Core Curriculum *for* OCCUPATIONAL & ENVIRONMENTAL HEALTH NURSING

American Association of Occupational Health Nurses, Inc.

THIRD EDITION

Edited by

MARY K. SALAZAR, EdD, RN, COHN-S, FAAN, FAAOHN

Professor
Department of Psychosocial and Community Health
University of Washington School of Nursing
Seattle, Washington

SAUNDERS
ELSEVIER

11830 Westline Industrial Drive
St. Louis, Missouri 63146

Core Curriculum for Occupational & Environmental Health Nursing
ISBN-13: 978-1-4160-2374-6
ISBN-10: 1-4160-2374-7

NOTICE

Nursing is an ever-changing field. Standard safety precautions must be followed, but as new research and clinical experience broaden our knowledge, changes in treatment and drug therapy may become necessary or appropriate. Readers are advised to check the most current product information provided by the manufacturer of each drug to be administered to verify the recommended dose, the method and duration of administration, and contraindications. It is the responsibility of the licensed prescriber, relying on experience and knowledge of the patient, to determine dosages and the best treatment for each individual patient. Neither the publisher nor the author assumes any liability for any injury and/or damage to persons or property arising from this publication.

ISBN-13: 978-1-4160-2374-6
ISBN-10: 1-4160-2374-7

Acquisitions Editor: Linda Thomas
Developmental Editor: Barbara Watts
Publishing Services Manager: Jeff Patterson
Project Manager: Jeanne Genz
Designer: Teresa McBryan

Printed in the United States of America

Last digit is the print number: 9 8 7 6 5 4 3 2

CHAPTER

5

Scientific Foundations of Occupational and Environmental Health Nursing Practice

JACQUELINE AGNEW

The science and practice of occupational and environmental health nursing are based on a synthesis of knowledge gained from multiple disciplines. It is essential that occupational and environmental health nurses understand the principles of the sciences that provide the theoretic, conceptual, and factual framework of the profession. In addition to the nursing and occupational and environmental health sciences (e.g., toxicology, industrial hygiene, and ergonomics), effective practice in this field requires knowledge and understanding of the public health (e.g., environmental health and epidemiology) and social/behavioral sciences. This chapter provides an introduction and overview of these foundation disciplines.

Nursing science

I Nursing Science in the Context of Public Health

A In the mid-1800s, Florence Nightingale (1820-1910) established public health as an important focus for nursing.

1. She emphasized the need for nurses to improve environmental conditions to protect the health of clients, thus laying the foundation for occupational and environmental health nursing.
   a. The major focus of her work was preventive rather than curative health service.
   b. She used statistical techniques to demonstrate the relationship between unsanitary conditions and preventable deaths.
   c. She developed a recordkeeping system that enabled her to improve the conditions in hospitals.
2. According to Nightingale, the five elements necessary for good health are: pure air, pure water, efficient drainage, cleanliness, and light.
3. She encouraged the development of nursing theory and research; her major influence was on nursing education.

B Current approaches to occupational and environmental health nursing can be viewed according to a model of public health developed by the Section of Public Health Nursing of the Minnesota Department of Health (Keller et al., 2004).

1. The Intervention Wheel, a revision of the Public Health Intervention Model, describes the application of nursing practice to populations, including workers, their families, and communities (Figure 5-1).
2. The Intervention Wheel is based on the actual work performed by public health nurses, including nurses in worksite practice settings.
3. According to this model, population-based practice focuses on populations, relies on community assessments, considers all determinants of health, emphasizes prevention, and intervenes at multiple levels.

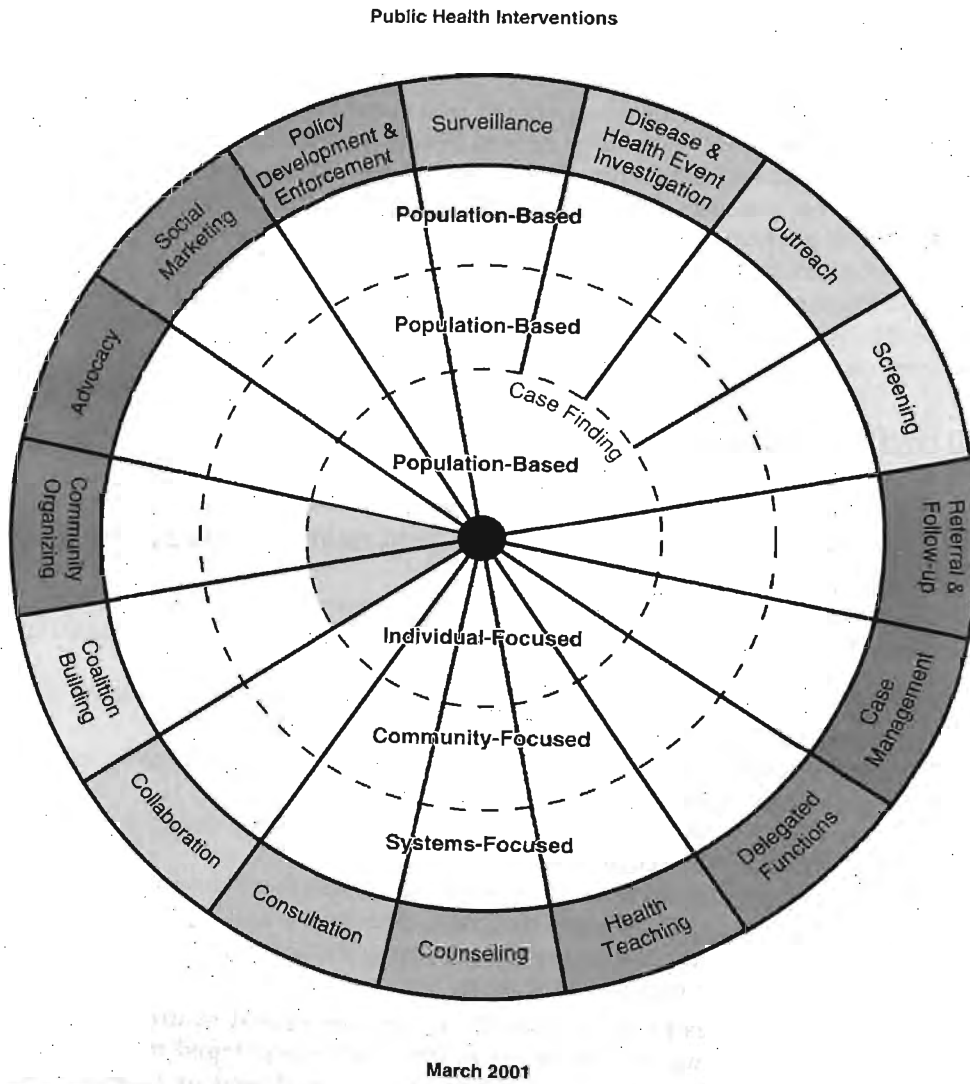

FIGURE 5-1 *Public health intervention wheel (Minnesota Department of Health, Division of Community Health Services Public Health Nursing Section) 2001*

4. Three levels of practice are identified: community, systems, and individuals/family.
5. Public health practice is described by 17 types of interventions, grouped into five general areas, termed "wedges":
   a. Surveillance, disease and other health event investigation, outreach, screening, and case finding
   b. Referral and follow-up, case management, and delegated functions
   c. Health teaching, counseling, and consultation
   d. Collaboration, coalition building, and community organizing
   e. Advocacy, social marketing, and policy development and enforcement

II Evolution of Occupational and Environmental Health Nursing Practice

A ***Nursing, Health and the Environment*** **(Institute of Medicine [IOM], 1995) is a landmark publication that defines and describes the role of nurses in environmental health. According to this publication:**

1. Environmental health is the "freedom from illness or injury related to exposure to toxic agents and other environmental conditions that are potentially detrimental to health."
2. Three themes are related to nursing and the environment:
   a. The environment is a primary determinant of health, and environmental health hazards affect all aspects of life and all areas of nursing practice.
   b. Nurses are well positioned to address environmental health concerns of individuals and communities.
   c. There is a need to enhance the awareness of and emphasis on environmental threats to the health of populations served by all nurses, regardless of their practice arena.

B **The expertise and competencies of occupational and environmental health nurses are relevant to the protection of health and safety in community settings and work settings (American Association of Occupational Health Nurses, 2003).**

C **Some of the most significant environmental conditions that are capable of harming the health of humans are experienced at work, where exposures are often higher than in other settings; the working population (population at risk) is characterized by the following:**

1. Generally healthy enough to hold a job
2. Of working age
3. Often of childbearing age

D **Occupational and environmental health nursing interventions should be population-based, supported by evidence, and reflect best practices.**

E **Occupational and environmental health nurses perform interventions depicted by the Intervention Wheel model; as examples:**

1. Nurses who establish, publicize, and monitor heavy metal screening programs and registries, followed by case finding, are performing surveillance, investigation, outreach, and screening functions at system, community, and individual levels.
2. Referral, case management, and delegated functions are accomplished at all three levels when occupational and environmental health nurses work with

health departments, worker populations, and high risk individuals to identify cases of tuberculosis, prevent further spread of the disease, and ensure treatment for those who are infected.

3. Teaching, counseling, and consultation take place through nursing activities aimed at informing health care providers and members of rural communities about risks of agricultural hazards and health effect prevention.
4. Partnerships with local health departments, community organizations, neighborhood residents, and parents to create safe play areas for urban children address the intervention areas of collaboration, coalition building, and community organizing
5. The areas of advocacy, social marketing, and policy development are exemplified by nursing practices that promote and enforce employer policies to prevent the transmission of workplace hazards into the home environment. Requirements might include provision of clothing changes, shower facilities, and worker training.

F Several factors determine the health of individuals and populations (US Department of Health and Human Services, 2000).

