Chapter 20

ENVIRONMENTAL HEALTH

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INTRODUCTION

People continually interact with their environment, consciously and unconsciously, voluntarily and involuntarily. These interactions can affect health and performance, and performance is critical to successful mission accomplishment. Therefore, military leaders and those who advise them must be aware of how environmental factors affect performance and how adverse effects on performance can be reduced or eliminated.

The field of environmental health is diverse. This chapter addresses its broad aspects from both a general and a military perspective. The general topics provide basic background information for many physicians, nurses, and others with little or no formal training in the field. The military topics provide useful information to all those with responsibilities for environmental health in military situations, including those trained in this field but who are making the transition from a civilian to a military workplace.

Environmental health concerns occur in all phases of military operations—whether in garrison or during mobilization, deployment, sustainment, and redeployment. They encompass deployments aboard ship, to highly industrialized air bases, and to primitive field settings. And although the traditional focus of environmental health on acute effects is still with us in the age of Agent Orange and Persian Gulf illness, chronic effects are now also quite relevant. Environmental health is a continuum of great breadth, and practices within each area need to be explicitly linked. This is also increasingly appropriate for the military because the military mission is evolving to encompass operations other than war, which often involve the military preventive medicine professional in issues well beyond those of traditional field sanitation. Knowledge of the enduring principles, which are relevant to all the services, will help prepare military public health professionals for their ever-expanding role. Military personnel have to appreciate the diversity and complexity of environmental health topics and functions, and the need for a team approach to prevent or solve environmental problems. The expertise of environmental health professionals, who often work as a multidisciplinary team, is truly needed to help plan and execute health and environmental protection for all military operations.

OVERVIEW OF ENVIRONMENTAL HEALTH

Definition

There are dozens of definitions of environmental health that reflect acceptance of basic concepts but show a lack of consensus about all aspects of the field. One that was developed by 75 federal, state, and local environmental health and protection leaders is:

> ...the art and science of protecting against environmental factors that may adversely impact human health or the ecological balances essential to long term human health and environmental quality. Such factors include, but are not limited to air, food and water contaminants; radiation; toxic chemicals; wastes; disease vectors; safety hazards; and habitat alterations.[1(p29)]

Alternate definitions for environmental health may encompass subject areas that are not included in this chapter or elsewhere in this text. The reader should consult other references for these topics.[2–7]

In the US Department of Defense (DoD), the working definition of environmental health is the science and practice of anticipating, recognizing, evaluating, and controlling environmental factors to prevent adverse health effects. Environmental factors include biological, chemical, and physical (including radiological) matter or phenomena.

Environmental Health Paradigm

To affect the environment or human health, a series of events must occur. A model for looking at these events is called the environmental health paradigm or chain (similar to the chain of infection) and includes a contaminant or environmental agent source, a mediation process, and a susceptible receptor (Figure 20-1).

Sources of environmental agents are ubiquitous in the natural environment, workplace, and home. Environmental agents may be anthropogenic or they may exist naturally in the environment, either at acceptable concentrations or at concentrations harmful to people (eg, radon, fluorides, arsenic, and nitrates in water sources). Examples of environmental agents and health threats are listed in Table 20-1. Some agents are released intentionally in quantities believed to be safe. Examples of these are incinerator emissions and wastewater treatment plant effluents. Accidental and deliberate unlawful releases also may occur.

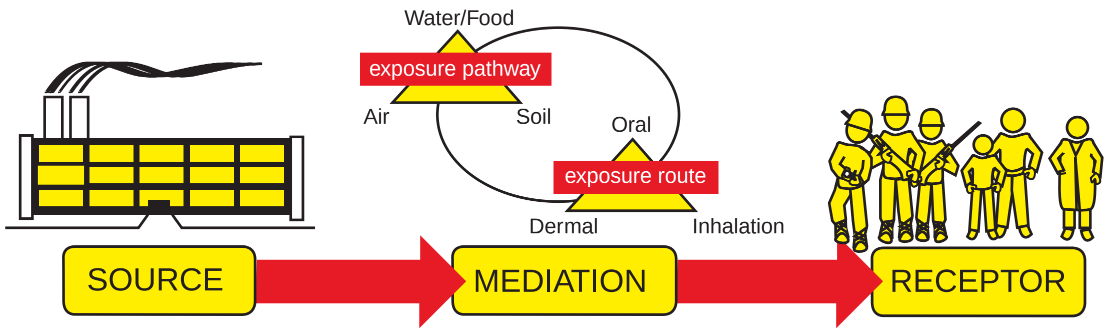

Fig. 20-1. The *Environmental Health Paradigm* depicts the movement of environmental contaminants from a pollution source to an ultimate receptor. This process involves contaminant movement through any or all environmental media (air, water, soil). People ultimately are exposed to pollution by ingestion, inhalation, skin absorption, or any combination of these. Understanding this process allows preventive medicine and environmental health professionals to intervene to mitigate or prevent adverse health effects.

Mediation is the process through which environmental agents travel by means of the exposure pathway (ie, air, soil, water) to susceptible receptors, whether human or some other form of life. The receptor can be challenged through dermal, inhalation, and ingestion routes. These agents may contact receptors directly, or they may successively pass through plants and animals and may increasingly concentrate at each level (bioaccumulation). Toxicity can increase or decrease due to chemical changes as substances pass through the environment or organisms (biotransformation). The exposure routes—inhalation, ingestion, skin absorption—provide an external exposure to the receptor. The nature and the concentration of the agent, the route of absorption, and other factors will determine the receptor's external dose.[8]

TABLE 20-1

EXAMPLES OF ENVIRONMENTAL AGENTS AND HEALTH THREATS

Parameter	Examples
Physical	
Ionizing Radiation	Alpha-, beta-, gamma-, and X-rays
Nonionizing Radiation	Radio frequency radiation, microwaves, lasers
Temperature Extremes	Heat, cold
Noise	Gun shot, aircraft engine
Chemical	
Heavy Metals	Lead, mercury
Solvents	Benzene, toluene, methylethyl ketone
Biological	
Viruses	Rabies (rhabdovirus), viral hepatitis
Rickettsia	Rocky Mountain spotted fever (*Rickettsia rickettsii*)
Chlamydia	Ornithosis (*Chlamydia psittaci*)
Bacteria	Plague (*Yersinia pestis*), food poisoning (*Clostridium botulinum*)
Fungi	Candidiasis (*Candida albicans*), histoplasmosis (*Histoplasma capsulatum*)
Parasites	Hookworm disease (*Necator americanus*, *Ancylostoma duodenale*), ascariasis (nematodes)

Scope

Based on the DoD's working definition, the scope of environmental health includes all topics that are considered environmental factors with the potential to cause adverse health effects. Science and practice are components; environmental health professionals must understand the relevant science and apply it in practice to protect human health, by both preventing and solving problems. In this approach, the practice of environmental health includes critical functions of setting standards, implementing controls, conducting monitoring, and setting policy.

Standards by definition are "accepted measures of comparison for quantitative or qualitative value."[9(p1131)] Environmental health standards are really consensus standards—they result from collective opinion or general agreement and are a compromise of conflicting opinions. These consensus standards are advocated by an organization (eg, the US Environmental Protection Agency [USEPA], the American Conference of Governmental Industrial Hygienists, the World Health Organization, individual countries, and groups of countries such as the North Atlantic Treaty Organization) for health and economic reasons and reflect minimally acceptable performance. Standards are also dynamic. Standards change because of (a) new knowledge and technology, such as improved analytical methods, and (b) changing social values, such as greater concern for human health and protection of the environment.

Standards and the standard-setting process contain four major components: science, economics, legal issues, and policy. Scientific aspects of environmental standards include basic science, toxicology, epidemiology, and modeling. The economic component addresses economic loss and potential profit caused by a standard. The legal component includes the ability to prosecute those who violate standards. The policy component involves such questions as whether or not there should be certain standards and when, where, and how the standard will be applied. Social values, scientific knowledge, and public opinion compete and often have quite diverse positions in the standard setting process.

The next critical function of environmental health is implementing controls. Environmental health professionals use three categories of control or control methods: engineering controls, administrative controls, and personal protective equipment. These control methods should generally be used in the order presented. That is, one should routinely try first to apply engineering controls to achieve a quality environment or meet standards or other desired conditions. An exception to this order would be to use administrative methods to remove or eliminate potential contaminants. The second choice should normally be administrative controls, such as reducing the work hours to limit total exposure. The last choice should be personal protective equipment because it is the most difficult to enforce.[10] Examples of controls include the following:

- Substituting less harmful material,
- Changing or altering a process,
- Using zoning to limit selected activities,
- Treating to remove specific contaminants, and
- Cleaning up past contamination.

To monitor by definition is "to check systematically or scrutinize for the purpose of collecting specified categories of data."[9(p765)] The categories of environmental monitoring are usually given as operational monitoring and health monitoring, although some might add regulatory monitoring as a third category. Operational monitoring is that surveillance done by managers and operators to ensure that facilities and processes are operating within design expectations. It consists of walk-through surveys, sampling and analysis, and decision making. Operational monitoring is conducted frequently, such as each shift or each day, but only a few parameters are analyzed.

In contrast, health monitoring is that surveillance done by health professionals. It consists of sanitary surveys, sampling and analysis, and interpretation or decision-making concerning the information and situation. One or more sanitary surveys should be conducted for each topical area on a periodic basis, such as initially, monthly, quarterly, or annually based on professional judgment. Sanitary surveys help environmental health professionals anticipate, recognize, evaluate, and control environmental factors that might adversely affect health. Sampling and analysis are also conducted for the same purpose and on a similar periodic basis. Often, many more parameters are analyzed than with operational monitoring but on a much less frequent basis, and certified laboratories are used if possible. Monitoring is not complete until interpretation or decision making has occurred. Primary decisions may be that the situation presents no significant threat (eg, water is safe to drink) or that specific actions need to occur to reduce risks of adverse health effects. Health decisions must be made by health professionals and not left to operational personnel by default.

Regulatory monitoring is a combination of operational and health monitoring. The regulator, the EPA for example, requires that certain monitoring or sampling and analysis be conducted and reported on a specified basis. Health professionals should not be satisfied with results from regulatory monitoring only because it often does not give the complete picture.

Policy is a selected course of action to achieve a desired result. The desired result is often expressed best by use of a vision statement, goals, and objectives. Policy studies should be conducted to help achieve better policy. A policy study is an assessment of the current situation, plus a vision for the more ideal situation, and an implementation plan for options to achieve the vision. Trying to see current reality clearly is the first step (Exhibit 20-1). Personal and organizational values, potential, and opportunities can help formulate a vision; setting goals and objectives helps communicate the vision more specifically to others. Making a commitment to create the desired results requires an awareness of obstacles and the available options and an implementation plan. Finally, it should be noted that any new choice will create a new situation with new problems.

Managing the Risk Process

The military medical community may be required to recommend how to implement environmental health standards or assist in developing militarily unique standards or to determine the applicability of standards to special populations (eg, refugees, prisoners of war, local nationals). In any of these situations, it is important for the medical community to understand how health-based criteria and standards are developed. Strategies to prevent or mitigate adverse environmental factors can be developed to manage risk by focusing on the environmental health paradigm.

There are three main phases in the development of health-based environmental standards: risk assessment, risk management, and risk communica-

EXHIBIT 20-1

POLICY STUDY PROCESS

1. Where are we now and where are we headed? Problems Attitudes, perceptions, behavior Institutions and infrastructure Resources	→	PROBLEM STATEMENT
2. Where do we want to go? Our values Our potential Opportunities	→	VISION Goals Objectives
3. What are the obstacles?	→	ISSUES Dilemmas
4. What are the best routes to get us to the objectives? Framework or map Criteria for success	→	POLICY OPTIONS
5. How do we take and hold the objective? Problems Attitudes, perceptions, behavior Institutions and infrastructure Resources	→	IMPLEMENTATION PLAN

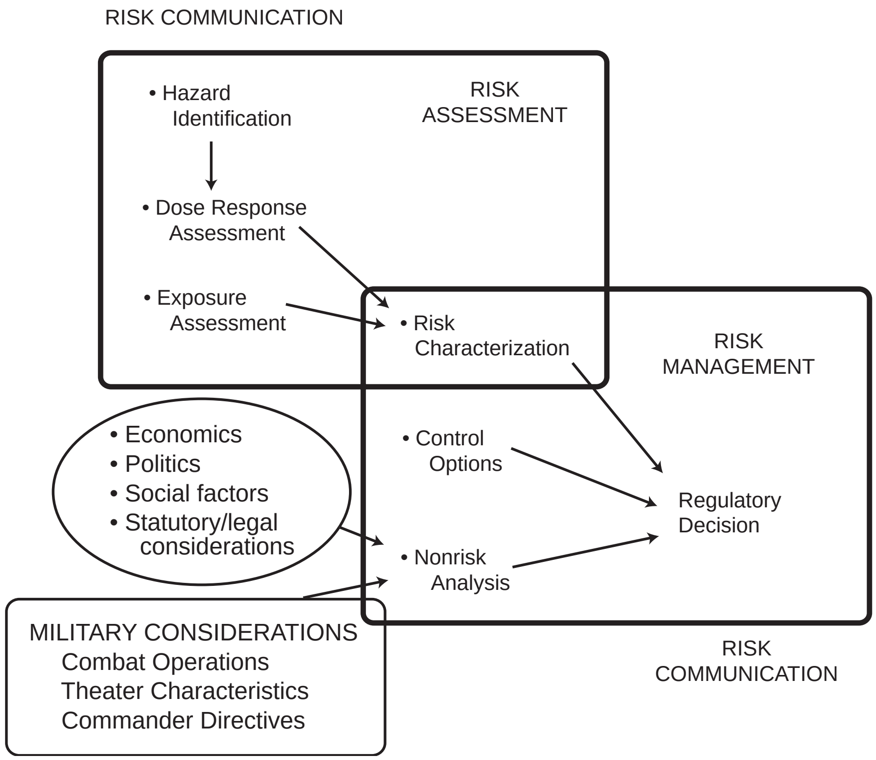

Fig. 20-2. The relationship between Risk Assessment, Risk Management, and Risk Communications. Risk assessment is the scientific determination of the potential health outcome that contaminants may inflict on people and the environment. Risk assessment, however, is only one component of risk management, which also includes a variety of other socioeconomic and technological factors and militarily specific concerns. Controlling risks typically is successful when major stakeholders are informed (risk communication) and involved in the process.

tion.[11] Their relationships to each other are illustrated in Figure 20-2. The risk assessment precedes the risk management process, but both involve several steps. Risk communication should occur throughout the process. Both the National Academy of Sciences[12] and the Presidential/Congressional Commission on Risk Assessment and Risk Management[13,14] describe and define issues associated with risk assessment and management and the necessary role stakeholders play to influence successful outcomes.

Risk Assessment

Risk assessment is the phase of the process in which health effects are identified and evaluated. The National Academy of Sciences[12] has identified four components of the risk assessment process—hazard identification, dose-response assessment, exposure assessment, and risk characterization. It defines each of these steps as follows:

- Hazard identification is the "process of determining whether exposure to an agent can cause an increase in the incidence of a health condition (cancer, birth defect, etc.)."[12(p19)]
- Dose-response assessment is "the process of characterizing the relationship between the dose of an agent administered or received and the incidence of an adverse health effect in exposed populations and estimating the incidence of the effect as a function of human exposure to the agent."[12(p19)]
- Exposure assessment is the "process of measuring or estimating the intensity, frequency, and duration of the human exposure to an agent currently present in the environment or of estimating the hypothetical exposure that might arise from the release of new chemicals into the environment."[12(p20)]
- Risk characterization is "the process of estimating the incidence of a health effect

under the various conditions of human exposure described in exposure assessment. It is performed by combining the exposure and the dose-response assessments. The summary effects of the uncertainties in the preceding steps are described in this step."[12(p20)]

Risk characterization is the final step in the risk assessment paradigm, and it overlaps with the risk management process. Even though it is an integral part of risk management, the risk assessment must not be influenced by the management factors. It is important for the risk assessor to communicate the estimated risk to the risk manager, and the method of expressing risk is critical. Typically the risk characterization is both qualitative and quantitative.[11] A qualitative risk characterization may be a narrative that describes the elements of the risk assessment and express hazard, exposure, and risk potential with terms such as "negligible," "minimal," "moderate," and "severe." Risk may be compared to common hazards expressed with comparative terms such as "less than," "equal to," or "greater than." A quantitative risk characterization expresses hazard and risk numerically by indicating a finite hazard measure per unit dose or exposure of an agent. An example is the percent change in response for each milligram of agent per kilogram of animal body weight.

