PRINCIPLES OF TOXICOLOGY

Environmental and Industrial Applications

Third Edition

Edited By

STEPHEN M. ROBERTS
Professor and Program Director,
Center for Environmental & Human Toxicology,
University of Florida,
Gainesville, FL

ROBERT C. JAMES
Senior Principal Scientist,
ToxStrategies, Inc.,
Boise, ID

PHILLIP L. WILLIAMS
Dean, College of Public Health and Georgia Power Professor of Environmental Health Science,
University of Georgia,
Athens, GA

WILEY

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

Library of Congress Cataloging-in-Publication Data:

Principles of toxicology : environmental and industrial applications / [edited by] Stephen M Roberts, Robert C James, Phillip L Williams. – Third edition.
pages cm
Includes index.
ISBN 978-0-470-90791-7 (cloth)
1. Toxicology. 2. Industrial toxicology. 3. Environmental toxicology. I. Williams, Phillip L., 1952- II. James, Robert C. III. Roberts, Stephen M., 1950-
RA1211.P746 2014
615.9′02–dc23

2014020557

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

CONTENTS

CONTRIBUTORS

T. Renée Anthony, Ph.D., Associate Professor, Department of Occupational and Environmental Health, University of Iowa, University of Iowa, College of Public Health, Iowa City, IA

Lisa A. Bailey, Ph.D., Senior Health Scientist, Gradient, Cambridge, MA

Barbara D. Beck, Ph.D., DABT, FATS, Principal, Gradient, Cambridge, MA

Michael S. Bloom, Ph.D., Associate Professor, Departments of Environmental Health Sciences and Epidemiology and Biostatistics, University at Albany School of Public Health, State University of New York, Rensselaer, NY

Janice Britt, Ph.D., Senior Managing Scientist, ToxStrategies, Inc., Tallahassee, FL

Brenda S. Buikema, M.D., M.P.H, Assistant Professor (Clinical), Department of Occupational and Environmental Health, University of Iowa, College of Public Health; and Division of Pulmonary, Department of Internal Medicine, Critical Care, and Occupational Medicine, University of Iowa, Carver College of Medicine, Iowa City, IA

William M. Caudle, Ph.D., Assistant Professor, Department of Environmental Health, Rollins School of Public Health, Emory University, Atlanta, GA

Harvey J. Clewell III, Ph.D., DABT, Director, Center for Human Health Assessment, Hamner Institute for Health Sciences, Research Triangle Park, NC

Rebecca A. Clewell, Ph.D., Hamner Institute for Health Sciences, Research Triangle Park, NC

Mary Jane Cunningham, Ph.D., Founder and President, Nanomics Biosciences, Inc., The Woodlands, TX

Steve Diamond, Ph.D., Vice President, Mid-West Division, Nanosafe, Duluth, MN

Michael R. Franklin, Ph.D., Professor, Department of Pharmacology and Toxicology, University of Utah, Salt Lake City, UT

Michele M. Garber, M.P.H., Senior Scientist, Hazardous Substance & Waste Management Research, Tallahassee, FL

Vincent F. Garry, M.D., MS., DABT, Professor (Emeritus), Department of Laboratory Medicine and Pathology, University of Minnesota, Minneapolis, MN

Fredric Gerr, M.D., Professor of Occupational and Environmental Health and Professor of Epidemiology, University of Iowa, College of Public Health; Iowa City, IA

Sherilyn A. Gross, Ph.D., Senior Health Scientist, Cardno ChemRisk Inc., Boulder, CO

Robert H. Heflich, Ph.D., U.S. Food and Drug Administration, National Center for Toxicological Research, Jefferson, AR

Georgia Hinkley, Ph.D., Research Associate, Center for Environmental & Human Toxicology, University of Florida, Gainesville, FL

Mary L. Hixon, Ph.D., Senior Toxicologist, Gradient Corporation, Cambridge, MA

Keith A. Houck, Ph.D., Principal Investigator, National Center for Computational Toxicology, Office of Research & Development, U.S. Environmental Protection Agency, Research Triangle Park, NC

Robert C. James, Ph.D., Senior Principal Scientist, ToxStrategies, Inc., Boise, ID

Richard S. Judson, Ph.D., Principal Investigator, National Center for Computational Toxicology, Office of Research & Development, U.S. Environmental Protection Agency, Research Triangle Park, NC

James E. Klaunig, Ph.D., Professor, Department of Environmental Health, Indiana University, Ellettsville, IN

Sailesh Konda, M.D., Procedural Dermatology/Mohs Surgery Fellow, Department of Dermatology, Loma Linda University Medical Center, Loma Linda, CA

J. Michael Kuperberg, Ph.D., Center for Biomedical & Toxicological Research, Florida State University, Tallahassee, FL

Lawrence H. Lash, Ph.D., Professor and Associate Chair, Department of Pharmacology, Wayne State University, School of Medicine, Detroit, MI

Ari S. Lewis, M.S., Principal Scientist, Gradient, Cambridge, MA

Cuiqing Liu, Ph.D., Postdoctoral Researcher, Davis Heart and Lung Research Institute, College of Medicine, The Ohio State University, Columbus, OH; and Associate Professor, Department of Physiology, Hangzhou Normal University, Hangzhou, People's Republic of China

Hongbo Ma, Ph.D., Assistant Professor, Zilber School of Public Health, University of Wisconsin – Milwaukee, Milwaukee, WI

Howard I. Maibach, M.D., ATS, Professor, Department of Dermatology, University of California San Francisco, San Francisco, CA

David B. Mayfield, M.S., DABT, Senior Toxicologist, Gradient, Seattle, WA

Gary W. Miller, Ph.D., Professor and Associate Dean for Research, Department of Environmental Health, Rollins School of Public Health, Emory University, Atlanta, GA

Martha M. Moore, Ph.D., Senior Manager, ENVIRON International Corp., Little Rock, AR

Meagan B. Myers, Ph.D., Division of Genetic and Molecular Toxicology, National Center for Toxicological Research, Food and Drug Administration, Jefferson, AR

David M. Reif, Ph.D., Associate Professor, Department of Biological Sciences, Bioinformatics Research Center, North Carolina State University, Raleigh, NC

Stephen M. Roberts, Ph.D., Professor and Program Director, Center for Environmental & Human Toxicology, University of Florida, Gainesville, FL

Eric S. Sobel, M.D., Ph.D., Associate Professor and Program Director, Rheumatology and Clinical Immunology, University of Florida College of Medicine, Gainesville, FL

Leah D. Stuchal, Ph.D., Research Assistant Professor, Center for Environmental & Human Toxicology, University of Florida, Gainesville, FL

Qinghua Sun, M.D., Ph.D, Divisions of Environmental Health Sciences & Cardiovascular Medicine, Davis Heart & Lung Research Institute, College of Public Health, The Ohio State University, Columbus, OH

Christopher M. Teaf, Ph.D., Associate Director, Center for Biomedical & Toxicological Research, Florida State University, Tallahassee, FL

Peter L. Truran, Ph.D., Resident Fellow, Center for Philosophy of Science, University of Minnesota, Minneapolis, MN

John E. Vena, Ph.D., Professor and Founding Chair, Department of Public Health Sciences, Medical University of South Carolina, Charleston SC

Phillip L. Williams, Ph.D., Dean, College of Public Health and Georgia Power Professor of Environmental Health Science, University of Georgia, Athens, GA

PREFACE

PURPOSE OF THIS BOOK

Principles of Toxicology: Environmental and Industrial Applications presents compactly and efficiently the scientific basis to toxicology as it applies to the workplace and the environment. The book covers the diverse chemical hazards encountered in the modern work place and natural environment and provides a practical understanding of these hazards for those concerned with protecting the health of humans and ecosystems.

INTENDED AUDIENCE

This book is a third edition and represents an update and expansion on the previous, very successful texts. The first edition of this book was entitled *Industrial Toxicology: Safety and Health Applications in the Workplace.* The current edition retains the emphasis on applied aspects of toxicology, while extending its scope to cover new areas of toxicology such as toxicokinetics, omics technology, nanotoxicology, and computational toxicology. The book was written for those health professionals who need toxicological information and assistance beyond that of an introductory text in general toxicology, yet more practical than that in advanced scientific works on toxicology. In particular, we have in mind industrial hygienists, occupational physicians, safety engineers, environmental health practitioners, occupational health nurses, safety directors, and environmental scientists.