1. *Biological* factors include genetic background as well as physical and mental health status.
2. *Behaviors* occur in response to an individual's experiences and may either cause biological changes or be influenced by biology. For example, smoking (behavior) may cause lung disease (biology); fair complexion (biology) may lead to avoidance of sun exposure (behavior).
3. The *social environment* includes interaction with others, housing and community services, and institutions such as school and places of worship. The social environment profoundly influences health and can affect behavior and the biological status of populations.
4. The *physical environment* can be the source of exposure to harmful agents: chemicals, pathogens, or physical hazards. Alternatively, the physical environment can be protective or encourage positive behaviors such as exercise.
5. Additional determinants of health are: (1) policies and interventions that relate to health behaviors and health outcomes; and (2) *access to quality care*, which is essential for optimizing the health of all.

G Workers and communities face multiple workplace hazards that place them at risk.

1. A *hazard* is defined as a substance capable of causing harm (Chapter 1 describes categories of hazards).
2. *Risk* is the probability that harm will occur.

H A systematic understanding of the relationships among health determinants and the principles that govern the association between hazards and health effects provides a basis for preventing morbidity and mortality and promoting health in a broad range of settings.

1. Workers, work-related exposures, and work environments illustrate one domain in which these principles apply.
2. The influence of industrial conditions on family and community members is another example of health and environment interactions.
   a. Families can be exposed to toxins transported home on workers' bodies or belongings.
   b. Industrial waste or effluent can reach the community.

3. Approaches to risk assessment and principles of health protection similar to those used in the workplace can be used to protect the health of communities faced with natural or manmade hazards in media such as food, air, soil, and water.

I The chief disciplines that assist the occupational and environmental health nurse to understand the agent-host-environment relationship are epidemiology, toxicology, and industrial hygiene; these are described in the following sections.

Epidemiology

III Overview of Epidemiologic Terms and Principles

Epidemiology is the public health science that is fundamental to describing and understanding relationships among agents, hosts, and their environments.

A Definitions related to epidemiology are as follows:

1. *Epidemiology* is the study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to the control of health problems.
2. *Incidence rate* is an epidemiologic term that describes the occurrence of new disease or injury per unit of time among persons at risk (Rothman & Greenland, 1998a).
   a. The numerator includes only new cases of disease during a given time period; the denominator includes everyone at risk of developing the disease during that period.
   b. Incidence, therefore, measures the probability (or risk) of developing disease.
   c. Incidence rates are useful for tracking trends in the development or resolution of disease.
3. *Prevalence* is an epidemiologic term that describes the proportion of the population with the condition at a given point in time or during a given time period.
   a. The numerator includes new and existing cases; the denominator includes all who are at risk of developing the disease, including those who have it.
   b. Prevalence measures the current burden of disease and is useful for measuring and projecting health care and health resource needs.

B Examples of applications of epidemiologic research include:

1. Controlling infectious diseases, such as tuberculosis among migrant farm workers
2. Controlling the effects of chemical hazards, such as asbestosis, mesothelioma, and lung cancers related to exposure to asbestos
3. Understanding genetic susceptibility to disease, such as coronary heart disease or cancer, which often result from a combination of hereditary and environmental factors
4. Understanding the effects of nutritional status, such as the link between a calcium intake and osteoporosis
5. Linking pathogens to specific disease processes, such as West Nile virus and its pattern of occurrence among humans
6. Identifying risk factors for illness or injury, such as work factors that lead to back injuries in health care workers

C Epidemiology has great relevance to occupational and environmental health nursing.

1. It serves as a tool for recognizing, identifying and preventing hazardous exposures.
2. Findings from epidemiologic studies of worker and community populations are often reported in the occupational and environmental health literature.
3. Epidemiologic studies help occupational and environmental health nurses provide high-quality health services.

IV Measures of Association

Evaluation of associations among exposures and health outcomes is central to epidemiology; criteria to evaluate causality based on an observed association include the following (Rothman & Greenland, 1998b):

A The strength of the association

1. The strength of the association refers to the degree of correlation between the exposure and disease.
2. It is important to remember that weak associations do not necessarily rule out a causal relationship between the exposure and disease.

B Consistency of the association

1. Similar findings result across several studies of the same association.
2. Conclusions are similar despite the use of different study designs, under different conditions, and in different populations.

C Temporality of the association

1. Studies demonstrate that the cause (exposure or independent variable) precedes the effects (disease or dependent variable) chronologically.
2. Temporality cannot be evaluated with a cross-sectional study.

D Dose-response relationship

1. As the degree of exposure increases, the risk for developing the outcome increases.
2. Lack of a dose-response relationship does not rule out a causal relationship.

E Plausibility of the association

1. The association is consistent with a plausible biologic explanation.
2. Knowledge of the natural history of the disease and results of animal and other laboratory experiments need to be considered.
3. Sometimes there is not enough scientific evidence to draw conclusions about biological plausibility.

V Sources of Epidemiologic Data

A Population-based health outcome data are available through a variety of public and private agencies; data include:

1. Census data (U.S. Census Bureau)
2. Vital statistics (U.S. Census Bureau)
3. National health surveys (National Center for Health Statistics)
   a. Population-based studies such as the National Health and Nutrition Examination Surveys and the National Health Interview Survey are conducted regularly.

b. Mandatory reporting systems capture data such as OSHA-recordable illnesses and injuries (Bureau of Labor Statistics).

4. Disease and death registries (e.g., from state and federal agencies or medical centers)

B **Exposure data are often more difficult to obtain, especially in environmental and occupational settings.**

1. Examples of exposure data are air monitoring data and biomarkers of exposure.
2. Data can be obtained from exposure registries such as those maintained for heavy metal exposure, certain pharmaceutics, and needlestick injuries.
3. Exposure status is sometimes estimated indirectly from information such as occupational history, dietary history, or location of residence.

VI Comparisons of Rates

A ***Relative risk*** **(also known as *rate ratio*) is a measure of the relationship between two incidence rates, that of the exposed and that of the unexposed population.**

B **An *odds ratio* is a good estimate of relative risk, but is derived from case control or cross-sectional studies.**

C ***Attributable risk*** **is a measure of the difference between two rates, one for the exposed and one for the unexposed populations. It describes the increased amount of risk attributed to the exposure.**

VII Types of Rates

Box 5-1 presents examples of the following rates.

A ***Crude rates*** **are based on the actual number of events for a given time period but do not reflect true differences in risk among subgroups in the population.**

B ***Characteristic-specific rates*** **allow one to compare rates for similar subgroups of two or more populations (e.g., age-specific or gender-specific rates).**

BOX 5-1

Using crude, specific, and adjusted rates to describe a health problem—an example

- *Crude Rates:* The crude rates of lung cancer in a population will not reflect the fact that older individuals are at higher risk for lung cancer. To look at the association between smoking and lung cancer, it would not be appropriate to compare crude rates of lung cancer in groups of smokers and nonsmokers who differ in age distribution.
- *Specific Rates:* Rates of lung cancer could be computed for age-specific groups, perhaps by decade of age, to examine differences in lung cancer rates by age.
- *Adjusted Rates:* The age-adjusted rates of lung cancer in the smoking and nonsmoking groups could be compared to examine the question of an association between smoking and cancer.

C ***Adjusted* (or *standardized*) *rates* reflect population differences by taking into consideration the distribution of important characteristics that may affect risk (e.g., age-adjusted rates).**

VIII Inferential Statistics

Inferential statistics, which are taken from a sample of a population, are used to make inferences about the entire target population (Eisen & Wegman, 2000)

A **A *hypothesis* is a supposition, resulting from observation or reflection.**

1. A hypothesis leads to predictions that can be tested.
2. Hypothesis testing involves conducting a test of statistical significance and quantifying the degree to which sampling variability may account for the observed results.

B **Some well-known tests of statistical significance include the t-test and chi-square test.**

C **A *p-value* is a quantitative statement of the probability that the observed difference (or association) in a particular study could have happened by chance alone.**

1. $p < 0.05$ means that the probability that the observed difference occurred by chance is less than 5%.
2. $p < 0.05$ is a frequently used level for referring to an association as statistically significant.

D **A *confidence interval* describes the magnitude of the effect and the inherent variability in an estimated statistic.**

1. A confidence interval indicates the stability of the true rate or other statistic that describes a population.
2. A 95% confidence level means that there is a 95% probability that the true rate of an observation lies within the calculated interval.

E **The *power* of a study is its likelihood of detecting a real association if one exists; power is affected by the following four variables:**

1. The magnitude of the effect (or association) or difference
2. The variability of the measures of interest
3. The level of statistic significance selected (alpha)
4. The size of the sample studied
   a. Larger sample sizes increase the stability of measurements made in an epidemiologic study.
   b. Power calculations based on the above variables suggest the appropriate sample size needed for an epidemiologic study.

IX Overview of Study Designs

Chapter 17, Section V.G, presents additional information.

A ***Experimental designs* are preferred for determining causality about study designs.**

1. In an experimental study, the investigator assigns the exposure (or putative cause) to the study subjects.
2. *Randomized clinical trials* and *intervention studies* are examples of experimental designs.
3. Experiments are limited by ethical constraints; that is, purposeful exposures of study subjects are not always appropriate

B ***Nonexperimental designs*** **that attempt to simulate the results of an experiment (had one been possible) are primarily** ***descriptive studies*** **or** ***analytic*** **(ex post facto)** ***studies.***

1. *Descriptive studies* generate hypotheses and therefore are not intended to determine causality.
   a. A *cross-sectional study* examines the relationship between diseases (or other health-related characteristics) and other variables of interest as they exist in a defined population at one point in time.
   b. An *ecologic study* looks at the group rather than the individual as the unit of analysis, usually because information is not available at the individual level.
2. *Analytic studies:* the investigator systematically determines whether risk of or a health-related condition is different for exposed and nonexposed individuals.
   a. A *cohort study* (also called a *prospective study* or *longitudinal study*) is an analytic study in which persons who are initially free of the disease (or outcome) but vary in one or more factors (such as exposure or potentially protective factors) are followed over a period of time for the occurrence of the disease (or outcome).
   b. In a *case-control study,* a group of persons with a disease (cases) are compared with a group without the disease (controls) to study the characteristics (such as exposure) that might predict, cause, or protect against the disease.
3. Table 5-1 lists advantages and disadvantages of cohort, case-control, and cross-sectional study designs.