It is reasonable to expect military preventive medicine practitioners to be health risk assessors and to advise risk managers, who may be commanders and makers of military doctrine or policy, on potential health outcomes associated with military activities. Therefore, it is important for the military preventive medicine practitioner to understand risk assessment and the factors that contribute to the process, especially issues of exposure duration and exposed population characterization. These factors may affect the magnitude of a federal or state standard and may not be applicable to military populations and scenarios. For example, the USEPA typically produces risk assessments that assume a lifetime of exposure and a broadly characterized exposed population to include sensitive subgroups, very young and very old people, and diseased individuals, which are not appropriate for active duty military members. For example, field military drinking water standards differ from their USEPA counterpart (see Field Drinking Water). The reasons for these differences become obvious when the MCLG (maximum contaminant level goal) formula's assumptions about the general United States population are compared with facts about service members in field environments. Active duty military typically serve from 2 to 30 years and only a small portion of that time is in the field; USEPA exposure standards are based on exposure duration of 70 years. Most military people are young, healthy adults; therefore, the age and health status range is smaller than that of the general population. Depending on environmental factors (eg, temperature) and activity, drinking water consumption for military individuals in the field may be much greater than the 2 L per day assumed for the general population. Various quantitative risk and exposure formulas and their bases can be found elsewhere.[15–19]

Risk Management

During the risk management phase, policy alternatives are weighed and the most appropriate regulatory action is selected. The risk characterization is integrated with engineering data and social, economic, and political concerns to reach a decision[12] (see Figure 20-2). Risk management may simply be deciding what to do about a problem, which requires the integration of a broad spectrum of scientific and nonscientific disciplines. It combines risk assessment with regulatory directives and with social, economic, technical, political and other considerations.[20] In the military, combat operations, theater characteristics (to include considerations for special populations such as prisoners of war, refugees, local nationals, and other civilians), and command directives also may influence this process. Sometimes a standard or criterion may be based on management factors rather than health. For example, a drinking water standard may be based on the current available technology for analyzing or treating a contaminant and thus may be higher than that suggested by the risk characterization.

Risk Communication

Throughout the risk assessment and risk management process there should be interaction between the risk assessor, the risk manager, and the affected community. This interaction, known as risk communication, encourages participation in the risk assessment and management process by all interested and affected parties. Risk communication is a method for informing the public and other stakeholders about the risks associated with hazards and the control strategies that are being considered.[11,13] It helps explain technical information to the general public and entails informing the community early, involving them in the decision-making process, using the media, and presenting truthful and frank information.[17,21] Military examples of those who should be informed include commanders, decision and policy makers, combat developers, and materiel developers. Service members are normally informed by their commanders or combat developers.

Managing the Environmental Health Program

Disciplines

Environmental health consists of a number of specialized areas that span a variety of related health, science, and engineering disciplines (Exhibit 20-2). Typically, environmental health situations are multifaceted and so assessments and problem solving require an integrated approach. Thus, a team of environmental health professionals with varied specialties and a sufficient depth of knowledge may be required. Exhibit 20-3 lists the military environmental health specialties that exist in the US Army, Navy, and Air Force.

EXHIBIT 20-2

ENVIRONMENTAL HEALTH DISCIPLINES

- Environmental Quality
  - Water Quality
    - Drinking Water
    - Wastewater
  - Air Quality
    - Ambient air (air pollution)
  - Soil Science
- Waste Management
  - Municipal Waste
  - Hazardous Waste
  - Medical and Infectious Waste
- Health Physics, Radiation Sciences
- Occupational Health and Medicine
- Bioacoustics
  - Occupational Noise
  - Environmental Noise
- Toxicology
  - Mechanic
  - Regulatory
  - Forensic

EXHIBIT 20-3

UNIFORMED MILITARY ENVIRONMENTAL HEALTH AND RELATED OCCUPATIONS

US Army
- Environmental Science Officer
- Environmental Engineer
- Entomologist
- Health Physicist
- Epidemiologist
- Audiologist
- Veterinarian
- Biochemist (Environmental Chemist)
- Medical Laboratory Specialist (Environmental Chemistry)
- Preventive Medicine Specialist
- Veterinarian Technician
- Preventive Medicine Physician
- Occupational Medicine Physician

US Navy
- Environmental Health Officer
- Industrial Hygienist
- Audiologist
- Preventive Medicine Technician
- Industrial Hygiene Technician
- Preventive Medicine Physician
- Occupational Medicine Physician

US Air Force
- Public Health Officer
- Bioenvironmental Engineer
- Public Health Technician
- Bioenvironmental Technician
- Flight Surgeon
- Preventive Medicine Physician
- Occupational Medicine Physician

Installation Versus Field Environmental Health Considerations

Environmental health practices and programs on military installations are similar to those of civilian health departments. The goal of an installation environmental health program is to maintain the health of service members so that they remain able to perform their military mission. Also, because the installation caters to military families and, usually, a nonmilitary workforce, environmental health standards and monitoring should be at a level to protect those groups.

Deployment Environmental Health Considerations

Because of the complexity of moving units to other geographical regions and often to a harsher environment, there are additional environmental health considerations that are associated with military operations. These are the planning, execution, and follow-up activities associated with military deployments, which may include war or humanitarian operations. Preventive medicine considerations in planning for such operations are discussed in Chapter 13, Preventive Medicine and the Operation Plan, and Chapter 41, The Challenge of Humanitarian Assistance in the Aftermath of Disasters, and they also apply to environmental health concerns. The basis for both preventive medicine and environmental health planning is the medical threat, which classically includes temperature extremes (eg, heat and cold injury) and infectious disease, whether transmitted by humans, arthropod vectors, food, or water. There also may be other threats specific to the geographical area, the local culture and customs, and the military mission. Countermeasures can be taken to prevent casualty loss from these conditions in the following areas: field sanitation practices, personal hygiene, immunizations, drinking water, field food service sanitation, waste disposal, and insect and rodent control.

Military field environmental health considerations can be organized into the three phases of predeployment, deployment, and postdeployment. Table 20-2 lists some environmental health areas that

TABLE 20-2

ENVIRONMENTAL HEALTH CONSIDERATIONS DURING PREDEPLOYMENT, DEPLOYMENT, AND POSTDEPLOYMENT

Action	Examples of Considerations
Predeployment	
Staff Coordination	Personnel, intelligence, operations, logistics, civil affairs
Operational Scenario	Operations plan, mission, deployment location, units, timetable, transportation, logistics, food and water supply, waste disposal, host-nation requirements, Status of Forces Agreement
Medical Intelligence	Weather, disease, health of supported populations, potable water, vectors, terrain and hydrography, plant and animal threat
Preventive Strategies	Prophylaxis, personal protection measures, education, supplies and equipment, checklists, written directives
Reconnaissance	Potential sites, threat assessment, local liaison, water sources, vector types, sampling and analytical needs, contaminant and pollution sources
Deployment	
Advance Party Actions	Site selection, threat assessment, local liaison, water quality, air quality, soil contamination, vector surveillance
Sustainment	Disease surveillance, environmental health surveillance monitoring, recommendations, training
Redeployment	Retrograde/Agriculture inspections, terminal prophylaxis, health record documentation
Postdeployment	
Deployment Summary	After action report, lessons learned
Postdeployment Briefs	Chain of command, commanders, deploying units
Medical Followup	Epidemic and sexually transmitted disease, medical surveillance
Equipment Preparation	Order new supplies, maintain and replace deployment equipment for next deployment

Adapted with permission from Chardon WX. Presentation at the Navy Occupational Health and Preventive Medicine Workshop, Virginia Beach, Va, 1996.

should be addressed during each of these phases. During predeployment, the environmental health planner should acquire information about the mission and help identify and plan activities that protect the health of the deploying service members. The planner should learn about the prospective operation through continuous interaction with other staff organizations as they answer the who, what, when, where, and why of the mission. This information can be acquired by interacting with the command staff: Personnel (S1, G1, J1), Intelligence (S2, G2, J2), Operations (S3, G3, J3), Logistics (S4, G4, J4), and Civil Affairs (S5, G5, J5). Medical preparation against environmental health hazards includes educating service members about the potential hazards and use of personal protective measures (eg, repellents, appropriate clothing, sufficient water consumption), checking health status to ensure it meets a deployment standard, and giving immunizations. As part of the predeployment process, the environmental health planner should determine environmental sampling and analysis requirements and identify the resources to support the need. The planner should participate in area reconnaissance operations to aid in specific environmental health preparation; conditions may require, for example, on-site analysis (with its special techniques and equipment) or containers and procedures for sending samples to a particular laboratory. There are centers of environmental expertise in all the services (Exhibit 20-4).

When the units are deployed into a theater of operations, environmental health professionals should continuously monitor health indicators that could show a breakdown in environmental health and sanitation. This may include monitoring disease rates and trends, food preparation practices, water quality, and the use of personal protective measures. Problems and deficiencies should be presented to commanders with recommendations for corrective action. Training and education should continue during the deployment to emphasize field sanitation practices and to assist with preventing disease and solving problems.

Before units leave a theater of operations, environmental health personnel may be involved with, if only in an assisting role, performing retrograde inspections of equipment and supplies to determine that cleaning has removed potential insects and plants that could cause disease or agricultural problems in another country. When units return to their home station, an important postdeployment environmental health activity is to replenish environmental health supplies and replace, repair, and maintain equipment to prepare for the next deployment. Environmental health trends, accomplishments, problems, and solutions should be documented in after-action reports. They should cite lessons learned and recommendations in addition to doctrinal and equipment deficiencies and needs.

EXHIBIT 20-4

SELECTED MILITARY ENVIRONMENTAL HEALTH ORGANIZATIONS

- US Army Center for Health Promotion and Preventive Medicine, 5158 Blackhawk Road, Aberdeen Proving Ground, MD 21010-5422
- US Navy Environmental Health Center, 2510 Walmer Avenue, Norfolk, VA 23513-2617
- US Air Force Human Systems Center; Institute for Environment, Safety and Occupational Health Risk Analysis; 2513 Kennedy Circle, Brooks Air Force Base, San Antonio, TX 78235-5123
- Armed Forces Medical Intelligence Center, Fort Detrick, Frederick, MD 21702-5004

Managing Environmental Sampling and Analysis

The actual or potential impact of environmental agents on health can only be determined if the offending agent is known, as well as how much of it is present, as is reflected in the risk assessment paradigm's hazard identification and the exposure assessment processes. To address these concerns, samples of the environment must be gathered and analyzed to determine information (eg, qualitative, quantitative; chemical, biological, radiological, physical) for decision making. Data from sampling and analysis efforts are useful to assess public health threats, exposures, and contaminations; to assess remediation effectiveness; and to satisfy regulatory requirements. There are numerous published sampling and analytical procedures for environmental agents.[22–33]

General Methods

There are two broad categories of methods for environmental sampling and analysis. One category is the use of direct-reading instruments, which capture a sample of the soil, water, or air; perform the analysis within the instrument; and provide an immediate reading of the concentrations of a contaminant on a display, such as a meter or digital readout. To provide accurate readings, direct-reading instruments must be calibrated, but even then they can be affected by rugged conditions in the field. Direct-reading instruments are only available for limited applications, and their data generally are not accepted by regulatory authorities. However, such instruments provide immediate results for decision makers. Environmental samples can also be obtained at the site of interest, packaged for transportation, and sent or taken to a laboratory for analysis. Disadvantages of this method include the potential sample degradation or contamination when transported to the laboratory and the delay between sample collection and analysis, which denies the decision maker immediate results.

Sampling Versus Analysis

Both the sampling events and the analytical events must be well planned and controlled to provide accurate, useful information that will result in meaningful public health decisions. The sampling and analytical process should produce data that are both scientifically valid and legally defensible.[34] The following paragraphs highlight considerations that should be addressed to enhance the quality of the information acquired.

Very precise procedures must be followed because the analytical results are only as good as the starting materials. Poor sampling can produce data that are inaccurate, inconsistent, and unexplainable; require repeat sampling, which then may delay decision making and mission completion; result in poor decision making, which may affect health; and cause unnecessary costs.

To avoid the perils of poor sampling, the following objectives should be considered. The samples should be representative of the area of interest. Thus, the sampling plan should be site-specific, and the sampling pattern should be statistically based (eg, random, grid, or judgment sampling).[34] The samples should be free of contaminants and substances that may alter or interfere with the analytical procedure. The collection procedure (eg, sample quantity, quality, frequency, matrix) should be appropriate for the analysis that will be performed, and this is best assured by coordinating with the laboratory in advance. Many contaminants must be preserved at the time of sampling to prevent them from degrading (thus giving a false result) before arrival at the laboratory. The sampling process should be fully documented (eg, date, time, location, number of samples, sample number, meteorological conditions, collector's name, activities, unusual circumstances). Other considerations include developing standard operating procedures (eg, equipment use, collection and handling procedures), specifying standard cleaning procedures between samples, collecting quality assurance samples (eg, blanks, duplicates or split samples, background samples), and performing quality assurance audits in the field.[34]

The desired outcome from laboratory analysis is to produce accurate and complete data when it is needed, in a form that can be understood, and at a reasonable price. The data that are produced should be of sufficient quality to allow decision making and problem solving. A laboratory may not be proficient merely because it routinely performs a given analysis or is certified.

Quality environmental laboratory analysis has multiple facets. When samples are received, there should be an accountability and documentation process that records the receipt event (eg, date, time, sample condition) and follows the sample through the laboratory to final disposition, which may include destruction, disposal, archiving, or passage to another laboratory. The data produced by the analysis may not be in a format that is useful or required by the requester, so it may need to be processed. For example, mass data may need to be converted to concentrations. Finally, the data should be reviewed for accuracy, reported to the requestor, and archived. Quality control samples must be analyzed with regular samples, and results must fall within acceptable limits. There should be a quality review that includes statistical control schemes of all the analytical phases.[35,36]

There are several factors to consider when determining the ability of a laboratory to analyze environmental samples properly. There is great variability in environmental samples (eg, drinking water, wastewater, soils, air, industrial products), and they frequently contain high levels of chemicals, called interferences, that can either obscure target contaminants or produce false-positive results. Competent laboratories recognize these facts and have well-developed systems in place to ensure that quality results are obtained and reported. The American Association for Laboratory Accreditation (A2LA) assesses testing laboratories for compliance with International Standardization Organization Guide 25, *General Requirements for the Competence of Calibration and Testing Laboratories, 1990*. This association accredits individual methods and procedures and not entire laboratories; a lab that is A2LA accredited to test for lead in paint may not be accredited to test for lead in water. It is important, therefore, that the accrediting certificate be examined to ensure that the desired testing is covered by the accreditation. Inserting blind (unknown to the analyst) quality control samples, reviewing data, and performing on-site laboratory visits are some of the effective techniques for monitoring laboratory performance.

Summary

The military preventive medicine practitioner frequently serves as a planner and staff advisor to provide medical opinions concerning potential health threats associated with military operations. Both environmental health standards and command emphasis are required to protect the military force from adverse health effects. However, military threats and operational scenarios may require modification of established standards and policy, which also may change the potential health risk. To advise commanders adequately, the preventive medicine practitioner should be familiar with the scope of environmental health, the nature of the science, the availability of environmental health professionals, and aspects of managing risks and programs.

ENVIRONMENTAL HEALTH TOPICS

The basic approach to environmental health practice—the discussion of the subject matter in term of standards, control, monitoring, and policy—will be applied here to fundamental environmental health topics. Drinking water, the first topic, is allotted more space than other topics to explain more fully how these principles apply.

Drinking Water

Municipal drinking water systems are used by the military to the extent possible for military bases and for civilian populations. The health functions with respect to drinking water are to set standards (or at least lead the effort), declare water potable or nonpotable (ie, make a decision based on standards, controls, monitoring, and policy), and provide advice for meeting standards.

Drinking Water Standards

Water standards in general depend on intended use, and municipal drinking water is only one use and results in one type of standard. Other standards exist for other uses. For example, industrial water standards might be more (or less) stringent than standards for drinking water, depending on the specific use. Other categories of water that have their own standards include military field drinking water, water for injection, recreational water, and shower or bathing water. Standards are dynamic; they change as knowledge, technology, and values change.

Drinking water standards can be classified according to the organization that sponsors them. Examples include World Health Organization (WHO) standards for international situations, USEPA standards for the United States, individual state standards within the United States, specific country standards for locations outside the United States, country-group standards in some locations (eg, standards of the Council of European Communities), and military standards for military field situations. Drinking water standards include the total package of requirements for the finished product, not just a specific parameter and its limitation. Therefore, one of the first questions to ask about drinking water is "Which standards apply?" For a civilian population outside the United States (eg, indigenous populations, refugees, migrants), appropriate standards could be WHO standards or the country's standards but not US military field standards.

Considerations for those drafting drinking water standards include safety factors, ability to analyze for a particular contaminant, duration of exposure, sensitive populations, protection of water sources, treatment processes, and policy. For example, some contaminant limitations have safety factors of 1,000 while others (eg, nitrates) have no safety factor. Some contaminants and specific limitations are listed in the standards—or omitted from the standards—because of our ability to analyze for them. As knowledge and capability improve, new parameters are added to the standards. Recent examples include synthetic organic compounds and trihalomethanes. Some contaminants might be too difficult to analyze for routinely, but treatment techniques have been found to control them. An example is *Giardia lamblia*. Therefore, some treatment techniques have been added to the standards, such as filtering surface water.