ORGANIZATION OF THE BOOK

This volume consists of 23 chapters. The early chapters establish the scientific basis to toxicology, which is then applied through the rest of the book. It discusses concepts such as absorption, distribution, and elimination of toxic agents from the body. Chapters 5–11 discuss the effects of toxic agents on specific physiological organs or systems, including the blood, liver, kidneys, nerves, skin, lungs, and the immune system.

The next part of the book addresses specific areas of concern in the occupational and environmental settings—both toxic agents and their manifestations. Chapters 12–15 examine the areas of great research interest—reproductive toxicology, developmental toxicology, mutagenesis, and carcinogenesis. Chapters 16–18 examine the toxic effects of metals, pesticides, and organic solvents.

The final part of the book is devoted to specific areas and applications of the toxicological principles from both the environmental and occupational settings. Chapters 19 and 20 cover the emerging areas of nanotoxicology and computational toxicology. Chapters 21 and 22 discuss epidemiologic issues and occupational/environmental health. Chapter 23 covers risk assessment.

FEATURES

The following features from *Principles of Toxicology: Environmental and Industrial Applications* will be especially useful to our readers:

- The book is compact and practical, and the information is structured for easy use by the health professionals in both industry and government.
- The approach is scientific, but applied, rather than theoretical. In this it differs from more general works in toxicology, which fail to emphasize the information pertinent to the industrial environment.
- The book consistently stresses evaluation and control of toxic hazards.

- Numerous illustrations and figures clarify and summarize key points.
- Case histories and examples demonstrate the application of toxicological principles.
- Chapters include suggested reading bibliographies to provide the reader with additional useful information.
- A comprehensive glossary of toxicological terms is included.

Stephen M. Roberts
Robert C. James
Phillip L. Williams

22

OCCUPATIONAL AND ENVIRONMENTAL HEALTH

Brenda S. Buikema, T. Renée Anthony, and Fredric Gerr

The purpose of this chapter is to introduce readers the practice of occupational and environmental health. Specifically, this chapter will define occupational and environmental heath and describe the:

- Historical events that shaped modern occupational and environmental health practices
- Fundamental characteristics of occupational and environmental illness
- Activities and goals of occupational and environmental health specialists
- Multidisciplinary approach to protecting workers' health
- Ethical issues relevant to occupational and environmental health practice

22.1 HISTORY OF OCCUPATIONAL HEALTH

Readers of this book should be familiar with the historical figures whose efforts shaped our modern occupational and environmental health practices as well as the occupational and environmental health disasters that serve as lasting reminders of the importance of preventing occupational and environmental illness and injury.

In 1587, Paracelsus, often considered the father of modern toxicology, wrote the first known monograph on occupational disease. However, the role of occupational risk factors in the development of disease was not widely appreciated until 1700, when the Italian physician, Bernardo Ramazzini, published the first known textbook of occupational medicine, entitled *De Morbis Artificum Diatriba* (*The Diseases of Workers*" in modern translation). Prior to its publication, there were few efforts to link work and illness, despite increasing development of metallurgy and other technologies. Ramazzini recommended that physicians ask their patients about their occupation and the conditions of their work. He also encouraged physicians to visit their patients' work sites to observe directly their working conditions. In particular, Ramazzini wrote, "*Liceat quoque interrogationem hanc adiicere, & quam artem exerceat*" ("I may venture to add one more question: what occupation does [the patient] follow?"). Ramazzini recognized noise, dusts, fumes, extremes of heat and cold, and awkward postures as risk factors for occupational disease and used this knowledge to reduce exposure to these hazards as a means of preventing occupational illness. Ramazzini's work contributed to subsequent efforts of other occupational health specialists and is widely credited with establishing the specialty of occupational medicine.

With the industrial revolution, certain workplace exposures became more common, leading to the occurrence and recognition of new occupational diseases. For example, in 1775, the British surgeon, Percival Potts, noted that occupational exposure to soot among chimney sweeps resulted in an increased risk of scrotal cancer, eventually leading to protective legislation for workers in Europe. Government medical positions were created in the second half of the nineteenth century in Great Britain, establishing occupational medicine as a legitimate part of public health and clinical medicine.

In 1911, the Triangle Shirtwaist Factory fire in New York City resulted in the death of 146 garment workers, which placed workers' health and safety concerns into the limelight both locally and nationally, leading to the reform of fire

Principles of Toxicology: Environmental and Industrial Applications, Third Edition. Edited by Stephen M. Roberts, Robert C. James and Phillip L. Williams.

safety codes and the inception of U.S. workers' compensation programs. This tragedy, resulting from locked fire exits in the factory, also resulted in the creation of the Office of Industrial Hygiene and Sanitation of the U.S. Public Health Service. It was one of the earliest U.S. federal responses to the growing hazards of industrialized work.

Just after World War I, Dr Alice Hamilton, the first woman to be a member of the faculty of the Harvard Medical School, became the leading American figure in the field of occupational and environmental medicine. As a pioneering advocate for occupational and environmental public health, she gave congressional testimony in opposition to the addition of tetraethyl lead to gasoline and correctly predicted widespread environmental lead contamination and an epidemic of lead toxicity as a consequence. In 1925, Dr Hamilton wrote *Industrial Poisons in the United States* and paved the way for growth and maturation of the field.

In 1930, contractor profits were placed ahead of workers' health by allowing dry drilling of silica-containing rock with inadequate ventilation during construct of the 3 mile Hawks Nest Tunnel in West Virginia. The resulting exposure to airborne crystalline silica resulted in the death of hundreds of workers who developed a severe and rapidly progressive form of *silicosis* (a disease of the lung resulting from inhalation of silica dust and characterized by scar tissue and impaired transfer of oxygen from air to blood). Hundreds more developed permanent lung disease. In terms of lives lost, this incident remains the single largest industrial disaster in U.S. history.

In December of 1952, a 5-day temperature inversion in London, United Kingdom, resulted in a dense ground-level fog that trapped soot, tar, and sulfur dioxide from household and industrial coal combustion. London residents developed chest pain, lung inflammation, and increased asthma incidents, with 4000 fatalities initially attributed to the event. While many who died of respiratory illness during the inversion were elderly or had preexisting lung conditions, increased fatality rates for both middle-aged and infant residents were observed during and immediately following the smog event. Today, estimates of 12,000 deaths are attributed to the event. In the wake of this tragedy, the British government began efforts to reduce household coal emissions in the ensuing 1956 Clean Air Act.

Such industrial disasters have affected not just previous generations but are still occurring in the current era. For example, in 1984, the unplanned release of methyl isocyanate gas from a Union Carbide plant into a densely populated neighborhood of Bhopal, India, resulted in the immediate death of approximately 2000 people and the onset of permanent lung disease among more than ten thousand residents. Neither the community nor local hospitals knew what was in the gas or were aware of its toxic effects. As a result, regulators in the United States developed a hazard communication standard to ensure that the hazards of occupational chemicals were clearly communicated to workers and, in conjunction with emergency response rules, to the neighboring communities and emergency responders. In 1986, an explosion at the Chernobyl nuclear power plant in Ukraine resulted in the immediate deaths of 28 workers and emergency responders, who again did not know the hazards of the radiation exposures they were facing. In 2005, an explosion in a British Petroleum refinery in Texas City killed 15 workers and injured 170 others because of violations of the process safety management standard, and in 2010, 29 coal miners died in a mine explosion at the Upper Big Branch Mine in West Virginia because inadequate ventilation allowed explosive dusts and gases to build in the mine.

While these cases illustrate the diversity of large-scale tragedies associated with industrial exposures, it is important to remember that many more workers are chronically exposed to hazardous chemicals that may be associated with health effects that may take years to develop.

Over the ensuing decades, multiple occupational and environmental health outbreaks have occurred in the United States and throughout the world. In the United States, the Occupational Safety and Health Act of 1970, which created both the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH), allowed for greater oversight and regulation of occupational exposures and furthered the field of occupational and environmental medicine in the United States. As a result of the contributions of both early and recent occupational health researchers and practitioners, the health and safety of workers has improved dramatically, especially in developed nations.