X Bias and Confounding in Epidemiologic Studies

Identification of associations that are not real is usually the result of biased study methods or the presence of confounding variables (Greenland & Rothman, 1998).

TABLE 5-1

Advantages and disadvantages of various designs of nonexperimental epidemiologic studies

Study design	Advantages	Disadvantages
Cohort or prospective	Good for study of rare exposures Allows classification of exposure before disease develops Can determine incidence of disease Can determine true relative risk Can follow multiple outcomes	Lengthy Large sample size required Generally expensive Potential for subject loss to follow-up
Case-control	Good for study of rare outcomes Can estimate relative risk by odds ratio Takes less time Less expensive Requires smaller sample size Can look at multiple risk factors	Exposure histories may be difficult to construct Recall bias can be a problem Must select appropriate control group
Cross-sectional	Generates hypotheses Useful in study of exposures that do not change (e.g., blood type)	Cannot determine causality Current exposure does not represent relevant past exposure

Source: Rothman & Greenland, 1998b.

A ***Bias* refers to systematic error in an epidemiologic study that results in an incorrect estimate of the association between exposure and risk of disease.**

1. Selection bias
   a. This type of bias occurs when the identification of subjects for inclusion in the study, on the basis of either exposure (cohort study) or disease (case control study) status, depends in some way on the other axis of interest.
   b. Selection bias can result from differential surveillance, diagnosis, referral, or rates of participation of individuals in the study.
2. Information (or observation) bias
   a. This type of bias results from systematic differences in the way data on exposure or outcomes are obtained from various study groups.
   b. Examples of information bias are recall bias, interviewer bias, loss of subjects to follow-up over time, and misclassification (Table 5-2).
3. Study results may be biased either toward or away from the null hypothesis—or in both directions.

B ***Confounding* results when the estimate of the effect of the exposure of interest is distorted because it is mixed with the effect of an extraneous factor; in occupational epidemiology studies, age, gender, and smoking status are often important confounding variables.**

C **Methods to avoid and manage study biases and confounding include the following:**

1. A strict study protocol with attention to how subjects are selected for study is a means of avoiding study bias in the design phase of the study.
2. Systematic, standardized data collection techniques that are consistent for all study participants will help avoid bias in the data collection phase.
3. Confounding can be avoided by making comparisons only among individuals with the same level of the confounding variable; this is also known as *controlling for the effect of the confounding variable.*

TABLE 5-2

Types of bias in epidemiologic studies

Type of bias	Description
Information	Exposure and outcome data are ascertained differently from study groups.
Recall	Individuals with negative outcomes are more likely to remember and report exposure.
Interviewer	Interviewers' prior knowledge of outcome status affects ascertainment of exposure information in interview.
Lost to follow-up	Prospectively, those with negative outcomes may be lost to follow-up at greater rate than controls.
Misclassification	Ascertainment of either exposure or outcome status is incorrect for some subjects.
Selection	Entry into study or control group is affected by factors related to exposure (case-control) or outcome (cohort).
Self-selection	Individuals' participation is affected by their knowledge of disease or exposure status.

a. In the design phase, matching subjects is a way to control for confounding.
b. In an experimental study, confounding is avoided by randomization of treatment between cases and controls.
c. In the analysis phase, confounding can sometimes be handled by stratifying or adjusting.
d. Subjects who are lost to follow-up should be evaluated to assess whether they differ in important characteristics from those who have remained in the study.

XI Screening

Screening is the practice of testing people who are as yet asymptomatic; its purpose is to classify them with respect to their likelihood of having a disease.

A **An implicit assumption of screening is that early detection will help prevent death or disability. Criteria for screening include the following:**
1. A recognizable presymptomatic stage of disease must exist.
2. An effective treatment must be available.
3. The screening test should have sufficient validity.

B **A sufficiently valid screening test is one that is highly sensitive and specific.**
1. *Sensitivity* is the ability of a test to identify correctly those who have the disease; a sensitive test yields few false negatives. Sensitivity is an especially important trait for initial screening tests, so that most of the population who truly have the disease or condition will be included in follow-up measures.
2. *Specificity* is the ability of a test to identify correctly those who do not have the disease; a specific test yields few false positives.
3. Sensitivity and specificity do not change when the prevalence of the disease in the population changes.

C **The *predictive value* of screening tests is the ability to predict disease status from test results.**
1. *Positive predictive value* is the likelihood that an individual with a positive test truly has the disease.
2. *Negative predictive value* is the likelihood that an individual with a negative test does not have the disease.
3. Levels of predictive value change when the prevalence of a disease in a population changes.
   a. As the prevalence of a disease in a population increases, the positive predictive value of the test will increase.
   b. However, as the prevalence increases, the negative predictive value will decrease.

D **Screening can be done for disorders related to work-site exposures or to nonoccupational causes.**
1. OSHA standards require periodic screening of some workers (Papp and Miller, 2000).
   a. Examples are workers exposed to asbestos, cadmium, or cotton dust.
   b. This type of screening is generally called *medical surveillance* in OSHA standards.
2. Screening for early detection is done for diseases such as breast cancer, prostate cancer, and colon cancer.

Toxicology

XII Overview of Toxicologic Terms and Principles

Toxicology is the study of the adverse effects of chemicals on biologic systems (Frumkin & Melius, 2000).

A **A *target organ* is the organ that is selectively affected by a harmful agent.**

B **A chemical is toxic—that is, it can cause harm—if all of the following five conditions are met:**

1. Its properties make it capable of producing harm
2. It is present in sufficient amount
3. It is present for sufficient time
4. It is delivered by an exposure route that allows it to be absorbed
5. It reaches the target body organ(s)

C ***Toxic agents* can be classified by their form of action on biologic systems.**

1. *Asphyxiants* deprive the body tissue of oxygen.
   a. Simple asphyxiants displace oxygen and cause suffocation; examples are carbon dioxide, nitrogen, and argon.
   b. Chemical asphyxiants prevent oxygen use by the cell, even when enough oxygen may be present; examples are carbon monoxide and cyanide.
2. *Corrosives* cause irreversible tissue death; ozone and acids are examples of corrosives.
3. *Irritants* cause temporary, but sometimes severe, inflammation of the eyes, skin, or respiratory tract; an example is ammonia.
4. *Sensitizers* cause allergic reactions after repeated exposure; examples are nickel and toluene diisocyanate (TDI).
5. *Carcinogens* are capable of causing cancer; examples are asbestos, coal tar, and vinyl chloride monomer.
6. *Mutagens* are toxins that cause changes to the genetic material of cells that can be passed on to future generations; known human mutagens include ethylene oxide and ionizing radiation.
7. *Teratogens* cause malformations in an unborn child; some teratogenic agents are organic mercury compounds, ionizing radiation, and some pharmaceutics.
8. Toxins may have more than one form of action and may act at more than one site. For example, formaldehyde is irritating to the eyes and respiratory tract, can irritate and sensitize the skin, and is suspected of being a carcinogen.

D **Assessing the characteristics of exposure considers the following:**

1. The *dose* of an agent is the amount that reaches the target organ.
   a. The dose is usually impossible to determine accurately.
   b. The dose is usually estimated by measuring the amount administered (as with drugs) or the amount in the environment to which a person has been exposed (as with work-related exposures or levels in media such as air, water, or food).
   c. Another means of estimating dose is by measuring biomarkers in body tissues as indicators of levels of the agent within the body or early physiologic changes due to exposure.
   d. Vapors or gases in the environment are usually expressed as parts per million (ppm).
   e. Solids (dusts or fumes) are expressed according to their weight per volume of air, usually as milligrams per cubic meter (mg/m^3).

f. Higher concentrations of substances are generally absorbed in greater amounts.
g. Longer or more-frequent periods of exposure also lead to greater absorbed doses.

2. Acute and chronic exposures
   a. *Acute exposure* occurs when exposure is short-term and absorption is fairly rapid.
   b. *Chronic exposure* refers to longer duration or repeated periods of contact.
   c. In general, acute toxic exposures tend to be at higher levels, and chronic exposures occur at lower concentrations.
3. *Guidelines and standards* that serve to evaluate the seriousness of an exposure.
   a. Examples of workplace guidelines are *threshold limit values;* examples of workplace standards are *permissible exposure limits* (described in detail in Section XXII).
   b. Guidelines and standards indicate upper limits of exposure concentrations that are not felt to pose a danger to workers who are exposed over normal work hours.
   c. Published limits cannot be viewed as definitely "safe" levels.
   d. Guidelines and standards may be controversial because of a lack of scientific data, lack of agreement over the levels associated with health effects, and the reality that levels that protect most individuals may yet affect susceptible subgroups.

XIII Major Exposure Routes

There are three major routes of exposure (Lippmann, 2000).

A ***Inhalation:*** **This is the most important route of exposure in the occupational environment, because it is the most common route by which occupational exposures are absorbed.**

1. Most absorption takes place in the alveoli, where blood flow is high and close to the inhaled air; to reach the alveoli, the substance is generally a gas or a particulate ranging in size from approximately 1 to 10 microns in diameter.
2. Absorption by inhalation is influenced by the rate and depth of respirations; thus individuals performing heavy physical labor may absorb substances at a higher rate.
3. Although the lung may serve as the target organ of some inhaled toxins, other substances gain entry through the lungs but exert their effect elsewhere in the body; examples are solvents and carbon monoxide, which have systemic effects.

B ***Cutaneous:*** **The skin does provide a barrier to most substances, but its effectiveness as a barrier varies according to its condition, site, and the properties of the chemical agent.**

1. Some substances cross the epidermal layer or enter through hair follicles.
2. Some substances may enter by the trauma of injection or impalement; this mode of entry is less common.
3. In general, gases penetrate most freely, liquids less freely, and solids that are insoluble in water or fats do not penetrate the skin.
4. Longer contact promotes higher levels of absorption.