Drinking water standards are divided into primary and secondary standards. Primary (or health) standards relate to those contaminants that cause acute or chronic health effects at the limitations established and affect the water's potability. Secondary (or aesthetic) standards relate to those contaminants that cause the water to appear unpleasant and unacceptable at the limitations established, such as unsightly appearance, bad odor, and bad taste and adversely affect the water's palatability. Secondary standards are important because if people find drinking water aesthetically unacceptable, they might seek unapproved sources that appear better but are nonpotable or they might become dehydrated because they are not drinking sufficient water. Other factors addressed in drinking water standards include physical contaminants such as pH, turbidity (or cloudiness caused by colloid particles), and color (caused by decaying vegetation); chemical contaminants, such as salts and heavy metals; biological contaminants, such as indicators for pathogenic microorganisms; and radiological contaminants. Military standards include a category for chemical warfare agents. Finally, within the United States, the USEPA develops health advisories for compounds that are a potential threat but for which there is no consensus to include them in the standards. See Table 20-3 and refer to the USEPA

TABLE 20-3

A SUMMARY OF DRINKING WATER STANDARDS WITH SELECTED EXAMPLES

Contaminants	Limitation*	Goal†
Microbiological		
Cryptosporidium	Not set	Not set
Giardia lamblia	Treatment (filtration)	Zero
Legionella	Treatment technique	Zero
Standard plate count	Treatment technique	Not set
Total coliforms	< 5% positive samples	Zero
Turbidity	< 0.5 NTU‡	Not set
Viruses	Treatment technique	Zero
Chemical—Inorganic		
Fluoride	4 mg/L	4 mg/L
Heavy metals	Specific for each	Specific
Nitrate	10 mg/L	10 mg/L
Chemical—Organic		
Acrylamide	Treatment technique	Zero
Benzene	0.005 mg/L	Zero
Endrin	0.002 mg/L	0.002 mg/L
Trihalomethanes	0.1 mg/L	Zero
Radionuclides		
Radium 226	20 pCi/L	Zero
Radon	300 pCi/L	Zero
Aesthetic		
Chloride	250 mg/L	NA
Color	15 color units	NA
Copper	1.0 mg/L	NA
Corrosivity	Noncorrosive	NA
Fluoride	2.0 mg/L	NA
Iron	0.3 mg/L	NA
Manganese	0.05 mg/L	NA
pH	6.5 - 8.5	NA
Sulfate	250 mg/L	NA
Total dissolved solids	500 mg/L	NA
Zinc	5 mg/L	NA

*Limitation refers to the Maximum Contaminant Level (MCL) or treatment technique
†Goal refers to the Maximum Contaminant Level Goal (MCLG) for health impact
‡NTU: nephalometric turbidity unit
NA: not applicable, goals have not been set for aesthetic contaminants
Adapted from United States Environmental Protection Agency. *Drinking Water Regulations and Health Advisories*. Washington, DC; EPA: 1996.

for an example of current drinking water standards.[37] Meeting current standards, however, will not necessarily guarantee potable and palatable drinking water.

Controls for Drinking Water

Controls to help achieve high quality for drinking water should be implemented at the source, during treatment to remove contaminants or achieve desirable quality, and during distribution and storage.

The most common sources of drinking water are surface water (eg, streams, lakes) and groundwater. Additional sources include rainfall, the oceans, and glaciers. How the source affects water quality and what possible controls can be put in place should be the focus of preventive medicine personnel. Categories of contamination include fecal contamination, other natural contamination, and industrial contamination. Fecal contamination comes from humans and both wild and domestic animals. Pathogenic microorganisms are the primary and continuous threat. The source of contamination can be a point source, such as an outfall or discharge of wastewater, or it can be a nonpoint source, such as a wooded area or pasture. Other natural sources of contamination include growth and death of algae, decay of other vegetation, erosion, and natural deposits of minerals that dissolve in the water. Industrial contamination may include point and nonpoint discharges, runoff, acid rain, leaking tanks, and use of industrial products in homes and on farms.

The conventional treatment for groundwater is disinfection, and the most common disinfectant is chlorine. Many groundwaters are well protected, and disinfection is sufficient treatment. However, natural or industrial contamination of groundwater can make more extensive treatment necessary. For example, natural deposits of fluoride or radium might dissolve into the groundwater and need to be removed.

Conventional treatment for surface water is coagulation (including chemical addition, rapid mixing, flocculation by slow mixing, and sedimentation), filtration, and disinfection. Figure 20-3 shows a design of a typical water treatment plant. Primary contaminants removed during coagulation are turbidity and color. Turbidity is caused by colloid particles such as clay and bacteria. Color-causing substances are macromolecules that result from decaying vegetation. The coagulation process creates conditions that destabilize charges on discrete particles and allow them to form flocs and settle out of suspension. Color-causing substances are precipitated by the coagulation process. In addition, other contaminants can be acted on by the coagulation process. For example, heavy metals often will be precipitated, depending on the pH of the water; some organic matter may be enmeshed with the floc. The coagulation process can be viewed as pretreatment before filtration, and it allows filters to operate longer and with fewer problems.

Filtration is used to remove remaining particles. It will remove much but not all of the turbidity, to include microorganisms. Rapid sand or multimedia filtration is normally used, but filtration is sometimes used without coagulation. Examples are slow-sand filtration and direct filtration of relatively clear surface waters, such as mountain streams or lakes. Other forms of filters include diatomaceous earth filters and synthetic membranes. Pressure filters use pumps instead of gravity to force the water through

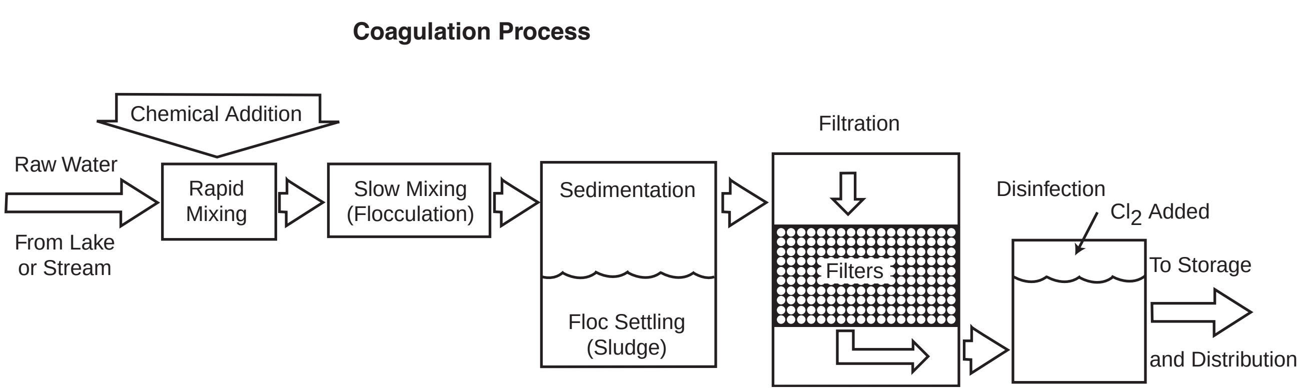

Fig. 20-3. Schematic of a Typical Water Treatment Plant. Generally, the treatment of drinking water involves unit processes to remove contaminants by causing them to coagulate and settle (they will be removed as sludge), to filter out additional contaminants, and to disinfect the final product to further reduce microbes.

the filter. Regardless of the type of filter, the purpose of filtration is to remove particulate matter, especially microorganisms, and make the disinfection process more effective.

Disinfection should always be used to inactivate pathogenic microorganisms. Various chemicals can be used; the more common ones are chlorine and ozone. Chlorine normally comes in the form of a gas or one of two salts [$NaOCl$ or $Ca(OCl)_2$]. The active component in water is the same regardless of the form initially used:

$$HOCl \longleftrightarrow H^+ + OCl^-$$

The effectiveness depends on pH (low pH is best), contact time (preferably 30 minutes or more), temperature (cold temperatures can require higher doses of chlorine), clarity and interferences (particles and compounds can make disinfection less efficient), and concentration of other chlorine-demanding substances, such as ammonia, in the water. Chlorine combines with ammonia to form chloramines, which are also disinfectants but are less efficient than free chlorine. Most public health officials prefer disinfection with free available chlorine rather than combined chlorine residual.

There are a variety of other treatment processes to remove specific contaminants or to condition the water. Drinking water is often conditioned to prevent or control corrosion during storage and distribution. Adjustment of pH with lime [$Ca(OH)_2$] is common practice for corrosion control. Fluoridation is used in many water systems to help prevent dental caries. Water softening can be used at the treatment plant or at the point of use to remove or reduce the level of hardness caused by calcium and magnesium. Reverse osmosis can be used to remove essentially all dissolved solids, such as salts; this process can treat brackish water, seawater, or water contaminated with high levels of nitrates, fluorides, and radium. Aeration can be used to oxidize minerals such as iron and allow them to precipitate or allow volatile organic compounds to transfer from water to air. Adsorption, for example using activated carbon, can remove selected organic compounds. Levels of pH can be adjusted to get optimum conditions for the coagulation process and disinfection. Because chemicals added for treatment are not pure, contaminants can enter the water along with any chemical. Also, contaminants can enter from materials such as plumbing fixtures because of corrosion and leaching.

Contaminants can and do enter the system during storage and distribution. Contaminants can enter by cross connections between drinking water mains or plumbing and sources of wastewater by direct contamination of open reservoirs, by corrosion or leaching of materials in contact with water (eg, lead, copper, and zinc in plumbing fixtures). Significant levels of lead in water at the point of use has motivated professionals since the 1970s to consider the building plumbing as part of the distribution system. The main significance of the decision to make plumbing part of the distribution system is that water must be treated by the purveyor so that dangerous levels of contaminants do not corrode or leach from the plumbing materials.

Some additional considerations for storage and distribution systems include disinfection, fire demand, and treatment at point of use. There should be a continuous residual of chlorine to show that water has not become contaminated with fecal matter. When water mains break or new mains are installed, the procedure is to disinfect with chlorine at high levels (ie, 50 mg/L for 24 hours) while the main is off line. Water mains are looped in distribution systems to keep water flowing and avoid dead ends; this replenishes chlorine and helps prevent biological growth. Fire demand can require oversized mains that result in low flows, loss of chlorine residual, and buildup of precipitation from corrosion.

Drinking Water Monitoring

Operational monitoring for drinking water is that monitoring conducted by plant operations personnel to help ensure that both treatment processes and equipment work correctly. Operational monitoring serves as a quality check on the potability and aesthetics of treated water. It consists of observations, sampling and analysis, and decision making by plant operators. Only a few parameters are analyzed but on a frequent basis (ie, daily or each shift). Specific analyses depend on the treatment processes and chemicals added. An example of drinking water operational sampling and analysis might be daily or every-shift analysis of turbidity, color, pH, chlorine residuals, fluoride, and even coliforms on raw and treated water. Operational analysis would probably not include pesticides, heavy metals, synthetic organic compounds, radioactivity, or microorganisms other than an indicator organism. Operations personnel must decide if a problem exists and when to adjust chemical feed rates or call health personnel or regulators.

Health monitoring for drinking water consists of a sanitary survey, sampling and analysis, and interpretation of results. The main question to be answered concerns the safety and potability of the water. A sanitary survey of the sources of municipal drinking water, the treatment plant, and the storage and distribution system should be done at least annually by a qualified health professional and should focus on detecting and eliminating sources of contamination from spills, poor design and operations, cross connections, and other such problems. Sampling must be done using correct containers, preservatives, holding conditions, and holding time. Analyses should consider requirements for onsite analyses versus analyses in a certified laboratory. Tests for most parameters listed in USEPA standards should be conducted before a water source is put into operation and then annually in the United States for surface water sources and once each 3 years for groundwater sources. Results showing high contaminant levels or suspected contamination are reasons to sample more often. Microbiological sampling and analysis must be conducted quite frequently—daily, weekly or monthly depending on the size and specific processes of the water system. Selected parameters should be tracked with microbiological indicators to give a true picture of the situation (eg, turbidity, pH, chlorine residuals). Finally, a health professional must consider data and other information and make a decision concerning water potability and palatability.

Policy

Policy issues for drinking water include goals, objectives, and resources, all of which affect the comprehensiveness of standards, controls, and monitoring. The goal may be to provide a sufficient quantity of drinking water at low cost while expecting consumers to use point-of-use devices or bottled drinking water to get quality taste. Or the goal may be to provide a safe and high quality drinking water regardless of cost. Policy questions for standards include which parameters or treatment techniques should be included as part of the standards. Policy issues for controls include how well the source is protected and whether to filter surface water, even if clear mountain lakes or streams are used as the source. One policy issue for monitoring is the frequency and specific parameters required for sampling and analyses during operational and health monitoring.

Drinking water is vital to maintaining human health; therefore, its sanitary quality is also vital. Managing drinking water production and distribution can be complex, and much of the science and technology is beyond the scope of this chapter but can be found elsewhere.[2–4]

Military Field Water

Water supply to service members in field situations is crucial to accomplishing the mission. Water must be both safe to drink and aesthetically pleasing. To prevent dehydration, service members must drink sufficient quantities of water. In addition, water is needed for food preparation and cooking, personal hygiene, medical treatment, laundry, cleaning equipment, and more. Total water needs for US personnel in desert environments are 76 L (20 gal) per person per day, with 15 L (4 gal) of that needed for drinking water.[38,39]

A team of military specialties is necessary to address all aspects of water supply, including standards, controls, monitoring, and policy. Health professionals play a vital role in the water supply team. Responsibilities for providing safe drinking water are divided among military staff. It is the role of logistics to purify, store, and distribute potable water and to develop equipment, but allied military forces often give responsibility for water purification to the engineers. The engineers' role in the US military is to develop water sources, including drilling wells. The medical role is to set health standards, certify water as potable, and provide technical advice for meeting standards. This includes health monitoring to certify water as potable and making recommendations for controls and policy to meet standards. The units are responsible for obtaining drinking water from only approved sources and ensuring that the water does not become contaminated. With these divided responsibilities, it is essential that all the parties coordinate so that essential tasks are not left undone.

Contaminants and Standards

Standards for field drinking water are regulated by two international agreements: the North Atlantic Treaty Organization's STANAG 2136 (Standardization Agreement 2136) and ABCA's QSTAG 245 (American, British, Canadian, and Australian's Quadripartite Standardization Agreement 245). QSTAG 245 was promulgated in 1985 and STANAG 2136 in 1994 with amendments added in 1995. Parameters and specific limitations listed are fairly consistent between the two standards; differences are minor. Sixteen contaminants are regulated under

TABLE 20-4

STANDARDS AND ROUTINE ANALYSIS FOR FIELD WATER

Contaminants* (listed under QSTAG 245)	Requirements of QSTAG 245 Short Term (< 7 d)	Long Term (> 7 d, < 1 yr)	Personnel Performing Analysis†
Microbiological			
Coliform	1 CFU/100 mL	1 CFU/100 mL	Health
Viruses	1 PFU/100 mL	1 PFU/100 mL	NA
Spores/Cysts	1 CFU/100 mL	1 CFU/100 mL	NA
Physical			
pH	5 to 9.2	5 to 9.2	Operational, Health
Temperature	2°C to 35°C	15°C to 22°	Operational, Health, Unit
Turbidity	5 NTU	1 NTU	Operational, Health
Total dissolved solids	1,500 mg/L	1,500 mg/L	Operational, Health
Color	NA	15 color units	Operational, Health
Chemical			
Arsenic	2 mg/L	0.05 mg/L	NA
Cyanides	20 mg/L	0.5 mg/L	NA
Mustard	0.2 mg/L	0.05 mg/L	NA
Nerve agents	0.02 mg/L	0.005 mg/L	NA
Chloride	NA	600 mg/L	Health
Magnesium	NA	150 mg/L	Health
Sulphates	NA	400 mg/L	Health
Radiological			
Mixed fission products	NA	0.06 μCi/L	NA

*In addition to contaminants listed in standards, disinfectants (eg, chlorine residual), when added for treatment, should be analyzed by operational, health, and unit personnel and compared to levels set by the command surgeon.
†As recommended in Miller R, Phull K, Smith E. An overview of military field water supply. *J US Army Med Dept*. 1991:9–13.
QSTAG: Quadripartite Standardization Agreement
CFU: colony forming unit
PFU: plaque forming unit
NTU: nephalometric turbidity unit
Sources: Department of the Army. *Quadripartite Standardization Agreement 245: Minimum Requirements for Water Potability*. 2nd ed. Washington, DC: DA; 1985. Miller R, Phull K, Smith E. An overview of military field water supply. *J US Army Med Dept*. 1991:9–13.