22.2 DEFINITION AND SCOPE

Industrial and commercial activities create a wide range of human health hazards in both the workplace and the general environment. In the workplace, exposure to machinery, toxic chemicals, physical agents (e.g., noise, heat, and radiation), and biological hazards result in illness and injury. Releases of toxic substances into ambient air and water have adverse environmental and human health effects. When manifesting as a well-defined human disorder, the adverse effect of an exposure to an occupational and environmental hazard is typically categorized as an *injury* or *illness*. An occupational injury is an adverse health event of nearly instantaneous onset resulting from a single, short-duration occupational exposure.[1] Examples include a burn experienced by a worker who has contact with steam escaping from a ruptured pipe

[1] Although nonoccupational injury (e.g., those resulting from automobile crashes) is an important public health problem in both developed and developing societies, it is typically studied and regulated separately from occupational injury.

TABLE 22.1 Examples of Organ System, Occupation or Setting, Specific Exposure, and Health Effects for Selected Occupational Diseases

Organ System	Occupation or Setting	Exposure	Disease
Respiratory	Shipyard, insulation installer/remover	Asbestos	Pulmonary fibrosis, lung cancer
	Foundry, sand casting	Silica	Pulmonary fibrosis, lung cancer
	Agriculture, farmer	Organic dusts	Hypersensitivity pneumonitis
	Painting and coatings	Toluene diisocyanate	Asthma
	Coal mining, coal dust	Coal dust	Coal workers' pneumoconiosis
Neurological	Automobile repair, mechanic	Organic solvents	Cognitive impairment
	Storage battery manufacturing	Lead	Kidney disease, neurological disease, anemia
	Construction, agriculture, others	Noise	Hearing loss
Dermatological	Healthcare workers, agricultural workers, others	Soaps, solvents, sensitizing agents, physical agents	Contact dermatitis, skin cancer
Hematological	Petroleum refining	Benzene	Anemia, leukemia
Kidney and bladder	Plating, battery manufacturing	Cadmium	Renal impairment
	Tanning and dying	Aniline dyes	Bladder cancer
Cardiovascular	Rayon manufacturing	Carbon disulfide	Atherosclerosis

and a broken leg experienced by a worker who falls from a roof. Of more interest to the study of toxicology, injuries from chemical exposures can also occur. Chemical injuries associated with short-term exposures typically require inhalation or dermal exposures to high concentrations of acutely hazardous chemicals. Examples include exposures to (i) airborne hydrogen sulfide, where a single exposure to concentrations above 700 mg/m^3 can cause rapid respiratory failure; (ii) dermal contact with phenol, which is rapidly absorbed through the skin and can result in irregular breathing, muscle weakness, and respiratory arrest; and (iii) skin contact with concentrated hydrofluoric acid, which causes both initial redness and pain and can result in hypocalcemia (low blood calcium) and death following contact with as little as 2.5% of the body's skin.

An occupational or environmental illness is an adverse health condition that occurs over some period of time after exposure to a hazardous agent. Examples of occupational and environmental illness include hearing loss among workers who experience prolonged exposure to noise, asthma (an obstructive lung disease) among workers with occupational exposure to the organic chemical toluene diisocyanate, and impaired cognitive function experienced by a child who ingests lead-based paint found in older housing. None of these illnesses occur immediately following the initial exposure.

Occupational illness can result from exposure to chemicals (e.g., pesticides from agricultural applications, solvents from printing operations, and metals from welding), minerals (e.g., asbestos from mining, silica from abrasive blasting, coal dust from mining), physical agents (e.g., vibration from construction equipment, radiation from radon intrusion), biological agents (e.g., hepatitis B from tattooing, tuberculosis from hospital patients, and human immunodeficiency virus from needlestick injuries), or psychosocial stressors (e.g., time and productivity demands from automated production lines). Some examples of the large variety of work-related diseases encountered by occupational medicine providers are provided in Table 22.1.

The goals of occupational and environmental health are to prevent, identify, and mitigate the adverse effects of occupational and environmental hazards among workers and exposed members of the public.

22.3 DATA SOURCES AND THE BURDEN OF OCCUPATIONAL AND ENVIRONMENTAL ILLNESS AND INJURY

Information on occupational injury and illness is available from several sources, each providing a partial characterization of the full impact of these conditions. The Bureau of Labor Statistics (BLS) of the U.S. Department of Labor is the primary federal entity responsible for collection of work-related illnesses and injuries statistics in the United States (www.bls.gov/). BLS occupational injury and illness information is obtained by compilation of injury and illness reports submitted by eligible employers as required by applicable U.S. OSHA law. There are limitations to these data, however. First, many employers are exempt from federal reporting requirements (e.g., farms with fewer than 11 employees and self-employed persons). Further, underreporting of injuries and illnesses by employers has been identified across many industrialized nations. Underreporting of occupational disease is common due to the chronicity and latency of many occupational diseases (discussed in the following text). In addition to the BLS, occupational illness and injury information can also be obtained from state and federal workers' compensation reports; however, substantial variability in compensation programs across states limits the utility of this information. As with BLS data, long latent interval diseases from occupational exposures may be neither recognized nor captured by worker's compensation systems.

The data that are collected can be analyzed by industry, exposure type, and reported adverse health effect. Ideally, this information is used for prevention efforts. For example, the OSHA recently issued an alert to workers in the salon industry to notify them of excessive levels of formaldehyde in professional hair care products (http://www.osha.gov/SLTC/formaldehyde/hazard_alert.html).

Despite limitations in its completeness, valuable information about the pattern and distribution of work-related injuries and illnesses can be obtained from BLS data. According to 2009 BLS data, 1,238,490 people experienced an injury or illness at work in private industry and state and local government agencies that required one or more days away from work. In private industry in 2009, 14,350 injuries and illnesses requiring time off from work were attributed to exposures to chemicals and chemical products. The breadth of illness and the extent of workers with these illnesses provide unique challenges to all occupational and environmental health specialists.

22.4 CHARACTERISTICS OF OCCUPATIONAL ILLNESS

Illness resulting from occupational and environmental exposures is often overlooked and underreported. This is unfortunate, since neither prevention nor effective treatment is possible unless the link between the exposure and the illness is recognized. A discussion of special characteristics of occupational and environmental illness is provided in the following text that, when understood, will assist in better recognition and prevention of these disorders.

The Biological, Clinical, and Pathological Characteristics of Occupational Illness Are Often Indistinguishable from Those of Illness of Nonoccupational Origin

Simply stated, the clinical and biological characteristics of a disease that results from occupational or environmental exposures are no different than those of the same illness resulting from other causes. Examples are numerous—lung cancer resulting from occupational exposure to asbestos is identical to lung cancer resulting from exposure to tobacco smoke or radon gas. Anemia from occupational exposure to lead may be identical to that resulting from iron deficiency or other diseases. Hearing loss caused by occupational exposure to noise is indistinguishable from hearing loss resulting from nonoccupational exposure to noise. Perhaps more than any other single fact, the similarity of occupational illness to nonoccupational illness makes it especially important to maintain a high level of vigilance (in medical terms, a high "index of suspicion") for occupational causes of common illness.

The Cause of Many Occupational Illnesses Is Multifactorial

Occupational and nonoccupational factors can act together in the causation of disease. For example, regular smokers of cigarettes have about a 10- to 15-fold increase in lung cancer risk. Persons with a history of occupational exposure to asbestos have about a fivefold increase in lung cancer risk. However, among persons exposed to both cigarettes smoke and asbestos, the risk of lung cancer is 50 or more times that of persons who have no exposure to either hazard. In this example, we see that the risks are not simply additive, but actually multiply by each other. Such synergy of the effect of multiple exposures has been well characterized for only a few combinations of exposure, but likely occurs often.

The Adverse Effects of Occupational Exposure May Begin after a Predictable Interval from Onset of Exposure

The adverse health effects of specific exposures may not be observed for many years after cessation of the exposure. The time period separating the onset of exposure to the clinical manifestation of illness is called a "latency period." For example, some persons exposed to airborne silica dust may not manifest scarring of the lung (i.e., silicosis) until more than a decade has passed (although it can occur both earlier and later than 10 years). Latency periods vary greatly across toxicants and illnesses. For example, organophosphate pesticide poisoning may occur within minutes or hours following exposure, whereas cancers resulting from occupational and environmental exposures (e.g., lung cancer from occupational exposure diesel exhaust) occur after a latency period of years to decades.

The Dose of a Toxicant Is an Important Predictor of Health Effects

As emphasized elsewhere in this book, the dose of a toxicant absorbed by an individual is a critical determinant of the resulting adverse health effects. For exposure–effect associations that are *stochastic* in nature (i.e., probabilistic), the dose is a primary determinant of the risk of disease. Stochastic dose–response relationships are observed for carcinogenic agents—as the dose of the carcinogen increases, the probability of developing cancer increases (however, the severity of the cancer itself is not a function of the dose).