5. Damage to the epidermal cells by chemicals or trauma, such as abrasions, can promote its further absorption.
6. Clothing or gloves can trap substances and lead to longer exposure periods.

C *Ingestion:* **In the occupational setting, ingestion is the least common route of entry. However, ingestion increases in importance in the case of other types of environmental exposures, such as food, water, and substances encountered through hand-mouth activity.**

1. Caustic or irritant chemicals, if ingested, can have a direct adverse effect on the gastrointestinal tract.
2. Some toxins act systemically following their absorption.
3. Smoking or eating at work sites can lead to consumption of toxins by way of contaminated hands, food, or smoking materials.

XIV The Dose-Response Relationship

This describes the relationship between the level of exposure (dose) and the resulting toxic effects (response) in a susceptible population of humans or experimental animals (Lippmann, 2000).

A Higher doses are generally associated with responses in a greater proportion of individuals.

B Identification of a dose-response relationship lends support to a theory that a substance causes a given effect.

C Dose-response curves provide a basis for evaluating a chemical's relative toxicity.

1. Terms that describe toxicity of a substance are *lethal dose, 50%* (LD_{50}) and *lethal concentration, 50%* (LC_{50}).
2. These terms refer to the dose (LD_{50}) or concentration (LC_{50}) that produces death in 50% of a group of experimental animals.
3. These indices are smaller for more-toxic agents. For example, the LD_{50} of acetone is 5,340 mg/kg, whereas hydrogen cyanide, a much more toxic compound, has an LD_{50} of 0.5 mg/kg
4. Animal studies are useful because they provide information about potential toxic effects or target organs in humans; however, they must be interpreted cautiously because of the many differences in response that exist among species.

XV Nature of Effects

A The effects of toxins with long latency periods may not be apparent until years after the exposure period.

B Work-related exposures commonly consist of chemical mixtures (McCauley, 1998); this is a concern because interactive effects may occur with two or more concurrent exposures.

1. *Synergistic effects* are effects caused by exposure to more than one toxin that surpass the sum of the separate effects of those toxins.
2. *Antagonism* between toxins results in an overall effect that is less than the sum of their separate effects.
3. *Potentiation* means that a chemical has no adverse effect on its own, but its presence increases the effect of another substance or makes that substance capable of exerting an effect. Potentiation is often seen with carcinogens.

XVI The Fate of Toxins in the Body

Once toxins are absorbed, their fate in the body varies (Frumkin & Melius, 2000):

A Excretion involves the elimination of the material from the body (Arble, 2004).

1. Some chemicals are excreted unchanged into expired air, urine, feces, bile, or perspiration.
2. Other avenues of excretion include milk, spinal fluid, saliva, and hair.
3. Most chemicals and their metabolic products are excreted through the kidney/urine pathway.

B Transformation is a process that results in a substance being changed in some way.

1. Chemicals may be transformed into substances that can be excreted by a process called *biotransformation*.
2. Products of biotransformation may be either less toxic or more toxic than their parent chemical.
3. This is an important concept when individuals differ in the rate at which they metabolize substances, because this rate can affect individual susceptibility to a toxin.

C Several factors affect the excretion of substances.

1. Many agents are not metabolized or excreted immediately, but instead are deposited in body tissue and slowly released and excreted over time.
2. *Half-life* is the term that describes the time it takes for one half of the total absorbed amount to be eliminated from the body.
3. The length of the half-life depends on the agent and the tissue in which it is stored; for example, the half-life of lead is more than 20 years in bone, compared with about 25 to 30 days in blood.

XVII Endogenous and Exogenous Host Factors

These factors can influence susceptibility and the magnitude of the toxic response.

A *Endogenous* factors are inherent to the individual and are beyond the control of that individual.

1. *Gender* may influence susceptibility to some toxins, although the cause of this difference is not well understood in all cases.
   a. Some cancers and other diseases are associated with gender.
   b. Women have a greater proportion of body fat and therefore may accumulate more lipid-soluble toxins than men.
   c. Other differences in metabolism, anthropometry, and genetic types may account for varying susceptibility to toxins.
2. *Genetic differences* may cause variation in metabolism, detoxification, excretion, and cellular response to toxins.
3. *Aging* is related to rate and efficiency of metabolism, levels of organ function, and patterns of excretion.
   a. Age-related factors may increase toxic responses among older adults.
   b. Similarly, children may experience increased susceptibility because of their higher respiratory and metabolic rates, less mature nervous systems, and immature livers, which lack the detoxification mechanisms of adults.
   c. Children are also more susceptible than adults to some cancers because they are growing and their cells are dividing more rapidly.

d. Pregnant mothers may be exposed to work-site agents that have the potential to cause perinatal malignancies or developmental disorders.

4. *Health conditions* can increase individual susceptibility to toxins; for example, heart disease can influence effects of exposure to asphyxiants that affect oxygen availability or utilization.

B Individuals may be able to exert some control over *exogenous* factors, because those factors are related to behavior or environmental conditions.

1. *Nutrition* factors, such as deficiencies, can enhance or inhibit absorption or toxic responses.
2. *Obesity* may promote more storage of lipid-soluble substances.
3. *Lifestyle* factors such as smoking or alcohol consumption increase overall chemical exposures that must be handled by the body and may increase susceptibility due to debilitation.
4. *Stress* can have an effect on the function of some organs, such as those of the cardiovascular, immune, and gastrointestinal systems.
5. Some adverse health conditions are temporary and manageable but may affect an individual's vulnerability to toxins.

NOTE: Table 5-3 presents some major effects seen in various body systems and gives examples of work-site exposures that cause them.

XVIII Examples of Exposures and Their Effects

Exposures may be classified in many ways, such as by their chemical properties (e.g., metals) or by their action (e.g., asphyxiants). This section presents some of the major groups of work-site toxins with information about selected examples (Sullivan and Kreiger, 2001).

A Metals are elementary substances that have specific properties, including opacity, conductivity, and ductility.

1. Arsenic, in the inorganic form, is found in operations such as mining, smelting, and electronics manufacturing and in products such as pesticides, paints, and wood preservatives.
   a. It is important to distinguish inorganic arsenic, which is toxic, from organic arsenic, which is not toxic but is found in foods such as seafood; dietary seafood can lead to high total arsenic levels in urine without any threat to health.
   b. Acute arsenic exposure leads to gastrointestinal symptoms, abdominal pain, and sometimes a garlic odor on the breath. This may progress to renal failure, shock, encephalopathy, and death.
   c. Chronic arsenic toxicity can lead to hyperpigmentation of the skin, hyperkeratosis, dermatitis, and skin cancer. A sign of arsenic exposure is the presence of Mee's lines, which are transverse white lines on the fingernails.
   d. Multiple systems can be affected by arsenic.
      1) Arsenic can cause a sensorimotor polyneuropathy, often noted in the hands and feet.
      2) Vascular effects can simulate Raynaud's syndrome or lead to gangrene of the extremities.
      3) Liver effects include cirrhosis and angiosarcoma.
      4) Respiratory effects include lung cancer.
      5) Anemia or leukopenia may result from bone marrow suppression.
   e. The treatment for arsenic toxicity is chelation.

TABLE 5-3

Potential toxic effects by system, with examples of toxins

System	Effects	Sources of exposure
Respiratory	Irritation	Hydrogen chloride, ammonia
	Sensitization	Isocyanates
	Fibrosis	Silica, asbestos, beryllium
	Carcinogens	Asbestos, arsenic, chromium VI
Dermatologic	Irritation	Acetone, carbon disulfide
	Corrosive burns	Alkali, hydrogen fluoride
	Sensitization	Chromate, nickel
	Carcinogenesis	Ultraviolet light, arsenic
Nervous system	Depression/altered consciousness	Carbon monoxide, solvents
		Lead, mercury, manganese
	Behavior and mood disturbance	Lead, solvents
		Toluene, mercury
	Cognitive disturbance	Carbon monoxide, manganese, pesticides
	Cerebellar impairment	
	Parkinson-like effects	
	Peripheral neuropathy	Acrylamide, *n*-hexane, methyl *n*-butyl ketone
Hearing and vision	Acid burns of eyes	Hydrochloric and tannic acid
	Alkali burns of eyes	Sodium hydroxide, calcium oxide
	Blindness	Methanol
	Deafness	Noise
Hematopoietic	Bone marrow suppression	Ionizing radiation, benzene
	Red cell lysis	Arsine, trinitrotoluene (TNT), naphthalene
Hepatic	Necrosis	Carbon tetrachloride, chloroform, tetrachloroethane
	Cirrhosis	Carbon tetrachloride
	Malignancy	Vinyl chloride monomer
Renal and Bladder	Nephrotoxicity	Heavy metals, carbon tetrachloride, chloroform
	Renal cancer	Coke oven emissions
	Bladder cancer	Benzidine, B-naphthylamine
Reproductive	Decreased sperm production	Ionizing radiation, heat
	Decreased female fertility	Ionizing radiation, carbon disulfide
	Spontaneous abortions	Ethylene oxide
	Congenital defects	Rubella, varicella

f. The OSHA standard for inorganic arsenic requires medical surveillance for exposed workers.

