points of views. Cannon described the physiological reactions as an action to stabilize the body to maintain the homeostasis and thought Seyle's concepts too stereotypical (51). Skinner found that the stress reaction is unique to every individual (52). Others (53) noticed that Seyle largely ignored psychological factors, especially the element of emotion. An alternative model focusing psychological factors has been developed by Lazarus and Folkman (54) and has had a great impact among psychologists.

10.3.1 The Nervous System and Stress

One of the functions of the nervous system is to integrate the different systems of the body and maintain homeostasis. The system has a high level of flexibility and capacity of rapid adjustment to new situations. The nervous system provides internal communication and relays information to and from the environment. The external information may be of physical or psychological character. The mix of information is processed in different centers of the brain and combined or associated with previous experiences, archetypical perceptions, and emotional loadings. Threatening situations and/or situations with a disturbing emotional tension are identified and initiates mobilization. This mobilizing is mediated by the *autonomic nervous system* (ANS).

The ANS has two divisions, the *sympathetic nervous system* (SNS) and the *parasympathetic nervous system* (PNS). The signals of the SNS and PNS are mediated to autonomic ganglia from where they are relayed to the effector organs. The SNS ganglia are connected in a chain on either side of the vertebral column. The PNS ganglia are located near or in the effector organs. The SNS ganglia have close interconnections, and thus activation of SNS often has a broad effect while the PNS ganglia have few connections and mostly an effect restricted to a single organ or organ system.

Physiologic results of SNS mobilization and activation include increased rate and strength of cardiac contractions and respiration, decrease in gastrointestinal activity, constriction of blood vessels in the skin, stimulation of the sweat glands, and dilation of the pupils. The adrenal medulla is also stimulated to produce more adrenalin (epinephrine) and noradrenalin (norepinephrine). Noradrenalin is also produced by the brain stem in the locus coeruleus. These catecholamines have complex effects acting as neurotransmittors and as hormones. Adrenalin and noradrenalin act similarly on some organs and differently on others. Two basic actions may be mentioned: (1) influence of the tone and contraction of muscles, and (2) influence on the metabolism of carbohydrate and fat. The actions are mediated by receptors in the cell membranes of the target cells. At least two kinds of adrenergic receptors are recognized, α-receptors and β-receptors. Contractile action on smooth muscle is mediated by α-receptors while metabolic effects and excitation of the myocardium are mediated by β-receptors.

Skeletal muscles are also mobilized in case of stress (55). Areas in the neocortex, the amygdala, and areas in the brain stem are engaged in preparing the muscles for physical activity by elevating muscle tone. Central activity in the amygdala area also may upgrade the level of muscular tone.

10.3.2 The Endocrine System and Stress

There is a chain of stress hormones that are activated during stress. First corticotrophin-releasing hormone (CRH) from the hypothalamus simulates the pituitary to release adrenocorticotropic

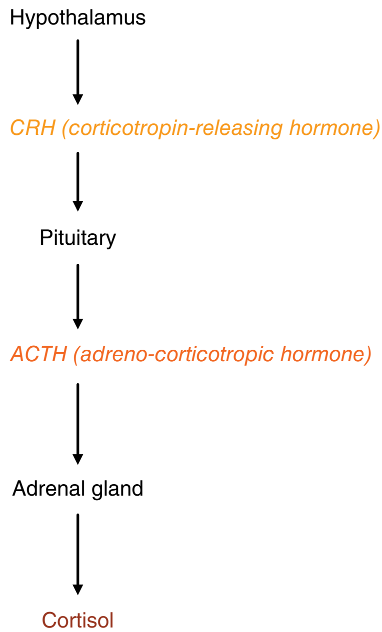


FIGURE 10.3 The HPA axis.

hormone (ACTH), which in turn stimulates the adrenal gland (cortex) to release cortisol (the most important of the stress-related hormones). The axis from hypothalamus via the pituitary to the adrenal cortex is called the hypothalamic–pituitary–adrenal (HPA) axis and is of fundamental importance in the activation of stress reactions (Figure 10.3).

Cortisol is so closely associated with stress that the concentration of cortisol circulating in the blood can be used as an index of stress. Cortisol can easily be analyzed in blood as well as in saliva. There is a normal variation in the concentration of cortisol in the blood over the day, with highest levels in early morning and lower levels in the evening. There are large differences in the level of cortisol between different individuals as well as in the variation over the day.

Cortisol has a number of physiological effects. Gluconeogenesis is stimulated and the availability of glucose is raised. Lipolysis is also stimulated, resulting in a release of fatty acids to the circulation. In cooperation with noradrenalin vasoconstriction is elicited, resulting in raised blood pressure. Water excretion in the kidneys is increased. Cortisol has a number of effects on the immune system, inhibiting antibody production and local inflammation. This antiphlogistic (inflammation-inhibiting) action is frequently used in different therapeutic applications.

Additional hormones (Figure 10.4) are released during stress as the anterior pituitary is stimulated. They are all regulated from the hypothalamus by centrally produced releasing factors. The sex hormones (luteinizing hormone (LH) and follicle-stimulating hormone (FSH)), growth hormone (GH), thyroid stimulating hormone (TSH) and prolactin are all involved in the stress complex. Oxytocin is a hormone known more for its effects of uterine contraction and milk led-down during birthing and "mothering." Oxytocin also has effects with regard to the individual's ability to cope with stress. Oxytocin stimulates relaxation, social learning, and trust. Thus oxytocin may be regarded as an anti-stress hormone. The production of oxytocin is stimulated by pleasant skin contact such as massage and gentle touch.

10.3.3 Acute and Chronic Stress

Stress and stress reactions have a common physiologic basis, but are manifested differently among individuals and their personal situations. It is not possible for an individual to take full control over these reactions but it is possible to learn some coping skills. The immediate reaction to stress is general and a reflex reaction. The ability to "switch off" the mobilization or cascade of stress reactions is varied among individuals and depends on many factors, including individual psychological and physiological variation, cultural background, and how life and work are organized.

The alarm reaction is mostly short lasting and the activity of the ANS may quickly be adjusted to normal (physiological effects mostly dissipate within 5 hours). This kind of stress should be regarded as a functional resource in arduous situations.

Chronic or long-lasting stress (as well as frequently repeated acute stress reactions) can be dysfunctional and dangerous. The effect of this

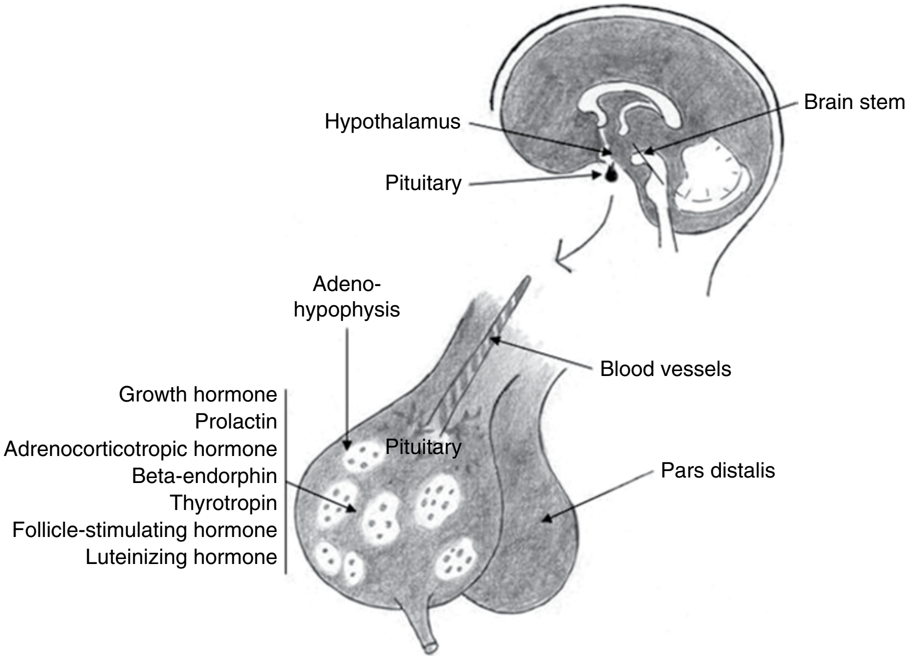


FIGURE 10.4 Anterior pituitary hormones.

kind of stress (the resistance stage according to Seyle) is different and related to a number of diseases. The behavior of people living with long-lasting stress changes: aggressiveness and irritation are elevated with, or finally replaced by, anxiety, depression, and exhaustion. A number of expressions have been used to describe this condition (burnout, chronic fatigue syndrome, neurasthenia, etc.).

Associated with these clinical behaviors are modifications in the functioning of the ANS (11, 56). Elevated tension in the somatic muscles occurs, but the individual is often not aware of the chronic muscle mobilization. However, this muscle tension may result in pain such as neck, shoulder, or back pain (57). The ability of the adrenals to produce elevated levels of cortisol may wane, and cortisol production may "burn out," resulting in a change in the[1] normal daily variation of cortisol concentrations (58, 59).

A long-lasting high level of cortisol also affects the brain, resulting in a declining number of functioning cortisol receptors. A size reduction in the hippocampus area has also been demonstrated, probably indicating declining capacity of learning and inadequate coordination of normal stress reactions (60).

Sex hormone production is also down-regulated in long-lasting stress. The result is a reduced interest in sex and lower fertility. The production of growth hormone (HGH or somatotropin) is likewise affected by stress. The down-regulation may be significant and stress-related dwarfism has been reported (61). The level of growth hormone may be associated with a number of other symptoms related to stress.

10.4 Chronic Stress-related Physiological Reactions

10.4.1 High Blood Pressure

Animal studies have shown that repeated stressful situations and chronic continuing stress modify the walls of the arteries, which promotes higher blood pressure (62, 63). This reaction in the arterial walls is associated with high activity in the SNS and high levels of cortisol production.

In modern Western societies the mean blood pressure of the general population escalates with advancing age. However, populations living in low-stress social conditions have no change in blood pressure over time (64, 65). Swedish men living in rural areas have lower blood pressure than men living in cities (66), and Swedish farmers have lower blood pressure than non-farming rural men, suggesting that both rural living and farming have protective effects. (34, 67).

10.4.2 Dyslipidemia

Those under stress with high activity of the HPA-axis system often have low levels of high-density lipoprotein (HDL; "good" cholesterol) and elevated levels of low-density lipoprotein (LDL; "bad" cholesterol) as well as elevated levels of free fatty acids (FFA). The mechanisms behind these changes in blood lipids are not fully understood.

10.4.3 Abdominal Obesity

The stress-related hormones, especially cortisol, promote accumulation of abdominal fat whereas the sex hormones and HGH (which are inhibited by chronic stress) have the opposite effect (68). Stress thus is a potent contributor to abdominal obesity and the metabolic syndrome.

10.4.4 Insulin Resistance

It is well known that cortisol decreases the cells' sensitivity to insulin, resulting in raising levels of blood glucose. Increased blood glucose stimulates the islets of Langerhans (the beta cells) in the pancreas to produce more insulin. Chronic or continuous stimulation forces the beta cells to produce more insulin to the point they cannot keep up the high demand of production over time. The beta cells finally fail, resulting in type II diabetes.

10.4.5 Mental Effects

Communication in the brain is mediated by a number of substances, including noradrenalin, serotonin, and dopamine, among others. Cortisol influences the activity and amount of several hormones, which in turn affect the amount and activity of these neurotransmitters, resulting in imbalanced brain chemistry. An imbalance in these brain chemicals is associated with conditions such as depression and anxiety disorders. High levels of cortisol are associated with changes in the female sex hormones and decreased thyroid-stimulating hormone: both are related to depression (69, 70).

10.4.6 Immunological Reactions

Cortisol has several depressive effects on the immune system. Long-lasting stress with high activity in the HPA axis suppresses the activity of a variety of different cells in the immune system and thus the risk of infections and other diseases is raised (71). It has been long recognized that exogenous cortisol can be used therapeutically in a number of autoimmune diseases, but also puts the patient at risk of infections.

10.5 Stress and Disease

10.5.1 Cardiovascular Disease

Stress may be associated with cardiovascular disease in two ways.

1. Acute stress can be a precipitating factor in heart attack or stroke. Stress can serve as a trigger of heart attacks (72) and chest pains (73, 74). The risk of serious disturbances in cardiac conduction is significant if stress is combined with arteriosclerosis of the cardiac arteries (75).
2. Chronic stress can be a cause in the development of the degenerative changes in the blood vessels resulting in heart disease or cerebral infarction. The combination of high blood pressure, dyslipidemia, abdominal obesity, and insulin resistance is described as metabolic syndrome. All these components of the metabolic syndrome have an association with chronic stress, and the metabolic syndrome is strongly related to the development of arteriosclerosis and cardiovascular diseases (76).

10.5.2 Mental Disorders

The prevalence of episodic depression in the general population is around 5%. Those with deep depression have a significant risk of suicide (Table 10.1). Depression is related to other chronic diseases, including cardiovascular disease (77, 78).

Several models have been presented to help explain how stress and depression are interrelated (69, 79). *Depression* is associated with changes in the production or efficiency of at least three neurotransmitter substances: serotonin, noradrenalin, and dopamine. Pharmacological treatment of depression targets these substances. It is also possible that psychotherapy may affect neurotransmitters. A combined psychological and chemical approach to treating depression (both affect the hypothalamus) affects the transmitter substances. Combined modalities for treating depression are commonly recommended.

Anxiety disorders like phobias, panic attacks, and generalized anxiety are conditions also related to stress. The imbalance of transmitters is again the likely cause.

Insomnia is regarded as a condition of raised physiological activity, a result of repeated or prolonged stress (80). Sleep disturbance is related to stress hormones. High levels of CRH, ACTH, and cortisol are associated with sleep disturbances (81).

Drug addiction has been shown in animal studies to be established more rapidly and with lower levels of the drug if the animal is stressed (82). Administration of cortisol supports known additive mechanisms (83). People who are more sensitive to stress and individuals who are exposed to stress during long periods have a somewhat higher risk of developing addiction.

Memory may be affected when stress is prolonged. When the concentration of cortisol is permanently high the hippocampus can be negatively affected, resulting in difficulties in memorizing and enhancing the process of disremembering (84). The number of nerve cells, dendrites, and synapses decreases, and the size of hippocampus decreases (85–87). The fact that individuals with Cushing's syndrome (a condition resulting in high levels of cortisol) develop a kind of dementia supports the hypothesis that cortisol may be a key factor in loss of memory (88). An HPA-axis dysfunction has been documented among patients with *chronic fatigue syndrome* (89, 90). This condition is characterized by slowed processing speed, impaired working memory, and poor learning of information (91).

People who have had highly traumatic experiences (e.g., a serious farm injury) may develop a chronic stress syndrome called *post-traumatic stress disorder* (PTSD). This is characterized by flashbacks, anxiety, and facial expression of fear, anhedonia (loss of ability to experience pleasure), startle and SNS activation. Many types of experiences are related to the development of this disorder (92–94). PTSD increases the risk of other medical disorders and produces a long-lasting suppression of the immune system (95). MRI studies of the brains of combat veterans with PTSD have demonstrated a significant reduction in the volume of the hippocampus (85).

Table 10.1 Depression has many faces

Depressed mood
Markedly diminished interest or pleasure in everything
Significant weight loss or weight gain
Insomnia or hypersomnia
Psychomotor agitation or retardation
Fatigue or loss of energy
Feeling of worthlessness or guilt
Diminished ability to think or concentrate
Recurrent thoughts of death

10.5.3 Other Diseases/Disorders

Chronic pain disorders may be associated with stress as the spinal cord decreases its ability to control pain. Repeated pain signals may be transformed into persistent hyper-excitability (96, 97). The normal dampening of pain by the spinal cord may be inhibited by a decreased production of serotonin (98). Reduced female sex hormones, among other hormones, may also increase the experience of pain (99).

Traumatic experiences during childhood and early life modify the sensitivity to pain during life (100). Intimate partner violence and child abuse may be an underestimated risk factor for a range of mental health issues, including chronic pain disorders (101, 102). Experiments on animals have shown that stress exposure early in life, for example separation from the mother, results in more stress reactions as adults, with a higher activity in the HPA-axis system (103). Stress reactions are more easily activated. Probably a significant number of people with chronic pain syndromes have easily activated stress reactions because of previous traumatic experiences.

Abdominal disorders, such as hyper bowel activity and abdominal pain, may be caused by stress. Furthermore, *gastric ulcers* and dyspepsia were traditionally regarded as diseases with a significant association with stress (104, 105). The bacterium *Helicobacter pylorus* is crucial for the development of ulcers but stress probably has an important role and cortisol concentration (see Cushing's disease) is related to gastric ulcers. The ability to cope with stress may be related to the fact that some people can keep the microorganism under control without any symptoms (106–108).

Irritable bowel syndrome (IBS) is a very common health problem, episodically affecting as high as 30% of a population. Clinical symptoms and signs include recurring pain, abdominal distension, diarrhea and possibly constipation. A significant proportion of IBS is related to stress (109, 110). Patients with IBS have a modified activity in the HPA axis, with somewhat raised levels of cortisol in the mornings and lower levels in the evenings. They also report more anxiety, have more depressive episodes, and lack social support (111). Psychological training programs have a positive effect with reduced frequency of symptoms and a better general wellbeing (112).

Cohen and coworkers (113, 114) have observed that the level of psychological stress is associated with greater infectivity of cold viruses. Their studies, along with others, have shown that stress with a raised activity in the HPA-axis system is related to a more rapid contraction of infectious diseases (115) and diseases of the immune deficiency system, such as HIV infection (116).

Stressful events and pain can trigger asthma attacks (117). Actions to control exposure to stressful events may successfully reduce the risk of further asthma attacks (118).

Autoimmune disorders like *rheumatoid arthritis* and *ulcerative colitis* may also be affected by stress. Stress can affect the progress of the disease by increasing sensitivity and reducing coping efforts, and can possibly affect the process of inflammation (119).

10.6 Measuring Stress

Measuring the level of stress may be of interest from an individual perspective as well as from an organizational perspective. Researchers have used a variety of methods and most of them fall into three main categories: laboratory methods, psychological measures, and self-reported surveys. Laboratory methods and psychological approaches have been used mostly in research. There are only a few clinical methods to evaluate individuals.

10.6.1 Laboratory Methods

The acute stress reaction may be assessed by measuring heart rate or blood pressure, or a combination of these: the rate pressure product (RPP). Muscle activity may be recorded by electromyography (EMG).

Measurements of catecholamines (noradrenalin and adrenaline) are not reliable as there are large and individual variations. The activity in the HPA axis may be evaluated by assessing the concentration of cortisol in saliva. However, there are also large temporal and individual variations with this hormone.

The level of blood glucose is related to stress. Some of the blood glucose is combined with hemoglobin and assessed as HbA1c. HbA1c is a measure of the average blood glucose concentration over several weeks and is related to long-lasting stress. This lab test is easy to do and the reliability is high.

10.6.2 Psychological Individual Methods

Holmes and Rahe (10) developed the Social Readjustment Rating Scale, noting a significant relation between high scores and cardiovascular disease. The antecedent factor may be chronic stress induced by social change.

The type A personality (120), especially the hostility factor, is significantly related to cardiovascular disease. A strong relationship between hostility and heart disease has been noted in other studies (121–123). A number of questionnaires are available to evaluate type A behavior.

There are a number of scales available to test for depression and anxiety. One of the oldest and most used is the Beck Depression Inventory (124) and another is the Self-rating Depression Scale (125). This scale is short (20 items), simple to administer, and has been used in many studies.

Daily life events and annoyances, in addition to traumatic life events, are related to stress and health outcomes. Several perceived stress scales are available, which are quite good at predicting headache and IBS (126–128).

Methods for general individual stress testing have also been developed, but these kinds of scales are fewer because stress is a complex condition. One scale used in Scandinavia is the Stress Profile (129).

To evaluate chronic pain conditions, analogue techniques have commonly been used. Pain is rated by observable behavior of the person. Visual analogue pain rating scales such as the McGill Pain questionnaire (130) has been available since the 1970s. Different scales have been developed to test for occupational stress in terms of risk of burnout (131).

10.6.3 Screening for Stress on an Organizational Level

Much of the stress people perceive is generated in the interrelationships between individuals (e.g., families and the workplace) (11, 132). Family farming often involves the overlap of family relations and workplace relations, creating a complex social environment.

Robert Karasek and Töres Theorell noticed that most adverse reactions of psychological strain (fatigue, anxiety, depression, and physical illness) occur when the psychological demands of the job are high and the worker's decision latitude (job discretion and job control) is low. From this concept, the working life could be described along a continuous scale: low strain–high strain, and passive–active. In a four-field diagram (Figure 10.5) different types of jobs could be identified along these lines as more or less active and more or less high strain (133).

The Karasek–Theorell model analysis of work-related stress has been widely used. Studies indicate that the economic burden of diseases attributable to job strain is large (134). Farmers, however, are regarded as having an active job, which may be an explanation for their reduced cardiovascular risk (135). A number of studies support a view that people in passive jobs have high strain and endure higher risks for cardiovascular disease and depression (136–139).

A number of screening instruments are available to check the level of job demand, decision latitude, and control over the work situation. Karasek and Theorell's first questionnaire (133) (Figure 10.6) has been supplemented with other items to include the dimensions of social support and perceived job security (140).

High functional personal social support reduces the risk of illness and death. Berkman and Syme (141) identified four main sources of social contacts of importance to reduced mortality: (1) marriage and life together, (2) contacts with relatives and friends, (3) membership of churches, and (4) and membership of other formal and informal groups. Good interpersonal support from colleagues, especially from supervisors, may also alleviate stress. Several scales measuring social support are available (142–144).

The ability to cope varies between individuals and is of great importance for long-term health

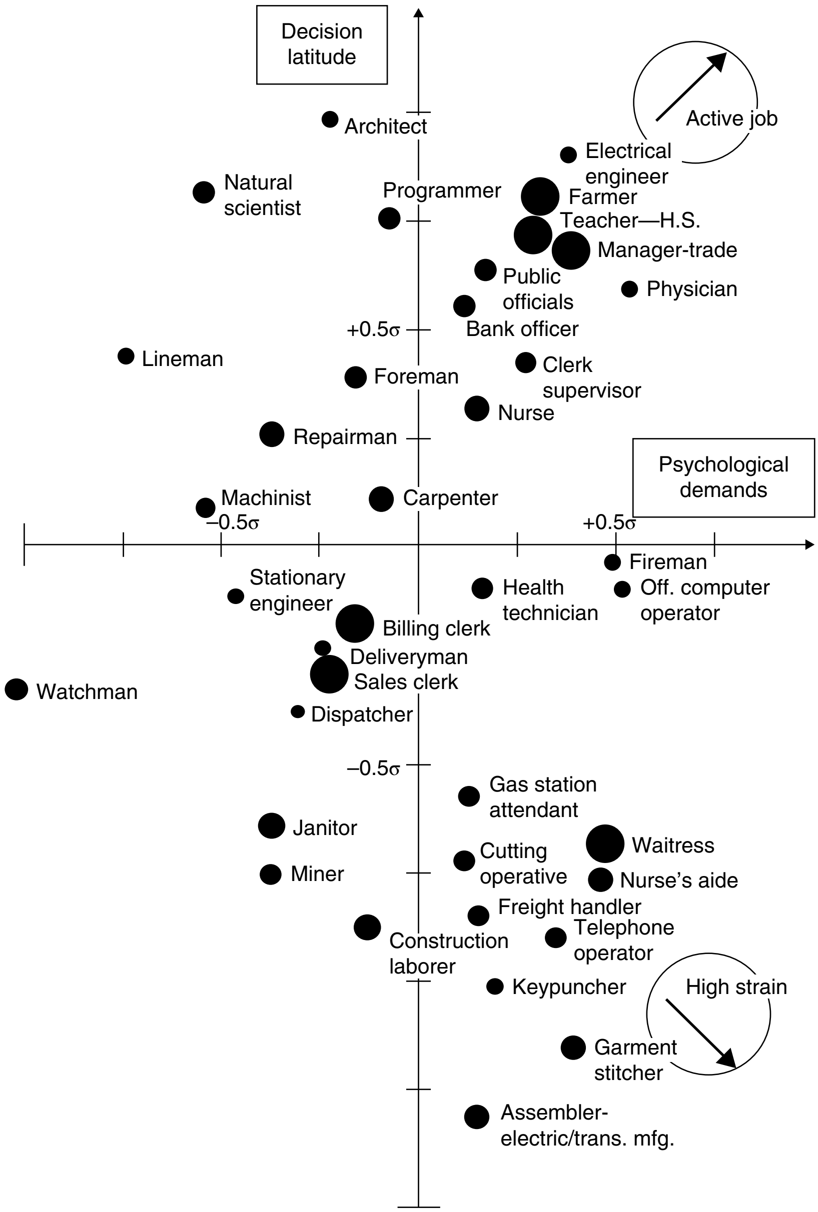


FIGURE 10.5 The Karasek–Theorell model.

status. Antonovsky determined that the ability to cope is related to a sense of coherence (SOC), or understanding the complicated structures that surround all of us (145). Antonovsky has developed an SOC scale, which has been widely used in different situations (146).

10.7 Management and Prevention of Stress Reactions

Historically, stress-management programs have tended to focus on solutions at the individual level. Recent research indicates that stress can be

	Often	Sometimes	Seldom	Never/ almost never
	1	2	3	4
1. Do you have to work very fast?	☐	☐	☐	☐
2. Do you have to work very intensively?	☐	☐	☐	☐
3. Does your work demand too much effort?	☐	☐	☐	☐
4. Do you have enough time to do everything?	☐	☐	☐	☐
5. Does your work often involve conflicting demands?	☐	☐	☐	☐
6. Do you have the possibility of learning new things through your work?	☐	☐	☐	☐
7. Does your work demand a high level of skill or expertise?	☐	☐	☐	☐
8. Does your job require you to take the initiative?	☐	☐	☐	☐
9. Do you have to do the same thing over and over again?	☐	☐	☐	☐
10. Do you have a choice in deciding *how* you do your work?	☐	☐	☐	☐
11. Do you have a choice in deciding *what* you do at work?	☐	☐	☐	☐

FIGURE 10.6 The Karasek–Theorell questionnaire. (By permission from Töres Theorell.)

effectively addressed by improving the relationships of the individual within the workplace. In the case of farmers stress may be addressed by improvement of relationships of the individual with his/her family, neighbors, and the local community, and by managing the developing negative perception of farmers from the general public and news media.

Health professionals, especially occupational health physicians and nurses, must listen to their patients for signs of stress. Very often a patient presents with a physical health problem. Only after establishing a confidential and trustful relationship between the patient and provider is it possible to determine stressors that might involve personal situations. Sometimes it is difficult to help the patient to realize that their reported symptoms are indicators of deeper problems such as family conflict or economic insolvency.

Although stress management is mostly focused on the individual, organizational factors have a key role in reducing stress for individuals. Farmers or groups of farmers often do not have access to occupational health physicians or other occupational health professionals working with occupational related stress (147). There is a need to develop and implement mental health programs to assist farmers and their families to identify and manage stress (2, 147).

10.7.1 Individual Therapeutic Methods

Behavior modification may be needed to help some people with chronic stress, for example individuals with a type-A personality or with excessive anxiety may be assisted with *cognitive* *therapy*. Cognitive therapy is based on the principle that people's beliefs, personal standards, and feelings of self-efficacy strongly affect their behavior (148).

Cognitive therapy includes a variety of strategies to change thoughts. Patients are trained to think about and evaluate their own behaviors. Patients with chronic pains, for example, very often exaggerate their perceived pain by dwelling on it, promoting their own dysfunction. Cognitive therapy for coping with pain (97, 149) relies on repeated weakened doses of pain or stress in an attempt to build up immunity against pain. Cognitive therapy for low back pain and other symptoms has shown greater effectiveness than traditional behavior modification or placebo (150–153).

Writing or talking about traumatic events (*emotional disclosure*) may help some people (154, 155).

Relaxation has been used to treat different stress-related conditions such as headache, tensions, migraine, and chronic pain conditions (156–158). Progressive muscle relaxation (159), meditative relaxation (160), mindfulness meditation (161), guided imagery and yoga are all examples of successful relaxation techniques.

Biofeedback electronic instruments are used to measure biological responses. Biofeedback can be used to decrease muscle tension as a component in stress management (150). Objective measures of responses are immediately available to the patient and enable them to learn to modify a response. Electromyography (EMG) biofeedback is the most commonly used method. Thermal biofeedback is based on the principle that skin temperature varies in relation to levels of stress (162).

Personal control is a fundamental element that enables people to cope with stress (163). However, the fundamental capacity to exercise control may be fixed during childhood and adolescence and thereafter may not be easily modified (145).

Studies indicate that *physical activity* may be a significant way to cope with stress (164). Physical activity modifies a number of biological reactions to stress in a positive way. Blood pressure, depression, sleeping disturbances, cognitive symptoms, and chronic pain are affected by physical activity. All kinds of exercise is helpful but running or walking in an open landscape or doing things together in a social context may be more effective than individual exercise with an exercise bicycle or lifting weights.

Good sleep is excellent therapy for stress. Some studies indicate that 8 hours of rest and sleep may not be enough (81) and many people need at least 10 hours for relaxation and sleep. To obtain restful sleep, relaxation before going to bed is important. Noise and conflicts should be removed from the bedroom.

10.7.2 Family, Neighbors, and Community

Personal conflicts must be solved to counteract stress, and often third-party assistance is necessary. Some individuals with a strong type-A personality may need individual therapy as they may be conflict-prone.

People who have high levels of social support are more able than others to cope with stress (165). The importance of social networks has been demonstrated in a number of studies (141) (Figure 10.7).

Healthcare professionals may help individuals to be more self-disclosing or to support others who are in need of support. Support groups with others in similar circumstances can be very valuable for some people (166).

Farmers gain stress reduction from working together. Contacts with neighbors develop social networks and may promote new techniques and new methods to reduce job overload. The interaction with others may be formal or informal and not necessary only with other farmers. Contacts with customers and food consumers may be stimulating and rewarding. Joint activities and inter-farmer support may be of importance in contacts with authorities and media, especially regarding animal welfare issues or conflicts of land-use etc.

Farmers must be socially astute when working with pesticides and odorous material like manure otherwise they will enhance neighbor conflicts, which can increase their stress. It is not enough to follow regulations and laws. Particularly when

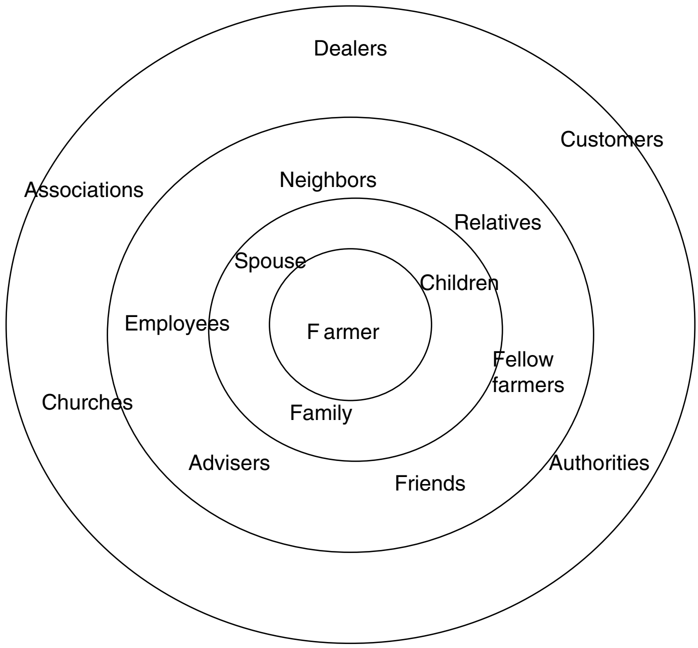


FIGURE 10.7 Social networks are a resource in coping with stress.

farming near towns, farmers must be proactive and develop a public relations practice to avoid conflicts. Practicing proper environmental protection and conservation methods is important, as well as communicating with neighbors to establish relationships and promote understanding of modern farming.

10.7.3 Stress and Workers' Compensation

Workers' compensation claims for mental injuries have increased over recent years. Many countries recognize mental stress as a compensable disorder at least among employees. In some countries laws and regulations practically exclude employers and entrepreneurs such as farmers from access to workers' compensation systems.

Physical and/or mental illness workers' compensation claims such as for post-traumatic stress or depression after a crash injury or amputation are mostly recognized while mental and related physical claims such as emotional stress-related disorders like myocardial infarction or gastrointestinal diseases often are dismissed. Mental disorders related to conflicts, supervision, or economic problems will mostly not be resolved (167). It is easy to understand that these kinds of claims often are followed by difficulties to objectively estimate both the extent of impairment and the causal factor. Unsolved ongoing conflicts on compensation are effective holdbacks for a quick and functional rehabilitation (168). Efforts to speed up these processes are always highly desirable.

10.8 Alcohol-related Health Problems

Several studies from different countries have reported low prevalence of alcohol-related diseases among farmers (169–172). This may be related to the selection of those fit for farming (healthy worker effect). Farmers are entrepreneurs with a wide personal and direct responsibility and work ethic. Too much drinking reduces the ability to optimize production, and increases the risk of injuries and breakdowns.

However, some farmers are alcoholics and need help to control their drinking. Overconsumption of alcohol produces direct health risks such as pancreatitis, liver cirrhosis, mental dysfunction, and injuries as well as indirect hazards like psychological impairments and social disruptions (173).

Farmers who drink excessively may neglect their land, buildings, and animals. Neglected animals may draw criticism from neighbors or legal action, increasing the farmer's stress level and worsening the farmer's health.

Most authorities agree that both genetic and environmental influences play a role in shaping alcohol abuse. Alcohol dependency syndrome is the medical model term for alcohol abuse (174). Cognitive and physiological theories have generated other models. One of these is the tension reduction hypothesis (175). The evidence behind this model is that alcohol decreases the stress response. Studies indicate that those who have the highest risk of developing problem drinking also have the strongest alcohol-affected stress-response dampening (176). In the context of the Australian prolonged drought and associated stress and related risk of mental-health problems, however, alcohol/drug use was not a common coping strategy (37).

To identify individuals with risky alcohol consumption different screening forms are available. The Alcohol Use Disorders Identification Test (AUDIT) (177) may be used and addresses consumption as well as problems. Another instrument often used to identify individuals with a destructive drinking is the Cut down, Annoyed, Guilty and Eye-opener (CAGE) model (Table 10.2). Patients who admit two of the four CAGE questions probably have alcohol dependence.

There are a number of chemical tests often used to identify overconsumption over time or in the short run. Measuring liver function has been used for a while, but the different tests mostly have low specificity and low sensitivity. Carbohydrate deficient transferrin (CDT) is a protein transporter typically increased in alcoholism and has a better specificity than traditional liver tests. It is widely used to estimate long-term overconsumption of alcohol. Phosphatidylethanol (peth) is a phospholipid formed only in the presence of ethanol. Peth is a good marker of previous alcohol consumption, with high specificity. The correlation with consumption over the last 2 weeks is significant.

Table 10.2 The CAGE questionnaire

1. Have you ever felt you should cut down on your drinking?
2. Have people annoyed you by criticizing your drinking?
3. Have you ever felt bad or guilty about your drinking?
4. Have you ever taken a drink first thing in the morning (eye opener) to steady your nerves or get rid of a hangover?

People with alcohol-related problems are more open to seek treatment today than in the past. There are a number of treatment models and settings. In addition, a great many alcoholics are able to quit drinking without formal treatment (178).

Alcoholics Anonymous (AA), founded by two alcoholics in 1935, is a well-known treatment program used around the world. According to AA, alcoholics never recover. They are always in the process of recovering and they should be abstainers for the rest of their lives. AA and other 12-step programs like the Minnesota model attract large numbers of people (179). Good temporary results are reported (180) but many cannot maintain lifelong abstention and drop out of AA.

Psychotherapy and cognitive therapy have also been proposed to help people with alcohol-related problems. These techniques may be operated in groups but individual programs may be preferable. It is not known how effective these kinds of programs are. In an analysis of a number of studies 25% were reported to maintain abstinence for at least one year (181).

Disulfiram (Antabus®) is a substance that interacts with alcohol to produce a number of unpleasant effects, such as flushing of the face, chest pains, nausea, sweating, headache, and difficulty breathing. It is not possible to drink alcohol while on disulfiram. This treatment requires a highly motivated and compliant patient, and it appears there is only partial long-term success (182). Acamprosate (Campral®), naltrexone, and nalmefene are other substances used often in combination with psychosocial methods to prevent relapses and enhance the therapeutic efforts.

Although most treatment programs aim for total abstinence, it is possible to transform some problem drinkers into moderate drinkers (178, 183, 184).

Most relapses in treatment programs occur within 90 days of the end of the program (similar to anti-smoking programs) (185). Programs with long-term goals incorporating relapse prevention tend to have the highest rates of success (186).

10.9 Suicides and Suicide Prevention

Suicide rates vary a great deal among countries, ethnic groups, with age, and over time (187). In Europe, Hungary has the highest rate and Greece the lowest. Declining rates as well as increasing rates have been reported. Youth suicides usually gain a great deal of publicity but the incidence is higher among adults and highest among old people. Individuals over age 85 have the highest suicide rate (188).

Alcohol consumption is associated with suicide, probably because of alcohol's disinhibiting effects, and/or the person is also depressed. A chronic alcoholic has a deteriorating affect toward life, and suicide may be an act to terminate a condition of deprivation, disability, and exhaustion.

However, the main cause of suicide is depression. Most estimates indicate that about 80% of all suicide victims are profoundly depressed. Studies of suicide victims consistently show low concentrations of serotonin in the brain (189). Low levels of serotonin metabolites are also found in the cerebrospinal fluid of people who have attempted suicide as well as high levels of cortisol (190). Those attempting suicide with low levels of serotonin metabolites are ten times more likely to die of suicide from a subsequent attempt compared to those who had normal levels.

Some studies suggest that farmers and workers in farming may have elevated suicide rates (188, 191–193), but other studies do not confirm these reports (4, 172, 194, 195). Most studies refer to official statistics and have no other referents, which leads to problems in identifying and controlling for confounders. Farmers often have access to guns for hunting or recreation, providing ready access to a suicidal tool. Suicides by farmers are commonly gun shots, in comparison with other groups (3, 196). More dramatic means of committing suicide as well as suicide ideation may indicate an overestimation of the suicide frequency (197).

Other studies indicate that the suicide incidence is raised in groups of farmers who have been oppressed by heavy economic problems or threats against their position as an independent entrepreneur (197, 198). This has been especially noted in Australia with reference to climate change and prolonged drought (199, 200). The problems they face may be so overwhelming that some farmers can see no alternative.

Exposure to pesticides has also been discussed as a risk factor for depression and suicide, but most studies do not provide much evidence for such a supposition (201–204).

Different intervention approaches may be used to reduce the number of suicides. After risk factors have been identified some measures may be taken in relation to persons under risk as well as in groups with elevated risks (38). Individuals who are depressed, who just have been informed of a serious disease (cancer or MS), or who have been confronted with large social difficulties may be contacted and supported to come under treatment and supervision (37). Firearms may be taken away.

Farmers support programs may be helpful. To be effective, contacts must be personal and persistent. Telephone hot lines have little or no effect on the rate of suicide for people who call (205). Some farmers with mental and social problems may need help to close down their business and find other ways of living (15, 37).

10.10 Summary

A number of recent studies and articles express concern for farmers' mental health related to upcoming new as well as traditional stress factors. Over the last two or three decades economic instability, technological imperfection, and climate change have introduced a kind of "modern stress," but at the same time new techniques and better capacity have reduced some of the previous hazards related to weather conditions and shortness of capacity in critical situations.

Few studies of farmers' mental health are available. A number of reports indicate suicidal ideation and committed suicides related to crises such as mad cow disease and draughts, and statistics from some nations or regions seem to support such a phenomenon. However, this is commonly observed related to different types of crisis and few if any longitudinal studies show any consistent overrepresentation of depression or suicides among farmers.

Alcohol as an alleviator of stress is a common popular notation and alcohol abuse has been discussed as a risk in a stressful farming context. Alcoholism and alcohol-related disorders are, however, less common among farmers than in the general population, which is probably related to selection mechanisms.

The concept of stress and its physiology was described by Hans Seyle 70 years ago and at that time it was shown that acute stress is a valuable capacity-increasing property and chronic stress a harmful disabling risk. Chronic stress is related to high blood pressure, dyslipidemia, abdominal obesity, insulin resistance, negative mental effects, and suppressed immunological reactions with a number of related diseases. The level of chronic stress is related to how work is organized, being lower in active jobs and more prominent in jobs with high strain. Farmers have an active job with significant psychological demands and wide decision latitude.

Changing living and working conditions in rural areas may impact farmers' general stress levels and ultimately their mental health. A cultural gap between the farming community and the rest of society has been noted as lack of understanding and mistrust, and more of an adversarial than cooperative relationship. In recent years an increasing number of conflicting interests have confronted the farmers as a group and often also individual farmers. Inspections on farms regarding food safety and animal welfare, activities from environmentalist groups, and the dependence of governmental subsidizing may also be disturbing as it is often related to considerable paperwork, changing regulations, and controls.

Key Points

1. Farmers are believed to have a job that is favorable for mental health with low risk for chronic stress related to self-control, decision latitudes, and positive psychological demands.
2. Changing living and working conditions related to conflicting interests, more inspections, and dependence of subsidizing may impact farmers' mental health as well as climate change and a more complicated technological work environment.
3. Clusters of suicides may be related to crises in production and operation environment conditions.
4. Alcohol abuse is a less prominent health problem among farmers relative to other working groups.

References

1. Gregoire A. The mental health of farmers. Occup Med. 2002;52(8):471–6.
2. Lunner Kolstrup C, Kallioniemi M, Lundqvist P, Kymalainen HR, Stallones L, Brumby S. International perspectives on psychosocial working conditions, mental health, and stress of dairy farm operators. J Agromedicine. 2013;18(3):244–55.
3. Booth N, Briscoe M, Powell R. Suicide in the farming community: methods used and contact with health services. Occup Environ Med. 2000;57(9):642–4.

4. Thelin N, Holmberg S, Nettelbladt P, Thelin A. Mortality and morbidity among farmers, nonfarming rural men, and urban referents: a prospective population-based study. Int J Occup Environ Health. 2009;15(1):21–8.
5. Bentham G, Haynes R. A raw deal in remoter rural areas? Family Practitioner Services. 1986;13:84–87.
6. Shucksmith A, Roberts D, Scott D, Chapman P, Conway E. Disadvantage in Rural Areas. Salisbury: Rural Development Commission; 1996.
7. Thelin A, Holmberg S. Type 2 diabetes among farmers and rural and urban referents: cumulative incidence over 20 years and risk factors in a prospective cohort study. Asia Pac J Clin Nutr. 2014;23(2): 301–8.
8. Thelin A. Psychosocial factors in farming. Ann Agric Environ Med. 1995;2:21–26.
9. Swisher RR, Elder GH, Jr., Lorenz FO, Conger RD. The long arm of the farm: how an occupation structures exposure and vulnerability to stressors across role domains. J Health Soc Behav. 1998;39(1): 72–89.
10. Holmes TH, Rahe RH. The Social Readjustment Rating Scale. J Psychosom Res. 1967;11(2):213–8.
11. Henry J, Stephens PM. Stress, health and the social environment. New York: Springer Verlag; 1977.
12. Manuck SB, Marsland AL, Kaplan JR, Williams JK. The pathogenicity of behavior and its neuroendocrine mediation: an example from coronary artery disease. Psychosom Med. 1995;57(3):275–83.
13. Levi L, Levi I. Guidance on Work-Related Stress. Spice of Life, or Kiss of Death? Luxembourg: Office for Official Publications of European Communities; 2000.
14. Quick JC, Quick JD, Nelson DL, Hurrell Jr JJ. Preventive stress management in organizations. Washington, DC: American Psychological Association; 1997.
15. Barlett PF. American Dreams, Rural Realities: Family Farms in crisis. Chapel Hill and London: University of North Carolina Press; 1993.
16. Dudley KM. The problem of community in rural America. Culture and Agriculture. 1996;18(2): 47–57.
17. DeLind LB. Social Consequences of intensive swine production: some effects of community conflict. Culture and Agriculture. 1998;26(1):80–89.
18. Seward JP, Larsen RC. Occupational Stress. In: LaDo J, editor. Occupational & Environmental Medicine. 4th edition. NewYork: Mc Graw Hill; 2004. p. 579–94.
19. Testa M, Leonard KE. The impact of husband physical aggression and alcohol use on marital functioning: does alcohol “excuse” the violence? Violence Vict. 2001;16(5):507–16.
20. Kiecolt-Glaser JK, Newton T, Cacioppo JT, MacCallum RC, Glaser R, Malarkey WB. Marital conflict and endocrine function: are men really more physiologically affected than women? J Consult Clin Psychol. 1996;64(2):324–32.
21. Golding JM. Intimate partner violenceas a risk factor for mental disorders: A meta-analysis. J Fam Violence. 1999;14:99–101.
22. Ellis EM. Divorce Wars: Interventions with families in conflict. Washington, DC: American Psychological Association; 2000.
23. Amato PR. The consequences of divorce for adults and children. J Marriage and the Family. 2000;62: 1269–87.
24. Stiernström EL, Holmberg S, Thelin A, Svärdsudd K. Reported health status among farmers and nonfarmers in nine rural districts. J Occup Environ Med. 1998;40(10):917–24.
25. Bird CE. Gender, household labor, and psychological distress. The impact of the amount and division of housework. J Health Soc Behav. 1999;40:32–45.
26. Stohs JH. Multicultural women's experience of household labor, conflicts, and equity. Sex Roles. 2000;42:339–362.
27. Lundberg U. Work and stress in women. In: Orth-Gomér K, Chesney M, Wenger NK, editors. Women, stress, and heart disease. Mahwah, NJ: Erlbaum; 1998.
28. Walen HR, Lachman MJ. Social support and strain from partner, family, and friends: Cost and benefits for men and women in adulthood. J Soc Personal Relationships. 2000;17:5–30.
29. Simkin S, Hawton K, Fagg J, Malmberg A. Stress in farmers: a survey of farmers in England and Wales. Occup Environ Med. 1998;55(11):729–34.
30. Donham KJ, Thu KM. Relationships of agricultural and economic policy to the health of farm families, livestock, and the environment. J Am Vet Med Assoc. 1993;202(7):1084–91.
31. Animal Welfare Act 2006.
32. Georgia Animal Protection Act 2000.
33. Francione GL, Garner R. The Animal Rights Debate: Abolition Or Regulation? NewYork: Columbia University Press; 2010.
34. Booth NJ, Lloyd K. Stress in farmers. Int J Soc Psychiatry. 2000;46(1):67–73.
35. Stiernström EL, Holmberg S, Thelin A, Svärdsudd K. A prospective study of morbidity and mortality rates among farmers and rural and urban nonfarmers. J Clin Epidemiol. 2001;54(2):121–6.
36. Rosmann MR. The agrarian imperative. J Agromedicine. 2010;15(2):71–5.

37. Thelin A, Stiernström EL, Holmberg S. Psychosocial conditions and access to an occupational health service among farmers. Int J Occup Environ Health. 2000;6(3):208–14.
38. Gunn KM, Kettler LJ, Skaczkowski GL, Turnbull DA. Farmers' stress and coping in a time of drought. Rural Remote Health. 2012;12:2071.
39. Berry HL, Hogan A, Owen J, Rickwood D, Fragar L. Climate change and farmers' mental health: risks and responses. Asia Pac J Public Health. 2011;23(2Suppl.): 119S–32.
40. Jacobs JA, Siegford JM. Invited review: The impact of automatic milking systems on dairy cow management, behavior, health, and welfare. J Dairy Sci. 2012;95(5):2227–47.
41. Day A, Paquet S, Scott N, Hambley L. Perceived information and communication technology (ICT) demands on employee outcomes: the moderating effect of organizational ICT support. J Occup Health Psychol. 2012;17(4):473–91.
42. Jamison CS, Wallace M, Jamison PL. Contemporary work characteristics, stress, and ill health. Am J Hum Biol. 2004;16(1):43–56.
43. Holmberg S, Thelin A, Stiernström E, Svärdsudd K. The impact of physical work exposure on musculoskeletal symptoms among farmers and rural nonfarmers. Ann Agric Environ Med. 2003;10(2): 179–84.
44. Berding V, Matthies M. European scenarios for EUSES regional distribution model. Environ Sci Pollut Res Int. 2002;9(3):193–8.
45. Donham KJ, Lee JA, Thu K, Reynolds SJ. Assessment of air quality at neighbor residences in the vicinity of swine production facilities. J Agromedicine. 2006;11 (3–4):15–24.
46. Donham KJ, Wing S, Osterberg D, Flora JL, Hodne C, Thu KM, et al. Community health and socioeconomic issues surrounding concentrated animal feeding operations. Environ Health Persp. 2007;115(2): 317–20.
47. Constance DH, Reny T. Corporate Chickens and Community Conflict in East Texsas: Growers' and Neigbors' Views on the Impacts of the Industrial Broiler Production. Culture and Agriculture. 2005;27 (1):45–60.
48. Evans GW, Lercher P, Meis M, Ising H, Kofler WW. Community noise exposure and stress in children. J Acoust Soc Am. 2001;109(3):1023–7.
49. Eriksson C, Hilding A, Pyko A, Bluhm G, Pershagen G, Ostenson CG. Long-Term Aircraft Noise Exposure and Body Mass Index, Waist Circumference, and Type 2 Diabetes: A Prospective Study. Environ Health Persp. 2014;122(7):687–94.
50. Thu K, Lasley P, Whitten P, Lewis, M, Donham KJ, Zwerling C, Scarth R. Stress as a potential risk factor for agricultural injuries.: Comparative data from the Iowa Farm Family Health and Hazard Survey (1994) and the Iowa Farm and Rural Life Poll (1989). J Agromedicine. 1997;4:181–92.
51. Seyle H. A syndrome produced by diverse nocuous agents. Nature. 1936;32:138.
52. Cannon WB. The Wisdom of the Body. 2nd edition. New York: Norton & Co; 1939.
53. Skinner JE. Psychological stress and sudden cardiac death: brain mechanisms. Boston: Martinus Bijhoff; 1985.
54. Mason JW. A re-evaluation of the concept of "nonspecificity" in stress theory. J Psychiatr Res. 1971;8(3):323–33.
55. Lazarus RS, Folkman S. Stress, appraisal, and coping. New York: Springer; 1984.
56. Lundberg U, Kadefors, R, Melin, B, Palmerud, G, Hassmén, B, Engström, P, et al. Psychophysiological stress and EMG activity of hte trapezius muscle. Int J Behavior Med. 1994;1:354–70.
57. Folkow B. Physiological aspects of the "defence" and "defeat" reactions. Acta Physiol Scand Suppl. 1997;640:34–7.
58. Veiersted KB, Westgaard RH, Andersen P. Electromyographic evaluation of muscular work pattern as a predictor of trapezius myalgia. Scand J Work Environ Health. 1993;19(4):284–90.
59. McEwen BS. Protective and damaging effects of stress mediators. N Engl J Med. 1998;338(3):171–9.
60. Björntorp P, Holm G, Rosmond R, Folkow B. Hypertension and the metabolic syndrome: closely related central origin? Blood Press. 2000;9(2–3):71–82.
61. Sapolsky R. Effects of stress and glucocorticoids on hippocampal neuronal survival. In: Brown MR, Koob GF, Rivier C, editors. Stress: Neurobiology and Neuroendocrinology. New York: Marcel Dekker Inc; 1990.
62. Sapolsky R. Why Zebras don't get ulcers. New York: WH Freemanm & Company; 1998.
63. Folkow B. Hypertensive structural changes in systemic precapillary resistance vessels: how important are they for in vivo haemodynamics? J Hypertens. 1995;13(12Pt2):1546–59.
64. Swales JD. Textbook of hypertension. Oxford: Blackwell Science Publishers; 1994.
65. Timio M, Lippi G, Venanzi S, Gentili S, Quintaliani G, Verdura C, et al. Blood pressure trend and cardiovascular events in nuns in a secluded order: a 30-year follow-up study. Blood Press. 1997;6(2):81–7.
66. Hollenberg NK, Martinez G, McCullough M, Meinking T, Passan D, Preston M, et al. Aging,

acculturation, salt intake, and hypertension in the Kuna of Panama. Hypertension. 1997;29(1 Pt 2):171–6.
67. Dahlö C. [Middle aged men living in the country have lower blood pressure than men living in the cities]. Lakartidningen. 1992;89(21):1874–7.
68. Thelin A. Work and health among farmers. A study of 191 farmers in Kronoberg County. Sweden. Scand J Soc Med Suppl. 1981;22:1–126.
69. Björntorp P. The regulation of adipose tissue distribution in humans. Int J Obes Relat Metab Disord. 1996;20(4):291–302.
70. Sapolsky RM. The possibility of neurotoxicity in the hippocampus in major depression: a primer on neuron death. Biol Psychiatry. 2000;48(8):755–65.
71. Sapolsky RM, Krey LC, McEwen BS. The neuroendocrinology of stress and aging: the glucocorticoid cascade hypothesis. Endocr Rev. 1986;7(3): 284–301.
72. Chrousos GP. The hypothalamic–pituitary–adrenal axis and immune-mediated inflammation. N Engl J Med. 1995;332(20):1351–62.
73. Gullette EC, Blumenthal JA, Babyak M, Jiang W, Waugh RA, Frid DJ, et al. Effects of mental stress on myocardial ischemia during daily life. J Am Med Assoc. 1997;277(19):1521–6.
74. Krantz DS, Sheps DS, Carney RM, Natelson BH. Effects of mental stress in patients with coronary artery disease: evidence and clinical implications. J Am Med Assoc. 2000;283(14):1800–2.
75. Orth-Gomer K, Wamala SP, Horsten M, Schenck-Gustafsson K, Schneiderman N, Mittleman MA. Marital stress worsens prognosis in women with coronary heart disease: The Stockholm Female Coronary Risk Study. J Am Med Assoc. 2000;284(23):3008–14.
76. Rosenfeld J, Rosen MR, Hoffman BF. Pharmacologic and behavioral effects on arrhythmias that immediately follow abrupt coronary occlusion: a canine model of sudden coronary death. Am J Cardiol. 1978;41(6):1075–82.
77. Kaur J. A Comprehensive Review on Metabolic Syndrome. Cardiol Res Pract. 2014;2014:943162.
78. Anda R, Williamson D, Jones D, Macera C, Eaker E, Glassman A, et al. Depressed affect, hopelessness, and the risk of ischemic heart disease in a cohort of US adults. Epidemiology. 1993;4(4):285–94.
79. Pratt LA, Ford DE, Crum RM, Armenian HK, Gallo JJ, Eaton WW. Depression, psychotropic medication, and risk of myocardial infarction. Prospective data from the Baltimore ECA follow-up. Circulation. 1996;94(12):3123–9.
80. Heim C, Owens MJ, Plotsky PM, Nemeroff CB. Persistent changes in corticotropin-releasing factor systems due to early life stress: relationship to the pathophysiology of major depression and post-traumatic stress disorder. Psychopharmacol Bull. 1997;33(2):185–92.
81. Sapolsky RM. Glucocorticoids and hippocampal atrophy in neuropsychiatric disorders. Arch Gen Psychiatry. 2000;57(10):925–35.
82. Bonnet MH, Arand DL. Physiological activation in patients with Sleep State Misperception. Psychosom Med. 1997;59(5):533–40.
83. Kryger MH, Roth T, Dement WC. Principles and practice of sleep medicine. Philadelphia: WB Saunders; 1994.
84. Piazza PV, Le Moal M. The role of stress in drug self-administration. Trends Pharmacol Sci. 1998;19(2): 67–74.
85. Robinson TE, Berridge KC. The neural basis of drug craving: an incentive-sensitization theory of addiction. Brain Res Brain Res Rev. 1993;18(3):247–91.
86. McGaugh JL. Involvement of hormonal and neuromodulatory systems in the regulation of memory storage. Annu Rev Neurosci. 1989;12:255–87.
87. Bremner JD, Randall P, Scott TM, Bronen RA, Seibyl JP, Southwick SM, et al. MRI-based measurement of hippocampal volume in patients with combat-related posttraumatic stress disorder. Am J Psychiatry. 1995;152(7):973–81.
88. Sheline YI, Wang PW, Gado MH, Csernansky JG, Vannier MW. Hippocampal atrophy in recurrent major depression. Proc Natl Acad Sci U S A. 1996;93(9):3908–13.
89. Magarinos AM, McEwen BS. Stress-induced atrophy of apical dendrites of hippocampal CA3c neurons: involvement of glucocorticoid secretion and excitatory amino acid receptors. Neuroscience. 1995;69(1): 89–98.
90. Starkman MN, Gebarski SS, Berent S, Schteingart DE. Hippocampal formation volume, memory dysfunction, and cortisol levels in patients with Cushing's syndrome. Biol Psychiatry. 1992;32(9):756–65.
91. Tomas C, Newton J, Watson S. A review of hypothalamic–pituitary–adrenal axis function in chronic fatigue syndrome. ISRN Neurosci. 2013;Sep 30:784520.
92. Papadopoulos AS, Cleare AJ. Hypothalamic–pituitary–adrenal axis dysfunction in chronic fatigue syndrome. Nat Rev Endocrinol. 2012;8(1):22–32.
93. Michiels V, Cluydts R. Neuropsychological functioning in chronic fatigue syndrome: a review. Acta Psychiatr Scand. 2001;103(2):84–93.
94. Resnick HS, Kilpatrick DG, Best CL, Kramer TL. Vulnerability-stress factors in development of post-traumatic stress disorder. J Nerv Ment Dis. 1992;180(7):424–30.

95. Schlenger WE, Caddell JM, Ebert L, Jordan BK, Rourke KM, Wilson D, et al. Psychological reactions to terrorist attacks: findings from the National Study of Americans' Reactions to September 11. J Am Med Assoc. 2002;288(5):581–8.
96. Roth S, Newman E, Pelcovitz D, van der Kolk B, Mandel FS. Complex PTSD in victims exposed to sexual and physical abuse: results from the DSM-IV Field Trial for Posttraumatic Stress Disorder. J Trauma Stress. 1997;10(4):539–55.
97. Kawamura N, Kim Y, Asukai N. Suppression of cellular immunity in men with a past history of posttraumatic stress disorder. Am J Psychiatry. 2001;158(3):484–6.
98. Melzack R, Wall PD. Pain mechanisms: a new theory. Science. 1965;150(699):971–9.
99. Flor H. Psychophysiological assessment of the patient with chronic pain. In: Turk DC, Melzack R, editors. Handbook of pain assessment. 2nd edition. New York: Guilford Press; 2001. p. 70–96.
100. Yunus MB. Towards a model of pathophysiology of fibromyalgia: aberrant central pain mechanisms with peripheral modulation. J Rheumatol. 1992;19(6):846–50.
101. Crofford LJ, Pillemer SR, Kalogeras KT, Cash JM, Michelson D, Kling MA, et al. Hypothalamic–pituitary–adrenal axis perturbations in patients with fibromyalgia. Arthritis Rheum. 1994;37(11):1583–92.
102. Anderberg UM, Marteinsdottir I, Theorell T, von Knorring L. The impact of life events in female patients with fibromyalgia. Eur Psychiatry. 2000;15:295–301.
103. Dillon G, Hussain R, Loxton D, Rahman S. Mental and Physical Health and Intimate Partner Violence against Women: A Review of the Literature. Int J Family Med. 2013;2013:313909.
104. Wong J, Mellor D. Intimate partner violence and women's health and wellbeing: Impacts, risk factors and responses. Contemp Nurse. 2014;46(2):170–9.
105. Plotsky PM, Meaney MJ. Early, postnatal experience alters hypothalamic corticotropin-releasing factor (CRF) mRNA, median eminence CRF content and stress-induced release in adult rats. Brain Res Mol Brain Res. 1993;18(3):195–200.
106. Brady JV, Porter RW, Conrad DG, Mason JW. Avoidance behavior and the development of gastroduodenal ulcers. J Exp Anal Behav. 1958;1 :69–72.
107. Weiss JM. Effects of coping responses on stress. J Comp Physiol Psychol. 1968;65(2):251–60.
108. Pare WP, Burken MI, Allen ED, Kluczynski JM. Reduced incidence of stress ulcer in germ-free Sprague Dawley rats. Life Sci. 1993;53(13):1099–104.
109. Levenstein S, Prantera C, Varvo V, Scribano ML, Berto E, Spinella S, et al. Patterns of biologic and psychologic risk factors in duodenal ulcer patients. J Clin Gastroenterol. 1995;21(2):110–7.
110. Delvaux MM. Stress and visceral perception. Can J Gastroenterol. 1999;13 Suppl A:32A–36A.
111. Richter JE, Obrecht WF, Bradley LA, Young LD, Anderson KO. Psychological comparison of patients with nutcracker esophagus and irritable bowel syndrome. Dig Dis Sci. 1986;31(2):131–8.
112. Patacchioli FR, Angelucci L, Dellerba G, Monnazzi P, Leri O. Actual stress, psychopathology and salivary cortisol levels in the irritable bowel syndrome (IBS). J Endocrinol Invest. 2001;24(3):173–7.
113. Rome I. A multinational consensus document on functional gastro-intestinal disorders. Gut. 1999;45(Suppl.2).
114. Cohen S, Tyrrell DA, Smith AP. Psychological stress and susceptibility to the common cold. N Engl J Med. 1991;325(9):606–12.
115. Cohen S, Tyrrell DA, Smith AP. Negative life events, perceived stress, negative affect, and susceptibility to the common cold. J Pers Soc Psychol. 1993;64(1):131–40.
116. Bonneau RH, Padgett DA, Shereidan JF. Psychoneuroimmune interactions in infectious disease: Studies in animals. In: Ader R, Felten DL, Cohen N, editors. Psychoneuroimmunology. 3rd edition. SanDiego, CA: Academic Press; 2001.
117. Cole SW, Naliboff BD, Kemeny ME, Griswold MP, Fahey JL, Zack JA. Impaired response to HAART in HIV-infected individuals with high autonomic nervous system activity. Proc Natl Acad Sci U S A. 2001;98(22):12695–700.
118. Sandberg S, Paton JY, Ahola S, McCann DC, McGuinness D, Hillary CR, et al. The role of acute and chronic stress in asthma attacks in children. Lancet. 2000;356(9234):982–7.
119. Schmaling K. Asthma. New York: Guilford Press; 1998.
120. Zautra A. Arthritis: Behavioral and psychosocial aspects. New York: Guilford Press; 1998.
121. Friedman M, Rosenman RH. Association of specific overt behavior pattern with blood and cardiovascular findings; blood cholesterol level, blood clotting time, incidence of arcus senilis, and clinical coronary artery disease. J Am Med Assoc. 1959;169(12):1286–96.
122. Almada SJ, Zonderman AB, Shekelle RB, Dyer AR, Daviglus ML, Costa PT, Jr., et al. Neuroticism and cynicism and risk of death in middle-aged

men: the Western Electric Study. Psychosom Med. 1991;53(2):165–75.
123. Rosenman RH, Brand RJ, Jenkins D, Friedman M, Straus R, Wurm M. Coronary heart disease in Western Collaborative Group Study. Final follow-up experience of 8 1/2 years. J Am Med Assoc. 1975;233(8):872–7.
124. Miller TQ, Smith TW, Turner CW, Guijarro ML, Hallet AJ. A meta-analytic review of research on hostility and physical health. Psychol Bull. 1996;119(2):322–48.
125. Beck AT, Beamesderfer A. Assessment of depression: the depression inventory. Mod Probl Pharmacopsychiatry. 1974;7(0):151–69.
126. Zung WW. A Self-Rating Depression Scale. Arch Gen Psychiatry. 1965;12:63–70.
127. Cohen S, Kamarck T, Mermelstein R. A global measure of perceived stress. J Health Soc Behav. 1983;24(4):385–96.
128. Kanner AD, Coyne JC, Schaefer C, Lazarus RS. Comparison of two modes of stress measurement: daily hassles and uplifts versus major life events. J Behav Med. 1981;4(1):1–39.
129. DeLongis A, Folkman S, Lazarus RS. The impact of daily stress on health and mood: psychological and social resources as mediators. J Pers Soc Psychol. 1988;54(3):486–95.
130. Searle A, Bennet P. Psychological factors and inflammatory bowel disease: A review of a decade of litterature. Psychol Health Med. 2001;6:121–135.
131. Fernandez E, Sheffield J. Relative contributions of life events versus daily hassles to the frequency and intensity of headaches. Headache. 1996;36(10):595–602.
132. Setterlind S, Larsson G. The stress profile: a psychosocial approach to measuring stress. Stress Med. 1995;11:85–92.
133. Melzack R. The McGill Pain Questionnaire: major properties and scoring methods. Pain. 1975;1(3): 277–99.
134. Maslach C. Burned-out. Human Behavior. 1976;5: 16–22.
135. Syme L. Control and Health. In: Steptoe A, Appels A, editors. Stress, personal control and health. Chichester: John Wiley & Sons; 1989. p. 3–18.
136. Sultan-Taieb H, Chastang JF, Mansouri M, Niedhammer I. The annual costs of cardiovascular diseases and mental disorders attributable to job strain in France. BMC Public Health. 2013;13:748.
137. Siegrist J. Adverse Health Effects of High-effort/low-reward Conditions. J Occup Health Psychol. 1996;1:27–41.
138. Berkman LF, Syme SL. Social networks, host resistance, and mortality: a nine-year follow-up study of Alameda County residents. Am J Epidemiol. 1979;109(2):186–204.
139. Berle BB, Pinsky RH, Wolf S, Wolff HG. A clinical guide to prognosis in stress diseases. J Am Med Assoc. 1952;149(18):1624–8.
140. Sherbourne CD, Stewart AL. The MOS social support survey. Soc Sci Med. 1991;32(6):705–14.
141. Broadhead WE, Gehlbach SH, de Gruy FV, Kaplan BH. The Duke-UNC Functional Social Support Questionnaire. Measurement of social support in family medicine patients. Med Care. 1988;26(7): 709–23.
142. Antonovsky A. Health, stress and coping: New perspectives on mental and physical well-being. San Francisco, CA: Jossey-Bass; 1979.
143. Antonovsky A. The structure and properties of the sense of coherence scale. Soc Sci Med. 1993;36(6): 725–33.
144. Rosmann MR. Agricultural behavioral health. J Agric Saf Health. 2002;8(4):347–8.
145. Bandura A. Social foundations of thought and action: A social cognitive theory. Englewood Cliffs, NJ: Prentice-Hall; 1986.
146. Meichenbaum D, Turk DC. The cognitive-behavioral management of anxiety, anger, and pain. In: Davidson PO, editor. The behavioral management of anexiety, depression, and pain. New York: Brunner/Mazel; 1976.
147. Turk DC. Physiological and psychological bases of pain. In: Baum A, Revenson TA, editors. Handbook of health psychology. Mahwah, NJ: Erlbaum; 2001. p. 117–131.
148. Compas BE, Haaga DA, Keefe FJ, Leitenberg H, Williams DA. Sampling of empirically supported psychological treatments from health psychology: smoking, chronic pain, cancer, and bulimia nervosa. J Consult Clin Psychol. 1998;66(1):89–112.
149. Kole-Snijders AM, Vlaeyen JW, Goossens ME, Rutten-van Molken MP, Heuts PH, van Breukelen G, et al. Chronic low-back pain: what does cognitive coping skills training add to operant behavioral treatment? Results of a randomized clinical trial. J Consult Clin Psychol. 1999;67(6):931–44.
150. Gardea MA, Gatchel RJ, Mishra KD. Long-term efficacy of biobehavioral treatment of temporomandibular disorders. J Behav Med. 2001;24(4):341–59.
151. Saunders T, Driskell JE, Johnston JH, Salas E. The effect of stress inoculation training on anxiety and performance. J Occup Health Psychol. 1996;1(2): 170–86.
152. Pennebaker JW, Barger SD, Tiebout J. Disclosure of traumas and health among Holocaust survivors. Psychosom Med. 1989;51(5):577–89.

153. Pennebaker JW, Garybeal A. Patterns of natural language use: Disclosure, personality, and social intergration. Curr Directions Psychologic Sci. 2001;10:90–3.
154. Sartory G, Muller B, Metsch J, Pothmann R. A comparison of psychological and pharmacological treatment of pediatric migraine. Behav Res Ther. 1998;36(12):1155–70.
155. Lehrer PM, Carr R, Sargunaraj D, Woolfolk RL. Stress management techniques: are they all equivalent, or do they have specific effects? Biofeedback Self Regul. 1994;19(4):353–401.
156. Carlson CR, Hoyle RH. Efficacy of abbreviated progressive muscle relaxation training: a quantitative review of behavioral medicine research. J Consult Clin Psychol. 1993;61(6):1059–67.
157. Jacobson E. Progressive relaxation: A physiological and clinical investigation of muscle status and their significance in psychology and medical practice. 2nd edition. Chicago: University of Chicago Press; 1938.
158. Benson H, Beary JF, Carol MP. The relaxation response. Psychiatry. 1974;37(1):37–46.
159. Kabat-Zinn J. Mindfulness meditation: Health benefits of an ancient Buddhit practice. In: Goleman D, Gurin J, editors. Mind/body medicine: How to use your mind for better health. Yonkers, NY: Consumer Reports Books; 1993. p. 259–75.
160. Blanchard EB, Appelbaum KA, Radnitz CL, Morrill B, Michultka D, Kirsch C, et al. A controlled evaluation of thermal biofeedback and thermal biofeedback combined with cognitive therapy in the treatment of vascular headache. J Consult Clin Psychol. 1990;58(2):216–24.
161. Rodin J, Langer EJ. Long-term effects of a control-relevant intervention with the institutionalized aged. J Pers Soc Psychol. 1977;35(12):897–902.
162. Steptoe A, Edwards S, Moses J, Mathews A. The effects of exercise training on mood and perceived coping ability in anxious adults from the general population. J Psychosom Res. 1989;33(5):537–47.
163. House JS, Landis KR, Umberson D. Social relationships and health. Science. 1988;241(4865):540–5.
164. Gottlieb BH. Theories and practices of mobilizing support in stressful circumstances. In: Cooper CL, editor. Handbook of stress, medicine, and health. Boca Raton, FL: CRC Press; 1996.
165. Haines J, Williams CL, Carson J. Workers' compensation for psychological injury: personal and environmental correlates. Work. 2004;22(3):183–94.
166. MacEachen E, Kosny A, Ferrier S, Chambers L. The "toxic dose" of system problems: why some injured workers don't return to work as expected. J Occup Rehabil. 2010;20(3):349–66.
167. Paxton R, Sutherland R. Stress in Farming Communities: Making Best Use of Existing Help. Newcastle: North Tyneside & Northumberland NHS Trust; 2000.
168. Walker LWJ. Self-reported stress symptoms in farmers. J Clin Psychol. 1988;44:10–16.
169. Hsieh HH, Cheng SC, Sharma A, Sanders RA, Thiessen C. The relation of rural alcoholism to farm economy. Community Ment Health J. 1989;25(4):341–7.
170. Thelin A. Morbidity in Swedish farmers, 1978–1983, according to national hospital records. Soc Sci Med. 1991;32(3):305–9.
171. Rehm JT, Bondy SJ, Sempos CT, Vuong CV. Alcohol consumption and coronary heart disease morbidity and mortality. Am J Epidemiol. 1997;146(6):495–501.
172. Edwards G. The alcohol dependence syndrome: Usefulness of an idea. In: Edwards G, Grant M, editors. Alcoholism: New knowledge and new responses. London: Croom Helm; 1977.
173. Edwards G, Gross MM, Keller M, Moser J, Room R. Alcohol-related disabilities. Geneva: World Health Organization; 1977.
174. Greeley J, Oei T. Alcohol and tension reduction. In: Leonard KE, Blane HT, editors. Psychological theories of drinking and alcoholism. 2nd edition. New York: Guilford Press; 1999. p. 14–53.
175. Sher KJ, Levenson RW. Risk for alcoholism and individual differences in the stress-response-dampening effect of alcohol. J Abnorm Psychol. 1982;91(5):350–67.
176. Saunders JB, Aasland OG, Babor TF, de la Fuente JR, Grant M. Development of the Alcohol Use Disorders Identification Test (AUDIT): WHO Collaborative Project on Early Detection of Persons with Harmful Alcohol Consumption–II. Addiction. 1993;88(6):791–804.
177. Sobell LC, Cunningham JA, Sobell MB. Recovery from alcohol problems with and without treatment: prevalence in two population surveys. Am J Public Health. 1996;86(7):966–72.
178. Room R, Greenfield T. Alcoholics anonymous, other 12-step movements and psychotherapy in the US population, 1990. Addiction. 1993;88(4):555–62.
179. Cunningham JA, Breslin FC. Exploring patterns of remission from alcohol dependence with and without Alcoholics Anonymous in a population sample. Contemporary Drug Problems. 2001;28:559–567.

180. Miller WR, Walters ST, Bennett ME. How effective is alcoholism treatment in the United States? J Stud Alcohol. 2001;62(2):211–20.
181. Krystal JH, Cramer JA, Krol WF, Kirk GF, Rosenheck RA. Naltrexone in the treatment of alcohol dependence. N Engl J Med. 2001;345(24):1734–9.
182. Davies DL. Normal drinking in recovered alcohol addicts. Quart J Studies Alcohol. 1962;24:321–332.
183. Alden LE. Behavioral self-management controlled-drinking strategies in a context of secondary prevention. J Consult Clin Psychol. 1988;56(2):280–6.
184. Hunt WA, Barnett LW, Branch LG. Relapse rates in addiction programs. J Clin Psychol. 1971;27(4): 455–6.
185. McLellan AT, Lewis DC, O'Brien CP, Kleber HD. Drug dependence, a chronic medical illness: implications for treatment, insurance, and outcomes evaluation. J Am Med Assoc. 2000;284(13):1689–95.
186. Ruzicka L. Suicide mortality in developed countries. In: Lopez AD, Caselli G, Valkonen T, editors. Adult mortality in developed countries: From description to explanation. Oxford: Clarendon Press; 1995.
187. Health, United States. National Center for Health. Hyattsville: Government Printing Office; 2001.
188. Åsberg M, Nordström P, Traskman-Bendz L. Cerebrospinal fluid studies in suicide. An overview. Ann N Y Acad Sci. 1986;487:243–55.
189. Roy A. Hypothalamic–pitutiary–adrenal axis function and suicidal behavior in depression. Biological Psychiatry. 1992;32:812–6.
190. Boxer PA, Burnett C, Swanson N. Suicide and occupation: a review of the literature. J Occup Environ Med. 1995;37(4):442–52.
191. Page AN, Fragar LJ. Suicide in Australian farming, 1988–1997. Aust N Z J Psychiatry. 2002;36(1):81–5.
192. Gallagher LM, Kliem C, Beautrais AL, Stallones L. Suicide and occupation in New Zealand, 2001–2005. Int J Occup Environ Health. 2008;14(1):45–50.
193. Stallones L, Doenges T, Dik BJ, Valley MA. Occupation and suicide: Colorado, 2004–2006. Am J Ind Med. 2013;56(11):1290–5.
194. Pickett W, Davidson JR, Brison RJ. Suicides on Ontario farms. Can J Public Health. 1993;84(4):226–30.
195. Kposowa AJ. Suicide mortality in the United States: differentials by industrial and occupational groups. Am J Ind Med. 1999;36(6):645–52.
196. Stallones L. Suicide mortality among Kentucky farmers, 1979–1985. Suicide Life Threat Behav. 1990;20:156–163.
197. Thomas HV, Lewis G, Thomas DR, Salmon RL, Chalmers RM, Coleman TJ, et al. Mental health of British farmers. Occup Environ Med. 2003;60(3): 181–5; discussion 185–6.
198. Zwerling C, Burmeister LF, Jensen CM. Injury mortality among Iowa farmers, 1980–1988: comparison of PMR and SMR approaches. Am J Epidemiol. 1995;141(9):878–82.
199. Guiney R. Farming suicides during the Victorian drought: 2001–2007. Aust J Rural Health. 2012;20(1):11–5.
200. Alston M. Rural male suicide in Australia. Soc Sci Med. 2012;74(4):515–22.
201. Woo JM, Postolache TT. The impact of work environment on mood disorders and suicide: Evidence and implications. Int J Disabil Hum Dev. 2008;7(2):185–200.
202. Pickett W, King WD, Lees RE, Bienefeld M, Morrison HI, Brison RJ. Suicide mortality and pesticide use among Canadian farmers. Am J Ind Med. 1998;34(4):364–72.
203. Van Wijngaarden E. An exploratory investigation of suicide and occupational exposure. J Occup Environ Med. 2003;45(1):96–101.
204. MacFarlane E, Simpson P, Benke G, Sim MR. Suicide in Australian pesticide-exposed workers. Occup Med (Lond). 2011;61(4):259–64.
205. Dew MA, Bromet EJ, Brent D, Greenhouse JB. A quantitative literature review of the effectiveness of suicide prevention centers. J Consult Clin Psychol. 1987;55(2):239–44.