QSTAG 245 (Table 20-4). US military regulations for field water supply must be at least as stringent as those of QSTAG 245 and STANAG 2136.[40–43] For example, US military regulations allow 1,000 mg/L for total dissolved solids, 1 NTU (nephalometric turbidity unit) for turbidity, 600 mg/L for chloride, 30 mg/L for magnesium, and 100 mg/L for sulfates, when consuming 15 L per day.[43,44]

Differences between drinking water standards in the United States and the QSTAG 245 and STANAG 2136 standards are due to different assumptions. QSTAG 245 and STANAG 2136 standards assume a healthy adult population consuming the water for no more than 1 year and a water consumption of 5 to 15 L per person per day. Long-term effects are ignored by QSTAG 245 and STANAG 2136. Field drinking water is assumed to be the only source of fluids available to service members. The best available source of raw water should be selected for field water. Field water standards are not truly appropriate for refugees or otherwise susceptible individuals, although water purified under field conditions might meet the standards set to protect susceptible persons. For example, QSTAG and STANAG standards do not list levels for heavy metals, nitrates, fluorides, pesticides, or synthetic organic compounds. Also, field water standards should not be used in situations where assumptions are no longer valid (eg, reuse of wastewater as a source for drinking water or shower water).

Controls

Sources should be selected not only to give flexibility to the forces but to limit contamination. Therefore, the best available source should be selected, and sources should be protected from further contamination. The treated drinking water should be protected from contamination during storage and distribution until it is actually consumed.

The US military uses Reverse Osmosis Water Purification Units (ROWPUs) to treat drinking water (Figure 20-4). The ROWPU uses processes of filtration, reverse osmosis, and disinfection. Allied countries use either ROWPUs or conventional surface water treatment processes such as coagulation, filtration, and disinfection or other filtration processes (eg, diatomaceous earth filtration). On land the US military uses chlorine, usually in the form of calcium hypochlorite, as the disinfectant.[43] The reverse osmosis process allows brackish water and sea water, in addition to fresh water lakes and streams, to be used as a source. Also, reverse osmosis is more likely to remove chemical warfare agent contaminants than more conventional treatments. ROWPUs come as 600 gallon-per-hour units (operating 20 hours per day) and 3,000 gallon-per-hour units. A limited number of ROWPUs with larger capacity are available. The capacity of ROWPUs can be a limitation when large quantities of treated water are needed, such as during some humanitarian assistance efforts.

Fig. 20-4. Reverse Osmosis Water Production Unit. This drinking water treatment unit employs reverse osmosis technology to remove chemical and microbial contaminants and is used by the military to produce potable water from raw water sources or public water systems of unknown quality. Bottom view: a distance view of treatment unit and water tank. Top right: a close up view of treatment unit. Top left: Membrane filters that have been separated from the unit for display.

Monitoring

Operational monitoring is the surveillance, sampling and analysis, and decision making performed by personnel to ensure that water purification equipment is working properly. Analysis does not include all contaminants listed in the standards (see Table 20-4) because extensive testing was conducted during research and development to determine the efficiency of the equipment and it is understood that health monitoring will be conducted.

Health monitoring consists of sanitary surveys, sampling and analysis, and interpretation of data and other information. Since contaminants can enter at the source of water, during treatment, and during storage and distribution, sanitary surveys should be conducted initially and periodically to assess and mitigate likely contamination. Sanitary surveys help water treatment professionals select among alternative sources, identify possible contamination, verify proper treatment, verify safe storage and distribution, and check on water discipline.

Sampling and analysis for health monitoring is conducted to help select among alternative sources and to verify the safety and palatability of treated water, including water in storage and distribution, by comparing analytical results to accepted standards. Routine health analysis concentrates on turbidity, chlorine residual, and an indicator for microbiological quality. A standard will dictate the analytical procedure, which in turn defines sampling and preservation techniques. Sampling and more extensive analyses should be conducted periodically (eg, initially, annually, when a significant change occurs, when problems are reported) by a qualified laboratory using prescribed analytical techniques.

Regardless of the standards and frequency of sampling and analysis, we can never be certain that water is absolutely safe. Some contaminant could enter the water after treatment or be present initially but not identified. Standards, controls, and monitoring provide information and data, but education and experience are needed to make a judgment. Other decisions about water potability and palatability include selecting sources, selecting treatment processes, and determining how to identify and solve problems. Since judgment is a large factor, a professional with expertise in water supply should routinely interpret data, assess information, and make decisions.

Policy

Important policy issues include allocation of sufficient resources to water supply and quality, maintenance of water discipline, need for bottled water, and certification of water as safe to drink. Coordination of responsibilities and having one person in charge overall are essential, both in a theater of operations and within each of the military services.

Using bottled drinking water can be appropriate at times in the field. Possible uses are in the initial phases of deployment when water treatment equipment is not present, not yet operational, or broken. It may also be useful temporarily for personnel in small, remote locations. Bottled water can contain the same contaminants as the source of water and should not be considered safe for consumption until tested; only approved bottled water should be consumed.

To assist health professionals in certifying that water is safe to drink, policy should specify the minimum water treatment requirements, such as treatment processes and chlorine residual. Other factors that may be addressed in policy include use of approved chemicals, equipment, and materials; use of approved raw water sources; restrictions on the use of nonapproved containers (eg, fuel tanks) to store or haul drinking water; maintenance of water containers; water surveillance at the unit and Field Sanitation Team (FST) level; and appropriate training for water equipment operators and health professionals.

Swimming Pools and Bathing Areas

Service members will participate in recreational swimming activities even in a theater of operations, but the morale benefits of swimming should not override environmental health considerations. Since many health concerns of swimming and bathing are similar to those for drinking water, this section primarily will compare waters for human contact with those for drinking.

Both safety and health problems exist for recreational waters. Diseases are transmitted through both ingestion and contact. For service members in field situations (especially outside the United States), contact with surface water could result in exposure to such diseases as leptospirosis; schistosomiasis; skin infections; eye, ear, nose, and throat ailments; and primary amebic meningoencephalitis.

Swimming Pools

In the United States, water used to fill swimming pools is assumed to be drinking water or water of equal quality. Therefore, standards for swimming pools concentrate on contaminants introduced by humans through use of the pool or from the treatment process. Standards for pools usually include total (or fecal) coliform and the standard plate count, chlorine (or other disinfectant) residual, pH level, alkalinity, color, turbidity, and temperature. Microbiological requirements are essentially the same as those for drinking water. The chlorine level is required to be high enough to be effective but not high enough to cause eye irritation. Turbidity levels are usually more stringent than those for drinking water, not just because the particles can interfere with disinfection but because turbid waters can hinder visibility. A drowning swimmer might go unnoticed in turbid water. Within the United States, states or local health authorities set standards and criteria for swimming pools. The military services have likewise established their own requirements for pools on installations (eg, the Army's TB MED 575[45]).

Swimming pool water is normally treated by filtration and disinfection. Filters are often rapid sand, multimedia, or diatomaceous earth. Typically, the pool water is pumped through the filter at a rate to result in three turnovers of the pool volume per day. If microbiological or turbidity problems occur, turnover rate and disinfection levels can be increased. Swimming should be temporarily prohibited if contaminant levels are considered excessive. Other controls for swimming pools include designing pools so that storm water does not enter the pool, having swimmers bathe before entering the pool area, and limiting the number of swimmers. For more details, see the services' technical bulletins on swimming pools or a current text such as Salvato.[2]

Health monitoring of public swimming pools should include a sanitary survey by a qualified health professional before the pool is placed in operation and periodically (such as weekly or monthly) afterwards, sampling and analysis of critical parameters such as those discussed above for standards, and a decision concerning safe use of the pool. The sanitary survey should include review of design, operational monitoring, pool rules and regulations, qualifications of operators, and safety and industrial hygiene considerations. Operational monitoring is concerned with keeping the pool safe on an hour-to-hour basis. Preventive medicine personnel should identify any "field expedient" swimming venues, which may lack attention to many of these force protection issues.

Policy for swimming pools include design considerations, rules and regulations for swimmers, and responsibilities for oversight. Managers of public pools generally must obtain a permit for their design and operation. Health authorities have responsibility to ensure that public pools are safe for users, and they should not hesitate to close pools if they are deemed unsafe. Those responsible for the health of service members should be similarly vigilant.

Natural Bathing Areas

Limitations for bacteriological quality of water used for natural bathing areas (eg, lakes, beaches, streams) are much less stringent than for drinking water or swimming pool water. For fresh and marine waters, a logarithmic mean of 200 CFU (colony-forming unit) per 100 mL for fecal coliform over a 30-day period is the current accepted limitation.[45] The reason for accepting poor quality water is that historically there have been very few reported disease outbreaks where the natural water was not highly contaminated. Caution still is warranted, however, and sanitary surveys are an important factor in deciding to open or close natural bathing areas. The bathing area should be free from obvious industrial, natural, and fecal contamination. The site should also be physically safe for swimmers, and water should be essentially free of turbidity so that swimmers remain clearly visible to lifeguards. Other health concerns for natural bathing areas are similar to those for swimming pools.

Wastewater Management

The practice of environmental health as it applies to wastewater management is the focus of this section; a more detailed discussion of wastewater technological and management issues can be found elsewhere.[2–4,46] Wastewater management procedures are opposite to those of drinking water. Instead of looking at source, treatment, and distribution, wastewater management professionals look at collection, treatment, and disposal. Disposal of wastewater and sludge has health implications. Options for disposal of wastewater are to streams or lakes, to the ocean, to land, or to reuse (no direct discharge). Options for disposal of sludge include to land, to sanitary landfill, and to reuse, but sludge must be tested to ensure that it is not hazardous. Hazardous wastewater sludge must be handled as hazardous waste. Problems from inappropriate disposal or management of wastewater and sludge include diseases spread by drinking water, by recreational water, or through eating contaminated fish and shellfish; nuisances (eg, unsightly situations, odors); and eutrophication (the accelerated degradation of lakes caused by the presence of excessive nutrients).

Wastewater Standards

Within the United States, wastewater standards are implemented through permits granted by the USEPA or state agencies under the National Pollutant Discharge Elimination System (NPDES) of Public Law 92-500. The discharger, whether a municipality, installation, or industry, must apply for a point-source discharge permit. Each permit is site-specific, but there are national minimum treatment requirements and specific toxic compounds can be listed.

The two bases for wastewater standards are identified minimum treatment requirements and specific use of receiving waters. Minimum treatment requirements in the United States are secondary treatment or its equivalent for domestic wastewater and best available technology for industrial wastewater. The USEPA determines treatment standards for specifically identified pollutants. States, local authorities, or interstate commissions can be more stringent than the USEPA to protect selected bodies of water. These stream quality requirements can result in standards that require advanced wastewater treatment or zero discharge and cost twice as much or more than minimum requirements. It is possible to negotiate with authorities on requirements beyond minimum treatment either to decrease costs or to better protect human health. Wastewater standards for overseas areas during deployment may be somewhat equivalent to US requirements.

Characteristics for typical raw or untreated domestic wastewater are shown in Table 20-5. In wastewater, the particles are normally suspended (as opposed to colloid particles in drinking water) and settle rapidly. Volatile suspended solids give an estimate of the organic content, or biodegradable portion, of suspended particles. Human and animal feces are present in domestic wastewater and must be treated or properly disposed of so that disease outbreaks are prevented. Organic matter in wastewater is measured as (*a*) biochemical oxygen demand (BOD), which is the amount of oxygen used by microorganisms to oxidize organic matter into carbon dioxide and water, normally measured after 5 days (BOD_5) of incubation time; (*b*) as chemical oxygen demand (COD); or (*c*) as total organic carbon (TOC). The rate of dissolved oxygen depletion during biodegradation indicates the likelihood of fish kills in receiving streams or lakes due to depleted oxygen levels if proper treatment is not carried out. Phosphorus and nitrogen are essential to biological growth during degradation of organic matter, but these compounds also contribute to eutrophication. Ammonia is toxic to fish. Nitrates can cause methemoglobinemia in people; infants are more susceptible. Extremes of

TABLE 20-5

TYPICAL RAW OR UNTREATED DOMESTIC WASTEWATER IN THE UNITED STATES

Particles		Microorganisms		Dissolved Solids		Priority Pollutants	
Total suspended solids	200 mg/L	Bacteria*	300×10^6/L	Organic		Organic	Unknown
		Viruses†	7×10^3/L	BOD	150 mg/L	Heavy metals	Unknown
				COD	220 mg/L		
				TOC	70 mg/L		
Volatile suspended solids	140 mg/L			Inorganic			
				Phosphorus	8 mg/L		
				Nitrogen	20 mg/L		
				pH	6.0 to 8.0		

BOD: biological oxygen demand
COD: chemical oxygen demand
TOC: total organic carbon
*Salvato J. *Environmental Engineering and Sanitation*. Somerset, NJ: John Wiley and Sons; 1992: 479.
†Salvato J. *Environmental Engineering and Sanitation*. Somerset, NJ: John Wiley and Sons; 1992: 339.

pH can kill aquatic life. Priority pollutants, as listed by the USEPA, are often poured down drains, and are present in some concentration in most domestic and industrial wastewater. These pollutants can adversely affect biological treatment facilities, end up in receiving waters, or end up in wastewater sludge.

A typical NPDES permit or standard for domestic wastewater is shown in Table 20-6. Note that "secondary treatment" is reasonably well defined in terms of pollutants and their levels. More stringent requirements are considered "tertiary treatment" or advanced wastewater treatment. Also, note that significant nutrient removal is considered to be "tertiary treatment," whether it is for one nutrient or several. Treatment processes will be discussed in more detail later.

TABLE 20-6

TYPICAL DOMESTIC WASTEWATER STANDARD (NPDES PERMIT)

Parameter	Secondary Wastewater Treatment	Tertiary/Advanced Wastewater Treatment
Flow	Volume/d	Volume/d
Total suspended solids	30 mg/L	< 10 mg/L
BOD_5	30 mg/L	< 10 mg/L
pH	6.5 to 8.5	6.5 to 8.5
Fecal coliform	200 MPN/100 mL	< 1 MPN/100 mL
Dissolved oxygen	> 5.0 mg/L	> 5.0 mg/L
Oil and grease	2.0 mg/L	1.0 mg/L
Total phosphorus	–	1.0 mg/L
Ammonia-nitrogen	–	1.0 mg/L
Total nitrogen	–	2.0 mg/L
Total residual chlorine	< 1.0 mg/L	< 1.0 mg/L
Temperature	–	+5°F of receiving water
Priority pollutants	–	< MCL
Toxicity tests	–	Quarterly/annually

BOD_5 biological oxygen demand after 5 days of incubation
MPN: most probable number
MCL: Maximum contaminant level

TABLE 20-7

POLLUTANTS REMOVED OR REDUCED DURING TREATMENT

Treatment Process	Main Pollutant	Other Pollutants
Primary (settling)	Suspended solids	BOD (and more)
Secondary (biological)	BOD	SS (and more)
Tertiary (depends on requirements)	May be BOD, N, NH^3, P, priority pollutants	May be SS, BOD, N, P and more
Disinfection	Pathogens	Fecal coliform

BOD: biologic oxygen demand
N: nitrogen
NH^3: ammonia
P: phosphorus
SS: suspended solids

Wastewater Controls

For municipalities and installations, the three methods for collecting wastewater have been sanitary sewers (which collect only wastewater), storm sewers (which should collect only storm water runoff), and combined sewers (which collect both domestic and industrial wastewater plus storm water runoff). Treatment processes and the main pollutants removed are listed in Table 20-7. A schematic of a typical domestic wastewater treatment plant is shown in Figure 20-5. Wastewater treatment for domestic wastewater consists of primary treatment (ie, settling of most suspended solids) and secondary treatment (ie, biological degradation of most organic matter or the equivalent chemical treatment). Tertiary treatment, also called advanced wastewater treatment, is used for additional degradation of organic matter, significant nutrient removal, or removal of priority pollutants. Biological treatment is normally aerobic and uses intentionally grown microorganisms suspended as flocs in an aeration basin or attached to surfaces. Chemical precipitation is normally used to remove phosphorus. Sludge produced by primary settling and during wasting of biological floc in secondary treatment is often further treated using anaerobic biological organisms or using chemicals such as lime, which conditions sludge to a pH of about 11. Wastewater is often but not always disinfected before disposal. If chlorine is the disinfectant, then dechlorination must be used at times to meet standards and prevent harm to aquatic life. The purpose of disinfection is to inactivate pathogenic microorganisms, and fecal coliforms are used as the indicator organism.

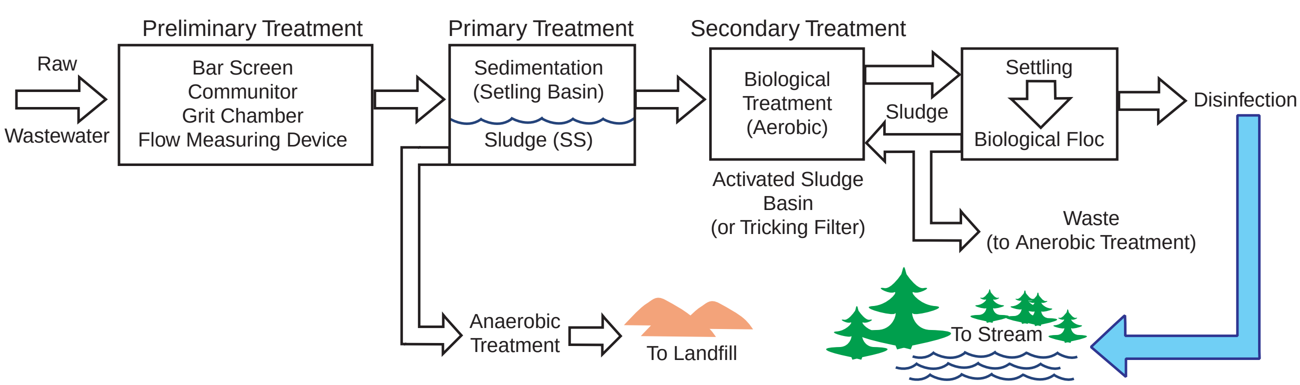

Fig. 20-5 Schematic of a Typical Wastewater Treatment Plant. Minimally, wastewater should receive primary (physical removal/settling) and secondary (biological) treatment, which can be followed by disinfection before discharge. More advanced processes (advanced or tertiary treatment) may be required for special wastes.