2. Beryllium is currently found in metal alloys, tools, and instruments, particularly in the aerospace industry, but was once used in manufacturing fluorescent lights and nuclear weapons.
   a. Acute toxicity to beryllium is a result of hypersensitivity of the lungs or mucous membranes.
   b. Allergic and irritant contact dermatitis with skin ulceration may also occur.
   c. Chronic beryllium disease, berylliosis, is marked by granulomas of the skin, lungs, and other organs. Other signs are dyspnea, cough, anorexia, fatigue, weight loss, and arthralgias.

   d. For more information about beryllium exposure, see AAOHN's Foundation Blocks (http://www.aaohn.org/).
3. Cadmium is found in battery manufacturing, electroplating, welding, and zinc and lead smelting. Cadmium is also present in cigarettes.
   a. The primary route of cadmium exposure is inhalation.
   b. Acute cadmium exposure can lead to metal fume fever or pulmonary edema.
   c. Cadmium causes renal failure, resulting from proximal renal tubular damage.
   d. Cadmium also causes osteomalacia, emphysema, and possibly lung and prostate cancer.
   e. The OSHA standard for cadmium-exposed workers requires, among other tests, medical surveillance for blood and urinary cadmium levels and urinary $Beta_2$-microglobulin.
4. Chromium is found in metal alloys, tanning and dye operations, and chromium plating; welding can also be a source of exposure.
   a. The principal forms that cause toxicity are trivalent and hexavalent chromium.
   b. Chromium exposure occurs through inhalation and absorption through cracks in the skin.
   c. Skin and mucous membrane exposure can lead to deep, painful ulcers and perforation of the nasal septum.
   d. Chronic exposure can lead to asthma or allergic contact dermatitis.
   e. The hexavalent form of chromium can cause lung cancer.
5. Lead exposure can arise from a number of sources. Examples include the manufacture or use of lead solder, paint, alloys, and ceramics, smelting, demolition, and radiator repair operations. The more common form of lead encountered today is inorganic lead; the organoleads were formerly used as gasoline additives.
   a. Lead is a significant environmental toxicant found in residential paint and soil, and is used in hobbies such as stained glass work and soldering.
   b. Routes of exposure to lead are inhalation and ingestion.
   c. Most lead is stored in the bone, but the toxicity of lead is related to the amount that reaches target organs.
   d. Gastrointestinal effects of lead such as constipation and abdominal colic are sometimes mistaken for other problems like appendicitis.
   e. Lead causes central nervous system effects, such as memory deficits, and mood disturbances, such as irritability and depression.
   f. Lead toxicity results in peripheral neuropathy that primarily affects motor nerves.
   g. Lead exposure can result in renal failure, gout, and possibly hypertension.
   h. Reproductive effects of lead include sperm abnormalities and effects on the fetus that can lead to spontaneous abortion or developmental delays in childhood.
   i. The OSHA standard for lead-exposed workers specifies medical surveillance requirements and medical removal criteria.
   j. The treatment for lead toxicity, in addition to removal from exposure, consists of chelation.
   k. AAOHN has developed a Lead Surveillance Screening Program (2003) available at http://www.aaohn.org./

6. Mercury is found in many products and processes, including the manufacture and repair of medical instruments, pesticides, and the preparation of dental amalgams. Organic mercury accumulates in fish.
   a. The three forms of mercury differ by mode of exposure and effect. Exposure to elemental mercury, the form used in thermometers, occurs through inhalation; inorganic mercury compounds are absorbed through the gastrointestinal tract and lungs; organic mercury is ingested.
   b. The classic triad seen with elemental and inorganic mercury toxicity are tremor, gingivitis, and personality changes that include shyness, paranoia, and labile mood.
   c. Stomatitis and dermatitis may also be present.
   d. Mercury exposure can cause renal dysfunction.
   e. A distal peripheral neuropathy can also result from mercury exposure.
   f. Organic mercury toxicity has been associated with ingestion of fish contaminated with methyl mercury.
   g. Organic mercury toxicity in adults has been associated with neurobehavioral changes, ataxia, tremor, and constriction of the visual field and has caused severe central nervous system defects in unborn children.
   h. Chelation is sometimes used to treat elemental and inorganic mercury toxicity.
7. Manganese exposure occurs during work activities such as mining, production of alloys, and use of agrochemicals. In several countries, it is contained in the gasoline additive commonly known as MMT (methylcyclopentadienyl manganese tricarbonyl) and can be present in car emissions.
   a. Although manganese is an essential dietary element, it causes health effects with high levels of exposure.
   b. The primary route of exposure to manganese is inhalation, but contamination of soil, dust, and food leads to risk of ingestion.
   c. Manganese is a known neurotoxin, causing psychologic and neurobehavioral disturbances, as well as Parkinson-like signs and other movement disorders (Levy & Nassetta, 2003).
   d. Exposure *in utero* has recently been implicated in impaired psychomotor development during early childhood (Takser, et al., 2003).

B Respirable dusts are solid particles that are capable of being suspended in the air and ultimately inhaled into the body.

1. Asbestos has been used for pipe and furnace insulation, tiles, automobile and train brakes, and other heat-resistant products; health risks occur when asbestos fibers become airborne.
   a. Different types of asbestos are associated with differently shaped fibers; the most common type in the United States is chrysotile.
   b. Pleural effusions and pleural plaques are seen with chronic asbestos exposure.
   c. Asbestosis is characterized by interstitial fibrosis.
   d. Mesothelioma occurs only with asbestos exposure and can affect the pleura or peritoneum; the latency period is 30 to 40 years.
   e. Bronchogenic carcinoma also can be caused by asbestos; the risk is much greater if a person exposed to asbestos also smokes.
   f. Asbestosis is possibly associated with cancers of the gastrointestinal tract.
   g. There is an OSHA standard that requires medical surveillance for asbestos-exposed workers.

2. Coal-dust exposure occurs primarily in coal mining.
   a. Coal-dust exposure causes coal workers' pneumoconiosis, also known as *black lung*.
   b. Changes are first noted on chest radiographs, starting in the upper lobes and resulting in progressive massive fibrosis.
   c. Coal-dust exposure is also associated with bronchitis and emphysema (chronic obstructive pulmonary disease).
   d. Coal dust may be associated with gastric cancers.
   e. Medical surveillance for underground coal miners consists of chest radiography and spirometry evaluations, administered as part of the Coal Worker's X-Ray Surveillance Program.
3. Silica exposure occurs in sandblasting, manufacturing of glass and pottery, mining of stone, and foundries.
   a. Acute, high-level exposure to silica leads to a severe alveolar consolidation process known as *acute silicoproteinosis or acute silicosis*.
   b. Silicosis is characterized by nodules in the upper lung lobes.
   c. Silicosis can be slowly progressive or can lead to progressive massive fibrosis.
   d. Silicosis puts an individual at increased risk for tuberculosis.
   e. Those with silicosis should be screened annually for tuberculosis.

C Solvents are capable of dissolving other substances.

1. Solvents are a diverse category of chemicals, defined by their ability to dissolve other substances; some are chemical reactants.
2. Many solvents are lipid soluble and can cross cell membranes easily.
3. Solvents generally have short half-lives in the body; they are metabolized in the liver and excreted through exhalation or in the urine.
4. Acute health effects of solvent exposure include central nervous system effects such as dizziness, confusion, convulsions, coma, and death.
5. Aspiration of solvents can sometimes lead to chemical pneumonitis, which can be fatal; this is the main risk when petroleum distillates are ingested.
6. Chronic health effects associated with solvents can include neurobehavioral dysfunction, peripheral neuropathy, liver disease, renal disease, dermatitis, and reproductive disorders.
7. Benzene is an aromatic hydrocarbon found in the petrochemical industry and as a component of gasoline.
   a. Chronic exposure to benzene can cause acute myeloblastic leukemia, aplastic anemia, and cytopenia.
   b. The OSHA standard for benzene-exposed workers includes requirements for periodic complete blood counts with criteria for follow-up and referral.
8. Carbon disulfide is sometimes used as a grain fumigant; exposure also occurs in the manufacture of rayon and rubber.
   a. Skin or eye contact with carbon disulfide can cause severe chemical burns.
   b. Chronic exposure to carbon disulfide can lead to nervous system effects of peripheral neuropathy, Parkinson-like effects, cranial neuropathies, and optic neuritis.
   c. Vascular effects of carbon disulfide include accelerated atherosclerosis with hypertension, elevated cholesterol, and changes in retinal blood vessels.
   d. Carbon disulfide is a reproductive toxin that causes decreased and abnormal sperm and increased risk of spontaneous abortions.

9. Ethylene oxide is used as a sterilant in hospitals; other exposures occur in industry.
   a. Acute toxic effects of ethylene oxide exposure include irritation of the eyes and respiratory tract and burns.
   b. Chronic exposure leads to neurotoxic and reproductive effects and possibly to chromosomal changes and leukemia.
   c. The OSHA standard for ethylene oxide includes medical surveillance requirements.
   d. Exposure-prevention efforts have included improvements in sterilization equipment and ventilation.
10. Formaldehyde exposure occurs in laboratories, during use of formaldehyde resins in particle board and other building materials, and in paper, rubber, and dye manufacturing.
   a. Acute exposure to formaldehyde leads to irritation of the upper and lower respiratory tract.
   b. Chronic formaldehyde exposure is linked to asthma and allergic dermatitis.
   c. Formaldehyde causes nasal cancer in animal models and is a possible human carcinogen.
   d. The OSHA standard for formaldehyde has medical evaluation requirements that include periodic administration of a questionnaire.
11. *n*-Hexane is used in thinners, glues, and the manufacture of rubber.
   a. *n*-Hexane causes a sensorimotor polyneuropathy.
   b. The toxic metabolite of *n*-hexane is 2,5-hexanedione.
   c. The distal portions of long nerves, such as those of the extremities, are most susceptible.
   d. The pattern of sensory loss is that of stocking-glove (feet/ankles and hands/wrists), and motor function is also impaired.
   e. After exposure ceases, the neuropathy often continues to worsen before improving; residual signs and symptoms may persist.
12. Methylene chloride is used as a degreaser and is the active agent in furniture strippers.
   a. Acute exposure to methylene chloride leads to central nervous system depression.
   b. Methylene chloride is metabolized to carbon monoxide; toxic effects are associated with this asphyxiant.
   c. The OSHA standard for methylene chloride requires medical surveillance.
13. Toluene has been used as a substitute for benzene and is used in many household products, including inks, aerosol paints, and dyes.
   a. Toluene is an irritant of the respiratory tract, causes central nervous system depression, and is toxic to the fetus.
   b. Toluene products, such as spray paint, are favored by solvent abusers. Long-term, high doses of toluene, such as those experienced by chronic abusers, are associated with severe neurobehavioral dysfunction, and cerebellar signs such as ataxia and poor coordination; abusers also commonly die from cardiac arrythmias.
   c. A major metabolite of toluene is hippuric acid; medical surveillance is based on urinary hippuric acid levels.
14. Trichloroethylene is commonly used in degreasing operations.
   a. High exposure levels cause liver and kidney toxicity.

b. The metabolite dichloracetylene causes trigeminal neuropathy with facial numbness and masseter muscle weakness.
c. Trichloroethylene may also cause optic neuropathy and may be linked to ventricular arrhythmias.
d. Symptoms are worse in the presence of ethanol; the combination of ethanol and trichloroethylene may cause what is known as the *degreaser's flush*.