Alternatively, for *deterministic* exposure–effect associations, the dose affects the severity of the disease. For example, the severity of the acute adverse effects of organophosphate pesticide exposure is highly dependent on the dose received. Virtually, all exposed persons, at sufficient doses, will exhibit well-characterized signs of toxicity.

People Vary Substantially in Their Responses to Occupational and Environmental Exposures

Considerable variability in both risk and severity of disease is observed among exposed persons even after dose has been considered. Such variability may be due to other environmental exposures in both work and nonwork settings (as noted earlier), individual characteristics (e.g., physical conditioning, nonoccupational health behaviors, and overall health status), and differences in genetic makeup across individuals. For example, workers who are exposed to a hepatotoxic agent such as carbon tetrachloride are at higher risk of liver toxicity if they are also regular consumers of ethyl alcohol, which is also known to be toxic to the liver.

22.5 THREE PREVENTION GOALS

In order to maintain the health and productivity of working people, occupational health providers are committed to three major prevention goals: (i) prevent hazardous exposures from occurring to minimize or eliminate the risk of occupational and environmental disease, (ii) identify early evidence of harm (i.e., preclinical disease) in order to prevent additional exposure and further harm, and (iii) diagnose and treat diseased individuals to prevent further health deterioration. Specific activities of occupational and environmental health professionals are described in the following text for each of these goals.

The first prevention goal is called *primary prevention*. Primary prevention is accomplished by lowering the risk of an occupational or environmental disease among healthy (i.e., disease-free) persons. To do so, occupational health professionals must recognize hazardous exposures and take steps to control them before resultant health consequences occur. Primary prevention in the workplace is often implemented by occupational health professionals specializing in *industrial hygiene*. Industrial hygienists are trained to anticipate, recognize, evaluate, and control exposures in the workplace to prevent sickness, impaired health and well-being, or significant discomfort among workers. For example, after recognizing hazardous airborne mercury concentrations in a work environment, industrial hygienists will identify and characterize the source of the vapor and work with engineers to find a safer substitute, change the facility ventilation, or otherwise contain the substance.

Industrial hygienists have prioritized exposure reduction approaches into a hierarchy of controls, described in Table 22.2. The most effective control measures focus on elimination or reduction of the hazard with methods that require no change to workers' behavior. Administrative controls, such as implementing work/rest cycles on hot days, require supervision reinforcement and workers' participation to minimize health risks. The final level of control, that is, use of personal protective equipment (e.g., respirator masks), relies on the worker to properly use and maintain protective equipment. While these are often effective to reduce exposures, they place the burden of protection on the worker and are usually considered the last line of defense for primary prevention. Primary prevention in occupational and environmental health may also be implemented by substituting less hazardous chemicals for ones in current use.

TABLE 22.2 Hierarchy of Control

Control Option	Description
Primary control: engineering	
Elimination	Eliminate the hazardous chemical use or overall process
Substitution	Replace the hazardous chemical with a less toxic chemical
Isolation	Enclose the process/locate process in unoccupied areas
Automation	Use automated equipment to transfer chemicals; use robotic equipment to perform worker activities
Ventilation	Increase general air movement in occupied spaces; provide localized ventilation where hazardous chemicals are generated
Secondary control: administrative	
Job rotation/supervision	Minimize the duration of exposure by rotating workers throughout the shift; supervision is critical to minimize chronic exposures
Tertiary control: personal protective equipment	
Respiratory protection	Provide certified respirators approved for the hazard of concern (must comply with regulatory standards)
Chemical protective clothing	Provide chemical-resistant clothing to prevent contact with hazardous chemicals (must select materials based on resistance to chemical(s) in use)

For example, over the past several decades, safer water-based latex paints have been used as a substitute for more hazardous solvent-based paints in residential and commercial building construction. This trend has substantially decreased exposure to organic solvents among construction painters. Substitution does not always eliminate health hazards of a particular industrial sector, however, as the new chemical may introduce unexpected hazards. For example, the commercial dry cleaning industry has focused on replacing perchloroethylene, a chemical hazardous to the nervous system and suspected of being cancer-causing agent, with 1-bromopropane (1-BP). However, workers handling the new chemical also exhibited neurological effects, including light-headedness and loss of sensation in the arms and legs (peripheral neuropathy). NIOSH investigations identified that exposures to 1-BP exceeded recommended exposure limits and recommended additional ventilation to reduce worker exposure. While the hazards of the substituted chemical, 1-BP, were well documented, sometimes, chemicals with ingredients of unknown toxicity are substituted for chemicals with known toxicity. In these cases, industrial hygienists must work with toxicologists to perform hazard assessments with appropriate analogous chemicals to anticipate hazards of substitution chemicals.

Sometimes, to minimize exposure, substitution or other exposure reduction controls are not feasible, and administrative changes are recommended, instead. For example, workers who are exposed to repetitive movements of their wrists and hands for 8 h per day may be instructed to rotate to other jobs to reduce the workers' risks of musculoskeletal conditions. It is important to recognize that such efforts are generally not as effective as reducing or eliminating exposure at the source. Finally, if exposure is not well controlled by engineering or administrative controls, personal protective equipment (e.g., respirators, gloves, earplugs) is often used. It is important to remember that personal protective equipment is rarely as effective as substitution of less toxic products or engineering approaches.

The next goal of occupational health practice is *secondary prevention*. Secondary prevention is implemented by screening for subtle disease states or for deviation from health early in its evolution, prior to overt clinical manifestation of illness (i.e., "early detection"). Early detection allows for the control of exposure or treatment of the health condition before more serious illness occurs. An example of secondary prevention is the monitoring of nickel–cadmium battery-manufacturing workers for evidence of the adverse effects of cadmium exposure on the kidney. When cadmium exposures are confirmed or suspected, biological measures of (i) cadmium absorption (i.e., cadmium concentration in the blood and urine) and (ii) early adverse effects of cadmium on the kidney (i.e., measurement of the protein beta-2 microglobulin in the urine) are often performed. Workers experiencing subtle adverse renal effects of cadmium exposure have elevated concentrations of beta-2 microglobulin in their urine despite the fact that no disease has yet occurred. These elevated concentrations indicate the need for removal of the worker from cadmium exposure to prevent the development of more advanced renal disease [29 CFR 1910.1027(L)(3)]. Another example of secondary prevention is provided in the OSHA lead standard [29 CFR 1910.1025]. The standard requires a medical surveillance program for all employees who are, or may be, exposed to lead at levels higher than the OSHA-designated action level for more than 30 days per year. As part of the program, medical examinations, blood lead levels, and laboratory tests of blood and urine are monitored. If the blood lead levels are elevated, then the medical surveillance program guides the healthcare provider on the appropriate action to be taken with the worker (i.e., removal from the environment until the worker's blood lead level decreases).

The third prevention goal of occupational health practice is *tertiary prevention*. Tertiary prevention is the diagnosis, treatment, and rehabilitation of a clinically overt occupational or environmental disease process with the goal of limiting the severity of the condition or its long-term consequences. An example of this would be recognition of occupational asthma and the subsequent treatment of the worker to prevent excessive inflammation and scarring of the air passages in the lungs.

22.6 ACTIVITIES OF OCCUPATIONAL AND ENVIRONMENTAL HEALTH PROVIDERS

Occupational and environmental health is a multidisciplinary field and is served by a wide range of health professionals. Each provider has specific educational requirements and professional certification, and typically, no one provider is sufficiently skilled to implement all of the components of a successful occupational and environmental health program. The major professional disciplines in occupational health are described in the following text, along with specific roles in illness prevention.

Occupational Medicine Physician

Occupational medicine physicians provide medical services to workers by providing routine examinations, performing medical surveillance testing, and evaluating and treating occupational illness and injury. These physicians are certified by the American Board of Preventive Medicine, and many have completed occupational medicine residencies, obtaining master's degrees in public health. Occupational medicine physicians work in multiple settings. In the past, many worked in large industrial facilities and were employed by a single company. More recently, they are likely to be a partner in an independent occupational medical practice that provides occupational medicine services under contract to many companies.