Treatment of small flows and individual homes is often by use of septic tank systems. These systems consist of collection (often within the home), treatment (the tank combines settling and anaerobic treatment), and disposal (to an underground drain field). Venting is essential since anaerobic treatment produces methane gas, hydrogen sulfide, and carbon dioxide. Sludge accumulates in the tank and must be disposed of periodically (every 3 to 5 years for individual homes), normally to the local wastewater treatment plant. Otherwise, sludge will eventually clog the drain field.

Industrial wastewater characteristics can be similar to domestic wastewater or present problems such as extremely high BOD (eg, diaries, meat processing plants), nutrient-deficient wastewater, fluctuations of pH, and discharge of priority pollutants (eg, synthetic organic compounds, heavy metals). Treatment can be for direct discharge or for discharge into a municipality's sanitary sewer. Proper treatment or pretreatment should occur before discharge. Treatment processes previously described are often used, plus chemical processes to control specific compounds. However, high BOD waste might be treated by the anaerobic process, nutrients might need to be added, and compounds might need to be removed and conditions adjusted to allow optimum growth of microorganisms for biological treatment. Sludge might need to be handled as a hazardous waste.

Wastewater can be recycled within a process (such as using rinse water effluent for initial wash water) or reused after treatment (such as for irrigation of golf courses). Indirect reuse occurs routinely by use of surface water from streams that have received wastewater discharges. This indirect reuse can be for potable or nonpotable purposes. Potable direct reuse, however, is not routinely acceptable practice although exceptions exist (eg, the National Aeronautics and Space Administration's space station program). Water reuse will require new standards to be developed for the particular situation because drinking water standards assume the source is of relatively high quality.

Wastewater Monitoring

Health monitoring for wastewater management consists of a sanitary survey, sampling and analysis, and interpretation of results. Wastewater must be collected and disposed of in a manner that does not harm human health and the environment. The professional conducting the sanitary survey looks at actual and potential sources of wastewater to decide if water from all sources is properly collected, at treatment to determine if it is proper, and at disposal to ensure it is properly done. When looking at sources, items to consider are individual systems versus the municipal or installation system, characteristics of surrounding industries, pretreatment versus treatment for discharge, proposed projects or developments that affect wastewater management, and pollution prevention. When looking at treatment, items to consider are the standards (eg, NPDES permit or equivalent), treatment processes used, chemicals added, and operations' adequacy for achieving standards. When looking at disposal, items to consider are the standards, the receiving water, the ultimate use of wastewater, and the disposal of sludge.

Sampling and analysis must be appropriate for decision making to help protect human health and the environment. Operational data are not sufficient. Periodic sampling and analysis for health concerns should be conducted separately from operational requirements and include all parameters listed in the standards plus priority pollutants and toxicity testing if industrial wastes could be present. Analysis should be conducted by a certified laboratory or equivalent military laboratory during deployment.

The main question to ask about interpretation of results is if wastewater collection and disposal is safe to humans and the environment. If not, then what must be done in terms of standards, controls, monitoring, and policy needs to be determined. A second questions is if health monitoring for wastewater management is adequate. Health monitoring is not complete until these questions are answered with affirmatives.

Operational monitoring by plant personnel helps serve as quality control for wastewater management, and it partially documents compliance with standards for some routine analyses that are best conducted on-site. Only a few parameters are analyzed but on a frequent basis (eg, daily or each shift). Specific analyses depend on the treatment processes and chemicals added. Typical factors for analysis would be pH, dissolved oxygen, suspended solids, chlorine residual, BOD_5, and flow. Analyses not likely to be performed by plant personnel include toxicity testing and testing for priority pollutants and nutrients. The decisions that plant personnel make include that there are no problems, that chemical feed rates or pump rates need adjusting, and that regulators or health personnel need to be called.

In addition to operational monitoring, regulatory sampling and analysis specifically listed in the NPDES permit are required in the United States. Some of it can be conducted by personnel on-site, but some sampling and much of the analysis are often conducted by a state-certified laboratory. Regulatory sampling and analysis alone do not fulfill requirements for health monitoring.

Policy

Policy issues for wastewater management include the degree of stringency for standards, controls, and monitoring, plus who makes which decisions. Wastewater standards may have been established through negotiation, but health professionals may or may not have been a major party to the negotiation. That is crucial because regulators might not care about the cost of compliance, and they might not be knowledgeable about health effects or environmental effects. But the standards set will greatly affect cost containment and risk management. Health professionals may interpret results from health monitoring and make decisions about adequacy of wastewater management but have sometimes left that decision to others (eg, plant operators) by default. Health professionals may also advocate pollution prevention and good management practices beyond mere compliance to contain costs and better manage risks. An additional issue for deployment is whether or not US forces should meet adequate standards for discharge of wastewater and sludge even though the host nation might not.

Managing Hazardous Materials

As countries industrialize and incorporate the use of new and advanced technology, they increase their use of potentially hazardous chemicals and radioactive substances. There is the potential of increases in incidents that expose people, including deployed US forces, to uncontrolled and dangerous quantities of such materials. One example occurred in Bhopal, India, in 1984 when 30 tons of methyl isocyanate were released accidentally from a chemical plant and caused 3,000 deaths and 200,000 injuries.[8] During the years 1953 to 1961, inorganic mercury was discharged from a plastics factory into the bay by the town of Minimata, Japan.[5] Bacteria in the water converted the inorganic mercury into an organic form, methyl mercury, which is more soluble and toxic. Passively absorbed by microscopic algae, the methyl mercury moved through the food chain—algae to zooplankton to fish—and became more concentrated at each level. Many people who consumed the contaminated seafood developed neurotoxicity and some died.

A more recent example with direct relevance to a US military operation is the massive oil well fires that occurred in 1991 associated with the Persian Gulf War when Iraqi forces purposely set the wells on fire. There was a potential for the occurrence of adverse health effects in US and allied military forces that were exposed to the oil combustion products. Even if the wells had not burned, their presence was a potential environmental health concern and should have been identified during the medical intelligence assessment for their potential to pollute water and food sources and to expose military forces to harmful vapors.

Military operational planners and intelligence analysts would be concerned about an area that military forces had to pass through or occupy if it recently had been sprayed with sarin (GB; *O*-isopropyl methylphosphonofluoridate), a chemical warfare nerve agent. They should be equally concerned about the area if it was an agricultural field recently sprayed with the insecticide Parathion (*O,O*-diethyl-*O*-*p*-nitrophenyl phosphorothioate [NB]). Both are organophosphate cholinesterase inhibitors, which adversely affect the nervous system. Potential threats that hazardous chemicals may pose for military forces and operations need to be assessed.

This section provides some simple definitions of hazardous material to allow the reader to recognize and identify them. It identifies various US laws and regulations that also offer some specific definitions and plans and programs to manage hazardous materials. The emphasis in this chapter is on chemical substances. For detailed information concerning radiation hazards please refer to chapter 29, Medical Response to Injury from Ionizing Radiation.

What Are Hazardous Materials?

A hazardous material is a substance that can cause an adverse effect, such as injury or death, to the body, the environment, or both. Whether there is an actual risk of such outcomes depends on other factors, such as the amount of the hazardous material (ie, exposure concentration), exposure time, dose-response relationship, and susceptibility of the final receptor. Several other similar terms that are sometimes used synonymously with hazardous material but may be referred to in specific laws and regulations include hazardous substances, toxic agents, and hazardous wastes. The term "hazardous substance" is synonymous with hazardous material and includes both chemicals and radioactive materials. Toxic agents are chemicals only. Eaton and Klaassen[8] differentiate between toxin, a naturally produced toxic substance, and toxicant, a toxic substance that is produced by or is a by-product of anthropogenic activities. Because this part of the chapter focuses only on chemicals, the terms hazardous material, hazardous substances, and toxic agents will be considered synonymous. Hazardous waste is discussed later in this chapter and refers to hazardous and toxic materials that are no longer used for their original purpose and must be disposed of.

There are numerous environmental laws and regulations that identify and address hazardous materials. Table 20-8 presents information concerning these regulations and the types of hazardous materials they address. Some of the regulations contain lists of chemicals that are considered hazardous.

Classifications (Chemicals)

There are various ways to classify hazardous materials. The method selected reflects the needs and interests of the classifier.[8] They may be classified according to chemical state (eg, organic, inorganic, acid, base, solvent), physical state (eg, solid, liquid, gas, vapor, particulate), type of toxicity (eg, systemic, carcinogenic, target organ), or industrial use (eg, catalyst, primer, explosive, denaturant, preservative). Another type of classification scheme that is based on physiological effect may have more military relevance because outcomes of exposure may affect an individual's ability to perform his or her mission. For example, some shoulder-fired missile weapon systems use perchlorate-based propellants that produce acid gases in their combustion product. These gases irritate the eyes and respiratory mucosa and may temporarily hinder the user and adversely affect a mission. Examples of physiological classes include the following.[47]

- Irritants (eg, ozone, hydrochloric acid, sulfuric acid),
- Asphyxiants (eg, carbon monoxide, hydrogen cyanide),
- Anesthetics (eg, cleaning solvents, alcohols, aldehydes),
- Systemic poisons (eg, mercury, lead, other heavy metals),
- Pneumoconiosis-producing dusts (eg, cotton dust, coal dust),
- Inert and nuisance dusts (eg, sawdust),
- Sensitizing agents (eg, toluene diisocyanate),
- Carcinogens (eg, asbestos, coal tar, benzene),
- Reproductive hazards (eg, dinitrotoluene), and
- Others (eg, mutagens, teratogens).

Hazardous Materials Management—United States

In the United States, there are various levels of controls designed to minimize the occurrence of adverse health or environmental events due to hazardous materials. Such controls are embodied in the types of laws that were presented earlier and are listed in Table 20-8. It is beyond the scope of this chapter to address the details of all the environmental laws that address hazardous materials. General hazardous materials management concepts that can be derived collectively from all of the laws are within the scope of this chapter. Important management concepts include regulatory requirements for registration and testing, design and planning, tracking and documentation, training, transporting, storing, use and handling, and disposal.

Laws like the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the Toxic Substances Control Act (TSCA) require that when new chemicals are proposed for the market, they must be assessed for their toxicity potential to people and the environment before they are approved or registered. If sufficient studies and tests have not been conducted, they must be done specifically for the assessment. Based on the assessment, the chemical may be approved for use as proposed, receive approval for limited use, or be banned from use. These laws also require that when significant new information is available or if there is a significant new use of the chemical, a new health assessment, and possibly additional testing, is required.

It is important to address hazardous material issues in the early stages of project concept and design. History has shown that trying to control pollutants as emissions or effluents can be costly and prone to accidents. Efforts are now directed to identifying hazardous materials during the design of a process and, ideally, eliminating them, whether by substituting nonhazardous materials or modifying the process to eliminate their use totally. This concept is known as pollution prevention, or P2. If the hazard cannot be completely eliminated, then it should be minimized as much as possible (eg, substitution with a less hazardous chemical or an engineering design that reduces the probability of accidental release). This process is a component of hazard minimization (HAZMIN).

When a hazardous chemical is procured by an organization, the chemical generally comes to a receiving point, is issued to the using activity, and is used by that activity. The used chemical, excess chemical, or outdated chemical is discarded as hazardous waste. The Resource Conservation and Recovery Act (RCRA) requires that hazardous waste be tracked and documented on a manifest from its point of generation to its point of final disposal—a concept frequently called "cradle-to-grave" tracking. Even though this process is required only when a substance is deemed to be a waste, hazardous

TABLE 20-8

SELECTED ENVIRONMENTAL HEALTH LEGISLATION AND GUIDELINES THAT ADDRESS HAZARDOUS MATERIALS

Statute	Federal Agency	Codes	Type of Hazardous Material
Clean Air Act (CAA)	USEPA	40 CFR 50/80	Priority and hazardous air pollutants
Clean Water Act (CWA)	USEPA	40 CFR 100-140, 400-470	Hazardous substance spills, toxic pollutants
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)	USEPA	40 CFR 300	"Superfund" sites, hazardous substances
Consumer Product Safety Act (CPSA)	CPSC	16 CFR 1015-1402	Injury or illness to consumers from products
Emergency Planning and Community Right to Know Act (EPCRA)	USEPA	40 CFR 350, 355 370, 372	Superfund Amendment Reauthorization Act, Title III
Federal Food, Drug, and Cosmetic Act (FFDCA)	FDA	21 CFR 1-1300	Food additives and nonadditives, cosmetics
Federal Hazardous Substances Act (FHSA)	CPSC	16 CFR 1500-1512	Labeling requirements (eg. toxics, corrosives)
Federal Insecticide, Fungicide, Rodenticide Act (FIFRA)	USEPA	40 CFR 162-180	Pesticides
Hazardous Materials Transportation Act (HMTA)	DOT	49 CFR 106-107, 171-179	Hazardous materials shipping
Marine Protection, Research, and Sanctuaries Act (MPRSA)	USEPA	40 CFR 200-238	Controls ocean dumping of sewage sludge/toxic substances, "Ocean Dumping Act"
Flammable and Combustible Liquids Code	NFPA	National Fire Code (NFPA 30)	Flammable and combustible liquids
Occupational Safety and Health Act (OSHA)	OSHA/DOL	29 CFR 1910, 1915, 1918, 1926	Workplace toxic chemicals
Oil Pollution Control Act	USEPA	40 CFR 112	Waste oil
Poison Prevention Packaging Act (PPPA)	CPSC	16 CFR 1700-1704	Hazardous household products packaging
Resource Conservation and Recovery Act (RCRA)	USEPA	40 CFR 240-271	Hazardous waste management
Safe Drinking Water Act (SDWA)	USEPA	40 CFR 140-149	Maximum Contaminant Levels (MCLs)
Toxic Substances Control Act (TSCA)	USEPA	40 CFR 700-799	New chemical hazard assessment and testing

USEPA: US Environmental Protection Agency; CPSC: Consumer Product Safety Commission; FDA: Food and Drug Administration; DOT: Department of Transportation; OSHA: Occupational Safety and Health Administration; NFPA: National Fire Prevention Association, DOL: Department of Labor

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Adapted with permission from The McGraw Hill Companies from: Eaton D, Klaassen C. Principles of toxicology. In: Klaassen C, Amdur M, Doull J, eds. *Casarett and Doull's Toxicology: The Basic Science of Poisons*. New York: McGraw-Hill; 1996.

chemical users are increasingly tracking the chemical from the time it enters their premises through its use to its final disposal.

Individuals who use, transport, or handle hazardous materials are required to be trained in the kinds of hazards and toxic effects that the material can produce. They also must be aware of emergency and cleanup procedures in case of accidents and spills. The Occupational Safety and Health Act requires initial and annual training for individuals who work with hazardous materials. They are to be aware of specific personal protective measures and be knowledgeable about the content, availability, and location of Material Safety Data Sheets (MSDSs). MSDSs are information papers, developed by manufacturers of hazardous materials, that provide details about chemical contents, health effects, personal protective measures, and fire, storage, and transportation safety.

Military Relevance

When US military forces deploy to foreign nations, they should be aware of potential harm to which they could be exposed from the hazardous materials practices of the host nation. Less-developed nations may have either no hazardous materials management program or a poorly enforced one. Also, they may not frequently use hazardous materials. All of these could increase service members' risk of being exposed to hazardous substances. It is important that chemical use and controls be a part of the medical intelligence estimate and assessment. Selected situations of interest follow.

Some agriculture chemicals may have toxicities similar to chemical warfare agents. For example, organophosphates and chlorinated hydrocarbon insecticides also adversely affect the human nervous system. Herbicides are toxic to people as well as plants. Paraquat, a nonselective contact herbicide, is severely debilitating and life-threatening, with the lung being the most susceptible target organ.[48] Also, some pesticides that are banned in the United States because of demonstrated toxicity to humans or the environmental or both are available in other nations. Examples include the neurotoxicants DDT (dichlorodiphenyltrichloroethane) and chlordecone (Kepone).[48,49]

Less-developed countries may not have stringent laws that control hazardous materials and wastes and forbid them from being dumped into the environment. This situation, among others, may allow hazardous materials and wastes to be exported from other countries, either legally or illegally, into less-developed areas for disposal. Thus, there may be a greater potential for air, water, and soil pollution than would be expected, given the industrial capabilities of the host nation.