D Pesticides are designed to destroy pests such as insects, nematodes, and rodents and have the potential to cause harmful effects in humans.

1. Pesticides are a potential toxin for agricultural workers, home pesticide users, and workers who manufacture these agents.
2. Organophosphates are one class of pesticide; it includes parathion and malathion.
   a. These pesticides inhibit acetylcholinesterase, allowing the accumulation of acetylcholine at synapses.
   b. Parasympathetic responses include diarrhea, urination, miosis, bronchospasm, emesis, lacrimation, and salivation ("DUMBELS") and bradycardia.
   c. Nicotinic responses include weakness, paralysis, muscle twitching, and tachycardia; central nervous system effects range from excitation to depression to seizures.
   d. Death is caused by respiratory failure.
   e. Treatment for organophosphate toxicity is atropine and 2-PAM (pralidoxime).
   f. Medical surveillance includes plasma and red blood cell cholinesterase levels.
3. Carbamates are a class of pesticide that includes aldicarb and carbaryl.
   a. Their action is similar to that of organophosphates, but symptoms are less severe and of shorter duration.
   b. The treatment is atropine, but not 2-PAM.
4. Organochlorines include the well-known examples of chlordane and DDT (dichlorodiphenyl-trichloroethane).
   a. Organochlorines are very persistent in the environment.
   b. In humans, these pesticide are stored in fat; consequently, they have a long half-life in the body.
   c. Because of their toxicity and persistence, carbamates are not commonly used at this time.
   d. Acute toxic effects are related to the nervous system and include weakness, paresthesias, mental status changes, and seizures.
   e. Chronic toxic effects include liver, kidney, and possibly carcinogenic outcomes.

E Asphyxiants are substances that deprive the tissues of oxygen.

1. Asphyxiants are inhaled and result in hypoxia or anoxia; angina and adverse effects to a fetus are other potential consequences.
2. Simple asphyxiants displace oxygen in the atmosphere; oxygen is then unavailable to the body.
   a. Examples are carbon dioxide, argon, methane, and nitrogen.
   b. Treatment for exposure to simple asphyxiants is oxygen.
3. Chemical asphyxiants interfere with the body's ability to transport or use oxygen.

4. Carbon monoxide (CO) is an example of a chemical asphyxiant; sources are incomplete combustion and methylene chloride metabolism.
   a. CO binds to hemoglobin; the affinity of hemoglobin for CO is much greater than it is for oxygen.
   b. The transport of oxygen is therefore inhibited.
   c. Long-term central and peripheral nervous system effects can result from acute exposure to CO.
   d. The treatment is oxygen, sometimes under hyperbaric conditions.
5. Hydrogen cyanide is another example of a chemical asphyxiant.
   a. Sources of hydrogen cyanide exposure are pesticides, gold and silver purification, combustion of some synthetic materials, and chemical processes.
   b. Hydrogen cyanide is characterized by an odor of almonds that many people cannot detect.
   c. Hydrogen cyanide inhibits cellular enzymes, preventing the use of oxygen for energy production.
   d. Treatment includes the administration of oxygen and the use of cyanide kits that include nitrites and thiosulfate; these help to bind and detoxify cyanide.

Industrial hygiene

XIX Overview of Industrial Hygiene

Industrial hygiene refers to the anticipation, recognition, evaluation, and control of environmental factors or stresses arising in or from the workplace, which can cause injury, sickness, impaired health and well-being, or significant discomfort among workers or among citizens (Smith & Schneider, 2000).

A **The field of industrial hygiene draws on knowledge from many scientific disciplines, including engineering, physics, chemistry, and biology.**

B **Professional organizations for industrial hygienists include the American Industrial Hygiene Association and the American Conference of Governmental Industrial Hygienists (Appendix I).**

XX Sources of Information to Facilitate Hazard Recognition

A ***Qualitative assessment* of the work site requires the following:**
1. Communication with key personnel, such as plant management representatives and supervisors, to learn about materials and processes
2. Communication with other occupational and environmental health professionals to learn about health problems that may be related to exposure
3. Communication with workers and their representatives to learn about their perceptions of exposure

B ***Observational assessments*, are achieved through strategies such as walk-through surveys, focused inspections, and job-hazard analyses. (Chapter 10 describes these and other strategies in detail.)**

C **Material safety data sheets (MSDSs) provide the following information (US Department of Labor [USDL], OSHA, 1998):**
1. Identification of the material
2. Hazardous chemicals and their common names

3. Physical and chemical properties
4. Routes of exposure
5. Acute and chronic health effects
6. First aid information
7. Exposure limits
8. Precautions for safe handling and use
9. Control measures
10. Organization responsible for preparing MSDSs and contact information

D Some caveats are in order when using information provided in MSDSs (Beach, 2002).

1. The quality of MSDSs is variable; the information is sometimes outdated and unclear, and may be inconsistent with the same materials from different manufacturers.
2. Recommended protective measures need to be considered in the context of the specific material's actual use and the control measures in effect.
3. An MSDS for a mixture may not include all chemical components, particularly if their concentration is low or if they are not recognized as hazardous.

XXI Sampling Methods

Approaches for estimating the dose of an exposure received by workers include personal and environmental *sampling* and biologic and medical *monitoring* (Lippmann, 2000). Chapter 10 provides additional details regarding sampling and monitoring methods.

A Some sampling techniques measure exposure before absorption has occurred.

1. Approaches to workplace sampling depend on the type of agent and the route by which it is absorbed by workers (Smith & Schneider, 2000).
   a. *Skin wipes* and *cloth patches* measure amounts of materials that have come in contact with the skin.
   b. *Noise dosimeters*, worn near the worker's ear, record work-site noise levels.
   c. *Airborne contaminants* can be assessed by means of personal monitoring at the worker's breathing zone or environmental monitoring in the work area.
2. Several important factors govern whether the sampling results truly represent worker exposure (Gross and Morse, 1996).
   a. The location of the sampling device with regard to the worker and source of contaminant should be based on worker location and movements.
   b. The workers to be sampled usually are those who are most highly exposed.
   c. Timing of sampling should take into account seasonal changes, shifts, unintentional releases, and other sources of variation.
   d. Length of sampling time generally represents a full shift.
   e. The number of samples depends on the type of instrumentation, concentration of the contaminant, and purpose of sampling.

B Biologic and medical monitoring identify the presence of a chemical in the body following exposure.

C Exposure records are extremely important and must be maintained for at least 30 years.

XXII Airborne Contaminants

Levels of airborne contaminants can be compared with the following guidelines and standards.

A **Permissible exposure limits (PELs) are developed by OSHA.**
1. PELs are promulgated by OSHA and are legally enforceable.
2. PELs are 8-hour, time-weighted averages of airborne exposure.

B **Threshold limit value (TLV) guidelines are developed by the American Conference of Governmental Industrial Hygienists (ACGIH).**
1. TLVs are published annually by that organization (Appendix I).
2. TLVs are 8-hour, time-weighted averages, with the following exceptions:
   a. *Ceiling levels*, or uppermost TLV levels, cannot be exceeded.
   b. *Short-term exposure levels* are the maximum, 15-minute, time-weighted averages permitted over a workday, with at least 60 minutes between successive exposures.

C **Recommended exposure levels (REL) are developed by the National Institute for Occupational Safety and Health (NIOSH); these levels are the exposures that, in the judgment of NIOSH, will not cause adverse health effects in most workers.**

XXIII Control Strategies for Occupational Exposures

Approaches to eliminating or reducing exposure to hazardous substances at the work site are ordered into a *hierarchy* based, in general, on their degree of overall effectiveness.

A ***Engineering controls*** **are the preferred way to reduce or eliminate exposures and include measures designed to enclose or isolate operations, improve ventilation, or removal or substitution of toxic materials.**

B ***Administrative controls*** **also minimize exposure and include monitoring or surveillance programs, worker rotation, and training to address work practices.**

C ***Personal protective equipment*** **such as ear plugs and muffs, safety goggles, gloves, coveralls, and respirators, are considered the least-preferred control strategy.**

Ergonomics

This section provides a general overview of ergonomics. A sample ergonomics program and more details about ergonomics and work-related musculoskeletal disorders are presented in Chapter 16.

XXIV Overview of Ergonomic Terms and Principles

The term *ergonomics* (sometimes known as *human factors*) refers to the study of the interaction between humans and their work (Konz & Johnson, 2000).

A **The term literally means the *laws* (from the Greek word *nomos*) *of work* (*ergos*).**

B **The field of ergonomics is multidisciplinary, involving health professionals, engineers, behavioral scientists, physiologists, and others.**

C **Its purpose is to prevent acute and chronic injuries, make work sites comfortable, enhance productivity, reduce fatigue and errors, and promote job satisfaction.**

D **Proper job design can make jobs appropriate for workers of both sexes and all ages; considerations are given to size, strength, visual capacity, hearing, capabilities, and limitations.**

E **Ergonomics seeks to fit the job to the person rather than the person to the job.**

XXV Work-Related Musculoskeletal Disorders

A **Several *musculoskeletal disorders* can be caused or aggravated by work-site factors (NRC, 2001).**

1. Affected tissue structures include muscles, tendons, ligaments, peripheral nerves, blood vessels, joints, cartilage, and bones.
2. Problems occur in the upper and sometimes lower extremities, cervical spine, and lower back; symptoms of musculoskeletal disorders include pain, swelling, erythema, numbness, and paresthesia.