Occupational medicine physicians provide both routine scheduled clinical services (i.e., preplacement examinations given before the start of work and medical surveillance examinations given periodically to workers with potentially hazardous exposures) and care for unplanned or unexpected injury and illness. Preplacement examinations are often given to workers who are going to work in high-noise areas (audiometric testing), who are required to wear respiratory protection (pulmonary function testing), and who perform emergency response activities. Employers in the United States are also authorized to engage in preplacement examination of other health parameters, such as physical strength. However, employers are limited in their use of this information by laws that protect against discrimination of disabled persons. Overall, the purposes of the preplacement examination include (i) assessment of whether the employee is physically able to perform all essential functions of the job, (ii) evaluation of the potential for an employee's health to put others at risk of harm, and (iii) assessment of the potential for an employee's health to put himself/herself at risk of harm as a result of specific exposures and conditions expected on the job.

Medical surveillance examinations given periodically to workers with potentially hazardous exposures are a critical component of *secondary prevention*. The OSHA specifies minimum medical surveillance examination requirement in numerous chemical-specific standards (e.g., 29CFR1910.1001–1096), hazardous waste operator standard (29CFR 1910.120), and respiratory protection standards (e.g., 29CFR1910.134). For example, on an annual basis, employers in the United States must provide workers routinely exposed to asbestos with an opportunity to be evaluated by a medical provider. As part of this evaluation, the employee will be asked questions about his or her breathing as well as be offered a physical examination. The worker will be evaluated with pulmonary function tests (using *spirometry*) to provide information about lung function and a chest X-ray to reveal early changes associated with asbestos exposure. These tests are performed on a regular basis so that those workers who are exhibiting early signs of disease can be removed from exposure. There are many substances and hazards for which the OSHA has mandated medical surveillance standards. Examples of these standards include monitoring for health effects of arsenic, asbestos, benzene, cadmium, lead, vinyl chloride, and noise exposures. Each agent has different requirements for physical examination and laboratory testing, and the occupational health provider should be knowledgeable of the specific details of them.

Occupational medicine physicians have a central role in *tertiary prevention* by diagnosing and treating occupational injuries and illnesses. Examples include medical providers suturing a laceration of the skin caused by contact with a cutting tool or diagnosing and treating asthma in a patient who complains of intermittent cough and shortness of breath while at work. After making a diagnosis and offering treatment, the provider typically also recommends work restrictions (i.e., limitations to specific occupational activities or exposures) to limit future harm.

Occupational medicine physicians may also be called upon to offer an opinion whether an individual worker's disease was caused by a specific occupational exposure. Often, these cases are linked to monetary settlements, either through the workers' compensation system or during a liability lawsuit. Occupational and environmental medicine providers who participate in these evaluations must have extensive knowledge of the patient's work and exposure history, medical history, and current health status. In addition, they must have knowledge of the medical literature supporting or refuting a linkage between the exposure and disease outcome. These cases are often complex and intellectually challenging.

Finally, occupational physicians perform the important role of providing education to workers. One-on-one education about health hazards, exposure risks, and the risk of illness from work-related and nonwork-related exposures is essential to each interaction with a worker.

Occupational Health Nursing

Occupational health nurses (OHNs) provide health and safety programs and services to workers, worker populations, and community groups. The practice focuses on prevention of occupational illness and injury and protection from work-related and environmental hazards. In addition, OHNs often engage in wellness and health promotion activities. They do so by engaging in the three levels of prevention described earlier. The services that OHNs provide include (i) initial clinical treatment of occupational injury or illness; (ii) case management, that is, the process of coordinating and providing oversight of all aspects of treatment and rehabilitation of individuals with occupational illness or injury; (iii) health promotion, which includes counseling or referral of workers to manage behavioral (e.g., smoking) or modifiable conditions (e.g., high blood pressure) that increase risk for adverse health outcomes; (iv) hazard detection and mitigation, often in collaboration with an industrial hygienist or a safety specialist; and (v) legal and regulatory compliance with multiple laws and regulations affecting employment and the work environment. Nurses can become a certified OHN through the American Board for Occupational Health Nurses. Currently, the United States has 12,000 OHNs.

Industrial Hygiene

As discussed previously, industrial hygienists are integral to the *primary prevention* of exposure-related disease in the workplace. Industrial hygienists are familiar with industrial processes, tools, and equipment and have the skills necessary to evaluate, quantify, and mitigate hazardous exposure. Industrial hygienists apply knowledge in basic sciences (e.g., chemistry, physics, biology, and toxicology) to conditions in workplaces to monitor, assess, and control exposures that may cause worker injuries and illnesses.

Industrial hygienists specialize in techniques to monitor worker exposures to chemical and physical agent hazards (e.g., noise, heat, and radiation) and to interpret these results to determine the risk of illness. Risk evaluations are conducted to determine whether exposures are sufficiently below regulatory limits and consensus standards. To assess compliance with state or federal OSHA standards, exposure measurements are compared to OSHA permissible exposure limits (PELs), found in 29CFR1910.1000 (for general industry, commonly referred to as the "Z-tables") as well as chemical-specific standards (29CFR1910.1001 through 1096). The PELs in the Z-tables were established at the inception of the OSHA in 1972, whereas chemical-specific standards have been introduced and updated over time. Because they are updated more frequently, industrial hygienists more commonly assess exposure risks provided in consensus guidelines, which are not legally enforceable by the OSHA but are based on more recent toxicological and epidemiological data. These include the NIOSH recommended exposure levels (RELs) and the American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values (TLVs™). The ACGIH TLVs are routinely reviewed and establish maximum concentrations that "nearly all workers" may be exposed to repeatedly, throughout a working lifetime, without adverse effect. The NIOSH, the agency responsible for recommending standards to OSHA and the Mine Safety and Health Administration (MSHA), develops RELs based on determinations of health risks from human or animal data and on assessments of levels that can be feasibly achievable. Previous to 1995, feasibility was not included in NIOSH RELs, but current updates must consider whether engineering controls can achieve these levels and whether analytical techniques are available to assess exposures below an established REL.

For example, a work site using acetone has to legally comply with the OSHA PEL of 1000 ppm (from the Z-tables). However, this value was based on the 1968 ACGIH TLV, which has been updated over the decades and now is set to 500 ppm to prevent adverse neurological effects. But the NIOSH has also established an 8 h REL for acetone at 250 ppm. Simply complying with an OSHA PEL from the Z-tables will *not* protect the health of the workforce, so an internal occupational exposure limit that sets the maximum exposure to all possible exposures at a workplace is often established. A good industrial hygienist evaluates the documentation that was used to generate the associated exposure limit to determine which exposure limit is most appropriate to protect workers' health. In many cases, there may be exposures or health effects associated with compounds for which there is no published exposure limit, and the hygienist must develop internal recommendations based on toxicological principles.

In addition to evaluating workplace exposures to hazardous chemicals and physical agents, industrial hygienists select, fit, and evaluate the performance of chemical protective clothing and respiratory protection. They are also skilled in evaluating the performance of and recommend changes to engineering control systems to remove contaminants where they are generated (local exhaust ventilation) or improve mixing and airflow in large work areas do dilute less hazardous contaminants in the workplace (general ventilation). Hygienists also develop and deliver chemical-specific hazard communication training, assist with preplanning emergency response teams, and work closely with occupational medicine physicians and OHNs.

After specialized education and work experience, these occupational health professionals can become a certified industrial hygienist (CIH) through the American Board of Industrial Hygiene (ABIH) or, in Canada, registered occupational hygienist (ROH) through the Canadian Registration Board of Occupational Hygienists. Currently, there are nearly 8000 CIHs worldwide.

Ergonomists

Ergonomics is the study of the relationship between the physical demands of work and the ability of the worker to meet those demands over time. Ergonomists examine the interaction of the physical workplace with the human body. Specifically, ergonomists evaluate and quantify the physical demands of the job, based on human performance needs for specific work tasks and the tools and equipment in use for completing that task. They work to design equipment, products, facilities, devices, tasks, and systems to minimize injuries and illnesses of the musculoskeletal system. The goal of ergonomics is often stated as "fitting the job to the worker rather than the fitting the worker to the job." Ergonomists are often asked to guide employers who want to control physical hazards for low back pain and upper limb disorders (such as rotator cuff tendonitis and carpal tunnel syndrome). To reduce the risk of low back pain, ergonomists design work with less frequent and forceful lifting, bending, twisting, and whole-body vibration (e.g., as experienced by truck drivers) experienced by workers. To reduce risk for upper extremity disorders, ergonomists design work processes with lower forces and frequencies of repeated upper limb motions and by arranging workstations and tools so that joints are not used at the extremes of their ranges of motion. Professional certification for ergonomists (CPE) is awarded through the Board of Certification in Professional Ergonomics in the United States and the Canadian College for the Certification of Professional Ergonomists (CCCPE) in Canada. There are currently 1500 certified ergonomists.