Another consideration with hazardous materials is that areas with little or no control of these materials may increase the access of hazardous materials to terrorists, who may contaminate military water sources or create acute exposure situations that could result in acute, delayed, or chronic health effects on US forces.

Concerns for the Preventive Medicine and Environmental Health Planner

There is some information that may be useful to the preventive medicine and environmental health planner concerning the potential for deploying military forces to encounter hazardous materials in a theater of operations. Figures 20-1 and 20-2 provide a conceptual frame for the types of questions that should be pursued and information acquired to develop a risk estimate. Examples of questions that may be considered are presented in Exhibit 20-5. Also, the planner should consider the history of recent hazardous materials incidents (eg, spills, air or water releases), occupational exposure history, terrorist activities, and any other unusual chemical incident. There may be a need to determine the composition of unknown substances or quantitate known ones; therefore, the planner should determine the availability of theater or local laboratory analytical capability.

Managing Waste

Integral to daily life is the generation of various types of waste. One form, wastewater, has been addressed previously and will not be addressed in this section. The other waste types discussed in this section, though, do have some common characteristics with wastewater. They may also consist of a mixture of potentially harmful chemical, biological, and physical agents, and they can have adverse public health effects if not handled properly. The forms of waste that are discussed in this section include solid waste, hazardous waste, and medical and infectious waste.

Solid Waste

Solid waste may consist of a variety of materials, to include "any garbage, refuse, sludge…and other discarded material, including solid, liquid,

EXHIBIT 20-5

HAZARDOUS MATERIALS CONSIDERATIONS FOR THE PREVENTIVE MEDICINE AND ENVIRONMENTAL HEALTH PLANNER

- What are the types of hazardous materials?
  - General use chemicals (eg, household items, commercial items)
  - Industrial chemicals (ie, large quantity substances that are used as reactants or are by-products of manufacturing processes)
  - Agricultural chemicals (eg, insecticides, herbicides, fungicides)
  - Other pesticides (eg, rodenticides, molluscacides)
  - Other, special chemicals (eg, munitions, propellants, explosives)
- Who uses the hazardous materials?
- Why are they using the hazardous materials?
- Where are the hazardous materials?
- When are the hazardous materials used?
- How are the hazardous materials used?
- Are there hazardous materials management controls (eg, laws and regulations)?
- Are hazardous materials management controls enforced?
- What is the recent history of hazardous materials incidents (eg, accidents, spills, air releases)?
- What are the known areas of air, water, and soil contamination?
- What is the recent history of occupational exposures?
- What is the recent history of terrorists events?
- Is there an unusually high use of particular chemicals other than in industry?
- What are the theater, in-country, and regional capabilities to analyze chemical substances?

semi-solid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations and from community activities."[2(p665)] In the United States, each person generates approximately 4 to 6 lbs of waste per day and more than 90% of it is paper, glass, metal, plastics, food, and yard waste.[2,5]

Proper solid waste management is important from a public health perspective. Improper disposal can result in groundwater being contaminated by chemical or radioactive substances or by pathogenic microorganisms. Uncontrolled wastes also attract insects, rodents, and other vermin that may become vectors for disease organisms. Improperly managed wastes also can be a nuisance by being aesthetically unpleasant, emitting foul odors, and attracting other types of animals. In addition to public health criteria, there are a variety of other factors not related to health that are considered in the design of recycling programs and solid waste collections and disposal systems. These include waste composition and volume, economics, collection frequency (also a public health factor), collection point (eg, curb versus alley), work rate of the collection crew, efficiency of the refuse truck routing, distance to the sanitary landfill or incinerator, time of year, habits, education, economic status, and commercial or industrial activity.[2] A local study is usually required to design a system to meet local requirements.

The major federal regulation that addresses solid waste management practices is the Resource Conservation and Recovery Act (Public Law 94-580, Subtitle D: Non-hazardous Waste). It provides federal money for approved solid waste plans, established design and permitting requirements for sanitary landfills, requires open dumps to be closed or upgraded to landfills, establishes protective measures for groundwater, and prohibits the open burning of solid waste. The criteria for municipal solid waste landfills are found in the Code of Federal Regulations (40 CFR 258).

The current focus of solid waste decision makers is on development of integrated solid waste management programs. This involves using a combination of approaches to handle targeted portions of the waste stream. The Pollution Prevention Act of 1990 established a hierarchy for integrated solid waste management. Source reduction is followed by recycling and reuse, which is followed by disposal. This management sequence is geared toward the goal of reducing the amount of waste that ultimately is disposed.

Source reduction may involve changing a process to result in less material used or the generation of less waste material or both. It may also involve using a different type of product that inherently produces less waste material, has less disposable packaging, or has a longer useful life. Lastly, efficient procurement to avoid over-ordering or ordering items that may not be used is a form of source reduction.

The reuse, recycling, and composting of materials also serve to reduce the waste stream and are the next options in the hierarchy. Basic reuse of materials is self-explanatory. Reuse can also involve procuring reusable rather than disposable products. Recycling involves the separation and collection of postconsumer materials. The materials are then reprocessed or remanufactured into usable products. The loop is closed when the recycled products are used. Composting is the controlled decay of organic matter in a warm, moist environment by aerobic microbial activity. The two major types of composting are of yard waste and municipal solid waste. The resulting humus or compost product can then be used, thus closing the circle.

The last solid waste management technique in the hierarchical succession is disposal. The two disposal methods are incineration (waste combustion) and landfilling. Incineration is a controlled combustion process for burning wastes to gases and ash. For combustion to occur, there must be adequate time to eliminate moisture, proper temperature at the ignition point, and sufficient turbulence to mix resultant gases with oxygen.[2] When compared to the landfill option, incineration offers several advantages. These include a minimal land requirement, a short hauling distance, no weather limitation, and the possibility that wastes may serve as an energy source. Disadvantages include initial high equipment costs and incinerator-generated air pollution.

Most solid waste, approximately 90% as of 1990, is disposed of in sanitary landfills.[50] Sanitary landfills are engineered and controlled methods of solid waste disposal that are distinctly different from open dumps. Open dumps typically are holes dug in the ground where people deposit waste with few or no controls. An open dump can also be trash heaped on top of the ground. RCRA now prohibits the use of open dumps and requires that existing ones be closed or converted to sanitary landfills. In contrast, sanitary landfills are designed precisely to prevent the public health and nuisance problems presented earlier in this section. They usually consist of a series of cells or trenches that are lined with low-permeability clay or a synthetic material to prevent leachate (ie, precipitation that percolates through the landfill) from reaching the groundwater. Other typical design features may include a leachate collection system of pipes that diverts leachate flow away from and further protects groundwater; a leachate treatment system; a system to collect or vent gas (eg, methane and hydrogen sulfide from anaerobic decomposition; this is the same process illustrated in Figure 20-6); and a system of wells (called groundwater monitoring wells) to monitor groundwater and determine the leachate's migration pattern and whether it reaches the groundwater.[2] Daily solid waste deposits are compacted by a bulldozer or similar type of equipment and are covered daily with earth or an artificial cover to discourage vermin and other animals from digging into the landfill. When a cell is full, it is covered with a multilayer cap that may consist of synthetic material or low-permeability clay overlain by a final cap of topsoil and vegetation. Usually only one cell at a time actively receives waste.

Operational and health monitoring are important components of a solid-waste management program. Health monitoring is a responsibility of public health professionals. During the sanitary survey, the health professional should assess storage, collection, and disposal procedures to determine if they are conducted in a sanitary manner. Operational records, methane gas production and migration, and well-monitoring data should be reviewed. There should be a visual inspection of waste sources and wastes that are delivered to the landfill to ensure that the waste is acceptable and suitable for disposal by this method. During the survey, the health professional should determine if there are any specially designated wastes (eg, asbestos, sludge) and that they are handled as required by permit. Sampling and analysis of the monitoring wells around a landfill detects contamination if it

Biochemical Reactions during Treatment

Secondary Treatment

$$\text{Organic Compounds} \xrightarrow[\text{O}_2\text{, P, N}]{\text{Microorganisms}} \text{CO}_2 + \text{H}_2\text{O} + \text{Microbes}$$

Example:

$$\text{Dextrose } (\text{C}_6\text{H}_{12}\text{O}_6) \xrightarrow[\text{O}_2\text{, NH}_3\text{, P}]{\text{Microorganisms}} \text{CO}_2 + 4\text{H}_2\text{O} + \underset{\text{(Microbes)}}{\text{C}_5\text{H}_7\text{NO}_2}$$

Nitrification

$$\text{NH}_3 \xrightarrow{\text{Nitrifiers}} \text{NO}_3 + \text{Nitrifiers}$$

[Conditions: O_2, pH, alkalinity, low BOD, temperature, others]

Biochemical Reactions during Anaerobic Treatment

Nonmethanogenic

$$\text{Organic Compounds} \xrightarrow{\text{Microorganisms}} \text{CH}_4 + \text{CO}_2 + \text{H}_2\text{S} + \text{Microbes}$$

Biochemical Reactions during Anoxic Conditions for Denitrification

$$\text{NO}_3 + \text{Organic C} \xrightarrow{\text{Denitrifiers}} \text{N}_2\text{(g)} + \text{Microorganisms}$$

[Conditions: anoxic, P, others]

Fig. 20-6. This simple view of the biochemical reactions that are involved in aerobic and anaerobic wastewater treatment shows that the products differ due to the presence or absence of oxygen and nitrogen compounds. Such conditions require specific types of microbes (eg, aerobes, anaerobes, nitrifiers, denitrifiers, methanogenic microbes, nonmethanogenic microbes) to react with the organic matter in wastewater.

occurs. Unless otherwise specified by the regulator, sampling and analysis should be conducted quarterly to monitor the concentrations of the chemical constituents stipulated by the permit or applicable regulation. Incinerator ash also should be analyzed to determine what is deposited into a landfill. Sampling and analysis should be conducted at least annually (or more frequently if required by the operating permit) by a certified laboratory. The health professional should assess the sanitary survey and monitoring results to determine if the solid waste management process is effective and protective of public health.

Operational monitoring of solid waste management is similar to health monitoring, but it tends to be done more often and not in as much detail. It is done by the operations personnel. They should make frequent observations of storage, collection, disposal, recycling, and composting operations and seek ways to reduce the amount of solid waste generated. Adjustments in operations or equipment should be made as necessary to maximize efficiency and safety and protect human health. Routine monitoring should include sampling and analysis of monitoring wells around the landfill and periodic inspection of refuse truck loads for the presence of recyclable items, special wastes not accepted in landfills, and hazardous wastes. Ultimately the operations personnel decide if they will accept certain wastes and handle them in a special manner based on state and federal regulations and permit requirements. Resolution of solid waste management problems, particularly those involving a regulatory violation, should be coordinated with supervisors and regulatory officials as appropriate.

Hazardous Waste

Hazardous waste is a type of solid waste that requires special handling and disposal. Waste is considered to be hazardous when it can cause or significantly contribute to an increase in adverse health outcomes or environmental effects.[2] Hazardous waste may exist as a solid, liquid, or gas and can include chemical, biological, and radioactive materials. Explosive and flammable materials also can be hazardous wastes. Factors that contribute to the hazardous condition of waste include its quantity, its concentration, and its physical, chemical, or infectious nature. Handling methods, use, storage, and disposal also may contribute to the hazard potential.

There are several federal environmental laws that address hazardous materials management. One of the major ones is the RCRA and its amendment the Hazardous and Solid Waste Act. The RCRA defines hazardous waste as "any material that may pose a substantial threat or potential danger to human health or the environment when improperly handled."[5(p667)] It identifies three classes of hazardous waste: listed, characteristic, and generator identified.[5,51] Listed wastes are found in Title 40 in the *Code of Federal Regulations*, Part 261.31–33. Characteristic wastes are those, not otherwise listed, that are toxic, ignitable, corrosive, or reactive. The generator may simply declare a waste to be hazardous and thus avoid the expense of having a laboratory analyze the waste. However, once declared as hazardous, such waste must be managed in accordance with the RCRA. The RCRA does not address several hazardous or potentially hazardous wastes, to include domestic sewage, industrial discharges (subject to the Federal Water Pollution Control Act), nuclear materials (subject to the Atomic Energy Act), toxic and hazardous household waste (usually not regulated), mining wastes, certain agricultural wastes (excluding pesticides), and medical and infectious waste.[2,5] Most states regulate medical and infectious waste and may have specific local requirements for any hazardous waste. Businesses and activities that generate less than 220 lbs of hazardous waste monthly are not required to comply with RCRA; however, as a good management practice, they may elect to follow the hazardous waste management principles to promote environmental stewardship and reflect concern for public and environmental health.

There are various disposal options for hazardous wastes that range from completely eliminating the need (eg, pollution prevention) to altering the wastes, and perhaps eliminating or reducing their hazards, through chemical, physical, and biological processes. Griffin[52] identifies the principles of hazardous waste treatment and disposal as being detoxification, volume reduction, and isolation from the environment. He specifies treatment and disposal types as being physical, chemical, biological, thermal, and fixation and encapsulation. Other examples of these processes, expanded to include pollution prevention options, in descending order of pubic health desirability, are process modification to eliminate the hazardous waste; waste reduction at the point of generation; recovery, segregation, recycling, reuse, and exchange; treatment by methods such as incineration, detoxification, biological breakdown, immobilization, and physical destruction; "secure" land burial (secure chemical landfill); deep well disposal (injection); and aboveground storage until an acceptable solution can he found. See Salvato[2] and Nadakavukaren[5] for more detailed discussion about these and other disposal options for hazardous waste. In comparison to the sanitary landfill discussed in the solid waste section, a hazardous waste landfill is required to have a double liner, a leak-detection system, a leachate collection system, an impervious cap, and groundwater monitoring wells.[5]

Both operational and health monitoring of hazardous waste management practices are very similar to that described earlier for solid waste. There are additional regulatory requirements for hazardous wastes due to the manifesting, tracking, and documentation requirements of the RCRA.

Medical and Infectious Waste

Solid waste that comes from medical or research facilities includes medical waste, infectious waste, biomedical waste, regulated medical waste, and hospital waste. During the mid- to late-1980s, medical waste was found washed up on beaches and in regular solid waste containers.[2] There was public concern that such waste could transmit disease to people. The ensuing regulations focused on controlling infectious agents, regardless of the term used to describe this waste. This discussion will use the "phrase medical and infectious waste."

Medical waste is defined in the RCRA even though there is not a federal regulation that requires management of medical and infectious waste. Most states, however, have established their own regulations. The RCRA definition for medical waste is "any solid waste that is generated in the diagnosis, treatment, or immunization of human beings or animals, in research pertaining thereto, or in the production or testing of biologicals."[2(p685)] The regulated categories are cultures and stocks of infectious agents and associated biologicals, human blood and blood products, pathological waste, isolation waste, used and contaminated sharps, and contaminated animal carcasses.[2,6] Specific examples are listed in Exhibit 20-6.

The goals of medical and infectious waste management are to control disease, optimize safety, and address public concerns. To accomplish these goals, a medical and infectious waste management program should have the following components: designation and identification, segregation at point of origin, packaging and labeling, storage, transport, treatment, and disposal.[6] Categories and specific items of medical and infectious waste should be identified and written in organizational operating procedures.

Medical and infectious waste should be segregated from other waste streams to allow special packaging and identification that will alert and enhance the safety of people who collect, transport, and dispose of the waste. Also, segregation directs the medical and infectious waste into a waste stream that requires distinctly different handling and disposal procedures from that of other wastes.

Packaging should be impervious to leakage and punctures, and appropriate for the waste type. For example, solid and semisolid items can be put in plastic bags, liquids in capped or stoppered bottles, and sharps in puncture-resistant containers. The universal biohazard sign (see Figure 20-7) or other

EXHIBIT 20-6

SPECIFIC EXAMPLES OF MEDICAL WASTE

- Specimens from medical and pathological laboratories
- Wastes from the production of biologicals
- Discarded live and attenuated vaccines
- Waste blood, serum, plasma, and blood products
- Pathological tissues, organs, body parts, blood and body fluids removed during surgery, autopsy, or biopsy
- Used and contaminated needles, syringes, surgical blades, pipettes, and pointed and broken glass
- Contaminated animal body parts and bedding if it was exposed to pathogens
- Soiled dressings, sponges, drapes, lavage tubes, drainage sets, underpads, and gloves from surgery and autopsy
- Miscellaneous laboratory waste, such as specimen containers, slides and coverslips, disposable gloves, lab coats, and aprons
- Waste from dialysis procedures
- Contaminated equipment

Source: Koren H, Bisesi M. *Handbook of Environmental Health and Safety, Principles and Practices.* Vol II. 3rd ed. Boca Raton, Fla: Lewis Publishers; 1996: 1–76, 187–192.

accepted clear marking identifying the contents as medical and infectious waste must be on the container. Typically, packages of medical and infectious waste are color-coded (eg, red or bright orange).

Fig. 20-7. The universal biohazard sign should be placed on any container, room, or vehicle that contains medical and infectious waste.

Storage time should be as short as possible. Medical and infectious waste storage areas should have limited access, should have the universal biohazard sign posted at entry points, and should not be used simultaneously for other purposes.