B **The major work-site risk factors for work-related musculoskeletal disorders of the upper extremities are repetition, force, mechanic stresses, awkward postures, low temperatures, and vibration (NIOSH, 1997). The goal in task and tool design is to avoid or minimize these risk factors.**

1. *Repetition* refers to the performance of the same or similar tasks again and again; for example, if one work cycle (a series of motions that is then repeated) lasts less than 30 seconds, or if, in the case of cycles lasting several minutes, there are subcycles that constitute more than 50% of the overall cycle, the job is generally considered repetitive
2. *Force* is exerted in tasks that require lifting weights, handling heavy tools, pinching with the fingers, or applying other grips while working.
3. The combination of repetition and force is particularly associated with carpal tunnel syndrome (NIOSH, 1997).
4. *Mechanical stress* refers to the forces that result from a worker's direct contact with work surfaces or tools.
5. The *compressive forces* that result from striking objects with hand-held tools or from leaning against hard surfaces or corners on work tables can lead to nerve compression disorders.

C **Work frequently requires workers to assume awkward positions for prolonged periods or repetitive shorter periods; deviation from neutral posture has been identified as a risk factor for injury, as illustrated by the following (NIOSH, 1997):**

1. Cervical spine injury—caused by extreme neck flexion and twisting
2. Back injury—caused by twisting at the waist; lifting with legs straight; bending and reaching repetitively; maintaining awkward postures for long periods; carrying, pulling, pushing, or lifting heavy objects from below the knees or above the shoulders; or lifting weight beyond one's capabilities
3. Shoulder injury—caused by raising the arm or elbow above midtorso without support, reaching behind one's body
4. Forearm/elbow injury—caused by repeated rotation (i.e., supination and pronation)

5. Wrist/hand injury—caused by repeated wrist flexion and extension, holding the hand in ulnar deviation

D ***Vibration*** **caused by power tools or other work equipment can adversely affect the upper extremities.**

E **Whole-body vibration, such as that experienced by drivers of trucks and heavy equipment, can affect the back, lower extremities, and possibly shoulder and neck.**

F ***Cold environmental conditions*** **have an effect on manual dexterity and muscle strength and may directly or indirectly cause hand disorders.**

XXVI High-Risk Jobs

Several types of jobs are considered particularly high risk in terms of ergonomic exposures:

A **Office work presents ergonomic hazards that are associated with equipment as well as with characteristics of the overall working environment.**

1. Work with technology such as computers may require individuals to assume static or awkward positions for typing if workstations are not properly adjusted.
2. Other conditions in the office environment that can introduce hazards include poor lighting, obstructions in walkways, slippery floors, and heavy objects.

B **Manual materials handling is a part of many jobs, from loading trucks and moving heavy goods to working in grocery stores.**

1. In addition to repeated bending, lifting, and twisting, this work sometimes involves exposure to vibration.
2. The risks of back injury are high for these types of jobs.

C **Assembly work is often machine-paced, giving the worker little control over the speed at which he or she works.**

1. Repetitive motions tend to be characteristic of assembly work.
2. Sometimes work is performed in static or awkward postures or with poorly designed tools.

XXVII Evaluating Risk Factors

Various methods can be used to evaluate work sites for ergonomic risk factors; each approach has its advantages and disadvantages.

A ***Interviews or questionnaires*** **ask workers directly about their work.**

1. Advantages: Workers have the most complete view of their tasks throughout all work periods. This method may reveal factors that might not otherwise be noted.
2. Disadvantages: There may be high variability in the way workers report their perception of work performance; reports may be incomplete or biased.

B ***Observation and use of checklist*** **involves observing workers while they work and noting any risk factors.**

1. Advantages: Observers using the same methods will look at all workers in the same way and thus introduce less variability; this method is fairly efficient—that is, one observer evaluates many workers in their work setting.

2. Disadvantages: People may change the way they behave when they are under observation; the limited time period for observation may cause some risk factors to be missed; and observers must be trained to be accurate and consistent.

C ***Videotaping and analysis*** **is done by taping the worker on the job and later conducting a detailed analysis of motions and other risk factors.**

1. Advantages: Analysis is recorded and does not rely on one person's assessment; tape can be repeated, slowed, or frozen to evaluate details of work tasks; measurement of time and motion can be highly accurate.
2. Disadvantages: Videotaping requires expensive equipment and experienced personnel; behavior may change during taping; only a small window of worker's time is recorded, and therefore it is not useful for evaluating highly variable tasks.

XXVIII Ergonomic Improvements

Some considerations and guidelines for analyzing or designing jobs are as follows (National Research Council, 2001).

A **General environment: Provide adequate illumination, comfortable levels of temperature and humidity; good visibility of labels and signs; and clear, audible auditory signals.**

B **Workstations and chairs: These should be adjustable to accommodate workers of different sizes.**

C **Layout: Place tools, controls, and materials in front of the worker to prevent twisting, reaching, and bending; keep work space free of obstacles.**

D **Postures: Avoid static postures; locate and orient work to promote neutral positions.**

E **Repetition: Engineer the product or process to reduce repetition; vary tasks; rotate workers to different jobs; allow rest time.**

F **Forces: Reduce the size and weight of objects held; use power grips rather than pinch grips; balance tools; provide correctly fitting gloves (not tight or bulky); sharpen tools often.**

G **Mechanical stresses: Ensure that handles on equipment fit the worker's hands; pad or eliminate sharp edges.**

H **Vibration: Eliminate vibrating tools if possible; isolate sources of vibration; keep tools and equipment properly maintained; maintain even floor surfaces to reduce vibration from driving; reduce driving speeds of vehicles such as forklifts.**

I **Lifting: Reduce size and weight of tools and objects that are lifted often; use mechanic lifting devices; use gravity to move work; raise the work (or lower the operator); provide grips and handles; reduce friction where objects are slid from one point to another; increase friction when objects are held; evaluate lifting tasks according to NIOSH lifting guidelines (NIOSH, 1994, http://www.cdc.gov/niosh/94-110.html)).**

J **Work organization: Staff adequately, alternate physically demanding and mentally demanding tasks vary the rate and nature of tasks as much as possible; provide breaks (more-frequent short breaks are generally better than less frequent long breaks).**

Injury epidemiology

XXIX Occupational Injury Epidemiology

The study of the natural history of injuries helps to define the host, agent, vector, and environmental (psychosocial and physical) factors that contribute to injury.

A Characteristics of occupational injury are as follows:

1. Occupational injuries are not random events.
2. Injuries are predictable and preventable.
3. Injuries result when energy is exchanged in a manner and dose sufficient to overcome the host's threshold of resistance in the presence or absence of certain environmental conditions (Table 5-4).

B The following are examples of sources of injuries:

1. *Mechanic or kinetic energy*—Impact of an object, dashboard, floor, knife, noise, extreme air pressure (explosion)
2. *Thermal energy*—Steam, flame, hot substances, and lasers
3. *Electric energy*—Man-made sources, such as high-tension wires, and natural sources, such as lightning
4. *Radiation*—Both ionizing and nonionizing, including sunlight, radioactive minerals, and radiotherapeutic devices, implants, and pharmaceutics
5. *Chemical energy*—Effects of acids, bases, poisons/toxins, and irritants
6. *Absence* of energy-producing mechanisms necessary to sustain life, such as absence of respiration secondary to drowning

C The energy-exchanging event causing an injury can be studied as a sequence of interactions viewed in pre-event, event, and post-event phases.

XXX Countermeasures

Strategies that are effective in preventing or reducing the extent of injuries were identified and categorized by William Haddon (1963; 1979) as control *countermeasures* (Table 5-5).

TABLE 5-4

Example of risk factor analysis for injury occurrence: a fracture

Host	Injury	Agent	Vector	Exposure event	Physical environment	Sociocultural environment
Individual • Age • Sex • Health status • Physical condition	Fracture	Kinetic energy	Cement floor	Slip and fall	Oil, grease, dirt, and water on floor; painted cement floor; equipment and supplies on floor; lighting; integrity of floor	Attitude toward housekeeping; costs associated with injuries and lost time not accounted for under department budget

TABLE 5-5

Haddon matrix: case example of control countermeasures—slips and falls on the same level in a maintenance area

Phase	Human factors	Environmental and engineering factors	Social, legal, and political factors
Pre-event	• Shoes—nonskid soles • Safety training—increase awareness • Establish work practices, including housekeeping	• Nonskid floor (paint, strips) • Oil/grease absorbing material for spills • Good lighting • Proper storage and use of equipment and supplies	• OSHA inspections and regulation compliance • Safety audit • Risk management—insurance losses and litigation
Event	• Padded clothing • Optimal physical condition of workers	• Energy absorbing floors (with nonskid surface) • Emergency notification system	• Injury investigation, reporting, and tracking • Coordination of medical care
Post-event	• Effective first-aid response • Interaction with ambulance and hospital emergency services	• Prompt access to work location • Access to first-aid equipment and supplies	• Emergency response system—triage, first aid, evacuation, and definitive medical care

Source: Haddon, 1963 and 1979. In Hayes, 1990.

A Pre-event countermeasures include:

1. Preventing the creation of the workplace or community hazard
2. Reducing the severity of the hazard
3. Preventing the release of the hazard
4. Modifying the rate of release of the hazard
5. Separating the hazard from the individual

B Event countermeasures include:

1. Placing a physical barrier between the hazard and the person
2. Modifying the basic qualities of the hazard
3. Increasing the individual's resistance to injury

C Post-event countermeasures include:

1. Rapidly evaluating the injury that has occurred or is occurring, preventing continuation of the injury, and mitigating or halting the extension of its effects.
2. After stabilizing the injured party, providing definitive medical and surgical treatment and rehabilitative and reconstructive care, with a goal of restoring the worker to an optimal level of functioning.