CHAPTER

11

Acute Injuries in Agriculture

Kelley J. Donham, Aaron Yoder, and LaMar Grafft

Reviewer: LaMar Grafft

11.1 Introduction

The focus of this chapter is acute occupational trauma in agriculture resulting from a wound or immediate damage by sudden one-time application of external force (1). Chronic and repetitive motion injuries are covered in Chapter 8. Protection and prevention are discussed briefly in the section on hazards and injuries in this chapter and are covered in more detail in Chapter 15.

This chapter provides a general description of fatal and non-fatal occupational injuries in agriculture and discusses the unique attributes of farm and agriculturally related trauma. Furthermore, this chapter provides: (1) injury statistics and epidemiological data, (2) rescue and medical treatment considerations, and (3) illustrative injury descriptions. It will help to provide an understanding of how agricultural injuries occur as well as assisting in anticipating medical implications and prevention opportunities.

The injury statistics and epidemiology section provides a comparative picture of the prevalence and types of agricultural injuries that occur in Western industrialized countries. The rescue and medical treatment section describes the medical challenges of managing these injuries for the best immediate and long-term outcomes for injured farmers and farm workers. The injury scenarios given in the third section should enhance understanding of agents, events, causes, treatment, prevention, and rehabilitation of acute traumatic injuries. These scenarios are augmented with special considerations for those who are first on the scene, first responders and rescue personnel, emergency medical technicians (EMTs) and transport personnel, emergency medical treatment providers, primary care providers, secondary/tertiary care providers, and providers of rehabilitation services.

11.2 Agricultural Injury Statistics and Epidemiology

Agricultural producers, including farmers, ranchers, farm workers and their family members, are exposed to many factors that contribute to the unacceptably high rates of fatalities and injuries in agriculture. These include exposures to hazardous machinery, unpredictable and potentially dangerous animals, fatigue, and a workforce that has a relatively high acceptance of risk of injury. North America is the main focus of this section,

Agricultural Medicine: Rural Occupational and Environmental Health, Safety, and Prevention, Second Edition.
Kelley J. Donham and Anders Thelin.

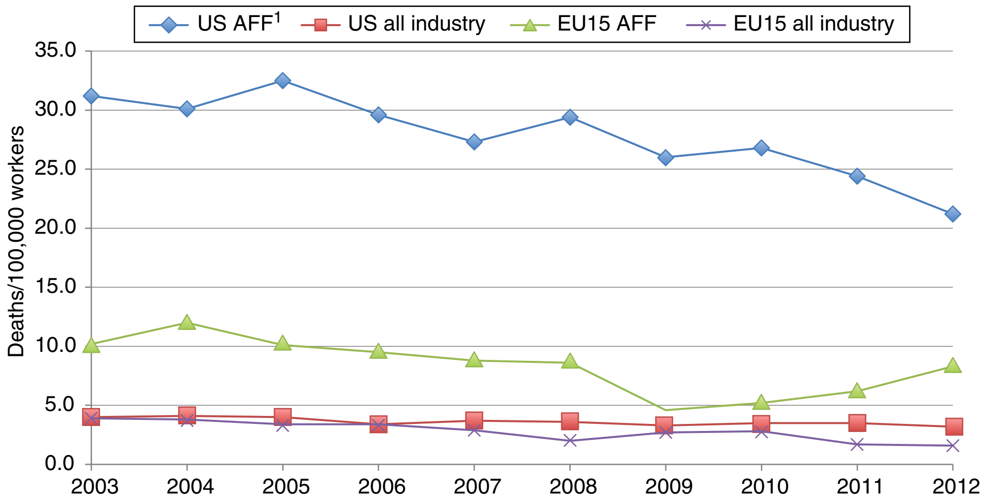


FIGURE 11.1 All industry and agricultural fatality rates EU15 and US. (Source: US Department of Labor BLS. 2014. Census of Fatal Occupational Injuries http://www.bls.gov/iif/oshcfoi1.htm and Eurostat, Statistical Office of the European Communities. 2014. http://ec.europa.eu/eurostat/web/health/health-safety-work/data/database.)
[1] AFF - All Form Fatalities

but comparisons with other Western industrialized nations are included.

Quantifying agriculture injuries continues to be difficult (2). Many countries do not have reliable data sources. Although patterns of fatal and non-fatal agricultural injury vary somewhat by geography and the associated type of agriculture, the general circumstances and nature of injuries are similar across production agricultural operations in Western industrialized countries. At highest risk for injury are farm and ranch owner/operators, especially elderly farmers and ranchers (3–5). Injury events related to tractors, notably tractor overturns and run-overs, are particularly lethal. Collisions between farm equipment and motor vehicles on roadways also contribute to agriculturally related fatalities, though it is often the motor vehicle occupants who suffer more serious injuries.

Agriculture consistently ranks as one of the highest injury risk sectors of all industries. Fatality rates for agriculture in the United States and the 28 countries of the European Union (EU) are consistently several times greater than the average rate for all industries combined (Figure 11.1). For these reasons, agriculture is often described as one of the most hazardous industries in which to work.

11.2.1 Fatal Agricultural Injuries: Statistics

The most reliable source of fatal injury data in the United States is the US Department of Labor (DOL) Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injury (CFOI) database (6). From this data, the National Institute for Occupational Safety and Health (NIOSH) Division of Safety Research reported that in 2014 374 farmers and farm workers died from a work-related injury and tractor overturns were still the leading cause of death (7).

EUROSTAT, the statistical office of the EU, is the most reliable source of EU injury statistics. EUROSTAT data show an average of 417 agriculturally related deaths per year from 2009 to 2012 (8).

The Canadian Agricultural Injury Reporting (CAIR) program, managed by the Canadian Agricultural Safety Association (CASA), is the main source of agriculturally related injury data for Canada. CAIR data for 2012 show an average 104 agricultural deaths per year in Canada from 1990 to 2008 (9).

In Australia, over the five reporting years from 2007/08 to 2011/12, 294 agriculture, forestry,

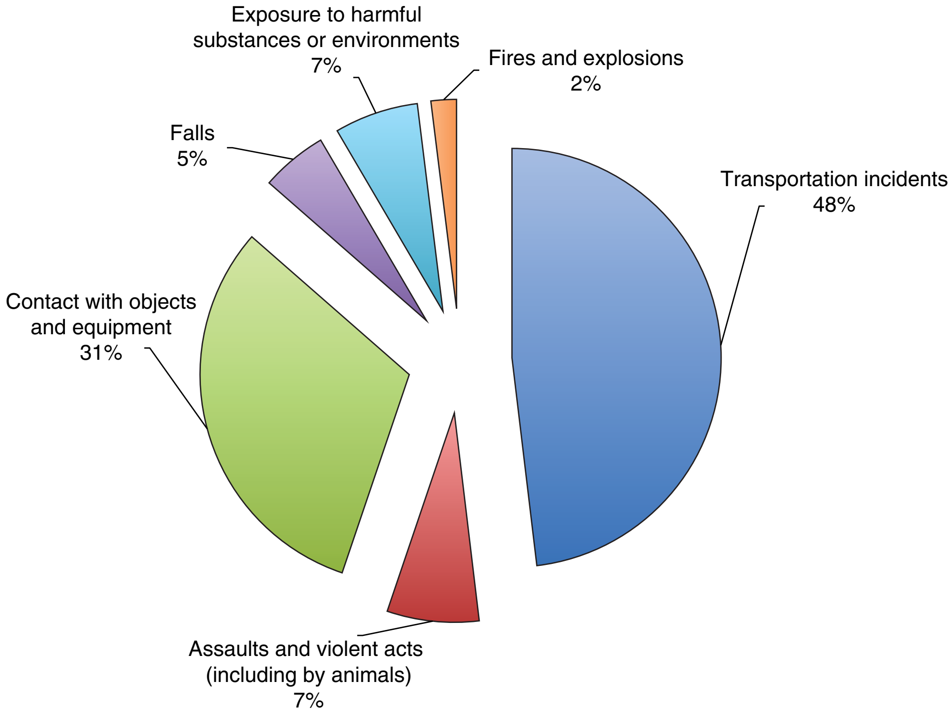


FIGURE 11.2 Agricultural injury event or exposure, US farms with over 10 employees. (Source: US Dept of Labor BLS. Injuries, Illnesses, and Fatalities (IIF) program. 2014. http://www.bls.gov/iif/home.htm.)

and fishing workers died from work-related injuries (10). Three-quarters of these injuries involved a vehicle. The total number of deaths equates to 16.81 fatalities per 100 000 workers, which is seven times the national rate of 2.29 (10).

In New Zealand, 112 agricultural production workers died from 2007 to 2013, which is 27% of all work-related fatalities (11).

Transportation incidents make up the largest portion (48%) of injury events or exposures for agricultural workers in the United States (Figure 11.2) (7). Traditionally health and safety professionals overlooked this category, but more recently increases in roadway collisions have led to a greater concern for this source of injuries. Transportation incidents are followed by contact with objects and equipment (31%) then assaults and violent acts (7%), including acts by animals.

Tractors and machinery continue to be a major source of fatalities in the US agriculture industry despite the 28.5% decrease from 1992 to 2007 in tractor overturn fatalities (12).

Entanglements are another type of machinery-related injury and occur in the moving parts of machines, for example:

- in the power take-off (PTO) and driveline between the tractor and implement
- in the secondary drives that transfer power to various parts of a machine
- in crop-gathering, -processing, -transfer, and -discharge mechanisms.

Entanglements also occur in stationary installations with moving machinery parts, such as augers and conveyors for handling commodities, livestock feed, and manure.

The non-machinery portion of US agricultural fatalities includes a mix of animal injuries, falls, suffocations in grain, electric current accidents, and drowning.

In summary for the United States, machinery-related incidents comprise the majority of deaths in agriculture and the majority of machinery deaths result from tractor-related events. Most tractor fatalities are overturns, followed by run-overs, roadway crashes, and PTO entanglements. Entanglements are the main cause of non-tractor, machinery-related fatalities. Non-machinery fatalities can arise from a broad spectrum of events.

Any global, regional, or national characterization of fatal farm injuries must take into account the substantial differences in agricultural practices, such as the impact of mechanization and health and safety regulations. For example, tractor overturn fatalities in Europe, Scandinavia, and Australia/New Zealand are dramatically lower because of a high proportion of their tractor fleets are equipped with a roll-over protective structure (ROPS) or ROPS cab. For example, between 1959 and 1990 in Sweden, the number of tractors with ROPS increased from 3% to 93% (encouraged by government policy) amid a 275% increase in the number of tractors in use (including new tractors with ROPS cabs) while tractor overturn fatalities dropped from 12 to 0.3 per 100,000 farm tractors (13, 14).

11.2.2 Non-fatal Agricultural Injuries

Obtaining comprehensive statistics for non-fatal events is more difficult than for fatal injuries. In the United States, there is only periodic not routine comprehensive national surveillance for non-fatal agricultural injuries (14).

In 1990, NIOSH implemented an extensive agricultural safety and health program to address the high risks of injuries and illnesses experienced by workers and families in agriculture. One component of this program was the development of a periodic surveillance program to track non-fatal injuries occurring to adults working in agriculture. An initial step in the development of the surveillance program was the completion of the Occupational Injury Surveillance of Production Agriculture (OISPA) survey (7). This survey was conducted to produce national and regional estimates of the number of occupational injuries to adults 20 years of age and older. NIOSH collaborated with the US Department of Agriculture's National Agricultural Statistics Service (USDA-NASS) to conduct the surveys for the years 2001, 2004, 2009, and 2012 (7). These data are presented in Table 11.1 (by type of farm association, e.g. household member) and Table 11.2 (by type of injury) (7).

Table 11.3 summarizes the national estimates of agricultural work-related injuries to adults (20 years and older) on US farms by body part injured, source of injury, and circumstances of injuries for 2001, 2004, 2009, 2012 (all years combined) (7).

The aggregated US figure for these years indicate that approximately 53% of injuries were associated with livestock operations and 47% were associated with crop operations.

In Canada, compiled data from 1990 to 2000 for hospitalized agricultural injuries indicated the most common causes were associated with animals first (injuries without open wounds), followed by machinery and falls (15). The most frequent primary diagnoses were fracture – lower limb (15.5%), fracture – upper limb (13.2%), open wound – upper limb (9.1%), and fracture – spine or trunk (8.8%).

In Finland (1992), the body parts injured most frequently were, in descending order, (1) the knee/lower leg/ankle, (2) hand, (3) head excluding eyes, (4) shoulder/upper arm/elbow, (5) foot, and (6) eyes. In Finland (1996), the body parts injured most frequently, also in descending order, were (1) lower limb from ankle to hip, (2) back and spine, (3) upper limb from wrist to shoulder, and (4) fingers (16).

Non-fatal injury data are often gathered by survey. More objective data may be found in health insurance claims, worker compensation claims, and medical or hospitalization records. The medical and non-medical costs associated with injury, for an individual or group, can be an indicator of severity.

Another indicator of severity is length of hospital stay. Of 14,987 machinery-related agricultural injury cases in Canada (1990–2000) grouped by primary diagnosis, the median length of hospital stay was 3 days, the mean 5.9, and the standard deviation 11.6 days (15). The top five injuries by length of stay in this list were (1) fracture of the spine and trunk (6 days), (2) internal injury of chest,

Table 11.1 National estimates of agricultural work-related injuries to adults (20 years and older) on US farms by type of adult worker

Type of adult worker	2001	2004	2009	2012
Household	56,661	58,914	35,190	43,987
Hired	19,095	12,166	6,659	9,995
Visitors	8,018	5,736	5,115	6,297
Unknown	3,728	3,512	368	778
Total [a]	87,503	80,329	47,332	61,057

[a] Estimates may not sum to total due to rounding.
Source: Occupational Injury Surveillance of production Agriculture Survey 2001, 2004, 2009 and 2012.

Table 11.2 National estimates of agricultural work-related injuries to adults (20 years and older) on US farms by nature of injury

Nature of injury	2001	2004	2009	2012
Bruise	8,856	9,720	4,744	5,307
Sprain/strain/torn ligament	16,638	17,548	10,114	8,720
Fracture	17,340	12,175	7,500	11,416
Cut	14,791	10,775	6,936	6,842
Multiple injury	9,623	9,839	5,548	3,747
Other injuries [a]	20,523	20,272	12,464	25,025
Total [b]	87,503	80,329	47,332	61,057

[a] Includes scrape/abrasion, dislocation, puncture/stab/jab, traumatic rupture, crush/mangle, amputation, nerve injury, burn/blister/scald, traumatic brain injury, and other/unknown injuries.
[b] Estimates may not sum due to rounding.
Source: Occupational Injury Surveillance of Production Agriculture Survey, 2001, 2004, 2009 and 2012.

pelvis, and abdomen (5 days), (3) injury to blood vessels (5 days), (4) fracture of a lower limb (4 days), and (5) open wound to a lower limb (4 days).

In the same Canadian study, hospitalized machinery-related agricultural injury incidents by primary diagnosis had a median 3-day length of stay, a mean of 6.9 days, and a standard deviation of 12.6 days. Canadian non-machinery incidents had a median stay of 2 days, a mean of 5.0 days, and standard deviation of 10.7 days. The top five injuries by median length of stay for non-machinery incidents were (1) injury to blood vessels, (2) fracture of the spine and trunk, (3) fracture of a lower limb, (4) internal injury of chest, pelvis, or abdomen, and (5) burns. The mean stay for this group of primary diagnoses ranged from 6 to 4 days.

To put injury statistics in perspective, risk factors must be considered as not every farm person has the same probability for suffering an injury. Risk factors can be divided into those that are relevant to the farm operation and those that are personal or health characteristics of the individual. Increased risk of an injury related to the farming operation include farms that have livestock production, large acreages, higher income, higher debt loads, require working longer than 50 hours per week, and farms where the operator lives on the farm. Health conditions that predict increased risk include depression, poor hearing and vision, back pain, taking prescription medications, and history of a prior injury. Personal and demographic risk characteristics include the young (less than 20) and the old (above 65), education beyond high school, and being of Hispanic or African descent. These risk factors can be used to help health and safety providers to counsel their patients and clients, and design prevention programs. Table 11.4 summarizes these risk factors, organized relative to farm or personal characteristics (17–26).

Summarizing, non-fatal agricultural injuries are a substantial component of the work injury toll in Western industrialized nations. Livestock

Table 11.3 National estimated of agricultural work-related injuries to adults (20 years and older) on US farms by injury characteristics, 2001, 2004, 2009, 2012 (all years combined)

Injury characteristics	All working adult injury estimates 2001, 2004, 2009, 2012
Nature of injury	
Scrape/abrasion	8,654
Bruise	28,627
Sprain/strain/torn ligament	53,020
Fracture	48,431
Dislocation	4,753
Cut	39,371
Puncture/stab/jab	11,797
Traumatic brain injury	7,296
Multiple injuries	28,757
Other injures [a]	45,515
Body part	
Head/skull	15,557
Face/neck	13,663
Shoulder/chest/back	47,708
Abdomen/pelvic region	7,398
Arm	15,133
Hand/wrist/fingers	56,383
Leg	36,371
Foot/angle/toes	30,182
Multiple body parts	24,630
Other body parts [b]	29,197
Source of injury	
Machinery	18,774
Parts/materials	21,126
Persons/plants/animals/minerals	79,841
Structures/surfaces	61,091
Tools/instruments/equipment	21,289
Vehicles	23,940
Other sources [c]	50,159
Injury event	
Contact with objects and equipment	90,950
Falls	55,057
Bodily reaction and exertion	36,423
Exposure to harmful substances/environments	10,701
Transportation accidents	18,444
Assaults and violent acts [d]	30,749
Other events [e]	33,894
Total [f]	276,221

[a] Includes traumatic rupture, crush/mangle, amputation, verve injury, burn/blister/scald, and other/unknown injuries.
[b] Includes internal injuries and other/unknown body parts.
[c] Includes chemicals and chemical products, containers, furniture/fixtures, and other/unknown sources.
[d] On-farm assaults are predominantly assaults by animals.
[e] Includes fires/explosions and other/unknown events.
[f] Estimates may not sum due to rounding.
Sources: Occupational injury Surveillance of Production Agriculture Survey, 2001,2004,2009 and 2012.

and machinery are the two principal agents involved in these events, which include being struck, caught, run over, entangled, and pinned. Most often these events result in strains and sprains, fractures, and open wounds to the upper and lower extremities or to the trunk of the body. The more severe multiple injuries affect several body parts and systems.

Table 11.4 Risk factors for occupational injuries in production agriculture

Characteristic	Reference
Farm/work operation characteristics	
Hours per week worked	(17–19, 23, 26)
Employee or contractor, low income, lack of safety training, lack of safety and guarding equipment	
Work with livestock production	
Higher acres farmed and higher average farm income	(18, 26)
High debt load	(22)
Residence on the farm	(18, 26)
Personal and human characteristics	
Symptoms of depression	(24)
History of a previous injury	(20)
Hearing impairment	(19)
Vision impairment	(20)
Prescription drug use	(19, 20, 22)
Elderly	(18, 21)
Young	(19)
<39 years	(20)
<20 years	(25)
Male	(18, 26)
African descent	(20)
Hispanic descent	(20)
Back pain	(23)
Education level beyond high school	(19)
Farm alone	(26)

11.3 Medical Considerations of Acute Agricultural Injuries

The previous section highlighted the statistics for acute traumatic injuries that occur in agricultural communities. There are unique considerations for the medical treatment of these injuries compared to workplace injuries experienced in other occupational settings. Injuries in agriculture stem from a complex chain of factors that include the culture and behavior of farm people, the nature of farm work, machines, animals, and the physical environment. This requires an understanding of the risks and circumstances as well as the resultant injuries. Special education regarding rural and agricultural trauma is therefore important in the preparation of rural health and safety professionals. The lack of on-farm observations and inexperience with actual farming and ranching further highlights the potential for gaps in understanding. The challenge of identifying and appropriately treating injuries plus managing recovery and rehabilitation among those engaged in agricultural activities places an important responsibility on the rural lay and professional responders and healthcare professionals, who must understand the environment in which their patients work and the requirements of the tasks they perform. The present section addresses these issues.

The actions and interactions of various lay and professional providers working as a well-prepared team or chain of responders interacting in an informed manner provides the best possible outcome for a farm injury victim. Members of this team include:

1. the first person on the scene, who may be a family member, co-worker, employee, or bystander
2. first responders, who may include fire-rescue and law enforcement personnel
3. the emergency medical services (EMS), which may include EMTs and others providing first aid, stabilization, and transportation to the

emergency room or the most appropriate healthcare facility
4. emergency room care providers
5. secondary and tertiary care providers
6. rehabilitation specialists.

Special considerations for managing acute agricultural injuries include the fact that they are confounded by the "triad of Ts": (1) excessive *time* until treatment, (2) excessive *trash* or wound contamination, and (3) excessive *trauma* to tissues and organs.

Regarding time, most farmers work alone and may be trapped or caught in a machine away from anybody and not noticed missing and not found for several hours following an injury. Often the first sign to a family member that something might be wrong is when the person does not return for the midday or evening meal. In the United States (and similarly in most Western industrialized countries) over 50% of farmers' spouses are employed off-farm, which is a factor in the delay in even realizing a person is missing till after the spouse's regular work hours have ended. Additional time is required for EMS to reach the scene, and even more time is needed to extract and transport the patient to the emergency room or advanced care. This elapsed time increases the adverse effects of blood loss, shock, tissue damage, and wound contamination. Military and trauma surgeons have identified the "golden hour" of time from injury to stabilization and primary medical care, which is closely related to the survivability and good outcomes of patients suffering severe traumatic injuries. Farm injury victims may not reach medical care for several hours.

The agricultural working environment is usually not a clean place. Soil, manure, microbes, oil, fuels, fertilizers, and plant protection chemicals are some of the substances that may contaminate a wound. Antibiotic-resistant infectious organisms are common in the farm environment, and may infect a wound and complicate treatment.

Agricultural machinery-related injuries may be extremely traumatic, with extensive tissue damage. Although these types of injuries may have a low probability of severe hemorrhage, they decrease the potential long-term functionality of the affected limb or body part. The severely devitalized tissue, combined with wounds that are often contaminated with animal manure or soil, can create an environment that provides ideal growth for anaerobic organisms like *Clostridium tetani* (which causes tetanus), or *Clostridium perfringens* (a common cause of gangrene).

Improved technology and facilities, including emergency communications, advanced treatment at the site, and improved transportation to high-level care facilities, have dramatically reduced deaths among roadway crash victims and battlefield casualties. However, these improvements have not accrued to the same extent to benefit the farm person who has suffered a serious farm injury because of the inherent time lag in locating, rescuing, and transporting the victim to a definitive care facility. Furthermore, there may be a lack of appropriately trained personnel in rural areas to manage these injury situations.

A basic understanding of farming, its people, their inherent occupational injuries, and special considerations for treating their injuries is vital for personnel in all links of the chain of responders to assure as near complete recovery as possible for farm injury victims.

11.4 First on the Scene/First Aid

11.4.1 General Considerations

The initial location and management usually comes from a relative or neighbor at the scene, which is probably located some distance from the nearest medical facility. Understanding rescue procedures and basic first aid methods is extremely important for those likely to be first on the scene. Familiarity with the victim coupled with lack of formal training can create problems for the safety of both the patient and the rescuer.

Confronted with a situation involving a family member or close friend, the person first on the scene may rush to rescue without considering their personal risk. The fact that nearly 60% of confined-space victims are would-be rescuers illustrates the magnitude of this hazard. A classic example is a situation where two brothers died trying to rescue their father from a manure pit (27). Similar situations have been repeated many times, resulting in many unnecessary deaths of family members and other first-on-the-scene responders. Farm family members and others in the rural environment who might encounter farm injury situations (28), including feed and seed salesmen, veterinarians, and milk truck drivers, should have training that includes the following basic components (28):

1. An understanding of the basic types and circumstances of acute agricultural injuries.
2. An understanding of how to assess a situation (prior to action) to avoid harm to the rescuer.
3. An understanding of how to prevent further harm to the victim, e.g. the first responder should know how to shut off equipment.
4. An understanding of how to summon the rescue and EMS, give them accurate directions to the injury scene.
5. An understanding of first aid and cardiopulmonary resuscitation (CPR) such as training offered by Red Cross or another similar program (29).

This knowledge base, and the general operational approach at the scene of an injury event as outlined below, will help to ensure the best outcome for the victim and the safety of the responders (30).

11.4.2 Designate a Leader

A worker who has had first-aid training or the senior person at the scene should assume leadership. This person should direct the rescue until the emergency services arrive and should update them on the situation, condition of the patient, and any treatment administered.

11.4.3 Assign a Specific Person to Call for Help

The emergency dispatcher will need to know the exact location and condition of access to and at the site of the incident (muddy, steep, rough), the type of equipment involved in the incident, the number of victims, and the extent of their injuries. A sentinel person might be needed to stand at the roadway access to direct the responders to the injury event location.

11.4.4 Assess the Rescue Situation

Evaluate the situation and develop a rescue plan. Stabilize equipment to minimize the chance of collapse or further injury. Actions to help should not exceed the limitations of the rescuers and available equipment.

11.4.5 Establish a Hazard Zone

Allow the rescuers room to work at freeing the victim. Only the rescuers should be in that area. This area may contain hazards such as fire, toxic or flammable gases, and structural damage.

11.4.6 Provide Emergency First Aid

Restore breathing and circulation if necessary. If bleeding, apply pressure to related pressure points. Administer any additional first-aid treatment.

11.4.7 Stay Calm

Calm the victim by keeping one rescuer near the victim at all times.

11.4.8 Preserve Tissues if Amputation Occurs

Surgical reattachment may be possible. Locate the appendage, wrap it in a moist towel, and put it in a plastic bag labeled to identify the patient. If saline solution or tap water is not available, contact lens fluid or even a soft drink may be used (31). Keep the part on ice but do not let it freeze, and make sure it gets transported to the emergency room with identification of the patient. Avoid clamps on the injured stump to protect vessels, nerves, and soft tissue and improve the prognosis for reattachment.

11.4.9 Decide to Call Immediately for Assistance, or Administer First Aid

The assessment skills and judgment of the person first on the scene are extremely important. Immediate recognition of the type and seriousness of the injury is crucial. If there is only one person first on the scene, that person will have to make a decision to render first aid immediately or go directly for help. This decision depends on the severity of injury, and the responder's judgment and ability to administer first aid correctly. The four most life-threatening conditions requiring immediate attention are blocked air passages, respiratory arrest, circulatory failure, and severe bleeding (32, 33). Ideally, every farm family member and rural business or service representative should be trained in basic first aid and CPR (29).

11.4.10 General First-aid Supplies

Every farm should have basic first-aid kits. These kits and their prescribed location and management is based on a basic principle of the Certified Safe Farm Program (34). If the first-aid supplies are not readily accessible, they will not be used, therefore a worse outcome of a minor or major injury will likely be the result. There should be two types of kit: (1) a comprehensive ("mother") kit to cover minor and severe trauma that also acts as a store to supply smaller personal kits and (2) personal kits (supplied from the mother kit) for minor trauma that the producer or worker should have in readily accessible locations, such as in a small belt-attached pack carried on their person or located in their farm truck, tractor, or harvester cab. A copy of Table 11.5 should be kept in the mother kit and be used as an inventory checklist. One person should be designated to regularly check and restock supplies as needed. The mother kit should be located in a central location(s) such as the machine shop, the farm office, or the home. First-aid materials should be kept in an enclosed container that keeps out dirt and water. The contents for both the personal and mother kits are given in Table 11.5, modified from the recommended USDA Cooperative Extension Service (35).

Health professionals in rural areas can perform a vital public service by facilitating first-on-the-scene training courses in their community. This training can complement high school or community college agricultural programs, 4-H programs, and agricultural business programs, and can occur wherever farm families gather. There is an extensive amount of reference and training material available through the US Cooperative Extension Service and others such as the National Farmedic Training Program of McNeil and Company (36).

11.5 First Responders and Emergency Medical Treatment, Rescue/Extrication, and Transport

Rural communities often have fire and rescue squads primarily composed of volunteers. These professionals are well trained in the basics of firefighting. In many cases they have been cross-trained in basic first aid and CPR to handle emergency or rescue situations. These services are often called on as first responders to an injury scene or extrication situation.

In addition to first responders, many rural communities have some level of EMS. These services are usually located within an ambulance service that may be a local governmental agency or a private enterprise, or affiliated with a hospital. The personnel of these services are more highly trained in medical care compared to first responders. They may be staffed with either volunteers or paid employees. The staff complete certificate training programs which contain set standards to progress through various steps of EMS training. These professionals have the ability to work under a set of standard protocols and under the guidance of a physician.

11.5.1 Training

Continuing education is important for both first responders and EMTs. However, resources for initial and continuing education for them may

Table 11.5 First-aid kits for the farm

Number	Item description	Size
Personal first-aid kit		
4	Adhesive bandages (e.g., Band-Aids)	1” × 3”
4	Alcohol or povidone iodine pads for cleaning small wounds	
1	An antiseptic or antibiotic spray for wounds (preferably in a pump bottle)	
2	Knuckle bandages	
1	Eyewash solution	
1	Gauze roll (cling gauze preferable)	2” roll
1	Adhesive tape roll	1” × 5 yards
Mother box first-aid kit		
1	Card with the phone numbers for the local emergency rescue service, the family physician, and the poison control center	
1	Basic first-aid manual (e.g., *The American Red Cross First Aid Manual*)	
1	Adhesive tape roll	1” × 5 yards
12	Adhesive bandages (e.g., Band-Aids)	1” × 3”
5	Adhesive bandages (e.g., Band-Aids)	2” × 4”
10	Butterfly closures	
5	Knuckle bandages	
1	Triangular bandage for use as a sling, splint, or to control bleeding	Large (36”)
4	Safety pins (e.g., to use to make a sling)	
5	Cotton-tip applicators	
1	CPR face shield	
1	Emergency thermal blanket	
4	Eyewash solution with eyewash cup	0.5 ounce
1	Eye pad	2” round
2	Finger splints	
12	Sterile gauze dressings	4” × 4”
1	Sterile trauma pad	8” × 10”
4	Examination gloves	
2	Instant cold compress	
1 each	Gauze roll (cling gauze preferable)	2” and 4”
1	Elastic bandage	3”
1	Bandage scissors (heavy duty to cut clothing material)	
1	Thumb forceps (tweezers)	
2	Antiseptic or antibiotic spray for wounds (preferably in a pump bottle)	
6	Antibiotic ointment	
1	8 ounces of sterile water and an antiseptic soap, such as Betadine, to wash wounds	
12	Alcohol pads for cleaning small wounds	
3	Povidone iodine pads for cleaning small wounds	
3	Sting relief pads	
12	Antiseptic towelettes	
1 each	Plastic bags (for storage and transportation of amputated limbs or other tissues)	Garbage – size, 2 kitchen size, and 2 liter-sized zip lock
1	Contents guide/refill information	

be limited by distance to the program venue, their lack of available time if they are volunteers, and insufficient financial resources to pay for the training.

Although these professionals may be well trained in basic firefighting and emergency medicine techniques, few of them are trained in the specifics of farm rescue and emergency medical treatment. There are many unique features of farm injuries for which regular training should be supplemented. There are well-recognized training programs to prepare rural service providers.

The most recognized program in the United States is Farmedic (36). This program was initiated in 1981 and now operates out of the private firm McNeil and Company in New York State. The main goal of Farmedic training is "to provide rural fire/rescue responders with a systematic approach to farm rescue procedures that address the safety of both patients and responders". Over 28,000 responders have been trained by this program in 48 US states and Canada, and instructors now exist in many regions of the United States.

Special training is needed to ensure rescuers are aware of further risks to the victim and to themselves as rescuers, and how to mitigate these risks. They are trained in farm fire and rescue situations such as extraction of a person entangled in a combine header or PTO shaft, engulfed in a grain bin, or downed in a silo. They can also extinguish a silo fire. They also learn about special rescue equipment and how to use it in specific farm rescue scenarios.

Rural farm fire/rescue services are equipped with standard tools such as rescue air bags, reciprocating saws, abrasive disk saws, hydraulic spreaders and cutters, and air chisels that are adequate to handle most automobile crashes. However, farm equipment is sturdier and made with stronger and thicker steel compared to the automobiles for which most rescue tools were designed. Often it is best, and more expedient, to take the equipment apart rather than destroy it to release the victim. Since rescuers may or may not know how to do this, it can be important to have a person at the scene familiar with the mechanics of the equipment, such as a neighboring farmer or an employee of a local farm machinery dealer. Dismantling the machinery may actually be safer for the victim, and also be preferred by the victim because his equipment is expensive, insurance may not cover this type of destruction, and the farmer will most assuredly be hoping to be able to use it again in the future.

11.5.2 Other Special Considerations of Farm Rescue

The American Academy of Orthopedic Surgeons book *Rural Rescue and Emergency Care* (37) describes three phases of rescue: locating, assessing and stabilizing, and transporting. The following sections emphasize the important considerations previously introduced in this chapter.

Locating

Finding the scene of a farm injury is often complicated. Even though many rural residences in the United States now have emergency (911) addresses with specific GPS coordinates, those coordinates will locate only the center point in the road in front of the driveway to the farmstead. The injury scene may be far from the farmstead or public roadway. Additionally, cell phones do not work in some remote areas. A first responder may need to designate a rendezvous point to meet the rescue team and guide them to the incident location. Direct access to the patient may also be complicated by inclement weather, lack of roads, and difficult surface conditions such as creeks and steep slopes.

Assessing and Stabilizing

The patent may be trapped or entangled in the machine. Freeing them may be complicated by the need to make immediate decisions regarding life-threatening issues alongside concerns about causing further injury by moving a person. For example, preventing the risk of a fire or explosion, contact with electricity from a downed wire, or contamination of the patient by various agricultural chemicals must be weighed against moving a victim with a possible spinal cord injury. It is essential for the rescuer to assess these hazards considering possible risk to him or herself, and risk of further harm to the victim. Extended incidents may require rescue personnel to provide emergency medical care for more than an hour, assume additional patient care responsibilities, exercise well-developed assessment techniques for delayed onset conditions, and cope with increasing stress and deteriorating patient condition (37).

Transporting the Patient

Fire/rescue vehicles may need to be equipped with four-wheel drive capability to reach the injury scene and get back to the main road for transport to the hospital. It may also be important to have a four-wheel drive vehicle or tractor at the scene to assist if rescue vehicles become stuck and need to be pulled out.

EMS personnel need excellent assessment skills to communicate with the local healthcare facilities. To ensure the best outcome for the patient they should be transported to the closest facility where they can be stabilized. Depending on the degree and nature of the injuries that decision may mean transport to a trauma center. If the distance and emergency nature of the injuries require a helicopter ambulance, that request should be made as early as possible following notification of the incident since the distance to these secondary or tertiary care facilities is usually much greater than that to the nearest primary care facility.

Sometimes the person first on the scene and/or the victim will choose self-transport. Transporting a person with what appears to be a simple injury, such as a broken arm or leg, can involve complications. Fractures should be properly immobilized before transport. Moving a person with a broken bone can damage the bone, cause additional bleeding, and otherwise adversely affect blood vessels, nerves, or other surrounding tissues. A first responder without first-aid equipment may have to call on his or her creativity, using rolled newspapers, magazines, or other materials to fashion a splint and immobilize the fracture.

The transport team or person must be prepared to provide information important to the emergency room personnel as they perform immediate care. The following questions can be used as a guide:

1. Was the patient's skin or clothing contaminated with any of the following materials that would make it necessary to get his or her clothes off and wash the skin? If so, what was the contamination?
   - Pesticides (what type: insecticide, cholinesterase inhibitor or herbicide).
   - Anhydrous or aqua ammonia fertilizer.
   - Fuels or fluids, e.g. gasoline, diesel, motor or hydraulic oils, or battery acid.
   - Animal wastes or soil contamination of an open wound.
2. Is there possible foreign body contamination of the wound?
3. Was there amputation of a body part that may be a candidate for surgical reattachment, and is the body part being transported with the patient?
4. Was the mechanism of the injury such that it might cause injuries that are not externally obvious (e.g., closed blow or crushing injury to the chest or abdomen)?

11.6 Emergency Room

The first goal of the emergency room personnel is to create no further harm, stabilize the patient, and make appropriate referral to the next level of care or release to the patient's home. Emergency room personnel should ascertain the information mentioned in points 1–4 above and provide care accordingly. If the patient has been exposed to fuels or chemicals, for example as a result of a tractor or machine overturn, the patient's clothes must be removed and the body washed thoroughly. If an amputation has occurred, the patient should be assessed for possible reattachment surgery following stabilization. The body part must be obtained from the injury scene, kept on ice, and brought to the emergency room. Also consider that the patient may have secondary injuries, such as pig bites on victims trapped around livestock, or injuries to the contralateral side, self-induced while trying to escape.

Possible wound infections resulting from antibiotic-resistant organisms of animal origin indicate avoiding classes of antibiotics that are commonly used on the farm (early beta-lactams (e.g. penicillin), tetracyclines, macrolids, sulfonamides) and starting with newer generations of antibiotics while waiting for culture and sensitivity assessments. Considering antibiotic coverage for anaerobic organisms, reasonable choices to start antibiotic therapy for a farm injury could include (1) amoxicillin, or a second- or third-generation cephalosporin, (2) an aminoglycoside (e.g., gentamycin), or (3) a combination of a cephalosporin and an aminoglycoside (e.g., cefuroxime and gentamycin).

Table 11.6 Recommendations for tetanus immunization in wound management

Immunization history	Minor, clean wounds		Severe, contaminated wounds	
	Tetanus toxoid	Tetanus immunoglobulin	Tetanus toxoid	Tetanus immunoglobulin
Less than three lifetime doses or unknown	Yes	No	Yes	Yes
Three or more lifetime doses, less than 10 years since last dose	No	No	Yes	No
Three or more lifetime doses, last dose more than 10 years ago	Yes	No	Yes	No
Three or more lifetime doses, last dose more than 5 years ago	No	No	Yes	No

Source: Reference Center for Disease Control and Prevention http://www.cdc.gov/vaccines/pubs/pinkbook/tetanus.html.

Consideration should be given to delaying wound closure until it is certain the infection is under control, or allow the wound to heal by secondary intention.

One should make sure the patient is up to date on his or her tetanus immunization. The current recommendation in the case of a clean minor wound is to immunize if less than three total doses, or unknown, or greater than 10 years since last dose. For severe, contaminated wounds, immunize if less than three lifetime doses (plus 250 IU tetanus immunoglobulin) or if greater than 5 years since last tetanus immunization (38, 39). Table 11.6 summarizes the recommendations for tetanus immunization in consideration with wound care (39).

11.7 Primary Care

Many of the special considerations for agricultural injuries in the emergency room carry forward into primary care treatment. All of the previous considerations need attention to assure they have been dealt with appropriately. If they have not been dealt with in the emergency room, they must be dealt with in primary care.

One can assume that the patient will be very anxious about ensuring the farm work gets done, and he/she will want to get back to work sooner than medically advised. Farmers are often stoic individuals and resist extensive care. The healthcare provider must consider the patient's concern that there often is no one else to do their work at home. There is no one to milk the cows, or feed the pigs, or plant, or harvest, creating a very anxious patient who is sometimes too motivated to get back to farming for his or her own good. It is therefore good to practice some "social medicine" in these instances. Call the farmer's neighbors or relatives and help make arrangements for temporary care of the farm. The Scandinavian countries are advanced in this regard, as they have a special service that provides relief work for farmers in time of sickness or vacation. Unfortunately, these services are not widespread internationally.

If the patient is to go home directly from primary care, the provider should assume the patient will be out working on the farm sooner than ideal and should therefore consider some accommodation to either prepare for an earlier, safe return to work or introduce something that may discourage the patient from working until healing is more assured. Examples might include (if a fracture is involved) making an extra heavy walking cast that can be protected from water and will hold up while performing work around the farm, or making a cast that will impede working to the extent that it will encourage the worker to stay off work for a while. Furthermore, if a laceration or surgery was involved, tension sutures could be used as a precautionary measure to help hold the suture line intact even under stress.

11.8 Secondary/Tertiary Care

If the patient has injuries that require secondary or tertiary treatment, such as reconstruction, attachment, or amputation, special consideration should be given to the patient's continued functioning as a farmer. The physician should discuss the options with the patient and his/her family, and consult with occupational and rehabilitation therapists for reconstruction, considering the patient's desire to continue farm work and the procedures that may result in maximum occupational function for the particular patient as opposed to cosmetic appearance. For some patients, an appropriate prosthesis may be better than a partially functioning reattachment. Certain kinds of prosthesis may provide much more function for the farmer. An occupational therapist can be a valuable consultant in these situations.

In general, for amputations there must be soft tissue padding over bony ends and amputation should be as distal as possible, especially in children, to preserve growing ends. Retention of a small amount of proximal humorous and similarly a small length of proximal radius and ulna may be of little value. It is important to preserve the knee. Above knee amputations should be in the midsection or distal end of the femur. Retaining the carpus can be important in hand injuries. Retention of a thumb is important as there is functional value if opposition between the digits and thumb can be achieved (40).

Return to an adequately functioning extremity often requires protecting repaired structures, controlling swelling, and restoring motion through occupational therapy. Unlike other industrial workers, who may be reassigned to other tasks or put on disability, the farmer may not have an option for disability and will most likely have a strong desire to return to farming.

11.9 Rehabilitation

There often is a gap in continuity of services once the injured farmer leaves hospital. Provision of rehabilitation services is very rare in rural communities and on the farm to facilitate the person achieving his/her maximum potential. Not only does the recovering injured farmer have physical problems to deal with, but he/she and the family may have mental health issues as well (discussed further below). The healthcare providers in the patient's community are now the primary professionals to assist the patient in returning to his or her full physical and mental health potential.

Good communication is necessary between the higher level healthcare providers and the local provider. This communication should include the nature of the injuries and the expected limitations and prognosis. The details of rehabilitation and assistive technology application are often left to the community. Fortunately, in the United States there is assistance for rehabilitation within the agricultural community through the National AgrAbility Project (41). Created in 1991, AgrAbility links the federal and state Cooperative Extension Service with non-profit disability service organizations to provide information, education, and technical assistance to serve people with disabilities who are employed in agriculture. Twenty states or regions (as of 2016) have USDA-funded or affiliated AgrAbility Projects. A healthcare provider who has a farming patient with a disability may contact the AgrAbility project in their region (41). AgrAbility will have rehabilitation specialists who will visit the farm, assess the patient and the farming operation, and assist the patient in achieving their potential of getting back to the business of farming. There are a number of other organizations that deal with disabilities in rural America. Although not specific for agriculture, they may be of help in your region. These programs are reviewed on the National AgrAbility website (41).

Injuries on the farm create a great deal of stress and mental health issues, which create barriers to full recovery. As in most cases the patient will have a strong economic and culturally motived desire to get back to farming. Anxiety and depression are likely to accompany the rehabilitation process, especially if the patient is not able or limited in the farm work they can do. Chronic injuries present even greater stress for victims. Many may face the loss of work capacity for an extended time period, chronic pain, and learning to deal with lifetime disability. Injured farmers may suffer from post-traumatic stress disorder, which can be disabling. Family disruptions may occur, especially with the loss of a child to a farm injury. Often a spouse assumes the role of total care provider for the injured person while at the same time having to increase their role in the farm work, plus they may be working off the farm to help make ends meet.

Apart from the serious psychological and social impact on patients and relatives, such injuries invariably have profound economic affects. In many instances a death or serious injury to the principal operator of the farm leads to the economic failure of that enterprise.

Mental health services in rural areas outside of primary care providers are not readily available. Too often there is a stigma in the rural community against admitting to the need for and seeking mental health services. Michael Rosmann (a clinical psychologist and farmer) founded AgriWellness to deal with mental health issues in the agricultural setting. AgriWellness holds conferences and training for professional and peer counselors to assist farmers and families with mental health issues regardless if there was an injury or not (42).

11.10 Hazards and Injury Scenarios

This section lists some of the common injury scenarios encountered by farmers, farm workers, and their family members. These scenarios are intended to give the reader a better understanding of the mechanisms of injury as well as the circumstances of the incidents and how the various participants in the chain of responders interact with the victim within the context of the particular incident. More than one body part or system is often involved. The scenarios are based on actual cases these authors (LG and KJD) have experienced, but some of the details have been fictionalized to emphasize teaching points. They are intended to provide an overview of some of the more common injury incidents as well as some of the confounding factors encountered in emergency situations. However, they are not inclusive of all potential types of agricultural injuries.

As mentioned earlier in the chapter, machinery is one of the main agents of causes of fatal and non-fatal injuries on farms and ranches. Machinery is term that covers a broad array of mobile and stationary equipment used in the industry of production agriculture.

11.10.1 Tractors and All-terrain Vehicle Injury Incidents

Tractors are used for tillage, planting, harvesting, and a variety of other tasks. Tractor overturns crushing the operator account for about 25% of all agricultural fatalities in North America. All-terrain vehicles (ATVs, also called quad bikes in Australia and New Zealand) and side-by-side utility task vehicles (UTVs) are used on almost every farm and ranch on a daily basis. ATV injuries have become much more common in the past decade and ATVs are the number one agent associated with fatal farm injuries in Australia.

ATVs can be and are used on rough terrain, and can easily overturn on the operator. They are designed to carry only the driver. UTVs are also used on very rough terrain but are designed to carry passengers and supplies, and most are equipped with roll-over protection. This type of machine has changed rapidly in recent years, with additional features and profiles for farm and ranch use being offered every year.

Descriptive Information

Tractors are often described by their uses and configurations, such as utility or row-crop, narrow or wide front, two- or four-wheel drive, wheeled or tracked. They are powered by engines from 20 to 500 horsepower (14–350 kilowatts) and weigh 700–23,000 kg before additional ballast weight is added. They are typically operated at relatively slow travel speeds in the field but some newer models can do 30 mph (48 km/h) or more on the road. They also perform as a mobile or stationary source for mechanical, hydraulic, and electrical power.

The operator's station may be open or enclosed in a cab, with or without a framework affording roll over protection (ROPS) for the operator in the event of a tractor overturn. Older operator enclosures, sometimes called soft cabs or weather cabs, do not have ROPS integrated into their design.

In the United States very few tractors manufactured before 1985 were equipped with ROPS because they were not engineered to accept ROPS until 1975 (and few were purchased as they were an optional item). It was not until 1985 that ROPS on new tractors was no longer an optional purchase, as they came installed from the factory due to an agreed upon industry standard. This situation means that approximately 40% of the tractors in the United States do not have ROPS and therefore have a high risk of a severe or fatal injury to the operator if the tractor overturns. After-market ROPS are available for most tractors manufactured since 1975 and some models manufactured earlier. Aggressive marketing and promotion by several public and private sources have resulted in some success in ROPs installation on older tractors.

Most Western European countries, Australia, New Zealand, and Canada have had relatively greater success in achieving a much higher percentage of tractors equipped with ROPs, compared to the United States, using a combination of regulation and marketing efforts. Tractor overturn fatalities are much lower in these countries as a result.

ATVs are typically ridden like a motorcycle, straddling the seat and steered with handlebars, but they have four wheels. They can accelerate rapidly and maneuver through all types of terrain. Common weights are 100–250 kg with top speeds up to 70 mph (100 km/h). While most US states restrict the use of ATVs to off-road, many countries allow ATVs to be used on public roadways.

UTVs can be built with either a bench seat or bucket seats for the operator and passengers. They may also have a second bench seat. These machines have weights up to 500 kg and speeds up to 40 mph (70 km/h). ATVs do not currently come from the manufacturer with roll-over protection. At least two private companies have designed and are marketing ROPS for ATVs, but their effectiveness is questionable and the ATV manufacturers do not support this effort (43). Most UTVs come from the factory with roll-over protection.

Injury Overview

In general terms, tractors are associated with approximately 40% of all traumatic fatalities on farms in the United States. About half the tractor fatalities involve overturns and about one quarter involve run-over of the operator, a passenger, or a bystander. The remainder includes motor vehicle crashes and entanglement in the PTO shaft. As northern EU countries generally have a higher percentage of tractors equipped with ROPS, tractor overturns are less common, which is why the United States has about a 25% higher occupational fatality rate than the EU.

If the tractor is not equipped with a ROPS, an operator is likely to be thrown against objects during an overturn, thrown to the ground and crushed as the overturn continues, or pinned under the tractor. Being run over by a tractor, other vehicle, or mobile machine can cause internal crushing injuries as the heavy machine's tires or tracks traverse portions of the body. Unexpected or uncontrolled movement of a machine during a rescue attempt can squeeze a helper or the operator between the machine and an implement or fixed structure. Unsecured objects (e.g., large round hay bales) lifted high by a loader or forklift can spill or roll into the operator's station, causing thoracic, cervical, or lumbar injury (44).

Injuries from operating ATVs and UTVs are primarily related to roll-overs and crashes. These injuries are similar to those sustained from any implement rolling over and crushing the operator or passenger.

Illustrative Scenario

Overturn

A 76-year-old male was using a tractor with a rotary brush cutter attached to the rear three-point hitch to mow a roadside ditch. Mowing along the shoulder of the road, the wheels on the downhill side of the tractor dropped into a washout and the tractor tipped onto its side. The tractor did not have a ROPS and rolled 180°. The operator was thrown clear of the tractor. The driver of an approaching car stopped and immediately called for emergency assistance. He then began to assist the slightly dazed farmer crawling out of the ditch. The farmer complained of neck, back, hip, and leg pain along with upper left quadrant abdominal tenderness. To the person first on the scene, he seemed to be breathing rapidly and with some difficulty.

Prevention. While this event would not have been prevented if the tractor had been equipped with ROPS, the injuries would have been reduced. If a tractor has ROPS, it should also have a seat belt, although a fastened seatbelt is usually not necessary to save the life of the operator as the ROPS prevents the tractor from rolling on top of the operator. However, with a seat belt in place, the operator would have remained protected within the frame of the ROPS, probably sustaining fewer injuries.

Operator Bypass Start Runover

John was in a hurry to feed his cattle and get on with the rest of the day's work. He jumped on the tractor and turned the ignition switch but the tractor would not start. He knew the problem was a bad starter motor solenoid switch, but had never had time to change it before. As he had done several times before, he used his plyers to jump across the starter terminals, bypassing the non-functioning solenoid switch. The engine cranked and started. In a quick moment the tractor, which he had inadvertently left in gear, moved forward, running over him before he could get out of the way. Luckily, the rear wheel got only his legs.

Prevention. Bypass start kits, a shield that covers the starter terminals, can be installed as a reminder that shorting across the terminals is dangerous, helping to overcome the root of the problem, which is lack of equipment maintenance and relying on human behavior to keep safe.

Bystander Runover

John, who was 12, got home from school and started chores. Every day was the same, doing his chores and watching his 3-year-old brother Justin, who was dropped off by the babysitter. (His parents both had jobs off the farm to help make ends meet and did not get home until 6:00 pm.) The cattle needed hay and John thought Justin would be okay playing in the hay storage area. John used the tractor with a front-end loader to pick up a large round bale and headed for the feedlot. He didn't realize Justin was following him, despite being told to stay put. John placed the bale carefully into the manger and shifted the tractor into reverse. As he backed away, the tractor lifted slightly. Looking ahead to see what he had run over, he saw his young brother's feet and legs come into view from under the tire.

Prevention. The family dynamics in this scenario is not that uncommon. Parents are responsible for their children, but they often need help. Organizations like Farm Safety for Just Kids (45) and the National Children's Center exist to help (46). The family could establish plans to account for their absence, such as arranging for extended hours for childcare or other family members and neighbors watching the child during these activities. A safe play area could be built on the farm that the youngster could not exit (46). Studying and following the North American Guidelines for Children's Agricultural Tasks (46) would help the parents assign tasks appropriate for the mental and physical development of the child. Local public health and farm organizations can help in instituting training for parents on these subjects.

Roll-overs and run-overs are the main sources of fatal injuries to adults, while run-overs are the major source of fatalities to children. Many other scenarios on farms can occur with any of the many self-propelled farm machines, tractors, or tractor-implement combinations.

First on Scene, First Responder, and Transport

An operator on a tractor that does not have a ROPS when it overturns has a high probability of dying outright from their injuries (47).

Survivors generally have broken bones as well as internal injuries. If the tractor is equipped with a ROPS or ROPS cab, the operator almost always survives the overturn (even without a seatbelt fastened, but with some – often serious – injuries. The victims may also have injuries from caustic or hot fluids. As the victim may have a spine injury, they should not be moved unless there is immediate danger.

The first-on-the-scene person should turn off the engine. Older diesel engines may require pulling a knob to shut off the fuel supply to stop the engine. Alternatives for a fire rescue responder to kill the engine would be discharging a CO_2 or halon extinguisher into the air intake (48).

A shear-type injury may occur when a tractor or other wheeled piece of equipment runs over an extremity, causing soft tissue to be pulled loose with underlying tissue and vascular disruption.

Emergency and Post-crisis Treatment

Explore for fractured skull (a depression in the skull may be evident). Explore for thoracic, cervical, and lumbar vertebral injury, which may result in potential paraplegia or quadriplegia. There could be a cervical fracture if the victim complains of pain or numbness in the neck or down the arms or legs. Chest injury possibilities include mechanical asphyxia, flail chest (multiple broken ribs resulting in difficult breathing), pneumothorax (air in the chest cavity), hemothorax (blood in the chest cavity), subcutaneous or mediastinal emphysema (air under the skin or in the space between the lungs) (37). Patients suffering from acute and complex spinal cord fractures and dislocations are managed according to established principles. Abdominal injuries may include laceration of the liver or spleen, rupture of hollow organs, or other penetrating wounds. Fractures with associated internal bleeding and lacerated rectum should be considered in the pelvic region.

Degloved tissue separated from its perfusing vessels may be present, risking loss of the involved appendage. It is especially important to recognize a concealed degloving since emergency defatting and reapplication of skin as a graft is necessary to save the appendage (49).

Recovery Care, Management, and Rehabilitation

These types of injuries call for special mental as well as physical rehabilitation. Farmers who suffer an injury that leaves them paraplegic or quadriplegic often still want to farm. Farm rehabilitation specialists have the means to help these people with special lifts to enter tractors, special operational adaptations so they can drive, and much more (41).

Spinal cord injuries are more than devastating to body functions. They entail serious psychological, economic, and social impacts on the patient and family, and a high cost to society (50).

Contributing Factors and Prevention

Table 11.7 categorizes the contributing factors to tractor-related injury events according to the man–machine–environment paradigm, and lists preventive strategies.

11.10.2 Skid-steer Injury Incidents

Descriptive Information

Skid-steers usage on farms has continued to grow as their capabilities have increased since their advent in the 1950s. They are compact, self-propelled machines with mechanical arms on one or both sides of the machine to lift and lower attachments that lift and carry loads and perform many other work tasks. Today they are commonly called skid-steers rather than skid-steer loaders because of the expanding range of attachments. Common agricultural tasks farmers perform with skid-steers include moving manure from animal facilities, moving large hay bales and silage, utility tasks such as digging post holes, and minor earth- or rock-moving projects.

The steering control of the skid-steer is hydraulically operated as are its lift arms and

Table 11.7 Analysis of contributing factors and prevention of tractor-related injury scenarios

Scenario	Personnel	Machine	Environment	Prevention
Tractor overturn	Farmer was elderly (76 years)	Tractor did not have ROPS	Steep terrain Washout with limited vision due to tall grass	Install ROPS on tractor or use newer tractor with ROPS Inspect the area to be mowed on foot before mowing Consider age-appropriate tasks for older farmers
Bypass start runover	Anxiety and focus on getting the tractor started and getting chores done Positive previous experience in bypass starting	Faulty solenoid switch Dead battery	Cold weather	Replace lockouts on tractor so it cannot be started when in gear Install a bypass start guard on the starter Install new solenoid switch and battery
Bystander runover	Youth: a 3-year-old together with a 12-year-old Parents not supervising as they were working elsewhere	No rearview mirrors on tractor	Because of the height of the feed bunk, the operator had to look forward while backing out so the front end of the loader would clear	Install safe play area on the farm Arrange for parental supervision or day care Discuss and assign age-appropriate tasks

many attachments. The operator is positioned at controls between or adjacent to the lift arm(s), and behind the attachment connected at the front of the lift arms. Operators enter and exit the operating station through the opening at the front of the machine, over or around the attachment, or from the side of machines designed with a single lift arm (51). Old model skid steers (many of which are still in use) are particularly hazardous as they do not have rollover protection, falling object protection, or side screens which block access to the scissoring movement of the lift arm(s) alongside the frame.

Injury Overview

Skid-steers are inherently less stable than tractors and can overturn more readily because of their short and relatively narrow wheel base. Bystanders can be run over during rapid forward and backward shuttle operations. During operations requiring lifting and lowering of the lift arms, an operator's head, neck, or shoulders placed outside of the side frame can be crushed in the scissoring action between the lowering lift arm and the side frame if there are no protective side screens. Since an operator may enter from the front and step over the controls, inadvertent actuation of the controls can occur, causing the bucket, if left in the raised position, to drop suddenly. Heavy material could fall backward into the operator's station from a raised, loaded bucket, injuring the operator. Because of the short wheel base, these machines tend to rock fore and aft forcefully when traveling over rough terrain, or when lowering and raising or dumping the loader/load. If the operator is not wearing a seat belt, and/or forward pitch protection is missing, the operator can be thrown out, risking injury from a run-over or being caught in the scissors action of the loader.

Illustrative Scenarios

Pinch or Crush

A 26-year-old pork producer was injured when he was caught between the frame of the skid-steer and the side lift arm of the loader. He was using the loader to load manure from a hog confinement building. The protective cage had been removed to permit operation under the low doorway of the building. The farmer was operating the foot pedals that raise and lower the bucket while leaning to the side to observe the bucket's position for dumping and to avoid hitting the building. He inadvertently lowered the bucket, which crushed him between the lift arm and the side frame.

Prevention. Never remove the protective cage. The building can be modified to allow access of the skid-steer, or a smaller model could be purchased.

First on Scene, First Responder, and Transport

Always proceed with the basics: scene safety, shut off equipment, stabilize equipment, and check the patient. As a first responder, assess the information provided by the first on the scene regarding the severity of the injury and request dispatch of what is deemed appropriate (and available), which may include an advanced rescue team, paramedic ambulance, and helicopter. The injuries sustained in the pinching scenario could include broken bones and internal damage. Even a closed fracture such as of the thigh or pelvis, which often results in damage to the bladder, can involve significant blood loss and falling blood pressure can mean many tissues no longer receive adequate oxygen (52). In the event that the person is conscious and talking, be cognizant of the fact that enough internal damage could have been done so that release of the pressure could cause massive internal bleeding and sudden death.

Emergency and Post-crisis Treatment

The farmer pinched by the skid-steer lift arms could have significant internal injuries, including broken ribs, punctured and collapsed lung, ruptured liver or spleen. Assessment of breathing ability, as well as breath sounds, should be performed immediately.

Recovery Care, Management, and Rehabilitation

These types of injuries may take an extended recovery period, and all the precautions and assurance of continuity of care as mentioned previously should be put in place.

Contributing Factors and Prevention

Operating a skid-steer without the protective enclosure and its side screens, and not wearing a seat belt, is an extremely hazardous combination. Proper maintenance is vital for all mechanical equipment. Safety devices need to be kept in place, function properly, and be well maintained.

Table 11.8 categorizes the contributing factors in skid-steer pinch and crush events according to the man–machine–environment paradigm, and lists preventive strategies.

11.10.3 Other Self-propelled Machinery Injury Incidents

Descriptive Information

Self-propelled agricultural machines are specialized machines for harvesting grain, tilling or planting fields, applying pesticides, or gathering stones and roots. Combines, windrowers, potato and beet harvesters, and sprayers are common self-propelled machines and the prevalence of others such as sugar cane harvesters varies with the specific commodities cultivated around the world.

Table 11.8 Analysis of Contributing Factors and Prevention of Skid Steer Injury Scenarios

Scenario	Personnel	Machine	Environment	Prevention
Pinch and crush	Behavior: removing the protective cage	Inherent design of the machine (lift apparatus adjacent to the operator's station) Machine lacking protective cage No interlock system to prevent lift arms from actuating when a person is not in the seat	Low and narrow building, making it more convenient to operate the machine without the protective cage	Remodel the building Replace the protective cage New machines have an interlock that prevents actuation of the lift arms if no one is in the seat

Crop-gathering, -cutting, -processing, -transfer, and -discharge mechanisms are powerful, designed to minimize blockage and aggressively move large volumes of material rapidly. Many of these mechanisms have high inertia and continue to operate for a period of time after power to them has been disengaged. They process crops rapidly, for example a modern combine will feed stalks through the snapping rolls at 3.0–4.5 meters per second, much faster than the reaction time of a person to release their grip on a jammed stalk, resulting in the operator's hand being pulled into the machine (53).

Injury Overview

Operators can become caught in the mechanisms and be drawn into the machines. Clothing or extremities can be entangled in drive mechanisms. Injuries may include a crushed or amputated hand or other appendage, lacerations, or degloving as body parts pass between a belt and pulley, chain and sprocket, rollers or the meshing teeth of a gear set.

Illustrative Scenarios

Cutting Mechanism

A 57-year-old hired farm worker had just taken the self-propelled chopper to the field to chop corn for silage. The machine normally gathered the four rows without hesitation, but corn rootworms had damaged the corn, causing the stalks to be downed and twisted by the wind. As he guided the machine slowly through the field, he became increasingly frustrated each time the throat of the chopper (the area that the corn stalks pass through just before they enter the rotating blades to be chopped) became plugged. After several instances of shutting off the machine, getting off and physically dislodging the stalk, he thought he would save time and energy by not shutting off the machine and dislodge the material with the chopper running. As he grabbed the pile of stalks, they pulled him into the machine; he could not let go quickly enough.

Prevention. The operator should never get off the equipment without shutting it off, even though it is much easier to unplug the machine while it is running. While this seems tedious after the first few times, there simply is no other safe way to clear it.

Snapping Roll Entanglement

A 78-year-old farmer was increasingly troubled with his loss of hearing, eyesight, and balance. On a cold morning he went to the field to harvest corn with his combine. The combined cold and moisture made the stalks tough and they would not feed readily though the snapping rolls. (The snapping rolls run parallel to each other, one on each side of a corn row. They intermesh and turn toward each other, pulling (snapping off) the ears of corn, the first in a series of processes in corn harvesting.)

When the corn stalks plugged in the snapping rolls, the farmer got off to remove the corn stalks. He did not shut the combine off. As he grabbed the stalks, they suddenly were pulled into the machine, and so was he as he could not let go his grip fast enough.

Prevention. The operator should never get off the equipment without shutting it off. While this seems tedious after the first few times, there simply is no other safe way to clear it. Replacing old equipment is an important safety plan as newer equipment is generally safer, for example newer combines are much more aggressive and are not easily plugged.

First on Scene, First Responder, and Transport

Disengage power, shut off the engine, and stabilize the machine, the scene, and the victim. Assess the injury and call for emergency transportation. Depending on how the person is caught, it may be possible to free them by cutting entangled clothing, disconnecting the drive mechanism, or completely dismantling part of the machine.

Entanglements in crop-engaging mechanisms may involve the most serious injuries and most complex extrication. The victim's body may block access. Portions of machines may be too strong to be moved with extrication tools such as the "jaws of life." It may be necessary to use common wrenches and sockets to dismantle the machine to free the victim. A local farm machine mechanic may more efficiently release the patient than a first responder fire and rescue service member.

Emergency and Post-crisis Treatment

Expect fractures, lacerations, avulsions, crushing injuries, and amputations in these situations.

Recovery Care, Management, and Rehabilitation

The same general considerations mentioned above are present in these injuries. These types of injuries may take an extended recovery period, and all the precautions and assurance of continuity of care mentioned previously should be put in place.

Contributing Factors and Prevention

The age of the second farmer was a contributing factor. Cognition, balance, and reaction time all were likely decreased at 78 years of age. The insect infestation in the corn and the weather were environmental factors in this scenario.

Managing frustration, frequent breaks, proper maintenance of and upgrading equipment, and working with extra patience when crops are not in good condition all help to reduce the risk from human factors that contribute to injuries.

11.10.4 PTO-powered Implement Injury Incidents

Descriptive Information

Many agricultural machines are made to be pulled and powered by a tractor. Mechanical power to these implements is transmitted to them by a rotating driveline called a power take-off (PTO) (54). Machines that use the tractor PTO for power do a myriad of jobs on farms and ranches, including harvesting, tilling, grinding feed, and spreading manure.

The PTO stub shaft, typically at the rear of the tractor, connects the PTO shaft to the implement. The PTO stub shaft is normally surrounded by a guard called a master shield or PTO shield**.** A driveline shield covers the rotating shaft, preventing loose things from wrapping around the shaft while it is turning. Older machinery may not have this guarding system, or it may be non-functioning or removed.

Injury Overview

Clothing, long hair, or a person's extremities can be entangled in the rotating shafts, such as a PTO driveline or other rotating shafts that are a component of the machine being powered by the tractors. Loose fitting or drawstring clothing, or long hair can make contact with the shaft and wrap around it. Consecutive wraps "lock" the material onto the shaft, which keeps turning and continuing to wrap up the loose material and body components within it or connected. This can happen in under a second, faster than a person's reaction time.

Injuries from rotating shaft entanglements can be some of the most traumatic in agriculture. Head injuries, spinal fractures, multiple fractured limbs, dislocations, amputations, scalping, and degloving or amputation of male genitalia are all possible. Less obvious but serious internal injuries may also occur, including flail chest, pneumothorax, hemothorax, pulmonary contusion, liver, spleen and myocardial tissue damage (37).

Illustrative Scenarios

PTO Entanglement

A 16-year-old girl and her older brother were helping their father dig post holes with a 40-year-old PTO-powered auger mounted on the back of the tractor. As it had been a summer with little rain, the soil was very hard, making it difficult for the auger to penetrate the soil. With only one hole left to dig, they encountered a particularly hard spot and the auger would not penetrate the soil at all. The young girl leaned on top of the machine to add weight, hoping it would help the machine function. However, the girl got too close to the unshielded shaft and her sleeve got caught and was wrapped around the shaft several times with her arm in it, resulting in multiple fractures of the humerus, radius, ulna, and metacarpus.

First on scene, first responder, and transport. Stabilizing the patient is very important because of the potential for massive and multiple injuries in this scenario. Extrication from a PTO or other drive shaft usually involves cutting the clothing or other wrapped material (if possible without further injury to the victim) and cutting the shaft or universal joint with a saw (e.g., a powered reciprocating saw with a metal cutting blade).

Emergency and post-crisis treatment. It is extremely important to keep the complete guarding systems in place on the tractor (master shield), the driveline shield to the implement, and the drive lines on the implement itself. The driveline shield must be checked regularly (with the power off) to make sure it is free from the rotating shaft inside.

Expect any of the injuries mentioned in the PTO injury overview, including brain injuries, symptoms of which may not appear until well after the injury event (55).

Recovery care, management, and rehabilitation. The recovery care and management usually takes specialists in vascular surgery and orthopedics. Decisions will have to be made about the most practical and functional (not necessarily aesthetically best) repair that can be accomplished, considering the patient's likely strong desire to return to farming.

Contributing factors and prevention. Weather (drought conditions) was definitely a factor in the PTO scenario described, as the equipment would not penetrate the hardened soil by itself, requiring additional weight. The human element was trying to fix the situation without perceiving the risk of the action. Furthermore, the old equipment was not properly guarded, providing the opportunity for entanglement.

Hydraulic Injection (56–58)

Oil hydraulics have been used in powered farm equipment since the 1960s to power hydraulic rams to raise heavy equipment, actuate devices, and drive turbine engines. The oil is conveyed in lines by high-pressure pumps (e.g., 3000 pounds per square inch (207 bar)). A 39-year-old farmer had been tilling his fields all day. When he stopped to re-fuel, he noticed hydraulic oil dripping from the connections at the rear of the tractor. He knew there was a leak and wanted to see if it was the connections or a hose. As he picked up one of the hoses to check it, he felt something like a hot wire puncture his hand, which was in fact hydraulic oil being injected deep into the soft tissues surrounding the tendons and ligaments. This is an emergency, and the patient must be seen by a surgeon (preferably an orthopedic hand surgeon) to open the wound and drain the foreign material to relieve the pressure from ensuing inflammation that might result in compartmental syndrome, risking loss of soft tissue as well as digits or the whole hand.

First on scene, first responder, and transport. In a hydraulic injection scenario, the victim and family members must be aware that this is an emergency (57). The victim should be taken to the nearest emergency room and the emergency room physician made aware of the possibility of hydraulic fluid injection.

Emergency and post-crisis treatment (57, 58). The usual injury is one of inadvertent injection of the finger or hand while checking a hydraulic line for leaks. Although the severity of the injury at the time of injection is not obvious, within an hour inflammation and swelling may rapidly reduce circulation as the foreign material migrates to tendon sheaths, ligaments, neurovascular bundles, and fascial plains (40, 58). Entrapment syndrome may soon develop, leading to loss of blood and nerve supply to portions of the hand. Immediate and aggressive surgical decompression, debridement, and drainage are necessary to preserve vital structures and prevent permanent disability, which may include amputation. Follow-up surgeries may be needed for scar revisions or tendon repair. Amputations are unfortunately common in approximately 50% of cases.

Contributing factors and prevention. Routine maintenance of all hydraulic hoses and components will reduce the chance of a hydraulic injury.

Checking for leaks in a pressurized hydraulic line should never be done with a bare hand. Lines with visual cracks and checks should be replaced without waiting for a leak.

Recovery care, management, and rehabilitation. The extended care for hydraulic injection injury or anhydrous ammonia burns largely depends on the extent of the injury. Rehabilitation plans will depend on the extent of the injury.

Roadway Collision

A 69-year-old farmer was driving her tractor with a forage wagon in tow on the two-lane state highway. As she approached her driveway, she turned on her left signal, not realizing that it was obscured by the large wagon she pulled behind. Just as she was making the turn, an automobile that had just started to pass her struck the side of the wagon. The force of the impact caused the farmer to lose control and the tractor and wagon veered off the road and into the ditch. Fortunately her tractor was equipped with a ROPS and she survived with minor injuries. The automobile was totally destroyed and the driver suffered severe injuries.

First on scene, first responder, and transport. Farm roadway collisions may involve manure or hazardous farm chemicals (e.g., ammonia) (37), which have implications for the health of the victims, bystanders, rescuers, and environment. Along with caring for a victim who may have their clothes saturated with toxic or caustic materials, a hazardous materials response team may be required to control the environmental consequences.

Emergency and post-crisis treatment (55). In the collision scenario, if there is contamination of clothing and skin with farm chemicals, removal of clothing and thorough washing of exposed body parts should be exercised. Exposure to anhydrous ammonia may necessitate rapid transport to a tertiary care center to save a patient's sight or their life as severe lung or skin damage may result (37).

Recovery care, management, and rehabilitation. The extended care for the victims of a roadway crash should follow the general principles discussed previously in this section.

Contributing factors and prevention. To help prevent roadway crashes, the official slow-moving vehicle emblem should be visible (required by law in most US states) along with flashing amber lights (not required by law in most US states). Extended mirrors should be fixed to tractors to improve visibility around broad loads and allow traffic approaching from the rear to be seen. The general public will be unaware of what the driver of a farm vehicle might do and often will not anticipate when a tractor operator may be turning. Furthermore, they do not realize the closing speed, short time to react and long braking distance required when traveling at 60 mph (100 km/h) approaching farm equipment ahead moving at approximately 3–30 mph (5–50 km/h). These hazards are seldom taught in driver education classes and are generally not part of the knowledge necessary to pass a driving test.

11.10.5 Auger Injury Incidents

Descriptive Information

Augers function to move grain or feed on farms in a wide range of applications, such as a fixed component of a grain storage facility, as a moveable unit, or incorporated as part of a mobile machine such as a grain cart or combine. They are powered by one of several means, such as an electric motor, gasoline engine, a tractor's hydraulic system, or a tractor PTO (59).

An auger is a spiraling band of steel (flighting) winding around a center shaft (like a screw). Usually encased in a metal cylinder, the powered rotation of the shaft causes the flighting to push the grain in the shaft to the end of the cylinder. Grain moves into the intake area of the auger, an area where the flighting extends beyond the tube to let the grain or feed be pulled into the cylinder and flighting. The intake area should be equipped with guarding that must be kept in place to prevent fingers, hands, and toes from being pulled into the auger. A person's clothing or extremities can be quickly pulled into the auger.

Grain or feed storage bins often have an open (uncovered) auger that moves grain or feed to the intake area for the unloading auger. The auger will move the grain or feed as long as it is immersed in the material. Entanglement is also possible in this auger.

Injury Overview

Injuries from an auger entanglement usually involve severe lacerations and extensive soft tissue damage. Amputation of fingers, hands, toes, arms, or feet is a common result of auger entanglements. Children may experience loss of an arm or leg, or a degloving injury.

Illustrative Scenarios

Auger Entanglement

A 20-year-old employee of a grain farm was unloading grain from a wagon into a hopper with an auger to load a semi-truck trailer for transport to a distant ethanol production plant. The weather was clouding up with rain in the forecast, so the operator wanted to make sure that all of the grain was out of the hopper and the auger. She reached down with her gloved hand and started to push the grain into the auger flighting. In an instant, the flighting caught her glove and pulled her hand into the auger tube, resulting in her hand and arm being pulled into the cylinder up to her shoulder.