Carts used to move medical and infectious waste within the facility should be cleaned and disinfected frequently. When the waste is transported from the facility, it first must be put in rigid or semirigid containers and then transported in closed, leakproof dumpsters or trucks. Trucks that are transporting medical and infectious waste should not carry anything else simultaneously and should be cleaned and disinfected before being used for other purposes.

Medical and infectious waste treatment is any method, technique, or process designed to change the biological character or composition of the waste. The treatment process can either render the waste noninfectious or render it unrecognizable. Treatment processes vary with the type of waste. Some examples include incineration, autoclave or steam sterilization, gas-vapor sterilization, thermal inactivation, chemical disinfection, irradiation, and discharge to sanitary sewer. Rendering medical and infectious waste unrecognizable, as by grinding, reduces the potential anxiety, fear, and misperception of a public health threat people may have if they encounter the treated waste. After treatment, medical and infectious waste can be disposed of in the same manner as regular, noninfectious solid waste.

Military Considerations of Waste Management

The preceding discussion about the various forms of waste management presented management principles and controls from the perspective of the United States. This level of detail was presented to demonstrate the complexity, both technological and regulatory, involved in managing waste in a manner that will protect public health. It also gives the reader a context for the following discussions concerning expectations in less-developed and underdeveloped countries and in the field that the military may experience in a theater of operations.

In less-developed and underdeveloped countries, there are a variety of conditions that may affect the process of waste disposal. Information about these conditions should be acquired as part of the medical intelligence gathering process. They should then be considered during the preventive medicine and environmental health planning process. Less-developed and underdeveloped countries will probably differ from the United States in aspects of culture, government, economics, and infrastructure. These factors have a direct effect on waste management practices. For example, the host country's government may choose to enact or enforce laws that govern waste management or it may not. Poor countries may have economic priorities (eg, feeding, clothing, and housing their people) that do not allow sufficient or any funding for waste disposal programs or construction and maintenance of a waste disposal infrastructure (eg, sanitary landfills, incinerators). Other situations that could affect waste management in such countries include overpopulation, relatively little living space, no or poor urban planning, poverty, a small tax base, and a fragile infrastructure.

Given these types of conditions, the environmental health planner might expect the following situations:

- minimal to no waste stream segregation,
- minimal to no disposal infrastructure and technology,
- individual and neighborhood disposal sites, with the most probable disposal method for all wastes being dumping (above and below ground) and open burning,
- minimal to no vermin control at storage and disposal sights, and
- scavenging through waste sites to find items that poverty-stricken people can sell or use.

When US military units deploy to such areas, they face the risk of increased exposure to hazardous and infectious waste materials and waste-contaminated water sources.

When US military forces deploy into a foreign country to conduct military or humanitarian operations, waste management is an important logistical consideration. The public health concerns associated with solid waste, hazardous waste, and medical and infectious waste can affect the health of deployed forces and adversely affect the military mission. Both logistical and preventive medicine planning should address waste management to prevent potential adverse health conditions. Host-nation requirements, Status of Forces Agreements, Final Governing Standards Related to the Department of Defense Overseas Environmental Baseline Guidance Document, and other agreements should be considered, especially concerning hazardous and medical and infectious waste disposal.

Waste handling procedures in a theater of operation depend on the tactical or operational scenario and the local resources available in the host nation. Using the local infrastructure and contracting waste services with local nationals may be the best and easiest way to manage waste. Such services may include solid waste and special waste (eg, hazardous, medical, and infectious) collection and disposal. However, if there is not a supporting infrastructure or contracting possibilities, if units are not located near such support, or if other tactical considerations prohibit such arrangements, then field disposal methods must be employed. Generally, the options are burial, incineration, or a combination of these two methods. Examples of these methods are presented in the section on field sanitation later in this chapter.

Food Safety and Sanitation

The multifaceted process that brings food from its producer to its consumer requires foods to be handled several times before they reach their final destination and thus provides multiple opportunities for contamination. This section discusses the agents and sources of foodborne disease and contamination and the controls that exist to prevent foodborne disease outbreaks.

Sources of Foodborne Disease and Contamination

There are several types of contaminants that can adulterate foods. These include biological (eg, microorganisms, parasites, seafood toxins, insects, rodents), chemical (eg, pesticides, cleaning agents), and physical (eg, broken glass, metal shavings) hazards. Improper storage, transportation, handling, preparation, and serving practices can provide the opportunity for contamination. Other examples of opportunities for contamination include spills and leaks (eg, sanitizers stored above bags of flour) and inappropriate handling and storage practices (eg, spraying pesticides in the air during food preparation and service).

Some foods may have spoiled or have pathogenic microorganisms on them when they arrive in a food establishment. For example, beef can contain *Clostridium perfringens* and fowl may have *Salmonella*. Allowing uncooked meat to come into contact with ready-to-eat cooked foods or foods that are not cooked before serving (eg, vegetables, fruits) is a means of cross-contamination. Allowing cooked or ready-to-eat foods to contact unsanitized surfaces that previously were in contact with raw meat is another example of cross-contamination.

In addition to physical contact, other factors are required for chemical and biological contaminants to cause illness. A toxic quantity of chemical substances must be consumed. In some cases, as with heavy metals leached from containers, this may be a cumulative phenomenon. Microbes must be present in sufficient quantities to produce disease, which is a function of the ability of the food to support growth (eg, its pH, water content, and nutrients), the temperature, and the contact time. Other factors that favor microbial growth include time and temperature abuse, improper cooking, acquisition from a nonapproved source, additives, and moisture.

Biological Hazards

The types of microorganisms that can cause foodborne illness are bacteria, viruses, and fungi. Detailed discussions concerning various microbial diseases spread by food are presented in Chapter 32, Outbreak Investigation. Given the proper environment (eg, moisture, nutrients, adequate temperature, oxygen for aerobes, lack of oxygen for anaerobes), microorganisms multiply at an exponential rate and can reach disease-producing concentrations in relatively short periods of time. For example, a typical bacterial growth curve, as seen in Figure 20-8, has four phases. Sanitation and other public health measures seek to prevent contamination or, if contamination occurs, reduce or eliminate microbial growth. Temperature and time control is one important way of limiting the log phase or extending the lag phase of the bacterial growth curve. The food service sanitation industry tries to keep hot foods hot (> 60°C, 140°F) and cold foods cold (≤ 5°C, 41°F). The so-called "danger zone" is between 5°C (41°F) and 60°C for a cumulative time of 3 to 4 hours. However, variances to this temperature range can be found in the latest edition of the *Model Food Code*, published biannually by the US Food and Drug Administration.

Bacterial pathogens can be classified, based on their mechanism of producing illness. Infective bacteria are vegetative cells that cause disease after ingestion (eg, *Salmonella, Escherichia coli)*. Toxin-pro-

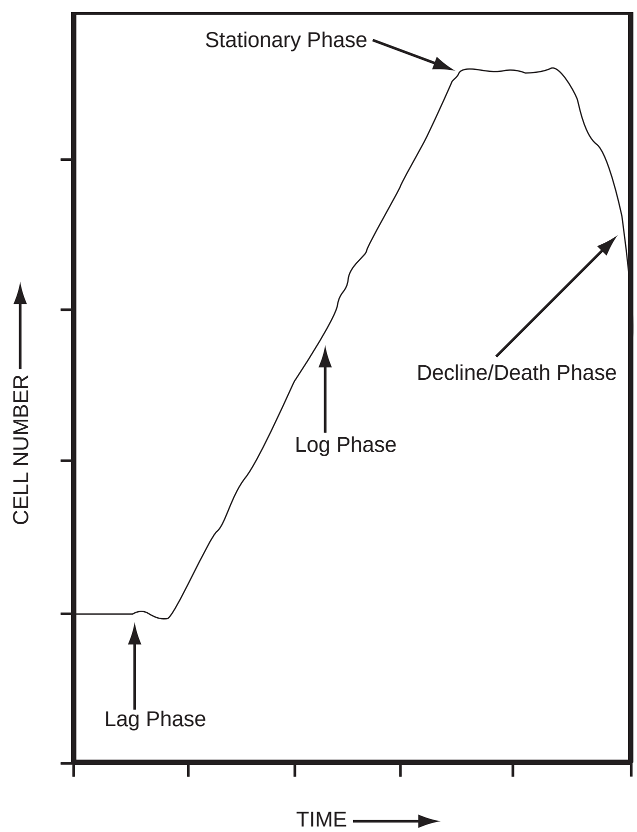

Fig. 20-8. Bacterial Growth Curve. When bacteria are introduced to a new environment, they go through several growth phases. As they adapt to the environment, there is little or no increase in population size (lag phase). Once adapted, the organisms reproduce at a logarithmic rate (log phase) until there is an equilibrium between the population size and available nutrients (stationary phase). When nutrients are depleted and can no longer support the organisms, the population dies (death phase).

ducing bacteria produce a toxin that causes disease when ingested (eg, *Staphylococcus*). Spore-forming bacteria (eg, *Clostridium botulinum*, *Bacillus cereus*) develop into a thick-walled, resistant spore when environmental conditions are harsh, such as when temperatures are extreme or there are insufficient nutrients, and become viable when favorable growth conditions resume. Thus, if foods come into contact with bacteria, measures taken to prevent foodborne illness must do more than kill vegetative cells. They must also be able to inactivate spores and denature toxins. Some bacterial toxins are heat labile, but others are heat stable and thus require higher temperatures and pressures for longer contact times to denature.

Hepatitis A and Norwalk viruses are examples of viruses that can cause foodborne illness. Both are associated with water and foods contaminated with human feces. Fungi such as *Aspergillus flavus* and *A parasilicas* produce an aflatoxin that is a hepatocarcinogen and may contaminate grains and nuts. Mushrooms (eg, *Amanita*, containing the neurotoxin ibotenic acid) also are fungi that can be deadly if ingested.[53]

Some pathogens that can contaminate foods are parasitic and include organisms that range in size from microscopic protozoa to macroscopic nematodes and tapeworms. *Toxoplasma gondii* is a protozoan disease agent found in cat feces and can contaminate a variety of raw meats. *Giardia lamblia* is another protozoan that frequently contaminates water, but it can also contaminate food. Nematodes (eg, *Trichinella)* and cestodes (tapeworms such as *Taenia*) can be found in beef and pork, and worms of the *Anasakis* genus are sometimes found in marine fish used for sushi.

Certain types of seafoods may be contaminated with toxins that can cause illness or death.[54] Certain large fish (eg, red snapper, grouper) and shellfish may bioaccumulate several toxins from dinoflagellates, the benthic algae that are food sources for some marine animals. The toxins are neurotoxic, may affect the gastrointestinal tract, and can produce cardiovascular effects. These include ciguatoxin. Scombroid poisoning is associated with mackerel, tuna, bonito, and skipjack and rarely is fatal. The musculature of improperly preserved or refrigerated fish degrades and releases histamine and another toxic factor, saurine, that causes nausea, vomiting, diarrhea, epigastric distress, and other food poisoning symptoms.

Insects can cause foodborne illness by mechanical transmission or as stored product pests. The common housefly (*Musca domestica*) and several cockroaches are examples of insects that can transmit disease-causing organisms by mechanical means. Some insects may infest foods stored in warehouses and kitchens. These pests eat and contaminate stored food so that it cannot be consumed by people.[7] Examples of these type of insects include the confused flour beetle, saw-tooth grain beetle, flour grain beetle, and cabinet beetle. Some leave body parts that when swallowed may choke or irritate people, and others excrete harmful substances.

Rats, mice, and other rodents can transmit foodborne diseases by mechanical transmission and directly through their own urine and feces. They can carry microbes and introduce contaminants such as hair and larvae casings. Three types of rodents typically infest food facilities in the United States: the roof rat (*Rattus rattus*), the Norway rat (*Rattus norveticus*), and the house mouse (*Mus musculus*).

Chemical Hazards

Chemical food contamination can cause adverse health effects that range from discomfort through incapacitation to death. The types of possible health effects are as numerous as the variety of chemicals that exist. Effects may be acute, chronic, or cumulative and typically are dose dependent. Chemicals in foods that may cause adverse effects are both endogenous and exogenous. Endogenous chemicals are those that occur naturally in foods (eg, vitamins, minerals, enzymes, micronutrients including heavy metals). Some of these, if ingested in sufficient quantities, can be toxic. Exogenous chemicals are those that are applied to foods either intentionally or accidentally. Intentional exogenous chemicals include additives (eg, colorants, antioxidants, flavor enhancers, preservatives) and pesticide. Even though these chemicals can be toxic, they are not the focus of this section. Further information on these types of chemical hazards can be found elsewhere.[55]

This section focuses on exogenous chemicals that become food contaminants because of an accident (eg, a spill) or neglect (eg, improper storage practices or mislabeled containers). Typical chemicals that may be found in food operations depend on the location and operation. For example, warehouses and distribution points may have fuels and oils to run forklifts; they may also have household chemicals, such as detergents and pesticides, collocated with foods. Vehicles may transport food items along with household chemicals when they transfer items to markets or restaurants. Food preparation and service facilities usually have cleaning chemicals (eg, detergents, sanitizers) and pesticides (eg, insecticides, rodenticides) on hand.

Some types of food storage and service containers may cause chemical contamination. High-acid foods (eg, citrus fruits, sauerkraut, fruit punches) may cause certain metals to leach out of the container and contaminate the food. This can occur with copper, brass, and galvanized containers; enamelware can leach antimony and cadmium and glazed pottery can leach lead.[7]

Physical Hazards

Foods can be contaminated by physical agents during processing, storage, transportation, preparation, and service. The types of agents that are considered here are items that accidentally may be mixed with foods. Examples may include broken glass, metal or wood shavings, dirt, and other debris.

Food Service Risks

In the retail industry, specific events have been reported to cause foodborne disease outbreaks more frequently than others. These include improper cooling of foods; lapse of a day or more between preparing and serving; infected persons handled non–heat-treated foods; inadequate time-temperature exposure during processing; temperature not kept high enough during hot storage; inadequate time-temperature exposure during reheating; and ingestion of contaminated raw ingredients or foods.[56]

Standards

There are several US federal government agencies that participate in food safety activities.

- The US Food and Drug Administration (FDA) is responsible for the safety, sanitation, nutrition, wholesomeness, and labeling of domestic and imported foods except meat, poultry, and some egg products. It is responsible for the Federal Food, Drug, and Cosmetic Act, which regulates food production, manufacturing, composition, quality, container amounts, and additives.
- The US Department of Agriculture (USDA) is responsible for the safety and quality of meat, poultry, eggs, egg products, and grain products. It promulgates and enforces the Federal Meat Inspection Act, Poultry Products Inspection Act, Egg Products Inspection Act, and the US Grains Standard Act.
- The USEPA regulates the manufacture, labeling, and use of all pesticides sold or distributed in the United States through a registration program authorized by the Federal Insecticide, Fungicide, and Rodenticide Act. It also establishes the maximum permissible levels of pesticide residue that may remain in or on food and animal feed and evaluates health and environmental information related to pesticide use.
- The National Marine Fisheries Service (National Oceanic and Atmospheric Administration, US Department of Commerce) conducts the National Seafood Inspection Program, a voluntary program to inspect vessels, processing plants, and retail facilities for sanitation and evaluate the quality of seafood products. This program served as the model for FDA legislation on seafood quality and safety.

States and local governments also enact regional food safety laws and regulations. Most states and local communities develop their food service sanitation regulations based on the FDA Model Food Code. The Food Code provisions include detailed time, temperature, and humidity charts for the cooking of meat; recommendations to ensure food service workers' health (eg, restricting infected employees) and hygiene practices (eg, cleaning, sanitizing, and maintaining utensils, equipment, and facilities); time limits for holding cooked foods safely outside of controlled temperatures; and provisions for shellfish safety.

Controls

The public health goal is to deliver foods to the consumer that are free from biological, chemical, and physical adulterants and thereby prevent the occurrence of foodborne illness. This goal is accomplished by applying both engineering and administrative controls throughout the production and distribution process. Generally, food safety regulations will specify the types of controls that must be implemented and followed.

Engineering controls in food safety practice include the design and construction of equipment that is used to process, store, transport, prepare, dispense, and serve foods. For example, the National Sanitation Foundation and the Underwriters[3] Laboratory publish criteria for the sanitary design of food-related equipment and will test equipment to determine if it meets the established criteria. Items that have been tested and certified by these organizations will bear their label. Food service sanitation regulations may require that equipment be approved by either of these organizations or meet similar design guidelines that are approved by local health authorities.

Time-temperature controls, employee health status checks, and food handling practices are considered administrative controls for food sanitation and safety.

Monitoring

Daily operational monitoring should be conducted by food service managers and workers. Managers should perform frequent inspections of workers to ensure that they are healthy (eg, no cold or influenza symptoms, no open sores) and perform their duties in a sanitary manner (eg, no direct hand contact with cooked food, washes hands after using the bathroom or handling raw meats), that raw products are not diseased or contaminated, that equipment operates properly and is sanitized frequently, that proper serving and storage temperatures are maintained, and that storage practices segregate potential contaminates, such as chemicals, from foods.