Other Specialists

Most manufacturing locations have a designated safety manager who administers many aspects of workers' health and safety. While they typically rely on industrial hygienists to focus on assessing health risks from exposures, such safety specialists are integral to educating workers on many health hazards and organizing ongoing health and safety initiatives with workers. Approximately 11,000 certified safety specialists (through the Board of Certified Safety Professionals) are employed in the United States.

Other specialists involved in occupational health include toxicologists, engineers (industrial and environmental), epidemiologists, and health physicists (radiation hazard specialists). These specialists are routinely consulted to provide technical expertise to previously described occupational health practitioners and are integral to successfully understanding health risks to workers and the general public.

Many occupational health technicians are also integrated into successful occupational health programs. The NIOSH provides approval for spirometry training courses, recommended for pulmonary function testers who are not licensed health professionals. The Council for Accreditation in Occupational Hearing Conservation (CAOHC) provides certification for audiology technicians to perform standard hearing testing (under the supervision of a professional audiologist supervisor). These technicians, among others, are useful to performing frequent, standard tests that are often required by occupational health regulations.

22.7 THE MULTIDISCIPLINARY APPROACH TO WORKERS' HEALTH

As illustrated in the previous section, the skills required to successfully protect workers' health require a team of experts with distinct skills who work together to maximize the health of the working people. It is rare that a full complement of providers is hosted at a given work site. The resources available at a given work site vary, typically depending on the size of a given work organization and the type of hazards that are present (Table 22.3). At a small facility, much of the day-to-day occupational health activities may be performed by a safety manger (with or without a CSP) or, in some cases, a human resources manager. At larger facilities, the safety manager is usually certified and the plant may employ an OHN: this team is typically responsible for managing injury/illness cases as well as proactive aspects of health and safety programs. For large national or multinational companies, there may be a corporate safety and health department and a corporate medical director: these groups establish internal company policies (such as which exposure limits to adopt and company-specific medical evaluation tests). Members of the corporate health staff often travel to multiple manufacturing sites to provide training, measurements, and interpretation of cases to assist local occupational health staff.

In recent times, a majority of manufacturing locations contract many occupational health services, including occupational health physician services, audiology, ergonomics, and industrial hygiene monitoring. For successful occupational health programs, it is critical for contracted services to be aware of specific hazards their clients' workplaces. For example, a physician needs to have a specific description of work duties, required personal protective equipment, and environmental hazards to determine whether an injured/ill worker can return to a particular job. A contracted audiologist must include noise exposure data on their hearing test reports to assess work-related hearing loss. An ergonomist must understand where musculoskeletal injuries are most common to determine where to focus an investigation and then must understand how workers interact with tools, equipment, and product to assess risk and recommend interventions. In short, occupational health professionals,

TABLE 22.3 Examples of Occupational Health Staff Structure By Facility Size and Risk

Size	Nature of OEH[a] Risks	On-Site Personnel	Corporate Assistance	Contracted Services
Small	Minimal chemical/noise hazards	Safety manager/human resources	None	IH monitoring, medical, nursing
	Chemical/noise	Safety professional, human resources	Access to corporate IH, safety	IH monitoring, medical, nursing, audiology
Medium	Minimal chemical/noise hazards	Safety professional	Access to corporate IH, safety	IH monitoring, medical, nursing
	Chemical/noise	Safety professional, nurse	Corporate IH, safety, medical	IH monitoring, medical, nursing, audiology
Large	Minimal chemical/noise hazards	Safety professional	Access to corporate IH, safety	IH monitoring, medical, nursing, audiology
	Chemical/Noise	Industrial hygienist Safety professional Nurse	Access to corporate IH, safety, medical	Medical

[a]OEH, occupational and environmental health.

whether contracted or employed at the facility, must work as a team to fully characterize health hazards and to prevent worker illnesses and injuries that may result from them.

Even with the diversity in occupational and environmental professional staffing at manufacturing locations, a common set of tasks are needed to protect worker heath. Specifically, the staff must identify and assess physical, chemical, and ergonomic hazards; quantify exposures and estimate risk based on exposure quantification; evaluate and recommend appropriate controls; and evaluate workers' health status. Figure 22.1 provides a generic template for understanding a general process for completing each of these tasks, illustrating the interrelatedness of the health paradigm. Tables 22.4 and 22.5 illustrate how each of the occupational health professionals may contribute to completing these tasks for two specific hazards that may be identified at a facility, i.e., chemical and lifting exposures, respectively. These tables highlight the interdisciplinary nature of occupational health protective services and how the resulting analysis from each professional is needed to complete a comprehensive risk assessment to ensure adequate health protection.

22.8 LEGAL AND REGULATORY ISSUES PERTINENT TO OCCUPATIONAL AND ENVIRONMENTAL HEALTH

The two U.S. federal agencies of the United States primarily responsible for the health and safety of workers are the OSHA, a unit of the of the U.S. Department of Labor, and the NIOSH, a component of the Centers for Disease Control and Prevention (of the Department of Health and Human Services). Both organizations were created by passage of the Occupational Safety and Health Act of 1970. The OSHA's mission is to "ensure safe and healthful working conditions for working men and women by setting and enforcing standards and by providing training, outreach, education and assistance." The OSHA is empowered to establish legally binding upper limits for exposure to occupational hazards (PELs) and to enforce such standards through on-site workplace inspections. If violations are noted, OSHA is empowered to fine the employer an amount based on severity of the violation. The NIOSH assists the OSHA by (i) providing the agency with scientific research on the human health effects of workplace exposures and (ii) making

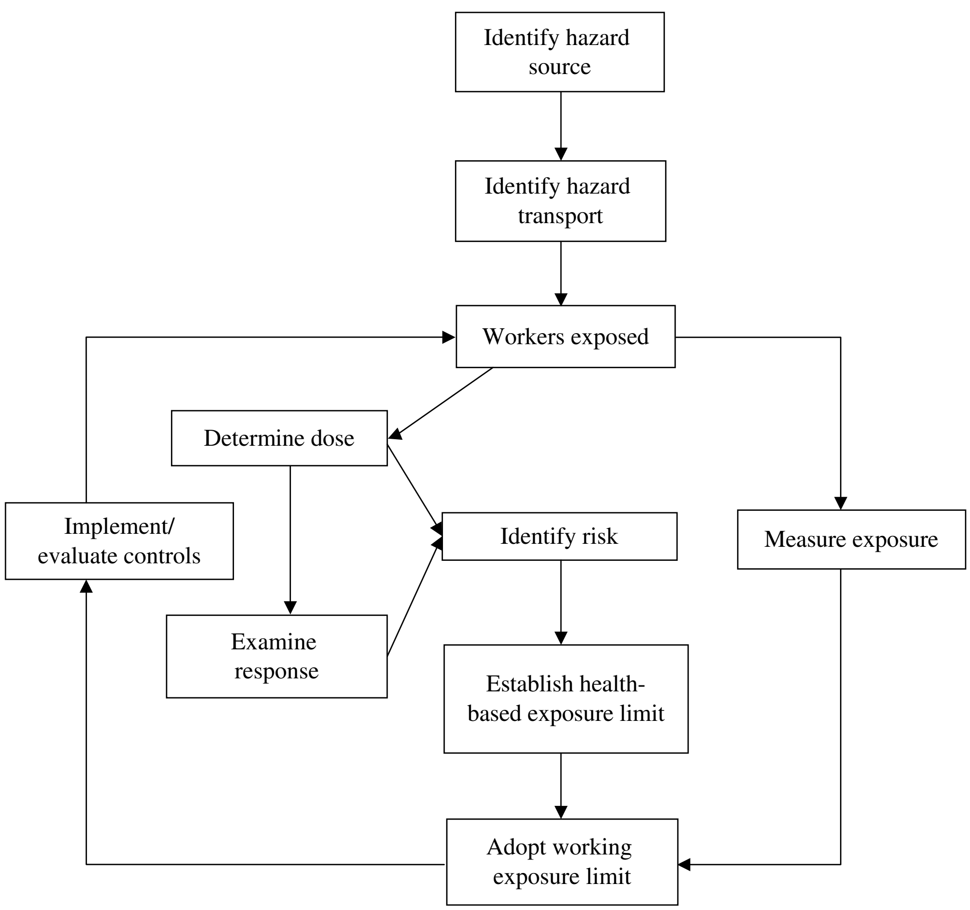

FIGURE 22.1 Process for assessing occupational health hazards and risks.