First on scene, first responder, and transport. The limb caught in an auger may have fingers amputated and will have massive lacerations. Blood loss may be minimal, inhibited by the pressure and crushing damage to the tissues and blood vessels. A rupture of a major vessel could result in excessive bleeding. Indirect pressure on the axillary or brachial, femoral, or popliteal artery can help control bleeding until the extremity is exposed, enabling application of direct pressure (37).

Emergency and Post-crisis Treatment

Expect massive lacerations, avulsions, and amputations. Keep in mind that the act of twisting and cutting a limb can also injure the joints and attachments of the affected limb.

Recovery Care, Management, and Rehabilitation

Auger injuries often require extensive reconstruction, although usually not as severe as PTO injuries. Long-term care and management should follow the general guidelines offered earlier in this chapter for agricultural injuries.

Contributing Factors and Prevention

This auger was not equipped with an intake screen to prevent the hand or glove from entering the flighting. The human element to this scenario is the unnecessary move to use the hands to feed the last few liters of grain into the flighting of the auger. A broom could instead have been kept by the auger to sweep up the excess grain. The environmental components of this injury included the concern for the residual grain in the hopper getting wet and spoiling or caking in the auger. The auger hopper could have been covered.

11.10.6 Livestock

Descriptive Information

Animal-induced injuries usually happen because the animals are frightened, are forced to do something they would rather not do, or are protecting a violation of their territory or their young. Animal-related injuries account for approximately 50% of all non-fatal farm injuries. Certain farm animals are more hazardous than others. Bulls, boars, and rams may be aggressive because of their natural territoriality. Some new cow and sow mothers have protective instincts that are stimulated to the point of aggression if a person gets between a cow and its newborn calf or causes a piglet to squeal. The need for the stockman to check birthing animals frequently or to administer treatments to newborns, combined with the element of human exhaustion, increases the risk of animal-related injury.

An animal mother's protectiveness or human behavior (sudden movements or striking the animal out of anger or an attempt to force an animal to move) may cause the animal to move suddenly following a fight or flight and escape response, injuring the farm worker. Erratic lacerations may occur while performing minor surgeries on animals, such as dehorning and castration.

Injury Overview

Hands, arms, and legs can become entangled in ropes and halters. Injuries vary from minor bruises and broken arms/fingers to loss of fingers. Crushing injuries with bruised or broken bones from kicks, butts, or inadvertent crushing against a solid wall are quite common, although injuries also occur from procedures occurring in open lots or pastures.

Illustrative Scenarios

Butted by Cow

A 57-year-old farmer was butted as he checked on a Holstein cow with a newborn calf. As he approached, the cow looked at him nervously. When he bent down to help the calf to its feet, the cow hit him in the back with her head. He fell, and the cow continued to butt him along the ground until he was able to crawl and roll under a barbed wire fence. He sustained fractured ribs, liver and spleen injuries, and a spinal vertebrae fracture.

First on Scene, First Responder, and Transport

Stabilization of this scene included removing any animals that may be in the area, or occupying them so they are not a hazard for the responders. Fractures of long bones, ribs, or spine and internal injuries are quite common in such incidents. Spinal and cervical immobilization is important if spinal injury is suspected.

Emergency and Post-crisis treatment

Expect long bone and rib fractures coupled with internal injuries. Skull fracture or severe concussion can result from a kick to the head. If the victim was rendered unconscious or otherwise unable to escape in the presence of pigs, they may also suffer loss of soft tissue from animal bites (37).

Recovery Care, Management, and Rehabilitation

Relative to machinery-related injuries, animal-related injuries are usually less serious and are most often closed injuries. However, there is a risk of infection from antibiotic-resistant organisms or anaerobic organisms causing tetanus or gangrene. Following the general principles for dealing with agricultural injuries as stated previously in this chapter will help to limit complications and shorten recovery.

Contributing Factors and Prevention

Working around new livestock mothers is very hazardous. Well-designed animal-handling facilities for moving, sorting, and loading animals are extremely important (60). Any animal pen where humans may also be working should have a secure quick-escape door. When handling newborn calves on pasture, a portable pen can be used set around a calf. The operator can get into the pen away from the cow, tend the calf, then exit and release the newborn. Such enclosures can be used in conjunction with a tractor, pickup, or ATV.

11.10.7 Farmstead: Grain, Silage, and Manure Storage (confined space) Injury Incidents

The farmstead presents a nexus of people and activities, machines and materials, which can be a source of injury for adults working on the farm, a dangerous playground for youngsters, and provide many tripping or falling hazards for the elderly. Among the hazards are those associated with maintenance work, hand tools, machines in the workshop, falling loads such as tires and stacked bales, entanglements in moving parts of conveying equipment, falls on the same level or from heights, entrapment in a confined space, and electric current injuries. The following sections describe just a few of the possible injury scenarios.

Chapter 3 describes the health hazards associated with grain and silage storage structures as well as manure storage structures.

Descriptive Information

Grain bins and grain transporters have a risk of grain engulfment and suffocation. Scenarios of grain engulfment include the most common situation in which a worker is in a bin when the bottom unloading equipment is turned on, pulling grain from under the victim, burying him or her in a matter of seconds. A second scenario is an avalanche of caked grain that suddenly releases from the sides of the bin, burying the operator. A third involves falling through a domed crust or bridge of caked grain that spans a cavity in the grain below. A fourth engulfment scenario is operating a high-capacity grain vacuum and sinking into the void in the grain created as the nozzle removes grain from under foot and surrounding material flows inward.

Manure storage structures may be outdoor lagoons and holding tanks, or deep pits under a CAFO building. In most situations, the manure is pumped out of the storage structure twice a year and spread or knifed into the soil to provide fertilizer for the crop.

Injury Overview

In grain engulfment, the victim is either suffocated with a blocked airway in a matter of minutes or remain alive but are trapped, able to breath, but unable to free themselves. There have been rare instances where an individual has been buried for an hour or more and has survived.

In animal waste storage, toxic hydrogen sulfide and asphyxiating gasses can be hazardous to both the livestock and the people who care for them. Like a carbonated beverage that is shaken, the hydrogen sulfide gas can be rapidly released to acutely toxic concentrations.

Illustrative Scenarios

Grain Engulfment

A 16-year-old boy had the task of moving grain from the 20,000 bushel (700 m^3) grain bin to a smaller holding bin that could more easily be used for grinding daily hog feed. He started the auger but no grain came out. He tried opening and closing the slide door covering the grain well where the unloading auger takes in grain. He also tried starting and stopping the auger, but nothing worked. He assumed that some spoiled grain had blocked the slide door deep within the center of the bin. He shut off the auger and took a 23 ft long (7 m) rod into the top of the bin and poked the rod down through the grain to dislodge the suspected blockage. When this did not work he decided to repeat the process, but with a co-worker on the outside to start the auger run so he could tell if the blockage was freed. After poking the rod down a few more times, the grain suddenly started flowing. The co-worker let the grain run for a few minutes before shutting off the auger. It was too late, the victim in the bin was buried over his head after just a minutes. A local fire rescue service recovered the body some 4 hours later.

Manure pit

John, a 56-year-old producer, raised pigs in a 3800 capacity confinement facility. He was working with his brother and a hired man, and they were nearly finished pumping out the liquid manure from the pit under the building when the hired man dropped a wrench into the pit. Without thinking, he went into the access hole to retrieve it and immediately passed out, falling face first into a few inches of liquid manure. Witnessing the event, and thinking the hired man had had a heart attack, John immediately climbed into the pit to help and was similarly overcome. Minutes later, John's brother came into the area and saw the two men lying in the pit. He called 911, then went in after the men. He became the third victim. All three bodies were retrieved from the pit by fire-rescue responders who used self-contained breathing apparatus (SCBA) respirators.

First on Scene, First Responder, and Transport

First responders and rescuers of flowing grain engulfment victims should use a lifeline that comes from the top center of the bin so that the rope is as near vertical as possible. The rope can either come through the filling port or pass through a pulley at the top center. If the victim is buried as deep as or deeper than their waist, the pressure is too high to pull them out. Pulling the grain away from the person is difficult because it will just flow back into the void from where it was removed. A portable structure or coffer dam needs to be used to surround the victim and keep the grain away. Grain rescue tubes have been developed for this purpose. Made of aluminum or heavy plastic, these portable panels fit together and can be easily assembled inside the grain structure around the victim. Similar devices can be made using sections made from plywood. If the person is completely engulfed they must be removed as quickly as possible. Cutting triangular-shaped flaps on opposing sides of the bin and allowing the grain to flow away from the victim is the most common method of rescuing a person in this situation.

Victims may be unconscious if they have not been able to breathe for 4 minutes or more. A very pale or bluish complexion, especially around the lips, is evidence respiration has stopped. Listen for a heartbeat, feel for a pulse at the neck or wrist, and look for the chest to move. CPR must be started immediately if there is no pulse. Grain or some other obstruction may be blocking the airway if the victim's chest does not rise (61). Look in the oral cavity and remove any grain or obstruction present.

Rescuers in manure storage environments must wear SCBA for their own protection. They also need to wear a lifeline and take a similar lifeline with them to hook onto the victim. Once retrieved from the pit, the patient should be assessed for a pulse and respirations. If there are none, consider CPR and rapid transport.

Emergency and Post-crisis Treatment

Expect an airway that is blocked with grain. Keep in mind that the temperature of the grain can be low enough to induce hypothermia.

In a manure pit scenario, if the victim survives the initial insult they need to medically monitored for up to 72 hours, as hydrogen sulfide (and other irritant gases) can cause acute as well as delayed critical pulmonary edema.

Recovery Care, Management, and Rehabilitation

Recovery and long-term management of a grain-engulfment victim depends on the degree of cerebral damage that might have occurred as a result of anoxia or hypothermia. Severe hydrogen sulfide exposure may cause chronic lung damage. Extended follow-up with a pulmonologist is recommended.

Contributing Factors and Prevention

In the grain engulfment scenario, the small amount of material that was spoiled and plugged the discharge area resulted from a wet harvest and not properly drying the first loads of grain loaded into the bin the previous fall. The big mistake was having the worker outside start the unloading auger running with the other worker still in the bin, the most common primary factor resulting in engulfment (62). The switch to activate the auger should be locked and tagged to prevent auger activation whenever a person is in the bin. Also, when entering a bin a person should wear a safety harness with ropes that can be used to extract a person in an emergency. A ladder fixed to the inside of the bin and used to gain egress would help reduce the risk of engulfment in many situations (63).

Regarding the manure pit incident, hydrogen sulfide is not commonly present unless the manure is agitated. SCBA is the only safe respirator for use in this and other acutely toxic environments. Anybody going into a manure pit (even with SCBA) should wear a safety harness attached to a rope with sufficient personnel and equipment able to extract them in the event of an emergency. This may take at least two people and/or a tripod with a pulley system to gain mechanical advantage.

11.10.8 Other Farmstead Injury Incidents

Descriptive Information

From materials stored unsafely, to structural problems with buildings, to low electrical wires and exposed liquid petroleum gas lines, farmsteads provide a vast array of potential injury situations.

Injury Overview

Injuries can include electric shocks from contact between an overhead electrical power line and a grain auger, long metal ladder, or section of irrigation pipe. Emergency situations and responses are not specific to agriculture, and general procedures should be followed (64, 65). Crushing and pinching injuries result from items falling on an individual. Broken bones occur in slips, trips, and falls from a different level or on the same level. Explosions or fires happen with spilled fuels, improperly stored flammable materials, and inadequate repair procedures.

11.11 Summary

Agriculture is one of the most hazardous of occupations in all Western industrialized countries discussed in this book because of the high rate of fatal and non-fatal injuries. This chapter delves into who, how, why, and prevention of these injuries, which are relatively similar among developed industrialized countries. The chapter is divided into three sections to help accomplish these aims: (1) injury statistics and epidemiological data, (2) rescue and medical treatment considerations, and (3) illustrative injury scenarios. These sections help to provide an understanding of how injuries occur as well as assisting in anticipating medical implications and prevention opportunities.

The human (cultural), environmental, and agent peculiarities in agriculture and the economic factors inherent in production agriculture make injury prevention complex.

Additional risk factors in agriculture (e.g., being young or old) are presented to assist health and safety providers in anticipating and preventing acute injuries, and to prompt to them to recommend preventive accommodations in the workplace and work environment, such as assigning tasks appropriate for the age, physical capabilities, and cognitive faculties of the workers.

Tractors and other machinery together clearly dominate the fatalities, standing out among a variety of other, relatively less important, individual agents. Animals and machinery are roughly equally dominant agents of non-fatal injury. These non-fatal injury events, and the all-too-frequently contaminated, mangled, crushed, multi-part trauma that results, challenge health-care providers serving rural, remote, and frontier communities.

The injury scenarios presented in this chapter provide context to the statistics for those first on the scene, first responders, EMTs, emergency room carers, tertiary carers, and rehabilitation specialists. We aimed to provide a deepened understanding of the uniqueness of acute agricultural injuries, relative to how they occur, treatment basics, complications, and long term outcomes of patients.

The knowledge, judgement, skill, expertise, and transfer of accurate information about the situation to the respective levels of care along this "chain of custody" will ensure the best outcome for the farm injury victim. Understanding this information can help health and safety professionals to have a greater awareness of the circumstances of their agricultural patients, allowing them to provide more useful consultation and participate in prevention programs.

Key Points

1. Occupational injury statistics in all Western industrialized countries indicate that the agricultural industry is one of the most hazardous occupations.
2. Injuries associated with tractor overturns are the most common fatal injuries in the United States, but are less common in northern EU countries, Australia, New Zealand, and Canada, where ROPS are more common on tractors. In Australia ATVs are associated with most fatalities.
3. Reported fatal farm injury rates are approximately 25% higher in the United States compared to other Western industrialized countries.
4. Non-fatal injuries are approximately 50% farm machinery injuries and 50% livestock-related injuries.
5. The following farm characteristics are associated with higher injury risk: (a) large acreage farms, (b) livestock farms, (c) farms with high debt loads, (d) farms with operator residence on the farm.
6. The following are individual personal and health characteristics associated with increased risk: (a) being young (under 20) or older (over 65), (b) history of prior injury, (c) taking prescription medications, (d) history of depression, (e) hearing or vision defects, (f) history of back pain.
7. Acute farm injuries differ and are more complicated compared to other acute occupational or roadway crashes for the following reasons: (a) the extended time required to locate, rescue, and transport the injury victim to an appropriate treatment location, (b) the extensive and massive trauma that may result from agricultural machines, (c) the extensive contamination of open wounds from animal manure, soil, antibiotic-resistant bacteria, motor oil and fuel, and various agricultural chemicals.
8. The best outcome for a victim of an agricultural trauma is if there is excellent knowledge, preparation, and communication between the various links in the chain of responders: first on the scene, fire rescue, EMT, hospital emergency room, secondary/tertiary treatment, and rehabilitation specialists.
9. Medical and rehabilitation specialists need to understand that farmers are likely to want to keep on farming, even after a severe injury, and therefore should attempt to counsel and provide services appropriate to their best long-term physical and mental health.
10. Acute injury events are caused by the nexus of imperfect human behavior, machine function, and animal behavior in an adverse external environment. Studying injury events (scenarios) helps to identify secondary preventive practices.
11. A broader primary prevention strategy depends on a total wellness approach, which includes identification and removal of hazards on the farm, education, and wellness promotion of the principal operator and employers. Details of this approach are given in Chapter 15.

References

1. Acute Trauma (definition). Centers for Disease Control; 2003 (accessed 8 January 2003). Available from: http://www.cdc.gov/niosh/injury/traumadef.html.
2. Takala J. Global estimates of fatal occupational accidents. Epidemiology. 1999;10(5):640–6.
3. Myers J. Injuries Among Farm Workers in the United States, 1993. National Insitute for Occupatioanl Safety and Health; 1997. Available from: http://www.cdc.gov/niosh/97-115.html.
4. Myers J. Injuries Among Farm Workers in the United States, 1994. NIOSH Publication No. 98–153. Cincinnati, OH: National Institute for Occupational

Safety and Health; 1998 (accessed 3 January 2016). Available from: http://search.cdc.gov/search?subset=NIOSH&query=Myers+JR.+%5B1998%5D.+Injuries+among+farmworkers+in+the+United+states+1994%2C+publication+98-153&action=search&utf8=%E2%9C%93&affiliate=cdc-main&sitelimit=www.cdc.gov%2Fniosh+%7C+blogs.cdc.gov%2Fniosh-science-blog%2F&searchButton.x=20&searchButton.y=10.

5. Myers J. Injuries Among Farm Workers in the United States, 1995. NIOSH Publication No. 2001–153. Cincinnati, OH: National Insitute for Occupational Safety and HealthS; 2001 (accessed 3 January 2016). Available from: http://www.cdc.gov/niosh/nioshtic-2/20021610.html.
6. Murphy DJ. Looking beneath the surface of agricultural safety and health. St. Joseph, MI: American Society of Agricultural Engineers; 2003. 103 p.
7. Occupational Injury Surveillance of Production Agriculture (OISPA) Survey for the years 2001, 2004, 2009 and 2012. Atlanta, GA: National Institute for Occupational Safety and Health, Division of Safety Research, Agricultural Safety (updated 15 December 2014; accessed 4 January 2016). Available from http://www.cdc.gov/niosh/topics/aginjury/oispa/default.htm.
8. Eurostat, your Key to European Statistics. European Union Commission; 2014 (accessed 28 January 2015). Available from: http://epp.eurostat.ec.europa.eu/portal/page/portal/health/accidents_work_work_related_health_problems/data/database.
9. Canadian Agricultural Injury Reporting (CAIR): Agricultural Fatalities in Canada, A summary of 19 years of injury data from 1990–2008. Winnepeg, Canada: Canadian Agricultural Injury Surveillance Program, with funding from the Canadian Agrisultural Safety Association; 2012.
10. Agriculture, Forestry and Fishing (occupational injury statistics for 2007–2008). Canberra, Australia: Work Safe Australia; 2011. p. 2 (accessesd 3 January 2016). Available from: www.safeworkaustralia.gov.au/…/Agriculture-Infor.
11. The Burden of Occupational Disease and Injury in New Zealand: Technical Report. Ministry of Business, Innovation and Employment; 2010 (accessed 28 January 2015). Available from: http://www.dol.govt.nz/publications/nohsac/bodi/083_content.asp.
12. Myers JR, Hendricks KJ. Agricultural tractor overturn deaths: Assessment of trends and risk factors. Am J Ind Med. 2010;53(7):662–72.
13. Pope S. Tractor ROPS…rollovers, rebates & retrofits. Brisbane, Queensland, Australia Government, Department of Industrial Relations; 2000.
14. Murphy D. Looking Beneath the Surface of Agicultural Safety and Health. St. Joseph, MI: American Society of Agricultural and Biological Engineers; 2003. 103 p.
15. Brison R, Pickett W. Agricultural Injuries in Canada for 1990–2003. Kingston, Ontario: The Canadian Agricultural Injury Surveillance Program; 2003.
16. Rautiainen R. Injuries and Occupational Diseases in Agriculture in Finland: Cost, Length of Disability, and Preventive Effect of a No-claims Bonus. Iowa City: University of Iowa; 2002.
17. Day L, Voaklander D, Sim M, Wolfe R, Langley J, Dosman J, et al. Risk factors for work related injury among male farmers. Occup Environ Med. 2009; 66(5):312–8.
18. Rautiainen RH, Ledolter J, Donham KJ, Ohsfeldt RL, Zwerling C. Risk factors for serious injury in Finnish agriculture. Am J Ind Med. 2009;52(5):419–28.
19. Sprince N, Zwerling C, Lynch C, Whitten P, Thu K, Logsden-Sackett N, et al. Risk factors for agricultural injury: a case-control analysis of Iowa farmers in the Agricultural Health Study. J Agric Saf Health. 2003 9(1):5–18.
20. McCurdy SA, Carroll DJ. Agricultural injury. Am J Ind Med. 2000;38(4):463–80.
21. Hard DL, Myers JR, Snyder KA, Casini VJ, Morton LL, Cianfrocco R, et al. Identifying work-related fatalities in the agricultural production sector using two national occupational fatality surveillance systems, 1990–1995. J Agric Saf Health. 1999;5(2): 155–69.
22. Xiang H, Stallones L, Chiu Y. Nonfatal agricultural injuries among Colorado older male farmers. J Aging Health Agric Eng Res. 1999;11(1):65–78.
23. Carruth A, Skarke L, Moffett B. Women in agriculture: risk and injury experiences on family farms. J Am Med Womens Assoc. 2001;56(1):15–8.
24. Park H, Sprince N, Whitten P, Brumeister L, Zwerling C. Risk factors for back pain among male farmers: Analysis of Iowa Farm Family Health and Hazard Surveillance Study. Am J Ind Med. 2001;40(6):646–54.
25. Youth agricultural work-related injuries treated in emergency departments – United States, October 1995–September 1997. Morbid Mortal Weekly Report. 1998;47(35):733–7.
26. Karttunen JP, Rautiainen RH. Occupational injury and disease incidence and risk factors in Finnish agriculture based on 5-year insurance records. 2013. J Agromedicine. 2013;18(1):50–64. doi: 10.1080/1059924X.2012.742029.
27. Donham K, Yeggy J, Dague R. Production rates of toxic gases from liquid swine manure: Health implications

for workers and animals in swine buildings. Biol Wastes. 1988;24:161–73.
28. Baker D, Lee R. Responding to Farm Accidents Columbia. University of Missouri Extension; 1995 (updated 4 October 2004; accessed 3 January 2003). Available from: http://extension.missouri.edu/p/G1950.
29. First Aid, CPR and AED Certification. Washington, DC: American Red Cross; 2014 (accessed 4 January 2016). Available from: http://www.redcross.org/take-a-class/program-highlights/cpr-first-aid.
30. First on the scene training module. Agricultural tailgate safety training. Columbus, Ohio: Ohio State University Extension; 2005 (accessed 1 January 2016). Available from: http://ohioline.osu.edu/atts/PDF-English/First-On-Scene.pdf.
31. Schnitz G, Fischer T. Farm Injuries. The Indian Hand Center; 1996 (accessed 3 January 2003). Available from: http://www.indianahandcenter.com/erg_farm.html.
32. Little D. The ABC's of First Aid. Homoeopathic Online Education, A Cyberspace Academy; 1998 (accessed 22 December 2002). Available from: http://www.simillimum.com/FirstAid/TheFirstResponder/Theabc's.html.
33. Standard First Aid safety oriented Modular Course Workbook. 3rd edition. Ottawa: St. John Priory of Canada Properties; 1990.
34. Donham K, Rautiainen R, Lang J, Schneiders S. Injuries and illness costs in the Certified Safe Farm Studies J Rural Health. 23(4): 348–355, 2007.
35. First aid kits for production agriculture. Farm and Ranch eXtension in Safety and Health (FReSH), Community of Practice; 2013 (accessed 4 January 2016). Available from: http://www.extension.org/pages/66377/first-aid-kits-for-production-agriculture.
36. Farmedic Instructors Course. Cortland, New York: McNeil & Company (accessed 4 January 2016). Available from: http://www.mcneilandcompany.com/farmedic/courses/.
37. Hensinger R, Rineberg B, Morrey B, Eilert R, Hogshead H, McCollough N, et al. Rural Rescue and Emergency Care. Worsing R, editor. Rosemont, IL: American Academy of Orthopaedic Surgeons; 1993.
38. Heyman DL (ed.). Control of communicable diseases manual. 20th edition. Washington, DC: American Public Health Association Press; 2014.
39. Tetanus. Vaccines and Immunizations. Atlanta: Center for Disease Control and Prevention; 2012 (updated 7 May 2012; accessed 29 January 2015). Available from: http://www.cdc.gov/vaccines/pubs/pinkbook/tetanus.html.
40. AgriWellness Incorporated home page; 2005 (accessed 4 January 2016). Available from: http://www.agriwellness.org/.
41. National AgrAbility Project, West Lafayette, IN: Purdue University; 2016 (accessed 4 January 2016). Available from: http://www.agrability.org/index.cfm.
42. Kostuik J. Amputations in Farming. Princ Health Saf Agric. 1989;355–6.
43. ATV Safety: Nine steps to stay safe. Federal Chamber of Automotive Industries; 2016 (accessed 4 January 2016). Available from: http://www.atvsafety.com.au/.
44. Friesen R, Ekong E. Spinal Injuries Due to Front-End Bale Loaders. Can Med Assoc J. 1988;138:43–6. Available from: http://www.cdc.gov/nasd/docs/d000301-d000400/d000397/d000397.html.
45. Farm Safety for Just Kids home page; 2012 (accessed 4 January 2016). Available from: http://www.farmsafetyforjustkids.org/.
46. North American Guildelines for Children's Agricultural Tasks. Marshfield, WI: Marshfield Clinic Research Foundation, National Children's Center for Rural Agricultural, Health and Safety; 2016 (accessed 4 January 2016). Available from: http://www.nagcat.org/nagcat/.
47. Tractor Overturns. Society of Teachers of Family Medicine Rural Interest Group; 2003 (accessed 3 January 2003). Available from: http://www.ruralfamilymedicine.org/clinical%20topics/tractor.htm.
48. Tyson B. Rescuing Farm Accident Victims. Athens, GA: University of Georgia College of Agricultural and Environmental Sciences/Cooperative Extension Service; 1994 (accessed 3 January 2003). Available from: http://pubs.caes.uga.edu/caespubs/pubcd/b1103-w.html.
49. Letts RM. Farm machinery accidents in children. In: Dosman JA, Cockcroft DW, editors. Principles of health and safety in agriculture. Boca Raton, FL: CRC Press; 1989. p. 357–61.
50. Kahn M. Spinal cord injuries in agricultural workers. In: Dosman JA, Cockcroft DW, editors. Principles of Health and Safety in Agriculture. Boca Raton, FL: CRC Press; 1998. p. 373–4.
51. Preventing Injuries and Deaths from Skid Steer Loaders. Publication number 98-117. Cincinnati, Ohio: National Institute for Occupational Safety and Health; 1998 (updated 6 June 2014; accessed 4 January 2016). Available from: http://www.cdc.gov/niosh/docs/98-117/.
52. Lycholat T. Traumatic Injuries. BBC Health; 2003 (accessed 2 January 2003). Available from: http://www.bbc.co.uk/health/healthy_living/fitness/injuries_trauma1.shtml.

53. Combine. Rural Family Medicine; 2003 (accessed 10 January 2003). Available from: http://www.ruralfamilymedicine.org/clinical%20topics/combine.htm.
54. PTO Entanglement. Society of Teachers of Family Medicine Rural Interest Group; 2003 (updated 16 January 2003; accessed 14 January 2003). Available from: http://www.ruralfamilymedicine.org/clinical%20topics/pto.htm.
55. What is TBI? Traumatic Brain Injury Resource; 2003 (accessed 2 January 2003). Available from: http://www.traumatic-brain-injury-resource.com/html/whatis.html.
56. Vaughn G. Hand Injuries, High-Pressure. eMedicine; 2003 (updated 7 January 2003; accessed 7 January 2003). Available from: http://www.emedicine.com/emerg/topic226.htm.
57. Mizani M, Weber B. High-pressure injection injury of the hand; The potential for disastrous results. Postgraduate Medicine Online; 2003. Available from: http://www.postgradmed.com/issues/2000/07_00/mizani.htm.
58. Johnston G. High-pressure injection injuries in farmers. Princ Health Saf Agric. 1998:375–6.
59. Augers. Rural Family Medicine; 2003 (accessed 9 January 2003). Available from: http://www.ruralfamilymedicine.org/clinical%20topics/augers.htm.
60. Grandin T. Humane Livestock Handling: Understanding Livestock Behavior and Building Facilities for Healthier Animals. North Adams, Massachusetts: Storey Publishing LLC Books; 2008.
61. Asphyxia: Cessation of Respiration. Homeopathic Online Education American Camp Association; 2002 (accessed 22 December 2002). Available from: http://www.simillimum.com/FirstAid/TheFirstResponder/FirstAidin/Asphyxia.html.
62. Kingman D, Spaulding A, Field W. Predicting the Potential of Engulfment Using an On-farm Grain Storage Hazard Assessment Tool. J Agric Saf Health. 2004;10(4):237–45.
63. Grain Bin Safety, Safey precautions. Urbana, Illinois: University of Illinois Extension; 2016 (accessed 4 January 2016). Available from: http://web.extension.illinois.edu/agsafety/equipment/grainbinsafety.cfm.
64. Edlich R, Farinholt H. Electrical Burns. eMedicine; 2002 (updated 18 November 2004; accessed 3 January 2003). Available from: http://www.emedicine.com/plastic/topic491.htm.
65. Chasmar L. Electrical Burns in Farmers. Princ Health Saf Agric. 1998:377–8.

CHAPTER

12

Veterinary Pharmaceuticals: Potential Occupational and Community Health Hazards

Kelley J. Donham

Reviewer: Jeffrey Bender

12.1 Introduction

Over 5000 pharmaceuticals are licensed for use in livestock production or veterinary medicine in the United States. These pharmaceuticals include antibiotics, immunizing products (biologicals), and a broad array of therapeutics, tranquilizers, analgesics, and anesthetics (1–3). They are used for the treatment or prevention of disease, to promote growth, for restraint, to relieve pain, or to induce anesthesia for surgery (4). A number of these agents are potential occupational or community health hazards by direct exposure through unintended needle sticks, contact with skin or mucous membrane, or indirect exposure through the air, water, or food (5). This chapter will review these potentially hazardous pharmaceuticals, describe the nature of the potential harm and treatment, and, most importantly, promote safe use and prevent harm.

12.2 Background and Overview

The modern age of pharmaceutical use in livestock production began (in the United States) in the late 1940s following the discovery of penicillin, and the development of vaccines and antisera to be used in the national swine cholera eradication program. Skin contact or aerosol exposure to antibiotics may occur, as they are often mixed into the animal's drinking water or feed for disease treatment or prevention, or for growth promotion. Antibiotics and other pharmaceuticals also may be administered by a hypodermic needle or by high-pressure needleless injection. When administering injections to a large number of animals, there are multiple opportunities for unintended needle sticks to the handler or assistant.

There are similarities between the regulations concerning pharmaceuticals for human use and

Agricultural Medicine: Rural Occupational and Environmental Health, Safety, and Prevention, Second Edition.
Kelley J. Donham and Anders Thelin.

veterinary pharmaceuticals in that the federal agencies require testing and licensing to assure the product is effective, and will not cause human or animal health or environmental concerns. The US Federal Food and Drug Administration (FDA) is responsible for assuring the efficacy and safety of all licensed drugs and biologicals for human use. The FDA and the US Department of Agriculture (USDA), Animal, Plant Health, Inspection Service (APHIS) work in tandem to ensure licensed veterinary pharmaceuticals for livestock and pets are effective, and will not cause undue harm to humans, animals, or the environment. The sometimes confusing jurisdiction is laid out in a memorandum of agreement between the two agencies (6). The basic agreement is that the USDA APHIS approves and regulates veterinary biologics (immunization) products (7) and the FDA is responsible for ensuring the efficacy and safety of all licensed veterinary drugs other than biologicals for use in animals, and for ensuring such products do not end up as health hazards in food products (8). There are comparable agencies in other industrialized countries.

There is one important difference between pharmaceuticals for human use and veterinary pharmaceuticals. Most pharmaceuticals for use in human medicine require a prescription from a licensed physician, while most veterinary pharmaceuticals do not (although there is variability in this policy among the developed countries). Veterinary pharmaceuticals are widely available to livestock producers through various sources, including farm supply stores, the internet, foreign markets, and service agents from the livestock integrating companies that contract their livestock production with private growers. This policy results in the use of many products under little or no professional control, increasing the risk for potentially harmful drugs to be inappropriately used. However, some drugs are not approved for use in food animals or must be administered or prescribed by a veterinarian (veterinary prescription only), and thus by regulation are not available over the counter. For example, the antibiotic chloramphenicol cannot be used in food animals because of concerns about human health risks, and brucellosis and rabies vaccines are to be administered only by a licensed veterinarian. The former is an example of a USDA regulated product and is part of a government disease-control program managed in the field by licensed veterinarians. Rabies vaccination of dogs and cats is required by most municipal jurisdictions.

The FDA licenses products as approved for specific purposes (e.g., antibiotic x for use as a subcutaneous injection in cattle for respiratory infections). Producers and veterinarians violating these regulations can be charged and fined or have their license removed. Furthermore, veterinarians cannot to use products “off label,” or “extra label,” that is, they cannot be used beyond the use listed on the FDA or USDA approved package label. Currently, in the United States there are pending regulations that will require greater supervision of antibiotics used in livestock. (Details of these regulations are discussed in more detail later in this chapter).

The EU strictly regulates veterinary pharmaceuticals that may pose public health or environmental hazards (9). The EU has adopted the “precautionary principle,” which (relative to the United States) is a conservative approach to protecting the public from suspected risks in the absence of scientific consensus. There are therefore more restrictions on the use of veterinary pharmaceuticals and growth enhancers in the EU. This also applies to animal food products from countries that allow for the use of certain growth-promoting pharmaceuticals.

As previously mentioned, many animal pharmaceutical products are readily available to the lay person. This may surprise human healthcare professionals, as some of these products are harmful if a person is unintentionally exposed. In addition to the risk of unintended exposures to veterinary pharmaceuticals, there is evidence of intentional usage of these products by livestock handlers for self-treatment (particularly antibiotics and pain medications) (10). There is also evidence that veterinary and human therapeutic agents excreted in fecal material applied to land may run off into surface waters and support the development of antibiotic-resistant bacteria (11, 12). Also, some veterinary products (e.g., psychotropic drugs and anabolic steroids) may be found in illicit human drug markets.

The intent of this chapter is to review several classes of pharmaceuticals and specific pharmaceuticals that may cause harm to humans who are unintentionally exposed through occupational, environmental, or intentional exposures. The population at risk to these exposures includes livestock producers, farm workers, veterinarians and veterinary assistants, and those who seek illicit use for themselves or others. The FDA Center for Veterinary Medicine (13) maintains a voluntary surveillance system on adverse drug reactions from veterinary pharmaceuticals in both animals and exposed humans. Other countries have analogous systems, for example the Veterinary Medicine Directorate in the UK (14–16). As these systems depend on voluntary reporting, any health professional, safety professional, veterinarian, or producer should report adverse incidents they encounter. This is important for prevention, as identified hazardous products can be quickly withdrawn if identified. Instructions for reporting to the FDA are found on the FDA website (13).

12.3 Veterinary Biologicals

12.3.1 Introduction and Overview

Biologicals are products developed from biological process (in vivo or in vitro) for the purpose of enhancing the immunity of animals to infectious diseases. There are several categories of biologicals, and it is important to understand the differences in their potential health hazards for humans.

Antisera

Antisera are products containing antibodies harvested and refined by in vitro processes such as a monoclonal antibody production. Unintentional injections with these products are a low health risk, but may cause local inflammation (e.g., foreign protein reaction). There are no other anticipated problems except for trauma from the needle stick or potential introduction of infectious agents into the skin or subcutaneous tissues.

Bacterins

The USDA definition (which we apply in this discussion) of a bacterin is a product made from killed bacteria (17). (Note that medical dictionaries define it as a killed or live modified bacteria product.) These products are designed to afford active immunity and usually include substances to enhance their immunogenicity (adjuvants).

Vaccines

A vaccine is a product of live bacterial or live or killed viral origin, developed to afford active immunity (USDA definition) (17). The living agents are altered to reduce virulence (attenuated) for the intended vaccinated species.

Adjuvants

Adjuvants are products that are incorporated with bacterins or vaccines to enhance the immunogenicity of the product. Adjuvants include products such as mineral oils, components of *Mycobacterium* organisms, and aluminum salts among other products. Adjuvants work by increasing the local inflammatory process, delaying the adsorption of the active agent from the site of inoculation and thereby stimulating the immune system over a longer period of time.

Toxoids

Toxoids are inactivated toxins (e.g., tetanus toxoid) that create active immunity.

Antitoxins

Antitoxins are products produced as described above for antisera. Antitoxins (e.g., tetanus antitoxin) produce passive immunity. Accidental inoculations with these products create a low-risk health problem. Local inflammation, trauma, and infection from a needle stick are possible.

12.3.2 Needle-stick Exposure Risks

Presented with a patient who has unintentionally stuck him- or herself with an animal immunizing product, the health provider should ascertain the type of offending agent. Knowledge of the type of product (according to the definitions above) will assist the provider in understanding the probable pathophysiology of the injury, making informed treatment decisions, and providing a probable prognosis. Important facts to remember are (1) any needle stick may cause an infection because the needle and skin are both likely to be contaminated, (2) inoculation with antisera or bacterin will not cause an infection from the product itself, but can cause an allergic reaction or inflammation (especially if the bacterin has a mineral oil and or *Mycobacterial* adjuvant), and (3) inoculation with a vaccine may cause an infection in the unintended host because it may contain live attenuated organisms (which may be infectious for humans (see Table 12.1) (18, 19). Inoculation with a toxoid or antitoxin will not cause an infection from the product itself, but may cause localized inflammation. The following sections provide more detailed information on needle-stick hazards.

Unintended exposure to needle sticks is one of several ways an individual may be exposed to a veterinary pharmaceutical. Unintended needle sticks are common in livestock producers, their employees, and veterinary personnel (12, 20–29). One surveillance report indicated that up to 80% of livestock producers and veterinarians or their assistants were unintentionally stuck the previous year (30). Unintended needle sticks may cause injury in one or more of the following ways:

1. *Infection from a contaminated needle.* Rarely are needles new or sterilized between livestock inoculations when treating many animals on the same day in a given herd, therefore these needles are likely to be contaminated with potentially infectious organisms from feces, skin surfaces, or other environmental sources. Although needle-site infections are seldom seen in the animals from this practice, such needle contamination may be likely to cause concern in an unintended human needle stick. Furthermore, these needles are usually large bore (e.g., 14–16 gauge), dull, and barbed. They can create a more severe traumatic injury when entering and withdrawing from the injection site compared to the smaller bore (e.g., 23–25 gauge) single-use needles commonly used in human medicine.
2. *Infection from an immunizing product injected into an unintended recipient.* Some vaccines contain organisms that may be attenuated (not infectious) for the target species, but not attenuated for the unintended host. Several such products (see Table 12.1) are infectious for humans (28).
3. *Inflammation (or other adverse effects) from the product injected into the accidental host.* Many veterinary vaccines may not be infectious, but the adjuvants within the product may be highly inflammatory, for example mineral oil alone or in combination with mycobacterial cell products (e.g., Freund's adjuvant). These substances are commonly used in bacterins for veterinary purposes and may be highly inflammatory when injected into a person (16, 26, 28–30). Freud's is not allowed in products for humans because of its necrotizing effect on subcutaneous and muscle tissue. In addition to biologicals, several additional veterinary products, such as hormones, sedatives, anesthetics, and antibiotics, may be accidentally injected into workers, causing severe reactions. These are discussed in later sections of this chapter.
4. *A hyperimmune reaction to a product for which the accidental host has been previously exposed.* In the event that a patient had previously developed an immune response to an infectious agent, then if subsequently injected with a biological for that agent, that person may develop a local allergic or systemic response to that product (31).

12.3.3 Symptoms, Clinical Signs, and Pathogenesis of Unintended Exposures to Animal Biologicals

This section describes various biologicals and how they are used by the health or safety provider to ascertain an accurate history of potential hazardous needle sticks. Brucellosis is an economically important infectious disease of cattle, sheep, goats, and pigs worldwide. Cattle brucellosis eradication programs are based largely on vaccination of female brood stock before pregnancy at 4–12 months of age. RB51 brucellosis vaccine replaced the former strain 19 in 1996, which was much more pathogenic in humans, causing numerous cases of brucellosis in veterinarians and occasional localized hyperimmune responses (31). Although RB51 is less pathogenic for humans, several cases of localized and systemic infections have been reported in veterinarians (32). Exposures occur from needle sticks, skin and mucous membrane contact with the vaccine, or direct contact with placental or fetal tissues from a pregnant cow infected with the RB51 vaccine strain (32).

In addition to brucellosis vaccine, contagious ecthyma, New Castle virus, and erysipelas vaccines can produce clinical infections in humans (14–16, 28). None of these diseases are required to be administered by a veterinarian, so infections may be present in producers and livestock workers. Contagious ecthyma vaccine for sheep and goats can cause a localized skin infection very similar to an actual field-acquired infection. Newcastle vaccine is administered via the aerosol route or in water to poultry flocks. If a person is not properly protected while handling or administering the vaccine, they may develop severe conjunctivitis and systemic influenza-like symptoms (20). Contagious ecthyma and Newcastle vaccine infections are self-limiting illnesses. There is no specific treatment and complete recovery usually occurs over a course of 2–3 weeks.

Erysipelas is a bacterial disease primarily of swine (caused by *Erysipelas rhusiopathiae*). Although most of the available immunizing products for erysipelas are bacterins (and therefore will not cause infections) a few are live vaccines and many cause an infection from an unintended needle stick. They may cause a localized and systemic disease similar to field-acquired erysipeloid (*E. rhusiopathiae* infection in humans). Treatment with macrolide antibiotics would be appropriate.

In addition to infection from the live agent within the biological, injuries from inflammation of the adjuvant in the product and/or infections from a contaminated needle are common. Johne's disease bacterin causes a particularly severe inflammatory reaction when accidentally inoculated (22). This product can only be administered by a licensed veterinarian. Johne's disease of cattle and sheep is a mycobacterium infection that produces a disease very similar to Crohn's disease in humans. The Johne's disease vaccine for sheep (Gudair vaccine) is used in Australia and New Zealand. Unintentional inoculation of sheep producers with the Gudair vaccine has resulted in several cases of severe inflammation and necrosis of subcutaneous and muscle tissues locally and peripherally as the vaccine material migrates along muscle bundles and tendon sheaths (26, 29). Inoculation in the hand has resulted in swelling and impingement of the blood and nerve supply to local tissues and digits, requiring amputations of digits.

The main hazardous substance in Johne's bacterin is the adjuvant, which is a mineral oil, combined with the killed agent (*Mycobacterium avium* subspecies paratuberculosis), which creates the tissue inflammation and necrosis.

E. coli bacterins also cause local tissue inflammation. Treatment of these agents should focus on the inflammatory response and potential infection from a contaminated needle. Only rarely do *E. coli* bacterins cause an entrapment syndrome such as observed with Johne's vaccines.

12.3.4 Treatment of Humans Exposed to Biologicals

Proper treatment depends on the collection of a thorough patient history and details about the exposed product. For patients exposed to RB51 brucellosis vaccine, the recommended treatment is 100 mg of doxycycline twice daily for at least 3 weeks (33). Additional treatment must be considered if the patient develops a hyperimmune response to the vaccine, which may include steroidal anti-inflammatories and osmotic diuresis to relieve swelling that might threaten restriction of the circulation or nerve supply to vulnerable body parts (e.g., the hand).

For needle sticks with biologicals that primarily cause local inflammation, first-aid treatment should include pressure below and upward to the site of inoculation, attempting to express some of the inoculum to the surface. Thorough cleaning of the wound with soap and water should follow. Consultation of the package insert or material safety data sheet (MSDS) should direct follow-up treatment. In absence of that information, careful supervision of the wound should occur to watch for clinical changes. If pain and inflammation should continue for some time following the injection (especially if the injection is in the hand) medical treatment is recommended. Ideally the patient should take the package label or MSDS sheet to the healthcare provider.

Medical interventions may include surgical drainage, irrigation, and debridement of the region of inoculation. Injection to the hand may be a medical emergency requiring a hand surgeon. There is the potential for loss of tissue and digits if not evaluated and treated in a timely manner. Surgical opening and debridement with aseptic bandaging and delayed closure until inflammation and infection appears controlled may be necessary. Coverage with a broad-spectrum antibiotic not generally used in livestock (e.g., vancomycin, linezolid, or dalbavancin) may be necessary for infected wounds.

This author (KJD) has investigated several cases of needle sticks involving the flexor tendon sheath of the index finger, which required surgical drainage to relieve compartmentalization. Jennissen, Wallace, Donham, and co-workers investigated nine cases of needle sticks injuries with livestock biologicals hospitalized at the University of Iowa (30). These cases typically resulted in inoculation of the non-dominant hand while attempting animal vaccinations. However, one case involved inoculation of the extensor muscles of the thigh, requiring surgical debridement, and one case involved a fungal osteomyelitis. A killed vaccine of circovirus and mycoplasma combination for swine was a common source of the injury in the non-reported and published cases reviewed above.

12.4 Antibiotics

12.4.1 Introduction and Overview

Antibiotics are used extensively in livestock and poultry production to treat sick animals, prevent infections in herds and flocks, and enhance the rate of growth and efficient utilization of feed. FDA approves certain antibiotics for use in food producing animals that are not essential to treatment of humans. Those antibiotics are listed in Table 12.1. Potential adverse occupational health effects in livestock producers from antibiotic exposures include direct toxicity of the antibiotic, allergenic reactions, and antibiotic-resistant infections. Community health concerns are focused on the relationship to the evolution of antibiotic-resistant infections in humans. The latter issue has created a longstanding and high-level public debate over if and how antibiotics should be used in livestock production. The following paragraphs will discuss these issues.

In recent years, there has been a heightened concern about the increase in antibiotic-resistant infections in both human and animal populations. The use of antibiotics in human medicine, veterinary medicine, and agricultural production has been heavily scrutinized since the 1990s (1, 34–39). The majority of antibiotics sold in the United States and Europe are used in food animals (50). Furthermore, a significant portion of the antibiotics used in US livestock production are used as sub-therapeutic feed additives for growth promotion rather than for disease treatment (51). These facts have fueled an extensive debate on the risk versus benefit of their use in livestock production (11, 12, 36, 40–58). Since the late 1960s there has been concern about environmental and public health hazards related to the use of antibiotics and the possible relationship to the world-wide development of antibiotic-resistant infections (59–63).

Although antibiotics have been used in livestock production for disease treatment since the 1940s, it was not until the early 1960s that antibiotics began

Table 12.1 Antibiotics approved for use in food-producing animals marketed in 2011: classification and sales (18)

Antimicrobial classification	Sales (kg)[b]
Tetracyclines[a]	5,652,855
Chlortetracycline	
Ionophores	4,122,397
Laidlomycin, lasalocid, monensin, narasin, salinomycin	
Pencillins[1]	885,304
Amoxicillin, ampicillin, cloxacillin, penicillin	
Macrolides[1]	528,836
Erythromycin, gamithromycin, tilmicosin, tulathromycin, tylosin	
Sulfas[1]	383,105
Sulfadimethoxine, sulfamerazine, sulfamethazine, sulfaquinoxaline	
Aminoglycosides	214,895
Dihydrostreptomycin, gentamicin, neomycin, spectinomycin, streptomycin	
Lincosamides[1]	190,101
Lincomycin, pirlimycin	
Cephalosporins[1]	26,611
Ceftiofur, cephapirin	
Amphenicols	ND
Florfenicol	
Diaminopyrimidines	ND
Ormetoprim	
Fluoroquinolones	ND
Danofloxacin, enrofloxacin	
Glycolipids	ND
Bambermycins	
Pleuromutilins	ND
Tiamulin	
Polypeptides	ND
Bacitracin	
Quinoxalines	ND
Carbadox	
Streptogramins	ND
Virginiamycin	
Aminocoumarins	ND
Novobiocin	

[a] Includes antimicrobial drug applications that are approved and labeled for use in both food-producing animals (e.g., cattle and swine) and non-food-producing animals (e.g., dogs and cats).
[b] kg = kilogram of active ingredient. Antimicrobials sales that were reported in international units (IU) (e.g., penicillins) were converted to kilograms. Antimicrobial class includes drugs of different molecular weights, with some drugs reported in different salt forms.
ND, no data available.

being added to animal feeds for growth promotion (40). This came about following research by animal scientists who discovered that low-level feeding of antibiotics to cattle, swine, and chickens not only increased their growth rate by 3–5%, but also made them gain weight while consuming less feed (increased feed efficiency), and egg production was improved (39, 64). A more recent study suggested that the gain is between 1% and 2% (54). (The variance likely depends on the particular strain of animal and antibiotics also appear to be more beneficial in low-hygiene farms). The sub-therapeutic use of antibiotics has declined or been banned in most EU countries, with declining use in the

United States and Canada. The current percentage of farm animals fed antibiotics in the United States is not known, but a 1999 national survey revealed that about 65% of young pigs (weaners and growers) and 47% of finishers were fed sub-therapeutic concentrations of antibiotics in feed (65). Chickens and veal calves have also been commonly fed antibiotics throughout a significant portion of their life cycle (66). There is less evidence for use of low-level antibiotics for disease prevention except for certain diseases (e.g., organic arsenicals and carbadox for bloody scours in pigs, and sulfa drugs for prevention of coccidiosis in poultry (67)).

How sub-therapeutic antibiotics work is not entirely clear, but there are several theories: (1) they have a direct effect on the metabolism of the animals by increasing the levels of insulin-like growth factor, (2) they bring about a change in the gastrointestinal flora that decreases bacterial competition for nutrients, enhancing the digestive processes (51), and (3) they bring about a reduction in pathogens that might be sub-clinically affecting the general health status of the animal (42, 68). Several studies have been conducted in the United States on the economic value of feeding sub-therapeutic antibiotics for growth promotion. Van Lunen (68) reported an economic advantage of $3.77 (in 2015 dollars; 69) per pig in feed and housing costs. Brorsen and colleagues (70) calculated an economic value for total US pork and poultry production of $798 million (in 2015 dollars; 69). These authors' models predict that consumers would pay the majority of the increased cost of production if antibiotics were not used. Other studies have shown a negative economic outcome of 93 cents lost per bird when feeding sub-therapeutic antibiotics (71). Of course these prediction models vary as to the parameters included in the algorithm. More definitive studies with a lifecycle analysis and rigorously defined variables need to be designed to give a more accurate economic benefit model.

Some scientists, some livestock producers, and some of the general public believe that antibiotics are necessary to produce livestock in the confined, intensive production systems that have emerged in Western agriculture since the 1970s. Others claim that focusing on excellent livestock management and sanitation will achieve the same gains in production without antibiotics (34, 44, 48). From a food safety perspective, Hurd (72) suggests that antibiotics are important in swine production to decrease the risk of zoonotic bacteria in the end product at the meat counter.

Besides livestock and poultry production there are other uses for antibiotics in agriculture, including orchard and horticultural plant production. For example, in orchards, aminoglycosides (e.g., streptomycin) are sprayed on some fruit crops to reduce the surface microbial growth (46). In ethanol fermentation of corn and other plants, antibiotics are used to counteract bacterial "infections" in processing, which can degrade the efficiency of production by up to 5% (73). The following antibiotics are commonly used in the ethanol fermentation process: macrolids (e.g., erythromycin, tylosin), aminioglylcosides (e.g., Virginiamycin, streptomycin), beta-lactams (e.g., penicillin), and tetracyclines. An additional concern is that antibiotics are showing up (over 50% in a 2008 FDA survey) in the animal feed byproducts of ethanol production (dried distillers' grain and solubles (DDGS)). These products are a valuable byproduct of ethanol production and account for about 20% of the industry revenue. DDGS is commonly incorporated in 10–20% of the feed rations for monogastric animals (e.g., pigs, poultry, and fish) and 10–40% of ruminant rations (e.g., beef and dairy cattle).

The amount of antibiotics used in these non-livestock processes is not known as the antibiotics are not acquired from "trackable" sources. The amounts may be much less than in livestock production. However, if the prudent policy is to reduce the overall use of antibiotics to help limit the promotion of antibiotic-resistant bacteria, perhaps these non-livestock production uses should be considered as part of a reduction strategy.

12.4.2 Occupational Health Exposure Risks

Acute Toxic Reactions

Although antibiotics as a class of drugs are generally not associated with acute toxicity, there is one notable exception. Tilmicosin is a macrolide antibiotic for use in cattle for respiratory infections. It is particularly effective for Gram-positive organisms and some Gram-negative organisms. However, in many monogastric animals (including humans) tilmicosin is a potentially lethal cardiotoxic drug (21, 74, 75). Children as well as adults have been adversely exposed (21). A 2006 (74) publication reported on 3168 exposure cases which occurred from 1992 to 2005. Sixty per cent of exposures were from needle sticks; the remaining were skin, eye, or mucous membrane exposures. Adverse symptoms were seen in 44% of those exposed. Most cases were from external tissue contact or sub-lethal dose injections. The primary symptoms included eye pain, burning sensation of the mouth, bad taste, pain and swelling at the site of injection, and abnormal electrocardiogram. Most of these patients fully recovered with standard wound care (74). However, severe health consequences have resulted from needle injections of greater than 0.5 mL (150 mg) tilmicosin. One hundred and fifty-eight (5%) of the 3168 cases reported by Veenhuizen were severely affected, resulting in 13 (18%) fatalities (74). Injections of 2–5 mL of Tilmicosin 300 mg/mL or greater than 600 mg may result in severe to fatal reactions, as exemplified by the following illustrative case.

Case Report

A Nebraska dairy farmer was carrying a syringe filled with tilmicosin 300 mg/mL in his pocket, the contents of which he was planning to inject into a cow with suspected pneumonia. He was kicked by another cow, driving the needle and the contents of the syringe into his inner thigh. He became dizzy and experienced chest pain and an accelerated heart rate. He was transported to a local hospital, where he died about an hour after the incident (75).

Tilmicosin is a potent calcium channel blocker that prevents calcium from entering the heart muscle cells, reducing muscle contractility and cardiac output, and leading to death from cardiac failure.

The treatment considerations for tilmicosin exposure have been recommended by several authors (74, 76, 77). Tilmicosin skin exposure can be treated by washing the exposed area with soap and water. For eye exposure, flush with an isotonic eye wash (if available) or just clean water. For injections, the primary first-aid treatment is to expel any injected material as quickly as possible by expression below and upward of the entry point of the needle. The second aim of emergency treatment is to slow the circulation from the affected area, reducing the potential for a toxic concentration to reach the cardiac muscle. If the injection site is a limb, this may be accomplished by applying a tourniquet between the injection site and the heart, and packing the affected area or limb in ice. Simultaneously, the nearest emergency room should be contacted and advised of the incident and agent, and the patient transported there as soon as possible. (There is about 15 minutes from the time of injection of a systemic toxic dose until severe symptoms begin.) Although there is no specific antidote for tilmicosin toxicity, dog studies suggest the following may have a positive effect: (1) IV calcium in the form of calcium gluconate or calcium chloride, (2) IV sympathomimetic drugs, for example dobutamine or dopamine, (3) supportive care, for example balanced electrolyte IV fluid therapy for hypotension, (4) avoid beta-adrenergic drugs, for example propranolol or epinephrine, as they seem to exacerbate the adverse cardiac event (76). Emergency numbers to call include:

1. Poison Control Center 1-800-222-1222 (United States)
2. Elanco 1-800-722-0987 (manufacturer of Micotil) (international).

Occupational Allergic Reactions to Antibiotics

Some of the common antibiotics used as growth promotors (or for treatment) in animal feeds include penicillin, tetracycline, sulfamethazine, and virginiamycin (a more detailed list is given in Table 12.2) (19, 36, 39). Of these, penicillin is the most commonly recognized antibiotic sensitizer, resulting in both dermal (78) and asthmatic symptoms. Dermal as well as respiratory exposure can occur when grinding, mixing, and handling feed that contains antibiotics. Aerosols of feed are produced during the mixing and grinding process and whenever the concentrates are handled or moved. Inhalation exposure can occur at any phase in the various processes of preparation, transportation, or feeding. Occupational exposures may occur at grain elevators and feed manufacturers or on the farm. Cases of allergic dermatitis and asthma or other systemic responses to antibiotic exposure are rare, but pose a real risk for a small percentage of the exposed population.

12.4.3 Antibiotic-resistant Organisms

Overview

In the late 1960s, a young farm girl in England became ill with a severe *Salmonella* gastrointestinal infection with systemic symptoms (37). Her physicians were hampered in their treatment because they could not find an antibiotic that was effective against the organism, and the little girl died. Public health officials then traced the origins of the infecting bacterium back to veal calves on the farm where she lived. Antibiotics had been extensively used in these calves and they were harboring resistant *Salmonella*, probably the same organism that caused the girl's death.

This case was highly publicized, creating a national concern that resulted in the appointment of a special commission to study the situation. That report (the Swan Commission Report) led to a progressive and evolving concern and policy discussions over the past four decades regarding the relationship of antibiotic use in farm animals with resistant infections in humans (79). The focus of that concern has been the sub-therapeutic use of antibiotics as growth promotors.

Several studies have shown that animals fed antibiotics (on farms where none had been previously used) rapidly developed resistant gut flora (80). Furthermore, producers and animal handlers in contact with these animals rapidly developed a similar gut flora and resistance pattern (80–82). The antibiotics used in livestock and humans, and their methods of use are given in Tables 12.2. The use of certain antibiotics has been shown to increase the degree of shedding of resistant organisms in the feces (83). This is thought to be caused by antibiotics reducing the population of susceptible organisms in the gut, thus reducing the competition for the resistant organisms, allowing them to multiply with less impedance (80).

The development and transfer of antibiotic resistance among microorganisms is well described and develops in one of several ways 12, 39, 44, 52, 53, 58:

1. A spontaneous mutation may occur that affords the organism antibiotic resistance.
2. Free fragments of genetic material or extra nuclear genetic material capable of reproduction on its own (plasmid) may be taken up from other disrupted cells and will transfer resistance to that cell.
3. A type of virus that infects bacterial cells (phage) that contains resistant genetic material may inject that material into a bacterial cell, giving it resistance.
4. A bacterium with a resistant plasmid may make direct contact with another bacterium (conjugate), transferring resistance.

In each of these cases, these new resistant organisms may multiply by binary fission, passing on resistance to succeeding generations. The source of the resistant genetic material may be non-pathogen, but the recipient may be a pathogen, therefore non-pathogens with resistant genetic material can serve as reservoirs of resistant genetic material for pathogens, resulting in new

Table 12.2 Antibiotics used in livestock production and human health (19)

Antibiotic class	Animal species	Used for treatment	Used for prevention	Used for growth promotion	All antibiotics used in livestock (%)	Human use	Bacterial resistance
Aminoglycosides (gentamycin, neomycin, streptomycin)	Cattle, poultry, sheep, swine	Yes	Yes	No	1.5	Yes	Yes
Beta-lactams (penicillins (amoxicillin and ampicillin), cephalsporins (third generation)	Cattle, poultry, sheep, swine	Yes	Yes	Yes No	6.2	Yes	Yes
Ionophores	Cattle, poultry, sheep	No	Yes	Yes	30	No	Yes
Macrolides (erythromycin, tilmicosin, tylosin)	Cattle, poultry, swine	Yes	Yes	Yes	4.3	Yes	Yes
Polypeptides (bacitracin)	Poultry, swine	Yes	Yes	Yes		Yes	Yes
Fluoroquinolones (enrofloxacin)	Cattle, poultry	Yes	Yes	No	0.1	Yes	Yes
Sulfonamides	Cattle, poultry, swine	Yes	No	Yes	2.7	Yes	Yes
Tetracyclines	Cattle, poultry, sheep, swine	Yes	Yes	Yes	41	Yes	Yes
Lincosamids	Swine Poultry	Yes	Yes	Yes	1.4	Yes	Yes

FDA reports

generations of disease-causing bacteria. These described mechanisms are well documented and explain the increasing reservoir of antibiotic-resistant genetic material and resistant organisms in the environment, and thus the greater potential for resistant infections in the human and animal populations.

The prevailing theory for the increasing number of resistant organisms is that the antibiotic usage (human, animal, non-animal agriculture) is producing selection pressure favoring organisms that developed resistance by one or more of the mechanisms described above. Use of sub-therapeutic feeding of antibiotics is thought to enhance the selection pressure.

Occupational Health Risks

Evidence suggests that farm workers, especially those around livestock, poultry, or fruit crop production, may be at greater risk of antibiotic-resistant infections relative to the general population (80, 81). Although there is insufficient research data to quantify this risk, healthcare professionals should always consider the possibility of resistant infections in their differential diagnoses when caring for livestock producers and consider relevant treatment options.

Another risk, in addition to direct contact with resistant bacteria, is delayed contact. One example of delayed contact is that of a patient who reported to her physician for a skin wound infection. The patient was put on a course of antibiotics for the skin infection, and within a few days developed a severe and highly resistant gastrointestinal infection. The resistant organism was traced to its likely origin in the animals on the patient's farm. Prior to treatment, the patient likely already had the resistant gut pathogens, but they were held at sub-clinical level by competition with other gut flora. However, administration of antibiotics for the skin infection reduced competition from the non-resistant organisms, giving the resistant organisms a competitive advantage to multiply, resulting in clinical enteritis. It is difficult to know how commonly this scenario occurs, but this may be one of the most important occupational or community health risks associated with the use of antibiotics in livestock and humans. Bartlett (84) reported in the *New England Journal of Medicine* that such inadvertent antibiotic-induced gastrointestinal infections occur 5–20% of the time with beta-lactam (e.g., penicillin) antibiotics and 2–5% of the time with other classes of antibiotics.

Public and Community Health

As mentioned above, the observed increasing presence of resistant infections in humans by our medical and public health communities is theorized to be driven by increasing ecologic pressure from the overuse and inappropriate use of antibiotics by the medical and veterinary professions, livestock producers, orchardists, and biofuel ethanol producers. Less than best practices from these sources include unnecessary and overuse, use of the wrong antibiotic or the wrong route of administration, insufficient dose, and insufficient time of use. The practice of long-term sub-therapeutic-level feeding of antibiotics to livestock is thought to be an important enhancing practice for resistant bacteria, as susceptible bacteria are not killed, leaving them to develop resistance and then proliferate (85). The reservoirs for resistant organisms and related genetic material are the gut and nasopharynx flora of humans and animals, healthcare facilities, drinking water, the air, and some of the animal food products we eat (47, 86–88).

12.4.4 How do Resistant Organisms Disseminate Among the Human Population?

Resistant organisms can come into the home through contaminated meat, milk, eggs, vegetables, and fruits (88). The FDA and the USDA, many livestock producers, veterinarians, and animal food processors team up to guard against food contamination. However, a small risk remains that meat, eggs, and milk may be contaminated with resistant organisms that are present at the time of purchase at the grocery store. Improper cooking, food storage, and unsanitary maintenance of the food preparation area, utensils, and the preparer's hands create exposure potential for household members. Contaminated water is another potential source of exposure to resistant organisms from livestock origin (89, 90). Runoff of manure from livestock operations into surface and ground waters (87, 91) (suggesting a drinking water hazard) and in the exhaust air from swine confinement buildings (suggesting a risk of aerosol exposure) (92, 93) also creates an additional risk of exposure of resistant organisms to the community.

12.4.5 Treatment of Antibiotic-resistant Infections in Farm Patients

Resistant infections may present in one of several forms, including gastrointestinal infection, wound infections, and urinary bladder infections. Culture and sensitivity prior to initiating antibiotic therapy may be especially important when treating farm patients relative to the general population. Treatment should be guided by the results of susceptibility tests in addition to consideration of an antibiotic class not generally used on the patient's farm. Table 12.2 lists antibiotic classes used in both animals and humans and their applications (19). Furthermore, one should consider that treatment of a farm patient with a urinary bladder infection (especially a patient who has had a urethral catheter) may encounter a resistant organism from the person's own intestinal flora. Finally, the healthcare provider should be alert to the fact that treating a farm patient with a broad-spectrum antibiotic for any infection may allow a resistant pathogen to overgrow in the gut flora and become clinically significant.

Health Effects Summary

As stated earlier, it is very difficult to quantify the presence of antibiotic-resistant infections in humans as a result of antibiotic use in livestock or the human community. There are scattered case reports of livestock producers acquiring a resistant infection directly from a farm animal or the environment. Additionally, there are reports of clinical infections arising from sub-clinical infections subsequent to antibiotic treatment allowing the resistant pathogens to multiply, creating clinical diseases. These cases may just be the tip of the iceberg as they are reported only when there is a special interest and/or resources to conduct the case-finding protocols.

Defining the cause-effect public health relationship between the high rate of resistant infections in humans and antibiotic use in animals is a challenging. The most sophisticated and longest surveillance program on this subject is the Danish Integrated Antimicrobial Resistance Monitoring and Research Program (DANMAP) (94), which since 1995 has surveyed antibiotic use and antibiotic resistance in humans and animals. Sub-therapeutic growth-promoting antibiotics were banned in Denmark in 2000 (94). Since that time, total antibiotic use in animals in the country has fallen by 50%, while use in humans has remained steady. Monitoring over the period has revealed little change in pig health in the country (95), some decrease in resistance in certain zoonotic pathogens in livestock (96), and some degree of parallel patterns of resistance of some zoonotic bacteria in livestock and meat products with patterns of human foodborne enteritis (94, 96).

A more detailed summary of the DANMAP results were reported by the Animal Health Institute as follows (97):

1. The prevalence of bacterial resistance to some antibiotics has gone down, while resistance to other antibiotics has gone up.
2. The amount of antibiotics prescribed by physicians for humans has remained relatively level over the decade.
3. Resistant infections in the human population increased early in the study, but leveled off as of 2010. One possible explanation for this is that the population of resistant bacteria in the environment is already so high that a feed ban on subtherapeutics may not affect what already exists.

Continued monitoring and analysis of the DANMAP data into the future will help to define the possible link and risk between sub-therapeutic and therapeutic use of antibiotics in animals and resistant infections in the human population. At this time it is clear that overall reduction in the use of antibiotics (humans and animals) is warranted, but the link between animal and human resistant organisms remains only partially defined (39, 40).

12.4.6 Prevention of Occupational Health Risks from use of Veterinary Pharmaceuticals

Prevention of Unintended Needle Sticks

The people responsible for the prevention of needle sticks include the individual farm owner/operator, the employer, and the prescribing veterinarian. The responsibilities can be divided as follows:

- Independent owner/operator
  - Proper animal restraint: this includes having adequate handling facilities and adequate help to manage large animals safely and humanely.
  - Read the package label and or MSDS for manufacturers' safety recommendations for each product used.
  - Use the one-handed injection technique as described by Rendell (http://www.farmerhealth.org.au/content/successful-training-program-preventing-farmer-injuries-whilst-injecting-livestock)
  - Use one dose per syringe fill (mainly for acutely toxic substances like Micotil 300).
  - Keep needle cover on until use.
  - Use needles that are sharp, not barbed, and the appropriate length for the application (e.g., for subcutaneous injection a ¼–½ inch needle is adequate).
  - Wear safety glasses to prevent spray in the eyes should the hub of the needle separate.
  - Consider use of retractable needle syringes.
  - Consider use of needleless injection equipment.
  - Do not carry a loaded syringe in a pocket or mouth.
  - Develop and maintain a safe sharps disposal program.
- Employers
  - Instigate and maintain safe and humane animal-handling facilities, including employee training.
  - Provide and maintain accessible information (including MSDSs, training, supervision, and acquisition of proper equipment and supplies to ensure that an effective program is in place for employees).
- Veterinarians
  - Consider the use of regional antibiograms (bacterial resistance patterns in the location) to guide treatment decisions.
  - Follow best practices developed by producer groups and the FDA (provide some examples).
  - Consider substitution of hazardous drugs with less potentially dangerous drugs, for example for Micotil, substitute possibilities are:
    - Enrofloxacin (Baytril) class fluoroquinolone
    - Tulathromycin (Draxxin) class macrolid
    - Florfenicol (Nuflor) class chloramphenicol.
  - Educate on prevention of all products dispensed and get signature of understanding for hazardous products that are on veterinary prescription.
  - Educate and advocate to clients on proper restraint facilities.
  - Provide a sharps disposal service.

Prevention of Occupational Hazards of Antibiotic Exposures to Workers Sensitized to Certain Antibiotics

It would be appropriate for sensitized persons to wear an N-95 filtering face-piece dust mask, safety goggles, and protective gloves (e.g., nitrile gloves) when antibiotics are incorporated into the grinding and mixing of feed, and when handling and delivering feed that contains antibiotics. Extra 1% oil can be added to the feed reactions to reduce dust aerosols.

Prevention of Antibiotic-resistant Wounds or Secondary Gastrointestinal Infections

Wounds with broken skin incurred around livestock operations should be treated as soon as possible by washing thoroughly with soap and water, applying an antibacterial agent such as 70% alcohol, peroxide, iodine, or topical antibiotic (e.g., bacitracin or polymyxin), and coverage with a sanitary bandage. Wounds that do not heal readily, especially deep wounds, should be seen by a medical professional. The patient should advise the medical professional if the wound occurred around livestock and a resistant infection could be considered.

It would be wise to inform the treating physician of any livestock exposures prior to symptomatic antibiotic treatment for a suspected bacterial infection. As most people working around livestock carry antibiotic-resistant bacteria in their gut, or oropharynx, antibiotic treatment may result in exacerbation of a resistant sub-clinical gastrointestinal or respiratory tract infection.

Prevention of Community Health Hazards of Antibiotic Exposures

Protecting the public from resistant infections includes a reduction in the reservoirs of resistant bacteria in the community. One possible reservoir discussed above (resistant organisms in animals) is in the fourth decade of debate. As previously mentioned, the EU has banned subtherapeutic use of antibiotics in animals, but the United States has not. However, a step toward reduction in such use was initiated by the FDA. In December of 2013, the FDA issued a new voluntary program to engage pharmaceutical companies to voluntarily change their approved labeled usage of "medically important" antibiotics. Such antibiotics are now to be labeled for use in animals only for treatment, prevention, or disease control, but not for growth promotion (98). Furthermore, all antibiotics of "medical importance" used in livestock production require a prescription from a licensed veterinarian. This policy assists in gaining greater professional oversight of the use of antibiotics in animals. These policies are intended to reduce the overall usage of antibiotics, while helping to ensure appropriate usage for animal health. However, no assurance can be given that this new policy will decrease the prevalence of antibiotic-resistant infections in humans.

It should be stated that most developed countries have fairly effective food safety programs that minimize exposure to antibiotics, resistant bacteria, and other pharmaceuticals that potentially come with our food. The FDA enforces regulations that specific lengths of time when antibiotics must be withheld from animals to ensure that meat, milk, and eggs are free of residues when they reach the consumer. Furthermore, meat, milk, and eggs are randomly tested at the processing plant, and contaminated products are diverted from human consumption if antibiotic residues are found. Farms identified as the origin of contaminated animal food products are investigated. Products are withheld from that farm until there are assurances that the product is antibiotic free. Fines may be levied for offending farms. The economic repercussions for today's food animal producers are great for antibiotic residue violations. This process may not remove 100% of the risk, but it does make the risk of public exposure to antibiotics in animal food products remote.

12.5 Hormones used for Growth Promotion

12.5.1 Introduction

In the early 1950s A.H. Trenkle from Iowa State University discovered that animals fed diethylstilbestrol increased their rate of weight gain, feed efficiency and grade of meat (improved taste and tenderness). Further research and development have resulted in a number of different hormones that are used today in livestock in the United States. Hormones uses in growth promotion include estrogens, progesterones, androgens/testosterones, and growth hormones (63). Generally there is no known occupational or public health hazard associated with products used as growth promotors. Other hormones are used for animal treatment that may have human health concerns. The next section will review the specific hormones used, why they are used, and the occupational or community health issues that may be associated with their use.

12.5.2 Estrogenic Hormones

Estrogenic hormones are commonly given to feedlot steers (castrated male cattle) for two reasons as they enter the feedlot for market fattening: (1) estrogens increase their rate of gain and feed efficiency, similar and additive to the effect of antibiotics. and (2) estrogens enhance the flavor and tenderness of the meat product by increasing fat deposits between the muscle bundles (marbling). These effects are obvious economic incentives in that it takes less time and less feed to grow a steer to market weight and the taste and texture of the product is improved. Meat is graded by the USDA as good, choice, or prime according to the physiologic maturing of the carcass (e.g., bone ossification, color of meat) and the degree of marbling (fat between the muscle bundles). The grade of meat from steers given estrogenic hormones may be elevated from their genetic capacity to a higher grade level by virtue of the increased marbling, for example from choice to prime. This makes the meat more valuable and increases the prospect of profitability for a beef producer.

The estrogen is administered via subcutaneous injection of a time-released pellet on the outside of the ear of the steer as they enter the feedlot. There is little risk of accidental injection or dermal or aerosol exposure to the worker. The pellets are designed so that the hormone is completely metabolized when the steer is slaughtered for meat. Furthermore, the tissues around the site of injection are discarded from the food chain, therefore there is a very low risk that any of the hormones reach the food chain.

Diethylstilbestrol (DES) was the initial estrogenic hormone used for growth promotion. DES was also used in human medicine to help maintain pregnancy in women who go into premature labor. However, an epidemiologic study conducted in the early 1980s found an increase in uterine cancer in women born to mothers who had received DES treatment during pregnancy. As a precaution DES was banned for use in food-producing animals. However, several new synthetic estrogens have been developed that have been cleared by the FDA for use in food-producing animals, therefore steers are still commonly injected with estrogenic hormones as they enter the feedlot. There have been no known occupational or consumer hazards with the use of these products in food-producing animals, but there is a certain segment of the consumer population that is against the use of estrogenic or any other hormones in food animals. The EU and several other countries prohibit the use of such products and imposed trade barriers on the import of meat from animals fed growth-promoting hormones. New trade agreements have been negotiated that allow exports of beef to the EU that have been certified by the USDA non-hormone-treated cattle program.

Progesterone is used in feedlot heifers (young, non-pregnant female cows) as they increase the rate of gain and feed efficiency. They may also be used as an estrous synchronization tool in brood cows. If a cattle producer wants to synchronize the birthing of his calves, he can put the cows on progesterone and when withdrawn they all can be impregnated within a short period of time. This will help the producer plan and manage the timely birthing of calves, which results in an even calf crop in terms of size and maturity. There are no known occupational hazards or consumer hazards.

12.5.3 Growth Hormone

Beginning in the 1990s the use of growth hormones in livestock production began to appear. The most commonly used growth hormone in agriculture today is bovine growth hormone (bovine somatotropin; BST) which is used in dairy cattle to increase milk production.

The hormone must be given by injection to each cow every 14 days during a portion of the lactation cycle. It is given to extend the peak of the milk production cycle and increase the total milk produced (average about 12% increase). BST also works to increase the butterfat content of the milk and feed consumption of the cow. There is no known occupational risk from an accidental inoculation to the administrator. In humans, BST that is ingested or injected is broken down with no measureable toxic effect. No evidence of the product is found in the milk nor is there any other known abnormality of the milk as a result of BST use. BST is authorized for use in 21 countries, but not in the EU or several other countries.

12.5.4 Anabolic Steroids

There are two growth-promoting compounds used in beef cattle that have also been found in illicit human markets. Trenbelone is an anabolic steroid used to increase muscle growth and appetite, and manage stress in male beef cattle during shipment (99, 100). It is administered like other growth-promoting steroids as an injected pellet under the skin in the back of the ear. It has had major use in cattle to manage stress in shipping. It may also be used in debilitated animals to assist in recovery. However, this drug has found an illicit use in humans as a body-building agent. It enhances muscle mass and helps to metabolize fat. Although it is a scheduled prescription drug in the United States, most EU countries, Canada, and Australia among others, it is available elsewhere over the counter.