XXXI Implications for Occupational and Environmental Health Nurses

A An understanding of occupational injury epidemiology will enable occupational and environmental health nurses to analyze, characterize, and minimize the potential for injury in their work setting.

B The occupational and environmental health nurse can use injury prevention and control principles to study, prevent, and control the occurrence of injury-producing events and the extent of injury.

Social and behavioral sciences

XXXII Effects of Social Conditions and Behavior on Health

Social and behavioral sciences examine the influences of social milieus and lifestyles on their health.

A Modern approaches to health services have been influenced by a variety of factors.

1. Life expectancy has substantially increased.
2. Patterns of disease have changed; the leading causes of death have shifted from infectious diseases to chronic diseases, often related to behaviors and environmental factors.
3. Traditional approaches such as the medical paradigm are not responsive to many modern-day health problems.

B Research in the behavioral sciences has examined the relationship between human behavior and the occurrence of illness and injury.

1. The behavior of individuals and groups is complex, and understanding behavior is a complicated process.
   a. People often make choices that they know are not good for their health (e.g., not wearing hearing protection).
   b. The key to effecting behavioral change is understanding the human thought processes that affect behavior (e.g., ear plugs are not comfortable).
   c. Focusing on behavioral strategies may result in healthier behavioral choices (e.g., allowing worker participation in selection of hearing protection devices).
   d. Behavioral approaches to research may also facilitate a better understanding of the neurologic and behavioral effects of certain exposures (to lead, for example).
2. Many theories and models have been developed to help us understand behavior. Chapter 14 presents examples of behavioral theories and models.
   a. These theories and models explain why people behave as they do.
   b. They provide a rich source of ideas that can be used to further our understanding of behavior.
   c. They enable health care providers to develop more effective interventions.

C Research in the social sciences has examined the contribution of social environments to the occurrence of illness and injury.

1. There is increased recognition of the relationship of social phenomena to health and illness outcomes.
2. Examples of social indices that may affect occupational health include rates of violence, divorce, and unemployment and the degree to which individuals have care-giving responsibilities or hold multiple jobs.
3. The provision of appropriate health services depends on complete understanding and appreciation of the nature of work and the social context of the workplace.

D Unique attributes of social and behavioral sciences include the following:

1. Qualitative techniques, which are more likely to be used for collecting data
2. Quality of life, which is an important outcome for the social and behavioral sciences; quality of life considers emotional, social, intellectual, physical, and spiritual health

XXXIII Health Promotion and Risk Reduction

Health promotion and risk reduction require an understanding of the psychosocial determinants of health (Glasgow, Lichtenstein, & Marcus, 2003).

A There is a need to develop organizational "healthy policy" as a strategy to improve workers' health.

1. Healthy policy facilitates and supports healthy behaviors.
2. Health-promoting and health-damaging policies of organizations are likely to receive increased scrutiny in the coming years (Oldenburg, Sallis, Harris & Owen, 2002).
3. Organizational change is a critical factor in achieving a healthy occupational environment.

B An important area that would benefit from the attention of the social and behavioral sciences is health promotion that reduces the effects of occupational and environmental exposures. The true benefit of this approach may only be apparent after several years.

C Social and behavioral sciences can identify and examine factors that threaten the health of workers.

1. The psychosocial environment of the workplace plays a critical role in the occurrence of occupational injury and illness. (See Chapter 15: Managing psychosocial factors in the occupational setting.)
2. The organization of work is influenced by the ideologies, values, and beliefs of people within the organization (managers and workers) and outside of it (scientists and government); these ideologies affect the social dimensions of the workplace.
3. The organization of work has been identified as a research priority by NIOSH (NIOSH, 1996).
4. Implementing strategies based on findings from social and behavioral investigations is likely to result in cost savings to employers and a better quality of life for workers.

REFERENCES

American Association of Occupational Health Nurses. (2003). Competencies in occupational and environmental health nursing. *AAOHN Journal, 51*(3), 290-302.

Arble, J. (2004). Toxicology Primer: Understanding workplace hazards and protecting worker health. *AAOHN Journal, 52*(6), 254-261.

Beach, J. (2002). The problem with material safety data sheets. *Occupational Medicine, 52*(2), 67-68.

Eisen, E. A, & Wegman, D. H. (2000). Epidemiology. In B. S. Levy and D. H. Wegman (Eds.), *Occupational health: recognizing and preventing work-related disease and injury* (4th ed., pp. 143-160). Philadelphia: Lippincott, Williams & Wilkins.

Frumkin, H., & Melius, J. (2000). Toxins. In B. S. Levy and D. H. Wegman (Eds.), *Occupational health: recognizing and preventing work-related disease and injury* (4th ed., pp. 309-333). Philadelphia: Lippincott, Williams & Wilkins.

Glasgow, R. E., Lichtenstein, E., & Marcus, A. C. (2003). Why don't we see more translation of health promotion research to practice: Rethinking the efficacy-to-

effectiveness transition. *American Journal of Public Health, 93*(8), 1261-1267.

Greenland, S., & Rothman, K. J. (1998). Measures of effect and measures of association. In K. J. Rothman and S. Greenland, (Eds.), *Modern Epidemiology* (2nd ed., pp. 47-64). Philadelphia, PA: Lippincott-Raven.

Gross, E. R., & Morse, E. P. (1996). Overview of industrial hygiene. In B.A. Plog, J. Niland, & P.J. Quinlan (Eds.), *Fundamentals of industrial hygiene* (4th ed., pp. 453–483). Itasca, IL: National Safety Council.

Hayes, W. (1990). Nursing advances in occupational injury prevention and control. In J.M. Radford (Ed.), *Recent advances in nursing (26). Occupational health nursing,* Edinburgh, Scotland: Churchill, Livingstone.

Institute of Medicine. (1995). *Nursing, health, and the environment* (A.M. Pope, M.A. Snyder, & L.H. Mood, Eds.). Washington, DC: National Academy Press.

Keller, L. O., Strohschein, S., Lia-Hoagberg, B., & Schaffer, M. A. (2004). Population-Based Public Health Interventions: Practice-Based and Evidence-Supported. Part I. *Public Health Nursing, 21*(5), 453-468.

Konz, S., & Johnson, S. (2000). *Work design: Industrial ergonomics* (5th ed.). Scottsdale, Arizona: Holcomb Hathaway Publishers.

Levy, B. S., & Nessetta, W. J. (2003). Neurologic effects of manganese in humans: A review. *Int J Occup Environ Health, 9*(2), 153-161.

Lippmann, M. (2000). Characterization of chemical contaminants. In M. Lippmann (Ed.). *Environmental toxicants: Human exposures and their health effects* (2nd ed., pp. 1-29). New York: John Wiley & Sons.

McCauley, L. A. (1998). Chemical mixtures in the workplace: Research and practice. *AAOHN Journal, 46*(1), 29-40.

National Research Council (NRC), National Academy of Sciences (NAS) (2001). Interventions in the workplace. In Panel on Musculoskeletal Disorders and the Workplace, *Musculoskeletal disorders and the workplace: Low back and upper extremities.* (pp. 310-329). Washington, D.C., National Academy Press.

National Institute for Occupational Safety and Health (NIOSH). (1994). *Applications manual for the revised NIOSH lifting equation..* (DHHS (NIOSH) publication 94-110): U.S. Department of Health and Human Services. Available at http://www.cdc.gov/niosh/94-110.html.

National Institute for Occupational Safety and Health (NIOSH). (1996). *National occupational research agenda.* (DHHS [NIOSH] Publication No. 96-115). Atlanta: U.S. Department of Health and Human Services.

National Institute for Occupational Safety and Health (NIOSH). (1997). *Musculoskeletal disorders and workplace factors. A critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back.* (DHHS [NIOSH] Publication No. 97-41). Cincinnati: U.S. Department of Health and Human Services.

Oldenburg, B., Sallis, J. F., Harris, D., & Owen N. (2002). Checklist of health promotion environments at worksites (CHEW): development and measurement characteristics. *Am J Health Promot, 16*(5), 288-99.

Papp, E. M., & Miller, A. S. (2000). Screening and surveillance: OSHA's medical surveillance provisions. *AAOHN Journal, 48*(2), 59-72.

Rothman, K.J., & Greenland, S. (1998a). Measures of disease frequency. In K.J. Rothman and S. Greenland, (Eds.), *Modern epidemiology* (2nd ed., pp. 29-46). Philadelphia, PA: Lippincott-Raven.

Rothman, K. J., & Greenland, S. (1998b). Causation and causal inference. In K. J. Rothman and S. Greenland. (Eds.), *Modern epidemiology* (2nd ed., pp. 24-26). Philadelphia, PA: Lippincott-Raven.

Smith, T. J. & Schneider, T. (2000). Occupational hygiene. In B. S. Levy and D. H. Wegman (Eds.), *Occupational health: recognizing and preventing work-related disease* and injury (4th ed., pp. 161-180). Philadelphia: Lippincott, Williams & Wilkins.

Sullivan, J. B., & Krieger, G. R. (2001). *Clinical environmental health and toxic exposures.* (2nd ed.) Baltimore: Lippincott Williams & Wilkins.

Takser, L., Mergler, D., Hellier, G., Sahuquillo, J., & Huel, G. (2003). Manganese, monoamine metabolite levels at birth, childhood psychomotor development. *Neurotoxicology,* 24, 667-674.

U.S. Department of Health and Human Services. (2000). *Healthy people 2010: understanding and improving health,* Washington D.C. Available at http://www.osha.gov/Publications/osha3084.pdf.

U.S. Department of Labor, Occupational Health and Safety Administration (1998). (p. 7) Chemical Hazard Communication, OSHA 3084 (revised 1998).