TABLE 22.4 Evaluation of Health Risk from Dust Exposure

Step	Possible Task	OH Professional	Collaborators/Comments
Identify hazard source	Identify composition, size, and source of dust	Industrial hygiene/safety professional	Engineering/production manager
Identify hazard transport	Determine how far dust transports	Industrial hygiene	—
Workers exposed	Identify workers and group by relative exposure	Industrial hygiene/safety professional/nurse	Human resources/area supervisor
Determine dose	Determine inhaled dose and monitor exposures	Industrial hygiene	—
Examine response	Examine literature and use medical diagnostics	Industrial hygiene/nurse/ physician	Consult toxicologist if literature is lacking
Identify risk	Identify health risks for range of exposures studied in dose/ response	Industrial hygiene	Toxicologist, epidemiologist, physician
Establish health-based exposure limit	Incorporate dose–response data with available exposure limits and documentation	Industrial hygiene	Engineering—feasibility input review by physician
Adopt working exposure limit	Finalize facility-specific exposure limit for this source	Industrial hygiene	Management needed to accept
Implement/evaluate controls	Improve ventilation system	Industrial hygiene/safety	Engineering/facilities
	Institute respiratory protection (RP) program		Physician/nurse—health evaluation for fitness to wear RP
Continued exposure assessment	Scheduled monitoring of exposure and workers' health	Industrial hygiene/safety physician/nurse	Annually if RP is required

TABLE 22.5 Evaluation of Health Risk from Lifting Task

Step	Task	Primary OH Professional	Additional Collaborators
Identify hazard source	Identify at-risk lifting tasks	Safety/IH/nurse	Ergonomist
Identify hazard transport	Identify additional full-shift lifting tasks	Safety/IH/nurse	Area supervisor
Workers exposed	Identify workers and groups by relative exposure	Safety/IH/nurse	Area supervisor
Determine dose	Determine exposure forces and patterns	Ergonomist	Nurse
Examine response	Evaluate MSD cases in exposed group	Nurse/physician	Ergonomist
Identify risk	Identify health risks for range of exposures studied in dose/response	Ergonomist	
Establish health-based exposure limit	Recommend maximum lift/exposure duration	Ergonomist	Safety
Adopt working exposure limit	Finalize facility-specific lift/exposure duration	Safety manager	Nurse
Implement/evaluate controls	Reengineer the job or work schedule to reduce exposures	Ergonomist, safety manager	Engineering, area supervisor, affected workers
Continued exposure assessment	Review ongoing implementation of work practice/job rotation effectiveness	Safety, nurse	

recommendations for exposure limits to OSHA. The NIOSH is also required to support the education and training of occupational health professionals and to fund research by academic investigators.

The U.S. Environmental Protection Agency (EPA) was created to protect human health and the environment by developing and enforcing environmental regulations. When Congress created the EPA in 1970, it also passed the Clean Air Act. This was followed in 1972 by the Clean Water Act, which was created to prevent pollution of the nation's surface waters. Other major environmental regulations followed, including the Toxic Substances Control Act (TSCA) in 1976, the Resource Conservation and Recovery Act (RCRA) of 1976, and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 (more commonly known as the *Superfund*). The latter two of these acts focus on the tracking and management of hazardous waste materials. The TSCA also gives the EPA the authority to require a manufacturer/importer of new chemicals to the United States to (i) submit a premanufacture notice that triggers the EPA's Office of Pollution Prevention and Toxics to perform a risk assessment for the new chemical and (ii) requires the manufacturer to protect employees below a new chemical exposure limit (NCEL) that is specified by the EPA from the risk assessment. The EPA also has regulatory authority to provide guidelines on indoor air quality, with regional experts available to provide guidance on radon, mold and moisture, and general indoor air quality concerns.

22.9 ETHICAL CONSIDERATIONS FOR THE OCCUPATIONAL AND ENVIRONMENTAL HEALTH PROFESSIONAL

Occupational and environmental health providers, regardless of discipline, have at least one professional organization dedicated to supporting their continued education and certification. Because of the potential for conflicts of interest and ambiguity of obligation, each of these professional organizations has a code of ethics that specify the scope of work and ethical behavior to which members must adhere. While specific details for each professional organization are provided, it is important to note that there are some common elements to each of these professional codes. Specifically, each requires professionals act to protect worker confidentiality, provide services within one's scope of expertise, represent all facts relevant to health and safety, and engage in ongoing professional development and education. Because occupational health providers often "serve two masters" (the workers they protect and the company that employs them), published codes of ethics provide an important framework for promoting professional practices that benefit those at risk of harm from hazardous exposures, even if not encouraged to do so by employers. Details are included in each of the discussions that follow.

Occupational Medicine

Just as with other fields of healthcare, ethical principles have been developed to guide occupational and environmental health providers. The first ethical principle is *confidentiality*. This principle is a cornerstone of the physician–patient relationship upheld throughout all fields of medicine. It is, however, particularly challenging in the field of occupational and environmental medicine. Confidentiality applies to both the written and verbal release of protected health information. In the United States, the *Health Insurance Portability and Accountability Act* (HIPAA) establishes the conditions under which healthcare providers may share a patient's protected health information. As such, medical records need to be maintained in a protected manner, and the sharing of patients' protected health information, in general, can only occur if the patient provides written consent to release the information. Confidentiality is not absolute, however. In certain legal settings, for example, a request for workers' compensation benefits, the employer and legal agencies involved in the adjudication of the claim have the right to access the employee's health information, *with regard to the claim*. In working with employers and workers' compensation insurance companies, occupational medicine providers are required to inform the workers that health information collected during the examination is not confidential and will be released to the employer and other third parties in order to process the claim.

In some cases, the duty to maintain confidentiality may conflict with other ethical duties, in particular, those of *nonmaleficence* and *beneficence*. Nonmaleficence is best thought of as the ancient requirement for healthcare providers to "do no harm." Beneficence goes beyond this requirement and obliges professionals to use their authority to be of benefit to patients and others. If, for example, during a physician–patient interaction, it becomes clear that other workers may also be at risk of adverse health effects by the same exposure that caused the patient to seek medical attention, the physician may have an ethical (and sometimes legal) responsibility to report this to third parties such as employers or public health departments. In these cases, the duty to protect the confidentiality of the patient may be in conflict with the need to protect the health of other exposed workers. Legal obligations may also be relevant in such situations. When ethical obligations are in conflict, it is critical for the practitioner to carefully examine the consequences of each possible action and to act in the manner that is most protective of the health of the public and most respectful of the rights of patients and workers.

Although it may seem obvious, an occupational medicine physician must always inform patients about their medical conditions, including discussions with the patient on the diagnostic and treatment options. This is also no different than any other physician–patient interaction. Given the setting, however, the provider also needs to disclose to patients therapeutic recommendations that may include relocation or job modification to avoid continued reexposure to certain hazardous environments.

The American College of Occupational and Environmental Medicine (ACOEM), the professional organization for occupational and environmental providers, has a code of ethical conduct to guide practitioners in the field (ACOEM 2012).

Occupational Health Nursing

The American Association of Occupational Health Nurses (AAOHN) has a code of ethics for OHNs. The code requires that OHNs provide health, wellness, safety, and other related services to clients with regard for human dignity and rights, unrestricted by consideration of social or economic status, personal attributes, or the nature of the health status. In addition, the AAOHN, like the ACOEM standard described earlier, requires the protection of confidential information and authorizes release only as "required or permitted by law." OHNs are also required to maintain competence and accept responsibility for professional judgment and actions.

Industrial Hygiene

The ABIH established the code of ethics for CIHs. This code requires that hygienists maintain high standards of integrity and professional conduct, accept responsibility for their actions, and continually seek to enhance their professional capabilities. Specific responsibilities to clients, employers, employees, and the public are also defined. First and foremost, the code requires that industrial hygiene services be delivered with objective and independent professional judgment. Because of the diverse nature of expertise in the comprehensive industrial hygiene field, professionals are required to recognize their limitations and only provide services for which they are qualified.

Industrial hygienists are required to maintain and respect confidentiality of sensitive information, as are other occupational health professionals. However, the industrial hygiene code of ethics clearly defines the obligation of CIHs to release information if directed to by the courts or government agency or if failure to release the information would likely result in death or serious physical harm to employees or the public.