Hormonal products used for growth performance in feed lot heifers contain both testosterone and estradiol (male and female hormones), for example Synovex (trade name). Similar to other growth-promoting hormonal products, they are injected in timed-release pellets under the skin on the back of the ear. These products are used to increase growth and feed efficiency in feedlot heifers. Similar to other anabolic steroids, these products have found illicit human markets (76).

12.6 Other Growth Promotors

Ractropamine is a beta-adrenergic agonist drug (adrenaline-like) fed to some pigs, cattle, and turkeys. Its effect in animals is to increase muscle size, rate of gain, and feed efficiency. As it is a feed additive, the main potential human exposure is dermal contact or inhalation developed from mixing, handling, and delivering feed containing the product (101). Wearing protective gloves, a dust mask, and eye protection is recommended when handling the product or feed containing the product. There is a potential but low probability of exposure from consumption of meat from animals fed ractropamine. Potential symptoms in humans who are exposed include increased cardiac heart rate and output, anxiety, increased respiratory rate, and headache. However, no adverse occupational or consumer health effects have been reported.

12.7 Hormones used in Veterinary Obstetrics

12.7.1 Introduction

Similar to human medicine, there are a variety of drugs that are used to assist obstetrical problems or other reproductive problems in veterinary medicine. These products are administered by injection and therefore unintentional inoculation is a concern. Pregnant women who are accidentally inoculated are particularly at risk (25). The two principle hormones to be discussed are oxytocin and prostaglandins.

12.7.2 Oxytocin

Oxytocin is a hormone naturally excreted from the posterior pituitary gland of mammals. Two of its primary actions are to cause uterine contraction, and milk "let down" from the mammary glands. The product may be used in most mammalian species, but is most commonly used in swine and cattle. The product is used if the animal is having a difficult time delivering, when enhanced uterine contractions may result in a delivery. An injection of oxytocin will result in almost immediate let down of milk, and effect a calming and nurturing attitude to the mother.

12.7.3 Prostaglandins

Prostaglandins are commonly used in cattle and swine to terminate pregnancy early, to induce parturition in the later stages of pregnancy, and to induce an animal to "cycle," that is, to come into estrus. Prostaglandin products are now used much more frequently than progesterone to synchronize estrous and calving. A dose of this product will directly affect the ovary, causing the corpus luteum to lyse and induce estrus in an animal.

The occupational problem with either oxytocin or prostaglandins is that they can cause abortion in pregnant women who may be accidentally inoculated. Oxytocinis more likely to cause abortion in the later stages of pregnancy, while prostaglandins may cause abortion any time during pregnancy (107). An additional potential occupational health risk with handling prostaglandins is that they can cause bronchoconstriction (asthma-like episode), resulting in a potential medical emergency. Asthmatics are at increased risk of a medical emergency from this exposure.

In agriculture today many women work in the gestation area of swine, beef, or dairy farms. They are often responsible for administering various hormones. Women working in these areas should be counseled as to the potential risk for accidental inoculation with oxytocin and prostaglandins. This author's (KJD) opinion is that pregnant women should not be allowed to handle these products.

12.8 Other Human Health Considerations of Veterinary Pharmaceuticals

Special properties of veterinary pharmaceuticals and their administration that are risk factors for occupational injuries include the following:

1. As farm animals are generally much larger than humans, veterinary pharmaceuticals for them are typically much more concentrated that human preparations. This means that a small dose (injection, dermal, or inhalation) may have a much higher content of active ingredient and therefore is more likely to be a possible human health risk.
2. Needles for farm animal hypodermic injections are much larger than those used for humans and are usually multiple use, resulting in greater trauma and increased infection risk from unintended contaminated needle sticks.
3. Veterinary pharmaceuticals can reach illegal human markets, resulting in a public health concern. The following pharmaceuticals have public health considerations in illicit markets (102):

   a. Testosterone and other anabolic steroids, including Trenbelone and Component E H or Synovex (a combination of testosterone and estradiol used as implants for growth promotion in feedlot heifers) have found illicit markets for use as performance-enhancing drugs in humans.
   b. Clenbuterol is a beta-2-andrenergic agonist (adrenalin-like drug) used for asthma and chronic obstructive pulmonary disease in horses. It is used by body builders to enhance muscle bulk, increase fat metabolism, and allow weight loss.
   c. Ketamine hydrochloride is an analgesic/anesthetic often used in veterinary medicine for cats and other species. This drug has found its way to street recreational use under the names "angel dust," "vitamin K," "Kit Kat," and "Cat Valium."

12.9 Summary

Pharmaceuticals are available for use in livestock production for treatment, disease prevention, or growth promotion of livestock and poultry. Many of these products are available to the lay producer without professional oversight. There are certain occupational risks for livestock producers who administer or handle these products, and there are certain community health risks to people who may be exposed to these products or resistant bacteria through the environment or animal food products. These pharmaceuticals can be divided into the following categories: (1) immunization products (biologicals), (2) antibiotics, and (3) hormones.

The occupational risks of biologicals include needle sticks, which may induce trauma, cause an infection with the microbe in a live vaccine preparation, result in tissue inflammation and tissue necrosis from the adjuvant in the product, or introduce infection from a contaminated dirty needle.

Occupational exposure to antibiotics may result (rarely) in adverse allergic reactions, acute toxicity (tilmicosin) or antibiotic-resistant infections. Community health risks are related to potentially acquiring an antibiotic-resistant infection.

The occupational risks of exposure to hormones used for growth promotion or milk production are minimal. However, for oxytocin and prostaglandins used in animal obstetrical treatments, exposed pregnant women risk abortion. There is a very low risk for community health exposures to animal hormones through meat or dairy products because of current FDA regulations and on-farm practices. However, certain anabolic hormones used as growth promoters or stress agonists in livestock have been found in illicit human channels and are used by athletes and body builders.

Health professionals and veterinarians can promote safety in the use of veterinary pharmaceuticals by gaining knowledge about the harmful aspects of the pharmaceutical products their clients/patients use. Veterinarians must be responsible for ensuring that their clients are knowledgeable users of the products they prescribe or dispense. Pharmaceutical companies must communicate the risks of the products they manufacture. The manufacturer provides an FDA or USDA (if a biological) approved package label which includes the approved usage and safety of the product. In addition, a high-quality and readily available material safety data sheet should also be provided. The medical practitioner and the veterinary practitioner should be aware of the harmful aspects of these products. They should also be aware of what products are being used by his/her patients so that they might anticipate potential hazards and be able to make an informed differential diagnosis if they are presented with a potential exposure situation. Both patients and healthcare providers should know that if there is an exposure situation (needle stick, etc.) the package label should be made available. Pregnant women should be advised of the hazards surrounding the use of oxytocin and prostaglandins. Strong recommendations should be made to women not to handle these products during pregnancy.

Prevention of needle sticks can be enhanced by having and maintaining good-quality, functional animal-handling facilities. Without proper restraint, animals can move unpredictably, resulting in an unintended injection of the operator.

For large agricultural operations, it is the responsibility of the owner/operator to train workers. This includes information on the health risks of all drugs used on the farm, proper injection technique, and the care and cleaning of hypodermic needles.

Finally, healthcare practitioners, veterinarians, and producers should all be aware of the growing risk of antibiotic-resistant infectious organisms. All involved should support the proper and conservative use of antibiotics. Prudent use of antibiotics in livestock production will help to reduce the negative environmental and direct human health risks of antibiotic use (103). Only through these methods can we help ensure there will be effective antibiotics for use in combating both human and animal diseases in the future.

Key Points

1. There is a vast and varied supply of pharmaceuticals used in livestock production (many in common use in human medicine) for the treatment of sick animals, the prevention of disease, and the enhancement of growth.

2. Most pharmaceuticals used in livestock production are readily available from a variety of sources to farmers and the lay public without professional veterinary oversight.
3. Most developed countries have effective regulatory agencies that license products based on prescribed use for effectiveness and safety in animals, humans, environment, and food.
4. Animal biologicals and vaccines may create a health hazard to farmers through unintended needle sticks, aerosol, or water exposures. The health risks of these products are increased if the agent is a live product and/or if there is a mineral oil-based adjuvant in bacterin or vaccine.
5. Antibiotics may cause harm in farmers from the direct toxic injection of one antibiotic in particular (tilmicosin), an allergenic response, or an antibiotic resistant infection.
6. The emergence of antibiotic-resistant infections in humans as well as animals is likely facilitated by the high usage of antibiotics in human medicine, animal production, ethanol production, and orchard production.
7. There are current policies and practices to reduce unnecessary use of antibiotics in livestock. However, it is unclear if the current policies can reduce antibiotic-resistant infections in humans.
8. Prevention of possible exposures to humans from pharmaceuticals used in livestock production includes the following:
   a. Science-based policies and enforcement in the licensing and use of animal pharmaceuticals.
   b. Farmer and worker education on the safe use of pharmaceuticals.
   c. Development of practices for the safe administration of pharmaceuticals, including appropriate syringe/needle handling and effective animal-handling and restraint facilities.
   d. Professional veterinary oversight of pharmaceuticals use and healthcare provider education about the products available and their potential hazards.
   e. Knowledge of where to obtain specific product hazard information, including;
      i. the local veterinarian
      ii. the product package insert
      iii. the material safety data sheet
      iv. the nearest poison control center (the general number in the United States is (1-800-222-1222)
      v. the product manufacturer
9. Pharmaceuticals are important economic and animal health tools in production agriculture. However, judicious use of these products (protecting occupational health, public health, animal welfare, and the environment) should be considered a component of sustainable agriculture (103).

References

1. Bennish M. Animals, humans, and antibiotics: Implications of the veterinary use of antibiotics on human health. Adv Ped Infec. 1999;14:269–90.
2. Boxall AB. Veterinary medicines and the environment. Handb Exp Pharmacol. 2010(199):291–314.
3. Plumb D. Veterinary drug handbook. 7th edition. Wiley-Blackwell; 2011. 804–5 p.
4. Cromwell GL. Why and how antibiotics are used in swine production. Anim Biotechnol. 2002;13(1):7–27.
5. Samadi S, Wouters IM, Heederik DJ. A review of bioaerosol exposures and associated health effects in veterinary practice. Ann Agric Environ Med. 2013;20(2):206–21.
6. Memorandum of Understanding Between the Animal and Plant Health Inspection Service, United States Department of Agriculture and the Food and Drug Administration. Washington DCL Department of Health and Human Services; 2013.
7. Veterinary Biologics. Washington, DC: US Department of Agriculture Animal Plant Health Insepction Service; 2015 (updated 18 November 2014; accessed 5 February 2015). Available from: http://www.aphis.usda.gov/wps/portal/aphis/ourfocus/animalhealth/sa_vet_biologics/.
8. About the Center for Veterinary Medicine. Silver Spring, MD: US Food and Drug Administration; 2015 (updated 27 January 2015; accessed 5 February 2015). Available from: http://www.fda.gov/aboutfda/centersoffices/officeoffoods/cvm/default.htm.
9. Koschorreck J, Kock C, Ronnefahrt I. Environmental risk assessment of veterinary medicinal products in

the EU – A regulatory perspective. Toxicol Lett. 2002;131(1–2):117–24.
10. Erramouspe J, Carlson R. Veterinarian perception of the intentional misuse of veterinary medicine in humans. J Rural Health. 2002;18(2):311–8.
11. Haguenoer JM. Do pharmaceutical waste and drug residue pose a risk to public health? Sante Publique (Bucur). 2010;22(3):325–42.
12. Kemper N. Veterinary antibiotics and their possible impact on resistant bacteria in the environment. In: Bonilla AR, Muniz KP, editors. Antibiotic resistance: causes and risk factors, mechanisms, and alternatives. Pharmacology – research, safety testing and regulation. New York: Nova Sciences Publishers; 2009.
13. Adverse drug experience (ADE) reports. US Food and Drug Administration; 2013 (updated 5 December 2013; accessed 13 February 2014). Available from: http://www.fda.gov/AnimalVeterinary/SafetyHealth/ProductSafetyInformation/ucm055369.htm.
14. Woodward KN. Assessment of user safety, exposure and risk to veterinary medicinal products in the European Union. Regul Toxicol Pharmacol. 2008; 50(1):114–28.
15. Woodward KN. Veterinary pharmacovigilance. Part 4. Adverse reactions in humans to veterinary medicinal products. J Vet Pharmacol Ther. 2005; 28(2):185–201.
16. Woodward K. Adverse reactions in humans following exposure to veterinary drugs. In: Woodward K, editor. Veterinary pharmacovigilance: adverse reactions to veterinary medicinal products. Chichester: Blackwell Publishing; 2009.
17. True Names and Product Codes. Washington, DC: US Department of Agriculture Animal Plant Health Insepction Service; 2015.
18. FDA Annual Report on Antimicrobials Sold or Distributed for Food-Producing Animals in 2011. Federal Drug Administration, Center for Veterinary Medicine, February 5, 2013 (updated 5 January 2016; accessed 6 January 2016). Available from: http://www.fda.gov/AnimalVeterinary/NewsEvents/CVMUpdates/ucm338178.htm.
19. 2011 Summary Report on Antimicrobials Sold or Distributed for Use in Food Producing Animals, September 2014. Federal Drug Administration, Center for Veterinary Medicine (accessed 6 January 2016). Available from: http://www.fda.gov/downloads/ForIndustry/UserFees/AnimalDrugUserFeeActADUFA/UCM338170.pd.
20. Geller R. Human effects of veterinary biological products. Vet Human Toxicol. 1990;32(5):479–80.
21. McGreigan M. Human exposures to tilmicosin (MICOTIL). Vet Human Toxicol. 1994;36(4):306–8.
22. Patterson C, LaVenture M, Hurley S, Davis J. Accidental self-inoculation with *Mycobacterium paratuberculosis* bacterin (Johne's bacterin) by veterinarians in Wisconsin. J Am Vet Med Assoc. 1988;192(9):1197–9.
23. Samanta A, Roffe C, Woods K. Accidental self-administration of xylazine in a veterinary nurse. Postgrad Med J. 1990;66(773):244–5.
24. Wiggins P, Schenker M, Green R, Samuels S. Prevalence of hazardous exposures in veterinary practice. Am J Ind Med. 1989;16(1):55–66.
25. Wilkins JI, Bowman M. Needle stick injuries among female veterinarians: Frequency, syringe contents and side-effects. Occup Med. 1997;47(8):451–7.
26. Jones G. Accidental self inoculation with oil based veterinary vaccines. N Z Med J. 1996;109(1030):363–5.
27. Nienhaus A, Skudlik C, Seidler A. Work-related accidents and occupational diseases in veterinarians and their staff. Int Arch Occup Environ Health. 2005;78(3):230–8.
28. Skilton D, Thompson J. Needlestick injuries. Vet Rec. 2005;156(16):522.
29. Windsor PA, Bush R, Links I, Eppleston J. Injury caused by self-inoculation with a vaccine of a Freund's complete adjuvant nature (Gudair) used for control of ovine paratuberculosis. Aust Vet J. 2005;83 (4):216–20.
30. Jennissen C, Wallace J, Donham K, Rendell D, Brumby S. Unintentional needlestick injuries in livestock production: a case series and review. J Agromedicine. 2011;16(1):58–71.
31. Spink WW. The significance of bacterial hypersensitivity in human brucellosis: studies on infection due to strain 19 Brucella abortus. Ann Intern Med. 1957;47(5):861–74.
32. Human exposure to brucella abortus strain RB51 – Kansas, 1997. MMWR Morb Mortal Wkly Rep. 1998;47(9):172–5.
33. Heymann D. Control of Communicable Diseases Manual. 20th edition. Washington, DC: American Public Health Association Press; 2014. 729 p.
34. Wierup M. The control of microbial diseases in animals: Alternatives to the use of antibiotics. Int J Antimicrob Agents. 2000;14(4):315–9.
35. Torrence M. Activities to address antimicrobial resistance in the United States. Prevent Vet Med. 2001;51(1–2):37–49.
36. Dunlop R, McEwen S, Meek A, Freindship R, Clarke R, Black W. Antimicrobial drug use and related management practices among Ontario swine producers. Can Vet J. 1998;39(2):87–96.
37. Gersema L, Helling D. The use of subtherapeutic antibiotics in animal feed and its implications on human health. Drug Intell Clin Pharmacy. 1986;20(3):214–8.

38. Johnston A. Animals and antibiotics. Int J Antimicrob Agents. 2001;18(3):291–4.
39. Khachatourians G. Agricultural use of antibiotics and the evolution and transfer of antibiotic-resistance bacteria. Can Med Assoc J. 1998;159(9):1129–36.
40. Laval A. Veterinary use of antibiotics and resistance in man: What reaction? Pathol Biol. 2000;48(10):940–4.
41. Marwick C. Animal antibiotics use raises drug resistance fear. J Am Med Assoc. 1999;282(2):120–2.
42. Randall L, Woodward M. The multiple antibiotic resistance (mar) locus and its significance. Res Vet Sci. 2002;72(2):87–93.
43. Sax H. Successful strategies against increasing antibiotic resistance. Therapeuishe Umschau. 2002; 59(1):51–5.
44. Schmidt C. Antibiotic resistance in livestock: More at stake than steak. Environ Health Persp. 2002; 110(7):A396–402.
45. Schwarz S, Chaslus-Dancla E. Use of antimicrobials in veterinary medicine and mechanisms of resistance. Vet Res. 2001;32(3–4):201–25.
46. Teale C. Antimicrobial resistance and the food chain. J Appl Microbiol. 2002;92(Suppl.):85S–9S.
47. Teuber M. Veterinary use and antibiotic resistance. Curr Opin Microbiol. 2001;4(5):493–9.
48. VandenBogaard A, Stobberingh E. Antibiotic usage in animals: Impact on bacterial resistance and public health. Drugs. 1999;58(4):589–607.
49. Van den Bogaard A. Human health aspects of antibiotics use in food animals: A review. Tijdschrift Voor Diergenees Kunde. 2001;126(18):590–5.
50. Palmer M, Adickes J, Chan C, Fox C, Johnson L, Katz D. The preservation of antibiotics for Medical Treatment Act of 2011. Fall Workshop in Applied Earth Systems Management. New York: Columbia University; 2011 (accessed 6 January 2016). Available from: http://mpaenvironment.ei.columbia.edu/files/2014/06/PAMTA-Final-Report-web.pdf.
51. Key N, McBride, W. Sub-therapeutic antibiotics and the efficiency of US hog farms. Am J Agric Econ. 2014 96(3):831–50.
52. De Vries LE, Christensen H, Skov RL, Aarestrup FM, Agerso Y. Diversity of the tetracycline resistance gene tet(M) and identification of Tn916- and Tn5801-like (Tn6014) transposons in *Staphylococcus aureus* from humans and animals. J Antimicrob Chemother. 2009;64(3):490–500.
53. Gupta A, Nelson JM, Barrett TJ, Tauxe RV, Rossiter SP, Friedman CR, et al. Antimicrobial resistance among Campylobacter strains, United States, 1997–2001. Emerg Infect Dis. 2004;10(6):1102–9.
54. Hueston W, Johnson J. Balancing the health impacts of antibiotic use in animal feed. Saint Paul, Minnesota: Food Policy Research Center, University of Minnesota; 2013 (accessed 22 January 2014). Available from: http://www.foodpolicy.umn.edu/policy-summaries-and-analyses/antibiotics/.
55. Loglisci R. Will the US hog industry ever kick its reliance on low-dose antibiotics? Seattle, Washington: Grist; 2014 (accessed 6 February 2014). Available from: http://grist.org/industrial-agriculture/2011-04-05-will-the-u-s-hog-industry-ever-kick-its-reliance-on-low-dose/.
56. Singer RS, Cox LA, Jr., Dickson JS, Hurd HS, Phillips I, Miller GY. Modeling the relationship between food animal health and human foodborne illness. Prev Vet Med. 2007;79(2–4):186–203.
57. Sapkota AR, Hulet RM, Zhang G, McDermott P, Kinney EL, Schwab KJ, et al. Lower prevalence of antibiotic-resistant Enterococci on US conventional poultry farms that transitioned to organic practices. Environ Health Perspect. 2011;119(11):1622–8.
58. Scott G. Antibiotic resistance. Medicine. 2009;37(10): 551–6.
59. Cornaglia G. The spread of macrolide-resistant streptococci in Italy. Alliance for Prudent Use of Antibiotics News Letter. 1998;16(1):1,4.
60. Dromigny J, Nabeth P, Perrier Gros Claude J. Distribution and susceptibility of bacterial urinary tract infections in Dakar, Senegal. Int J Antimicrob Agents. 2002;20(5):339–47.
61. Hart S, Korey E, Stamatis G. Nearly one-third of *Streptococcus pnemoniaae* resistant to newer antibiotics: study in doctor's office patients points to resistance rates in children. Kid Source Online; 1998 (accessed 6 January 2016). Available from: http://www.kidsource.com/kidsource/content4/resistent.antibiotics.html.
62. Skold O. Resistance to trimethoprim and sulfonamids. Vet Res. 2001;32:261–73.
63. Sundluf S, Cooper J. Human health risks associated with drug residues in animal-derived foods. Vet Drug Residues. 1996;636(5–17).
64. The science source for food, agricultural, and environmental information. Ames, Iowa: Council for Agricultural Science Technology; 2014 (accessed 6 February 2014). Available from: www.cast-science.org.
65. Dewey CE, Cox BD, Straw BE, Bush EJ, Hurd S. Use of antimicrobials in swine feeds in the United States. Swine Health Prod. 1999;7(1):19–25.
66. Antibiotics in Animal Feed. Report Number 88. Ames, IA: Council for Agricultural Science and Technology, Iowa State University; 1981 (accessed 7 January 2016). Available from: http://www.cast-science.org/media/cms/CAST_R88_Antibiotics_in_Animal_Feed_11030A32261B8.PDF.

67. Corwin R. Economics of gastrointestinal parasitism of cattle. Vet Parasitol. 1997;72(3–4):451–7; discussion 7–60.
68. Van Lunen TA. Growth performance of pigs fed diets with and without tylosin phosphate supplementation and reared in a biosecure all-in all-out housing system. Can Vet J. 2003;44(7):571–6.
69. CPI Calculator. Washington, DC: US Department of Labor; 2014 (accessed 6 February 2015). Available from: http://www.bls.gov/data/inflation_calculator.htm.
70. Brorsen BW, Lehenbauer T, Ji D, Connor J. Economic impacts of banning subtherapuetic use of antibiotics in swine production. Oklahoma State University; 2001 (accessed 13 February 2014). Available from: http://agecon.okstate.edu/faculty/publications/156.pdf.
71. Graham JP, Boland JJ, Silbergeld E. Growth promoting antibiotics in food animal production: an economic analysis. Public Health Rep. 2007;122(1):79–87.
72. Hurd HS, Brudvig J, Dickson J, Mirceta J, Polovinski M, Matthews N, et al. Swine health impact on carcass contamination and human foodborne risk. Public Health Rep. 2008;123(3):343–51.
73. Olmstead J. Fueling resistance? Antibiotics in ethanol production. Minneapolis, MN: Institute for Agriculture and Trade Policy; 2009 (accessed 6 January 2016). Available from: http://www.iatp.org/files/258_2_106420.pdf.
74. Veenhuizen MF, Wright TJ, McManus RF, Owens JG. Analysis of reports of human exposure to Micotil 300 (tilmicosin injection). J Am Vet Med Assoc. 2006;229(11):1737–42.
75. Von Essen S, Spencer J, Hass B, List P, Seifert SA. Unintentional human exposure to tilmicosin (Micotil 300). J Toxicol Clin Toxicol. 2003;41(3):229–33.
76. Lust EB, Barthold C, Malesker MA, Wichman TO. Human health hazards of veterinary medications: information for emergency departments. J Emerg Med. 2011;40(2):198–207.
77. Preventing worker deaths and injuries when handling Micotil 300. Cincinnati, OH: National Institute for Occupational Safety and Health, Centers for Disease Control; 2007.
78. Dal Monte A, Laffi G, Mancini G. Occupational contact dermatitis due to spectinomycin. Contact Dermatitis. 1994;31(3):204–5.
79. Prudent use in animals. Chapter 3. Seventh Report. Select Committee on Science and Technology. House of Lords; 17 March 1998 (accessed 6 January 2016). Available from: http://www.parliament.the-stationery-office.co.uk/pa/ld199798/ldselect/ldsctech/081vii/st0706.htm.
80. Levy SB, FitzGerald GB, Macone AB. Changes in intestinal flora of farm personnel after introduction of a tetracycline-supplemented feed on a farm. N Engl J Med. 1976;295(11):583–8.
81. Padungton P, Kaneene J. Campylobacter species in humans, chickens, pigs, and their antimicrobial resistance. J Vet Med Sci. 2003;65(2):161–70.
82. Smith JL, Drum DJ, Dai Y, Kim JM, Sanchez S, Maurer JJ, et al. Impact of antimicrobial usage on antimicrobial resistance in commensal *Escherichia coli* strains colonizing broiler chickens. Appl Environ Microbiol. 2007;73(5):1404–14.
83. Williams R, Rollins L, Pocurull D, Selwyn M, Mercer H. Effect of feeding chlortetracycline on the reservoir of *Salmonella typhimurium* in experimentally infected swine. Antimicrob Agents Chemother. 1978;14(5):710–9.
84. Bartlett JG. Clinical practice. Antibiotic-associated diarrhea. N Engl J Med. 2002;346(5):334–9.
85. Lathers C. Role of veterinary medicine in public health: Antibiotic use in food animals and humans and the effect on evolution of antibacterial resistance. J Clin Pharmacol. 2001;41(6):595–9.
86. McDermott P, Zhao S, Wagner D, Simjee S, Walker R, White D. The food safety perspective of antibiotic resistance. Animal Biotechnol. 2002;13(1):71–84.
87. Campagnolo E, Johnson K, Karpati A, Rubin C, Kolpin D, Meyer M, et al. Antimicrobial residues in animal waste and water resources proximal to large-scale swine and poultry feeding operations. Sci Total Environ. 2002;299(1–3):89–95.
88. Swartz MN. Human diseases caused by foodborne pathogens of animal origin. Clin Infect Dis. 2002;34(Suppl.3):S111–22.
89. Esiobu N, Armenta L, Ike J. Antibiotic resistance in soil and water environment. Int J Environ Health Resources. 2002;12(2):133–44.
90. Kolpin D, Furlong E, Meyer M, Thurman E, Zaugg S, Barber L, et al. Pharmaceuticals, hormones, and other organic wastewater contaminants in US streams, 1999–2000: A national reconnaissane. Environ Sci Technol. 2002;36(6):1202–11.
91. Sengelov G, Agerso Y, Halling-Sorensen B, Baloda S, Andersen J, Jensen L. Bacterial antibiotic resistance levels in Danish farmland as a result of treatment with pig manure slurry. Environ Int. 2003;28(7):581–95.
92. Zahn J. Evidence for transfer of Tylosin and Tylosin-resistant bacteria in air from swine production facilities using sub-therapeutic concentrations of Tylan® in feed. J Animal Sci. 2001;79:189.
93. Ferguson D, Smith T, Donham K. The efficiency of biofilters at mitigating airborne MRSA from a swine nursery. J Agric Saf Health. 2015;21(4):217–27.

94. DANMAP home page; 2014 (accessed 6 February 2014). Available from: http://www.danmap.org/.
95. Aarestrup F, Jensen V, Emborg H, Jacobsen E, Wegener H. Changes in the use of antimicrobials and the effects on productivity of swine farms in Denm. Am J Vet Res. 2010;71(7): 726–33.
96. Wgener H. Improving food safety through a one health approach: Workshop summary, A15, in Antiboitc Resistance-Linking Humans and Animal Health. Washilngton, DC: National Academy of Sciences, National Acacemy Press; 2012.
97. Antibiotics in livestock: frequently asked questions. Animal Health Institute; 2014 (accessed 13 February 2014). Available from: http://www.ahi.org/issues-advocacy/animal-antibiotics/antibiotics-in-livestock-frequently-asked-questions/#16.
98. Miller M. FDA nixes feed-grade antibiotics. Pork Network; 2012 (accessed 6 February 2014). Available from:http://www.porknetwork.com/pork-news/FDA-nixes-feed-grade-antibiotics--147044875.html.
99. Hunt DW, Henricks DM, Skelley GC, Grimes LW. Use of trenbolone acetate and estradiol in intact and castrate male cattle: effects on growth, serum hormones, and carcass characteristics. J Animal Sci. 1991;69(6):2452–62.
100. Revalor-xs; US Food and Drug Administration; 2007 (accessed 13 February 2014). Available from: http://www.fda.gov/downloads/AnimalVeterinary/Products/ApprovedAnimalDrugProducts/FOIADrugSummaries/ucm062321.pdf.
101. PAYLEAN 9 and PAYLEAN 45 (Ractopamine Hydrochloride). US Food and Drug Administration; 2006 (accessed 6 February 2014). Available from: http://www.fda.gov/downloads/AnimalVeterinary/Products/ApprovedAnimalDrugProducts/FOIADrugSummaries/ucm115647.pdf.
102. Wohlers A, Smith DR, Griffin D. Safe use of animal medicines. Contract No.: G1576. Lincoln, NE: University of Nebraska-Lincoln; 2005.
103. Horrigan L, Lawrence R, Walker A. How sustainable agriculture can address the environmental and human health risks of industrial agriculture. Environ Health Persp. 2002;110(5):A256.

Chapter

13

Zoonotic Diseases: Overview of Occupational Hazards in Agriculture

Kelley J. Donham

Reviewer: James Wright and Christine Petersen

13.1 Introduction

Zoonotic diseases are those infections common to animals and man (1). This definition differs slightly from the WHO definition: "those infections which are naturally transmitted between nonhuman vertebrate animals and man" (2). The former definition will be applied in this chapter as it accommodates certain infections transmitted to both animals and man from soil or other inanimate sources such as histoplasmosis and tetanus, but not directly between animals and humans. Kruse and others have reviewed patterns of zoonoses transmission that have been recognized since ancient history (3). Zoonotic diseases have been associated with agricultural production as it arose in the Middle East over 15,000 years ago. Cultivating crops and domestication of animals brought humans into more direct contact with zoonotic agents as they existed in nature, feral animals, or the animals they domesticated.

The objective of this chapter is to assist the reader to anticipate, recognize, diagnose, treat, and prevent occupational and environmental zoonoses in their farms or rural patients/clients. Because at least 40 of the over 200 recognized zoonoses are occupational hazards for agricultural workers, it is beyond the scope of this text to cover them all in detail. To accomplish the objective, rather than discussing details of specific diseases, the following seven basic concepts will be discussed: (1) the relative agricultural occupational health risk of zoonoses, (2) trends and patterns of zoonoses, (3) emerging zoonoses, (4) ecologic aspects of zoonoses, (5) epidemiology of zoonoses, (6) classification of zoonoses, and (7) prevention. Details of the infections that are most important as agricultural occupational hazards in developed countries are given in Tables 13.1 and 13.2. Table 13.1 summarizes zoonotic disease hazards relative to various species of livestock (1, 4-7). Table 13.2 summarizes the important characteristics of those diseases (1, 4-7). Table 13.3 provides a summary of preventive procedures to reduce the risks of zoonotic infections in agricultural producers, their families, and workers. These tables follow the text at the end of this chapter.

Agricultural Medicine: Rural Occupational and Environmental Health, Safety, and Prevention, Second Edition.
Kelley J. Donham and Anders Thelin.

13.2 Significance of Zoonotic Disease

Over 200 zoonoses are distinguished worldwide (8, 9). Sixty per cent of the infectious diseases humans suffer are zoonotic (10) and 75% of new or emerging human diseases are zoonoses (4, 5, 8, 10-14). Approximately 80 zoonoses occur in industrialized countries, and at least 40 of these are health hazards for agricultural workers (15). Thirty-one of these infections will be covered in this chapter in tabular form (see Tables 13.1 and 13.2 at the end of this chapter). They will be discussed relative to the primary reservoirs, livestock, or environment that poses the greatest risk and the method of transmission.

Several zoonotic diseases are major economic burdens for the livestock industry (e.g., brucellosis and tuberculosis among 19 others on the US Department of Agriculture list for control or surveillance) (16). Seven (including brucellosis and tuberculosis) are zoonotic infections and therefore the USDA controls benefit occupational and public health. Similar eradication programs exist in most developed countries. The magnitude of the cost of eradication control programs is exemplified by US control of brucellosis, which cost $54 million annually in the early days of the program. However, the program has resulted in reduced animal health costs from $400 million in 1952 to $1 million in 2012 annually and a dramatic decrease in humans cases of the disease (16). Canada spent over $2.5 billion in 2003-2004 for surveillance and control of bovine spongioform encephalopathy (17). Similarly, large sums are expended in the United States by the combined efforts of the Federal Drug Administration, the Department of Agriculture, and the Public Health Service to prevent zoonotic infections from reaching the public through potentially contaminated red meat, poultry, and dairy products. Additional costs of zoonoses include those associated with the diagnosis, treatment, and prevention of these diseases in humans. Furthermore, zoonoses in meat supplies may cause foreign nations to stop imports, causing financial loss of export dollars.

Historically, the numbers of people affected by zoonoses are remarkable. Bubonic plague was estimated to have caused over 135 million deaths during three major pandemics, which commenced in years 542, 1346 and 1894. Typhus killed one million Europeans during World War I, and influenza killed an estimated 15 million people during the worldwide epidemic of 1918–1919 (18). Today, influenza and pneumonia together are the seventh leading cause of death in the United States. Growing evidence indicates that animals, especially domestic pigs, migrating water fowl, and chickens, are important reservoirs of influenza for humans (19). According to the US Center for Disease Control, the most recent outbreak of Ebola (a zoonotic disease) in West Africa resulted in the death of 11,315 people in 2014.

In addition to acute health problems, zoonoses may cause chronic health problems and are often associated with considerable psychological stress. Examples of these diseases include Lyme disease, Q fever, brucellosis, and histoplasmosis (1).

Although zoonoses are recognized as a significant health problem, especially among risk groups such as farmers, accurate prevalence and incidence of diseases is difficult to obtain for several reasons (15). First, there is no comprehensive zoonotic illness reporting system. Public health agencies in most developed countries require reporting of only a few zoonotic infections. For example, in the United States the US Center for Disease and Prevention requires only 24 zoonoses to be reported (20, 21). Second, mildly infected persons may not seek medical care. Third, many clinical zoonotic infections seen by physicians remain undiagnosed and therefore unreported. Diagnosis is complicated because (1) clinical manifestations of many zoonoses are variable and non-specific, mimicking those of influenza, (2) there is a lack of physician awareness (21), and (3) diagnostic support for these diseases is limited. For all of these reasons, only a small percentage of human zoonotic infections are diagnosed, treated, and reported. Even less data exist on the magnitude of disease transmission from humans to animals, since the focus for public health study of zoonoses is directly on human health.

13.3 Forces Affecting Trends and Patterns of Zoonoses

Many interrelated factors affect the existence, maintenance, and dispersion of infectious agents in human (or animal) populations. Regarding zoonotic diseases, the following factors shape the incidence, prevalence, and epidemiologic patterns of zoonoses (22, 23).

1. *Human and economic demographics*. The global population is ever-increasing and an escalating proportion of those people are of low socioeconomic status. These are vulnerable populations, as most live in societies with inadequate public health infrastructure to prevent/manage infectious diseases. Co-morbid factors increase the risk of zoonotic infection and poor outcome in developing countries or immigrant workers, and where there is low nutrition status and other chronic disease (e.g., tuberculosis and various parasitic diseases).
2. *Increased populations of immunocompromised persons* (organ transplant patients, cancer patients, HIV infected, the elderly) create additional populations vulnerable to infections.
3. *Decreased "herd immunity"*. A decreased pool of exposed people, especially those working on farms, who are mildly exposed over time, resulting in the development of protective immunity. People new to animal agriculture, for example immigrant workers, children, and farm visitors, may be more susceptible to such zoonotic infections as they have no or limited immunity to agents in the farm environment.
4. *Altered use of the environment or extreme climate events that disturb natural ecosystems* may create an environment favorable to disease agents, reservoirs, and vectors (e.g., increase in Argentine hemorrhagic fever virus infections in Argentine farm workers as more land was given over from pasture to crops, creating an environment favorable for field worker contact with the body fluids of the reservoir field mouse). Increased floods have resulted in a greater risk for leptospirosis. Lyme disease in the northeast and Midwest of the United States may have increased because of loss of biodiversity allowing the deer mouse reservoir to increase (24, 25).
5. *Increased international travel increases the risk of transmission of zoonoses* and other infections. For example, West Nile virus was probably introduced into North America by mosquito vectors or reservoir birds in an airplane from Africa or the Middle East (26).
6. *Microbial adaptation may lead to increased risk*. For example, zoonotic influenza viruses have the ability to rapidly mutate to new strains, which may have new virulence capacities and the host may have no immunity to the new strain. Several bacterial pathogens have rapidly developed resistance to antibiotics and multiplied in susceptible populations (e.g., methicillin-resistant *Staphylococcus aureus*).
7. *Environmental changes* such as global warming trends may increase the range and density of insect vectors, which may enhance the range of arbovirus encephalitis, Lyme disease, and other vector-borne diseases.
8. *Intensive livestock production may increase risk of zoonoses* as they offer a population of host animals in close contact. Thousands of replications of an infectious agent can occur rapidly in such an environment, resulting in a higher probability of new strains with potentially enhanced virulence for swine and other species, including humans.
9. *Increased presence of reservoirs of zoonotic agents in wildlife* either in the wild or farmed offers increased risk of zoonotic infectious in agricultural people. For example, wild elk and buffalo in the Yellow Stone National Park area of Wyoming in the United States and wild pigs in the southern United States are reservoirs for brucellosis. Escaped farmed deer and elk in the Midwest United States present hazards of spreading bovine spongiform encephalitis. Wild badgers are reservoirs of tuberculosis in cattle in the UK.

All these factors increase risk among human populations. The interaction of these factors creates changes in the natural ecology of an infectious agent and thus changes in disease patterns in animal and human populations. Considering an infectious microbe within its natural nidus helps to understand its existence and thereby provides insight to control and prevention as an occupational/public health hazard. Schwabe (27), in his classic textbook of veterinary public health, eloquently summarized the concept of the natural nidality of zoonotic infectious agents, describing how and why zoonotic outbreaks occur. Infection and sporadic disease are natural components of ecosystems. In natural undisturbed ecosystems (those in which all inhabitants have evolved balanced interrelationships with each other and their environment) infectious agents typically maintain a steady low rate of infection in the host population. Such an ecosystem is called the agent's nidus**.** Disease outbreaks are the result of a change in the natural balances of ecosystems. Natural ecosystems change slowly through time as a result of processes such as erosion, changes in climate, or geophysical events. However, human intervention often speeds and escalates large-scale ecosystem changes. As ecosystems and the interactions among organisms change, a frequent result is a change in the number and types of organisms present. For example, if ecologic changes create a more favorable environment for an arthropod vector of a zoonotic disease or a vertebrate host for a zoonotic disease, then one might see an epidemic of that zoonotic disease in the community. Introduction of a new feral species into an ecosystem can result in an epidemic if this species is host to an infectious agent or if the new species is a disease vector. For example, from medieval times to the turn of the last century, bubonic plague epidemics were initiated by human actions when the disease was carried on ships harboring rats infected with the bacterium *Yersinia pestis*. Rats exited the ships into port cities, initiating plague in a new location.

Similarly, introduction of new domestic species into a natural ecosystem can lead to disease outbreaks when these species transmit infectious agents from native vertebrates to humans. For example, agricultural practices involved with raising cattle in the Midwestern United States have led to the potential transmission of rabies from skunks to cattle through bites and then to people through exposure to saliva from infected cattle.

People who enter environments where zoonoses are present increase their risk of acquiring a zoonotic infection. Examples include cases of Lyme disease in hikers who are bitten by *Ixodes* species of ticks and Colorado tick fever in campers bitten by *Dermacentor* species ticks.

Alteration of the abiotic components of an ecosystem can result in changes in the population structure of the flora and fauna that could lead to disease outbreaks. For example, a sheep production operator in the Midwestern United States moved his lambing operation to a concentrated indoor facility. As some of the ewes carried the Q fever organism, *Coxiella burnetii*, the indoor environment was seeded with this infectious agent. New farm workers in this environment were exposed, resulting in a major outbreak of Q fever in the workers.

New disease agents can enter an ecosystem through agent mutation or a change in a host's physiology resulting in selection of virulent strains. For example, it is fairly clear that new influenza strains are produced in domestic animals and transmitted to humans before protective immunity can be formed (10). If a host's body is considered an ecosystem, a change in its environment (e.g., in the host's nutrition, climate, physiological state, etc.) can lead to an increase in the number of infectious agents and transmission to other hosts. For example, *Salmonella* is commonly carried in the gut of many animal species. Antibiotics and stress can change the gut flora, decreasing the microbial competition in the gut, thus increasing the numbers of *Salmonella* organisms shed, which increases the risk of transmission to other domestic animals or humans. The ecology of a zoonotic agent is shaped by the nine factors mentioned above, resulting in the transformation of epidemiologic disease patterns caused by the specific agent. Ecological principles can be used in predictive mode for future disease patterns.

13.4 Historical Trends in Zoonoses

The factors mentioned above have shaped and will continue to shape the future epidemiology of zoonoses. Some diseases have changed from widespread epidemic patterns to geographically localized and sporadic endemic cases, for example bubonic plague. Several bubonic plague pandemics have occurred throughout history. The disease is now isolated to sporadic cases in certain local ecosystems in North America, Asia, Europe, and Africa.

In developed industrialized countries, infectious diseases decreased in importance relative to chronic diseases during the second half of the 20th century. This is thought to be due to better nutrition, improved public health measures, better environmental sanitation, and effective antibiotic therapy. However, beginning in the 1980s, there has been a resurgence of infectious diseases and 75% of these diseases are emerging or re-emerging zoonoses (28).

13.4.1 Emerging and Re-emerging Zoonotic Diseases

Since 1990 in North America, Europe, and other countries we have seen the emergence of Lyme disease, hantavirus infections, West Nile encephalitis, spongiform encephalopathy, monkey pox, new strains of zoonotic avian or swine associated influenza, methicillin-resistant *Staphylococcus aureus*, severe acute respiratory syndrome (SARS), and Middle East respiratory syndrome (MERS) (22, 23). We have seen the emergence of NIPAH virus in Malaysia and Bangladesh, and Hendra virus in Australia (22). Although increased rapid regional and global transportation of people and animals has increased the risk of disease transmission, most zoonoses (with exceptions discussed later in this chapter) occur as sporadic cases among people in certain risk categories in defined geographical areas and not as widespread epidemics. Zoonoses are therefore primarily occupational and environmental hazards (e.g., affect farmers and agricultural workers) and occur in those with specific risk factors and work that bring them into close association with the natural nidus of the disease.

13.5 Future Trends in Zoonoses

Future trends of zoonoses are likely to include the increased emergence of new or newly introduced infections stimulated by the high degree of mobility of people and agricultural products, intensification of livestock production (23), and spillover of infections into livestock from wildlife reservoirs (22, 29). However, there will probably be a continued decrease in human cases of some zoonoses where control/eradication programs are established, such as for brucellosis and bovine tuberculosis. The frequency of zoonoses contracted from feral animals will likely increase as participation in outdoor recreational and occupational activities continues to rise.

Future zoonotic epidemics will probably be rare (except for certain zoonoses that are transmissible among humans, e.g. influenza). Migratory waterfowl are vast reservoirs for potentially zoonotic influenza viruses. Should the close association of swine and poultry production allow a recombination of an avian virus with a swine virus that is transmissible to and among people, an epidemic of severe influenza could result (30). Natural or human-induced disasters, climate change, or changes in agricultural practices may create a different scenario. Furthermore, intentional events (e.g., bioterrorism or agroterrorism) or unintended events (e.g., a foreign arthropod vector escaping from an airplane coming from an endemic country) could result in a new zoonotic disease outbreak.

Besides influenza, other zoonotic diseases are on the emerging watch list, including Nipah virus (Malaysia), hepatitis E from swine (worldwide), variant Creutzfeldt-Jakob disease in the EU and Japan, and Hendra virus in Australia (30).

Zoonotic infectious agents have basic physiologic attributes and ecologic parameters that differentiate them from species-specific human infections. These factors result in characteristic epidemiologic patterns of zoonoses. Understanding these patterns can help the health and safety professional to anticipate, diagnose, and prevent zoonoses on farms and in rural clients and patients.

13.6 General Epidemiologic Considerations of Zoonoses

The following epidemiologic characteristics capsulize the patterns of zoonoses as a human health risk (20, 29).

1. Zoonotic infectious agents typically have a broad potential host range. For example, the bacterium *Francisella tularensis*, which causes tularemia, has been isolated from over 100 mammalian species and numerous other vertebrates. However, many of these species are "accidental hosts" and are not significant in the perpetuation of the disease cycle.
2. Zoonoses often cause severe economic burdens because of the loss of diseased animals, the cost of prevention and eradication programs, and the cost of treating infections in animals or humans.
3. The majority of zoonoses are anthropozoonoses, being maintained primarily by a vertebrate host species other than humans.
4. Animals are often inapparent carriers of zoonotic pathogens. They may be infected sub-clinically, but are infectious and pose a health hazard for humans and other livestock without presenting demonstrable disease.
5. Two primary patterns exist relative to the communicability of zoonotic agents between humans.
   a. Humans are usually dead-end hosts for zoonotic pathogens. They typically do not transmit their infection to other people or animals. Like most cases of agricultural zoonoses, they appear as sporadic cases associated with livestock or their environments.
   b. Animal agents can enter the human population sporadically, but then adapt to become transmissible among humans, resulting in epidemics. Examples include zoonotic influenza A, HIV, Ebola, NIPAH virus, and SARS.
6. Human zoonotic infections typically result in morbidity but rarely in mortality. For example, leptospirosis, brucellosis, histoplasmosis, and Q fever can all cause moderate to severe illness, but if properly treated they rarely lead to death.
7. Many zoonoses have non-specific, variable clinical signs and symptoms that mimick influenza.
8. Specific groups of people have an increased risk of acquiring infection. These risk groups include those with greater than average contact with animals (e.g., farmers, veterinarians, meat-processing plant workers, rural residents, pet owners, or those engaging in outdoor activities).
9. Many zoonotic infections in humans are never diagnosed because they lack specific clinical signs and symptoms or because health and safety professionals lack awareness of these diseases or lack access to adequate diagnostic support. Thus, statistics for the rate of zoonotic diseases in the human population are largely much lower than the actual rate.

Three classification schemes aid in understanding and recognizing zoonoses that present hazards to client/patient populations. Using these schemes can help to manage information on specific zoonotic diseases and focus on the most relevant information.

13.7 Classification of Zoonotic Infections

Zoonotic diseases can be classified in one of three ways: (1) according to the major reservoir of the infectious agent, (2) according to the mode of transmission of the infectious agent among natural host species, and (3) relative to work with different species of livestock and poultry. An understanding of these classification systems can increase comprehension of the natural history of these diseases and thus help the healthcare or safety professional to assess risk, and therefore enhance diagnosis and prevention (27).

Major reservoir zoonotic groupings include zooanthroponoses, anthropozoonoses, and amphixenoses. A *zooanthroponosis* is a zoonotic disease for which humans are the natural hosts of the infectious agent (27). Other vertebrate animals acquire infection through contact with humans, for example dairy farmers infected with *Mycobacterium tuberculosis* can transmit this infection to their cattle.

An *anthropozoonosis*, in contrast, is a disease for which a vertebrate animal species other than a human is the natural host. Humans are then infected through direct, indirect, or vector contact with diseased animals. Most zoonoses that pose a potentially significant human health hazard belong to this group. For example, leptospirosis is primarily a disease of domestic cattle, swine, and numerous wildlife species. If a person becomes infected with leptospirosis, it is almost certain that the organism was obtained from an animal rather than through contact with another human.

Amphixenosis refers to a disease for which humans and other vertebrate species serve equally well as natural hosts. Infections may be transmitted freely between the two types of hosts. It often is difficult to determine if human infections are acquired from animals or other humans. Examples of amphixenoses include infections due to certain strains of *Staphylococcus, Streptococcus, Escherichia coli* and *Salmonella* that are not host-specific. A specific example of concern since 2004 is methicillin-resistant *Staphylococcus aureus* (MRSA). Although human and animal species carry different MRSA strains, they are readily transmitted between human and animal hosts.

Zoonoses can be classified by the primary modes as direct zoonosis, cyclozoonosis, metazoonosis, and saprozoonosis (27). Direct zoonoses requires only one vertebrate species host to maintain the infectious agent. For example, the rabies virus is maintained (primary animal reservoirs vary by geographic region) in wild skunk, bat, raccoon, fox and coyote populations of North America and transmission is by direct contact (usually bite wound) from an infected animal with a susceptible animal. *Cyclozoonosis* refers to a zoonotic disease that requires two or more vertebrate hosts for maintenance of the infectious agent. The tapeworm *Echinococcus granulosis,* for example, is maintained in a cyclical transmission pattern involving sheep who ingest tapeworm eggs passed in the feces of dogs, which then encyst in sheep viscera. The life cycle is completed when dogs ingest the infected tissues of the sheep and adult tapeworms develop in the dogs' intestines.

A *metazoonosis* is an agent that requires both a vertebrate and an invertebrate host for maintenance of the infectious agent, such as Saint Louis encephalitis. A mosquito may maintain the virus temporarily, but it must transmit the virus from an infected vertebrate to a susceptible vertebrate for amplification of the infectious agent.

A *saprozoonosis* refers to a disease caused by an infectious agent that is maintained in a fomite (e.g., soil, water, or another type of inanimate object). Histoplasmosis, for example, is contracted when animals inhale spores from soil with high concentrations of avian or bat feces, where the organism grows.

Hazards associated with different livestock species is the third classification type (15). This classification is subjective and less exacting than those previously mentioned. However, this system is intended to assist the professional to anticipate zoonotic hazards in their practice region associated with different livestock species. Tables 13.1 and 13.2 should be used to create a list of relevant zoonotic hazards in a given practice area to increase awareness of the hazards and develop preventive programs. There are at least 40 zoonoses that are occupational hazards for people who work in agriculture and other occupations involving animal contact. Farmers, veterinarians, packing plant workers, and hair and hide industrial workers are all at risk of acquiring diseases such as brucellosis, ornithosis, anthrax, and contagious ecthyma, among others. Table 31.1 helps to sort the hazards according to farm type.

For example, dairy producers are at risk of zoonotic fungal ring worm, Q fever, and pseudocowpox, while swine producers are at risk of MRSA, *Streptococcus suis*, and *Erysipelothrix rhusiopathiae* infections. Risk classification by livestock production type is not a hard and fast scheme, but it can be a significant help in obtaining a pertinent case history and a differential diagnoses for healthcare providers. A detail of this scheme is seen in Table 13.1.

13.8 Prevention

Prevention of zoonotic diseases in farmers, families, and workers has been described in several articles, including a compendium from the National Association of State Public Health Veterinarians (20, 31-34). The following information and Table 13.3 (seen at the end of this chapter) summarize preventive procedures according to the scientific literature, along with the personal and practical experience of this author (KJD)

Prevention of zoonoses in agricultural operations necessitates a "one health" approach that includes the attending veterinarian, area physician, public health professional, extension agent, safety consultant, and producers. Prevention should include the following elements: (1) keeping livestock and poultry free of disease, (2) sound personal and environmental hygiene, (3) proper use of personal protective equipment, (4) keeping premises clean of potentially disease-carrying/disseminating insect vectors and vermin (e.g., flies, mosquitos, rats and mice), (5) separation of pets (dogs and cats) from livestock (because certain diseases, e.g. salmonella and MRSA, may be transmitted to pigs), and (6) assured farmer, family, and worker wellness. There is not a single specific formula for different types of farms and regions. However, more details about the general principles of prevention are given in Table 13.3.

13.9 Summary

Because zoonotic diseases are difficult to recognize, clinicians must have knowledge of potential zoonotic pathogens in their respective regions. They should have knowledge of the basic ecology of these agents in order to ascertain a proper occupational history and subsequently an assessment of risk for patients/clients, leading finally to a diagnosis and appropriate treatment and prevention. Three possible consultants that are readily available in North America, as well as most developed countries, include local practicing veterinarians, veterinarians in public health sections of colleges of veterinary medicine or colleges of public health, and public health veterinarians at the city, county, or state health departments. Consultants at the national level include public health agencies such as the US National Center for Emerging and Zoonotic Infectious Diseases (4) (or analogous agencies in other countries) and the World Health Organization Zoonoses and the Human-Animal-Ecosystems Interface (9).

Details of specific zoonotic diseases of agricultural occupational significance are given in Tables 13.1 and 13.2. The 31 diseases summarized in these tables represent those diseases with the greatest agricultural occupational significance to those working in agriculture in North America and other developed countries. Table 13.1 groups these 31 zoonoses into six categories according to the occupational risk associated with specific types of livestock production (i.e., swine, dairy cattle, beef cattle, sheep, poultry, and the general rural environment) (15). This classification is based on the experience and judgment of the author (KJD). This classification is not exact as several of these diseases could be contracted from several types of livestock, but it does provide a general guide for the professional by listing primary zoonotic hazards in their own practice region that may help to inform preventive and diagnostic practices.

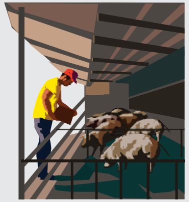
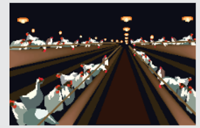
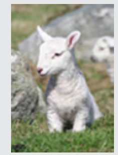
The overall organizing structure is meant to help the reader manage a large amount of information according to exposure. For example, if the reader is dealing with swine producers, there should be only five or six zoonotic disease risks that immediately come to mind, out of the some 40 zoonotic diseases across agriculture that could be occupational diseases.

In Table 13.2 each disease is outlined in terms of the factors necessary to assess risk, establish preventive procedures, and make correct diagnoses. The table includes information on the natural history of the infectious agent, modes of transmission to humans, typical symptoms and signs, questions pertinent to determining a relevant patient history and laboratory confirmation, and prevention strategies. (see Tables 13.1, 13.2, 13.3 following key points).

Key Points

1. Zoonoses are diseases common to animals and humans (includes diseases that have a non-animal common source, such as soil, and those where humans are the main reservoir and can transmit them to animals).
2. Zoonoses are vastly underreported, but they encompass about 64% of all infectious diseases and over 70% of emerging and re-emerging diseases.
3. West Nile virus, swine influenza, avian influenza, MRSA, *Streptococcus suis,* Lyme disease, and Hanta virus are all diseases that have emerged or re-emerged as agricultural/rural hazards in the past two decades. Multiple interactive reasons account for each disease.
4. The reasons for these emergent diseases include increasing human populations, increased international travel, microbial adaptation, increased intensification of livestock production, more wildlife reservoirs (24), and climate change.
5. An example of the above is the emergence of West Nile virus in a New York zoo avian population. It was probably unintentionally transmitted from mosquitoes in the Middle East or Africa, transported in airplanes landing at a New York airport where the mosquito reservoir and vector escaped.
6. The general epidemiologic characteristics of zoonotic infections are (a) a broad potential host range, (b) they are anthropozoonoses, being maintained primarily by a vertebrate host species other than humans, (c) animals are often inapparent carriers of zoonotic pathogens, (d) humans are usually dead-end hosts for zoonotic pathogens, (e) many zoonoses have non-specific, variable clinical signs and symptoms, mimicking influenza, (f) many zoonotic infections in humans are never diagnosed, and (g) risk groups for zoonoses include those with greater than average contact with animals (e.g., farmers, veterinarians, meat-processing plant workers, and rural residents) immunocompromised individuals, children, and people new to the farm environment.
7. Three classification systems of zoonoses help health and safety professionals to manage the large amount of information on zoonotic diseases. Based on the main reservoir host, anthropozoonoses are diseases where animals are the primary host, transmitting the diseases to humans. Zooanthroponooses are diseases in which humans are the primary host, transmitting the disease to animals. Amphizenoses are infections where the primary host and reservoir may be either human or animal.
8. Direct zoonoses are transmitted by direct or close indirect contact. Saprozoonoses are transmitted through soil or another common non-animal source. Cyclozoonoses require at least two hosts to accommodate a developmental stage of the agent. Zoonotic disease hazards can be classified depending on the specific livestock farmed and the practices involved, for example in swine production, swine flu, MRSA (35-44), *Streptococcus suis*, and erysipeloid are occupational hazards. There are different hazards for (a) dairy farms, (b) sheep or goat farms (45), (c) broiler chicken or turkey farms (46, 47), and (d) chicken egg-laying operations.
9. The following Tables 13.1, 13.2, and 13.3 provide details of specific agricultural zoonotic hazards and prevention.

Table 13.1 Agricultural occupational zoonotic disease hazards and estimated relative risk[a] (1, 4-7)

Infectious agent/disease	Swine	Beef cattle	Dairy cattle	Poultry	Sheep and goats	Rural environment
Bacterial agent				 	 	
Anthrax	+[b]	+++	++	**0**	++	+**0**
Brucellosis	++	++	+++	**0**	++	**E** (feral swine)
Collibabacillosis (*E. coli*)	++	+	++	+	+	**E (contaminated well water)**
Erysipeoloid (*Erysipelothrix rhusiopathiae*)	+++	**0**	**0**	**0**	**0**	++**0**
Leptospirosis (*Leptospira interrogans*)	++	+++	++	**0**	**0**	++**E** (swimming in farm ponds, streams)
Lyme (*Burellia burgdorferi*)	**0**	**0**	**0**	**0**	**0**	++**E** (tick vector)
Methicillin-resistant *Staphylococcus aureus* (MRSA)	+++	+	++	+	**0**	+**E** (air inside/outside livestock buildings)
Streptococcus suis	+++	**0**	**0**	**0**	**0**	**0**
Salmonellosis	++	++	++	+++	+	**0**
Tetanus (*Clostridium tetani*)	**0**	**0**	**0**	**0**	**0**	++**E** (soil)
Tularemia (*Fransicella tularensis*)	**0**	**0**	**0**	**0**	+++	++**E** (biting flies, ticks, small rodents, rabbits)

Tuberculosis (*Mycobacterium tuberculosis, M. bovis*)	**0**	+	++ (rare in developed countries, contact with infected cattle and drinking unpasteurized milk)	**0**	**0**	**0**
Viral agents						
Arthropodborne encephalitis, West Nile virus, eastern equine encephalitis (EEE), western equine encephalitis (WEE)	**0**	**0**	**0**	**0**	**0**	**++E** (all mosquito borne)
Hanta virus	**0**	**0**	**0**	**0**	**0**	**+E** (aerosolized fecal dust, small feral rodents)
Argentinian hemorrhagic fever	**0**	**0**	**0**	**0**	**0**	**+++E** Argentina field mouse reservoir
Hepatitis E	++	**0**	**0**	**0**	**0**	**+E** (potential contaminated water from swine operations)
Influenza A	+++ (strains H_1N_1, H_1N_2, H_3N_2, H_7N_9)	**0**	**0**	+++ (strains H_5N_1, H_7,N_7, H_7N_3, H_9N_2,H_7N_2)	**0**	**+E** (reservoir in wild migrating water fowl)
NIPAH virus (only in Malaysia, Bangladesh, and other South-East Asian countries)	++ (not currently seen in swine)	**0**	**0**	**0**	**0**	**+E** (reservoir in fruit bats)
Contagious ecthyma or Orf (pox virus)	**0**	**0**	**0**	**0**	+++	**+E** (contact with sheep/ goat housing)

(*Continued*)

Table 13.1 (Continued)

Infectious agent/disease	Swine	Beef cattle	Dairy cattle	Poultry	Sheep and goats	Rural environment
Pseudocowpox (worldwide) and cowpox (Europe)	**0**	+	+++	**0**	**0**	**0**
Rabies (Lyssa virus)	+	+++	++	**0**	**0**	**++E** (bats, skunks, raccoons, fox)
Rickettsial agents						
Q fever	**0**	+	+++	**0**	+++	**++E** (contact with sheep housing)
Rocky Mountain spotted fever	**0**	**0**	**0**	**0**	**0**	**++E** (tick vector)
Ornithosis (*psittacosis*)	**0**	**0**	**0**	++ (mainly a concern in poultry-processing plant workers)	**0**	**0E** (wild migrating birds a possible reservoir for range-raised turkeys)
Parasitic agents						
Hydatid disease (*Echinococcus grnaulosis*)	**0**	**0**	**0**	**0**	**0**	**+E** (ingestion of infected canine feces)
Visceral larval migrans *Ascaris lubricoides* (swine) *Procyonis ballisascaris* (raccoons) *Toxicara* species (dogs and cats)	+++ (ingestion of swine feces infected with *Ascaris lumbricoides*)	**0**	**0**	**0**	**0**	**++E** (ingestion of dog, cat, or raccoon feces)

Dermatophytes or fungal ring worm	**+** (*Microsporu nanum*)	**++** (*Trychophyton verrucosum*)	**+++** (*Trychophyton verrucosum*)	**0**	**+** (*Trychophyton verrucosum, Microsporum canis, M. gypseum)*	**+E** (contact with cattle housing)
Soil/fecal origin fungal agents						
Histoplamosis, Blastomycosisi, Coccidiomycosis, Norcardiosis	0	0	0	0	0	**++E** (soil or soil contaminated with old avian or bat feces)

[a] There is no "official" publication quantifying the relative risk of agricultural zoonoses. The hazards listed here are based on analysis of science-based information and the author's (KJD) experience and judgment.
[b] Zoonoses are listed under the livestock species posing a relative high degree of occupational hazard for farm workers.
+++ Relatively high hazard. Primary livestock operation source for worker exposure.
++ Relatively moderate hazard. Other possible/secondary livestock source for worker exposure.
+ Relatively low hazard. Probably not an animal source.
E Environmental source (e.g., soil or insect vector).
0 Not a known hazard. Not a known animal or environmental source of infection.

Table 13.2 A guide to 31 zoonotic infectious occupational hazards in agriculture[1] (1, 4-7)

Disease (Common names)	Etiologic agents	Health effects (A) Human (B) Animal	Animal hosts (A) 1. Zooanthroponosis[1] 2. Anthropozoonosis[1] 3. Amphixenosis[1] (B) Specific animals infected	Mechanisms of transmission (A) Reservoir (B) 1. Direct-zoonosis[2] 2. Meta-zoonosis[2] 3. Sapro-zoonosis[2] 4. Cyclo-zoonosis[2] (C) Specific mechanisms	Epidemiology (A) Populations at risk (B) Geographic distribution	Treatment	Control and prevention
			Bacterial infections				
Anthrax (malignant pustule, wool sorter's disease)	*Bacillus anthracis*	(A) Localized skin lesions usually on hands or arms Pulmonary form less common but much more severe with high case fatality rate Gastrointestinal form is least common (B) Usually overwhelming bacteremia and septicemia with rapid death in cattle, sheep, and goats Less acute in horses, pigs, and dogs	(A) 2 (B) Cattle, sheep, goats, horse, pig, dog	(A) Soil Water (stagnant ponds near incubator areas) (B) 1, 3 (C) Direct contact with infected animals, their carcasses, body parts, animal fertilizers or feeds Inhalation of spores from hair or hide of infected animals Consumption of improperly cooked meat from infected animals	(A) Sheep and goat producers Cattle producers Veterinarians and other animal health workers Hair and hide processors Abattoir workers (B) Worldwide in endemic foci May be transported to distinct locations with hair and hides from infected animals	1. Penicillin and its derivatives 2. Ciprofloxacin 3. Doxycycline 4. Fluroquinolones	1. Vaccination of animals in endemic areas 2. Personal protection when handling potentially infected animals or tissues 3. Animals that have died from anthrax do not necropsy, deep burial of unopened carcass and covered with lim 4. Vaccination of humans at high risk (limited availability, mainly military personnel)
Brucellosis (undulant fever, Malta fever, Bangs disease)	*Brucella abortus* *B. suits* *B. melitensis* *B. canis*	(A) Generalized prolonged influenza-like illness, spiking fevers, myalgia, malaise Occasional chronic forms include lesions of heart valves, abscesses of bone, liver, or other body parts (B) Abortions Possible chronic infections of lymph nodes, urogenital, bone and other tissues	(A) 2 (B) Cattle, swine, sheep, goats Less common are dogs, camel, deer, and buffalo Wildlife reservoirs in United States are bison, elk, wild pigs	(A) Cattle, swine, sheep, goats, dogs (each have primary species of *Brucella*) Other susceptible animals less important (B) 1, possibly 2 (C) Direct contact with infected animals or their tissues, especially placenta and abortion products Ingestion of unpasteurized milk and cheese products from infected animals Possible airborne transmission	(A) Cattle, swine sheep, goat producers primarily Abattoir workers Feral hog hunters (B) Worldwide, especially in dairy areas Rare today in industrialized countries due to eradication program In United States feral swine, elk, and bison in Yellowstone area of Wyoming	1. Children: trimethoprim sulfamethoxazole, 21 days aminoglycosides, 21 days 2. Adults: doxycycline + rifampin, 30 days	1. Eradication of disease in the primary livestock species (several countries have established such programs) 2. Personal protection when handling feral hogs or other potentially infected animals, especially following abortion Sanitation of the animal environment Pasteurization of milk products
Colibacillosis hemolytic uremic syndrome (HUS)	*Esherichia coli*	(A) Gastroenteritis mainly Possible wound infections or abscess Cystitis 0157:H7 strain, possible toxic-renal syndrome (B) Gastroenteritis mainly Possible wound infections or abscess	(A) 1, 2, or 3, depending on specific strain (B) All livestock species, most mammals feral or domestic 0157:H7 strain in cattle	(A) Animals are the reservoir for some strains, humans for some, and both humans and animals for other strains (B) 1 (C) Direct or indirect contact with infected animal and waste Accidental ingestion of organism via hand-to-mouth contact or ingestion of contaminated food or water	(A) Livestock and poultry farmers Petting zoos General public food and water (B) Worldwide	1. Neomycin 2. Chloromycetin 3. Gentamycin	1. Excellent personal and environmental sanitation 2. Vaccinate animals with autogenous bacterin.

Erysipeloid (pork finger, fish finger, swine erysipelas)	*Erysipelothrix rhusiopahtiae*	(A) Skin, soft tissue lesions with regional lymphadenitis, pain and swelling Possible local spread of lesions from primary site Possible endocarditis and or brain abscess (B) Acute-septicemia with high fever, skin lesions and death loss Chronic-polyarthritis myocarditis	(A) 2 (B) Swine mainly Also chickens, turkeys, and sheep Also found in slime layer on fish	(A) Animals: swine, sheep, chickens, turkeys Environmental: soil, slime layer on fish (B) 1, 3 (C) Direct contact: contamination of a cut or break in skin with soil or infections materials from animal or tissues	(A) People raising or handling swine, sheep, or poultry Abattoir workers and meat cutters Fish-processing workers (B) Worldwide	Beta-lactams (e.g., penicillin, augmentin) Cephalosporins, 21 days	1. Control by swine vaccination, adding only erysipelas-free animals to the herd 2. Humans: proper treatment of cuts and wounds 3. Environmental sanitation 4. Abattoir workers: protective gloves, proper treatment of cuts, environmental sanitation
Leptospirosis (Weil's disease, swine herd's disease, swamp fever, mud fever)	*Leptospira interrogans* Many different serovars involved	(A) Generalized febrile, influenza-like illness of variable severity Mild cases: malaise, myalgia, symptoms of meningitis, vomiting Severe cases: hepatorenal involvement, jaundiced, case fatality ratio 20–40% (B) Abortion Hepto-renal involvement with jaundice, possible kidney failure Healthy carriers are common	(A) 2 (B) Cattle, swine, and the main livestock species infected Sheep and goats less common Dogs, rats Wildlife, including squirrels, raccoons, mice, shrew, bandicoot, fox, jackals, hedgehogs	(A) Cattle, swine, rats mainly, but most other susceptible animals also Water, muddy soil (B) 1, 3 (C) Direct and indirect contact with urine from infected animals Contact with blood or abortion products of infected animals Contact with water contaminated with urine from infected animals	(A) People working with cattle or swine People working in rice paddies contaminated by urine of infected animals Abattoir workers People swimming in contaminated water Hunters and trappers (B) Worldwide, specific serovars vary with locality	1. Aminoglycoside (e.g., streptomycin), 21 days 2. Tetracycline (e.g., doxicycline), 21 days	1. Control infection in livestock with good environmental sanitation, immunization, and proper veterinary care 2. Prevent infected animals from urinating in water where humans have contact 3. Personal protection of workers when handling infected animals or tissues 4. Rodent control
Lyme disease	*Borrelia burgdorferi*	(A) Variable systemic disease with skin lesions at tick bite site Acute influenza-like symptoms may be followed by cardiac and neurological symptoms, which may be followed by chronic arthritis and neurological symptoms (B) Most species asymptomatic Dogs may have severe arthritis	(A) 2 (B) Several small rodent species, deer, and dogs	(A) Small wild rodents, *Peromyscus leucopus* (deer mouse) in North America) Several species of Ixodes ticks (B) 2 (C) Tick bites from Ixodes ticks	(A) People working or spending time outdoors in endemic regions (B) Western and eastern Europe, Australia, Asia, North America	1. Doxicycline, 200–400 mg/day for 17 days 2. For chronic cases: ceftriaxone for 6 months	1. Avoid tick bites 2. Wear protective clothing, pant legs tucked into socks or boot tops 3. DEET insect repellant (can use up to 100% DEET) 4. Body and hair inspection when returning from endemic areas

(*Continued*)

Table 13.2 (Continued)

Bacterial infections							
Disease (Common names)	**Etiologic agents**	**Health effects** (A) Human (B) Animal	**Animal hosts** (A) 1. Zooanthroponosis[1] 2. Anthropozoonosis[1] 3. Amphixenosis[1] (B) Specific animals infected	**Mechanisms of transmission** (A) Reservoir (B) 1. Direct-zoonosis[2] 2. Meta-zoonosis[2] 3. Sapro-zoonosis[2] 4. Cyclo-zoonosis[2] (C) Specific mechanisms	**Epidemiology** (A) Populations at risk (B) Geographic distribution	**Treatment**	**Control and prevention**
MRSA	Methicillin-resistant *Staphylococcus aureus*, livestock-associated strain, ST398	(A) Livestock strains of low virulence in humans Mostly sub-clinical, possible skin lesions, abscesses, rarely lung and other distant infections (B) Mainly sub-clinical carriers in pigs, mastitis in dairy cows, skin lesions mainly in other animals	(A) 3 (B) Livestock-associated strain ST 398, pigs, cattle, poultry, horses mainly	(A) Humans, pigs, cattle, poultry, horses (B) 1, possibly 2 (C) Direct close contact, aerosol from contaminated dusts inside or outside livestock buildings	(A) Livestock workers mainly with swine and to a lesser extent all other live-stock or poultry species (B) Europe, North and South America, most coun-tries around the world where it has been looked for	1. Effective antibiotics include linezolid, vancomycin, and rifampin 2. For decolonization, bactrim for nasal swab 3. Note that most ST398 strains are resistant to tetracyclines	1. Screen new workers for nasal carriage before entry into swine facilities 2. Use of carrier-elimination treatment before new workers enter buildings 3. Practice highly hygienic biosecurity protocols, including sanitized shower facilities, towels, and work clothes
Salmonellosis	*Salmonella typhimurium* (2000 serotypes)	(A) Gastroenteritis of variable severity depending on dose and virulence of specific organism May produce bacteremia and septicemia (B) Gastroenteritis Bacteremia and septicemia possible in severe cases Often infected but show no symptoms	(A) 1, 2, and 3 (depend-ing on the strain) (B) Dairy animals and poultry are particularly important in agriculture All livestock and most mammalian and amphibian species are susceptible Poultry deserve special mention	(A) Fecal oral in gastrointestinal tract of most livestock species Water, soil contaminated with animal waste (B) 1 or 3 (C) Direct or indirect contact with infected animals or their environment Consumption of unpasteurized milk Meat, milk, or egg foods Animal food products	(A) Livestock workers, particularly dairy Those who drink unpasteurized milk or consume improperly prepared or stored animal food products (B) Worldwide	1. Neomycin 2. Chloromycetin 3. Gentamicin	1. Practice sound animal hygiene and management 2. Detection and eradication of mastitis in dairy herds 3. Pasteurization of milk 4. Sanitary preparation and storage of animal food products 5. Prudent use of antibiotics to prevent resistant infection
Pig streptococcus	*Streptococcus suis*	(A) Skin infections, possible fatal meningitis (B) Skin infections, highly fatal meningitis in young pigs	(A) 2 (B) Carrier sows	(A) Carrier sows (B) 1 (C) Direct or close indirect contact	(A) Swine producers and workers, especially in farrowing facilities. (B) North America and Europe	Treat with beta-lactams (penicillin group)	1. Screen new sows coming in to the herd 2. Segregate and treat those positive 3. Screen workers for nasal carriage before entry into swine facilities 4. Practice hygienic biosecurity practices 5. Clean, treat with topical antibiotics, and cover skin abrasions and cuts occurring within the environment

Tetanus (lockjaw)	*Clostridium tetani*	(A) Tonic clonic convulsions Spastic contraction of skeletal muscles Respiratory failure Death (B) Hyperirritability of central nervous system Tonic clonic Spastic paralysis Death	(A) NA (B) Sheep and horses mainly Other animals more resistant	(A) Soil Large intestine of herbivores and to a lesser extent carnivores (B) 3 (C) Wound contamination with soil or feces contaminating spores, anaerobic conditions in wound required for organism to germinate and produce toxin	(A) Punctures or deep cut wounds, especially in areas where herbivore animals were raised Infants with umbilical infections of unvaccinated mothers (B) Worldwide	1. Debride, clean wound 2. Antitoxin + tetanus toxoid if previously unimmunized 3. Penicillin or devivatiues 4. Anticonvulsants for seizures	1. In humans: proper treatment of open wounds to prevent infection 2. Immunizations (every 10 years) with tetanus toxoid, repeat following severe exposures if last toxid longer than 5 years (see Table 11.6)
Tularemia (rabbit fever)	*Francisella tularensis*	(C) Four forms: ulceroglandular-most common form, localized wound infection with generalized symptoms, cellulitis with regional lymphadenitis Oculoglandular: severe conjunctivitis with regional lymphadenitis	(A) 2 (B) Infections found in 125 species of invertebrates: ticks, mosquitoes, deer flies, horse/sheep flies, fleas Sheep are most important for agricultural exposure	(A) Sheep Infected mammals Ticks and other blood- sucking arthropods Contaminated water (B) 1, 2, and 3 (C) Handling infected sheep Bites from blood-sucking anthropoids, mainly horse and deer flies	(A) Sheep ranchers, shearers, and handlers Outdoor occupation or recreation where exposure to blood-sucking arthropods is common Hunters, trappers (B) North America Mexico	1. Aminoglycoside (e.g., streptomycin), 7.5–15 mg/15g for 21 days 2. Alternatives: ciprofloxacin, doxicycline	1. Personal protection (gloves and dust mask) when handling potentially infected sheep or wild mammals 2. Avoid drinking untreated surface water from ponds and streams
		(A) Pulmonary pneumonia with severe generalized symptoms Typhoidal gastro-enteritis, fever, toxemia, ulcers in mouth, pharynx and esophagus (B) Varies according to species, some rodents and lagomorphs are most susceptible, prolonged generalized illness fatal septicemia Sheep, other rodents and birds have intermediate susceptibility with non-fatal generalized illness Carnivores have low susceptibility, usually with sub-clinical infection are sheep and arthropods	Other important exposures are lagomorphs and small rodents (rabbits and muskrats are important reservoirs for hunters and trappers) Contaminated water in endemic areas	Handling infected rodents, lagomorphs (hunters and trappers) Consumption of water from a stream or pond Possibly inhalation Cat bites	European continent Turkey Iran China Japan		1. Thoroughly cook mean from small wild mammals 2. Wear gloves when handling or cleaning small wild mammals

(*Continued*)

Table 13.2 (Continued)

			Bacterial infections				
Disease (Common names)	**Etiologic agents**	**Health effects** (A) Human (B) Animal	**Animal hosts** (A) 1. Zooanthroponosis[1] 2. Anthropozoonosis[1] 3. Amphixenosis[1] (B) Specific animals infected	**Mechanisms of transmission** (A) Reservoir (B) 1. Direct-zoonosis[2] 2. Meta-zoonosis[2] 3. Sapro-zoonosis[2] 4. Cyclo-zoonosis[2] (C) Specific mechanisms	**Epidemiology** (A) Populations at risk (B) Geographic distribution	**Treatment**	**Control and prevention**
Tuberculosis (TB)	*Mycobacterium bovis* and *M. tuberculosis*	(A) Chronic (B) Granulomatous Pneumonia or granulomas of intestinal mesenteric lymph nodes, leads to a chronic debilitating condition	(A) 3 (B) Mainly dairy cattle, usually asymptomatic	(A) Cattle, wild bison, and elk are reservoirs for *M. bovis* in North America Badgers are reservoirs in the UK Humans are reservoirs for *M. tuberculosis* (B) 1 (C) Aerosol from exhalation of an infected animal, drinking unpasteurized milk from an infected animal	(A) Dairy farmers, dairy workers Consumers of raw milk and milk products (B) Decreasing with eradication programs in developed countries, otherwise common worldwide	In humans a combination of the following is recommended: ethambutol, isoniazid, pyrazinamide,;rifampin, rifapentine	1. The eradication program needs to continue in most countries 2. Program tests cattle for TB, and removes them from the herd if positive result found 3. Pasteurize milk
Zoonotic viral infections							
Arbovirus encephalitis West Nile virus (WVN) Eastern equine encephalitis (EEE) Western equine encephalitis (WEE) Venezuelan equine encephalitis (VEE)	Flavivirus Togavirus Togavirus	(A) Influenza-like illness of variable severity, WNV and EEE are most severe Encephalitis and neurological disease most common with WNV and EEE VEE not a concern for humans (B) Most animal species are asymptomatic, except WNV is fatal to a wide variety of avian species Horses may be severely affected by WNV, EEE, WEE, and VEE	(A) 2 (B) A variety of avian species Horses for WNV, EEE, WEE, and VEEE	(A) Several species of mosquitoes WNV: most birds are susceptible, often fatal in crows and related birds EEE, WEE, VEE, and SLV infect various wild ground-nesting birds, who remain sub-clinical reservoirs (B) 2	(A) Anybody spending time outdoors in endemic areas (B) WNV: Africa, EU, North America EEE, WEE:	1. Supportive treatment 2. Acyclovir or ribivirin if used early in the disease course 3. Corticosteroids to reduce brain swelling	1. Mosquito control 2. Protection from mosquitoes: 3. covered clothing DEET repellant avoid being outside at dusk 4. Horses can be vaccinated for WNV, EEE, and WEE
Contagious ecthyma (Orf)	Pox virus	(A) Skin lesions on hands and arms Start out as small papules, progress to large vesicles which then ulcerate Last 4–8 weeks (B) Vesicular lesions in the mouth and on the lips	(A) 2 (B) Sheep mainly, but also goats also	(A) Sheep Goats The animal environment (e.g., animal sheds, feed bunks, etc.) (B) 1, 3 (C) Direct contact with infected animals or their environment, especially handling and examining infected animals	(A) People raising or handling sheep or goats, especially young animals (B) Worldwide where sheep are raised	Symptomatic, wound protection, topical antibiotics to prevent bacterial infections	1. Isolation of infected animals 2. Wearing protective gloves when handling or treating infected animals or working in their environment 3. Practice excellent sanitation of the animal environment 4. Vaccine (live attenuated) available for sheep and goats, but the vaccine will cause Orf-like lesions in persons accidently exposed to it

Hepatitis E	Calici virus	(E) Similar to hepatitis A Mild to moderate febrile illness Children and pregnant women at an increased risk (25% case fatality)	(A) 2 (B) Pigs and humans	(A) Pigs feces – oral route (B) 1, 2	(A) Anyone with exposure to pigs or contaminated drinking water (B) Mainly in developing countries Also in United States and Mexico	No known treatment	Sanitation in pig production and in people working with pigs, e.g. hand washing
Hanta virus Pulmonary syndrome (HVPS), Renal syndrome (HVRS)	Bunya virus (various strains)	(C) HVPS: variable severity Influenza-like then pulmonary edema, 38% case fatality HVRS: initial influenza-like followed by hypotension, varying degrees of renal failure	(A) 2 (B) Various species of wild rodents (rats and mice) Deer mouse is a common carrier	(A) Species of wild rats and mice Asymptomatic life-long carriers (B) 1 (C) Aerosol transmission via rodent droppings, food contamination by rodent feces, urine, and saliva	(A) Farmers, loggers, outdoor recreation, cleaning out rodent nests or working in areas contaminated by rodent droppings (B) EU countries, North and South America, eastern Europe, Asia	1. Symptomatic, often critical care treatment 2. Antiviral (ribavirin) helpful if started early	1. Reduce habitat for feral rodents where humans live 2. Personal protection when cleaning where rodents have been (gloves, respirator) 3. Use hypochlorite sanitization solution to clean and control dust
Venezuelan hemorrhagic fever (VHF)	Guanarito virus GTOV) of the Arenaviridae family	(A) One of the group of hemorrhagic fevers 30% case fatality if untreated (B) No known animal health concerns	Local field mouse host and reservoir (short-tailed cane mouse)	Inhalation of aerosolized droplets of saliva, respiratory secretions, urine, or blood from infected rodents	Mainly in the western states of Argentina Field workers exposed following crop harvest	Ribavirin IV is helpful, along with symptomatic treatment and IV fluids	1. A dust mask and rubber gloves would be helpful at time of crop harvest when handling crop residue 2. Although experimental vaccines have been prepared, no approved vaccines are available at this time
Influenza (grippe)	Myxovirus Influenza A Swine strains that have infected humans: N_1N_1, N_1N_2, N_3N_2, H_7N_9 Avian strains that have infected humans: H_5N_1, H_7N_7, H_7N_3, H_9N_2, H_7N_2	(A) Variable effects depending on virulence of the specific strain Swine and avian strains transmissible to humans, avian strain more severe in humans (B) Mild to severe upper respiratory illness with generalized symptoms Wild avian (ducks and geese) asymptomatic carriers	(A) 1, 2, or 3 (the various interrelationships are not completely understood) (B) Swine, horses, poultry, domestic and wild ducks and geese Swine may serve as mixing vessels which allow creation of new human communicable strains	(A) Infected animals The specific roles of swine, horses, and birds as reservoirs of influenza for humans are yet to be determined (B) 1, possibly 4 (C) Direct contact, primarily respiratory droplet from infected animals	(A) Swine handlers primarily, persons working with poultry (B) Worldwide	1. Supportive/ symptomatic 2. Antiviral agents, e.g. amantadine, rimantadine	1. Provide excellent sanitation in the animal environment, including ventilation: vaccinate horses swine vaccine separate housing of poultry and swine prevent contact between feral avian and domestic avian species and swine 2. Swine workers should receive annual seasonal influenza vaccinations

(*Continued*)

Table 13.2 (Continued)

Bacterial infections							
Disease (Common names)	**Etiologic agents**	**Health effects** (A) Human (B) Animal	**Animal hosts** (A) 1. Zooanthroponosis[1] 2. Anthropozoonosis[1] 3. Amphixenosis[1] (B) Specific animals infected	**Mechanisms of transmission** (A) Reservoir (B) 1. Direct-zoonosis[2] 2. Meta-zoonosis[2] 3. Sapro-zoonosis[2] 4. Cyclo-zoonosis[2] (C) Specific mechanisms	**Epidemiology** (A) Populations at risk (B) Geographic distribution	**Treatment**	**Control and prevention**
Milker's nodules (paravaccinia)	Paravaccinia subgroup of pox virus	(A) Wart-like nodules on the skin of hands and forearms (B) Nodules on the teats and udders of cows	(A) 2 (B) Cattle	(A) Infected cattle (B) 1 (C) Direct contact with teats and udders of cows with active lesions Hand milking or washing the udder and teats prior to machine milking are primary exposures	(A) Dairy cow milkers and handlers (B) Europe and the United States	1. No specific treatment 2. Treat/prevent secondary bacterial infections with topical antibiotics	1. Separation of infected animals 2. Protective gloves when milking or treating infected cattle
Newcastle disease (in poultry synonyms are pseudo-fowl pest, pneumoencephalitis)	Paramyxovirus	(A) Conjunctivitis Occasionally mild influenza-like illness (B) Disease varies depending on the specific virus strain Three main forms: mild respiratory illness respiratory form with nervous involvement in chicks severe highly fatal pneumonencephalitis	(A) 2 (B) Chickens primarily, turkeys also Many other avian species may be infected but are primarily asymptomatic	(A) Infected avian species, domestic or wild (B) 1 (C) Direct or indirect contact with infected birds, their environment, or their tissues Direct contact with Newcastle vaccines in water or aerosolized	(A) Poultry workers Those who administer aerosol vaccines to chicken flocks Poultry-processing plant workers (B) Worldwide	1. Symptomatic 2. Avoid sunlight 3. Anti-inflammatory/antibiotic eye drops	1. Most developed countries have eradicated the severe form and have programs to keep it out of the country 2. Outbreaks do occur and a test and slaughter program is invoked 3. Effective vaccines are available, but they can infect workers 4. Protective clothing and full face respirators should be used when handling sick birds or vaccine 5. Practice good sanitation and personal hygiene in poultry-processing plants
Nipah virus	Virus of the para-myxoviridae family, related to Hendra (a zoonoses of horses in Australia)	(A) Initial influenza-like progresses to encephalitis 40–70% case fatality (B) High morbidity in swine herds, but low mortality Respiratory symptoms	(A) 1 (B) Pigs, fruit bat (*Pteropodidae* spp.)	(A) Fruit bats (*Pteropodidae* spp.) (B) 1 (C) Pigs to people by virus in urine and respiratory secretions Fruit bats to pigs by virus in saliva and urine or by handling or eating virus-contaminated fruit	(A) Swine farmers and family (B) Outbreaks in Malaysia and Bangladesh	No specific treatment known, symptomatic and palliative	1. Eradication of infected swine 2. Limiting exposure of pigs to flying bats

Rabies	Rhabdovirus	(A) Progressive encephalitis with personality changes and hyperactivity to external stimuli resulting in spastic contractions of skeletal muscles, usually resulting in dysphasia, respiratory failure, and death (B) Variable encephalitis depending on species, but usually behavior changes, paralysis of muscles of mastication, death	(A) 2 (B) Many species of domestic and wild mammals Mainly cattle and horses as agricultural risk sources Species of canidae, mustecidae, and viveridae	(A) Reservoirs vary depending on geographic location, include skunks, bats, and raccoons of North America, foxes in EU (B) 1 (C) Direct contact via bite wound or contamination of pre-existing wound with saliva Aerosol transmission is rare	(A) Animal handlers working with bovine and equine species Agricultural workers in outdoor areas where disease is endemic Unvaccinated cats and dogs on farms can be secondary sources having acquired rabies from a wild animal population (B) Occurs in most areas of the world except Australia and most islands in the Caribbean and Hawaii	1. Post-exposure immunization for exposed 2. Thorough washing of bite wounds with soap and water	1. Vaccination of pets and livestock 2. Removal of reservoir host 3. Pre-exposure vaccination of people at high risk
Zoonotic ricketsial infections							
Rickettsia, Q fever (query fever)	*Coxiella burnetti.*	(A) Generalized febrile illness with pneumonitis Possible endocarditis Possible abortion Case fatality rate < 10% (B) Often asymptomatic May cause abortion, especially in sheep	(A) 2 (B) Cattle, sheep, goats Many small wild animal species	(A) Cattle, sheep, goats Ticks Several species of small wild mammals (B) 1, 3 (C) Inhalation of airborne organisms in dust Direct contact with infected animals, particularly placenta and placental fluids Consumption of raw milk	(A) Farmers and farm workers in contact with animals or cleaning up the animal environment or assisting at birthing of calves or lambs (B) Worldwide	1. Tetracycline (e.g., doxicycline) 2. Fluroquinolones (e.g., difloxacin or ciprofloxacin)	1. Personal protection when handling potentially infected animals (especially during parturition) 2. Respiratory protection when working in a dusty environment potentially contaminated with the organism 3. Immunization
Psittacosis (ornithosis, fowl chlamydiosis)	*Chlamydophila psittaci* (formerly *Chlamydia psittaci*)	(A) Variable depending on strain Generalized febrile illness with headache, constipation, and pneumonitus (B) General latent or subclinical Under stress symptoms may be seen, including depression, emancipation, and respiratory distress	(A) 2 (B) Turkeys primarily Also ducks, geese, and chickens also Psittacine birds Many species of wild birds who flock (starlings, pigeons etc.)	(A) Subclinically infected poultry, psittacine birds, and many species of wild birds (B) 1 (C) Direct contact with infected birds, their tissues or fecal material via direct contact of mucous membranes, or inhalation	(A) People raising and handling poultry, particularly turkeys Poultry-processing plant workers People handling psittacine birds (B) Worldwide	1. Tetracycline (e.g., doxicycline) 2. Erythromycin (14 days)	1. Personal protection when handling infected birds, their environment, or their carcasses 2. Eliminate carrier state by feeding birds tetracycline 3. Screen animals before they enter processing plant 4. Personal protection for poultry-processing workers

(*Continued*)

Table 13.2 (Continued)

Bacterial infections							
Disease (Common names)	**Etiologic agents**	**Health effects** (A) Human (B) Animal	**Animal hosts** (A) 1. Zooanthroponosis[1] 2. Anthropozoonosis[1] 3. Amphixenosis[1] (B) Specific animals infected	**Mechanisms of transmission** (A) Reservoir (B) 1. Direct-zoonosis[2] 2. Meta-zoonosis[2] 3. Sapro-zoonosis[2] 4. Cyclo-zoonosis[2] (C) Specific mechanisms	**Epidemiology** (A) Populations at risk (B) Geographic distribution	**Treatment**	**Control and prevention**
Echinococcosus (hydatid disease)	Echinococcus granulosus	(A) Chronic-progressive space-occupying lesions of the liver, lung, or other body organs Symptoms vary depending on type and extent of tissue involvement Anaphylactic shock may occur if the echinococcus cyst ruptures (B) Sheep, goats: space-occupying lesion of liver, lung, brain, or other tissue Usually fatal over a long period Dog (primary host) asymptomatic or mild enteritis	(A) 2 (B) Sheep, goats, and a few wild ruminants are secondary hosts Several species of candiae are primary hosts	(A) Maintenance depends on transmission cycle between sheep and dog (B) 4 (C) Dog eats infected tissue of sheep, adult tapeworm develops in gut of dog, eggs shed in dog feces, humans pick up eggs via fecal–oral route	(A) Sheep herders, sheep handlers, especially those that keep dogs (B) Western United States Latin America Mediterranean coast countries Southern Russia Middle East Kenya Australia New Zealand	1. Surgery to remove cysts 2. Repeated aspiration and injection of cyst with anthelmintics such as mebendazole or niclosamide	1. Control depends on breaking the dog–sheep cycle 2. Eliminate parasite from dogs with parasiticides 3. Avoid dogs with possible infections 4. Avoid feeding tissues of infected sheep to dogs by sanitary disposal of dead sheep and offal
Zoonotic parasitic infections							
Trichinosis	*Trichinella spiralis*	(A) Flu-like illness with fever, periobital edeima (B) Asymptomatic	(A) 2 (B) Pigs, bears, sea mammals	(C) Infected meat of pigs, bears, and sea mammals	(D) Those consuming improperly cooked or frozen pork, bear meat, or sea mammal meat	Usually no treatment required	1. No feeding of pigs with any feed (including garbage) that may contain pork) 2. Rodent control around swine 3. Properly cook/freeze pork
Visceral larval migrans	Swine intestinal roundworm (*Ascaris lumbricoides*) and raccoons (*Baylisascaris procyonis*) Canine and feline roundworm (*Toxocara canis*, *T. cati*, and *T. leonina*)	(A) Meningitis, infection of the eye, heart muscle, and brain are three of the major health outcomes *B. procyonis* is more severe than *A. lumbricoides* (B) Mild symptoms of loss of weight and unthrifty appearance	(A) 2 (B) Mainly swine and raccoons for agricultural worker hazards, although most animal species, including dogs, have roundworms that may cause human illness	(A) Swine, raccoons, dogs (B) 3, 4 (C) Eggs are passed in the feces of infested animals Humans accidently ingest these eggs, which hatch out and immature worms migrate through the body tissues Illness depends on where the worms migrate and how many migrate	(A) Workers with swine Working in the environment where dogs or raccoons defecate (which can be in many buildings on a farm) (B) Swine *A. lubricoides* is worldwide *B. procyonis* human infections have been reported in Europe and North America	Treatment is with the parasiticide albendazole or drugs of similar category	1. Regular worming of swine, especially if they are on ground rather than cement or slatted floors 2. Locating and removing raccoons from farm buildings, and sanitary removal of their feces (which they deposit in common locations) 3. Use of a respirator and rubber gloves when handling raccoon feces is important 4. The feces should be deeply buried or burned

Blastomycosis South American blastomycosis Coccidioidomycosis	*Blastomyces dermatiditis* *Paracoccidioides brasiliensis* *Coccidioides immitis*	(A) Variable illness similar to other deep mycoses Generalized illnesses with pulmonary involvement South America form more likely to have skin lesions (B) Dogs most likely to be affected with generalized symptoms and pulmonary involvement	(A) NA (B) Humans, dogs, many other species	(A) Soil (B) 3 (C) Inhalation of soil or bird or bat feces	(A) Anybody working in endemic areas where soil is aerosolized (B) *B. dermatiditis*: south/central Canada, Midwest United States, Central and South America, Western Europe *P. brasiliensis*: Latin America *C. immitis*: south-west United States	Itraconazole 200–400 mg/day for 6 months or ketoconazule or amphotacin B	Prevent inhalation of dust (use of respirator) when working in areas such as old farm structures or when disturbing soil in endemic areas
Dermatophytosis (ringworm, taenia dermatomycosis)	*Trichophyton verrucosum* *T. equinum* *T. mentagrophytes* *Microsporum canis* *M. nanum* *M. gallinaciae*	(A) Skin infection of variable severity Crusty inflamed lesions that tend to clear centrally, pustules may develop in the active portion of the lesion Lesions usually occur on face, arms, and head (B) Similar to humans except lesions usually much less inflamed and dry May be patches of hair loss May be sub-clinical infections	(A) 2 (B) Most animal species have their own fungal agents which cause skin infections The infected animal species important in agriculture include cattle, goats, sheep, horse, rat, swine, and chicken	(A) *T. verrucosum* (cattle mainly, sheep and goats also possible) *T. equinum* (horses) *T. mentagrophytes* (rat) *M. canis* (dog, cat) *M. nanum* (swine) *M. gallinaciae* (chicken) The environment (barns, feed bunks, corals, etc.) may serve as a reservoir The organism lives for long periods of time (B) 1 (C) Close direct contact of bare skin with infected animals or their environment	(A) Farmers and livestock handlers People who milk infected animals are particularly at risk Children are at greater risk than adults (B) Worldwide	1. First try topical treatment with imidazoles (chlortrimazole or ketaconazole) 2. Systemic treatment may be necessary with fluconazole or ketaconazole	1. Practice excellent animal health programs (e.g., sound nutrition, excellent environmental sanitation, prevent overcrowding) 2. Isolate infected animals 3. Wear protective gloves and clothing when handling infected animals 4. Practice good personal hygiene
Zoonotic fungal infections							
Histoplasmosis	*Histoplasma capsulatum*	(A) Often subclinical Variable, depending on dose and immune response of the individual Usually a febrile illness with influenza-like symptoms, cough, pneumonitis, usually recover in 2–3 weeks Chronic forms may be extremely severe and very difficult to treat, with chronic pneumonitis, liver infections, bone infections or other tissues (B) Often sub-clinical Similar to human illness	(A) None of the above Animal relationship to humans comes from the fact that the organism grows particularly well in soil contaminated with fecal material of birds or bats These species may also act to distribute the organism in nature (B) Most animals have sub-clinical infections Dogs are the primary animal species that develop illness	(A) Soil, particularly that contaminated by aged feces of birds or bats (B) 3 (C) Inhalation by producing aerosols of the organism during disturbance of soil that contains the organism (e.g., cleaning or razing old chicken coops, working in areas where old bird roosts have been)	(A) Farmers as well as others who live and work in endemic areas of infection Immunocompromised people are at high risk of disseminated disease (B) Worldwide, in specific localities where soil and climatic conditions are favorable for growth of the organism	1. Amphotericin B 2. Ketoconazole, dapsone, and rifampin are alternatives	Wetting down soil and wearing a good particle-filtering respirator when working in a dusty environment conductive for growth of the organism (e.g., old bird roosts, old poultry houses, etc.)

(*Continued*)

Table 13.2 (Continued)

Bacterial infections							
Disease (Common names)	**Etiologic agents**	**Health effects** (A) Human (B) Animal	**Animal hosts** (A) 1. Zooanthroponosis[1] 2. Anthropozoonosis[1] 3. Amphixenosis[1] (B) Specific animals infected	**Mechanisms of transmission** (A) Reservoir (B) 1. Direct-zoonosis[2] 2. Meta-zoonosis[2] 3. Sapro-zoonosis[2] 4. Cyclo-zoonosis[2] (C) Specific mechanisms	**Epidemiology** (A) Populations at risk (B) Geographic distribution	**Treatment**	**Control and prevention**
Zoonotic infections protein particle							
Variant Creutzfeldt–Jakob disease (vCJD) Transmissile spongiform encephalopathy (TSE) Mad cow disease	An abnormal infectious protein particle	(A) An unusual progressive/ fatal encephalopathy leading to dementia, ataxia, and death (variant form of Cruetzfeldt–Jakob disease) (B) Progressive encephalopathy leading to altered behavior, ataxia, and death	(A) 2 (B) Cattle (only species known infectious for humans) Elk, mink, cats, sheep also have TSE	(A) Infected cattle (B) 1	(A) People consuming brain or nerve tissue from infected cattle (B) Animals mainly in the UK, EU, Japan Two cases in Canada	There is no known treatment	1. Detect infected animals and eliminate them from the food chain 2. Do not eat brain/spinal cord tissues of cattle 3. Do not feed dead herbivore animals to cattle

[1] There is no "official" publication listing zoonotic infectious hazards. Different authors may list different hazards. The risks listed here are based on analysis of science-based information, primarily for North America and other developed countries, and the author's (KJD) experience and judgment.

Table 13.3 Generic checklist for prevention of zoonoses in livestock and poultry production farmers and workers

Biosecurity: Keep livestock and poultry disease free

- Institute a biosecurity program to keep disease out of the operation. This may include limiting access of people and keeping unknown disease status animals out of the operation (specific recommendations are seen in literature from the regional veterinarian, specific livestock producers' organizations, and Extension Service).
- Introduce only known disease-free animals into the herd/flock. Acquire new stock from known disease-free vendors, and/or test and quarantine new animals coming into the herd or flock.
- Institute a complete preventive veterinary care program for the herd/flock that addresses all animal health parameters.
- Surveillance of animal health. This may include specific diagnosis of diseases outbreaks and routine screening of animals for relevant zoonoses that may result in sub-clinical infections in animals (e.g. MRSA, leptospirosis, Q fever).

Worker wellness

- Pre-employment worker health screening considerations should include:
  - immunodeficiency illnesses (as these workers are at increased risk)
  - screening for tuberculosis (dairy operation workers)
  - screening for MRSA (swine and poultry workers)
  - Blood draw for banked serum for possible future diagnostic use by comparison to titer at the time of an acute illness (a titer rise to an agent helps confirm or rule out specific infections).
- Possible pre-employment MRSA screening (swine and poultry).
- Obtain and store a pre-blood serum for possible use at a later date to compare serologic status to an acute febrile illness which will help to diagnose possible zoonoses.
- Educate family and hired workers about possible zoonotic hazards and prevention in the particular operation.
- Worker immunizations should include influenza (swine and poultry).
- Establish policies that workers with influenza-like symptoms should stay at home until fever dissipates.
- Establish policies, facilities, and first-aid equipment for skin wounds (an excellent route of entry for some zoonotic illnesses). This should include immediate cleaning of the wound with soap and water, and application of an antiseptic bandage.
- Establish sanitary toilets and hand-washing facilities, and help ensure they are used.
- Establish a sanitary eating space with sanitary hand-washing facilities.

Personal protective equipment (PPE)

- Establish appropriate and practical PPE policies relevant to the particular operations and species involved that may include one or more of the following:
  - clothing and shoes/boots on site that are regularly cleaned and sanitized, worn only while on the job, and not taken off premises
  - safety glasses
  - N95 respirator
  - neoprene gloves
  - disposable obstetrical sleeves (dairy, cow/calf herd, swine-farrowing operations)
  - appropriate PPE kept accessible in a sanitary storage facility on site and readily available to all exposed when needed.
- Sanitary shower facilities for use before and after work as needed/required for biosecurity policies (mainly swine operations).

Facility/environmental sanitation

- Regular cleaning of the animal facilities, which may include power washing with a biocide, (depending on the operation and facility).
- Control of insects that may be mechanical fomite or vectors of disease (e.g., flies, mosquitoes).
- Control of vermin (rats and mice).
- Limit access to livestock facilities of owned or feral dogs and cats that may potentially bring in diseases, or carry them to another facility (mainly swine and sheep operations).
- Sanitary, accessible gender-specific toilets for all workers.

MRSA, methicillin-resistant *Stahphycoccus aureus*.

References

1. Acha P, Szyfres B. (ed). Zoonoses and Communicable Diseases Common to Man and Animals. Volume I, Bacterioses and Mycoses. Volume II, Chlamydioses, Rickettioses, and Viroses. 3rd edition. Washington, DC: Pan American Health Organization, World Health Organization; 2003.
2. Marano N, Pappiaoanou M. Historical, new and reemerging links between human and animal health. Emerging Infectious Diseases. 2004; 10(12):2065-6.
3. Kruse H, Kirkemo A, Handeland K. Wildlife as source of zoonotic infections. Emerging Infectious Diseases 2004;10(12):206–72.
4. Center for Emerging and Zoonotic Infections home page. Centers for Disease Control and Prevention; 2014 (updated 18 August 2014; accessed 26 August 2014). Available from: www.cdc.gov/ncezid.
5. Zoonotic Diseases. Ames, IA: Center for Food Security and Public Health, Iowa State University; 2013 (accessed 6 January 2016). Available from: http://www.cfsph.iastate.edu/Zoonoses/.
6. Kraus H, Weber A, Appel M, Enders B, Graevenitz AV, Isenberg HD, et al. Zoonoses Infectious Diseases Transmissible from Animals to Man. 3rd edition. Washington, DC: American Society of Microbiology Press; 2003.
7. Steele J, Jacobs L, Arambulo P, Hillyer G, Hopla C (eds). Handbook Series in Zoonoses. Volumes 1 and 2. Boca Raton, FL: CRC Press; 2000.
8. Zoonoses and food safety. Geneva: World Health Organization; 2011 (accessed 22 August 2014). Available from: http://www.who.int/foodsafety/zoonoses/en/.
9. Zoonoses and the Human–Animal–Ecosystems Interface, Geneva: World Health Organization; 2015 (accessed 10 February 2015). Available from: http://www.who.int/zoonoses/en/.
10. Zoonotic Diseases. Atlanta, GA: Centers for Disease Control and Prevention, US Public Health Service; 2013 (updated 18 October 2013; accessed 10 February 2015). Available from: http://www.cdc.gov/onehealth/zoonotic-diseases.html.
11. Heinen P. Swine Influenza: a Zoonosis. Veterinary Sciences Tomorrow; 2003 (accessed 5 January 2016). Available from: http://www.col.ops-oms.org/prevencion/influenza/docsgenerales/Swine_Influenza.htm.
12. Kilbourne E. The Molecular Epidemiology of Influenza. J Infect Disease. 1973;127:478–87.
13. Taylor L, Latham S, Woolhouse M. Risk factors for human disease emergence. Phil Trans R Soc Lond B Biol Sci. 2001;356:983–9.
14. Erhardt C. Ranking of causes of death. In: Berlin J, editor. Morbidity and Mortality in the United States. Cambridge: Harvard University Press; 1974. p. 25.
15. Donham K. Zoonotic diseases of occupational significance in agriculture: A review. Int J Zoonoses. 1985;12:163–91.
16. National Select Agent Registry. Animal and Plant Inspection Services, US Department of Agriculture; 2014 (updated 12 August 2014; accessed 22 August 2014). Available from: http://www.selectagents.gov/.
17. Overview of the Canada and Alberta BSE Surveillance Program. Alberta Agriculture Forestry; 2015 (accessed 6 January 2016). Available from: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/cpv9336.
18. Hubbert W, McCulloch W, Schnurrenberger P. Diseases Transmitted from Animals to Man. 6th edition. Springfield, IL: Charles C. Thomas Co; 1975. p. 147–8.
19. Basic information about avian influenza (bird flu). Centers for Disease Control and Prevention. Available from: www.cdc.gov/flu/avian/facts.htm.
20. Burke RL, Kronmann KC, Daniels CC, Meyers M, Byarugaba DK, Dueger E, et al. A review of zoonotic disease surveillance supported by the Armed Forces Health Surveillance Center. Zoonoses Public Health. 2012;59(3):164–75.
21. Kersting AL, Medeiros LC, LeJeune JT. Zoonoses and the physicians' role in educating farming patients. J Agromedicine. 2009;14(3):306–11.
22. Bengis RG, Leighton FA, Fischer JR, Artois M, Morner T, Tate CM. The role of wildlife in emerging and re-emerging zoonoses. Rev Sci Tech. 2004;23(2):497–511.
23. Higgins R. Emerging or re-emerging bacterial zoonotic diseases: bartonellosis, leptospirosis, Lyme borreliosis, plague. Rev Sci Tech. 2004;23(2):569–81.
24. Swihart R, DeNicola A. Public involvement, science, management, and the overburdance of deer: can we avoid a crisis? Wildlife Society Bulletin. 1997;25:382–7.
25. Levy S. The Lyme Disease Debate: Host Biodiversity and Human Disease Risk. Environ Health Perspect. 2013;121:A120–A125. Available from: 10.1289/ehp.121-a120 (online 1 April 2013).
26. West Nile Virus in the United States: Guidelines for Surveillance, Prevention, and Control. Fort Collins, CO: Centers for Disease Control and Prevention, US Department of Health and Human Services, Public Health Service; 2013 (accessed 5 January 2015). Available from: http://www.cdc.gov/westnile/resources/pdfs/wnvguidelines.pdf.
27. Schwabe C. Veterinary medicine and human health. Baltimore: Williams and Willins; 1969.

28. Baker WS, Gray GC. A review of published reports regarding zoonotic pathogen infection in veterinarians. J Am Vet Med Assoc. 2009;234(10):1271–8.
29. Aramini JJ, Stephen C, Dubey JP, Engelstoft C, Schwantje H, Ribble CS. Potential contamination of drinking water with *Toxoplasma gondii* oocysts. Epidemiol Infect. 1999;122(2):305–15.
30. Murphy F. Emerging Zoonoses. Emerging Infectious Diseases. 1998;4(3).
31. Fish D. Environmental risk and prevention of Lyme disease. Am J Med. 1995;98(4A):2S–8S; discussion S–9S.
32. Compendium of Animal Rabies Prevention and Control. National Association of State Public Health Veterinarians. Morbidity Mortality Weekly Reports. 2005;54(RR03):1-8 (accessed 6 January 2016). Available from: http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5403a1.htm.
33. Wedlock DN, Skinner MA, de Lisle GW, Buddle BM. Control of *Mycobacterium bovis* infections and the risk to human populations. Microbes and infection/Institut Pasteur. 2002;4(4):471–80.
34. Model infection control plan for veterinary practices. National Association of State Public Health Veterinarians, Richmond, Virginia; 2006 (accessed 5 January 2016). Available from: https://public.health.oregon.gov/DiseasesConditions/CommunicableDisease/Veterinarians/Documents/ModelInfectionControlPlan.pdf.
35. Bisdorff B, Scholholter JL, Claussen K, Pulz M, Nowak D, Radon K. MRSA-ST398 in livestock farmers and neighbouring residents in a rural area in Germany. Epidemiol Infect. 2012;140(10):1800–8.
36. Graveland H, Duim B, van Duijkeren E, Heederik D, Wagenaar JA. Livestock-associated methicillin-resistant *Staphylococcus aureus* in animals and humans. Int J Med Microbiol. 2011;301(8):630–4.
37. Harper AL, Ferguson DD, Leedom Larson KR, Hanson BM, Male MJ, Donham KJ, et al. An overview of livestock-associated MRSA in agriculture. J Agromedicine. 2010;15(2):101–4.
38. Leedom Larson KR, Smith TC, Donham KJ. Self-reported methicillin-resistant *Staphylococcus aureus* infection in USA pork producers. Ann Agric Environ Med. 2010;17(2):331–4.
39. Leonard FC, Markey BK. Methicillin-resistant *Staphylococcus aureus* in animals: a review. Vet J. 2008;175(1):27–36.
40. Liu D, Chai T, Xia X, Gao Y, Cai Y, Li X, et al. Formation and transmission of *Staphylococcus aureus* (including MRSA) aerosols carrying antibiotic-resistant genes in a poultry farming environment. Sci Total Environ. 2012;426:139–45.
41. Masclaux FG, Sakwinska O, Charriere N, Semaani E, Oppliger A. Concentration of airborne *Staphylococcus aureus* (MRSA and MSSA), total bacteria, and endotoxins in pig farms. Ann Occup Hyg. 2013;57(5):550–7.
42. Osadebe LU, Hanson B, Smith TC, Heimer R. Prevalence and characteristics of *Staphylococcus aureus* in Connecticut swine and swine farmers. Zoonoses Public Health. 2013;60(3):234–43.
43. Smith TC, Harper AL, Nair R, Wardyn SE, Hanson BM, Ferguson DD, et al. Emerging swine zoonoses. Vector Borne Zoonotic Dis. 2011;11(9):1225–34.
44. Smith TC, Pearson N. The emergence of *Staphylococcus aureus* ST398. Vector-Borne Zoonotic Dis. 2011;11(4):327–39.
45. Human Orf virus infection from household exposures – United States, 2009–2011. Morb Mortal Wkly Rep. 2012;61(14):245–8.
46. Starr MP, Reynolds DM. Streptomycin resistance of coliform bacteria from turkeys fed streptomycin. Am J Public Health Nations Health. 1951;41(11Pt1):1375–80.
47. Friese A, Schulz J, Zimmermann K, Tenhagen BA, Fetsch A, Hartung J, et al. Occurrence of livestock-associated methicillin-resistant *Staphylococcus aureus* in Turkey and broiler barns and contamination of air and soil surfaces in their vicinity. Appl Environ Microbiol. 2013;79(8):2759–66.

Chapter 14

International Agricultural Safety and Health

Kelley J. Donham

14.1 Introduction

An important aim of this second edition of *Agricultural Medicine* is to provide greater coverage of international agricultural medicine. Although this book emphasizes the agricultural medicine issues found in North American agricultural commodity export countries (i.e., the United States, Canada, and Mexico), its information relates to production agriculture in all Western-style industrialized countries. The chapter includes three sections written by agricultural medicine experts outside of North America, representing other major agricultural commodity trading blocs. Although there are many similarities in agricultural health and safety hazards among these countries, variations do exist. Specifically, the authors make comparisons to the United States, Canada and the other more developed agricultural economies in the following areas:

- types and processes of commodity production
- culture of farmers, families, and workers
- agricultural injury and illness statistics
- agricultural health and safety regulations
- resources for agricultural medicine (funding, organizations, research, services, etc.)
- unique illness and injury conditions.

The regions chosen for inclusion in this chapter represent those with Western-style agricultural economic development. Agricultural medicine in developing countries is beyond the scope of this book, as the major health and safety issues in those countries are vastly different from those in more developed countries. Developing countries deserve a separate book entirely devoted to agricultural medicine in those countries.

The countries/regions chosen for inclusion in this chapter include:

- the Mercosur 4 countries of South America (Argentina, Brazil, Paraguay, and Uruguay)
- Australia and New Zealand
- countries in the EU.

Agricultural Medicine: Rural Occupational and Environmental Health, Safety, and Prevention, Second Edition.
Kelley J. Donham and Anders Thelin.

Section

A

Agricultural Medicine in South America – The Mercosur 4: Argentina, Brazil, Paraguay, and Uruguay

Marcos Grigioni and Kelley J. Donham

Reviewer: Kelley J. Donham

14.1A Introduction

This chapter provides a comparative picture of agricultural and related health and safety issues for farmers and rural workers in the primary agricultural countries of the Mercosur. The Mercosur is a South American economic trade block formed in 1991 with the principal countries of Argentina, Brazil, Paraguay, and Uruguay. Venezuela was added in 2012. The bloc includes 240 million persons, with a GDP of $3 trillion. The original four countries have a rapidly developing agricultural economy that is supply-side market driven similar to North America, the EU, and Australia/New Zealand. The new technologies in agricultural production are facilitating the transition from the former local/regional production model to an export model (Paraguay and Uruguay) and enlarging and affirming the export pattern of the others (Brazil and Argentina). The principal crop expansion is soybean. The extent of this transition has been so prominent it is referred to as sojización, roughly translated as soyafication. This transformation brings these four countries into a similar category, the Mercosur 4 (M4), for discussion with the other developed agricultural economies (North America, Australia, and the EU).

Although many of the agricultural health and safety hazards discussed previously in this chapter are common to all the developed countries' production systems, some comparative aspects are discussed below, including differences in (1) types of commodities and production processes, (2) the culture of the workers, (3) agricultural injury and illness statistics, (4) health and safety regulations, (5) resources for agricultural medicine (organizations, research, services, etc.), and (6) special/unique illness or injury conditions. This chapter will provide a picture of Argentina primarily, comparing it, along with the other M4 countries, to North America, the EU, and Australia/New Zealand.

14.2A Types of Production and Processes

The M4 countries have in common long-standing traditions in rural production with a variety of products and processes, each with its own risks, dangers, and preventive methods. Argentina is a

Table 14.1A Agricultural production: country comparison (8)

Country	Land under cereal production, 2012 (millions of ha)	Farm workers in millions, 2008	Net agricultural growth per capita, 2007 (%)
Argentina	10.37	1.43	1.19
Brazil	19.56	11.65	128
Paraguay	1.46	0.81	1.28
Uruguay	1.50		1.24
United States	60.27	2.67	1.00
Canada	14.15	0.34	1.00
EU	57.56	0.77	
Australia	19.42	0.44	0.69

farming and ranching country where food production holds a strategic place within the current economy, with 31 agrifood chains (1, 2). These chains are primarily a Latin-American agricultural and rural development concept from the 1980s. They are public-private cooperative organizations that help to organize and facilitate the various aspects of food production (e.g., beef, poultry, wheat, dairy) from the farm to supplying it to the consumer.

Total agricultural production contributes 7% of value-added (net) GDP of the M4. Data from the World Bank and the US Department of Agriculture indicates that Brazil, Paraguay, and Uruguay contribute 5.7%, 21%, and 10% net, respectively, to GDP, compared to under 4.7% for the United States (2013) and approximately 2% for Australia and the EU. Agriculture in Argentina accounts for 48% of total exports. Besides livestock, the principal crops are cotton, rice, sunflower, corn (6, 133, 378 hectares (ha) planted 2012–2013), soybeans (20, 035, 572 ha planted 2012–2013), sorghum, and wheat (3,648,070 ha planted 2013–2014) (3, 4).

In Uruguay, 2012/13 crop agriculture covers an area of 1,500,000 ha (total agricultural area 16.4 million ha), with soybean (1,050,000 ha), wheat (450,000 ha), corn, barley, sunflower, rice (181,000 ha), sugar cane (5) and 186,000 ha other. In Brazil in 2012/13, crop production was estimated at 188,658 million tons of grain, where the main crops were cotton, rice, feijao (a type of edible bean), millet, soybeans, sorghum, and wheat (6). In 2008, Paraguay had an area with temporal and permanent vegetable crops of 3,365,203 ha (total agricultural land 31,000,000 ha). Major crops included soybean, cotton, sugarcane, wheat, corn, snuff, rice, sesame, and bananas (7).

Table 14.1A provides comparative data that suggests the total land area under cereal production in the M4 countries is about half that of the United States and the EU, but about twice that of Australia and Canada (8). The M4 produces significantly more beef than the United States or the EU, and Australia, but fewer pigs. Also, the M4 (not including Uruguay and Venezuela) reports some 13.89 million farm workers, approximately 3.5 times the combined total farm workers reported for the United States, Australia, and the EU. Regarding the percentage of agricultural growth per capita, the M4 countries report gains between 19% and 28%, compared to statistics reported for the comparative developed agricultural economies. In general this suggests that the transition of the agricultural economies in the M4 countries is at an earlier stage relative to comparative economies, which are more mature, with a higher proportion of potential land under cultivation and fewer workers per unit of commodity production.

A major trend in agriculture in the region in recent years has been an increase in crop production (mainly soybeans) and a decline in cattle production. Large amount of previous pasture land has been taken out and planted into crops. Table 14.2A provides some comparative data of

Table 14.2A Comparative livestock production data of the M4 and other developed agricultural economies (5–7,9–18)

	Cattle stock (head)	Pig stock (head)	Ovine (head)	Sea fishing (tons)	Milk production (millions of liters)	Milk production (head)	Agricultural land (km^2 × 10^6)
Argentina	51,646,544 (2014)	3,437,003 (2012)		818,702 (2013)	11,338 (2012)		1.48
Uruguay (2012)	11,411,000		8,225,000	77,000	2,177		0.14
Paraguay (2008)	10,496,641	1,072,655				477,759	
Brazil	169,900,049 (2006)	31,949,106 (2006)	13,856,747 (2006)	785,366 (2010)	21,433 (2006)		2.75
United States	95,000,000 (2014)	66,026,785 (2012)	5,364,844 (2012)			9,252,272 (2012)	4.11
EU	90,000,000 (2013 estimate)	150,000,000 (2013 estimate)	90,000,000 (2013 estimate)				1.88
Australia	92,000,000 (2008	2,289,000 (2010)	2,289,000 (2010)			2,542,000 (2010)	1.48

livestock production among these countries (5–7, 9–18).

Fruit growing and horticulture are also important, especially in small family farms. Forestry is significant mainly in Uruguay with 1,812,000 ha of total forest area (5).

The M4 countries have great potential for the growth of agricultural production (mainly Brazil and Argentina). Their large area (more than 400 million ha), diverse climate, flora, fauna, and geography (terrain, ponds, mountains, distances to towns, etc.) afford opportunities for continued agricultural growth and the accompanying health and safety challenges for worker health and safety. Along with transitioning of pasture land to crops, forests are cleared for cropland. These changes invoke environmental challenges by decreasing biological diversity, reducing the carbon sequestration that was supplied by the native forest and flora, and reducing the water storage and recharge capacity previously offered by the native landscape.

The changes mentioned above, along with new hazards for the health and safety of agricultural workers in Argentina and the other M4 countries have accompanied the process of "sojización". Sojización (which primarily refers to the major transition to soy bean production) has been a consequence of globalization, with the expansion of agriculture in a capitalistic, market-driven system similar to what has evolved over the past four decades in other developed agricultural economies. Until about 35 years ago, farming in the Pampas region (the main agricultural area of Argentina) was based on the production of wheat, corn, and sunflowers, along with ranching on natural grasslands. These farming practices required the farmer to be living close to the land. The advent of new technologies such as more productive seed varieties, fertilizers, chemicals to control pests and weeds, onset of tillage, new crops (soybeans), new markets (China), firm international prices, and convenient new uses of crops (biofuels) favored the expansion of soybean cultivation at the expense of other traditional and diverse crops and livestock production. Dairy and livestock (mainly cattle and sheep) were displaced to marginal provinces outside the Pampas (Buenos Aires, Cordoba, Santa Fe). In the agricultural core zone, only pockets of extensive livestock production remain, located in low-lying flood-prone areas. Furthermore, cattle feedlots have been introduced in the region, reducing the numbers of "grass-finished" beef, increasing "grain-finished" beef and resulting in a net large decrease in cattle numbers.

The agricultural frontier was expanded thanks to the great capacity of the soybean plant to adapt to areas where agricultural production had not previously occurred. Hundreds of thousands of hectares in the Argentinian northern provinces were planted with soybean, displacing livestock and forestry, and producing large-scale deforestation (19). The same process has occurred in Brazil and Paraguay. In Uruguay the soybean area has expanded, but the main source of income for 65% of farms is still animal production.

The Argentinian agricultural frontier was also extended to the provinces of the west (San Luis) and Patagonia (Río Negro), where corn crop production is in the process of being established. All these advances into new regions with different climatic, cultural, geographic, and population characteristics generate new challenges for agricultural health and safety, as farmers and rural workers accustomed and trained to perform a certain type of rural production (for example sheep production in Patagonia) are now working on expansive crop production, using powerful new machines and chemicals for which they have little or no training or experience, particularly regarding safety. Moving producers or contractors from the Pampas to new and remote areas leads to increased risks because these remote areas are far from health centers and lack infrastructure (e.g., poorly maintained roads, limited telecommunication, and few first aid and fuel stations). The distance farmers must travel has generated a new risk of crashes between farm machinery and vehicular traffic on rural routes. This situation is also present in some areas of Brazil, Uruguay and Paraguay.

At the same time, agriculture has evolved, becoming more specialized and mechanized, increasing productivity (increasing crop production processes while decreasing required labor). The complexity of the administrative aspect of agricultural production (e.g., taxes, management, purchasing, and payments) has shifted the farmer from the countryside to the desktop to meet financial management demands. Hence, the producer works fewer hours in the field, devoting more time to management, and therefore has a physical and mental workload that differs from 30 years ago.

As mentioned previously, beef cattle feedlots have been introduced as this production system uses less land, allowing more for soybean and other crop production, and providing a local source of grain for the feedlot cattle. In a country where vast tracts of land were once used for extensive cattle and sheep grazing, the current economic model of agricultural production compels the use of the feedlot, a more compact style of livestock production. In 2008, 3.6 million beef cows were fed in lots to market weight (20).

This development has led to different environmental working conditions for producers, workers, and rural families living in the region (21). The rapid and profound changes in the types of production, progress to new areas (agricultural frontier), changes in the relations of the labor and economic markets have had consequences for many farmers and workers, who now may suffer from stress, depressive symptoms, increased injuries, hypertension, stroke, insomnia, and gastritis, factors that decrease concentration, mental focus and physical strength, threatening their quality of life and safety. Ambrosi and Maggi found that distractions were the leading cause (50% of cases) of accidents suffered by a group of Brazilian farm workers (22).

New technologies and products (e.g., chemicals, fertilizers, and machinery) generate anxiety in the adopters of these technologies, which will likely persist until they are properly understood and competently managed. During this training period (for the management of machines and handling of substances), the possibility of an injury or illness is high. In Paraguay, 78% of farms use fertilizers, pesticides, and animal pharmaceutical products (7). The sale and use of agrochemicals in Brazil is increasing steadily, with the amount used (insecticides, herbicides, fungicides) nearly doubling in the period from 2009 to 2013. The amount of fertilizer supplied to the consumer from 2004 to 2013 has increased by about 50% (31 million tons in 2013) (6), indicating increased occupational risks from these hazardous substances.

Modern farm equipment, including GPS guidance systems, fertilizers, plant protection products, and genetically modified crops, has been embraced by the vast majority of producers in these countries, as it has in developed countries.

14.3A Culture and Demographics

The rural population in Argentina has decreased from 3,587,039 in 2001 to 3,023,751 in 2012 (16% decline) (23), confirming a profound change in residence from rural to urban. This trend is repeated in Uruguay, which has a rural population of 175, 613, of which 43% are women (24). Brazil has over 30 million people living in rural areas (23) and the estimated 2014 Paraguay rural population is 2,792,873 (52.8% men and 47.2% women) (25). Although this rural to urban shift in population has been prominent in the past two decades, there remain 36 million people living and working in rural areas, many associated with agriculture. This population includes many that can be classified as special risk populations (e.g. women, children, elderly, and migrant and seasonal workers).

In Argentina and Uruguay the number of productive agricultural farms and the number of producers has declined as farm size has increased. Argentina has 335,000 farms, Uruguay 44,781, Brazil 5,175,636 and Paraguay 289,649 (7, 26–28), making a total of 5.8 million farms in the M4. In comparison there are 2.2 million farms in the United States and 11.8 million in the EU.

Argentine´s agricultural population (2002 census) was 1,233,589 (202,423 producers, 589,947 family members, and 441,218 workers and others). Uruguay's 2011 census revealed an agricultural population of 144,383 (temporary workers not included) (26, 27).

In Argentina the number of hectares farmed on owned land has decreased (by 8.4 million ha), but farmed hectares not owned (leased, sharecropped, or contracted) has increased. The process of sojización has been the main driving force of this trend. The new production technologies have brought increased production with a reduced number of man hours per hectare. Also, the emergence of "sowing pools" (called network companies in Uruguay) has influenced rural demographic changes. A sowing pool consists of temporary joint investors (banks, financial institutions, agri-suppliers, producers, and professionals such as agronomists and veterinarians). They lease lands, utilize contract services, develop the business of sowing and reaping, and then share the profit. Large numbers of land owners lease their fields to these companies, choosing to live in towns or cities and abandoning their rural homes. Many other factors, as in other developed countries, have influenced this demographic shift (21).

The act of moving to towns or cities has generated a change from the old concept of the field as workplace and residence. The generational transfer of inheritance left by parents to several children has resulted in those inheriting land receiving small tracts of land insufficient to support their own equipment and operations. Thus, many farmers have abandoned their farm productivity, renting fields or outsourcing the work and control, allowing them to pursue off-farm economic activity (29).

The trend of urbanization with fewer and larger farms continues throughout the other developed agricultural economies. Similar structural changes have evolved more recently in the M4. This trend has challenged small farms to make a sustainable family income. Furthermore, as farm size has changed and technology has developed, it is extremely difficult for farms handed down through generations to remain viable because of the costs involved to achieve the required economy of scale.

The sowing pool concept for crop production in the United States, the EU, and Australia is uncommon, as the vast majority of farms remain operated by families. However, many of these family farms have increased their land base by renting or leasing land (e.g., 60% of the land farmed in Iowa is rented). However, this is different in meat, poultry, and egg production, primarily in the United States and to a lesser extent in the EU and Australia as there are many swine, cattle, and poultry production systems that have been built by investors with varied backgrounds.

14.4A The Demography of those Engaged in Agricultural Production

Eight rural population groups can be discussed relative to agricultural safety and health:

1. *Rural producers*: Although the trend in the M4 has been toward very large industrial-type farms, there remains a heterogeneous group of producers in Argentina that can be classified into small, medium and large farm operators. The variables used for this typology include land tenure: up to 100 ha is a small farmer, 100 to 500 ha medium, and over 500 ha large producer (29). Two other important considerations are relevant to rural producers in Argentina. First, a family farmer is defined as the person or group of persons, related or not, who live in the same household as a family system. For example, they share food expenses or other essentials for living and may contribute to the workforce development activity in rural areas. In the case of indigenous populations the core family farmer is equivalent to the concept of community. These cores are typically small producers. According to the Registration of Family Farming Cores report of 2014, there are 86,721 core family farmers. Their geographical distribution encompasses all regions of Argentina and the type of production (over 191 products) is diverse: livestock (cattle, sheep, goats, poultry, swine, horses, rabbits, etc.), crops (vegetables, cereals, fruit, vegetables, fodder, oilseeds, forest, nurseries, aromatic plants), fishing, aquaculture, beekeeping, handicrafts, hunting and gathering,

agro-industrial production (sweets, preserves, cheeses, sausages, drinks, etc.), and rural tourism. (30). An additional consideration is the importance of small farmers in Argentina. They account for 71% of total Argentine farmers, occupy only 13.5% of the agricultural land, produce 19.2% of the total value generated in domestic rural production, are closely associated with family farming, and cultivate at least 191 products (cereals, fruits, flowers, herbs, and forestry) (31, 32).

In 2006, Brazilian family farms numbered 4,367,902, representing 84.4% of the Brazilian rural establishments and 24.3% (80.25 million ha) of total land farmed. Rural establishments operated by firms or companies (non-family farms) comprise 15.6% of total rural establishments, occupying 75.7% of the land area. The average area of core family farms was 18.37 ha and of non-family farms 309.18 ha. The Agricultural Census showed 12.3 million people linked to family farming. Family farming was the main generator of jobs in rural Brazil. Eleven million workers (90%) had kinship with the producer, and 81% of these family workers lived on the farm (33). The work practices were conveyed from parents to children, therefore unsafe practices may perpetuate over generations. Lack of safe and healthful work practices modeling and mentoring of parents and guardians of children is a concern in this type of production.

2. *Families of producers*: In Argentina, work teams are composed of workers (non-family) or relatives who, in line with rural tradition, are incorporated to accomplish various tasks. This Argentine tradition was also a common practice in the past in the United States, but is less common today as machines have replaced most of the physical labor previously required for tasks such as hay or grain harvest.
3. *Unregistered workers*: These are workers without social and legal benefits because they are not registered with the labor department (an employer obligation). They are usually Argentine residents, and have low-quality jobs characterized by arbitrary remuneration, excessive working hours, lack of health and safety practices, and lack of access to state pension systems. Fifty-one per cent of workers were not registered based on inspections from 2005 to 2014 (34). However, the number of unregistered workers has been declining due to the work of worker representatives, employers, and the state.
4. *Temporary workers or "swallows"*: Argentine "swallow workers" (called migrant and seasonal workers in North America) are those who leave their homes and move according to the work seasons of crop production. This category of worker is characterized by low-quality labor tasks and precarious labor conditions. Today, 350,000 people work in manual harvesting of crops, traveling with the rhythm of agricultural seasons in different regions of the country. Although there are numerous regulations to protect these workers, they share similar issues with the migrant and seasonal workers of the United States and other developed countries, including job insecurity, low wages (often based on production goals), poor housing, nomadic work, multiple and changing employers, underemployment in off-work periods, lack of social benefits, and lack of work contract security (35).
5. *Registered workers* (in the system of government administration and the official institutions, labor department, social security, etc.): Hired workers who have an official and regulated relationship between worker and employer and receive social benefits, including worker compensation, health risk insurance and other benefits. The employers and/or the workers are required to declare injuries and occupational diseases to receive medical attention and other benefits. This information is the source of the only official occupational health and injury statistics.
6. *Independent rural workers*: Since these workers are not required to report their illnesses or accidents to authorities, no health or injury statistics are available for them.
7. *Agricultural professionals* (agronomist engineers, animal scientists, veterinarians, etc.): These professionals are usually self-employed, so they are not required to disclose accidents or illnesses.

8. *Rural contractors*: These are rural participants who provide agricultural services. Rural contractors are engines of the economy, for example in Argentina they accomplish over 90% of the harvest of grain grown in the country and 70% of the planting and application of agrochemicals. They are also responsible for processing 90% of stored forages and 100% of the preparation of irrigation systems for crops and forestation. Rural contractors are strategic players in agricultural development. There are between 16,000 and 18,000 contractors across Argentina, with an annual increase of 2%. These contractors are often also farmers who have their own land and/or hire others. Their teams may comprise both relatives and unrelated employees (36).

Comparing Uruguay to Argentina and Brazil, 9% of the work force in Uruguay (107,563 males and 30,312 females) is employed in the agricultural sector. Fifty-seven per cent work with livestock (bovine), 9% in forestry, 32% in agriculture, and 2% in fishing. Fifty-five per cent of these workers are salaried employees, while the rest are independent family farmers, unpaid family workers, or self-employed workers. While women work mainly in poultry and nurseries, about 25% of livestock workers are women. In Uruguay there is a relative aging of farmers and farm workers. Livestock farming had 70% of workers and farmers aged 60 and above, while crop production (grains) and forestry, had 8% and 5%, respectively (37).

Regarding education in Uruguay, 77% of those working in rural activities had not completed high school. In addition, 31% had no social security coverage (mostly family farmers and unpaid family workers). Half of these had no coverage in 2012 (over 22,000 people) (24). In Paraguay 766,307 people (36% females) worked in agriculture (2013) (38).

In Brazil (2006), 16,568,205 people worked in agriculture (30% women). The number of women working in agriculture was relatively equally divided between work with animals and seasonal crop work (28).

The related farming groups in the M4 appear similar to what is present in North America, and perhaps to a lesser extent in the EU and Australia. However, it may not be so common to have cooperative farming groups in North America and the other industrialized economies. Also, contract harvesting may not be as common in the other countries (perhaps with the exception of wheat harvest in western North America) compared to the contracted harvest in the M4.

14.5A Agricultural Injury and Illness Statistics: the Current Status of the Health and Safety of Agricultural Populations

14.5.1A Injuries and Illnesses in Farming Populations: Argentina

In Argentina, a major obstacle to understanding health and safety is the absence of official statistics for all participants of farming. The only official statistics are those relating to registered rural workers and tabulated by the Ministry of Labor. Table 14.3A shows the available statistics for agricultural injuries in Argentina in 2013 (39, 40). The data include work injuries, injuries from crashes during transport to and from work, occupational diseases, and aggravations of prior injuries or diseases.

Compared to other Argentine industries, agricultural occupational injury and disease rates were second highest in 2012–2013. Agricultural worker injury or disease average length disability time was highest at 41.6 days. Occupational fatalities in 2013 included two

Table 14.3A Agricultural occupational injury statistics for Argentina, 2013 (39,40)

Number of covered workers	Total cases reported	Incidence rate (per thousand)	Injuries resulting in days off work or disability (%)	Fatalities per 100,000 cases	Fatalities per 100,000 covered workers
355,249	36,332	95.9	94	211.9	21.7

Table 14.4A Farm fatalities reported in newspapers and other media for Argentina, 2013–2014

Causes, agents of injury	Fatal occupational injuries among farmers, 2013	Fatal occupational injuries among farmers, 2014
Entrapment by agricultural machinery (weeding, grain elevator, etc.)	3	2
Entrapment by tractor rollover	2	11
Crash: vehicle traffic accident with machinery	1	
Tractor run-over	1	3
Entanglement by power take-off of tractor	2	
Run-over by seeder	1	
Entrapment/run-over by harvester	1	1
Insect bite	1	1
Fire/burns	4	
Vehicle: road accident (mainly pick-ups)	15	9
Cause unknown		1
Suicide	3	3
Electrocution: contact with electric current	3	5
Firearm accident	2	
Crash resulting in grain engulfment and asphyxiation	1	
Drowning		1
Assault weapons: murder	6	10
Trampling by animals and fall from horses, injuries from animals	2	4
Exposure to electric power lightning	1	1
Exposure to extreme temperatures: cold/heat		2
Airplane crash during crop dusting	1	
Vehicle crash with barge: cattle		1
Pipeline gas explosion		2
Total cases	50	57

women and 73 men. Of these, 49 died from occupational injuries or diseases and the others because of road vehicle and farm equipment crashes during transport to and from the field. The incidence rate of occupational fatalities decreased by 14.3% between 2012 and 2013. Occupational diseases of agricultural workers make up about 2.7% of all reported cases in all branches of work activity (39, 40).

Although official statistics are only available from registered workers, newspaper reports can help supplement the picture of farming injuries. Table 14.4A shows a summary of a broad search of the news media for agriculture-related farm fatalities.

Of farmers who died in 2013, 50% were 61 years or older, whereas in 2014, 57% were 51 years or older.

14.6A Support Professionals in Agriculture

As with producers, there are no official statistics for professionals working in support services in agriculture, and therefore it is not possible to provide a detailed picture of occupational health and safety indicators for this group. However, research has revealed that 75.5% of 94 veterinarians from the midwest of Santa Fe Province had suffered an occupational injury in the year prior to the survey (41, 42). Molinar et al. (42) reported that veterinarians are at high risk of acquiring a zoonotic infection, especially brucellosis among recent graduates.

14.7A Injuries and Illnesses in Farming Populations: Uruguay, Paraguay, and Brazil

The data available for Uruguay and Paraguay are more limited than for Argentina. However, the data that are available indicate many similarities to the other M4 countries. Table 14.5A summarizes some of the available data for Uruguay (43).

Access to updated statistics for occupational accidents in Paraguay is very difficult, as reported by various other authors (43, 44).

The data available for Brazil revealed a reduction in occupational injuries in agriculture from 26,852 in 2011 to 23,440 in 2013 (45). Table 14.6A lists the reported injuries in 2013 according to type of production (45).

Further details of agricultural occupational injuries and sources in Brazil are displayed in Table 14.7A (46).

The available statistics suggest a profound need to develop systematic and continuing education activities for agricultural occupational health and safety for all these agricultural participants. Agricultural medicine may provide solutions for the rural sector in these countries.

Compared to other countries with developed agricultural systems, there are similarities in injury and illness statistics. In these developed countries, the rate of agricultural occupational injuries and fatalities is among the highest of all occupations, and when compared to the mean for

Table 14.5A Number and percentage (relative to all industry sectors) of injuries and occupational diseases in Uruguay (43)

	2008		2009		2010	
Total occupational injuries and illnesses, all industry sectors	52,207		49,906		51,626	
Industry sector: agriculture, livestock, fishing	7,741	14.8%	8,478	17.0%	8,502	16.5%

Table 14.6A Injuries at work by type of agricultural production in Brazil, 2013 (45)

Type of production	Number of injuries
Crop production (annual crops: soybeans, wheat, cotton, sugar cane, etc.)	6,839
Livestock production	5,215
Perennial crops	4,729
Forestry production	2,827
Support activities for agriculture, livestock and services postharvest	1,862
Production of certified seed	1,171
Horticulture and floriculture	425
Fishing and aquaculture	372

Table 14.7A Agricultural occupational injury statistics according to type of production (National Classification of Economic Activities (CNAE)) for Brazil, 2012 (46)

CNAE job classification	Incidence total (per 1000)	Incidence of occupational diseases (per 1000)	Incidence of injuries (per 1000)	Incidence of disability (per 1000)	Mortality rate (per 100,000)
0111 Cereal crop	9.17	0.06	6.07	9.03	10.96
0112 Cotton and other seasonal crops	22.12	0.09	18.60	21.84	18.05
0113 Sugar cane	27.24	0.10	22.16	23.62	6.82
0114 Snuff (tobacco)	23.33	0.46	3.66	23.33	–
0115 Soybean	19.37	0.17	14.28	19.02	21.73
0119 Other crop cultivation	18.00	0.15	12.02	17.66	29.43
0121 Horticulture	7.23	0.15	4.96	6.89	3.79
0122 Flowers and ornamental plants	8.74	0.06	4.87	8.37	6.24
0131 Oranges	30.82	0.08	25.17	28.54	6.16
0132 Grapes	25.09	0.10	17.30	24.52	51.63
0133 Other fruit	15.84	0.12	9.04	15.12	5.81
0134 Coffee	13.21	0.05	9.98	12.95	9.59
0135 Cacao	6.93	–	3.29	6.93	–
0139 Other plant cultivation	50.43	0.07	41.76	34.20	3.74
0141 Certified seed	82.85	0.69	70.42	78.60	100.38
0151 Livestock production: bovine	11.81	0.07	7.65	11.76	8.52
0152 Other large livestock animals	12.10	–	7.84	11.75	17.04
0153 Goats and sheep	7.61	–	4.76	7.61	47.58
0154 Pigs	16.89	0.05	11.20	16.34	–
0155 Poultry	18.23	0.42	11.92	16.98	12.27
0159 Other livestock	5.94	–	3.86	5.79	14.84
0161 Agriculture support services	4.44	0.03	3.06	4.10	5.68
0162 Livestock production support services	17.24	0.45	11.40	16.47	13.58
0210 Forest plantations	29.55	0.22	21.15	25.92	15.77
0220 Native forest production	12.79	–	8.98	11.52	25.42
0230 Forestry support services	22.15	0.14	16.01	15.01	12.19

(*Continued*)

Table 14.7A (Continued)

CNAE job classification	Incidence total (per 1000)	Incidence of occupational diseases (per 1000)	Incidence of injuries (per 1000)	Incidence of disability (per 1000)	Mortality rate (per 100,000)
0311 Sea fishing	12.94	–	6.36	12.71	–
0312 River fishing	9.22		9.22	9.22	–
0321 Aquaculture: maritime	19.21	0.20	12.28	18.82	19.81
0322 Aquaculture: river	11.15	–	5.40	10.97	17.99

all occupations it is two to nine times higher than the average. Although occupational injury and illness data for farmers and farm workers are perhaps better studied in the developed industrial agricultural economies, there is an important and well-defined need for more complete and accurate occupational injury statistics for farmers in the M4 countries. Generally the agricultural fatality rate is similar in Argentina (21.7 per 100,000) to the United States (20.2 per 100,000), but about 30% higher compared to the EU and Australia. (A more detailed comparison of injury and illness statistics can be seen with data from the United States, EU, and Australia in Chapter 11.)

14.8A Resources and Organizations in the M4

14.8.1A Agricultural Medicine in Argentina and Brazil

Agricultural medicine has been a slowly emerging discipline in Argentina. As an example of progress, agricultural medicine has been chosen as the theme to be developed during the 16th Conference on Continuing Education for Sanitary Co-responsible, organized by the College of Veterinary Medicine of the Province of Santa Fe. It was also chosen for the required course registration for new vets graduates in October 2014.

Since 2013 a program called Health and Safety for the Agricultural Family has been held by the Cooperative Federated Farmers Argentinos (AFA SCL) (an organization with more than 36,000 members).

Various official institutions are conducting outreach and training in Argentina, including the Ministry of Labor, the Animal Health Service (SENASA), and the National Institute of Agricultural Technology (INTA). An example of such training is the Health and Safety Course for Agricultural Enterprises. This course is offered annually at the Experimental Station of the National Institute of Agricultural Technology in San Pedro. Other courses are offered with varied frequencies and themes (e.g., safe handling of agrochemicals, operating machinery, zoonoses). Producer organizations and other related rural workers (unions, social work, etc.), as well as private agricultural machinery and supply companies, also organize training activities on health and safety.

A small group of professionals in Argentina and Brazil is dedicated entirely to agricultural safety in association with various institutions, universities, and the work injury insurance industry. The main professionals linking to agricultural occupational health and safety are engineers and technicians in occupational health and safety, agronomists, and veterinarians. The news media outlets in rural areas disseminate information, recommendations, and safe work methods to the agricultural sector.

There are very few formal training programs in agricultural health and safety. However, the Faculty of Agronomy at the University of Buenos Aires offers a postgraduate degree in hygiene and safety in agricultural labor (47). Other universities occasionally host workshops and training sessions on various aspects of rural health and safety.

Research in the field of agricultural health and safety is limited in Argentina, Uruguay, and

Paraguay, but is more common in Brazil. The agriculture and research communities recognize the numerous hazards in agriculture and the need for research in the field (48, 49).

The structural, cultural, geographic, and varied production processes in agriculture create a complex industry, imposing great challenges for researchers and trainers. Comprehensive planning would best address important issues for research, education, training, and prevention. Such joint planning would ideally include universities, government institutions, producer/rural worker organizations, agricultural companies, private institutions, and others related to agricultural production.

14.9A Special/unique Illness or Injury Conditions

14.9.1A Argentina Hemorrhagic Fever

Argentina hemorrhagic fever (AHF) is a zoonosis caused by the Junin virus (an arena virus), which is exclusively found in the Argentine Republic. Its reservoir is a small field mouse, *Calomys musculinus*. The disease is endemic in the provinces of Santa Fe, Córdoba, La Pampa, and Buenos Aires. It is on the Ministry of Labor's List of Occupational Diseases. The largest numbers of cases occur during the months of autumn and winter (April–August), with a peak in May coinciding with the harvest season. It is four times more common in men and nine times more common in the rural population compared to the general population. In 1958, the geographic endemic area of AHF was 16,000 km^2, with a total of 270,000 inhabitants exposed. The endemic area currently covers an area of 150,000 km^2 with a population of over 5,000,000. The incidence by area can be as low as 1/100,000 or as high as 355/100,000. This incidence is variable in time, being generally higher for a period of between 5 and 10 years in new endemic areas, subsequently subsiding to lower incidence rates. Children under 14 years make up about 10% of annual cases. Human infection occurs mainly through contact with sites contaminated with the urine, saliva, or blood of the rodent (crop fields during harvest). Like most zoonotic infections, person-to-person transmission is rare.

AHF is one of several hemorrhagic fever diseases having some clinical similarities to dengue or Hanta virus illness. The incubation period of AHF is between 6 and 14 days. Onset features a mixture of symptoms including fever, malaise, and headache. Symptoms that develop later include myalgia, back pain, arthralgia, dizziness, nausea, and vomiting. (The absence of cough and nasal congestion is useful to differentiate it from acute respiratory infections.) Further course of the infection is marked by exanthema (rash) on the face, neck, and upper trunk, and petechiae (small blotchy hemorrhages) on the thoracic skin under the arms and on the underside of the arms. The gums are inflamed and often bleed. The tongue has a hairy or furred appearance due to necrosis of the epithelial cell of the papillae, resulting in patients' breath having typically halitosis. Characteristic lesions in the throat include an exanthema with petechial (rash) and small vesicles (blisters). Lymph nodes in the neck are usually enlarged. After a week, oliguria (lack of urine production) and dehydration may often be seen due to kidney dysfunction. Neurological symptoms may be seen, including irritability, drowsiness, and slow cognitive response time. In women there is an almost constant presence of menorrhagia (bloody uterine discharge). Complications include cardiovascular shock and secondary bacterial infections such as pneumonia. Following the acute stage, 70–80% of patients improve (50, 51).

Treatment includes administration of plasma from patients who have been cured. Administered within 8 days of the onset of symptoms, this treatment reduces mortality to less than 1%. Ten per cent of treated patients develop latent neurological syndrome (NTS) between 4 and 6 weeks after the acute illness (51).

Prevention includes control (reservoir) of the field mouse *Calomys musculinus*. A vaccine against this zoonoses (Candid #1 vaccine) has been integrated within the National Immunization

Program (52). The vaccine has resulted in 95% protection from a single dose. The conditions that must be met for individuals wishing vaccination include:

- reside or work in one of the four provinces where there have been cases in recent years
- over 15 years of age
- have not previously received vaccine Candid #1
- must not be pregnant or breastfeeding
- must not present with chronic disease or an acute illness
- must not be receiving systemic corticosteroids or other immunosuppressive drugs
- must not have received other vaccines and/ or gamma-globulin within the previous month (51).

14.9.2A Urban–rural Conflict

In recent years and in many regions of the M4, technological advances have eased agricultural labor requirements. Coupled with high international commodities prices, economic circumstances have allowed rural farmers to have a more comfortable lifestyle. Also, the younger generation, having specialized and trained in new agricultural techniques and philosophy, have achieved unprecedented agricultural development. This change has been upsetting for many non-agricultural rural people and urbanites. This portion of the population has little knowledge or appreciation of "modern" agriculture and the efforts farmers have made to progress and advance in this complex and hazardous economic activity. Conflicts of ideology and toleration of sharing agricultural and non-agricultural environments and lifestyle around expanding urban fringes have also created urban-farmer confrontation and stress. Crop fields have transitioned to crop fields adjacent to cities. Urban residents fear the possible health hazards of agrochemicals farmers use near populated areas. Similar stress and complaints have resulted from residents living near feed lots where odors, dust, and noise are emitted. Further conflict has resulted from the growth of cities pushing the development of new barrios (residential neighborhoods) into rural areas, encroaching on and limiting the neighboring agricultural land, resulting in economic loss for farmers. Producers are stressed by the presence of urban dwellers near their farms and the accompanying cultural clashes of lifestyle, delinquency, and criminality (theft of machinery, tools, supplies, etc.), slaughter or stolen animals, burning of crops (e.g., wheat), torn silo bags, etc.

This clash of interests, recognized and heeded by relevant stakeholders, must be balanced in order to continue agricultural production in harmony with society and the environment. To accomplish this, extensive discussions are occurring among environmental interests, state agencies, and representatives of producers.

In developed countries similar urban–agriculture conflicts are occurring. This is especially true in the intensive livestock-producing areas of the Midwest United States.

14.9.3A Health and Safety of Farm Youths

Although there are no official statistics in Argentina for children who are injured or die in rural areas, pediatricians have warned of this problem (53, 54). We have searched news media outlets for farm youth injuries and summarize the results in Table 14.8A. The risk pool is large, as the National Agricultural Census of 2002 reported over 342,000 children less than 15 years of age living on Argentine farms (26). Fatalities in farm youths found in the media happened during recreational activities, when accompanying parents at work, or during their daily activities (see Table 14.8A).

When children help their parents or others in rural tasks, legislation exists to help protect their welfare (Law 26727, scheme of agricultural work (55, 56)). The following points summarize this legislation.

1. Children older than 14 years and under 16 years of age may be employed on farms that are operated by a parent or guardian, but not for more than 3 hours per day and 15 hours

Table 14.8A Fatal injuries and illnesses in agricultural youth in Argentina: sources and agents of injury (information collected from news media reports)

Age (years)[a]	2013	2014
<3	13	9
3–5	6	9
6–8	4	5
9–10	3	5
11–13	6	7
14–16	1	8
Causes		
Machinery injuries	6	9
Animals: related injuries	7	12
Suffocation in grain	3	1
Drowning	11	10
Carbon monoxide poisoning		1
Electrocutión	1	2
Rural road collisions	1	4
Zoonoses		1
Run-over	3	3
Suicide		1
All-terrain vehicle crashes	1	
Total	33	44

[a] One case, the age was not known.

per week, and only if the work is not painful, dangerous, and/or unhealthy.
2. Children under 16 years cannot work on non-family operations whether paid or not.
3. Scheduled work for adolescents should be undertaken only during the morning or evening, and must not exceed 6 days and 32 hours per week.
4. It is forbidden to employ those under 18 years in jobs that are painful, dangerous, or unhealthy.
5. Farm employers shall provide employees with proper living quarters and qualified childcare personnel for children during the work day.

In Brazil (2006), those under 14 years old working on farms numbered over one million, with 56% boys and 44% girls (all mainly on family farms) (28).