Additional ethical obligations require the hygienist to properly use credentials, to only use the CIH designation for work that is under his/her control, to provide truthful and accurate presentations in public statements, and to recognize the intellectual property rights of others. The ABIH frequently revises its code of ethics and announces changes to their membership. The full code of ethics is available at the ABIH website.

Ergonomists

The CCCPE code of ethics outlines professional responsibilities of confidentiality, recordkeeping, integrity, and impartiality. Specific concepts of integrity are outlined, including disclosing conflicts of interest; adequately representing facts and expressing opinions, with clear distinction; informing clients of limitations in his own qualifications and in the work product or services provided; and immediately informing the client of any error that may have been made. Similar to the industrial hygiene code, an ergonomist may not claim skills beyond his capability and is obligated to act in the interest of the client.

22.10 SUMMARY AND CONCLUSION

Despite regulations and recommended standards put in place to protect workers' health, serious hazards continue to exist in occupational settings. Identifying hazards in the work environment requires the expertise of many occupational and environmental health providers and is most efficient and effective when these professionals work as a team. While occupational hazards change over time and new hazards emerge with the development of new technologies and production techniques, the methods applied to assessing and controlling hazards to evaluating and treating affected workers are universal. The dedication and commitment of occupational health practitioners, relying on scientific data for determining risk and making evidence-based interpretations, are essential to the protection of workers' health.

The main points of this chapter are:

- Occupational injuries and illnesses are extremely common and include a wide spectrum of conditions.
- The historical foundations of occupational and environmental health date back to the 1700s and have been shaped by ongoing advances in technology and industry.
- The three overarching goals of occupational and environmental health are primary (prevent exposure), secondary (prevent disease development), and tertiary (prevent disease from progressing) prevention of injury and illness.
- Occupational diseases are often indistinguishable from nonoccupational disease and are multifactorial in nature.
- Occupational health providers perform many activities including diagnosis and treatment of disease, evaluation of fitness for duty, assessment of causality, medical surveillance, and education of workers and employers.
- The occupational health field is composed of practitioners from many disciplines who work together to optimize the health and safety of workers.
- Practitioners in occupational and environmental health must adhere to a widely accepted code of ethics.

ACKNOWLEDGMENT

The authors are grateful to Drs Howard Frumkin and Edward Galaid for their contribution to the chapter on this topic in the previous edition of this book.

SUGGESTED READING

Abrams HK. A short history of occupational health. J Public Health Policy 2001;22(1):34–80.

American Association of Occupational Health Nurses. 2009. Code of Ethics and Interpretive Statements. Available at http://www.aaohn.org/membership/membership-marketplace/code-of-ethics-and-interpretive-statements-details.html. Accessed July 11, 2014.

American College of Occupational and Environmental Medicine. 2001. Careers in Occupational and Environmental Medicine. Available at http://www.acoem.org/Page2Column.aspx?PageID=7392&id=992. Accessed March 13, 2011.

American College of Occupational and Environmental Medicine. 2011. ACOEM Code of Ethics. Available at http://www.acoem.org/codeofconduct.aspx. Accessed July 11, 2014.

American Industrial Hygiene Association. 2007. Joint Industrial Hygiene Associations Member Ethical Principles. Available at https://www.acgih.org/Member_Ethical_Principles.pdf. Accessed July 11, 2014.

Blanc P. Occupational and environmental medicine: the historical perspective. In: Rosenstock L, Cullen MR, Brodkin CA, Redlich CA, editors. *Textbook of Clinical Occupational and Environmental Medicine*. 2nd ed. Philadelphia: Elsevier Saunders; 2005.

Brodkin CA, Rosenstock L. Asbestosis and asbestos-related pleural disease. In: Rosenstock L, Cullen MR, Brodkin CA, Redlich CA, editors. *Textbook of Clinical Occupational and Environmental Medicine*. 2nd ed. Philadelphia: Elsevier Saunders. 2005

Canadian Centre for Occupational Health and Safety. 2006. Hazard Control. OSHA Answers. Available at http://www.ccohs.ca/oshanswers/hsprograms/hazard_control.html. Accessed August 7, 2014.

Centers for Disease Control and Prevention (CDC) 2011. The National Institute of Occupational Safety and Health (NIOSH). Available at http://www.cdc.gov/niosh/about.html. Accessed April 15, 2011.

Cullen MR, Rosenstock L. Approach to the patient. In: Rosenstock L, Cullen MR, Brodkin CA, Redlich CA, editors. *Textbook of Clinical Occupational and Environmental Medicine*. 2nd ed. Philadelphia: Elsevier Saunders; 2005a.

Cullen MR, Rosenstock L. Social issues in the practice of occupational and environmental medicine. In: Rosenstock L, Cullen MR, Brodkin CA, Redlich CA, editors. *Textbook of Clinical Occupational and Environmental Medicine*. 2nd ed. Philadelphia: Elsevier Saunders; 2005b.

Cullen MR, Rosenstock L, Kilbourne EM. Introduction to occupational and environmental medicine. In: Rosenstock L, Cullen MR, Brodkin CA, Redlich CA, editors. *Textbook of Clinical Occupational and Environmental Medicine*. 2nd ed. Philadelphia: Elsevier Saunders; 2005.

Franco G. Ramazzini and Worker's Health. Lancet 1999;354; 858–861.

Hamilton A. Lead poisoning in the United States. Am J Public Health 1914;4:477–480.

Hammond EC, Selikoff IJ, Seidman H. Asbestos exposure, cigarette smoking and death rates. Ann N Y Acad Sci 1979;330: 473–490.

Herzstein J. Susceptible populations. In: Rosenstock L, Cullen MR, Brodkin CA, Redlich CA, editors. *Textbook of Clinical Occupational and Environmental Medicine*. 2nd ed. Philadelphia: Elsevier Saunders; 2005.

Keyserling W. Monroe Occupational ergonomics: promoting safety and health through work designs. In: Levy BS, Wegman DH, Baron SL, Sokas RK, editors. *Occupational and Environmental Health: Recognizing and Preventing Disease and Injury*. 5th ed. Philadelphia: Lippincott Williams & Wilkins; 2006.

Levy BS, Wegman DH, Baron SL, Sokas RK. Occupational and environmental health: an overview. In: Levy BS, Wegman DH, Baron SL, Sokas RK, editors. *Occupational and Environmental Health: Recognizing and Preventing Disease and Injury*. 5th ed. Philadelphia: Lippincott Williams & Wilkins; 2006.

Lukes E. The nursing process and program planning. AAOHN J 2010;58(1):5–7.

Occupational Safety and Health Administration. About OSHA. Available at http://www.osha.gov/about.html. Accessed April 15, 2011.

Occupational Safety and Health Administration (OSHA). OSHA Lead Standard. Available at http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10030. Accessed April 11, 2011.

Occupational Safety and Health Administration. Substance Safety Data Sheet. Available at http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=10036&p_table=STANDARDS. Accessed January 15, 2012.

Parker JE. The occupational and environmental history and examination. In: Rom W, editor. *Environmental and Occupational Medicine*. 4th ed. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins; 2007.

Rom WN. The discipline of environmental and occupational medicine. In: Rom W, editor. *Environmental and Occupational Medicine*, 4th ed. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins; 2007.

Silverstein B, Watters MT. Regulations in practice: assessing and enforcing compliance with health and safety regulations. In: Levy BS, Wegman DH, Baron SL, Sokas RK, editors. *Occupational and Environmental Health: Recognizing and Preventing Disease and Injury*. 5th ed. Philadelphia: Lippincott Williams & Wilkins; 2006.

Smith TJ, Schneider T. Occupational and environmental hygiene. In: Levy BS, Wegman DH, Baron SL, Sokas RK, editors. *Occupational and Environmental Health: Recognizing and Preventing Disease and Injury*. 5th ed. Philadelphia: Lippincott Williams & Wilkins; 2006.

Tarlo SM, Chan-Yeung M. Occupational asthma. In: Rosenstock L, Cullen MR, Brodkin CA, Redlich CA, editors. *Textbook of Clinical Occupational and Environmental Medicine*. 2nd ed. Philadelphia: Elsevier Saunders; 2005.

U.S. Department of Labor, Bureau of Labor Statistics. 2010. Nonfatal Occupational Injuries and Illnesses Requiring Days Away from Work, 2009. USDL-10-1546. Available at http://www.bls.gov/news.release/archives/osh2_11092010.pdf. Accessed July 11, 2014.