14.9.4A Farm Machinery and its Influence in Rural Accidents

Old machines create a high risk for injury as they lack the safety guarding and ergonomic features of new machines. In recent years, with a good agricultural economy, purchase of new equipment has been possible. As both Brazil and Argentina have substantial agricultural machinery manufacturers, a ready domestic supply of new machines has been available, which has had a positive impact on rural work. Modern machines have multiple protective technological advances and meet many recent safety laws (57). In Brazil, Standard NR-12 (Safety at Work in Machinery and Equipment) provides technical references, basic principles, design, and safeguards to ensure the physical health of workers. Annex IX to the regulation includes safety standards for equipment such as silos and dryers. New machines also require less maintenance and thus less frequent contact with dangerous parts of the machine. These factors potentially reduce injuries from agricultural equipment (58).

In Argentina, although 33% of injuries in farming are related to machines and equipment (59), there are only voluntary and optional safety standards for agricultural machine manufacturers. (This is similar in the United States, but with industry standards that are applied to almost all new equipment by the manufacturer. The EU has regulated certification.) In a 2014 survey of 678 producers in the provinces of Santa Fe, Buenos Aires, and Cordoba 72% of respondents said that they evaluate the safety features of a piece of equipment when they buy it. This author (MG) thinks it important to empower farmers to assert their right to choose machines with all necessary safety measures certified to accepted standards to help prevent injuries.

14.10A Summary

Beginning in the 2000s a large sector of production agriculture in South America began a transformation from local and regional economies to a global supplier of agricultural products, mainly soybeans and other small grains. Livestock production has been partially replaced by grain production, but beef cattle has remained a primary product, but trending toward feedlot compared pasture-finished cattle. Four of the five countries (Argentina, Brazil, Paraguay, and Uruguay) of the South American trading bloc (the Mercosur 4 or M4) make up the primary countries that have embraced the new agricultural technologies, which have focused primarily on expansion of soybean production (sojización). Agricultural products in these countries contribute nearly half of their export income and up to 15% of their GDP.

Currently, there are 36 million people living and working on rural lands in these four countries. However, with the recent production transformation an increased rate of urbanization has been ongoing. Fewer farmers, and larger and fewer farms with high-level technologies have replaced the requirements of human labor. The workforce consists of land owners working with family or non-family workers and/or with contractors, who conduct much of the crop planting and harvesting. An important component of the rural workforce is hired farm workers, some of whom travel to different farms for seasonal work.

Regarding statistics on occupational injuries and illnesses, official data is limited to hired workers who are registered with the government for the purposes of social and work benefits. However, most rural workers are not registered and data are not collected on the self-employed, leaving a large void in occupational injury and illness data. However, injury and illness data can be supplemented with newspaper and other media coverage (although this information source is fraught with incomplete information and biased by coverage mainly of serious events). The available data suggest a similar picture of the agents of agricultural injuries to that for developed countries. Agricultural injury and fatality rates are among the highest compared to other occupations in these countries. Fatal tractor overturns, all-terrain vehicle crashes, and machine entanglements are important agents of fatal injuries. However, road accidents between farm vehicles are much more prominent as well as assaults and murder with a deadly weapon.

Agricultural medicine is a new and growing interest in the M4 countries, with Argentina leading the way. The author (MG) has been a leader of a special program for health and safety for agricultural families since 2013. This is a program for the 36,000 members of the Cooperative Federated Farmers of Argentina that seems to be the nidus of advancement of agricultural medicine in the M4 region.

Unique agricultural health risks in the region include Argentinian hemorrhagic fever, a zoonotic infectious disease involving a small rodent reservoir (field mouse) that sheds the viral agent in its saliva and urine. Field workers and rural residents are the most exposed through contact with the infectious agent in the environment, especially during harvest and post-harvest work in grain fields.

The M4 countries are also experiencing social stress and conflict between farmers and urban residents as a result of social, economic, and cultural clashes as urbanization infringes on the agricultural environment. Urbanites do not easily accept the transitioned agricultural economy, which is highly technology-based and has a business model not dissimilar to that of other industries. Similar to developed countries, urban residents are concerned about environmental pollution with agricultural chemicals. They are also concerned about odors and air contamination from livestock operations. This conflict increases the mutual stress between agricultural producers and urban populations.

The M4 countries are now prominent players in the international agricultural product market place. Agricultural medicine is an evolving field, led particularly by Argentina in the M4. One of the major requirements for advancement in this field is an improved statistical base for agricultural injuries and illnesses.

Key Points

1. The M4 have in common long-standing traditions in rural production (like the United States, the EU, and Australia), with a variety of products and processes each with its own risks, dangers, and preventive methods.
2. The M4 countries have great potential for the growth of agricultural production (mainly Brazil and Argentina) due to large areas of land that are still native forests or grasslands. This is a potential not available to countries such as those of the EU, which do not have new areas to plant. However, as production expansion is linked to potential increased local, regional, and global pollution and climate change concerns, such expansion must observe and plan for prevention of these unintended consequences.
3. In Argentina and the other M4 countries, new agricultural technologies have resulted in the expansion of soybean production (sojización). This process has resulted in significant changes, with important implications for the health and safety of agricultural workers and farmers.
4. The agricultural frontier has expanded and displaced livestock and forestry lands to crop production (mainly soybeans).
5. The demographic trend in the M4 is fewer farmers, with larger and fewer farms (a similar trend to that in the developed agricultural economy countries). The use of new, better, and high-technology farming methods has reduced the requirement for human labor.
6. The rapid and profound changes in agricultural production have consequences for farmers and workers, who may suffer from occupational physical and psychological (stress) conditions.
7. Although the rural population has decreased, there are more than 36,000,000 people working and/or living in agricultural regions in the M4 countries, with a high number of women, children, elderly and migrant or seasonal workers (risk populations).
8. The participants in the M4 rural regions are diverse and include farmers, their family members, contractors, professionals, and permanent or seasonal workers, providing a great complexity to management and control of health and safety. This complexity is similar to that of the United States and perhaps to a lesser extent the EU and Australia.
9. Family farming continues to be an important part of agricultural production in M4 countries, similar to some types of production (crops) of in the UK, Australia, and the United States.
10. Unlike the EU, the United States, and Australia, the major obstacle to understanding agricultural health and safety in the M4 countries is the absence of official statistics for all participants of farming. The existing official statistics are only for registered rural workers. Newspapers and other media are important sources that supplement the picture of farm injuries and illnesses.
11. In the M4 countries the rate of agricultural occupational injuries and fatalities is among the highest of all occupations. Their rates are consistently much higher than the average rate for all occupations in each individual country (similarly to developed countries). The available data suggest a similar picture for the specific agents of injury in developed countries.
12. Agricultural medicine is a new but growing interest in the M4 countries, with Argentina leading the way.
13. Unique agricultural health risks in the region include Argentinian hemorrhagic fever, a zoonotic infectious disease.
14. The M4 countries are also experiencing social stress and conflict between farmers and urban residents as a result of social, economic, and cultural clashes where urbanization has begun to infringe on the

agricultural environment. Similar to other developed countries, urban residents are concerned about environmental pollution with agricultural chemicals, odors, and air contamination.

15. Fatal injuries and illnesses in agricultural youth are a big concern in the M4 countries as they are in the United States, the EU and Australia.
16. The agricultural health and safety situation shows the imperative need for more and better preventative actions, and the development of a national strategy (as in the United States, the EU, and Australia) to train and protect farmers, workers, and their families. One of the major requirements for advancement in agricultural medicine is an improved statistical base for agricultural injuries and illnesses (as used in Australia) (60).

References

1. Trade reforms and food security. Chapter 10, Capital market liberalizaiton of the Latin American agrifood system. Food and Agriculture Organization, Rome, Italy. The United Nations, 2002 (accessed 15 January 2016). Available from: http://www.fao.org/docrep/005/y4671e/y4671e0f.htm
2. Garcia-Winder M, Riveros H, Pavez E, Rodriquez D, Lam F, Arias J, Herrera D. Agrifood Chains: A tool for strengthening the institutional framework of the agricultural and rural sector. The International Institute for Cooperation on Agriculture; 2009 (accessed 15 January 2016) Available from: http://repiica.iica.int/docs/B1617i/B1617i.pdf.
3. Bragachini M, Casini C, Saavedra A, Mendez J, De Carli R, Behr E, Errasquín L, et al. Evolución del sistema productivo agropecuario argentino. Actualización Técnica N° 73. Instituto Nacional de Tecnología Agropecuaria – Ministerio de Agricultura, Ganadería y Pesca. Cosecha y Postcosecha. Manfredi; 2012 (accessed 9 January 2016). Available from: http://www.cosechaypostcosecha.org/data/pdfs/EvolSistemaProdAgropArgentino2011.asp.
4. Sistema Integrado de Información Agropecuaria. Ministerio de Agricultura, Ganadería y Pesca. Ciudad Autónoma de Buenos Aires (accessed 2 January 2015). Available from: http://www.siia.gov.ar/_apps/siia/estimaciones/estima2.php.
5. Uruguay en cifras. Ministerio de ganadería, agricultura y pesca de la República Oriental del Uruguay. Departamento de Estadísticas Agropecuarias. Montevideo; 2013 (accessed 2 January 2015). Available from: http://www.mgap.gub.uy/portal/page.aspx?2,diea,diea-resumen-de-la-informacion,O,es,0.
6. Estatísticas e Dados Básicos de Economía Agrícola Setembro/2014. Brasilia: Ministerio da Agricultura, Pecuária e Abastecimiento, Secretaría de Política Agrícola, Departamento de Economía Agrícola; 2014 (accessed 2 January 2015). Available from: http://www.agricultura.gov.br/arq_editor/Pasta%20de%20Setembro%20-%202014(1).pdf.
7. Censo Agropecuario Nacional 2008. San Lorenzo: Ministerio de Agricultura y Ganadería de Paraguay, Dirección de Censos y Estadísticas Agrícolas; 2009.
8. Statistics in Category: Agriculture. Food and Agriculture Organization compiled at NationMaster. Available from: http://www.nationmaster.com/country-info/stats/Agriculture.
9. Nation Master. Food and Agriculture Organization; 2014. Available from: www.nationmaster.com/country-info/stats/agri. http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/7218.0.55.001Oct%202014?OpenDocument.
10. Eurostat Statistics Explained. European Union; 2015 (updated 8 July 2015; accessed 16 January 2016). Available from: http://europa.eu.eu/eurostat/statistics-explained/ir.
11. Census of agriculture. Pigs and Hogs, and Cattle and Calves. Historical highlights: 2012 and earlier years. Washington, DC: US Department of Agriculture; 2015 (accessed 16 January 2016). Available from: http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_US/st99_1_012_013.pdf all pigs & hogs and http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_US/st99_1_012_013.pdf.
12. Census of Agriculture. Poultry inventory and numbers sold: 2012 and 2007. Washington, DC: US Department of Agriculture; 2015 (accessed 16 January 2016). Available from: http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_US/st99_1_032_033.pdfpoultry.
13. Census of Agriculture. Sheep and lambs inventory 2012. Washington, DC: US Department of Agriculture; 2015 (accessed 16 January 2016). Available from: http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_US/st99_1_028_031.pdf.
14. Existencias bovinas 2014. Buenos Aires: Ministerio de Agricultura, Ganadería y Pesca de Argentina, Servicio Nacional de Sanidad Animal; 2015.

Available from: http://www.senasa.gov.ar/contenido.php?to=n&in=552&io=2768715.
15. Ganadería-Porcinos. Anuario porcinos 2012. Buenos Aires: Ministerio de Agricultura, Ganadería y Pesca de la Nación. Available from: http://www.minagri.gob.ar/site/ganaderia/porcinos/02-Informes/_archivos/000005-Anuario/120000-Anuario%202012%20Información%20de%20Porcinos.pdf.
16. Informe de Coyuntura 2013. Buenos Aires: Subsecretaria de Pesca y Acuicultura; 2008. Available from: http://www.minagri.gob.ar/site/pesca/pesca_maritima/04=informes/01-informes_de_coyuntura/_archivos/200007-2013/131201_Informe%20de%20coyuntura%20-%20Diciembre%202013.pdf.
17. Estadísticas 2012. Buenos Aires: Ministerio de Agricultura, Ganadería y Pesca de Argentina Subsecretaría de Lechería; 2014. Available from: http://www.minagri.gob.ar/site/_subsecretaria_de_lecheria/lecheria/07_Estadísticas/index.php.
18. Boletim estatístico da pesca e aquicultura 2011. São Paula: Ministério da Pesca e Aquicultura; 2013. Available from: http://www.mpa.gov.br/images/Docs/Informacoes_e_Estatisticas/Boletim%20MPA%202011FINAL.pdf.
19. Reboratti C. Un mar de soja: la nueva agricultura en Argentina y sus consecuencias. Rev. Geogr. Norte Gd. 2010;(45):63–76.
20. Robert S, Santángello F, Albornoz I, Dana G. Estructura del feedlot en Argentina. Nivel de asociación entre la producción bovina a corral y los titulares de faena. Buenos Aires: Instituto de Promoción de la Carne vacuna Argentina; 2009 (accessed 31 December 2014). Available from: http://www.ipcva.com.ar/files/Trabajo%20integracion%20feedlot.pdf.
21. Lopez M, Arbeletche P, Carvalho S, Perugorria A. Intensificación ganadera a partir de la expansión sojera. Un análisis comparativo de Argentina y Uruguay. VII Jornadas interdisciplinarias de estudios agrarios y agroindustriales. Buenos Aires; 2013.
22. Ambrosi J, Maggi M. Acidentes de trabalho relacionados às atividades agrícolas. Acta Iguazu. 2013;2(1):1–13.
23. Indicadores de Agricultura. Costa Rica: Análisis Estratégico Instituto Interamericano de Cooperación para la Agricultura. Centro de Análisis estratégico para la Agricultura; 2013 (accessed 31 December 2014). Available from: http://www.iica.int/Esp/Programas/AnalisisEstrategico/Documents/indicadores/RegionSur/argentina.pdf and http://www.iica.int/Esp/Programas/AnalisisEstrategico/Documents/indicadores/RegionSur/Brasil.pdf.
24. Censos 2011. Montevideo: Instituto Nacional de estadísticas; 2012 (accessed 31 December 2014). Available from: http://www.ine.gub.uy/censos2011/resultadosfinales/pais%20poblacion.html.
25. Datos de actualidad. Asunción: Dirección General de Estadísticas, Encuestas y Censos; 2014 (accessed 7 January 2015. Available from: http://www.dgeec.gov.py/.
26. Censo Nacional Agropecuario 2002. Buenos Aires: Instituto Nacional de Estadísticas y Censos; 2004 (accessed 31 December 2014). Available from: http://www.indec.mecon.gov.ar/agropecuario/cna_principal.asp.
27. Anuario 2014. Montevideo: Ministerio de anadería, agricultura y pesca de la República Oriental del Uruguay; 2014 (accessed 31 December 2014). Available from: http://www.mgap.gub.uy/portal/page.aspx?2,diea,diea-anuario-2014,O,es,0.
28. Censo Agropecuario 2006. Rio de Janeiro: Instituto Brasileiro de Geografia e Estatística. Banco de Dados Agregados (accessed 31 December 2014). Available from: http://www.sidra.ibge.gov.br/bda/agric/default.asp?z=t&o=11&i=P and http://www.sidra.ibge.gov.br/bda/tabela/listabl.asp?z=t&c=956.
29. Gonnella M, Langanoni H, Peyrano G, Fugante M, Droveta J, Giuliani E, et al. Contratos Agrarios: incidencia en la producción. Revista Agromensajes de la Facultad. Rosario: Facultad de Ciencias Agrarias, Universidad Nacional de Rosario; 2009. p.27.
30. Registro Nacional de Agricultura Familiar. Buenos Aires: Informe Nacional Básico por Región 2014. Ministerio de Agricultura, Ganadería y Pesca de Argentina. Ciudad Autónoma de Buenos Aires; 2014 (accessed 1 January 2015). Available from: http://www.renaf.minagri.gob.ar/documentos/InformeNacional2014.pdf.
31. Scheinkerman E, Foti M, Roman M. Pequeños Productores en la República Argentina: importancia en la producción agropecuaria y en el empleo en base al censo nacional agropecuario 2002. 2nd edition. Buenos Aires: Secretaría Agricultura, Ganadería, Pesca y Alimentos, Instituto Interamericano de Cooperación para la Agricultura; 2007.
32. Dossier. Buenos Aires: Registro Nacional de Agricultura Familiar, Ministerio de Agricultura, Ganadería y Pesca de Argentina, Ciudad Autónoma de Buenos Aires; 2010 (accessed 1 January 2015). Available from: http://www.renaf.minagri.gob.ar/documentos/DOSSIER_ReNAF-0910.pdf.
33. França C, Del Grossi M, Acevedo Marques V. O censo agropecuario 2006 e a agricultura familiar no Brasil. Brasilia: Ministerio do Desenvolvimento Agrario; 2009 (accessed 2 January 2015). Available from: http://www.mda.gov.br/sitemda/sites/sitemda/

files/user_arquivos_64/pageflip-4204232-487363-lt_El_Censo_Agropecuario-2062342.pdf.
34. Boletín de Estadísticas Laborales. Buenos Aires: Regularización del trabajo, Ministerio de Trabajo, Empleo y Seguridad Social de la Nación, Ciudad Autónoma de Buenos Aires; 2015 (accessed 2 January 2015). Available from: http://www.trabajo.gov.ar/left/estadisticas/bel/belDisplayCuadro.asp?idCuadro=182&idSubseccion=5.
35. Fumagalli S, Diano M, Gómez J, Lopez I, Payeres D, Scrimaglia M. Condiciones y medio ambiente de trabajo de los trabajadores temporarios migrantes del cultivo de semilla de papa. La Plata: Premio Concurso Bialet Masse, Ministerio de Trabajo de la Provincia de Buenos Aires; 2011 (accessed 2 January 2015). Available from: http://www.trabajo.gba.gov.ar/informacion/masse/2011/categoriaB/B_FUMAGALLI-DIANO-GOMEZ-LOPEZ-PAYERES-SCRIMAGLIA.pdf.
36. Ministerio de Agricultura, Ganadería y Pesca Dirección Nacional de Contratistas Rurales e Insumos Agrícolas, Ciudad Autónoma de Buenos Aires; 2011 (accessed 2 January 2015). Available from: http://64.76.123.202/site/agricultura/contratistas_rurales/index.php.
37. Durán Fernández V, Pérez Quesada G. El empleo en las cadenas agroindustriales 2012. Anuario OPYPA 2013. Montevideo: Ministerio de Ganadería Agricultura y Pesca República Oriental del Uruguay; 2013 (accessed 2 January 2015). Available from: http://www.mgap.gub.uy/opypapublicaciones/ANUARIOS/Anuario2013/material/pdf/22.pdf.
38. Encuesta permanente de hogares 2013. Asunción: Dirección General de Estadísticas, Encuestas y Censos; 2014 (accessed 2 January 2015). Available from: http://www.dgeec.gov.py/Publicaciones/Biblioteca/EPH/Boletin%20Empleo%20EPH 2013.pdf.
39. Accidentabilidad – Resultados índices anuales de accidentabilidad laboral. Buenos Aires: Superintendencia de Riesgos del Trabajo. Ciudad Autónoma de Buenos Aires; 2013 (accessed 2 January 2015). Available from: http://www.srt.gob.ar/index.php/index.php?option=com_content&view=article&id=508&Itemid=167&anio=2013.
40. Informe Anual de Accidentabilidad Laboral. Reporte Anual 2013. Resumen Ejecutivo. Buenos Aires: Superintendencia de Riesgos del Trabajo. Ciudad Autónoma de Buenos Aires; 2013 (accessed 2 January 2015). Available from: http://www.srt.gob.ar/estadisticas/anuario/2013resumen.pdf.
41. Tarabla H. Risk veterinarians working in midwestern province of Santa Fe, Argentina. InVet. 2009;11(1): 39–47.
42. Molineri A, Perez L, Signorini ML, Tarabla MD. Zoonoses in rural veterinarians in the central region of Argentina. Aust. J. Rural Health. 2013;21:285–90.
43. Recopilación de los principales indicadores de siniestralidad y enfermedad ocupacional en Iberoamérica. Madrid: Organización Iberoamericana de Seguridad Social; 2012 (accessed 3 January 2015). Available from: http://www.oiss.org/estrategia/IMG/pdf/Informe_sobre_siniestralidad.pdf.
44. Rodriguez C. Perfil diagnóstico en Seguridad y Salud en el trabajo del Cono Sur, Argentina, Brasil, Chile, Paraguay y Uruguay. Geneva: Organización Internacional del Trabajo; 2006 (accessed 3 January 2015). Available from: http://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---safework/documents/policy/wcms_212043.pdf.
45. Acidentes do Trabalho – Tabelas-Quantidade de acidentes do trabalho, por situação de registro e motivo, segundo osetor de Atividade Econômica 2011/2013 – Quantidade de acidentes do trabalho, por situação do registro e motivo, segundo a Classificação Nacional de Atividades Econômicas 2011/2013. Brasilia: Ministério da Previdencia Social; 2014 (accessed 3 January 2015). Available from: http://www.previdencia.gov.br/aeps-2013-secao-iv-acidentes-do-trabalho-tabelas/.
46. Anuário Estatístico de Acidentes do Trabalho 2012. Indicadores de Acidentes do Trabalho. Tabelas dos indicadores. Brasilia: Ministério da Previdencia Social; 2014 (accessed 3 January 2015). Available from: http://www.previdencia.gov.br/estatisticas/aeat-2012/tabela-dos-indicadores/.
47. General description of specialization in health and safety in the work of agriculture. Facultad de Agronomía. Buenos Aires: Universidad de Buenos Aires; 2013 (updated 6 August 2013; accessed 3 January 2015). Available from: http://epg.agro.uba.ar/esp-higiene/especializacion-en-higiene-y-seguridad-en-el-trabajo-agrario.
48. Maia L, Rodrigues L. Saúde e segurança no ambiente rural: uma análise das condições de trabalho em um setor de ordenha. Ciência Rural, Santa Maria. 2012;42(6):1134–9.
49. Da Silva R, Nääs I, Silveira N, Moura DJ. Insalubridade do trabalhador na produção animal: uma questão de educação e informação. Brasilia: Agência Embrapa de Informação Tecnológica; 2006 (accessed 3 January 2015). Available from: http://www.agencia.cnptia.embrapa.br/Repositorio/Insalubridade-trabalhador-producao-animal_000gy2ydy2d02wx7ha0b6gs0xs36np7q.pdf.
50. Administración Nacional de Laboratorios e Institutos de Salud. Buenos Aires: Red Nacional de Servicios de

Fiebre Hemorrágica Argentina, Ciudad Autónoma de Buenos Aires; 2014 (accessed 5 January 2015). Available from: http://www.anlis.gov.ar/cnrl/wp-content/uploads/2014/05/rn-servicios-fiebre-hemorragica.pdf.
51. Boletín Informativo de Fiebre Hemorrágica Argentina. Buenos Aires: Ministerio de Salud de la Provincia de Buenos Aires; 2012 (accessed 5 January 2015). Available from: http://www.ms.gba.gov.ar/sitios/regionsanitaria4/files/2012/09/sala-fiebre-hemorragica-argentina.pdf.
52. Calendario nacional de Vacunación Programa Nacional de Control de Enfermedades Infecciosas. Buenos Aires: Ministerio de Salud de la Nación, Ciudad Autónoma de Buenos Aires; 2014 (accessed 5 January 2015). Available from: http://www.msal.gov.ar/images/stories/ryc/graficos/0000000527cnt-2014-01_calendario-vacunacion_2014_final.pdf.
53. Malamud, B. Los niños no tienen branquias. Córdoba: Sociedad de Pediatría de Córdoba; 2012 (accessed 5 January 2015). Available from: http://www.sapcordoba.com.ar/novedades_ver.asp?id_noticia=1358.
54. Waisman I, Nasta C, Ubeda C, Miranda D, Zabala R, Navarro L, et al. Manual de Prevención de Lesiones. Sociedad Argentina de Pediatría. 3rd edition. FUNDASAP; 2012.
55. Aparicio S, Aguilera M. Niños trabajadores en el agro argentino. Familias campesinas y de asalariados rurales. Mitos y creencias en torno al trabajo infantil rural. XXVII Congreso de la Asociación Latinoamericana de Sociología. Buenos Aires: Asociación Latinoamericana de Sociología, Acta Académica; 2009.
56. Ley 26,727 Régimen Trabajo Agrario. Buenos Aires: Ministerio de Economía; 2011 (accessed 5 January 2015). Available from: http://infoleg.mecon.gov.ar/infolegInternet/anexos/190000-194999/192152/norma.htm.
57. Svendsen K, Aas O, Hilt B. Nonfatal Occupational Injuries in Norwegian Farmers. SafHealthWork. 2014;5:147–51.
58. Queiroz H, Queiroz A. Características dos acidentes de trabalho com máquinas do setor agrícola nas regiões brasileiras. XLIII Congresso Brasileiro de Engenharia Agrícola. Campo Grande: Associação Brasileira de Engenharia Agrícola; 2014 (accessed 6 January 2015). Available from: http://www.sbea.org.br/conbea/2014/livro/R0554-1.pdf.
59. Boletín Estadístico Anual sobre Accidentabilidad por sector Agricultura, Caza, Silvicultura y Pesca, Año 2012. Buenos Aires: Superintendencia de Riesgos del Trabajo, Ciudad Autónoma de Buenos Aires; 2014 (accessed 2 January 2015). Available from: http://www.srt.gob.ar/estadisticas/sector/01_agr/2012/2012.pdf.
60. Fragar L, Franklin, R, Coleman, R. The farm injury optimal dataset. Version 1.2, Publication No.: 00/10. Moree: Rural Industries Research and Development Corporation and Australian Centre for Agricultural Health and Safety; 2000.

SECTION

B

Agricultural Medicine in Australia and New Zealand

Susan Brumby

Reviewer: Kelley J. Donham

14.1B Introduction

Australia, including the island of Tasmania and other associated island components of a common land shelf, makes up the smallest of the seven continents on Earth. The Australian continent, along with New Zealand, is also known as Australasia. Its basic style of production agriculture, socioeconomic status, culture, ethnic makeup, and demography has many similarities to North America and Europe. However, there are differences, which this chapter will highlight in a comparative approach relative to North America.

Australia has a highly competitive and profitable agricultural sector and is one of the world's largest exporters of wheat, beef, dairy, and wool products. Approximately 60% of all Australian agricultural produce is exported, mainly to South-East Asia, China, and Japan, contributing 2.4% to the nation's gross domestic product (GDP) (1).

Production agriculture in Australia has climatic and natural resource challenges, primarily because it is the driest inhabited continent on Earth. Relative to other continents, Australia has the least amount of water in its rivers and the most nutrient poor and unproductive soils (2). However, in 2012–2013 approximately 397 million ha of land (around 52% of Australia's total area) was used in agricultural production (3).

Australia, with a population of 23.7 million (2015 estimate), is one of the least densely populated countries globally, having fewer than three people per square kilometer. Eighty per cent of the population lives on the coastal areas, making it highly urbanized. This urbanization creates challenges for farming communities as distance to essential services such as health and education is a substantial barrier to assistance and opportunities.

New Zealand lies 1600 km south-east of Australia and also has a highly competitive and profitable agricultural sector, being one of the world's largest exporters of dairy products, including milk, butter, and cheese being their top commodity export for the year ending 2012 (4). Agriculture provides 5.1% of New Zealand's GDP, and its top trading partners include Australia, China, and the United States. New Zealand has a land mass of 268,680 km^2 divided into two main islands, with a population of 4.45 million and a density of 15 people per square kilometer, five times higher than Australia (5). Because of its size no one lives further than 150 km from the sea, but most people live in cities. New Zealand is also unusual in that it only has only two native land mammals, both bats, unlike Australia, which has numerous native mammals and also feral animals such as wild pigs, camels, horses, and dogs, which add to the spread of disease such as leptospirosis and Q fever. Both countries are islands and free of foot and mouth disease. They also have strict quarantine requirements to maintain their biosecurity status. However, both countries are vulnerable to climate change, with predictions of hotter and longer heat waves, more extreme weather events, and increased bushfires (6).

14.2B Differences in Types of Agricultural Systems

Australian and New Zealand farmers are among the least subsidized in the world as a percentage of farm revenue relative to the governmental support provided to farmers in the United States and the EU. This fact is supported by data from the Organization of Economic Cooperation and Development (OECD), which lists Australia and New Zealand farmers as the least subsidized in its 34 member countries, which include emerging economies such as Brazil, Indonesia, and China. The only non-OECD country with lower subsidies is the Ukraine (7). Both Australia and New Zealand rely heavily on export markets for their agricultural commodities as they both produce far more than is required for their domestic markets. Given the lack of subsidization, the small domestic market, strong reliance on global markets, and competing with more heavily subsidized nations (Norway, the United States and the EU) can create economic stress for farmers.

14.3B Working Characteristics

Similarly to the United States, the principal operators of family farms in Australia are mostly male, with women making up 28%. Many of these women also work off-farm to supplement farm income (similar to the United States). In Australia the median age of farmers is 55 years (58 in the United States), making them much older than other Australia workforces (40 years) but similar to other industrialized nations. This is also compounded by 23% of farmers being aged 65 years or older, compared with just 3% of other workforce populations (8).

The New Zealand agricultural workforce also differs from other sectors, with the average age of farmers, especially sheep and beef farmers, over 50 years (9). This can cause issues with work health and safety. However, New Zealand dairy farmers and their employees (they rely heavily on migrant labor) comprise a younger cohort.

In both Australia and New Zealand efforts are being made to encourage young men and women into agricultural careers and farming.

Whilst the workforce demographic is similar in Australia, New Zealand, and the United States, there are workplace differences. In the United States there are many more intensive concentrated animal-feeding operations (CAFO) and housed agriculture industries such as pork, poultry, horticulture, and dairy. There is also a lot of cheap labor, with pay rates starting at around $8 per hour (10) compared to minimum rates in Australia of $16.80 per hour with a 25% loading (for benefits) for casual work (11). It also seems that in the United States there are fewer onerous regulations around the provision of benefits such as superannuation (retirement pay and social services) and health care. Also, in the United States some undocumented foreign workers may not even be receiving the minimum pay rates. However, Australia and New Zealand have both seen a recent increase in migrant labor with the use of the temporary work subclass 457 visas where employers sponsor overseas workers for up to 4 years in jobs that cannot be filled from the local labor market. These special work visa positions require workers to receive training (12). A working holiday visa has also been introduction that allows for extension if travelers complete 3 months' work in a rural or regional area of Australia. In New Zealand the agricultural sector is also looking for skilled and unskilled workers, particularly in the dairy sector where they are short of 2000 workers (13).

14.4B Agricultural Injuries and Illnesses

Research undertaken by Fragar and Depczynski (14, 15) showed that farming men in Australia have higher rates of death from cardiovascular disease, suicide, and certain cancers when compared to urban populations. (This differs from the United States and northern Europe, where farmers die less often from cardiovascular diseases and cancer compared to the general population.) Other research shows that farm men and women face higher mental health burdens due to social isolation, socio-economic constraints, increased alcohol intake (16), and lack of exercise, and are an increasingly aged workforce (17, 18). Hearing loss is evident at higher rates and occurs at an earlier age due to noise exposures in the workplace. This hearing loss also contributes to stress and poor mental health outcomes (19, 20).

Mental health issues and higher suicide rates have been evident in farming populations and numerous studies have found that rather than seek assistance rural people will conceal distress and may have limited capacity or social competence to identify stressors and act on them (21, 22). A review of the literature showed that New Zealand farmers experienced high levels of stress due to uncontrollable factors in the work environment, such as government regulations, trade and globalization, climatic conditions, and labor shortages (23). Many of these factors are also common globally, particularly in the dairy industry, which New Zealand relies on heavily (24). Concern about high and increasing rates of rural suicide in New Zealand caused their Farm Safe commission to review and look at improving prevention, detection, and response to stress and mental illness.

It is not only mental health issues that delay farm men and women to seek assistance. A study by emergency medicine physician Tim Baker showed that when suffering with chest pain, the further farmers live from a health service the longer they will wait at home in pain, and that when they do act over 10% will attend an inadequate or closed health service (25).

Many of the health disparities mentioned above for Australia and New Zealand are similar to those for US and northern European farmers. One exception is that male Australian farmers experience higher rates of cardiovascular disease, diabetic risk indicators, and higher alcohol consumption. Furthermore, compared to the general high suicide rates reported in Australian farmers, reports of excess suicide rates in the United States are inconsistent, with excesses associated with times of severe economic stress, animal loss, and severe climate aberrations.

14.5B Occupational Health and Safety Legislation

Agriculture is not exempt from either federal or state health and safety laws in Australia. In 2011 there was a move to harmonize all the state and territory laws for one Work Health and Safety (WHS) Act and one Work Health and Safety Regulations Act. All the states agreed to do this with the exception of Western Australia and Victoria. In New Zealand agriculture is covered by a single Act, the Health and Safety in Employment Act 1992 (26). This Act provides legislation to promote the health and safety management in places of work, with its focus on the prevention of harm arising out of work activities.

Similar to North America and the EU, both the Australian and New Zealand agriculture sectors have some of the highest levels of workplace injury, disease, and fatalities compared to all occupations. Currently both countries have a strategy to address these unacceptable rates. In New Zealand an extensive review was undertaken by Lovelock and Cryer (27) between 2000 and 2009 to update knowledge on injury and disease, and develop a platform to move forward. Since then, the Department of Labor, Health and Safety has initiated the Agriculture Sector Action Plan, which has involved an impressive list of agricultural stakeholders committed to reduce the number of injuries and fatalities (28). The strategic areas of focus include:

1. agricultural vehicles and machinery, where in 2003–2008 73% of deaths involved a workplace vehicle (including all terrain vehicles (quad bikes))
2. the physical and mental health and wellbeing of agricultural workers
3. slips, trips, and falls
4. animal handling.

These basic areas of hazard are quite similar to those that are important in the United States, where more than half of all fatalities are associated with farm machinery, and non-fatal injuries are divided nearly equally between machinery-associated injuries and animal-associated injuries.

In Australia, agriculture, forestry, and fishing is also one of the key areas of focus for Safe Work Australia (similar to the Occupational Safety and Health Administration in the United States), with the unenviable record of a high-risk workforce with an unacceptable number of traumatic workplace deaths, including bystanders and children (29). Figure 14.1 shows agriculture, forestry, and fishing with the highest proportion of working fatalities for 2010–2011, and also a decade of recording the second highest proportion of working fatalities. With a new workplace strategy commencing in 2012, agriculture is the main focus to try and reduce the number of fatalities (30). Similarly to New Zealand, 75% of the 294 fatalities between 2007 and 2012 involved vehicles. Australia had 16.81 fatalities per 100,000 workers, which is seven times the national rate of 2.29 for all occupations combined.

The United States has consistently recorded about a 20% higher agricultural fatality rate than Australia and New Zealand, and the EU had 20.2 fatalities per 100,000 in 2012. However, in comparison to all occupational fatalities combined in the respective countries, the United States is similar to Australia and New Zealand, with agricultural fatality rates six times higher compared to 3.2 per 100,000 for all occupations.

Both Australia and New Zealand have strict rules on roll-over protection structures (ROPS) for tractors and both have significant financial

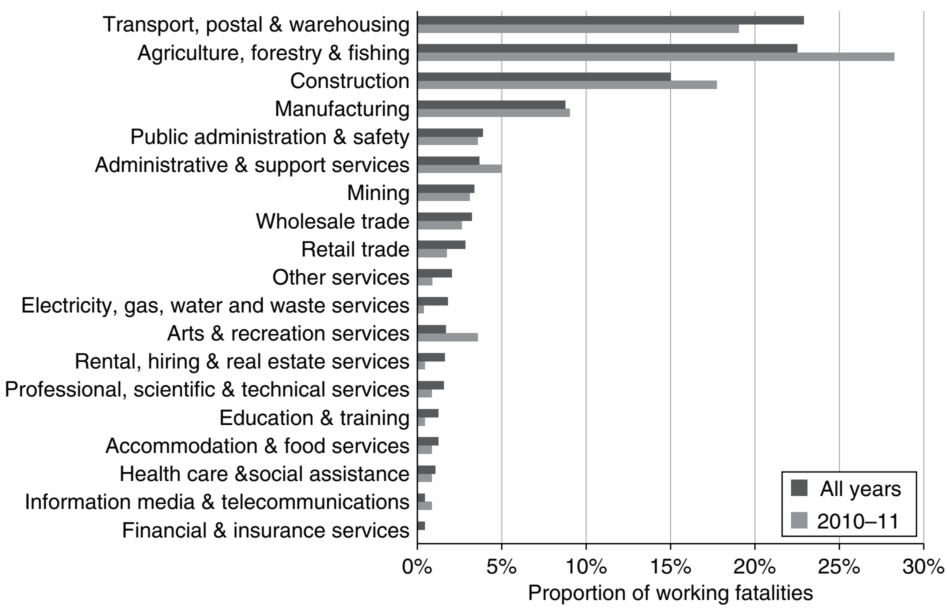


Figure 14.1 Proportion of working fatalities by industry showing all years and 2010–2011. (Source: Safe Work Australia, 2012.)

initiatives to get ROPS fitted on tractors, with a corresponding reduction in deaths seen as a result (31). The United States has not had strict rules on ROPS for agricultural tractors, except for operations with more than 10 employees. Although most tractors manufactured in the United States after 1984 have ROPS, an estimated 40% of the farm tractors used the United States are not equipped with it. This fact alone is a likely explanation for the higher fatality rates in United States agriculture.

An area of intense health and safety interest is quad bikes (also known as all-terrain vehicles, ATVs). These have recently replaced tractors as the biggest killers of people on farms in Australia by a ratio of almost 2:1 (32). A recent study estimates that quad bike fatalities resulted in significant costs to the Australia economy totaling some $288.1 million in 2001–2010 (33). There have also been numerous representations from governments and unions for quad bikes to be fitted with crush protection and improved stability, as the majority of fatalities are due to being crushed by the bike (34). There are also calls to ensure that motorcycle helmets are worn at all times. New Zealand is currently going through a quad bike harm reduction project which involves a multi-prong approach with education and information provided, enforcements visits from the Department of Labor, issuing of compliance notices, and phone surveys to detect behavior change on quad bike use (35).

Comparing to the United States, ATVs are used commonly on most farms. However, only 5% of farm fatalities are associated with ATVs while 23% are associated with tractors. This may change, however, as more new tractors with ROPS replace old tractors on United States farms. However, as more stable and protective ATV designs are used, the Australian experience that quad bikes become the biggest cause of death may also be realized in the United States

14.6B Skin Cancer

Skin cancer is Australia's most common cancer and includes basal cell, squamous cell, and melanoma, with the incidence higher in rural and regional areas (36). It has also been known for some time that globally farmers are at increased risk of some cancers due to occupational exposure of UV (37). According to International Agency for Research on Cancer data on melanoma, New Zealand has a higher age-standardized incidence rate than Australia at 35.8 vs. 34.9 per 100,000 people (38). Although skin cancers (mainly basal cell and squamous cell) are the most prevalent cancers among farmers in the United States, melanoma incidence and mortality rates in both Australia and New Zealand are more than twice as high as those in United States, Canada, and the UK. Predictions are that with the impact of climate change the incidence of skin cancers will continue to rise in Australia (39).

14.7B Agricultural Health and Safety Resources

In the United States the National Institute for Occupational Safety and Health (NIOSH) has funded 10 centers of agricultural health and safety in nine states. The state of Iowa also funds Iowa's Center for Agricultural Safety and Health. Australia's farmers have benefited from the Australian Centre for Agricultural Health and Safety (http://www.aghealth.org.au), based in Moree, New South Wales, and the National Centre for Farmer Health (http:// www.farmerhealth.org.au), based in Hamilton, Victoria, where the award-winning Sustainable Farm Families (SFF) program was initiated. The SFF engaged successfully with over 2500 farm men and women to address health, wellbeing. and safety issues on their farms (40). The future sustainability of both these centers are in jeopardy as of 2015, and they are fighting for ongoing funding and resourcing. Most states and territories in Australia have farm lobby groups and a federal voice with the National Farmers Federation (http://www.nff.org.au) in Australia and the New Zealand Farmers Federation (http://www.fedfarm.org.nz) in New Zealand. There are also numerous industry bodies where levies from produce sold are distributed, for example Dairy New Zealand is funded through a levy on milk solids(http://www.dairynz.co.nz/about-us/how-we-operate/), with further funds from government and co-investors. Similar bodies and levies exist in Australia for wool, meat, grain, dairy, etc. These industry bodies have mostly defined themselves on the development of new products and finding new markets. It is only in recent times that some have become interested in the health of their human resource, their farmers.

14.8B Conclusion

There is still much work and research to be done to address the unique health challenges that farm men and women experience. Some areas of new and additional research include possibly under-recognised and under-diagnosed respiratory disorders, zoonotic diseases, agrichemicals, and neurological diseases in farming populations. Improved engagement and farmer-specific programs are needed to address common and preventable lifestyle diseases, such as cardiovascular disease and diabetes, and the insidious but debilitating preventable issues such as poor mental health, hearing loss, and chronic musculoskeletal injuries. As declared in the Hamilton Charter for Farmers Health by the conference delegates (41), it is up to all of us to ensure that "poor farmer health is not normalised as a by-product of agricultural production."

Key Points

1. Both Australia and New Zealand rely heavily on export markets for their agricultural commodities and are very vulnerable to global fluctuations.
2. Australia and New Zealand have the lowest agricultural subsidisation rates of the OECD countries.
3. Agricultural worker (employee) entitlements and conditions (including social security and retirement, minimum pay, etc.) are higher in Australia and New Zealand in comparison to the United States.
4. Quad bikes are the biggest cause of on-farm death in Australia and New Zealand.
5. Both Australia and New Zealand have skin cancer and melanoma mortality rates that are twice as high as those for the United States, Canada, and the UK.
6. Climate change predictions include longer and hotter heatwaves, more extreme weather events, and increased bushfires.
7. Agriculture forestry and fishing had the highest proportion of workplace deaths in 2010–2011 in Australia.
8. Poor farmer health should not be normalized as a by-product of agricultural production (41).
9. In comparison to North America, the following points are noted:

   a. Production agriculture in Australia has greater challenges because of climatic limitations (drought prone), greater recent climate change concerns, less fertile land, less government subsidies, and higher labor input costs. Although New Zealand has more precipitation and fertile land, the other challenges as listed for Australia are similar.
   b. Wellness indicators for Australian farmers are relatively poor compared to the United States (more cardiovascular disease, cancer, and unhealthy alcohol consumption).
   c. The occupational fatality rates for farmers is about 20% lower in Australia and New Zealand compared to the United States.
   d. The most common cause of occupational fatalities in Australia and New Zealand is ATV crashes, while in the United States tractor-related injuries are the most common cause of fatalities.
   e. The types and causes of most chronic and non-fatal illnesses and injuries are similar in Australia, New Zealand, and the United States.
   f. Sustainable funding and resources for agricultural health and safety are challenges for Australia, New Zealand, and the United States.

References

1. Australia's Agriculture, Fisheries and Forestry at a glance 2012. Canberra: Department of Agriculture Fisheries and Forestry; 2012.
2. About Australia. Canberra: Department of Foreign Affairs and Trade; 2014 (accessed 13 December 2014). Available from: http://www.dfat.gov.au/facts/env_glance.html.
3. Agricultural Commodities, Australia 2012–13. Canberra: Australian Bureau of Statistics; 2014.
4. Invest in New Zealand. Ministry of Business Innovation and Employment; 2014 (accessed 11 December 2014). Available from: https://www.newzealandnow.govt.nz/investing-in-nz/opportunities-outlook/economic-overview.
5. New Zealand in profile 2014. Wellington: Statistics New Zealand; 2014.
6. Reisinger A, Kitching RL, Chiew F, Hughes L, Newton PCD, Schuster SS, et al. Australasia. In: Barros VR, Field CB, Dokken DJ, Mastrandrea MD, Mach KJ, Bilir TE, et al., editors. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge and New York: Cambridge University Press; 2014. p. 1371–438.
7. Agricultural Policy Monitoring and Evaluation 2013: OECD Countries and Emerging Economies. OECD Publishing; 2013. ISBN 978-92-64-19053-5 (print).
8. Australian Social Trends – Australian farming and farmers. Canberra: Australian Bureau of Statistics; 2012.
9. Lok Kara. Essential Skills Work Submission. 2014.
10. Wage and Hour Division. Washington, DC: US Departmnet of Labor; 2014 (accessed 13 December). Available from: http://www.dol.gov/whd/minwage/america.htm.
11. National Minimum Wage Order 2014. Canberra: Fair Work Commission; 2014 (accessed 2014 11 December]. minimum wages]. Available from: https://www.fwc.gov.au/awards-and-agreements/minimum-wages-conditions/national-minimum-wage-orders.
12. Australian Government. Fact Sheet 48b – Temporary Work (Subclass 457) Visa Canberra: Deaprtment of Immigration and Border Protection; 2014 (accessed 10 December 2014). Available from: https://www.immi.gov.au/media/fact-sheets/48b-temporary-business-visa.htm.
13. Ministry of Business Innovation & Employment. Agriculture and Forestry New Zealand Govt.; 2014 (accessed 2014 10 December]. Available from: https://www.newzealandnow.govt.nz/work-in-nz/nz-jobs-industries/agriculture-forestry-jobs.
14. Fragar L, Depczynski J, Lower T. Mortality patterns of Australian male farmers and farm managers. Austr J Rural Health. 2011;19(4):179–84.
15. Fragar L, Franklin R. The health and safety of Australia's farming community. Canberra: Rural Industries Research Development Corporation and Australian Centre for Agricultural Health and Safety; 2000. ISBN 0 642 58141 X.
16. Allan J, Meister P, Clifford A, Whittenbury K, Alston M, Ball P. Drug and Alcohol Use by Farm and Fishing Workers. Canberra: Rural Industries Research and Development Corporation; 2012.
17. Alston M. Who is down on the farm? Social aspects of Australian agriculture in the 21st century. Agric Human Values. 2004;21:37–46.
18. Brumby S, Kennedy A, Chandrasekara A. Alcohol consumption, obesity, and psychological distress in farming communities – an Australian study. J Rural Health. 2013;29(3):311–19.
19. Canton K, Williams W. The consequences of noise-induced hearing loss on dairy farm communities in New Zealand. J Agromedicine. 2012;17(4):354–63.
20. Williams W, Forby-Atkinson L, Purdy S, Gartshore G. Hearing loss and the farming community. J Occup Health Saf Austr N Z. 2002;18(2):181–6.
21. Fraser CE, Smith KB, Judd F, Humphreys JS. Farming and Mental Health Problems and Mental Illness. Int J Social Psychiatry. 2005;51(4):340.
22. Hogan A, Scarr E, Lockie S, Chant B, Alston S. Ruptured identity of males farmers: Subjective crisis and the risk of suicide. J Rural Social Sci. 2012;27(3):118–40.
23. Huat Bin Ang. Occupational Stress Among New Zealand Farmers – A Review. Labour, Employment and Work in New Zealand 2010;2010.
24. Lunner Kolstrup C, Kallioniemi M, Lundqvist P, Kymalainen HR, Stallones L, Brumby S. International perspectives on psychosocial working conditions, mental health, and stress of dairy farm operators. J Agromedicine. 2013;18(3):244–55.
25. Baker T, McCoombe S, Mercer-Grant C, Brumby S. Farmers with acute chest pain are uncertain how and when to seek help: A pilot study. Emerg Med Australasia. 2011;23(3).
26. Health and Safety in Employment Act, (1992).
27. Lovelock K, Cryer C. Effective Occupational Health Interventions in Agriculture – Summary report no.5. Dunedin: Injury Prevention Research Unit, University of Otago; 2009.
28. Workplace Health and Safety Strategy for New Zealand to 2015 – Agriculture Sector Action Plan. Wellington: Department of Labour; 2012. p. 20.

29. Work-related traumatic injury fatalities, Australia 2010–2011. Canberra: Safe Work Australia; 2012.
30. Australian Work Health and Safety Strategy 2012–2022. Canberra: Safe Work Australia; 2012. ISBN 978-0-642-78566-4 (PDF online); ISBN 978-0-642-78565-7 (Print).
31. Day L, Rechnitzer G, Lough J. An Australian experience with tractor rollover protective structure rebate programs: process, impact and outcome evaluation. Accident Analysis & Prevention. 2004;36(5):861–7.
32. Herde E, Lower T. Farm-Related Injuries Reported in the Australian Print Media. Moree: Australian Centre for Agricultural Health and Safety; 2011.
33. Lower T, Pollock K, Herde E. Australian quad bike fatalities: what is the economic cost? Austr N Z J Public Health. 2013;37(2):173–8.
34. Union issues safety ban on quad-bike use. Australian Worker's Union; 26 May 2011 (accessed 26 October 2012). Available from: http://www.awu.net.au/970655_5.html.
35. Guidelines for the Safe Use of Quad Bikes. Wellington: Department of Labour; 2011.
36. Cancer in Australia: an overview. Canberra: Australian Institute of Health and Welfare and Australasian Association of Cancer Registries; 2006; 2007.
37. Blair A, Zahm SH. Cancer among farmers. Occup Med. 1991;6(3):335–54.
38. Ferlay J, Soerjomataram I, Ervik M, Dikshit R, Eser S, Mathers C, et al. GLOBOCAN 2012 v1.0 Cancer Incidence and Mortality Worldwide. Lyon: International Agency for Research on Cancer; 2012.
39. Makin J. Implications of climate change for skin cancer prevention in Australia. Health Prom J Austr. 2011;Dec 22 (Spec. No.):S39–41.
40. Brumby S, Willder S, Martin J. The Sustainable Farm Families Project: changing attitudes to health. Int Electronic J Rural Remote Health Res Ed Prac Policy. 2009;9(1012).
41. The Hamilton Charter for Farmer Health. Hamilton: National Centre for Farmer Health; 2010 (accessed 13 August 2013). Available from: http://www.farmerhealth.org.au/page/hamilton-charter-farmer-health.

Section

C

Agricultural Medicine in: The European Community

Christina Lunner Kolstrup and Peter Lundqvist

Reviewers: Anders Thelin and Kelley J. Donham

14.1C Introduction

Agriculture, including forestry, plays an important part in the economic, cultural, and political life of Europe. It is very diverse, with a variety of crops and livestock produced as a consequence of cultural and geographical differences. As in other parts of the world, farming in Europe has excessive associated occupational injuries, fatalities, and acquired disease hazards.

The European continent covers 44 countries bordered by the Arctic Ocean to the north, the Atlantic Ocean to the west, the Mediterranean Sea to the south, and the Black Sea and connected waterways to the south-east. Europe is the second smallest in land area of the seven continents. However, it is the third largest in total population, and the second most densely populated. Furthermore, Europe has the second highest economic productivity per person (1).

14.2C Diversification of Agricultural Production in Europe

The agricultural industry of Europe was formed by the topography and the cultural and political history of its various regions. North of the Alps the agricultural landscape is open and the settlements are mostly gathered in villages. In large parts of England, Denmark, southern Norway, and Sweden, settlings are scattered as a result of radical land parceling according to land tenure policies during the 1700s and 1800s. Farms and small plots of land are often separated by hedges or embankments in the more peripheral parts of Brittany, Ireland, western and northern England, and north-western Spain. In the Mediterranean regions the landscape is characterized by relatively small areas of arable land, as well as large areas with minor forests and scrubland for grazing and firewood. Vineyards for wine and olive trees are grown on the slopes. Along the coastlines of Spain, France, and Italy, fruit and vegetable crops are intensively farmed and irrigated (1). The diversity in production reflects regional variation in the observed agricultural health and safety issues. In the early 1950s, the European Union (EU, a political–economic union) was established and today the EU comprises 28 of the 44 countries in Europe. This chapter will primarily focus on the main agricultural health and safety aspects of 27 of the EU member countries (1) and their differences compared to North America.

14.3C Differences in Types of Commodity Production and Processes Relative to North America

The EU countries cover 4.4 million km^2, with a population of approximately 500 million (1, 2). One-third of the land area (180,435,000 ha) is used for agricultural purposes, of which 50% is used for the production of cereals. Forest land also constitutes a large area of about 158 million ha. Europe accounts for a very large share of the world production of several crops (e.g., 80% of all rye, 66% of all potatoes and oats, and 40% of all wheat). In the temperate regions of northern and north-western Europe, oats and barley are common crops and on better soils so is wheat. On the sandy soils in northern Germany and to the east, rye grain species are characteristic crops. In northern Europe, crop rotation is common, and tuber and root vegetables like potatoes and sugar beet are common crops. In some parts of Europe a large proportion of rapeseed (canola) is grown for oil production and as a protein source for animal feed. Canola is one of the main domestic sources of protein in animal feed to supplement fish meal and imported soybeans. In southern Europe, wheat, barley, and maize (corn) are grown mainly as a carbohydrate energy source in animal feeds. Olive groves occur extensively around the Mediterranean and wine is grown particularly in France and Italy, constituting an important part of the total agricultural export product. Large areas of maize (corn) are grown in the lower Danube river plain areas of Hungary, Romania, Ukraine, and southern Russia. Maize is also grown in Italy and France. During the 1980s, this crop was also introduced on a large scale in the northern European countries, such as Belgium and the Netherlands. Rice occurs in northern Italy and southern Spain, and citrus for pulp is grown mainly in Spain and Sicily. Greenhouse cultivation of vegetables and flowers is particularly common in the Netherlands and the cultivation of early vegetables in southern France, Brittany, and Cornwall (England) (1–3).

In 2010, there were 11.8 million farms in the EU countries with an average size of 14.4 ha (36 acres), compared to the United States with 2.2 million farms with an average of 176 ha (441 acres). Sixty-nine per cent of the EU farms were less than 5 ha (12.5 acres, 1 ha = 2.5 acres), accounting for only 7% of the agricultural land (3). The average farm size was highest in the UK, with 70 ha (175 acres), and 21% of the UK farms had more than 100 ha (250 acres) of agricultural land. In many other countries farm size lies between 10 ha (25 acres) and 30 ha (75 acres) per farm. The smallest farm units are found in southern Europe, in countries such as Romania, Poland, Portugal, Greece, and Italy. In Slovakia and the Czech Republic, respectively, 91% and 89% of the agricultural land was found on farms with more than 100 ha (250 acres). In France, the Netherlands, Norway, and Sweden the governments have encouraged specialization, rationalization, and expansion to large-scale operations (1–3).

Agriculture in Europe is generally characterized by highly mechanized farm operations and high yields, but it is also characterized by large internal differences. The Russian Federation has, for example, despite a relatively well mechanized agriculture, much poorer yields than the UK and the Netherlands. In some Eastern European countries of the former Soviet Union (e.g., Romania, Bulgaria, and Albania) agriculture was organized in very large units under state or collective control. However, smaller areas were set aside for family farms, which often had a higher production per unit area and accounted for a large part of the production of potatoes, vegetables, and fruit. In Eastern Europe following the dissolution of the Soviet bloc land companies have purchased and aggregated small landholdings to large farms. Amongst these large farms, there still remain small family farms, but also a lot of land that remains unfarmed. Family farms have remained dominant in Poland, Hungary, the Czech Republic, and Slovakia. Unlike the rest of Eastern Europe, they are mainly privately owned. In Western Europe agriculture is primarily dominated by family farms, similar to the United

States, where 95% of farms are family farms. However, in several countries of Western Europe large agricultural estates and operations are present (often held over from feudal times) (1–3).

Cereal production often occurs along with livestock production, which is well developed, especially in the countries around the North Sea. There have been considerable structural changes in EU livestock farming since the 1980s. Smallholders on mixed farms have gradually given way to larger-scale, specialized livestock operations. Even though the number of livestock farms and animals has declined, more efficient farming methods have led to higher meat and milk yields (2, 3). In 2012, the EU had approximately 88 million cattle of which 23 million were dairy cows, mainly housed in Germany, France, and Poland. There were 145 million pigs mainly in Germany, Spain, France, Denmark, the Netherlands, and Poland. Sheep (83 million) are mainly products of the UK and Spain, and 13 million goats (2011) are produced in Greece. The average herd size for EU dairy farms is not exactly known, but about 75% of the 1.7 million dairy farms have fewer than 10 dairy cows. The largest numbers of dairy farms are found in Romania, and Poland. The UK, Germany, and Italy have the largest number of large-scale dairy farms, with more than 100 dairy cows per farm (3). Approximately one-third of the world's meat production (approximately 40 million tons of meat from cattle, pigs, sheep, lamb, goats and poultry) comes from Europe (1, 3). A few of the EU countries account for the majority of the meat production, for example the majority of beef is produced in France, Germany, Italy, and the UK. Pork meat is produced primarily in Germany, Spain, France, Poland, Italy, Denmark, the Netherlands, and Belgium. Meat from sheep, lamb, and goats is produced primarily in the UK, Spain, and Greece. The majority of EU dairy production is concentrated in the UK, Germany, Spain, France, and Italy. The largest producers of cheese are Germany, France, and Italy.

EU farmers are or have been highly subsidized and EU policy has led to regional specialization and more efficient agriculture production. Within the EU, a common agricultural policy (CAP) governs with the objectives of increasing agricultural production, providing stability in food supplies, ensuring a high quality of life for farmers, stabilizing markets, and ensuring reasonable prices for consumers. It has guaranteed a high price for agricultural products to farmers, which has in part led to surplus production. In the former Soviet Union the exact the opposite happened, and agricultural productivity has declined. The EU has had to import grain and soybean meal for animal feeds, mostly from the United States (1).

In summary, agricultural production in the EU is different in size and technology from that in North America. Farms in the EU are mostly small family farms, often with integrated crop and livestock production, but very large, specialized confined animal feeding operations (CAFOs) and mono cropping systems exist. The diversity of productions systems and products also mirrors the different climatic conditions in Europe. This also results in the different occupational hazards, risk factors, and health issues that European farmers, farm workers, and farm families face.

14.4C Differences in the Culture of the Workers

EU agriculture is highly mechanized and highly efficient compared to that of less developed countries. As a consequence, a relatively small percentage (about 5%) of the total population is employed in the agricultural sector in the EU (similar to the United States and other more developed countries). Furthermore, farming is tending to become less important as a source of employment in rural areas even though it still plays a vital role in preserving rural landscapes. About 10 million people are engaged in agriculture, of which about 2 million are full-time employees and more than 4 million are temporarily employed, generally used to cover seasonal work peaks (4). (These demographic figures of agricultural employment and labor are quite similar to those for the United States). It is estimated that 66% of seasonal workers are migrant workers migrating within the EU. However in the southern EU migrant workers also come from Northern Africa (4). The highest percentages of the population working in agricultural (in 2012) were found in Romania (29%), Poland and Greece (13%), Portugal (10%), and Lithuania (9%). Germany, Belgium, the Netherlands, Italy, the UK, Sweden, and Denmark had the lowest proportions of agricultural workers (less than 5%) (1, 3). The number of jobs in agriculture is steadily decreasing. This is a continuing trend linked to global economic developments and is observable in all technologically advanced countries. The decline of agricultural employment across the EU must also be considered in terms of production types. Farming accounts for 9% of jobs on average in countries where more labor-intensive production dominates, such as Italy, Spain, Greece, and Portugal. In comparison, only 3% of jobs are in agriculture in northern EU where crop and livestock farming are more common, more mechanized, and require less labor (4).

The average age of farmers in the EU is 55 years (58 in the United States), but there are differences between northern and southern Europe. Generally, the proportion of elderly farmers is higher in the Mediterranean countries, with nearly 50% of the farmers over 55 years of age compared to only 1% in Germany. The percentage of farmers under 35 is 4% in Portugal and 6% in Italy. Family labor still dominates in EU agriculture, for example family members accounted for 97% of the agricultural workforce in Finland. The highest proportion of non-family workers was found in the UK and Denmark (4). Farm owners are predominately male, but, as in the United States and other developed countries, women are becoming increasingly engaged in agriculture. It is estimated that about one-third of the total agricultural workforce is female (5). The proportion of female farm workers is especially high in Portugal (52%) and Austria (49%). In Sweden about 50% of farm workers are female and women are even more prevalent in livestock production (4, 6). Similar trends are seen in North America, but are not quite as pronounced.

14.5C Differences in Agricultural Injury and Illness Statistics

The diversity of agriculture, climate, technical advancement, culture, farming structure, and regional legislation in the EU is reflected in the diverse picture of occupational health and safety hazards. In a statistical portrait of work and health in the EU (1994–2002), agriculture, including hunting and fishing, had the highest fatal and non-fatal injury rates compared to other industries, 11.8 per 100,000 workers compared to 6.0 per 100,000 for all workers (7) (The 2012 EU agricultural fatality rate for the United States shows an agricultural fatality rate of 20.2 per 100,000 (38% higher) and an non-fatal rate of 3,200 disabling injuries or illnesses per 100,000 (about 50% of EU data)). In the EU, the statistics reveal that 3.2% of the agricultural workforce had permanent health problems or disabilities caused by work-related disease (7). A study has shown that farmers in general have lower morbidity rates, especially for cardiovascular diseases and mental diseases, but also cancer diseases (similar in the United States). Furthermore, EU farmers have fewer diseases of the digestive, uro-genital, respiratory and locomotor systems, and skin, and injuries to women (8). Regarding mental health, several studies have shown that farmers report few mental health problems (9). In a survey conducted in 2000 on working conditions in EU agriculture, 40% of the workforce stated that their health was at risk because of work, 15% handled dangerous substances, 8% considered that their health was being put at risk of allergies because of work, over 10% considered that they had been put at risk of skin problems at work, and nearly 30% were exposed to vibrations at work (10). The study also revealed that more than 20% of agricultural workers reported being exposed to noise at work, almost 60% were exposed to painful posture at work, nearly 50% carried heavy loads, and over 50% were exposed to repetitive hand movements (half the time or more). However, only 30% of workers felt that they were well informed about the risks at work (10). These figures have only marginally declined over the years despite numerous implemented measures. In some EU countries the statistics on fatalities, injuries, and occupational diseases related to agriculture are not systematically registered or registered at all. In the EU the most common cause of serious and fatal agricultural injuries involves moving and overturning tractors and other motorized farm equipment. About 25% of fatalities in US farmers are from tractor overturns, but this is less of a problem in the EU as roll-over protective structures (ROPS) are required on tractors (discussed in more detail below). Other causes of injury involve falling from heights, being hit by falling objects, being trapped by objects collapsing or overturning, and handling of livestock. Injuries on farms also occur during maintenance of machinery or equipment and handling of animals (11). Tractor-related fatal injuries remain a concern, but as EU directives have made it compulsory to have roll-over protection, this source of injury has reduced the number of fatalities and serious injuries to a very large degree.

Even though the injury rate is higher for men, women also report high levels of injuries in the agricultural sector. However, female workers may not be covered by occupational safety and health legislation. Women working in agriculture may be exposed to the same hazards and risk factors as male workers, but, similar to North America, they may also face additional risk factors, particularly to reproductive health (e.g., from hormones used in animal treatments, carbon monoxide in farm buildings, infections acquired from livestock, and possibly insecticides) (5). Additionally, women may be at greater risk of work-related musculoskeletal disorders in the neck and upper limbs, especially those working in dairy farming (12–15). As in most western developed economies, agriculture is unusual in the fact that the place of work may also be the family home. This implies that children may be at risk from workplace hazards in agriculture. In addition, visitors to farms may bring children with them, perhaps unaware that they are entering workplaces. (These factors all occur in North America too.) According to the International Labor Office (16) the average incidence of non-fatal farm injuries in the EU was about 50% higher among workers of 18–24 years of age compared to other age groups. Sweden is one of the countries in the EU that has specific regulations for children and youth workers on farms, but not all countries in the EU cover child protection in their occupational safety and health legislation. About two-thirds of the fatal events involving children are related to vehicles. Other causes of fatal accidents include machinery, drowning, suffocation, and contact with animals (17). Many of the hazards and gender issues described above are very similar to those experienced in the United States.

14.6C Differences in Health and Safety Regulations

The EU has developed and agreed on standard regulations concerning workplace health and safety, but each country has made minor modifications to coincide with local and regional conditions. In most EU countries the occupational health and safety regulations also apply to agriculture and only a few countries have specific regulations for agriculture. (This is different in the United States and such regulations do not take effect (with the exception of California, Washington, and Oregon) unless there are 11 or more employees on the farm.) There are several EU safety and health regulations. Directive 89/391/EEC introduced measures to encourage improvements in the safety and health of workers in the workplace. The purpose of the directive is to secure a minimum level of safety and health at work and it mandates responsibility to the employer to take care of the safety of his/her employees (17). Furthermore, the EU has specific directives concerning noise (2003/10/EC) and vibration (2002/44/EC), with precise limits on maximum exposure, guarding of machinery (98/37/EC), and tractor safety (2003/37/EC). According to these directives, the manufacturer is responsible for the safety of a machine placed on the market (17). In Sweden, some regulations are issued especially for the agricultural sector regarding pesticides, working with animals, and use of tractors, whereas regulations regarding ergonomics for the prevention of musculoskeletal disorders, noise, vibrations, gases, chemical and microbiological hazards, use of personal protection equipment, working alone, and young workers are more general but include agriculture (18). In Sweden, all employers, including farmers, are obligated to investigate, correct hazards found, and follow up that the work environment is satisfactory and prevents ill-health and injuries (19). Another example of comprehensive EU regulations concerns ROPS, which is required for tractors and other agricultural vehicles. The effectiveness of this legislation is shown in the number of fatalities in tractor turn-overs, which decreased from 1.6 to 0.2 per 10,000 Finnish farmers (17). In several, but not all, EU countries farmers are covered by different insurance systems. As an example, Farmers' Social Insurance Institution (Mela) in Finland is mandatory for all farms with at least 5 ha (12.5 acres) of farmland and covers self-employed farmers, their spouses, and salaried family members (salaried non-family workers are insured by other workers' compensation insurance carriers). In Denmark, all employees are included in an insurance system covering occupational injuries and diseases which is paid by the employer (mandatory) and all self-employed Irish farmers are covered by the Irish Safety, Health and Welfare at Work legislation (20).

14.7C Differences in Resources for Agricultural Medicine

Farmers have different possibilities for accessing occupational health care and services in EU countries. Finland is an example of a country with a well-developed voluntary occupational health service for farmers (21). An occupational health nurse and local agricultural advisor visit farms according to an established schedule to survey working conditions at least every 4 years. In Norway only 8300 farmers (15%) are affiliated to occupational health services, but they appear to be satisfied with the outcomes and services provided (22). In Sweden approximately 37% famers use occupational health services for regular health screenings (23). Furthermore, specific measures have been taken in Sweden to prevent injuries among children on farms (24) and there is a safe farm program for Swedish farmers involving training and farm walk-through with a farm safe specialist (23).

14.8C Special/unique Agricultural Illness or Injury Conditions

European countries, specifically those in the EU, vary in their living and working conditions. The differences are affected by the variation in the level of mechanization versus exposure to manual work, exposure to environmental factors, and access to technical solutions. In general there are many similarities in the types of general agricultural occupational injuries, illnesses, hazards and related issues between the EU, North America, Australia, and New Zealand.

Key Points

This chapter is based on the available facts from the EU and other selected references. The authors have focused the discussion in a comparative sense on the United States, Canada, and other western countries with more developed agricultural industries.

1. The EU countries have a total of 11.8 million farms. Sixty-nine per cent of these farms have fewer than 5 ha and account for only 7% of the agricultural land.
2. EU farmers are or have been highly subsidized and this EU policy has led to a regional specialization and more efficient agricultural production.
3. About 10 million people are engaged in agriculture (approximately 5% of the total workforce in the EU), of which about 2 million are full-time employees and more than 4 million are temporarily employed,

usually to cover seasonal work peaks. It is estimated that 66% of seasonal workers are migrant workers migrating within the EU.

4. Agriculture, including hunting and fishing, had the highest fatal and non-fatal injury rates (11.8 per 100,000 workers) compared to all other industries (6.0/100,000). Although the EU agricultural fatality rate is similar to those of Canada, Australia, and New Zealand, the comparable rate in the United States is about 38% higher, but the fatality rates for all occupations are similar.
5. About two-thirds of children killed in agriculture are involved in accidents related to vehicles. Other causes of fatal accidents include machinery, drowning, suffocation, and contact with animals.
6. Several studies have shown that farmers report few mental health problems. In the United States stress and depression are common during economic downturns and weather disturbances.
7. Farmers in general have lower morbidity rates, especially for cardiovascular and mental diseases, and cancer. Additionally, EU famers compared to the general populations in EU countries have fewer diseases of the digestive, urogenital, skin, respiratory and locomotor systems.
8. In most EU countries occupational health and safety regulations apply to agriculture as well as other industries and only a few countries have specific regulations for agriculture.
9. Farmers have different ways of accessing occupational health care and services in EU countries, with Finland and Norway good examples of countries with well-developed occupational healthcare systems.
10. In general there are many similarities between EU countries and North America, Australia, New Zealand, and other Western more developed economies relative to the type of general agriculture and health and safety issues. The main points of comparison (relative to the United States) are as follows:

- The trend toward larger, more specialized farms in the EU is similar in the United States.
- The demographics of the agricultural workforce have similar metrics, with most farms being family farms, the principal operators aging, and more women emerging in agriculture as operators and employees.
- The EU has more stringent regulations on health and safety on farms.
- The United States has about a 38% higher agricultural occupational fatality rate.
- The EU has regulated that all farm tractors will have ROPS, leading to a very low tractor roll-over fatality rate. The United States has no regulation for ROPS on farms with fewer than 11 employees. Tractor over-turns remain the largest source of fatal injuries.
- The United States reports about a 50% lower non-fatal occupational injury rate.
- The EU (at least in Scandinavian countries) has greater access to occupational health services for farmers.
- The United States has more research, outreach centers and organizations for agricultural health and safety.

References

1. Germundsson T, Möller J. Jordbruk i Europa [Agriculture in Europe] (in Swedish); 2015 (updated 13 January 2015; accessed 19 January 2015). Available from: http://www.ne.se/uppslagsverk/encyklopedi/lång/europa/näringsliv/jordbruk.
2. EU agriculture – Statistical and economic information. Eurostat; 2013 (updated 13 January 2015; accessed 19 January 2015). Available from: http://ec.europa.eu/agriculture/statistics/agricultural/2013/index_en.htm.
3. Jordbruket i EU [Agriculture in Europe]. In: Yearbook of agricultural statistics 2014, including food statistics.

Örebro: Statistics Sweden, Agriculture Statistics Unit; 2014. p. 392. Available from: http://www.jordbruksverket.se/download/18.37e9ac46144f41921cd21bda/1403096026056/Kap+13+Jordbruket+i+EU.pdf.
4. Employment. Agri-info.eu; 2007 (updated 2007; accessed 19 January 2015). Available from: http://www.agri-info.eu/english/t_employment.php.
5. Agriculture. European Agency for Safety and Health at Work; 2014 (updated January 2015; accessed 19 January 2015). Available from: https://osha.europa.eu/en/sector/agriculture.
6. Kolstrup C. Work Environment and Health among Swedish Livestock Workers. PhD thesis. Alnarp: Swedish University of Agricultural Sciences. Acta Universitatis agriculturae Sueciae nr 2008:43. Available from: http://pub.epsilon.slu.se/1758/1/Kappa_C_Kolstrup_Epsilon.pdf.
7. European Commission and Eurostat. Work and Health in the EU. A statistical portrait: data 1994–2002. Luxembourg: Office for Official Publications of the European Communities; 2004. Available from:http://bookshop.europa.eu/en/work-and-health-in-the-eu-pbKS5704807/;pgid=Iq1Ekni0.1lSR0OOK4MycO9B0000BQ5Q1o6o;sid=be4wgwICcicwhVa4AfquJGAnzy1M0wXRaz0=?CatalogCategoryID=82cKABstbqMAAAEjs5EY4e5L.
8. Thelin A. Morbidity in Swedish farmers, 1978–1983, according to national hospital records. Social Sci Med. 1991;32(3):305–9. Available from: http://www.sciencedirect.com/science/article/pii/027795369190108O.
9. Lunner Kolstrup C, Kallioniemi M, Lundqvist P, Kymäläinen H-R, Stallones L, Brumby S. International perspectives on psychosocial working conditions, mental health, and stress of dairy farm operators. J Agromedicine. 2013;18(3):244–55. DOI:10.1080/1059924X.2013.796903.
10. Paoli P, Merllié D. 2001. Third European survey on working conditions 2000. Luxembourg: Office for Official Publications of the European Communities; 2001. p. 86. Available from: http://eurofound.europa.eu/sites/default/files/ef_files/pubdocs/2001/21/en/1/ef0121en.pdf.
11. Pinzke S, Lundqvist P. Occupational accidents in Swedish agriculture. Agric Eng Res. 2007;13: 159–65.
12. Lunner Kolstrup C. Work-related musculoskeletal discomfort of dairy farmers and employed workers. J Occup Med Toxicol. 2012;7:23 (Open Access). DOI:10.1186/1745-6673-7-23.
13. Pinzke S. Changes in working conditions and health among dairy farmers in Southern Sweden. A 14-year follow-up. Ann Agric Environ Med. 2003;10: 185–95. Available from: http://www.aaem.pl/pdf/10185.htm.
14. Holmberg S, Stiernström E-L, Thelin A, Svärdsudd K. Musculoskeletal symptoms among farmers and non-farmers: a population-based study. Int J Occup Environ Health. 2002;8(4):339–45. DOI:10.1179/107735202800338623.
15. Stål MU, Gustafsson BM, Johnsson B. Milking is a high-risk job for young females. Scand J Rehab Med. 1996;28(2):95–104.
16. World day of safety and health at work. Geneva: ILO Publications, International Labour Office; 2005. Available from: http://www.ilo.org/legacy/english/protection/safework/worldday/products05/report05_en.pdf.
17. Pyykkönen M, Aherin B. Occupational health and safety in agriculture. In: Jakobsson C, editor. Sustainable agriculture. Uppsala: Baltic University Press; 2012. p. 391–401. Available from: http://www.diva-portal.org/smash/get/diva2:603516/FULLTEXT01.pdf#page=386.
18. Reed S, Douphrate DI, Lundqvist P, Jarvie P, McLean G, Koehncke N, et al. Occupational health and safety regulations in the dairy industry. J Agromedicine. 2013;18(3):210–8. DOI:10.1080/1059924X.2013.796902.
19. Swedish Work Environmental Authority. 1977. Arbetsmiljölagen (1977:1160) (In Swedish) http://www.av.se/lagochratt/aml/. Work Environment Act (1977:1160) (In English) http://www.av.se/inenglish/.
20. International Dairy Research Consortium. Workshop report 2013. Colorado: Colorado State University. Available from: http://csu-cvmbs.colostate.edu/Documents/idrc-2013-meeting-report.pdf.
21. Kallioniemi MK, Simola A, Kinnunen B, Kymäläinen H-R. Stress in farm entrepreneurs. In: Langan-Fox J, Cooper CL, editors. Handbook of Stress in the Occupations. Cheltenham: Edward Elgar Publishing; 2011. p. 385–406.
22. Brunes, O. Status of occupational health, working environment and safety in Norway. In: Proceedings of Nordic Meeting on Agricultural Occupational Health; 2006 August 21–23; Kuopio, Finland.
23. Danielsson, A. The current situation of farmers' OHS in Sweden. In: Proceedings of Nordic Meeting on Agricultural Occupational Health; 2006 August 21–23; Kuopio, Finland. Available from: http://www.ttl.fi/partner/nmaohs/programme/scientific/Documents/Danielson_NMAOHS2014.pdf.
24. Svennefelt AC, Lundqvist P. Swedish guidelines for children´s agricultural tasks. Part II. In: Proceedings of Nordic Meeting on Agricultural Occupational Health; 2006 August 21–23; Kuopio, Finland.

CHAPTER

15

Prevention of Illness and Injury in Agriculture

Kelley J. Donham

Reviewer: Jean McCandless

15.1 Introduction

Those working in production agriculture feed the world. Their productivity facilitates urban development along with the arts, sciences and general industry. A central theme of this book has been the recognition, treatment, and prevention of health and safety hazards of this high-risk occupational group. The sustainability of our society depends on a sustainable agriculture. In turn, a sustainable agriculture depends on the health and safety of the agricultural population who do the work. This chapter focuses on the expectation that implementation of the principles described will assist in their sustainability.

Creating healthy and safe agricultural working environments poses unique concerns (1, 2). Challenges include the strong cultural and belief systems of agricultural people (3), socioeconomic issues, numerous and isolated operations, special risk populations, and unique hazards of the work environment. These challenges vary across different sectors of agriculture. While small independent family farms may present the greatest challenge, health and safety promotion on larger farms with employed farm workers presents its own difficulties. The following sections will include the relative effectiveness of different paradigms of intervention as well as a "hierarchy of prevention" (Figure 15.1) and the relative characteristics and strengths of each. Barriers to intervention and prevention will also be discussed.

Personal protective equipment was briefly discussed relative to the hazards defined in Chapters 3, 6, and 9. This chapter will extend discussion of personal protective equipment (PPE) (see details of PPE description selections and fitting in Appendix A).

Finally, integrated multimodal prevention interventions have proved to have a higher likelihood of improving health and safety in the agricultural population over time relative to single-modal interventions. Examples of such interventions are included in this chapter.

Murphy (4) and Aherin (5) have reviewed the history and development of prevention in agricultural health and safety. They point out that contributions to this field have historically come from industrial safety, industrial engineering, education, psychology, and public health. In addition, they have described a hierarchy of prevention effectiveness that places elimination of the hazard at the top, followed by enforcement of regulations and standards, and then awareness-raising education and training to change behavior. Most health and safety specialists agree with this hierarchy (Figure 15.1). A primary aim of

Agricultural Medicine: Rural Occupational and Environmental Health, Safety, and Prevention, Second Edition.
Kelley J. Donham and Anders Thelin.

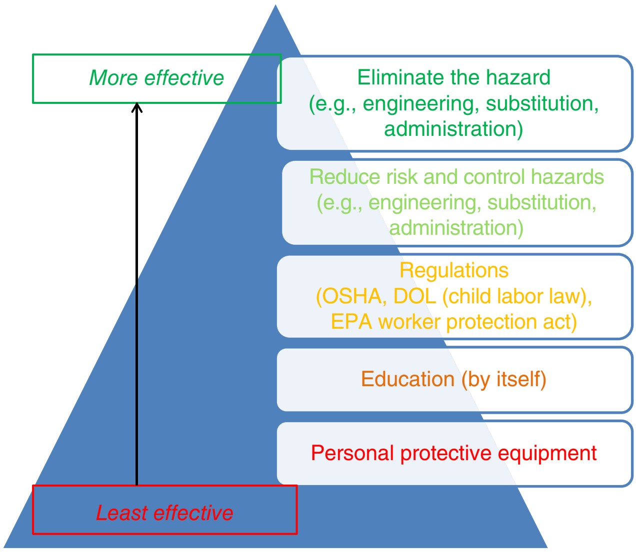


FIGURE 15.1 Hierarchy of prevention in agriculture.

this chapter is to assist health and safety practitioners in developing new prevention programs based on attention to this hierarchy, science-based current theory in the field, and prior experience.

15.2 Barriers to Prevention Intervention

Intervention programs must address the variations in the size, management, labor, and environment of farms from small family farms to large industrial-style farms. Prevention programs must also address the diversity of individuals (physical and cultural) who work within these different structures.

15.2.1 Small Family Farms

The Nature of Farming

Compared to other industries (where management and labor are separate), small family farm owner/operators represent both labor and management. Over 80% of those working in production agricultural (even in the developed economies) retain the characteristics of small family farms. However, with the trend of farming enterprises becoming larger, they tend to acquire the characteristics of other industrial enterprises (separate labor and management) but retain some characteristics of family farms.

Economics

The economic aspects of agriculture were discussed in the introductory chapter. Farming has always presented an economic challenge for the individual producer. However, the growth of the supply side economic policy for agriculture beginning in the early 1970s, and the global economy of the late 1990s, have resulted in a highly productive agriculture while commodity prices have remained nearly level relative to continually rising production costs, resulting in an ever-narrowing profit margin for the producer (6). The producer must be frugal and is likely to use old and often unsafe equipment, rely on unpaid family labor, and choose not to allocate resources to safety and health applications (7). Producers and their insurers need to understand that agricultural injuries have a profound economic impact on the individual family and the local economy. Based on 1992 data Leigh and co-workers (8) found that in the United States non-fatal farm injuries annually cost about $25,435 per injury, with a total of $13 billion (adjusted for inflation to 2015 dollars). Another economic analysis (reported in 2002) resulted in findings that indicate that installation of roll-over protective structures on tractors in the United States would annually save the public $1.5 billion ($2 billion in 2015 dollars) (9). As economic sustainability is a prime concern of producers, health and safety professionals should use such economic data to help create behavioral change in the farming population by providing financial incentives for reduced occupational health and safety hazards. The marginal economy of farming and the cultural peculiarities of farmers challenge health professionals to be creative and persistent in finding ways to promote health and safety. The challenges vary among different agriculture sectors.

Culture

The challenge of cultural values creates challenges to prevention.

> "*If anybody is going to tell me how to be safe on my farm, they had better first come out here and walk a mile in my shoes.*"
>
> The late Myron Zumbach, corn and cattle producer, Coggin, Iowa

This excerpt from a video we produced presents a common producer's view on farm safety, elucidating the challenge of creating safe and healthful farming operations. Myron is typical of many smaller agricultural producers in industrialized countries. Proudly, they resist interference from outside entities, especially if it is the government, or outsiders who have no agricultural credentials. They are averse to regulations. They do not trust government to be practical. They perceive the government and other non-agricultural entities providing "assistance" as impeding their productivity and increasing their operating expenses. Farm people in most of the developed world share to some degree a common culture of pride, independence, work ethic, mistrust of institutions, retain a need to be understood and respected. When challenged on their record on health, safety, and the environment, they usually present a defensive posture. Farmers accept risk of occupational injury and illness as part of their job. Farm productivity is often more important to farmers and ranchers than health and safety. This cultural perspective has been present in farming for over 200 years. Thomas Jefferson, the third president of the United States, justified the new proposed federal system that would allow the farming population not to lose representation relative to an urban aristocracy as follows (10):

> "*Cultivators of the Earth are the most valuable of citizens. They are the most vigorous, the most independent, the most virtuous, and they are tied to their country and wedded to its liberty and interests by the most lasting bonds.*"
>
> Thomas Jefferson, 1785

These attributes of the farmer have been referred to as the "agrarian myth". It still permeates farming communities in the United States, and perhaps to a lesser extent in other industrialized countries. Farmers feel they are in a noble profession that "feeds the world" and have a covenant with society and thus a right to farm with little interference.

Although issues of independence and self-reliance are important to farmers and ranchers, they generally have not taken charge of their occupational health and safety problems (11, 12). Instead, numerous farm safety non-governmental and governmental organizations have emerged (see Table 1.2). However, these organizations have not largely been led, or actively participated in, by active farmers (13). Funding for these sources has instead come from the government or private donations. Long-term sustainability or expansion of effective health and safety initiatives is unlikely unless proactive leadership, resources, and incentives develop within the agricultural community and associated agricultural businesses, and more health and safety legislation is enacted that is effective, enforced, and accepted by the farm community.

As the former conditions are not in effect at this time, health and safety professionals are left to understand and accept the culture of farmers and work within the existing cultural and economic parameters. Furthermore, resources to initiate and sustain effective prevention programs are limited in rural communities, adding to the challenge.

Further reflection on behavioral patterns of farmers reveals a "cultural conundrum" regarding their occupational health and safety. Most farm people are cognizant of the injury hazards they encounter (14), but when an injury does happen, the individual generally accepts all blame for the occurrence of the event. The following example is from an interview this author (KJD) had with a farm injury victim, questioning him as to how the injury happened:

> "*I was just careless; I just did a stupid thing. I knew that the grain auger did not have a shield over it, and I just got my hand too close when trying to push the remaining grain into the machine.*"

When asked how farm injuries could be prevented, he said "We need to have more education about this problem and be more careful." Farmers know about major safety hazards, but do not seem to think beyond "being careful" around hazardous machines nor do they associate "being safe" with actions to remove the hazard before an injury event occurs. This illustrates the failing of *awareness-level educational models*. The old formula of "education will create attitudes that lead to behavior change" has not resulted in a reduced risk of injuries and illness. The most difficult thing to change in prevention is human behavior, therefore the most effective interventions are those that do not depend on human behavior. Being human, we forget, take short cuts, become harried, and make mistakes – even though we know the hazards.

In addition to cultural barriers, geographic dispersion raises challenges to create a network of farms/farm people in a program. The small family farm is largely unregulated by health and safety officials, so the decision to initiate a comprehensive prevention program is voluntary. Trust in the program manager is crucial and incentives must be perceived as worthwhile for the extra effort and expense. Also, as many of these smaller farms have limited resources, any expenditure needs to hold the promise of substantial economic benefits in the long run.

Small family farms also include family members that may have special health risks and needs that differ from the primary operator. These special populations (as discussed in Chapter 2) include women, children, the elderly, and farm workers. The specific health and safety issues of these populations must be covered in comprehensive prevention programs for family farms.

15.2.2 Large Farms with More Than 10 Workers

Large farms (in the United States), as discussed previously, come under the scrutiny of occupational health and safety regulators. The major difference is the employees, and the fact that the ultimate responsibility of the health and safety of the employees belongs to the principal operator. Specific regulations pertain to these operations and by law the employer must comply with them or enforcement may be implemented.

Migrant and seasonal farm workers (MSFWs) are usually employed by large farms. Most industrialized countries have regulations that help protect MSFWs. In the United States migrant health clinics supported by the government provide acute care. Unions and advocacy groups draw attention to safety issues and help to promote protective policies. However, many work hazards for this population still remain and need to be addressed (2, 15). Chapter 2 provides further information about this population's needs.

Non-minority farm workers may be employees of a small family farm or a large regulated farm. They experience similar hazards to MSFWs, but are not afforded all the protections given to them (e.g., access to free health care). Furthermore, because many non-minority workers may work on small family farms, they are not afforded the same degree of protection as those working on large farms.

These barriers and challenges to injury and illness prevention can be addressed through design and application of science and theory-based interventons. Prevention intervention and theory are researched and practiced in several disciplines within the broader field of occupational safety and health. These disciplines include the safety professions (safety engineering, human factors engineering), public health (epidemiology, surveillance, health behavior), industrial hygiene, ergonomics, occupational and primary health care, and educational and social psychology.

The most effective programs for long-term improvement in health and safety have been comprehensive multimodal programs that incorporate theory and methods from several of these professional fields. These methods will be discussed in the remainder of this chapter along with specific examples of effective programs.

The various modalities of prevention are all not equal in their effectiveness, and several special disciplines in the field of agricultural health and safety emphasize different prevention modalities. A hierarchy of prevention modalities is given here, followed by a description of the approach of the various health and safety disciplines in addressing the basic hierarchy of modalities.

15.3 A Hierarchy of Prevention Modalities

A hierarchy of methods provides an organizing scheme for the broad concept of prevention. This hierarchy is based on a review and interpretation of both safety and public health literature. It represents a broad-based consensus among the occupational health and safety disciplines, and organizes modalities from most to least effective according to a common consensus among public health professionals and safety professionals (Figure 15.1).

1. Eliminate the hazard through
   a. engineering
   b. administration
   c. substitution
2. Minimize and control the safety and health risk by
   a. engineering through safe guards
   b. administrative means
   c. substitution of risky substances or processes for safer ones
3. Regulation and enforcement
4. Education and training for safe and healthful behavior
5. Application of PPE

15.3.1 Eliminate the Hazard or Minimize and Control Risk

Most health and safety specialists agree that safety-minded engineering can be highly successful in preventing occupational injuries and illnesses (16–18). Since the engineering model assumes that human beings will err and put themselves at risk, the first goal is to engineer out the hazard to protect the operator (19, 20). However, complete elimination of the hazard may not be possible or practical. As a result, safety engineering includes its own hierarchy of methods in order of effectiveness that includes (4):

1. Completely elimination of the hazard
2. Application of safeguarding technologies
3. Employment of warning signs
4. Training and instruction for the operator and workers
5. Use of PPE (see Appendix A for details)

Items 3–5 above are also elements of the educational and the public health approach to prevention, and will be discussed in those sections.

Elimination of the hazard is the ultimate goal of safety engineering. There are five essential principles to reaching this goal:

1. Hazard analysis
2. High product reliability
3. Fail-safe design
4. Monitoring and structural safety factors
5. Passive protection.

Hazard analysis traces the sequence of events leading to an injury. Fault-tree analysis is a specific type of hazard analysis involving all the events and structures that link to an injury event. The engineering correction is in the design of a mechanical feature that eliminates the weak link(s) in the operation. For example, to prevent a run-over, an operator must be sitting in the seat and push down on the clutch before the machine will start (interlocks).

The *fail-safe design* principle is used in electrical circuits (e.g., ground fault circuit interrupters (GFCIs)) to prevent electrocutions from electrical hand tools. It may be installed in the service, power outlet, or the appliance itself. It measures the amount of current leaving and returning back to the service. In the event of even a slight difference (leakage), the GFCI will shut off service to that line immediately, preventing a possible electrical shock to the operator.

Passive protection can be effective in eliminating the risk of injury in agriculture. Clearly the most important passive protection system in agriculture is the roll-over protective structure (ROPS). Installation of this device eliminates a fatal outcome if the tractor should overturn in 75% of events. Additional protection is provided with use of a seatbelt, which eliminates fatalities in 99% of events (21, 22). However, nearly 400% of tractors in the United States do not have ROPS (23). A discussion of legislation and programs to enhance ROPS installation is given in Chapter 11. Another important example of passive protection is the shield used to prevent the bypass start of a tractor. Should the main electrical start switch (usually activated by the key) fail to activate the solenoid switch on the starter of a tractor, the bad connection can be bypassed by standing next to the starter motor, usually in front of the rear wheels of the tractor, and jumping across the connections from the battery where they attach to the starter. However, all too often the tractor has been left in gear, and as the tractor starts, it jumps forward, running over the operator. A shield covering the terminal connections prevents this type of injury.

Limitations of Engineering Prevention

Although engineering can be a highly effective means of injury prevention, there are still significant limitations. Most engineering solutions are applied by the manufacturer on new equipment. However, farm machinery may remain in service for several decades and older machines often lack modern safety features. Retrofit equipment is expensive. Most producers are not economically or culturally motivated to expend resources for safety retrofit items. Furthermore, many retrofit items may not be available, as manufacturers are often reluctant to make retrofit safety equipment or have it installed on old machinery as it may not be an economical business for them and may increase their liability if the safety device fails.

However, there are a few programs, some with incentives, to promote and facilitate investment in new engineering controls for old machines, primarily for ROPS. In the United States ROPS incentive programs are available from some State Farm Bureau organizations, and the New York State Center for Agricultural Health and Medicine (24).

Developing and installing new engineering safety equipment on machines is subject to economics and marketing. If new engineering design and deployment on machines puts one company at an economic, liability or marketing disadvantage with competitors, then such engineering is not likely to happen.

Safety features can be defeated, for example bypass starting shields, power take-off shields, gear and pulley shields all can be removed. Interlocks can be disengaged; warning devices can be turned off. This is likely to happen if they interfere with the convenient operation of the machine. As a result, safety features must be designed in a manner that will not inconvenience the operator.

Failures in engineering interventions may not become apparent until injuries occur. How humans interact with a machine (use the machine) highly influences the risk of an injury event.

Awareness of unintended use resulting in an injury provides numerous incidents, which the manufacturer may not be aware of for several years, as active surveillance of injuries is not an ongoing process (which indicates the importance of detailed and routine injury surveillance). Despite these limitations, engineering controls are one of the most effective strategies for reducing agricultural injuries.

15.3.2 Regulation and Enforcement

Regulation and enforcement are high in the order of prevention modalities, coming after engineering interventions. Although regulation and enforcement have resulted in important improvements in several hazardous industries (e.g., mining and construction), few regulations have been applied to agriculture in the United States. Fatal agricultural injury rates have remained relatively flat over time relative to other industries. It is unclear whether the lack of regulations and enforcement is the reason for this. (However, the fact that agricultural injury rates in the United States are 30% higher than in other industrialized countries (see Chapter 11) where more regulations are in effect suggests that regulations are effective (25)). Farm organizations and farm groups (especially in the United States) have not welcomed regulations and have often actively resisted them. Additionally, in the United States the sociopolitical culture has generally given higher importance to individual rights than to the protection of groups, thus creating an unfavorable environment for farm safety regulations. However, there are important existing regulations in the United States for agriculture. Two agencies are mandated to promulgate and enforce these regulations: the Occupational Safety and Health Administration (OSHA) within the Department of Labor (DOL) and the Environmental Protection Agency (EPA).

Regulations under the DOL originated when Congress passed the 1970 Occupational Safety and Health Act. This law was established with the goal of providing a safe and healthful work environment for all workers, and covered the following major areas (26):

1. OSHA publishes rules and regulations in Occupational Health and Safety Standards manual, Parts 1910 and 1928.
2. States can choose to have the federal government run the OSHA program in their states (26 states) or run their own state plan (24 states).
3. The law requires that state plan programs be equivalent to or more protective than federal laws.
4. The Federal Government supplements 50% of the cost of state plan programs.
5. The 1976 Small Farm Exemption Amendment stated that federal funds could not be used to inspect or enforce OSHA regulations on farms with fewer than 11 employees (note that the small farm exemption does not apply to a farm that has a periodic or permanent labor camp; see details of the small farm exemption below).
6. Agricultural operations with 11 or more employees (on any given day in a year) and/or a temporary labor camp must follow OSHA regulations for agriculture. (Family members are not counted in the number of employees.)
7. Regulations in Part 1928 pertain specifically to agriculture, including safe storage and handling of anhydrous ammonia, signs and tags must be in place to remind workers of hazards, and engineering standards for tractor roll-over protection and machinery guarding.
8. The employer must provide employee safety training and have material safety data sheets (MSDS) accessible.
9. Although few specific exposure standards in 1910 apply to agriculture, there is a General Duty Clause which states that:

> Employers must provide their employees with a workplace free from recognized hazards likely to cause death or serious physical harm. Employers can be cited for violating the General Duty Clause if there is a recognized hazard and they do not take reasonable steps to prevent or abate the hazard (26).

Organic dust exposure serves as an example of the application of the General Duty Clause. OSHA has no permissible exposure limits for organic dust in the air. However, a large body of literature documents the respiratory health hazards for confined livestock production facility workers when organic dust exposures exceed 2.5 mg/m^3 and/or ammonia exceeds 7 ppm (27). The General Duty Clause could be invoked, requiring employers to reduce exposures even though there are no OSHA exposure limits for organic dusts.

10. Farmers of any size operation may request an inspection from the OSHA consultation program without fear of reprisal.
11. Exemptions to OSHA include those farms with fewer than 11 employees (small farm exemption).
12. The small farm exception does not apply to non-production agricultural activities on a farm (e.g., processing, direct sales etc.).
13. A farm with periodic or permanent labor camp is not exempted, even if there is only one laborer in the camp.

Small Farm Exemption

Although the intent of the OSHA law pertains to all farms, even those with just one employee, in 1976, following pressure from farm groups, the Small Farm Exemption amendment was passed (28). This provision made it illegal to spend federal dollars to inspect or enforce regulations on farm businesses with fewer than 11 employees, as (even for one day) at any time during the year.

> However, for all farms, reporting of injury or illness incidents is required for an event resulting in three or more fatalities or hospitalizations.

(Details of the small farm exemptions are given in Table 15.1; 28).

The small farm exemption amendment to the OSHA Act effectively eliminated nearly 90% of US farms (1,900,000 farms with an estimated 3,000,000 workers) from coverage (28–30). However, three of the 24 state plans cover farms with even a single employee (Washington, Oregon, and California). In these states injury and fatality rates are more than 30% lower compared to the average for all other states (16, 25).

Table 15.1 US Occupational Health Administration's Appropriation Act exemptions (small farm exemption) for farming operations (28)

OSHA activity	Farming operations with 10 or fewer employees and no temporary labor camp activity within the past 12 months	Farming operations with more than 10 employees or a farming operation with an active temporary labor camp within the past 12 months
Programmed safety inspections	Not permitted[a]	Permitted[b]
Programmed health inspections	Not permitted	Permitted
Employee complaint	Not permitted	Permitted
Fatality and/or two or more hospitalizations	Not permitted	Permitted
Imminent danger	Not permitted	Permitted
11(c) (whistleblower investigation)	Not permitted	Permitted
Consultation and technical assistance	Not permitted	Permitted
Education and training	Not permitted	Permitted
Conduct surveys and studies	Not permitted	Permitted

[a] Federal funds *not permitted* to be used for stated activity.
[b] Federal funds *are permitted* to be used for stated activity

There are specific OHSA regulations that pertain primarily to protection of migrant workers. For example, sanitation facilities are required in the field (e.g., toilets, hand washing) and in labor camp housing (e.g., toilets, showers) (31).

Other countries have had more success in achieving regulations for agricultural safety and health, but generally, compared to other industries, agriculture remains relatively unregulated. A comparison of regulations existing in several industrialized countries is seen in Table 15.2 (32–39).

Larger farms have a greater potential for developing effective health and safety programs compared to small farms. These farms have more resources, can afford newer and safer equipment, and many have a labor management structure that can better assure compliance with safety programs. Unfortunately, farms coming under OSHA purview are rarely actively regulated. A major reason for this is that the approximate 100,000 large farms in the United States are geographically dispersed, often in remote locations that cannot be monitored by the minimal number of inspections and enforcement personnel employed by the Federal or state OSHA programs. Other reasons include lack of trained personnel, unpopularity of the law among employers, and lack of concern on the part of the general public.

In addition to the OSHA law, the DOL has health and safety responsibilities for child labor under the Fair Labor Standards Act of 1938. The child labor laws within this Act aim to protect working children under 16 from harm on the job, prevent work from limiting their access to education, and prevent substandard pay. The Wages and Hours Division of the DOL enforces child labor laws within the Fair Labor Standards Act.

These laws do not apply to youths working their families' farms. They do apply to youths working on non-family farms (40). The law limits work hours when school is in session for youths under 16 years of age (14 with parental permission). Application by individual states may be more, but not less, strict than the Federal law (26). For youths under 16 working in agriculture, regulations prevent exposure to high-risk hazards as specified under Occupations Order for Agriculture (HOOA) (41). Particular hazardous activities that youths under the age of 16 are not allowed to perform (except for the stated exemptions given below) are identified in Table 15.3 (40–43).

The exemptions to the HOOA are as follows (40):

> Youths 14 and 15 years of age are exempt from HOOA if they:

1. are employed by their parents (or stand in) on farms owned or operated by their parents;
2. are student learners in a legitimate vocational agriculture program (applicable to items 1–6 in Table 15.3);
3. have had certificate of training in the tractor and or machine operation program offered by 4-H Extension or a vocational agriculture training program. The exemption is applicable to items 1 and 2 in Table 15.3. These training programs are offered in many states. They are described on the Pennsylvania State University Extension website (42).

Additional exemptions allow (with written parental permission) 12- and 13-year-old youths to be employed on farms where a parent or parental stand-in is employed. Ten- and 11-year-olds may not be employed for more than 8 weeks in total duration during a season from June 1 to October 15. Youths must be local permanent residents. Employers must obtain a permit from the Secretary of Labor to hire a youth of this age.

In 2011, the DOL proposed amendments to the law that would upgrade HOOA to create parity with youth labor laws in industries other than agriculture (43). The proposal remained applicable only to work on family farms, but increased the age of application to age 18 years and below from the previous 16 years. Furthermore, additional hazardous tasks were added to HOOA, including certain provisions for working with animals, pesticides, manure

Table 15.2 Regulations in agricultural health and safety (32–39)

	Regulation name	Effective date	Target group	Description	Document location
International					
International Labour Organization	International Labour Standards	Since 1919, has developed standards	All employers and workers	Labor standards developed as conventions (member nations must ratify, are legally binding) and recommendations in four primary areas: (1) free association (unions), (2) forced labor, (3) discrimination, and (4) child labor 185 countries have ratified most of eight parts The United States has ratified only two of eight conventions	http://www.ilo.org/global/standards/introduction-to-international-labour-standards/lang--en/index.htm
International Labour Organization	C184 Safety and Health in Agriculture Convention (No. 184)	September 2003	Agricultural employers and workers	Recommendations supplementing C184 Safety and Health in Agriculture Convention 2001, concerning occupational safety and health surveillance, and preventive and protective measures	http://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO:12100:P12100_ILO_CODE:C184
North America					
United States Congress	29 CFR 00 Migrant and Seasonal Agricultural Worker Protection Act	31 March 1989	Migrant and seasonal agricultural workers	Remove activities detrimental to migrant and seasonal agricultural workers; require farm labor contractors to register; assure protection for migrant and seasonal agricultural workers, agricultural associations, and agricultural employers	Code of Federal Regulations, Title 29 (Labor), Chapter 5 (Wage and Hour Division, Department of Labor), Part 500 http://www.dol.gov/compliance/guide/mspa.htm
United States Department of Labor, Occupational Safety and Health Administration	29 CFR 1910.142 Federal Migrant Housing Regulations	27 June 1974	Migrant and seasonal agricultural workers	Migrant agricultural labor housing constructed or substantially renovated since 3 April 1980 must comply with these standards of the Occupational Safety and Health Administration	https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9791
United States Department of Labor, Occupational Safety and Health Administration	29 CFR 1928 Occupational Health and Safety Standards for Agriculture Reverts to 1910 standard of if no specific coverage in 1928	1970	Agricultural employers and workers	This part contains occupational safety and health standards applicable to agricultural operations	http://www.epa.gov/pesticides/safety/workers/PART170.htm
United States Environmental Protection Agency	40 CFR 170 Worker Protection Standard for Agricultural Pesticides	20 October 1992	Agricultural employers and workers	The Worker Protection Standard require an agricultural employer or a pesticide handler-employer to ensure that each worker and handler subject to the standard receives the required protection	http://www.epa.gov/pesticides/safety/workers/wpsinterpolicy.htm

Mexico					
Secretariat of Labor and Social Security	Official Mexican Standard NOM-003-STPS-1999 Official Mexican Standard NOM-007-STPS-2000	28 June 2000 9 September 2001, modification 2003, effective 2004	Agricultural employers and workers	Agricultural activities: Use of pesticides and materials of vegetable nutrition or fertilizers Safety and health To establish the safety conditions which the installations, machinery, equipment, and tools utilized in agricultural activities must consist of in order to prevent risks to the workers	http://www.mexicanlaws.com/STPS/A_Diagram_of_Mexican_Labor-Health_and_Safety.htm
European Union					
European Directives	Occupational Health and Safety (Tractor Safety) Regulations 1986	16 April 1986		Issued under the Occupational Health and Safety Act 1985 (CIS 88-1751) Applies to tractors; use of safety devices (machine guards, protective frames, power take-off guards) Measures protecting the safety of passengers are prescribed Minors (under 18 years) may only drive tractors if they have received adequate training or if they are under the supervision of an experienced tractor driver CIS No. 93-1771	https://osha.europa.eu/en/legislation/directives
Other areas					
Australia and New Zealand	National Standard for Plant	1994	Farmers and farmworkers	Each state has its own regulations The 1994 National Standard for Plan was an attempt to standardize	http://www.worksafe.com.au/
Argentina			Law covers all employees and youth	Health and safety laws are pertinent only to those who register as employees Also covers those who are not citizens	http://www.worksafe.com.au/

Table 15.3 Hazardous Occupations Orders for Youth in Agriculture (HOOA) (40–43)

The Secretary of Labor has found and declared that the following occupations in agriculture are hazardous for minors less than 16 years of age. No minor under 16 may be employed **(off their family farm)** at any time in these occupations except as exempted.
The restrictions in categories 1 and 2 below are exempted if the youth has a certificate of attendance in an approved tractor or machinery safety course.

(1)[2] Operating a tractor of over 20 PTO horsepower, or connecting or disconnecting an implement or any of its parts to or from such a tractor				
(2)[2] Operating or assisting to operate (including starting, stopping, adjusting, feeding or any other activity involving physical contact associated with the operation) any of the following machines:	Corn picker, cotton picker, grain combine, hay mower, forage harvester, hay baler, potato digger, or mobile pea viner	Feed grinder, crop dryer, forage blower, auger conveyor, or the unloading mechanism of a powered self-unloading wagon or trailer	Power post-hole digger, power post driver, or non-walking-type rotary tiller	
(3) Operating or assisting to operate (including starting, stopping, adjusting, feeding, or any other activity involving physical contact associated with the operation) any of the following machines:	Trencher or earthmoving equipment	Fork lift	Potato combine	Power-driven circular, band, or chain saw
(4) Working on a farm in a yard, pen, or stall occupied by:	Bull, boar, or stud horse maintained for breeding purposes	Sow with suckling pigs, or cow with newborn calf (with umbilical cord present)		
(5) Felling, bucking, skidding, loading, or unloading timber with butt diameter of more than 6 inches				
(6) Working from a ladder or scaffold (painting, repairing, or building structures, pruning trees, picking fruit, etc.) at a height of over 20 feet.				
(7) Driving a bus, truck, or automobile when transporting passengers, or riding on a tractor as a passenger or helper				
(8) Working inside:	A fruit, forage, or grain storage designed to retain an oxygen-deficient or toxic atmosphere	An upright silo within 2 weeks after silage has been added or when a top unloading device is in operating position	A manure pit	A horizontal silo while operating a tractor for packing purposes
(9) Handling or applying agricultural chemicals classified under the federal Insecticide, Fungicide, and Rodenticide Act (as amended by Federal Environmental Pesticide Control Act of 1972, 7 U>S>C. 136 et seq.) as Toxicity Category I, identified by the word "Danger" and/or "Poison" with skull and crossbones; or Toxicity Category II, identified by the word "Warning" on the label	Specified tasks include cleaning or decontaminating equipment, disposal or return of empty containers, or serving as a flagman for aircraft application			
(10) Handling or using a blasting agent, including but not limited to, dynamite, black powder, sensitized ammonium nitrate, blasting caps, and primer cord				
(11) Transporting, transferring, or applying anhydrous ammonia				

Source: Excerpted from the Fair Labor Standards Act, US Department of Labor, http://www.abe.iastate.edu/Safety/clb102.htm.

pits, storage bins, tobacco, and powered equipment. However, this proposal was met with strong resistance from the agricultural community and was withdrawn.

Possible fines may accrue if these orders are violated, but the HOOA is not well monitored or enforced unless there is a complaint. As a result, it serves functionally as a voluntary educational program rather than a regulatory one.

The effectiveness of the HOOA educational programs is questionable. Evidence from two doctoral dissertations have shown no decrease in injuries for youths who have taken the training specified under HOOA (44, 45). Furthermore, Risenberg and Bear (46) found that this training may be associated with an increase in injuries. (An observation that may be associated with exposure, as trained youths may have more work exposure, than as a direct causal effect of the training. A similar increase in automobile crashes with youths taking driver training programs has also been noted (47).)

In addition to the health and safety regulations of the DOL, the US EPA has two areas of regulation aimed at prevention of pesticide poisoning, as authorized under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947. The first deals with training and certification of those intending to apply restricted-use pesticides (pesticides with the potential to cause human or environmental health consequences if mishandled). Initiated in 1975, the EPA instituted an interagency agreement with the US Department of Agriculture to fund state extension services to conduct training and certification in two categories of pesticide applicators (private and commercial) (48). Training and examination is generally required to obtain the certification, but the specifics of certification requirements vary among states and can be more, but not less, stringent than EPA standards. For example, the EPA requires an examination for commercial applicators, but not private applicators (farmers mostly). Some states require an examination (a 90-question exam) for both categories, and some states do not require examination for private applicators. Also, states vary in their requirements for re-certification, ranging from 3 to 5 years. Approximately 130,000 private and 120,000 commercial applicators are re-certified yearly.

The second area of regulation the EPA administers is the Worker Protection Standard (WPS) (34). Enacted in 1992, the aim of the WPS is to protect farm employees from the adverse health effects of pesticide exposures. Family members working on their own farm are exempted. Unlike the OSHA standard, there is no minimum number of employees required before the WPS applies. The standard includes required training for workers in pesticide safety and use of PPE (see Appendix A for details). In addition to training, the employers must provide access to safety information for the chemicals used, insure workers are kept away from treated areas until safe, and, supply facilities and resources for decontamination and emergency assistance.

The limitations of engineering approaches to eliminate or reduce hazards were discussed above. Regulations also have limited effectiveness as there are cultural and resource barriers to expand coverage to a larger percentage of the exposed population. Education, although lower on a hierarchy of effectiveness, is by far the most common intervention practiced. The following section will discuss the theory and methods of education that increase the potential for educational and training efforts to be effective in reducing injury and health incidents.

15.3.3 Education and Training for Safe and Healthful Behavior

Education for prevention in agricultural health and safety can be divided into education for health and safety professionals, and education for farmers, ranchers and their families and employees. These audiences differ substantively in culture and educational background. The approach of the trainer to delivery of the material, the expectations for outcomes, the receptivity of the audience, the expectations for understanding and the use of education in prevention differ markedly.

Education for Health and Safety Professionals

Regarding professional education, agricultural medicine is an evolving specialty in the field of rural and occupational health and safety (49). Numerous publications have identified that most training in the medical and health sciences and safety includes little or no specific education in the field of agricultural health and safety (50–52). Professionals who deliver health care or safety services to agricultural populations need to know the unique hazards, farm culture, medical treatment, and prevention parameters required in order to best serve agricultural populations. Without this knowledge, the effectiveness of the education is compromised and unintended harm can occur, as documented by many authors (51). The National Agricultural at Risk Conference (United States) in 1989 reported a need for agricultural medicine training of 8000 nurses, 1000 industrial hygienists, and numerous other health and safety professionals at all levels, including physicians, mid-level practitioners, safety specialists, veterinarians, and public health officials (52).

Recognition of the need for such agricultural medicine training was first acknowledged with a course for medical students and graduate students in rural health and agricultural medicine in 1974 at the University of Iowa College of Medicine (6). In 1995, an effort was undertaken to develop a national curriculum for occupational health nurses in agricultural communities (53). Continued development of a national curriculum has occurred with the building capacity program based at the University of Iowa (54–56). Two national consensus processes were held to develop and evaluate core topics and competencies for an interdisciplinary national/international 40-hour core course in agricultural medicine for a broad range of health and safety professionals, including but not limited to healthcare providers, public health, veterinarians, and safety professionals (56). The building capacity course has expanded to nine states as well as Australia, Turkey, and Sweden. Recent advances have included a version of this core course being offered in conjunction with the annual conference of the International Society for Agricultural Safety and Health (ISASH). Evaluation of the translation of this training into the practice of agricultural preventive medicine has been positive (54, 55).

Education of Farmers, Ranchers, and Farm Workers

Education has been the most common type of prevention intervention employed for agriculture producers and farm workers. The tradition and background of long-term professionals involved in outreach to agricultural populations (e.g., extension), the lack of other health and safety professions, and understanding and application of other modalities of prevention, the culture of the agricultural population (they are receptive to education compared to more invasive or comprehensive methods), and the relative ease and low expense of providing passive voluntary information rather than more comprehensive programs all contribute to its acceptance. However, as previously mentioned there is little evidence that awareness-level "information only" programs result in significant long-term improvement in injury and illness outcomes (57, 58). Wilkins reported that injury training for principal operators had no relation to installation of ROPS (59). In one study, Westaby found safety knowledge negatively associated with agricultural injuries (60). Published reports of educational programs indicate that evaluation is difficult and often not conducted in a comprehensive manner because of lack of outcome data and controls (61, 62). DeRoo, Rautiainen, (58) and Lehtola and Rautiainen (63) conducted extensive reviews of prevention programs and found only a few educational intervention programs that had been effectively evaluated or were scientifically controlled. Only a few have shown effectiveness in reducing injuries and illnesses. Most often, only limited evaluation was available, such as calculating the short-term retention of information and increased short-term use of PPE (64). Numerous prevention programs have been directed toward farm youths (65–67). Many assume that young children are more amenable to behavioral change, with results carrying on into later life (63). There is also the assumption that children will bring safety information home to influence parents to adopt safer behaviors (69). However, the long-term outcome impact of education for youths on adults is difficult to track (70). Although these programs may have had a preventive effect, it is difficult to prove (71, 72).

On the other hand, education is well accepted by the agricultural community and fits with their cultural norms of independence and regulation-adverse propensity. However, it is clear that education can assist in promoting health and safety only if it is beyond an awareness level approach, is theory-based, and is part of a community-based, integrated multimodal intervention (73–76).

The assumed aim of health and safety education for the agricultural community is to enhance adoption of health- and safety-conscious behavior. However, as program evaluation has shown, this outcome is not a given. Research from the fields of educational and social psychology has developed several theories of how educational approaches can change human behavior. The following is a brief review of these theories and how theory is important to understand and include in the development of preventive education for the farm community.

Educational and Social Psychological Theories of Behavior Change

All too often educational interventions are initiated assuming that if information is delivered, knowledge will be gained by the intended audience and behavior change will follow. Rautiainen and DeRoo's review, along with other published manuscripts, reports that this outcome is unlikely (5, 57, 77, 78). It is important to incorporate information about how people learn and adopt new behaviors in all educational interventions.

Two major approaches to learning and behavior adaptation are behaviorism and cognitivism/constructivism (79–82). A general overview of these theories can be helpful in designing intervention programs for supporting farmer health and safety.

Behaviorism posits that learning and behavior adaptation results from positive and negative reinforcement. It supports the notion that rewards and disincentives can encourage adoption of specific behaviors. Incentives help people strengthen existing behaviors or support the development of new behaviors by providing rewards. Use of disincentives or penalties can be effective in managing behavior, but in general they do not strengthen the development of independent thinking or self-sufficiency (80).

In contrast, in *constructivism or cognitivism theory*, the learner accesses prior knowledge, compares it to new information, and decides to integrate or reject one or the other. The learning process then is a complex one that may call for disruption of old learning to accommodate new information (79).

These theories help us understand how a person can learn or modify their behavior. Many of the individual theories have been analyzed and modified over time to accommodate new findings. Table 15.4 compares behavioral theories to constructivism/cognitivism and provides examples of some specific agricultural health and safety

Table 15.4 Models of educational/behavioral change theory (79–85)

Constructivism/cognitive theories	Behavioral theories
• Extended parallel-processing model	• Behavioral-based safety
• Health belief model	• Community organization theory
• Precede/proceed model	• Diffusion of innovations theory
• Public health model	• Ecological/social ecological model
• Review of multiple behavioral change theories	• Transtheoretical model (stages of change)
• Social cognitive theory	
• Theory of reasoned action/theory of planned behavior	

interventions that have incorporated these theories (79–84). The following paragraphs describe specific models of either cognitive or behavioral dimensions.

The *health belief model* (based on cognitivist theory) is perhaps the most common model used in agricultural health interventions. This model is based on education that facilitates understanding risk in the work environment, the benefits of adopting change, and ways to overcome barriers to adopting change. The change occurs as the learner weighs the balance between the risk and benefit of adopting the change. Elements of behaviorism have been incorporated in some health belief model applications, as incentives may be added as persuasion to support the benefit side of the equation, offering a clear course of action at acceptable costs and supporting the learner to take action. *Social learning theory* includes the elements of cognition and behavior of the Health Belief Intervention (79, 80). Social learning is learning by observation, imitation, and modeling. Evidence that social theory learning and behavioral mentoring transpire naturally on farms is reported in a 2010 publication entitled *The Farm Apprentice: Agricultural college students' recollections of learning to farm safely* (85). This research showed that the major determinants of beliefs, attitudes, and behavior of farm youth about farm safety was obtained through observation and modeling of their parents (85). The attitudes and behaviors of peers and other community members also influence social learning. The social learning concept can also be incorporated with other cognitive learning and behavior theories. Program examples which combine social learning with the health belief model include:

1. respiratory health protection in swine confinement workers (86, 87)
2. the Certified Safe Farm program (88, 89)
3. tractor risk abatement and control (24)
4. farm safety walk about (90)

While it is important to understand theories of how individuals learn and then adopt newer safe and healthy behaviors, these theories are based on research with individuals as opposed to population groups. They address specific hazards, such as safe operation of tractors and ATVs, work with animals, wearing hearing protection, etc. For general broad-scale population prevention programs to improve health and safety, more than just individual theory application and interventions that target multiple hazards rather than limited hazards (e.g., hearing only) are required. For example, some studies suggest that farm health and safety interventions are enhanced if there is peer pressure to adopt preventive practices (83, 84). A comprehensive review of farm health and safety interventions shows that the greatest success is achieved when using well-designed, comprehensive programs that are theory-based, use multiple modalities, and have integrated program prevention interventions (58, 63). Three newer conceptual approaches incorporating all these elements are the Population Health Approach (83, 84), the One Health Approach, and the Total Worker Health program (91). The *Population Health Approach* focuses on addressing the variety of socioeconomic and environmental variables that affect the health of all people in a community. Szreter (92) eloquently describes its history, which dates back to the Industrial Revolution in the early and mid-1800s. The Population Health Approach focuses on the health disparities between lower and higher socioeconomic classes. It is well described by the Canadian National Public Health Agency as a "collaborative, multidisciplinary integration of social, economic, mental, physical, clinical, and environmental health; with shared responsibilities and multiple strategies" (93).

The *One Health Approach*, originally described by the veterinary public health epidemiologist Calvin Schwabe in the mid-1960s, is a co-equal, collaborative effort between the veterinary and human health professions. Its goal is to improve population health through collaborative research and practice among the various health disciplines. The One Health Approach has become international in scope (94).

Total Worker Health is an approach defined by the US Center for Disease Control (CDC), National Institute for Occupational Safety and

Health (91). It stems from the 2004 national symposium Steps to a Healthier Workforce and a second symposium, Worklife 2007. The latter resulted in the CDC funding centers of excellence for total worker health, of which there are now four. Total Worker Health integrates general health promotion with occupational health prevention. It is multidisciplinary and aims to integrate social, physical, mental, behavioral, and occupational health and safety.

Translation of theory to effective education for behavioral change is discussed later in this chapter as a component of the Iowa Model of Multiple Modalities. This experiential-based model combines elements of cognitive and behavioral theories. The goal of the model is to simplify translation of theory into effective programs.

15.3.4 Application of Personal Protective Equipment

PPE includes devices and materials to protect workers from exposure to various substances and physical factors. It includes protection equipment for the respiratory system, hearing, eyes, head, feet, and skin. As mentioned previously, PPE should not be a first or only prevention method, as it may not be protective for a variety of reasons and in some cases may actually cause harm (e.g., excess cardiorespiratory stress, heat stress, and interference with visual or audible hazard warning). The following lists potential barriers that require management to help ensure effective protection without causing harm (see Appendix A for details):

1. PPE is often uncomfortable and hot, putting additional physical workload on the person and possibly increasing the risk for heat stress.
2. PPE (hearing and respirators) can create difficulty in communication, e.g. talking and being understood.
3. Respirators may present a medical risk to those with a cardiorespiratory ailment or those with claustrophobic tendencies.
4. Training, experience and monitoring are necessary to ensure the worker has the correct respirator for the particular exposure, and that the respirator is worn and fitted properly.
5. Wearing a respirator may produce a false sense of security, resulting in the worker allowing unhealthy exposures (e.g., PPE may not be completely protective if it is not the correct PPE for the exposure, is incorrectly fitted and worn, is not maintained or does not function properly).
6. PPE must be conveniently available at the exposure site or it will not be worn at all.
7. Convenient PPE supply and knowledge of use of PPE are rare in rural areas.
8. Cultural factors may create barriers for workers to wear PPE (e.g., not peer supported);

There are few situations in agriculture where OSHA regulations require use of PPE. The exceptions (US) are those operations with more than 10 employees, where an OSHA permissible exposure limit (PEL) is exceeded, where there is evidence of a hazard from science-based information, or the employer provides or advises their workers to wear PPE. If either of the latter two occurs with respiratory or noise exposures, then an OSHA-approved respiratory or hearing protection program would have to be instituted. Such prescribed programs invoke considerable expense and resources to institute and manage.

Although PPE does have an appropriate place in many agricultural operations, because of all the caveats mentioned above it should be considered secondary or as an adjunct to source control among other components of a control program.

The appropriate selection and use of PPE in a prevention program requires substantial knowledge and understanding of the basic principles of their application. In order to not detract from the flow of information provided in this chapter, details of proper selection, use, cost, acquisition, and further resources are given in Appendix A (which follows Chapter 15).

15.4 Specialized Health and Safety Disciplines

The hierarchy of preventive measures described above to improve the health and safety of agricultural workers and their families would remain an abstraction without specialized professionals to implement proactive programs. Several professional specialties play important roles in implementing preventive measures. These include those from the areas of occupational safety (safety engineering, human factors engineering, safety specialists) and public health (public health practice, industrial hygiene, ergonomics, occupational and primary health care, and professionals in education and social psychology). The following paragraphs describe the contributions of these professionals to agricultural health and safety.

15.4.1 Safety Professions

Safety engineering involves the design and development of devices that eliminate or reduce the risk of an injury should a hazardous event occur. The design and development of ROPS (which manufacturers agreed to install on new tractors) is an excellent example of effective safety engineering. Development of the "lock and load" systems eliminated the necessity for a farmer to handle insecticides applied with the seed in a corn planter.

Human factors engineering has similarities to ergonomics, which are discussed later. It is a combination of the sciences of engineering design, psychology, human anatomy, and physiology. It focuses on designing machines that can be operated effectively and safely by a person based on their cognitive and physiologic capabilities, rather than trying to make the person conform to the machine. Examples of human factors engineering in agriculture include the design of the cabin of a tractor in which the gauges, lights, warning devices, and controls are displayed so that the operator can readily see and operate the machine in a safe and productive manner. As more machinery is used in crop production, applied human factors engineering in the design of machines becomes increasingly important to the safety and health of the operator (88).

Safety professionals are people who practice safety prevention using a variety of techniques. The education and training of workers is a common method. Risk management and control involve an in-depth investigation of an operation to assess the sources of hazards, prioritize risks, and design a management-based, economic program application to reduce the risk. This is an emerging concept in production agriculture as promoted and developed by safety specialists and insurance companies. Certified safety professionals have been shown by examination to have attained a high degree of knowledge about safe practices and procedures in a variety of industrial applications.

Extension professionals appeared very early in the history of agricultural health and safety. For several years the US Department of Agriculture provided a small amount of money to the States Extension Service to provide safety training. Extension efforts today include providing training to youth tractor and machinery safe operation (HOOA), pesticide applicator certification training, and general safety education programs.

Public Health Professions: Occupational Health Research and Practice

The public health approach to agricultural health and safety is increasingly used in various industrialized countries (91–93). In a similar approach to engineering, the public health approach to injury and illness prevention assumes that people will make mistakes sometimes. However, public health proposes different ways of overcoming human error. Public health includes a broad concept of health, including physical health, mental health promotion, disease, injury and disability prevention. Public health integrates several scientific fields, including surveillance, epidemiology, health behavior, social marketing, and evaluation. Program evaluation is a key principle of public health, as evaluation results are used to improve interventions (16). Surveillance is critical to understanding the size and nature of the problem and also to measure the success of an intervention. Examples of interventions that contain elements of a public health approach are given in references 95–103 (specific surveillance data are discussed in Chapters 1 and 11).

Epidemiology is a critical component of the public health approach. Although traditionally applied to infectious diseases and other health concerns, William Haddon is credited as the first person to apply epidemiologic principles to injury investigation (104). L.W. "Pete" Knapp was perhaps the first person to apply epidemiologic principles to agricultural injuries (105). In its simplest form, application of the epidemiologic approach to injuries the discovery and integration of three basic components of causation contribute to an injury event (106):

1. human behavior
2. faulty attributes of the machines being used
3. the environment (e.g., adverse weather, distractions, etc.)

These three components are often referred to as "man, machine, environment".

Observational epidemiology or simple descriptive epidemiology provides clues to the causes of an event. Analytical epidemiology involves the study of many events, the interactions of those events, the establishment of rates, and statistically significant risk factors based on analysis of multiple variables. Once risk factors are understood, interventions can be specifically designed to control them. The public health epidemiologic approach rejects the notion that injuries are caused by "accidents" (i.e., uncontrollable acts of God). Thus public health rejects use of the term "accident" as it denies the reality that all injury events can be prevented. Expanding on the man, machine, environment analysis, Haddon (104) proposed a matrix to study injury events. He suggested that these factors can be analyzed at various times of the event, that is, pre-event, event, and post-event, thus identifying the controllable areas to prevent future injury events.

Social marketing is another tool used in public health to promote wellness. Social marketing adapts concepts from commercial marketing to promote behavior change (107, 108). Commercial marketing attempts to create a change in behavior so that people will buy a certain product or service. Social marketing attempts to sell an idea that will create a specific health behavior change. This concept is just beginning to be used in agricultural health and safety in a more formalized manner (107). Because of the lack of regulations and enforcement, delivery mechanisms for retrofitting newer engineering controls and evidence of effective awareness-level education programs, agricultural health professionals believe that social marketing may contribute to the prevention of agricultural illnesses and injuries.

The Tractor Risk Abatement and Control: the Policy Conference workshop (23) called for social marketing as an important tool to promote installation of ROPS on tractors and to discourage extra riders on tractors and other machines. A more recent document on tractor safety, the National Agricultural Tractor Safety Initiative, also called for social marketing as a tool to enhance installation of ROPS on tractors (109). Social marketing has been used effectively in other public health applications such as sun protection (Australia) and anti-smoking campaigns (most industrialized countries). However, the success of social marketing in agriculture remains questionable. One agricultural social marketing program aimed to decrease pesticide exposures in horticulture workers resulted in little evidence of reduced illness or exposure (76). However, there are several other social marketing programs in the planning process, and evaluation of these programs will help guide such efforts in the future.

One disadvantage of social marketing is that it is expensive. In order to affect a large number of people, or a large geographical area, expenditures can easily reach millions of dollars. In addition, it takes a long time to see the results of social marketing; perhaps as long as 5–10 years to detect a difference. The amount of money and long-term commitment to such a project is beyond the reach of most agricultural health and safety programming.

Surveillance is another important public health approach to prevention in agricultural health and safety. It was initiated by the US NIOSH and DOL. Examples of programs that emphasized surveillance include Farm Family Health Hazard Surveillance and Nurses Using Rural Sentinel Events. Other examples of larger public-health-based programs include Iowa's Center for Agricultural Safety and Health (I-CASH) (110), the Agricultural Health and Safety Section of the California Department of Health Services (111), and NIOSH's Fatality Assessment (112). These programs integrate surveillance, epidemiology, industrial hygiene, and ergonomics. More details of these programs are given in Table 15.2.

Industrial Hygiene

Industrial hygiene is a public health profession that integrates engineering, chemistry, physics, engineering, and biology. The methods used to control hygiene problems are multifactorial and include the identification and removal of the source of hazardous agent(s) by changing work practices or processes, ventilation, and/or proper selection and use of PPE. Examples of the use of industrial hygiene principles in agriculture include:

- measurement of dust and gas exposures in livestock confinement buildings
- designing and evaluating oil-sprinkling systems to suppress dust in livestock buildings (108)
- replacing hazardous chemicals with less toxic substitutes such as the replacement of organophosphates with microbial insecticides or genetically-modified resistant crops
- evaluation of respirator effectiveness for work in livestock confinement buildings.

The industrial Hygiene Profession began in 1904 when the US Public Health Service established training for it (114). Since that time, industrial hygiene has developed into an internationally recognized profession with the objectives of:

- recognition of the relationship of hazardous exposures to health in the workplace
- measurement and evaluation of hazardous agents
- formulation and implementation of a plan to control or eliminate the hazard.

Industrial hygienists have great potential to effect change in agricultural health and safety. The Agriculture at Risk Report indicated that up to 1000 hygienists could be used in the United States to address the issue of agricultural occupational health and safety. However, as few industrial hygienists currently practice in the agriculture industry, resources and specific training in agricultural health have not been sufficiently developed (52, 115).

The University of Iowa is the only known program that provides specific academic training of hygienists for agriculture (116).

Application of PPE has been a special area of industrial hygiene from the technical standpoint. Use of PPE is emerging rapidly in production agriculture and can be an important component of an overall prevention program. However, there are important guidelines and caveats to safe and effective use of PPE, as discussed in Appendix A.

Ergonomics

Ergonomics focuses on the physical work environment and prevention of musculoskeletal diseases caused by repetitive motions, adverse postures, and other excess stresses on the musculoskeletal system. The primary approach begins with assessment of work tasks relative to the physical demands on the worker, and proceeds to designing modifications to the machine or processes, physical activity, and tools of work to accommodate the physiology and anatomy of the worker. Historically, the major application of ergonomics in agriculture has been in repetitive manual labor in fruit and vegetable growing where farm workers are tasked with long hours of stooped labor and other stressful postures in planting, tending, and harvesting processes (35). Recent changes in agricultural work present new opportunities for ergonomic applications in agriculture. As agriculture becomes more industrial in scope, specialization and repetition of work tasks has increased (e.g., large dairy farms, pork-producing operations, intensive crop production), resulting in increased repetitive motion injuries (117, 118). Further challenges include the increasing number of women working in agriculture, where work tasks and processes have historically been accomplished by men with different physiologic and anatomic characteristics and tolerances (114). The limitations of ergonomic solutions include fitting ergonomic interventions to the beliefs, culture, and prior practices of the workers. For example, to reduce back strain in field workers, long-handled hoes have been recommended to replace short-handled hoes. However, in several instances the workers rejected the long-handled hoes because they believed they could do a better job of weeding the crop with the short-handled hoe (even at the expense of extra strain on their backs) (119).

Occupational Medicine and Primary Health Care

Prevention in health care for the agricultural workforce is best implemented in primary care occupational health services. Such services combine a variety of preventive as well as clinical services.

Occupational health services generally began to evolve in the late 1940s. They provided pre-employment physical exams, acute medical treatment of injuries and illnesses, surveillance, medical screening, and education of workers on occupational exposure risks and prevention. By the 1950s, many of the larger industries included occupational health services as a part of their worker health programs.

In Scandinavia in the late 1970s it was recognized that many small business workers, including farmers, did not have adequate access to occupational health services. The staff of the acute care medical services lacked the training or interest to detect and treat illnesses caused by occupational exposures. As a result, small industry-specific occupational health services began to evolve. In 1978, the Swedish Farmers Occupational Health Service (Lantbrukshälsan) was instituted (120). This voluntary program developed with support from the Swedish Farmers' Union, the government health service, and the individual farmer, with each paying a third of the cost. An estimated 40 clinics were established around the country, serving 40% of all farmers. These clinics were locally managed by trained nurses and staffed with industrial hygiene technicians and physical therapists. Unfortunately, the Swedish program ended in 2002 as a result of financial difficulty. However, the Swedish Farmers' Union still employs a person who deals with occupational health issues. They also have a funding mechanism that allows them to conduct agricultural occupational health research.

A program similar to the original Swedish one was developed in Finland in 1979. This program was integrated into existing municipal health service clinics in rural farming areas (approximately 350 healthcare clinics) (121). As of 2006, these services reached 41% of the farming population (40,000 people). The healthcare staff began receiving training in agricultural medicine in 1981. On-farm safety audits are slowly progressing in this service.

In 1987, the Iowa Agricultural Health and Safety Service Program was founded in at Iowa's Institute of Agricultural Medicine (now the Institute for Rural and Environmental Health, University of Iowa) (122). Modeled on the Swedish and Finish systems, these clinics were managed by nurses, with assistance in industrial hygiene and medicine from the University of Iowa. Twenty clinics associated with either rural hospitals or county health departments emerged across the state, serving farming communities within their region and providing clinical screenings, occupational health consultation, and selection and fitting of PPE. The Agricultural Medicine Training program at the University of Iowa was developed to train the health and safety professionals serving these clinics. The name of the program was later changed to the AgriSafe Network. In 2003, AgriSafe Network became a not-for-profit corporation to accommodate a growing national and international audience

(123). North Carolina and Nebraska adopted the AgriSafe model, and have been developing and expanding these services since 2010. In 2012, the AgriSafe Network changed its focus from initiating and facilitating local clinics to educating health professionals in agricultural medicine.

The Norwegian Farmers' Association for Occupational Health and Safety (NFAOHS) was established in 1994 (124). It is funded and managed by the Norwegian Farmers' Union and the Norwegian Farmer and Smallholder's Union, in partnership with the Department of Agriculture. Staffing is similar to that described for the programs in Sweden, Finland and the United States. The individual clinics are associated with state-run clinics in the region. The integrated services offered by these occupational health services have been universally well received by the farmers. The farmers appreciate being seen by health professionals who understand agriculture and empathize with the difficulties and exposures inherent in their occupation.

Most of these services have not been in place long enough to measure long-term results. Nevertheless, most have shown success in increasing the use of PPE and reducing healthcare costs (6). The Lantburkshälsan organization in Sweden showed a reduction in noise-induced hearing loss in the farm population from 25% to 50% through the introduction of widespread use of hearing protection (18). A reduction in cardiovascular diagnoses and higher scores in a number of wellness measures was seen in farmers using the occupational health service compared to farmers not using such a service (125). Furthermore, the AgriSafe clinic network in Iowa has employed the Certified Safe Farm program, which encourages farms to achieve a defined standard of safety and wellness. This program has shown a combined decrease (compared to controls) in self-reported out-of-pocket medical expenses and payouts by insurance companies for occupational injuries and illnesses of 27%. It has also shown a significant reduction in an acute respiratory and systemic condition called organic dust toxic syndrome. (The Certified Safe Farm program is discussed in depth later in this chapter as an example of a multimodal intervention program.)

Other intervention research projects have included on-farm safety inspection. Rasmussen reported on a Danish intervention research project that had two elements of an occupational health service (an on-farm safety audit and in-depth education) (126). The reported results of this study included a 23% reduction in all injury rates and a 40% reduction in more severe (medically treated) injuries. The Farm Safety Walkabout program, developed by Iowa's Center for Agricultural Safety and Health, is designed as a video-guided activity for children and parents to walk around the farm and identify and remove hazards. Legault and Murphy (127) developed a self-inspection guide for farmers to find and remove hazards around the farm. Murphy developed a web-based program based on a self-audit called the Farm/Agricultural/Rural/Management Hazard Analysis Tool (FARM-HAT) (128) Two Finnish researchers (129) reported on a project comparing farm inspections by farmer peer groups and trained professionals. Evaluation revealed that the farms visited by the peer group resulted in more improvements on the farm.

Many farmers believe their healthcare system is failing them when it comes to occupational health concerns (14). While farmers think their providers do not know, understand, or care about their farm exposure hazards (130), medical care providers and veterinary practitioners can have a positive effect on the health and safety of their farm clients without markedly changing practice patterns (78, 130). Veterinarians tend to have credibility with the farm community as sources of human health information (14). Table 15.5 shows 12 ways practitioners can expand their farm health and safety work with patients or clients (49, 123, 130–132).

Table 15.5 Checklist to help health and safety practitioners to implement individual or local community health and safety interventions with patients or clients (49,123,130–132)

1. Develop a working knowledge of local agriculture by asking farm patients questions about it, visiting their farms, talking to local Extension agents, and reading farm magazines.
2. Learn about individual patients' farms or ranches. Ask them questions about their operations in order to determine their specific risks and develop appropriate occupational health histories for the primary operator and their family. This will help the practitioner anticipate possible occupational health issues, as well as strengthening patient/client relations by demonstrating an interest in the individual's farming operation and health.
3. Be a source of information and referral for patients or clients. Make current pamphlets and brochures available. Identify key websites that provide up-to-date information.
4. Keep current with advances in agricultural production and economics by regularly reading farm magazines and newspapers.
5. Subscribe to one or more of the scientific journals that deal primarily with agricultural health issues, for example *Journal of Agromedicine*, *Journal of Agricultural Safety and Health*, *International Journal of Agricultural Medicine and Environmental Health*, and *Journal of Industrial Medicine*.
6. Promote local farm health and safety events and programs such as Farm Safety Day Camps. (128)
7. Communicate and consult within your interdisciplinary health community (veterinarians, physicians, physician assistants, nurses, etc.) about your patients and clients. For example, if a physician has a patient with an unusual infectious disease, a call to his/her veterinarian may help pinpoint a zoonotic disease that may have come from the patient's farm.
8. Get to know and consult with other non-medical professionals in your community, such as your county or area Extension agent, your state agricultural safety specialist, vocational agricultural teachers, and 4h staff. They can provide information and assist in putting on farm community prevention programs for patients/clients.
9. Facilitate development of community farm health and safety organizations, such as Farm Safety 4 Just Kids (129) and AgriSafe Network (119) (see Table 15.1).
10. Become active in a local, state, national, or international organization for agricultural health and safety.
11. Understand the culture and lifestyle of the farm patient population and implement wellness promotion as part of your services for the farming population.
12. If there are migrant or seasonal workers in the practice catchment area, become familiar with resources to assist with cultural, translation, and transportation barriers.

15.5 Multimodal Interventions

Although the total numbers of agricultural injuries and fatalities has declined over the past 30 years, the *rate* of fatalities has not changed a great deal. Even with the excellent work of many health and safety professional practitioners and researchers, the outcomes have not resulted in as much improvement as might have been expected. The evidence base suggests that the way forward is to raise awareness of this lack of improvement in the risk from agricultural injuries and illnesses, and prepare a multidisciplinary group of professionals to challenge this concern in their daily work to design and implement more comprehensive broad-scale multimodal interventions based on science-based theory, cultural norms, and building on past experience and interventions that are well designed and rigorously evaluated with positive outcomes. That goal is the essence of the remainder of this chapter.

The six European and American programs listed below meet the key criteria of being comprehensive, utilizing multiple modalities, and having integrated preventive programming. These programs will be reviewed as examples of potential future programs to build on or from. All are multimodal and include components and concepts of behavioral and/or cognitive/constructive behavioral change theory, population, community health-based, and broad-based prevention. They provide important models for long-term improvement in the overall health and safety of the agricultural community. The programs are:

1. farm health programs in Finland and Norway
2. Respiratory Disease Prevention in Swine Confinement Workers

3. AgriSafe and Certified Safe Farm programs in America
4. Sustainable Farm Families in Australia
5. farm safety programs without medical components
6. farm-based wellness program.

15.5.1 Farm Health Programs in Finland and Norway

Comprehensive total farm health and safety programs began in Sweden and Finland in the late 1970s (120, 121). Norway established such a program several decades later (124). These programs include farm audits with technical support to correct safety hazards. They are comprehensive total worker health programs which supply PPE and provide farm community education programs, farmer wellness programs, and farm occupational health screening. Physicians, nurses, and safety technicians (e.g., safety specialists and/or industrial hygienists) work collaboratively to implement them.

15.6 Respiratory Disease Prevention in Swine Confinement Workers

The principles of the total worker health approach were also implemented in the Iowa Respiratory Disease Prevention in Swine Confinement Workers program (86, 87). Peer-group educational programs and farm audits with technical support to remedy hazards were combined with wellness and occupational health clinical screening and personalized health coaching (49, 79).

15.6.1 AgriSafe and Certified Safe Farm Programs in America

The Iowa Health and Safety Service Network (now the AgriSafe Network) was established to provide wellness services, clinical screening, and education on agricultural health and safety to farm families (122). The Certified Safe Farm (CSF) program combines the health service and wellness components of the AgriSafe Network with a technical checklist-driven third-party audit, peer-group education, and incentives for the attainment of specified safety goals (88, 89). This comprehensive program combines the educational and behavioral theories of the health belief model, the reasoned actions and planned behaviors of the cognitivism model, and social learning theory. Behavior theory is also involved through the offer of a $200 incentive, awarded if participants meet the health and safety goals of the program to become a Certified Safe Farm. A fundamental concept of the CSF program is the cultural and economic reality that the base goal of a business model of most farms (and most non-farm businesses) is to make a profit. Health and safety are integrated as a component in that model. A fundamental goal of the CSF program is to make health and safety an added value component (that is self-evident to the producer) of the economic bottom line of the farm). Using Maslow's theory of hierarchy of needs (133) as a prediction model, achievement of a higher order of farm economic and family sustainability can be built if health and safety is at the base. Figure 15.2 suggests a model of farm sustainability and can be enhanced through incorporating the health and safety of the primary operator, family, and employees. Direct input into the economic bottom line can and should come from the reduced costs of health and casualty-related insurance (lower medical costs should bring lower premiums). Furthermore, farm service, supply, machinery dealers, and farm lenders should offer the sustainable operations rewards benefits as preferred customers. A second model incorporated in the CSF program comes from Andrew Savitz, who posits that the sustainability of a business has three components (paraphrased from Savitz): (1) healthy farmers, families, and workers, (2) a healthy economy, and (3) healthy farming practices that do not pollute the environment. The CSF

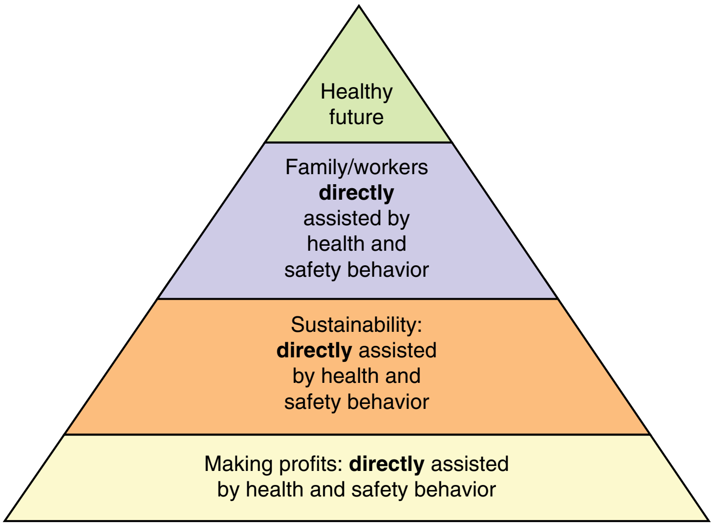


FIGURE 15.2 Incentive-based behavioral change prevention programs aim to make health and safety a value-added product on the farm. The incentives are insurances, chemical and machinery dealers and lenders.

program advocates that healthy farmers, families, and workers are important components of a sustainable business model (134).

The CSF program requires participants to reach a defined level of performance in removing safety hazards in order to attain CSF status. Incentives for certification include potential insurance discounts and discounts on agricultural production inputs such as feed, seed, and farm loans. The CSF program includes components of all methods displayed in the hierarchy of prevention model (Figure 15.1). Standards of safety are set and trained CSF auditors both rate the farms and assist the farmers in making corrections so they can become certified. For example, an auditor could help a farmer obtain the required safety equipment and the specific PPE they need to become certified. The CSF farm must have a health and safety plan with goals that are based on science and input from the farm operators/managers.

The CSF healthcare professional (usually a nurse or other mid-level practitioner) must be trained in agricultural medicine since they conduct the clinic screenings, review the screening results, and develop a personal/family health and occupational exposure control plan for the specific farm operation. The healthcare professional will contact the client to discuss progress on the plan and wellness goals during the year.

Trained CSF program auditors have an agricultural background, which enables them to develop on-farm intervention plans that are practical and within the economic, social, and cultural reference of the farm family. They can assist the farmer to make safe changes that are low cost. They may also connect farmers with resources such as the New York Center for Agricultural Medicine and Health or the Farm Bureau. Some states (e.g., Virginia) will provide monetary assistance to farmers to help finance a new ROPS for a tractor. Positive outcomes of the CSF program include a sustained increase in the use of PPE, reduced respiratory illnesses, important farmer-responsible removal of on-farm safety hazards, reduced medical care costs, and a reduction in serious farm injuries (88, 89, 135).

CSF is a total worker health program founded in Iowa that has now been implemented in North Carolina (88), Wisconsin (89), and Nebraska.

15.7 Sustainable Farm Families in Australia

The Sustainable Farm Families program in Australia is another total worker health program that includes clinical wellness screening and peer-group educational workshops for both wellness and agricultural illness and injury prevention. This program combines the cognitivism theory of planned behavior and reasoned action along with social learning theory (136). However, the program differs from the CSF program in that there is no third-party on-farm safety audit and technical assistance component.

15.7.1 Farm Safety Programs Without Wellness Components

The following are two examples of farm safety programs that are comprehensive and multimodal but do not have wellness components:

1. the Farm Injury Prevention program in Denmark (126)
2. the Farm Agricultural Rural Management–Hazard Analysis Tool (FARM-HAT) (128).

The Pennsylvania State University Extension Program in America uses a FARM-HAT with farmers. It is a web-based program based on a checklist to guide farmers through a process of hazard detection, control, and development of a general farm safety plan. Although there is no wellness component to FARM-HAT, it does incorporate components of the cognitivism theory of planned behavior and reasoned action.

15.8 Farm-based Wellness Program

The Rural Health Initiative is a notable farm wellness program that conducts farm (home) visits to provide health screening and health coaching (86). This US program, based in the state of Wisconsin, primarily offers wellness services. However, the farm safety hazard audit component of the CSF program has been trialed successfully and is now an optional component of the program (130).

15.9 Developing Comprehensive Prevention Programs

Comprehensive programs are essential for the overall improvement of health and safety on farms. Based on 25 years of field experience of implementing various levels and types of intervention programs, Iowa's Center for Agricultural Safety and Health put forth a conceptual model that could be considered for others interested in designing new comprehensive interventions. This model is called the Iowa Model of Integrated Multimodal Prevention Intervention.

15.10 Iowa Model of Integrated Multimodal Prevention Interventions

This multimodal approach combines basic principles from the fields of safety education, social and educational psychology, cognitive and behavioral theories, public health, wellness, clinical medicine, epidemiology, engineering, industrial hygiene, ergonomics, and regulation. Integration of these principles is used to accomplish the goals of this model:

1. education to facilitate behavior change
2. removal of health and safety hazards on the farm
3. establishment of individual farm-specific goals for health and safety
4. improvement of the overall health and safety of farm property, livestock, and equipment
5. improvement of the overall sustainable economic base of the farming operation
6. development of total worker health for producers, their families, and workers.

In order to simplify and translate these theories and principles, we propose a model equation (Figure 15.3) that supports inclusion of as many of the listed variables as possible in the design of an intervention. Table 15.6 is a checklist that can be used to assist inclusion of these principles in an intervention. Numerous studies in the aviation and healthcare fields have shown the effectiveness of the use of checklists to help overcome the human deficiencies of forgetfulness and lack of attention to detail (137).

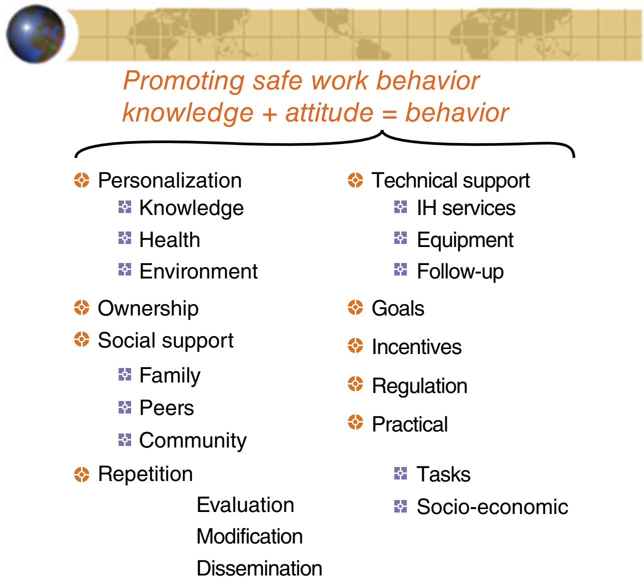


FIGURE 15.3 The Iowa Model of Multiple Modes of Intervention. To enhance the probability that health and safety education intervention reduces the risk of injuries and illnesses in farmers and their families, best practices should include as many of these factors as possible.

Table 15.6 The Iowa Model of Multiple Modes of Intervention: a checklist for best practices for positive outcomes of education as a component of a farm health and safety intervention

√ **Personalization of Information:** Trainers should direct whose problem it is, "This is you, family, and employees – not me!" (knowledge, health, environment)

√ **Ownership:** Famer must accept, "This problem is mine, my family's, my workers'"

√ **Social support:** We are all in this together (family, peers, neighbors, community)

√ **Repetition:** This is not just a one-shot deal (evaluation, modification, dissemination)

√ **Technical support:** Don't tell me I've got to get this protective device or PPE, but tell me how and where (tools, equipment, industrial hygiene services, follow-up)

√ **Goals:** How safe does my farm need to be? What health goals should I have? How do I know when I get there?

√ **Incentives:** How does this add to the bottom line? Insurance discounts? Discounts on farm services and supplies? Discounts on farm loans? (making safety a value-added farm product – this is huge!)

√ **Regulations:** Make sure the producer is aware of health and safety regulations and that they practice them.

√ **Practical:** If your recommendations/programs are not practical to the producer, they will not be accepted.

15.11 Education to Facilitate Behavior Change

Earlier in this chapter we discussed the evidence of the failure of awareness-level education in the prevention of agricultural injuries and illnesses. Based on prior research, education can be effective if it is delivered with certain parameters, and especially if it is a component of a multimodal intervention. This section describes the parameters that will enhance the probability of an effective educational intervention.

Figure 15.3 suggests that an education program will not necessarily lead to an attitude change and a long-term safe and healthful behavior change. To facilitate the desired outcome, several elements (as many as possible) must be incorporated into the program as follows. An education program should be personal (e.g., on *your* farm, with an unguarded open manure pit, the risk of *your* child falling and drowning in that pit is 10%). The farmer must take ownership of the problem. The educator cannot remove hazards; only the farmer can do that.

The education program must include social support of the whole family, peers, and community in identification of hazards on their farm. Community farm safety programs should be led by local farmers. The program must be sustainable. Technical support is essential (e.g., if a power take-off (PTO) shield is needed or certain PPE is needed, there must be technical support to assist the farmer to obtain and properly use these items, otherwise it likely will not happen). Established goals must be incorporated, for example the farm must attain a documented certain safety score (e.g., 85% CSF score) and health level (e.g., BMI of 26 or lower, cholesterol below 250 etc.) (143). Incentives are important as it is critical that the program has a positive effect on the economic bottom line of the farm (e.g., insurance, bank loans, farm supply and services, farm equipment sales all could provide discounts or rebates for safety, as they all have a stake in a healthy and safe farmer and farming operation). Extremely important is the practicality of the recommendations (138). The operator will weigh the cost versus the practicality of the program. If the practicality is not obvious, relative to cost, the program will not be accepted.

Finally, the education program should make the operator aware of the health and safety regulations applicable to their farm operation and assist them to meet these requirements. However, careful consideration is required to approach this situation, as US farmers and ranchers are wary of government intervention.

15.12 Removal of Farm Health and Safety Hazards

Removal of farm health and safety hazards is critical in this model. True to human nature, farmers become so familiar with their environment they do not see (or perceive the risk of) the hazards around them. The CSF model (and other models) uses a checklist of farm safety hazards. The CSF model employs a trained third-party auditor equipped with the checklist to assist the farmer in identifying hazards that can be addressed in a practical manner and at an economical cost. In addition, the auditor rates the farm according to safety, with a goal of 85%. As the farmer's main priority is to ensure a profit at the end of the year, any expense is highly scrutinized. This model intends to show how a safe farm can add positively to the bottom line through education on the cost of a farm injury, the potential for reduced insurance premiums, and reduced costs charged by machinery dealers, lenders, and farm supply and service companies.

15.13 Development of Total Worker Health

An occupational health clinical screening for hearing loss, skin cancer, respiratory function, and musculoskeletal functions, along with basic wellness measurements (e.g., cholesterol, blood pressure, blood sugar, and BMI), provides valuable information about the health of people living on the farm or ranch. In the CSF model, clinical screening was the most highly rated and attractive component of the program. In over 10 years of evaluation of the CSF, results have included reduced severe injuries, reduced respiratory illness, reduced medical care costs, removal of farm hazards, investments in safety by the farmer, and improved wellness (135, 136).

Furthermore, the farmers not only accepted the program, but embraced it and were willing to recommend it to others (139). Other models have also shown positive results. The challenge now is to develop a system to build on these programs and disseminate them broadly and sustainably.

15.14 Summary

Because of the nature of farming and farm culture, farmers, ranchers and other production agricultural workers are not leading occupational health and safety efforts in most countries, although there are some notable exceptions, such as Farm Safe Australia (140) and the United Farm Workers Organization in the United States (141). Most prevention has been carried out by governmental and voluntary non-governmental organizations. Although regulations have proven to be one of the most effective ways to reduce health and safety hazards in agriculture, few regulations directly affect independent small farming operations, and these existing rules are not regularly enforced. Most regulations in agriculture pertain to large farms, particularly where migrant and seasonal workers are employed.

Engineering interventions represent effective preventive methods for newer equipment and buildings, but not on the bulk of older machines and facilities in use. Owner/operators of small farms may not be able to afford new equipment and structures, leaving more hazardous equipment and buildings in use for many years without effective engineering protection.

Educational programs have been the main approach used in agricultural health and safety prevention. These programs have primarily been awareness-level efforts. There has been little evidence that they have been effective in reducing illnesses and injuries over extended periods. A comprehensive, multifaceted model that combines education with multiple levels of interventions provides the most successful health and safety prevention programming. This includes provision of occupational health screenings, on-farm safety audits, and performance incentives.

Key Points

1. Prevention of injuries in illness in agriculture is complicated by cultural and economic barriers, which must be understood, accepted, and considered in the design and application of any prevention intervention.
2. The order of prevention effectiveness is to first remove the hazard, followed by minimizing risk, both through efforts that eliminate or minimize a human behavioral response, as humans have and will continue to make mistakes, take chances, and make bad decisions. Engineering and management considerations are highly effective in overcoming innate human behavior fallibility.
3. Regulations can be an effective method of prevention. However, due to the numerous and geographically dispersed operations, inspection and enforcement is difficult. Furthermore, regulations are not well accepted by the agricultural community, particularly in the United States, where due to the small farm exemption over 80% of the farm population is effectively not covered by state or federal occupational safety and health regulations.
4. Although education for behavioral change is the most commonly practiced prevention method, and is acceptable to the agricultural population, it usually does not have the desired outcome of reducing injuries and illnesses. In order to increase the probability of education effectiveness best practices for a possible positive outcome should include:
    a. a theory base
    b. farmer personalization, ownership, peer social support, goals, incentives, and practical support (Table 15.6).
5. PPE should only be a component of a preventive program as effectiveness relies heavily on a human behavioral response, and could result in harm if it is not properly used (see Appendix A).
6. The most effective programs are voluntary, long-term, multimodal comprehensive programs that include incentives that are obvious to the producer will enhance the economic bottom line and the sustainability of the farm.
7. The Certified Safe Farm, Sustainable Farm Families, the Farm Hazard Analysis Tool, and the farmer occupational health programs of Norway and Finland are examples of integrated multimodal comprehensive programs that should be considered for expansion and/or as models to build on.
8. Such comprehensive programs require the significant effort of the people who control the resources, policy change, and monitoring. However, individuals can accomplish effective prevention by considering the principles outlined in this chapter, especially Table 15.5, which provides specific recommendations that an individual health or safety provider can accomplish, and Figure 15.3 and Table 15.6, which list the elements of an educational effort that will improve the probability of effectiveness.

Appendix A

Principles of Appropriate Selection of Personal Protective Equipment

This appendix provides details of PPE descriptions, selection, and health and safety considerations in their use.

15.1A Respiratory Protective Equipment (Respirators)

15.1.1A Types of Respirators

There are two basic types of respirators: (1) air purifying and (2) air or atmosphere supplying. The latter supplies air through a hose by way of an air pump or from compressed cylinders to the operator into a mask sealed around the face. The most common type of this device is self-contained breathing apparatus (SCBA), often used by firemen or scuba divers. This type of device must be used (rather than air-purifying respirators) in atmospheres that afford immediate danger to life or health (IDLH) (e.g., hydrogen sulfide emission from liquid manure in a swine or dairy building, entering an airtight silo, or entering a non-airtight silo where there is danger of silo gas). Air-purifying respirators are not sufficient to protect a person in an IDLH environments. There are very rare applications for a producer to need a SCBA, and specific certification of training and equipment is required.

There are many applications for air-purifying respirators in agriculture. However, training and knowledge of their selection and use are required for effective and safe use. The basic types of air-purifying respirators are:

1. Particulate-filtering respirators (dust, mist, and fumes)
   a. Filtering face-piece half-mask, usually disposable
   b. Half-face elastomer (non-disposable) with particle-filtering replicable cartridges
2. Chemical cartridge respirators
   a. Half-face mask (same as in 1b) with cartridges that are designed to filter or absorb low levels (in the range of the permissible exposure limit) of hazardous gases. Different cartridges are designed for different gases, and they are color coded to help in choosing the proper cartridge. These are replaceable screw-on cartridges. They may be fitted with a particle pre-filter.
   b. Chemical cartridge respirators may be fitted with a particle pre-filter, which provides protection from dusts as well as low-level gases.

15.1.2A NIOSH Certification and Protection Factor Designation

NIOH tests and certifies respirators (OSHA publish the results) in a laboratory setting for their performance and for quality assurance. They provide an Assigned Protection Factor (APF) based on their testing which designates its filtration efficiency under perfect fit conditions. For example, if the APF designation is 10, the concentration of the contaminant on the inside of the mask is 10 times lower in concentration than that outside the mask. The APF is a conservative number as it is set in the lower range of multiple test results (142). The NIOSH certification on the package (look for a label, e.g. DHHS NIOSH TC-84A-xxx) predicts the performance of the respirator if it is fitted, worn, or maintained correctly. The AFP may be lower than labeled if it is not fitted, worn, or maintained correctly. Additional loss of protection can occur because of some loss of facial seal associated with the movements of the worker. In this case another label, the workplace protection factor (WPF), may be used. NIOSH does not regularly test for the WPF, but employers or a separate researcher may conduct such studies. Unless specifically tested, it may be assumed that the WPF is only 50% of the labeled APF (assuming correct fitting, wearing, and maintenance).

The maximum use concentration (MUC) is the concentration of a substance a particular respirator can protect the worker from. It is calculated by multiplying the APF by the permissible exposure limit (PEL). However, to be safe, the WPF or its estimate should be used in calculating the MUC. For example, a worker in a swine building loading out hogs to market may be exposed to dust concentrations up to 15 mg/m^3. If the label on the dust mask indicates an APF of 10, the worker would be exposed to 1.5 mg/m^3 of dust, an acceptable limit. However, assuming a WPF of half that (i.e., 5), the concentration of dust reaching the breathing zone of the worker would be 3 mg/m^3, higher than the research-based recommended maximum exposure of 2.5 mg/m^3. A respirator of APF 15 or higher would be necessary to ensure adequate protection.

15.1.3A Terminology for the Type of Respirator

The filtering media has certain characteristics that indicate the expected performance of a respirator. Efficiency is expressed as the percentage of the particles that does not penetrate the filter, so it is designated as 95%, 99%, or 99.97% efficient (the latter is defined as a high-efficiency particulate (HEPA) air filter, at 0.3 μm and above). In metal fabricating, casting, and molding operations cutting oils are often used to lubricate and cool the metal cutting process. As an oil aerosol may be generated, a certain class of filter materials in respirators is made to resist oils. This leads to the following designations: N = no oil resistance, R = partial oil resistance, and P =complete oil resistance. As there are few situations in production agriculture where aerosolized oil would be an occupational concern, a N95 respirator (non-oil resistant, 95% efficient filtration) would be adequate in the majority of tasks.

15.1.4A Proper Fitting of a Respirator

The WPF of any respirator largely depends on how well the respirator fits the face of the wearer. The goal is a perfect seal around the face so that all the inhaled air must flow through the filter material. A respirator fit test is the objective way to determine if a proper seal is attained. A fit test would rarely be done on small farms, but it is required of employers if the operation comes under OSHA regulations (more than 10 employees, and either there is a task that exceeds the published PEL or ceiling exposure limit, or the employer recommends and/or supplies respirators to his/her employees). Fit testing is a component of a respirator protection program (discussed below). Fit testing is conducted under very precise procedures published by OSHA (150). A qualitative test is conducted while the worker wears the respirator within a hood, where a substance that can be tasted is sprayed into the hood. The fit test is passed if the wearer cannot taste the substance under the specified condition. A quantitative test involves a machine that counts particles outside and inside the mast. A proper fit is determined by the calculated decrease between the particles outside compared to inside the mask.

The objective of a fit test is to choose a properly fitting respirator for the individual and train them how to wear it. For workers who have been fit tested, and for most small farms where fit tests are not required, a user seal check will help to ensure a proper fit. This is accomplished by blocking the air or exhaust port. Exhaling with mild pressure should not allow air to escape around the mask. On inhaling slightly the mask should collapse slightly. As respirators are of different designs, if it is not obvious how to block the air inlet or exhaust port the manufacturer's directions should be consulted. The seal test should be carried out every time the respirator is worn.

Facial hair, deep scars, or an abnormally small, large, or misshapen face may create a difficult or impossible seal. For such cases, if the worker needs respiratory protection a loose-fitting powered air-supplying respirator (PAPR) may be required. PAPRs have fans that pull air first through a filter before forcing it into a partially enclosed helmet, creating a positive pressure so that no outside air comes into the helmet.

15.1.5A Medical Evaluation for Fitness to Wear Respirators

Some individuals may be unable to or should not wear respirators as the device may complicate an existing cardiorespiratory condition or the person may have claustrophobic tendencies, making it psychologically challenging for them to wear a respirator. Cardiorespiratory conditions that may limit a person from wearing a respirator include severe asthma, chronic bronchitis, emphysema, hypertension, and cardiac insufficiency. Medical evaluations are required as a component of a respirator program (142).

15.1.6A Respirator Protection Program

A respiratory protection program is required if the operation comes under OSHA regulations (more than 10 employees, and either there is a task that exceeds the published PEL or ceiling exposure limit for respiratory exposures, or the employer recommends and/or supplies respirators to his/her employees). Undertaking a respiratory program is very expensive and time-consuming. There are nine major components of the program, including quantifying the hazardous exposure, proper selection, and fitting of appropriate respirators, medical evaluation, fit testing, regular cleaning, disinfection and protective storage of respirators, and detailed record keeping (142). Table 15.1A lists major manufacturers of respirators, as well as non-profit organizations that sell and provide consultation on selection, and university and governmental organization who can provide further consultation. Table 15.2A shows a pictorial description of the basic types of respirators, relative cost, and user comments. Table 15.3A provides a selection guide for respirators. Listed are examples of appropriate respirators for different types of tasks. A subjective priority ranking is suggested based on the relative protection needed for the task, cost, and user's preference from a previously published survey (143).

15.2A Hearing Protection

Hearing protection devices (along with respirators) are tested and rated by NIOSH. They assigned noise reduction ratings (NRRs) for various types of hearing protectors. The NRRs range from around 10 to 30, which means they reduce the external noise pressure that reaches the middle ear by 10 dB or 30 dB, respectively. Selection of hearing protection should always include an indication on the device of NIOSH certification and a NRR number. Any NRR in the range of ±20 is acceptable for most agricultural work. However, just as respirators are only as effective as the fit or seal around the face, so hearing protectors are only as effective if they cover or fit into the ear canal to block the sound pressure. Training and experience are therefore important in choosing the best-fitting and most comfortable device for a worker, and then learning how to check for a sound seal. One seal test that can be used is with the devices installed in both ears, a hand is cupped over each ear independently and then removed. Then the hands are cupped over both ears and removed. If there is a louder sound when the hand is removed, the device is probably not sealed well. Although most hearing protectors are designed to block sound pressure, a relatively new concept in hearing protection is the electronic noise-canceling device. These devices produce a computer-generated sound to the ear at the opposite side of the sound sign-wave curve, thus canceling the sound. These devices do not depend on a complete seal, and it is possible to have a conversation with work comrades while wearing one, while still preventing high exposure to the dominant noise source.

Hearing devices must be kept clean and disinfected with multiple use, otherwise infection and irritation of the ear canal may result.

A hearing protection program is required if there are more than 10 employees, and if there is evidence that exposure above an average of 85 dB over an 8-hour work period is exceeded. Like respirator programs, hearing protection programs are time-consuming and costly. For the workers' benefit and for economic reasons, it is always best to reduce noise or respiratory exposures so that these programs are not required.

Table 15.1A Manufacturers of personal protection equipment (PPE) with international sales and non-profit/governmental suppliers with consultation services

Company name	Comment	Contact information
Manufacturers of PPE		
International Safety Equipment Association	A trade organization of PPE manufacturers This site is a guide to manufacturers of specific types of PPE with an international perspective Manufacturers will typically provide consultation on their own PPE products, but not necessarily on a comparative assessment of PPE needs for an individual operation	http://www.safetyequipment.org/
3M Corporation	General manufacturers of PPE with particular emphasis on respirators	http://m.3m.com/wps/portal/3M/en_US/PPE_Mobile/Home/?WT.mc_id=m.3m.com/PPESafety
Moldex	Manufacturers primarily of respirators and hearing protection	http://www.moldex.com/
MSA	An international company primarily oriented to the mining industry Manufacturers of head gear and other PPE, along with environmental testing equipment	http://www.msasafety.com/global/
National Draeger, Inc	An international company, primarily oriented to the mining industry They manufacture some general PPE, along with respirators and environmental testing equipment	http://www.draeger.com/Sites/enus_us/Pages/Chemical-Industry/Occupational-Health-and-Safety.aspx
Honeywell Safety	Manufacturers of a full line of PPE and safety equipment	http://www.honeywellsafety.com/USA/Home.aspx?LangType=1033
Scott Safety	Manufacturers mainly of respiratory PPE, but also market a general line of PPE	https://www.scottsafety.com/Pages/ScottHome.aspxhttps://www.scottsafety.com/Pages/ScottHome.aspx
Centurion Safety	Manufacturers primarily of head, eye, and hearing protection	http://www.centurionsafety.co.uk/
Elvex	Head and chainsaw safety	http://www.elvex.com/chain-saw-protection.htm
Vispro Safety	Primarily manufacturers of head and eye protection, with a smaller line of respirators and other PPE	http://www.visproprotection.com/esp
Wilson Safety	Manufacturers of a broad range of PPE	http://www.willsonsafetywear.com/
Non-profit/governmental PPE suppliers and consultation services		
AgriSafe Network	The AgriSafe store has a mail-order service of PPE from a variety of manufacturers Phone or email consultation with providers is available to help ensure the correct items are provided for the specific application	www.agrisafe.org/
New York Center for Agricultural Health and Medicine	The online safety store provides a full range of PPE from various manufacturers Phone or email consultation for PPE selection is available.	http://www.nycamh.com/programs/ppeonlinecatalog/
NIOSH-funded agricultural health centers: • US NIOSH • US OSHA	Consultation and advice on PPE may be available from these governmental organizations, but not sales or service of PPE	http://www.cdc.gov/niosh/oep/agctrhom.htmlhttp://www.cdc.gov/niosh/topics/smbus/guide/guide-5.htmlhttps://www.osha.gov/SLTC/personalprotectiveequipment/

Table 15.2A Characteristics of air-purifying respirators

Type of respirator	Picture of device	Used for dusts/fumes/mist	Used for gases	APF[a]	WPF[b]	Approximate cost	Remarks and user evaluation
Half-face disposable (N95) Mechanical Filter		Yes	No	10	13	$1–$2 each With exhalation valve $4–$6 each	• Moderate breathing resistance, increases with use • Good vision, eye comfort, convenient • Good for temperature, moisture, communication • Models with exhalation valve decrease moisture build-up, and help prevent fogging glasses
Half-face elastomeric (non-disposable) with particulate filter Mechanical Filter		Yes	No	10	22	$15–$40 for mask $7–$8 per pair of particle filters	• Ease of breathing and communication, good skin comfort, temperature, fit; communication better than disposable • Preferred by producers over disposable • Must be regularly maintained, disinfected, and stored in a clean dry space • Replacement dust filters available
Half-face elastomeric (non-disposable) with chemical cartridge/color code and particulate dust cap: ammonia – green organic vapor – olive		Yes	Only or low concen-trations, in the range of the regulated worker exposure limits	10	22	$15–$40 for mask Chemical cartridges $8–$25 per pair	• Same advantages as for elastomer half-face seen above • Cartridges are selected for protection of low-level irritant gases or fumes • Particle pre-filters available to attach before the cartridge, thus filtering particles as well as gases • Selecting the correct type of particulate or gas cartridge is critical • Particulate pre-filters available
Full-face elastomeric respirator and gas mask		Yes (with particulate filter)	Yes A higher capacity than the half faced cartridge, but not for use in IDLH[3] environ-ments	50		$120–$150	• Breathing ease similar to half-face elastomer • More uncomfortable and confining than half face • Provides eye and face protection • Larger capacity canisters rather than cartridges • Correct type of canister must be selected

Loose fitting (e.g., powered air-purifying, PAPR) Purifying		Yes	Yes	25	30	$800–$1,200	• Advantages over disposable or elastomer half-face masks are ease of breathing, communication, better temperature and comfort of eyes and skin • Disadvantages include increased weight, less convenient, and increased cost • Mainly for dust filtering, but gas canisters are available similar to half-face elastomer respirators
Atmosphere (air) supplying respirator (self-contained breathing apparatus, SCBA)		No	Used in IDLH atmosphere and/ or oxygen deficient atmosphere	100		$1,800–$2,300	• Few instances for use in agriculture • Not to be used by the average farmer or worker • Requires significant training and experience for safety use • Only respirator type safe to use in an IDHL environment

[a] APF, assigned protective factor (OSHA), according to laboratory tests with perfect seal.
[b] WPF, workplace protective factor, actual protection of workers in livestock production task.
IDHL, environment with immediate danger to life and health

Table 15.3A Selection guide of respirators according to hazard exposure: specific hazards/tasks and relative recommended respirator type for use

Class and constituents of hazard	Tasks resulting in exposure	Respirator type selection guide and relative ranking[a]					
		A[1]	A[2]	A[3]	A[4]	A[5]	S[6]
Inorganic dusts							
Field dust/road dust (soil, sand, rock, small amounts of mold spores, bacteria, and other organic matter)	• Soil tillage operations (plowing, disking, harrowing, etc.)	1	2			3	
	• Driving farm equipment on or working near dirt or gravel roads	1	2			3	
	• Harvesting operations (combining soybeans, sorghum, or other grains; mechanical harvesting of potatoes, tomatoes, and other food crops; manual harvesting of grapes)	1	2			3	
Organic dusts							
Grain dust	Working at grain elevators or feed mills	2	1			3	
	• Transporting (trucking) and storage of grain	1	2				
	• On-the-farm handling, transporting, and storage of grain	1	2				
	• Grinding and mixing feed, and feeding livestock						
Dusts from swine or dairy operations (grain dust, manure dust, bacteria, mold spores, bacterial toxins (endotoxins), swine dander, insects, insect parts, ammonia adsorbed to dust)	• Working in confinement or other swine housing	2	1			3	
	• Moving, sorting, trucking swine	2	1			3	
	• Working in livestock/dairy barns	2	1			3	
Dusts from poultry operations (grain dust, manure, feather dust, bacteria, mold spores, endotoxins, insects, insect parts, ammonia adsorbed to dust)	• Working in confinement poultry housing	2	1			3	
	• Loading, sorting, unloading birds	2	1			3	
	• Handling and treating birds	2	1			3	
	• Poultry processing/unloading	2	1			3	
	• Cleaning out old chicken houses	2	1			3	
Moldy corn or other grains	• Moving spoiled grain out of storage	2	1			3	
	• Cleaning out moldy grain from storage bins	1	2			2	
Moldy silage	• Opening up non-airtight silos, throwing off the spoiled top layer	3	1			2	
Moldy hay	• Moving, handling or feeding moldy hay, either loose hay or bales that have to be broken up (usually only important when done indoors)	2	1			3	
Low levels of irritant gases and vapors							
Ammonia	• Working in poultry and livestock housing (primarily chickens, turkeys, swine, veal)			1	2	3	
	• Working with anhydrous ammonia			1	2	3	
Hydrogen sulfide	• Working in and around liquid manure storage or handling liquid manure from livestock confinement structures (use organic vapor cartridge, with dust pre-filter, olive in color)			1	2	3	
	• Working inside livestock confinement structures with liquid manure storage under a slatted floor (use organic vapor cartridge with dust pre-filter, olive in color)			1	2	3	
Welding (metal fumes: zinc, cadmium, iron oxide, manganese; gases: nitrogen dioxide, ozone, fluorides)	• Welding, especially in poorly ventilated areas, and especially on galvanized metals	1	2				
Anhydrous ammonia	• Working with anhydrous ammonia where a leak or escape of the gas, especially in an enclosed space				1		2
Pesticides[b]							
Insecticides (such as organophosphates and some carbamates)	• Mixing and applying insecticides			1	2	3	
	• Working in sprayed field before proper re-entry time						
Fumigants (such as methyl bromide, chloropicrin, etc.)	• Applying fumigants on stored grain				1	2	
	• Entering an enclosed structure where a fumigant has been recently applied						1
Herbicides	• Working with concentrate (respirators usually not needed)						

(*Continued*)

Table 15.3A (Continued)

Class and constituents of hazard	Tasks resulting in exposure	Respirator type selection guide and relative ranking[a]					
		A[1]	A[2]	A[3]	A[4]	A[5]	S[6]
High levels of toxic gases or oxygen-deficient environments[c]							
Hydrogen sulfide	• Working inside livestock confinement buildings with storage pit under the building while the pit is being agitated or emptied	X	X	X	X	X	1
	• Entering a liquid manure storage pit anytime	X	X	X	X	X	1
Oxides of nitrogen	• Entering a silo (or chute) which has been filled with fresh silage within the previous 2 weeks	X	X	X	X	X	1
Oxygen-deficient environments	• Entering an airtight silo which has been filled with silage, haylage, or high moisture grain	X	X	X	X	X	1
	• Entering a non-airtight silo or grain bin which has recently been filled with high moisture grain	X	X	X	X	X	1
Carbon monoxide	• Emergency entry or rescue in an environment where there was a known or suspected high carbon monoxide concentration from an internal combustion engine, or malfunctioning heating system	X	X	X	X	X	1

1–3, highest to lower recommendation; x, not recommended.
A[1]=Disposable Half-faced particle filtering (e.g. N95)
A[2]=Non-disposable, Half-Face, Elastomer
A[3]=Chemical Cartridge, Half-face, elastomer
A_4=Full-face chemical cartridge, elastomer;
A[5]=Loose-fitting (e.g. positive air supplying respirator [PAPR])
S[6]= Self Contained Breathing Apparatus (SCBA)
[1] $A_{1=}$ Disposable mechanical filter respirators
[2] A_2 =Mechanical filter respirators
[3] A_3 =Chemical cartridge respirators
[4] $A_{4=}$ Gas masks
[5] A_5 =Powered air-purifying respirators
[6] S = Air Supplying, Self-contained breathing apparatus

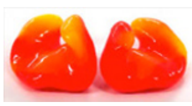
Note: Air-supplying respirators (B) should only be used by people trained in their use. Local volunteer fire department personnel may be first contact when an emergency arises requiring SCBA equipment. It is not recommended that farmers or ranchers attempt to use such equipment without proper training.
[a] Rankings are based on a subjective priority ranking by the authors and content consultants. 1–3 is the highest to lowest priority of acceptable respirators for use in the specified situation. The ranking is based on a combination of effectiveness of protection, comfort and freedom from interference while performing required tasks, and cost.
[b] In most applications, respirators are not needed when handling or applying insecticides, herbicides, or fungicides. However, for all pesticides follow the recommendations for PPE as printed on the package label or the material safety data sheet (MSDS).
[c] Environments of immediate danger to life or health (IDHL).

Table 15.4A displays the various types of hearing protectors, their NRRs, the relative costs, and wearer information that is helpful in selection (144).

15.3A Protective Eyewear

Corneal abrasions, foreign body penetration, and chemical burns are all common eye injuries in agriculture. Less common eye concerns include flash burns from welding and pterygium. The latter is caused by long-term UV light, wind, and dust. Pterygium is scar tissue that slowly grows from the nasal side of the eye across the cornea and may progress to cover a portion of the pupil. Safety glasses made of polycarbonate or trivex (they could be tinted, although both substances block UV light) should be commonly worn whether in the field or inside the shop to prevent eye injuries. There are models that can be selected

Table 15.4A Characteristics of hearing protection devices (144)

Types of hearing protection device	Picture of device	Noise reduction factor	Approximate cost	Remarks and user evaluation
Earplugs: expandable, formable foam Mechanical Filter		26–33	$0.13–$1.00 each	• Least cost protection • Effective if inserted properly • Proper insertion requires experience and time • Plug is rolled as thin as possible and inserted by pulling tip of ear to straighten the ear canal
Earplugs: pre-molded, tethered cord or band Mechanical Filter		24–27	$0.90–$1.20 each	• Easy to insert • Can be used with hat • Tether yields more convenient access as needed
Earplugs: canal caps, banded		16–23	$4.50–$6.00 each	• Similar efficiency as pre-molded • Less irritating and less moisture build-up because they do not penetrate the ear canal • More expensive than pre-molded
Earplugs: custom molded for individual use, reusable		21–29	$140–$170 each	• More effective as they account for individual anatomical variation • Less comfortable, with moisture build-up in ear canal • Must be cleaned and sanitized • Storage in clean and dry container
Ear muffs		20–30	$10–$25 $40–$60 with AM/FM radio reception $300–$500 with two-way radio communication	• Effectiveness diminished with poor seal to face (facial hair, facial scar, hat) • Hot in warm environment • May include two-way radio communication
Noise-canceling devices		29–49	$30–$200	• Cancels external noise electronically • Normal speech communication possible while wearing • May be equipped with two-way radio communication

Source: Hearing Protection Compendium, Center for Disease Control. Accessed at http://www.cdc.gov/niosh/topics/noise/hpdcomp/?p=0:3.

to accommodate eye glasses. Also available are models that combine protective and corrective lenses. Goggles are important for protection from irritant chemicals or particles. Goggles with indirect ventilation that have two lenses separated by a vented air space prevent fogging yet do not allow fumes to penetrate to the inside of the goggles. Table 15.5A provides examples of protective eyewear, along with selection criteria.

15.4A Protective Clothing

In agriculture, clothing is an important component of protection from abrasions, irritants, toxic chemicals, and the sun. Standard cotton or combined synthetic work clothes offer protection, especially for abrasions and dry chemicals. If fabrics are treated with a hydrophobic (water-repelling) spray (e.g., with a silica, carbon, zinc, or manganese base), regular work clothes can provide additional partial protection against liquids. When needed, higher levels of protection can be provided by specialized disposable suits made of synthetic non-woven materials (e.g., Tyvek). Judgment must be used in wearing or requiring workers to wear protective clothing. Protective clothing increases the risk of heat stress. In a few instances in production agriculture complete coverage with non-breathable clothing is required. For pesticides, the package label and MSDS sheet will provide guidance. Table 15.5A provides details of protective clothing along with selection criteria (145–148).

15.5A Welding Protective Gear

As farmers and ranchers often serve as their own repair people, welding is occasionally required. Welding (particularly electric arc-welding) produces extreme light energy that can damage the superficial layers of the eye (cornea and conjunctiva) as well as the retina (called arc flash, arc eye, and welder's eye). Symptoms include eye pain and photophobia (eye pain from light exposure). Arc-welding light can also cause burns to exposed skin. For eye and facial protection, a welder's helmet is essential. The helmet is equipped with a dark-tinted polarized lens that is difficult to see through. The welder must get the welding rod into the vicinity of the metal to weld, then flip the dark lens down before the arc strikes, allowing welder to see what he/she is doing. Too often the arc strikes before the lens is flipped down, causing a risk of arc-flash burn. Relatively new advances in the field include an auto-darkening lens with liquid crystal display technology that allows the welder to see what he/she is to weld (the lens darkens instantly as the arc flashes, providing protection from flash burns). This technology should be a priority when purchasing a welding helmet. Acetylene-oxygen torch welding emits a relatively lower amount of light energy, but requires the welder to wear green-tinted goggles.

Arc-welding and blow-torch metal cutting result in extensive emission of sparks, which can burn skin on contact or start a fire on clothing. Protective non-flammable sleeves or a jacket is important for burn protection. Arc- or torch-welding can also result in emission of fumes that can cause illness in the welder. The most common source of such illness is zinc fumes from welding galvanized metal. A welder's respirator should be worn in addition to eye and head protection to prevent metal fume poisoning.

Welder's gloves are also important, as handling hot metal can cause severe burns. The appearance of a piece of metal will not give a warning that it is hot enough to burn if handled. Table 15.6A provides detailed information and tips for the selection of protective equipment for welders (145, 147, 148).

15.6A Chainsaw Protective Gear

Farmers, ranchers, farm workers (occasionally), and of course forestry workers commonly use chainsaws. The chainsaw is one of the most efficient, productive, yet dangerous power tools. Injury risk can be minimized with experience, proper cutting technique, proper maintenance, and proper use of approved PPE. Newer machines

Table 15.5A Characteristics of protective devices and materials for eyes and skin (145–148)

Types of device	Picture of device	Approximate cost	Remarks and user evaluation
Protective eye wear: glasses Mechanical Filter		$2.00–$22.00 per pair	• Select for proper fit • Choose product with ANSI certification • Select polycarbonate or Trivex lens • Select wraparound design • Accommodate wearing over corrective lenses
Protective eye wear: goggles Mechanical Filter		$3.00–$10.00	• Best to select indirect vent/anti-fog goggles • If using for protection from anhydrous ammonia, goggles must seal tight to the face and be either indirectly vented or non-vented • Accommodate wearing over corrective lenses
Protective clothing: gloves		$2.00–$4.00 per pair (unlined re-usable) $0.25–$0.50 per pair (disposable)	• Neoprene or nitrile gloves for general agricultural use • For pesticide exposures, consult package label or MSDS for recommend PPE • Disposables for single usage only • Non-disposable gloves should have cuff to prevent dripping onto arms • Non-disposable gloves should be unlined; wash inside-out after use • Single-use cotton under gloves may improve comfort with unlined disposables
Protective outer clothing: regular cotton material work clothes		$30–$50	• Provides some protection for dry materials but little protection for liquid exposures • Must be laundered after each use • Protection improved with woven-in Teflon or other non-fibrous synthetic material • Protection improved by spraying with durable water-repellant hydrophobic material (e.g., Scotchgard™, Europlasma™, Liquipel™)
Protective outer clothing: aprons		$10.00 -$12.00 each	• Recommend chemical-resistant material during mixing, loading, or applying in potential for contact with spray or dust • Level C (splash and dry chemical protection) adequate in most instances • Less risk of heat stress for worker

(*Continued*)

Table 15.5A (Continued)

Types of device	Picture of device	Approximate cost	Remarks and user evaluation
Protective outer clothing: single-use coveralls		$9.00–$15.00 each	• Tyvex material, uncoated (level C protection) • Comfort Guard™ material provides protective and breathable material to reduce heat stress • Useful for mixing or loading or spraying with undiluted chemicals

ANSI, American National Standards Institute; MSDS, material safety data sheet; PPE, personal protective equipment.

Table 15.6A Characteristics of protective devices and materials for welding and chainsaw operation (145,147,148)

Types of devices	Picture of device	Approximate cost	Remarks and user evaluation
Welding helmet: regular Mechanical Filter		$40.00–$60.00 each	• Best if equipped with flip-up flash shield for rapid deployment to protect eyes from flash burn
Welding helmet: auto-darkening		$40–$200	• Auto-darkening eye shield does not depend on human response to flip eye shield in place • Prevents potential flash burn (corneal or retinal inflammation)
Welding respirator N-95		$24–$50	• Especially important when welding galvanized (zinc-containing) metals • A regular N95 with exhalation valve may be used in place of the welding respirator for short-time exposure (lower cost)
Welding gloves		$16–$19	• Prevent burns from metal sparks and handling hot metals

(*Continued*)

Table 15.6A (Continued)

Types of devices	Picture of device	Approximate cost	Remarks and user evaluation
Welder protective clothing		\$18–\$20 (sleeves) \$30–\$40 (jacket)	• Prevent burns from metal sparks and hot metals
Chainsaw helmet		\$40–\$60	• Prevent head, eye and face injuries, and provides hearing protection
Chainsaw chaps		\$60–\$80	• Kevlar thread impregnated material essential to protect legs • Choose chaps that enclose backs of legs as well as front for increased protection and to prevent trip hazard from trimmings being caught in closure of open-backed chaps
Chainsaw gloves		\$20–\$30	• Protection from laceration
Chainsaw boots		\$90–\$120	• Select for traction • Steel toe and instep

Note: The National Fire Protection Association certifies protective clothing are equipped with safety technologies to minimize vibration energy to the hands and arms, a chain brake to stop the chain in an emergency, and a throttle lock to require activation by the operator before the throttle can be engaged.

As hand and arm injuries are the most common injuries, a protective jacket and protective gloves are highly recommended. Legs are the second most common site of injury, and chainsaw chaps are highly recommended. These chaps are filled with Kevlar fibers, and if the chain hits and cuts into the chaps, the Kevlar fibers will instantly entangle in the chain and drive gear to stop the machine and prevent or substantially reduce the injury. Chaps that can be closed at the back are recommended to protect the back of the legs and prevent slash and trash (trimmings for felled trees) from catching in the enclosure straps thereby creating a trip hazard. A chainsaw helmet with attached face shield and sound protection ear muffs is essential to protect the head from injury from falling limbs, eyes and face from projected wood chips, and hearing from excessive noise. Hearing protection can be enhanced by inserting ear plugs in addition to using the ear muffs attached to the helmet. Details of chainsaw protective equipment are given in Table 15.6A (145, 147, 148).

References

1. Fragar L. Policy issue. Agricultural health and safety in Australia. Aus J Rural Health. 1996;4(3):200–6.
2. Schenker MB. Preventive medicine and health promotion are overdue in the agricultural workplace. J Public Health Policy. 1996;17(3):275–305.
3. Jones P, Field W. Farm safety issues in Old Order Anabaptist communities: unique aspects and innovative intervention strategies. J Agric Saf Health. 2002;8(1):67–81.
4. Murphy D. Safety and Health in Production Agriculture. St. Joseph MI: American Society of Agricultural Engineers; 1992.
5. Aherin RA, Murphy DJ, Westaby JD. Reducing Farm Injuries: Issues and methods. St Joseph, MI: American Society of Agricultural Engineers; 1992.
6. Donham KJ, Mutel, CF. Agricultural medicine: The missing component of the rural health movement. J Fam Prac. 1982;14(3):511–20.
7. Arcury T. Occupational injury prevention knowledge and behavior of African-American farmers. Hum Organ. 1997;56(2):167–73.
8. Leigh JP, McCurdy SA, Schenker MB. Costs of occupational injuries in agriculture. Public Health Rep. 2001;116(3):235–48.
9. Pana-Cryan R, Myers ML. Cost-effectiveness of roll-over protective structures. Am J Ind Med. 2002; Suppl.2(2):68–71.
10. Kelsey TW. The agrarian myth and policy responses to farm safety. Am J Public Health. 1994;84(7):1171–7.
11. Loos C, Oldenburg B, O'Hara L. Planning of a community-based approach to injury control and safety promotion in a rural community. Aust J Rural Health. 2001;9(5):222–8.
12. Moore E, McComas J. Acceptance of an injury-prevention program in rural communities: a preliminary study. Prehosp Disaster Med. 1996;11(4):309–11.
13. Palermo T, Ehlers J. Coalitions: partnerships to promote agricultural health and safety. J Agric Saf Health. 2002;8(2):161–74.
14. Thu K, Donham KJ, Yoder D, Ogilvie L. The farm family perception of occupational health: a multistate survey of knowledge, attitudes, behaviors, and ideas. Am J Ind Med. 1990;18(4):427–31.
15. Nawrot R, Wright W. Make it safe: an injury prevention program for Hispanic farm workers and families at work and play. Int Elec J Health Ed. 1998; 1(4):219–21.
16. Myers J, Bloomberg L. Farm industry slips through cracks: public health principles should be utilized to reform, improve agricultural injury prevention efforts. Occup Health Saf. 1993;62(11):56–60.
17. Myers ML. Prevention effectiveness of rollover protective structures – Part I: Strategy evolution. J Agric Saf Health. 2000;6(1):29–40.
18. Thelin A. Epilogue: agricultural occupational and environmental health policy strategies for the future. Am J Ind Med. 1990;18(4):523–6.
19. Powers JR, Harris JR, Etherton JR, Ronaghi M, Snyder KA, Lutz TJ, et al. Preventing tractor rollover fatalities: performance of the NIOSH autoROPS. Inj Prev. 2001;7(Suppl.1):i54–8.
20. Rains GC. Initial rollover effectiveness evaluation of an alternative seat belt design for agricultural tractors. J Agric Saf Health. 2000;6(1):13–27.
21. Reynolds SJ, Groves W. Effectiveness of roll-over protective structures in reducing farm tractor fatalities. Am J Prev Med. 2000;18(4Suppl.):63–9.
22. Owusu-Edusei KJ. Net monetary benefit of cost-effective rollover protective structures (CROPS): an estimate of the potential benefits of the CROPS research project. J Agric Saf Health. 2008;14(3):351–63.

23. Donham K. Tractor risk abatement and control; the policy conference. Iowa City, IA: College of Public Health, University of Iowa; 1997.
24. ROPS retrofit Program. New York Center for Agricultural Health and Medicine; 2016 (accessed 9 January 2016). Available from: https://www.nycamhoutreach.com/ropsr4u/.
25. Somervell PD, Conway GA. Does the small farm exemption cost lives? Am J Ind Med. 2011;54(6): 461–6.
26. Guidance for Hazard Determination for Compliance with the 29 CFR 1910.1200. US Department of Labor, Bureau of Labor Statistics; 2014 (accessed January 9, 2016) Available from: https://www.osha.gov/dsg/hazcom/ghd053107.html.
27. Donham K. Respiratory dysfunction in swine production facility workers: dose-response relationships of environmental exposures and pulmonary function. Am J Ind Med. 1995;27(3):405–18.
28. Policy Clarification on OSHA's Enforcement Authority at Small Farms. US Department of Labor; 2014 (accessed 11 January 2016). Available from: https://www.osha.gov/dep/enforcement/policy_clarification_small_farms.html.
29. Census of Agriculture. US Department of Agriculture; 2002 (accessed 23 February 2005). Available from: http://www.nass.usda.gov/census/.
30. Farm Numbers and Land in Farms Final Estimates 1998–2002. US Department of Agriculture; 2004 (accessed February 2015]. Available from: http://www.nass.usda.gov/Publications/Todays_Reports/reports/fnlo0211.pdf.
31. Fact Sheet 51: Field Sanitation Standards under the Occupational Safety and Health Act. US Department of Labor (revised July 2008). Available from: http://www.dol.gov/whd/regs/compliance/whdfs51.pdf.
32. Introduction to International Labour Standards. International Labour Organization; 2016 (accessed 9 January 2016). Available from: http://www.ilo.org/global/standards/introduction-to-international-labour-standards/lang--en/index.htm.
33. Code of Federal Regulations, Title 29 (Labor). Part 500, Chapter 5. Wage and Hour Division, Department of Labor (accessed 9 January 2016). Available from: http://www.dol.gov/dol/cfr/title_29/chapter_v.htm.
34. Worker Protection in Agriculture, Employment Law Guide. Wages and Hours Worked. US Department of Labor (accessed 9 January 2016). Available from: http://www.dol.gov/compliance/guide/mspa.htm.
35. Temporary Labor Camps. Occupational Safety and Health Standard 1910.41 (accessed 9 January 2016). Available from: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9791.
36. Pesticide Worker Safety. Agricultural Worker Protection Standard. US Environmental Protection Agency (updated 3 November 2015; accessed 9 January 2016). Available from: http://www.epa.gov/pesticide-worker-safety/agricultural-worker-protection-standard-wps.
37. A diagram of Mexican Labor Health and Safety. Mexican Laws (accessed 9 January 2016). Available from: http://www.mexicanlaws.com/STPS/A_Diagram_of_Mexican_Labor-Health_and_Safety.htm.
38. Euro directives on safety and health at work. EU-OSHA; 2016 (accessed 9 January 2016). Available from: https://osha.europa.eu/en/legislation/directives.
39. Work place safety Australia (accessed 9 January 2016). Available from: http://www.worksafe.com.au/.
40. Fair Labor Standards Act. US Department of Labor (accessed 10 January 2016). Available from: http://www.dol.gov/compliance/laws/comp-flsa.htm.
41. Child labor requirements in agriculture under the Fair Labor Standards Act. Child Labor Bulletin No 102. Document HW-1295. US Department of Labor (revised June 2007). Available from: http://www.dol.gov/whd/regs/compliance/childlabor102.pdf102.
42. National Safe Tractor and Machinery Operation Program. State College, PA: Pennsylvania State University; 2014 (updated February 2014; accessed 9 January 2016). Available from: http://extension.psu.edu/business/ag-safety/youth-safety/national-safe-tractor-and-machinery-operation-program.
43. US Labor Department proposes updates to child labor regulations. US Department of Labor, Bureau of Labor Statistics; 2014 (accessed 5 January 2016). Available from: http://www.dol.gov/opa/media/press/whd/WHD20111250.htm.
44. Silletto TA. Implications for agricultural safety education programs as identified by Iowa farm accident survey [unpublished doctoral dissertation]. Ames, IA: Iowa State University; 1976.
45. Williams DL. Iowa's farm people characteristics and agricultural accident occurrence. PhD dissertation. Ames, IA: Iowa State University; 1983.
46. Risenberg L, Bear W. Instructional impact on accident prevention. Engineering a safer food machine. St Joseph, MI: American Society of Agricultural and Biological Engineers; 1980. pp. 138–44.
47. Robertson LS. Injuries: causes, control strategies, and public policy. Lexington, MA: Lexington Books, DC Heath & Company; 1983.
48. Certification and Training of Pesticide Applicators. Environmental Protection Agency; 2014 (updated

26 February 2014; accessed 24 October 2014). Available from: http://www.epa.gov/pesticides/safety/applicators/applicators.htm.
49. Donham K. Agricultural Safety and Health: A Profession? J Agromedicine. 2009;14(1):5–8.
50. Forastiere F. ILO Program on Occupationa Safty and health in Agriculture. Article 31, October 1999. International Labor Organization; 1999 (accessed 26 October 2014). Available from: http://www.ilo.org/safework/areasofwork/WCMS_117367/lang--en/index.htm.
51. Hansen E, Donohoe M. Health Issues of Migrant and Seasonal Farmworkers. J Health Care Poor Underserved 2003;14(2):153.
52. Merchant J, Kross B, Donham K, Pratt D. Agriculure and Risk: a Report to the Nation. Iowa City, IA: University of Iowa; 1989.
53. Donham KJ, Venzke, JK. Agricultural occupational health nurse training and certification. J Agromedicine. 1997;4(1):105–16.
54. Fisher EL, Donham KJ. Agricultural medicine core course: building capacity for health and safety professionals. J Agromedicine. 2011;16(2):106–16.
55. Rudolphi J, Donham, K. Increasing the number of trained health and safety professionals in agricultural medicine: Evaluation of the Building Capacity Program 2007–2013. J Agromedicine. 2015;20(1):21–30.
56. Rudolphi J, Donham K. Toward a national core course in agricultural medicine: The building capacity concensus process. J Rural Health. 2015;20(1):77-83.
57. Murphy DJ, Kiernan NE, Chapman LJ. An occupational health and safety intervention research agenda for production agriculture: does safety education work? Am J Ind Med. 1996;29(4):392–6.
58. DeRoo LA, Rautiainen RH. A systematic review of farm safety interventions. Am J Prev Med. 2000;18(4Suppl.):51–62.
59. Wilkins JR, 3rd, Engelhardt HL, Bean TL, Byers MV, Crawford JM. Prevalence of ROPS-equipped tractors and farm/farmer characteristics. J Agric Saf Health. 2003;9(2):107–18.
60. Westaby JD, Lee BC. Antecedents of injury among youth in agricultural settings: a longitudinal examination of safety consciousness, dangerous risk taking, and safety knowledge. J Saf Res. 2003;34(3):227–40.
61. Kidd P, Scharf T, Veazie M. Linking stress and injury in the farming environment: a secondary analysis of qualitative data. Health Educ Q. 1996;23(2):224–37.
62. Kidd P, Reed D, Weaver L, Westneat S, Rayens MK. The transtheoretical model of change in adolescents: implications for injury prevention. J Saf Res. 2003;34(3):281–8.
63. Lehtola MM, Rautiainen RH, Day LM, Schonstein E, Suutarinen J, Salminen S, et al. Effectiveness of interventions in preventing injuries in agriculture – a systematic review and meta-analysis. Scand J Work Environ Health. 2008;34(5):327–36.
64. Mandel JH, Carr WP, Hillmer T, Leonard PR, Halberg JU, Sanderson WT, et al. Safe handling of agricultural pesticides in Minnesota: results of a county-wide educational intervention. J Rural Health. 2000;16(2):148–54.
65. Liller KD. Teaching agricultural health and safety to elementary school students. J Sch Health. 2001; 71(10):495–6.
66. Liller KD, Noland V, Rijal P, Pesce K, Gonzalez R. Development and evaluation of the Kids Count Farm Safety Lesson. J Agric Saf Health. 2002;8(4):411–21.
67. Kidd P, Townley K, Cole HP, McKnight R, Piercy L. The process of chore teaching: implications for farm youth injury. Fam Community Health. 1997;19(4):78–89.
68. Reed DB, Kidd PS, Westneat S, Rayens MK. Agricultural Disability Awareness and Risk Education (AgDARE) for high school students. Inj Prev. 2001; 7(Suppl.1):i59–63.
69. Steffen R, Niedbalski G. Farm safety day campus: developing a definition using the Delphi method. J Agric Saf Health. 1998;4(2):109–17.
70. Reed DB, Westneat SC, Kidd P. Observation study of students who completed a high school agricultural safety education program. J Agric Saf Health. 2003; 9(4):275–83.
71. Elkind PD, Pitts K, Ybarra SL. Theater as a mechanism for increasing farm health and safety knowledge. Am J Ind Med. 2002;Suppl.2(2):28–35.
72. Cole HP, Kidd PS, Isaacs SG, Parshall M, Scharf T. Difficult decisions: a simulation that illustrates cost effectiveness of farm safety behaviors. J Agromedicine. 1997;4(1/2):117–24.
73. Morgan SE, Cole HP, Struttmann T, Piercy L. Stories or statistics? Farmers' attitudes toward messages in an agricultural safety campaign. J Agric Saf Health. 2002;8(2):225–39.
74. Brandt V, Struttmann T, Cole H, Piercy L. Delivering health education messages for part-time farmers through local employers. J Agromedicine. 2001;7(3):23–30.
75. Hjort C, Hojmose P, Sherson D. A model for safety and health promotion among Danish farmers. J Agromedicine. 2003;9(1):93–100.
76. Flocks J, Clarke L, Albrecht S, Bryant C, Monaghan P, Baker H. Implementing a community-based social

marketing project to improve agricultural worker health. Environ Health Perspect. 2001;109(Suppl.3): 461–8.
77. Karr C, Murphy H, Glew G, Keifer MC, Fenske RA. Pacific Northwest health professionals survey on pesticides and children. J Agromedicine. 2006;11(3–4): 113–20.
78. Guin SM, Wheat JR, Allinder RS, Fanucchi GJ, Wiggins OS, Johnson GJ. Participatory research and service-learning among farmers, health professional students, and experts: an agromedicine approach to farm safety and health. J Agromedicine. 2012;17(1):22–9.
79. Steven J, Robbins S, Schwartz B, Wasserman E. Psychology of Learning and Behavior. 5th edition. New York: WW Norton; 2001.
80. Kohn A. Punished by Rewards: The Trouble with Gold Stars IP, A's, Praise, and Other Bribes. Boston: Houghton Mifflin; 1999.
81. Gielen AC, Sleet DA, DiClemente RJ (eds). Injury and Violence Prevention: Behavioral Science Theories, Methods, and Applications. San Francisco: Jossey-Bass; 2006.
82. Dahlberg CB, Toal SB, Swahn M, Behren CB. Measuring violence-related attitudes, behaviors and influence among youth: a compendium of assessment tools. 2nd edition. Atlanta, GA: US Center for Diseases Control and Prevention, National Center for Injury Prevention Control; 2005. Available from: http://www.cdc.gov/ncipc/pub-res/behavioral/default.htm.
83. Sweller J. Cognitive load theory, learning difficulty, and instructional design. Learning and Instruction. 1994;4(4):295–312.
84. Slavin RE. Educational Psychology: Theory and Practice. 10th edition. Boston: Allyn and Bacon; 2012. 608 pp.
85. Sanderson L, Dukeshire SR, Range LC, Garbes R. The farm apprentice: agricultural college students recollections of learning to farm "safely". J Agric Saf Health. 2010;16(4):229–47.
86. Ferguson K, Gjerde C, Mutel C, Donham K, Hradek C, Johansen K, et al. An educational intervention program for prevention of occupational illness in agricultural workers. J Rural Health. 1989;5:33–7.
87. Donham K, Merchant J, Lassise D, Popendorf W, Burmeister L. Preventing respiratory disease in swine confinement workers: Intervention through applied epidemiology, education, and consultation. Am J Ind Med. 1990;18:241–62.
88. Schiller LF, Dingledein DM, Strebel RR. Incorporating occupational health interventions in a community based participatory preventive health program for farm families: a qualitative study. J Agromedicine. 2010;15(2):117–26.
89. Certified Safe Farm of North Carolina. Greenville, NC: North Carolina Agromedicine Institute; 2014 (updated 2014; cited 31 October 2014). Available from: http://www.ecu.edu/cs-dhs/agromedicine/CSF.cfm.
90. Hawk C, Gay J, Donham K. The Farm Safety Walkabout Handbook. Des Moines, IA: Iowa Department of Publc Health, Institute for Agricultural Medicine; 1992.
91. Total worker health. Center for Disease Control, National Institute for Occupational Safety and Health (updated 4 January 2016; accessed 12 January 2016). Available from: http://www.cdc.gov/niosh/twh/.
92. Szreter S. Rethinking McKeown: The Relationship Between Public Health and Social Change Am J Public Health. 2002;May;92(5):722–5.
93. Population health. Public Health Agency of Canada (updated 22 January 2013; accessed 12 January 2016). Available from: http://www.phac-aspc.gc.ca/ph-sp/index-eng.php.
94. One Health Initiative home page; 2014 (accessed 30 October 2014). Available from: http://www.onehealthinitiative.com/index.php.
95. Chapman LJ, Schuler RT, Wilkinson TL, Skjolaas CA. Agricultural safety efforts by county health departments in Wisconsin. Public Health Rep. 1996;111(5):437–43.
96. Huneke J, VonEssen S, Grisso R. Innovative approaches to farm safety and health for youth, senior farmers and health care providers. J Agromedicine. 1998;5(2):99–106.
97. Browning SR, Westneat SC, Donnelly C, Reed D. Agricultural tasks and injuries among Kentucky farm children: results of the Farm Family Health and Hazard Surveillance Project. South Med J. 2003;96(12):1203–12.
98. Hubert DJ, Ullrich DR, Murphy TH, Lindner JR. Texas entry-year agriculture teachers' perceptions, practices, and preparation regarding safety and health in agricultural education. J Agric Saf Health. 2001;7(3):143–53.
99. Hubler C, Hupcey J. Incidence and nature of farm-related injuries among Pennsylvania Amish children: implications for education. J Em Nursing. 2002;28(4):284–8.
100. Kumar A, Varghese M, Mohan D. Equipment-related injuries in agriculture: an international perspective. Inj Control Saf Promotion. 2000;7(3): 175–86.
101. Stueland DT, McCarty JE, Stamas P, Jr., Gunderson PD. Evaluation of agricultural rescue course by providers. Prehosp Disaster Med. 1996;11(3):234–8.

102. Yoder AM, Murphy DJ. Evaluation of the Farm and Agricultural Injury Classification Code and follow-up questionnaire. J Agric Saf Health. 2000;6(1): 71–80.
103. Fragar L, Houlahan J. Australian approaches to the prevention of farm injury. N S W Pub Health Bull. 2002;13(5):103–7.
104. Haddon W, Jr. A note concerning accident theory and research with special reference to motor vehicle accidents. Ann N Y Acad Sci. 1963;107:635–46.
105. Knapp LW, Jr. Agricultural injury prevention. J Occup Med. 1965;7(11):545–53.
106. Mausner J, Kramer S. Epidemiology – An Introductory Text. 2nd edition. Philadelphia: WB Saunders; 1985.
107. Yoder AM, Murphy DJ. Using social marketing to address barriers and motivators to agricultural safety and health best practices. J Agromedicine. 2012;17(2):240–6.
108. What is social marketing? Your guide to an essential tool for health communication (accessed 9 January 2016). Available from: http://www2a.cdc.gov/cic/documents/cdc/cleared/social_marketing.pdf.
109. Swenson E. National Agricultural Tractor Safety Initiative. Washington, DC: University of Washington; 2004.
110. Iowa's Center for Agricultural Safety and Health home page; 2015. College of Public Health. University of Iowa (accessed 9 January 2016). Available from: http://www.public-health.uiowa.edu/ICASH/.
111. Occupational Health Surveillance and Evaluation Program. California Department of Health Services; 2014 (updated 4 November 2015; accessed 5 January 2016). Available from: http://www.cdph.ca.gov/programs/ohsep/Pages/default.aspx.
112. Fatality Assessment and Control Evaluation (FACE) Program. Atlanta: National Institute for Occupational Safety and Health; 2014 (updated 26 August 2014; accessed 6 November 2014). Available from: http://www.cdc.gov/niosh/face/.
113. Nonnenmann MW, Donham KJ, Rautiainen RH, O'Shaughnessy PT, Burmeister LF, Reynolds SJ. Vegetable oil sprinkling as a dust reduction method in swine confinement. J Agric Saf Health. 2004; 10(1):7–15.
114. The Industrial Environment – Its Evaluation and Control. US Department of Health, Education, and Welfare, PHS, CDC, NIOSH; 1973. p. 1–5.
115. Donham KJ, Storm J. Agriculture at Risk: A Report to the Nation – A Historical Review, Critical Analysis, and Implications for Future Planning. J Agric Saf Health. 2002;8(2):9–35.
116. Agricultural Safety and Health. Iowa City, IA: Heartland Center for Occupational Safety and Health, College of Public Health, University of Iowa; 2014 (accessed 9 January 2016). Available from: http://cph.uiowa.edu/heartland/academic-programs/ag-safety.html.
117. Douphrate DI, Gimeno D, Nonnenmann MW, Hagevoort R, Rosas-Goulart C, Rosecrance J. Prevalence of work-related musculoskeletal symptoms among US large-herd dairy parlor workers. Am J Ind Med. 2014;57(3):370–9.
118. Fethke NB, Merlino LM, Gerr F, Schall MC, Cassidy A, Branch CA. Musculoskeletal pain among Midwest farmers and associations with agricultural activities. Am J Ind Med. 2015; 58(3):319-30.
119. Vanderwal L, Rautiainen R, Kuye R, Peeka-Asa C, Cook T, Ramirez M, et al. Evaluation of long- and short-handled hand hoes for land preparation, developed in a participatory manner among women vegetable farmers in The Gambia. Appl Ergon. 2011;42(5):749–56.
120. Hoglund S. Farmers' health and safety programs in Sweden. Am J Ind Med. 1990;18(4):371–8.
121. Notkola V, Husman K, Tupi K, Virolainen R, Nuutinen J. Farmers' occupational health programme in Finland, 1979–1987. Soc Sci Med. 1990;30(9):1035–40.
122. Gay J, Donham K, Leonard S. The Iowa Agricultural Health and Safety Service Program. Am J Ind Hygiene. 1990;18:385–9.
123. AgriSafe Network home page; 2014 (updated 2014; accessed 22 August 2014). Available from: http://www.agrisafe.org/.
124. Norsk Landbruksrodgivning home page (accessed 9 January 2016). Available from: http://www.lhms.no/.
125. Thelin A, Stiernstrom E, Holmberg S. Differences in the use of health care facilities and patterns of general risk factors in farmers with and without occupational health care programs. Int J Occup Environ Health. 1999;5(3):170–6.
126. Rasmussen K, Carstensen O, Lauritsen JM, Glasscock DJ, Hansen ON, Jensen UF. Prevention of farm injuries in Denmark. Scand J Work Environ Health. 2003;29(4):288–96.
127. Legault ML, Murphy DJ. Evaluation of the Agricultural Safety and Health Best Management Practices Manual. J Agric Saf Health. 2000;6(2): 141–53.
128. Farm Health and Safety Hazard analysis tool (FARM-HAT) home page. Pennsylvania State University Extension, State College, Pennslylvania; 2016

(accessed 9 January 2016). Available from: http://extension.psu.edu/business/ag-safety/farmhat.
129. Heikkonen J, Louhevaara V. Empowerment in farmers' occupational health services. Ann Agric Environ Med. 2003;10(1):45–52.
130. Walsh M. Farm accidents: their causes and the development of a nurse-led accident prevention strategy. Em Nurse. 2000;8(7):24–31.
131. Farm Safety Day Camps 2005. Progressive Farmer Magazine (accessed 3 March 2005). Available from: http://www.farmsafetyday.com/Pages/VisitorHomePage.php.
132. Farm Safety for Just Kids home page; 2005 (accessed 23 February 2005). Available from: http://www.fs4jk.org/madams.html.
133. Maslow AH. A Theory of Human Motivation. Psychol Rev. 1943;50:370–96.
134. Savitz AW. The triple bottom line: How best run companies are achieving economic, social and environmental success: How you can too. San Franciso: Jossey-Bass/Wiley; 2006.
135. Rautiainen RH, Lange JL, Hodne CJ, Schneiders S, Donham KJ. Injuries in the Iowa Certified Safe Farm Study. J Agric Saf Health. 2004;10(1):51–63.
136. Brumby SA, Willder SJ, Martin J. The sustainable farm families project: changing attitudes to health. Rural Remote Health. 2009;9(1):1012.
137. Stone JF, Hanna M, Guo C, Imerman P. Protective headgear for midwestern agriculture: a limited wear study. J Environ Health. 2001;63(7):13–9, 21.
138. McCullagh M, Lusk S, Ronis D. Factors influencing use of hearing protection among farmers – A test of the Pender Health Promotion Model. Nurs Res. 2002;51(1):33–9.
139. Kline A, Leedom-Larson K, Donham KJ, Schneiders S, Rautiainen R. Farmer Assessment of the Iowa Certified Safe Farm Program. J Agromedicine. 2007; 12(3):33–43.
140. Farm Safe Australia home page; 2005 (accessed 23 February 2005). Available from: http://www.farmsafe.org.au/.
141. United Farm Workers home page; 2005 (accessed 23 February 2005). Available from: http://www.ufw.org/.
142. Assigned Protection Factors for the Revised Respiratory Protection Standard. Washington, DC: US Department of Labor Occupational Safety and Health Administration; 2009. p. 47.
143. Popendorf W, Merchant JA, Leonard S, Burmeister LF, Olenchock SA. Respiratory protection and acceptability among agricultural workers.) Appl Occup Environ Hyg. 1995;10(7):595-605.
144. Hearing protection device compendium. National Institute for Occupational Safety and Health (updated 19 October 2015; accessed 12 January 2016). Available from: http://www.cdc.gov/niosh/topics/noise/hpdcomp/.
145. Stone J. Cover Up with Coveralls and Aprons. Fact Sheet Pm-1563. Ames, IA: Iowa State University Extension; 1994 (accessed 9 January 2016). Available from: http://nasdonline.org/static_content/documents/1273/d001071.pdf.
146. MSDS, material safety data sheet; PPE, personal protective equipment. American National Standards Institute.
147. Personal protective equipment. Private Pesticide Applicator Safety Education Manual. St Paul, MN: University of Minnesota Extension; 2013 (accessed 9 January 2016). Available from: http://www.extension.umn.edu/agriculture/pesticide-safety/ppat_manual/Chapter%208.pdf.
148. Weigel R. Personal Protective Equipment for Agriculture. Laramie, WY: University of Wyoming Extension; 2012 (accessed 9 January 2016). Available from: http://www.wyomingextension.org/agpubs/pubs/B1233.pdf.

Index

Note: Page numbers in *italics* refer to Figures; those in **bold** to Tables.

Agricultural Medicine: Rural Occupational and Environmental Health, Safety, and Prevention, Second Edition.
Kelley J. Donham and Anders Thelin.

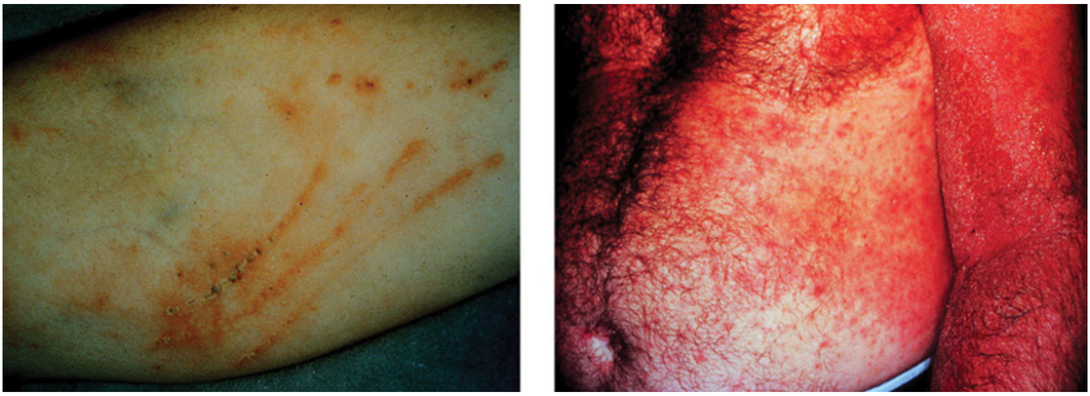


FIGURE 4.1 Rhus allergic contact dermatitis. Left: linear pattern, sub-acute stage. Right: diffuse pattern aerosol exposure from burning brush containing poison ivy plants and wearing no shirt.

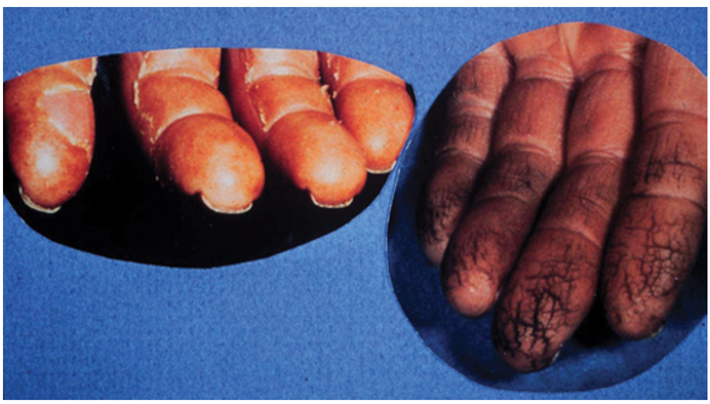


FIGURE 4.2 Bulb finger: allergic and or chronic contact dermatitis. The allergen is tulipan A and the irritant is butyrolactone.

Agricultural Medicine: Rural Occupational and Environmental Health, Safety, and Prevention, Second Edition.
Kelley J. Donham and Anders Thelin.

FIGURE 4.3 Phytophoto-irritant contact dermatitis may be caused by plants of the Apiaceae family, which includes celery, carrot, and parsnip among others. The juices from these plants contain a furocoumarin that becomes a toxic irritant when exposed to sunlight.

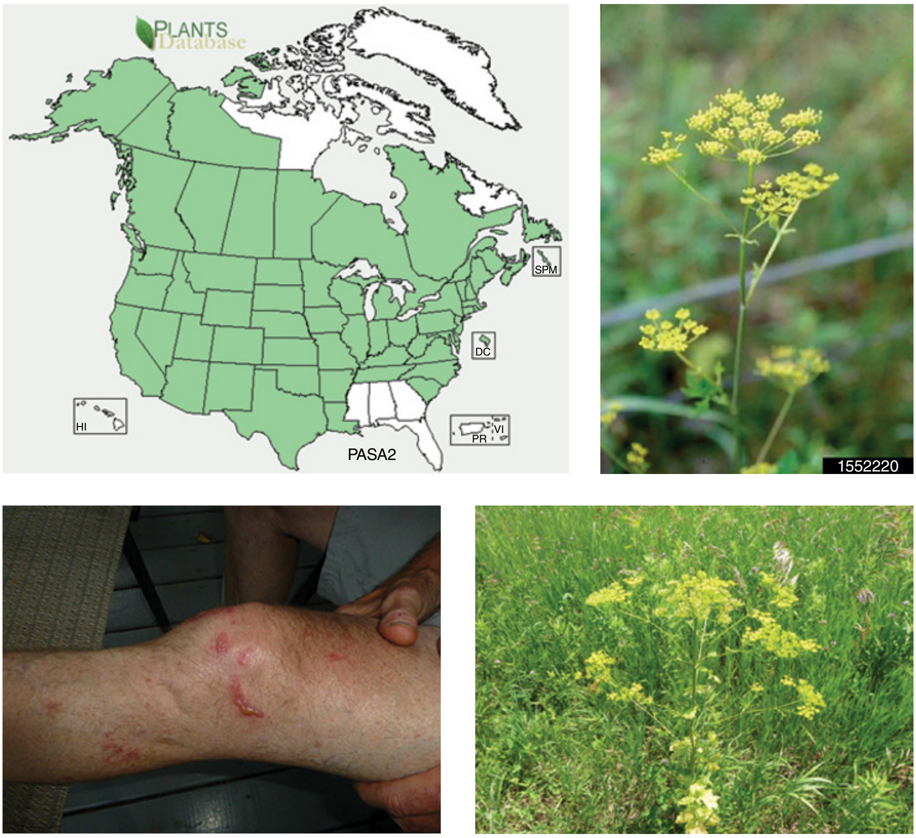


FIGURE 4.4 Wild parsnip (*Pastinaca sativa*) from the Apiaceae family is an invasive species that grows wild throughout most of North America, Canada, and northern Europe. It has a similar furocoumarin to other plants of this family and can cause a severe phytophoto-irritant contact dermatitis, as shown here on a leg. (Source: USDA, http://plants.usda.gov/core/profile?symbol=PASA2.)

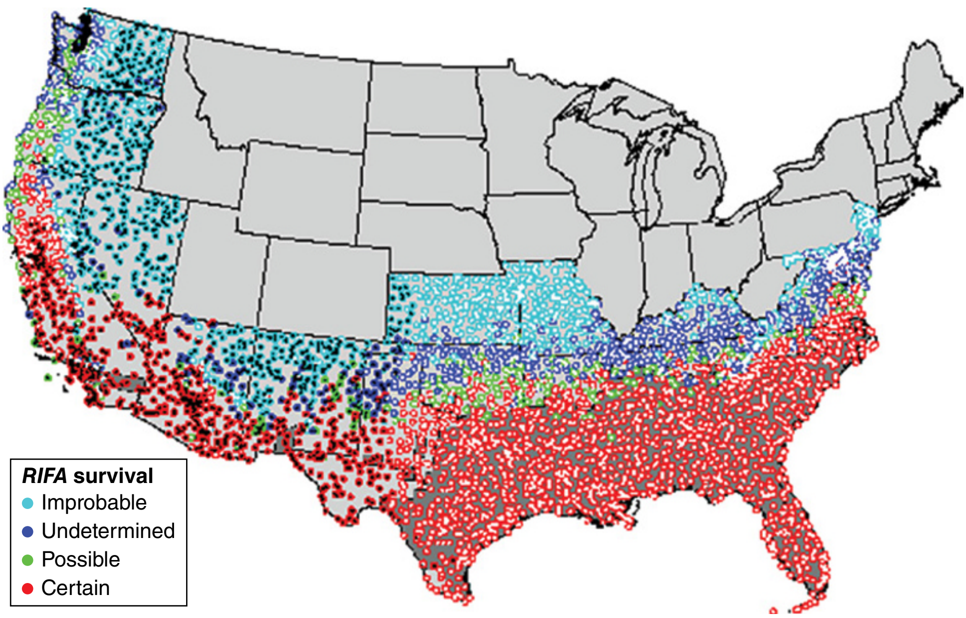


FIGURE 4.5 Potential US range expansion of the invasive fire ant based on climate and other ecologic conditions. (Source: USDA, Agricultural Research Service http://www.ars.usda.gov/research/docs.htm?docid=9165. Date last modified 5.10.2006.)

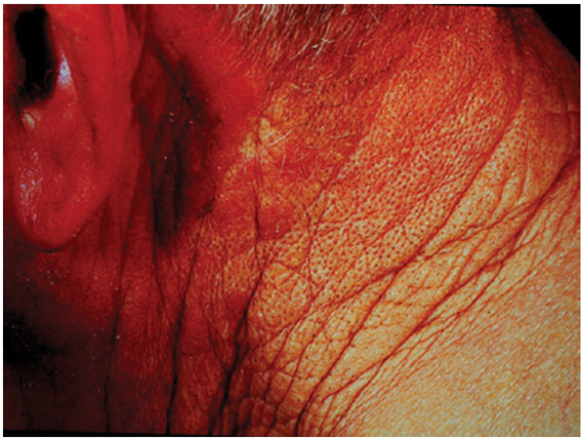


FIGURE 4.6 Compare the thickened and wrinkled skin from chronic exposure to skin protected by the shirt collar on this 65-year-old farmer.

FIGURE 4.7 Actinic kerratoses.

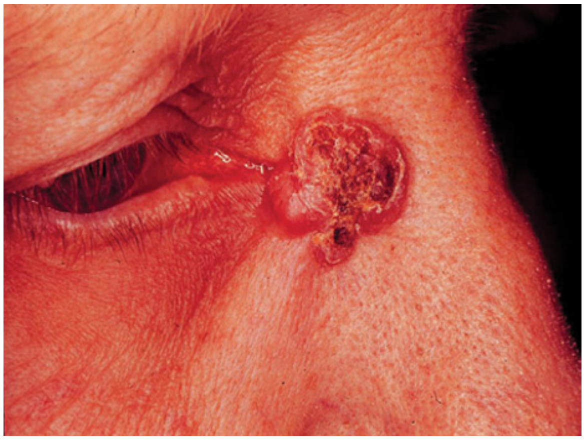


FIGURE 4.8 Basal cell carcinoma.

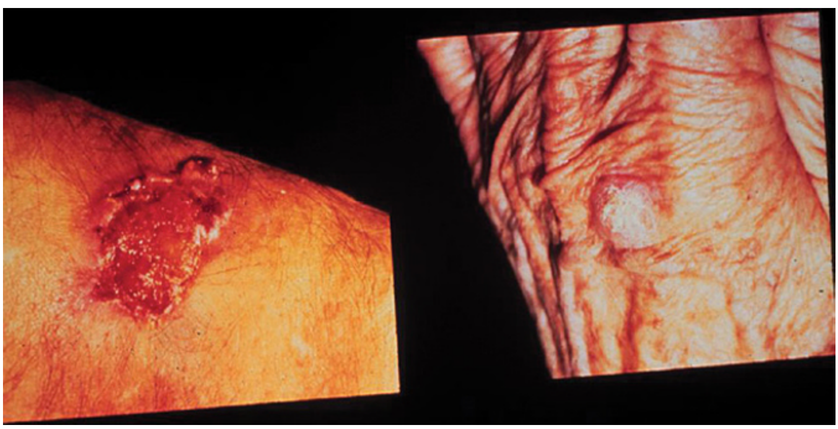


FIGURE 4.9 Squamous cell carcinoma: two different clinical appearances.

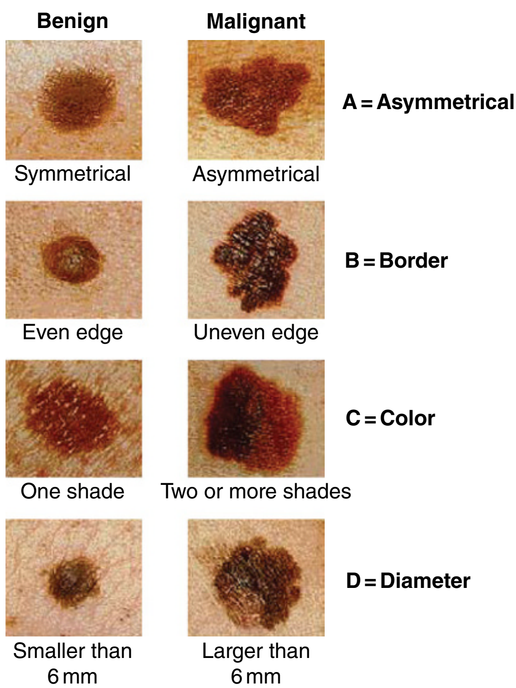


FIGURE 4.10 The ABCDs of melanoma aid in the presumptive differentiation of a mole (nevus) from a melanoma. (Source: http://www.cancer.gov/types/skin/moles-fact-sheet#q9.)

FIGURE 9.7 The intermittent blanching episodes of the fingers and hands are referred to as primary Raynaud's disease (a hereditary or developmental condition). This condition, also called "white fingers," is caused by a spasm of blood vessels supplying the hand. It may also be caused or exacerbated by occupational long-term use of hand-held vibratory tools ("vibration white fingers") and it is triggered by cold weather conditions.