Health monitoring is performed by a health professional, traditionally a sanitarian or veterinarian. In the US military, Army veterinarians are responsible for approving and monitoring all food procurement sources and activities for all of the military services (see Chapter 30, The Role of Veterinary Public Health and Preventive Medicine During Mobilization and Deployment). Sanitarians (and the military equivalents) are the professionals that monitor the public health aspects of facilities that serve food. Public health monitoring is performed less frequently than operational monitoring.

Health monitoring frequency sometimes is established based on hazard potential factors such as operation size, food types, past inspection performance, and disease outbreak history. The Hazard Analysis Critical Control Point (HACCP) process can be a tool for determining appropriate monitoring frequency.[57] It involves identifying and monitoring the critical and more-hazardous points in food preparation by analyzing each food process; identifying the critical control points (CCP) of each process; establishing critical limits that should not be exceeded as preventive measures of each CCP; monitoring CCPs; correcting deficiencies; and maintaining records to document the system.

An extensive discussion of the numerous areas that are evaluated during a food service sanitation inspection is not possible within this chapter, but Exhibit 20-7 shows some areas that are reviewed during a typical inspection. Additional detail concerning these and other inspection areas, other aspects of food safety and sanitation, and foodborne illnesses can be found elsewhere.[2–5,58]

Field Food Sanitation

Sanitary food practices during military field and combat operations can be vital to the success of a unit's mission. Some foodborne illnesses can completely incapacitate service members or substantially decrease their overall ability to perform. Either is undesirable in a tactical situation. All of the principles and most of the practices applied to installation and civilian food service operations are applicable to field food service operations. The goal is the same in field, installation, or civilian food operations: to prevent foodborne illness.

Food must be protected from adulterants (biological, chemical, and physical) during transportation, storage, preparation, and service. Time-temperature control also remains important. In a theater of operations, health monitoring of these processes is performed by Army veterinarians and preventive medicine personnel. Army veterinarians are responsible for approving and monitoring food procurement sources. They also monitor storage and processing facilities, such as warehouses and food ration points. Environmental health and preventive medicine personnel monitor unit-level food service operations.

Dining facility managers should perform daily operational monitoring in the same manner as described earlier. Unit field sanitation personnel also should provide daily monitoring and frequently advise the commander on the sanitary conditions of the local food service operation.

Generally, the same areas of interest shown in Exhibit 20-7 are applicable to field food service operations; however, there are a few requirements that are applicable specifically to the field situation. These are discussed in an Army technical bulletin[58] and include prohibition of the use of potentially hazardous foods as leftovers; use of Meals-Ready-to-Eat when there is no or inadequate refrigeration; guidance on sanitizing local produce and fruits grown with human excrement fertilizer; and use of field-expedient methods for handwashing, waste disposal, and cleaning and sanitizing utensils and food preparation equipment. An Army field manual[59] has diagrams of these devices.

Ambient Air Quality and Pollution

Air contaminated with harmful substances has a direct entrance to the body. Vapors and gases can diffuse across the alveolar membranes, through capillary cells, and quickly enter the bloodstream to be carried to various regions of the body. Irritant vapors and gases also can react directly with and damage lung tissue. Particulates can lodge in lung tissue and elicit local responses such as fibrosis. The harmful effects that chemicals may exert when inhaled makes air quality a major public health concern and a concern for the military when deploying to a theater of operations.

Selected Health Concerns

Air pollutants can cause significant adverse health effects resulting in acute or chronic illness and death. This discussion presents selected air contaminants that may be of concern during military operations, as reviewed by Costa and Amdur,[60] to exemplify the range of physiological and toxic events that can occur.

EXHIBIT 20-7

FOOD SERVICE SANITATION INSPECTION AREAS

	Food Protection	
Sanitary quality	Product protection	Food storage
Food preparation	Leftovers	Transportation
Personal medications		First-aid supplies
	Food Service Personnel	
Employee health	Medical examinations	Personal cleanliness
Employee practices	Training	
	Equipment and Utensils	
Materials	Sealing compounds	Design and fabrication
Installation	Cleaning and sanitizing	Handling
Location	Maintenance and replacement	Storage
	Sanitary Facilities and Controls	
Water supply	Steam	Sewage
Plumbing	Toilet facilities	Linens
Garbage, refuse	Handwashing facilities	Pest management
	Construction and Maintenance of Food Service Facilities	
Floors	Ceilings	Lighting
Ventilation	Premises	Utility lines
Cleaning facilities	Cleaning equipment	Dressing rooms
Lockers	Walls	Service lines
	Mobile Food Units	
Beverages	Ice	Water system
Waste retention	Retention tank flushing	Storage units
Training	Operations	Construction
Potable water	Servicing facility	Servicing operations
Single-service articles	Special requirements	
	Temporary Food Service	
Equipment	Single-service articles	Water
Sewage	Handwashing	Floors
Walls	Food preparation areas	Ceilings
	Vending Machine Operations	
Food supplies	Equipment location	Special requirements
	Administrative Procedures of the Food Service Sanitation Program	
Inspection reports	Sanitizer effectiveness	Disease outbreaks

Adapted from: US Department of the Army. *Food Service Sanitation*. Washington, DC: DA; 1991. TB MED 530.

Sulfur Dioxide. Sulfur dioxide is a criteria pollutant under provisions of the Clear Air Act that is associated with emissions from fossil fuel combustion and industrial facilities such as coal-burning power plants, metal smelters, boilers, and oil refineries.[5] It can affect the body or the environment directly as sulfur dioxide or as sulfuric acid.[60] Sulfur dioxide is water soluble and thus can irritate the upper airway, cause bronchoconstriction by inhibiting the cervical vagosympathetic nerve, increase mucus secretion by goblet cell proliferation, and increase air flow. The increased airflow also increases the dose received and allows sulfur dioxide and other contaminants to penetrate to the deep lung. When sulfur dioxide is oxidized by photochemical processes or catalyzed by metals, it can form sulfuric acid, a respiratory irritant, and can affect pulmonary function.[60] Metal smelting or fossil fuel combustion can produce small metal oxide particles that may adsorb the acid and transport it long distances. Sulfuric acid may cause respiratory irritation due to its acidity and increase flow resistance because of bronchoconstriction. Its toxicity is associated with both concentration and particle size because smaller particles penetrate deeper into the lung. Acute effects from sulfuric acid exposure include biphasic alterations in mucociliary clearance (ie, concentrations less than 250 $\mu g/m^3$ increase clearance but greater than 1,000 $\mu g/m^3$ decrease clearance) and impaired macrophage function at 500 $\mu g/m^3$. Daily exposure to sulfuric acid at concentrations of 100 $\mu g/m^3$ or greater may impair clearance (also a biphasic response) and cause chronic bronchitis.

Particulate Matter. Particulate matter is a mixture of organic and inorganic materials that vary in composition and toxicity.[60] It may be composed of metals, gases, and other substances. Even though practically all metals can be found in particulate matter, the most common ones are those associated with fossil fuel combustion (eg, transition and heavy metals) and those common to the earth's crust (eg, iron, sodium, magnesium). Gases and vapors may interact with particulate matter to enhance delivery to the lungs and cause adverse health effects. For example, sulfuric acid adsorbed to metal particles with a mean aerodynamic diameter of 0.1 µm distribute the acid wider and deeper in the lung, causing irritation greater than that expected from the acid alone. When sulfur dioxide absorbs into sodium chloride droplets in the presence of a transition metal, it can oxidize to sulfate to form sulfuric acid, which can cause pulmonary irritation. Particle size is related to where and how deep particulate matter can deposit in the respiratory system. Generally, particulate matter with a mean aerodynamic diameter of less than 10 µm is considered sufficiently small to deposit at lung levels that adversely affect health. Chemicals that are water soluble can have enhanced toxicity because of increased bioavailability and pulmonary residence time. Diesel exhaust in urban areas has been shown to contain a significant amount of particulate matter and is an example of a chronic health concern because it is considered to be a potential human carcinogen.[60]

Ozone. Ozone is a photochemical air pollutant that can irritate the lungs and can cause death by pulmonary edema.[60] Its effects are cumulative and depend on concentration and time. A substantial portion of inhaled ozone penetrates into the deep lung due to its poor water solubility. Its greatest deposition occurs in the acinar region from the terminal bronchioles to the alveolar ducts (the proximal alveolar ductal region). Exercise increases the dose received because of the increased lung tidal volume and air flow rate. Some of the effects caused by exposure to ozone include epithelial cell injury along the entire respiratory tract, inflammation, and altered permeability of the blood-air barrier; these are reversible. Pulmonary function effects include concentration-related decrements in forced exhaled volumes and increased nonspecific airway reactivity. In animals such as rats, mice, and hamsters, exposure to ozone before challenges with aerosols of infectious agents (eg, *Streptococcus*, *Klebsiella pneumoniae*) produced a higher incidence of infection than in control animals. Studies of ozone mixed with other air pollutants (eg, nitrogen dioxide and sulfuric acid) suggest that there may be potentiation or additive effects.

Carbon Monoxide. Carbon monoxide concentrations in the atmosphere originate from both natural (eg, forest fires) and humanmade (eg, automotive vehicles) sources.[3] Between 1988 and 1995, carbon monoxide concentrations in the ambient atmosphere ranged between approximately 5 and 7 ppm (parts per million); however, in urban areas they reach levels as high as 70 to 100 ppm due to vehicular traffic.[2,3] Carbon monoxide is a chemical asphyxiant that produces carboxyhemoglobin, which has a 220-times greater affinity for hemoglobin than oxygen. Thus, carboxyhemoglobin prevents systemic transport of oxygenated blood, resulting in characteristic hypoxic signs and symptoms. The brain and heart are most sensitive to hypoxia because of their high oxygen demands. Acute carbon monoxide poisoning may cause subendocardial infarction, cerebral edema, and congestion and hemorrhages in all organs. In addition to exposure from ambient air pollution, heavy cigarette smoking (two packs a day) and occupational exposure to methylene chloride also can produce carboxyhemoglobin.

There are numerous other atmospheric contaminants that can cause adverse health effects in humans. For example, in addition to criteria air pollutants, the Clean Air Act Amendments of 1990 specifically list 189 hazardous air pollutants. A few additional examples are listed in Table 20-9.

Contaminants and Standards

In the United States, the first federal law for air quality was established in 1955 as the Clean Air Legislation and amended in 1960 and 1962. The Air Quality Act of 1967 replaced the 1955-based legislation and subsequently was amended in 1970, 1977, and 1990 as the Clean Air Act. Some collective features the various laws share are control of emissions from both stationary and mobile sources, including vehicles, and the recognition that states have primary responsibility for air quality, monitoring requirements, and application of control technologies. The Clean Air Act obligates the USEPA to develop air quality criteria, standards for sources of hazardous air pollutants, and regulations for accidental release of extremely hazardous chemicals to protect public health.[2,3,5] The Clean Air Act of 1990 has eleven parts (or titles) that address criteria and control of specific contaminants, research, training enforcement, and other issues.

Salvato[2] identifies several other federal laws that affect air quality, to include the Resource Conservation and Recovery Act; the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund); and the Emergency Planning and Community Right-to-Know Act, also called Superfund Amendment and Reauthorization Act Title III (SARA Title III).

Controls

Air pollution control strategies and treatment options are designed either to control emissions at the source or to dilute them after they are released. Since the emissions contain both gases and particulates, controls and treatments must be designed to address each. Specific examples of control technologies can be found elsewhere.[2,6]

Monitoring

Koren and Bisesi[6] cite three reasons for monitoring air pollution: (1) to provide an early warning

TABLE 20-9

EXAMPLES OF CLEAN AIR ACT CRITERIA POLLUTANTS AND HAZARDOUS AIR POLLUTANTS AND THEIR MAJOR HEALTH EFFECTS

Contaminant	Health Effects
Lead	Retardation and brain damage, especially in children
Nitrogen dioxide	Respiratory illness and lung damage
Asbestos	Asbestosis, cancer
Beryllium	Lung diseases; also affects liver, spleen, kidney, and lymph glands
Mercury	Affects brain, kidneys, and bowels
Vinyl chloride	Lung and liver cancer
Arsenic	Cancer
Benzene	Leukemia
Radionuclides	Cancer
Formaldehyde	Irritates mucous membranes, increased airway resistance
Acrolien	Irritates mucous membranes, increased airway resistance and tidal volume

system for potential health effects, (2) to assess air quality and compare it to standards, and (3) to track trends and specific polluters. Air pollution monitoring consists of both operational monitoring and health monitoring.

Operational monitoring usually is performed by site workers and consists of frequent observation, testing, and assessment of equipment, conditions, and processes to determine if air pollution controls are functioning properly. This may consist of inspecting waste streams or chemicals to ensure that the appropriate types and quantities of substances are being processed, because inappropriate substances may cause or increase air pollution. Also, production and processing equipment and pollution control equipment should be evaluated to determine if they are operating within design specifications. Testing may consist of reviewing the output from continuous monitors or data from grab samples used to determine if air emissions exceed permit and other regulatory requirements. When observations or testing reveal that conditions are not normal, then operational monitors should alert the appropriate health or regulatory agency to allow an assessment of health implications and implementation of corrective measures.

As discussed with other environmental health concerns (eg, drinking water, wastewater) health monitoring for air pollution also includes a sanitary survey, sampling and analysis, and interpretation.

Policy

Generally, policy issues for air quality concerns include economic, political, and technological considerations. Specific examples are the degree of stringency for standards, interstate (eg, acid rain) and international (eg, ozone depleting substances) issues, and control technology. Air quality statutes require establishment of primary standards to protect public health and secondary standards to protect public welfare. Secondary standards relate to "effects on soils, water, crops, vegetation, manmade materials, animals, wildlife, weather, visibility and climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well-being."[61(p65640)]

Military Significance

Air quality issues may affect military operations and should be considered by the preventive medicine and environmental health planner. The information in the hazardous material management section and in Exhibit 20-5 is applicable for considering potential air pollution sources. Air pollution's potential to cause acute effects obviously can hinder the ability of military personnel to perform their mission. Potential longer-term and delayed effects also should be considered. For example, the combustion products from the Kuwait oil well fires during the Persian Gulf War could have resulted in acute and chronic adverse health conditions to exposed US and allied military forces and affected tactical capabilities. A health risk assessment of air sampling data showed that ground level concentrations of selected contaminants were negligible and not expected to cause adverse health effects.[62]

Another example of a military-related air quality situation occurred in Ploce, Croatia, in 1996 during Operation Joint Endeavor.[63] A brake-lining facility was located next to the billeting office, motor pool, and administrative spaces of French units involved with port operations and transportation. Also on the site was an Italian compound with military police and medical personnel. There was an unknown odor around the factory, possibly from the matrix material used to contain the asbestos in the brake linings. Commanders were considering moving the units to other locations if there was a demonstrated or potential health hazard. Air sampling for asbestos fibers did not produce any observable fibers, and there were no abnormal cases of lung distress nor increased incidence of respiratory illnesses. A number of service members were questioned about their health, and none expressed any respiratory concerns. The units did not relocate. The importance of air quality in Bosnia-Herzegovina is emphasized further because it is a component of environmental exposure surveillance.[62] When coupled with geographic information system technology, exposure of US force personnel to air contaminants can be monitored as a proactive public health approach to protect US forces from environmentally related disease.

FIELD SANITATION

Introduction and Definition

Environmental health concerns during military operations are different from those of a civilian health department or fixed military installation. The differences can be attributed to the nature of field operations, which tend to be in more environmentally hostile and often more primitive environments.

To reduce and minimize disease and nonbattle injuries, measures of preventive medicine and environmental health are integrated into military operations and doctrine. Also, throughout a theater of operations there are a variety of preventive medicine and environmental health organizations and professionals who provide advice and services to commanders and units (see Exhibit 20-3; Chapter 12, Preventive Medicine Considerations in Planning Multiservice and Multinational Operations; and Chapter 13, Preventive Medicine and the Operation Plan). However, the number of preventive medicine personnel in a theater of operations is not sufficient to assign a preventive medicine professional to each company or similarly sized unit. For example, an Army division, which may have 100 or more companies and up to 21,000 soldiers, is authorized 6 preventive medicine professionals: one Preventive Medicine Officer, one Environmental Science Officer, one Preventive Medicine Noncommissioned Officer, and three Preventive Medicine Specialists. This relatively small number of preventive medicine personnel and the large geographic area over which a division may be spread makes it impossible to provide direct environmental health support to each company-sized unit. To compensate for this shortfall, unit leaders and individual service members must learn environmental health practices that prevent disease and injury and incorporate them into daily practices, operations, and missions. These measures are called field sanitation.

The principles of field sanitation should be practiced in all of the military services; however, the following discussion is based on the US Army model, as described in the Army Regulation *Preventive Medicine*[64] and Field Manual *Field Hygiene and Sanitation*.[59] Other publications that describe various field sanitation practices are listed in Exhibit 20-8.

Command Responsibility and the Unit Field Sanitation Team

Field sanitation is a command responsibility. Commanders at all levels have the overall responsibility for maintaining optimum health conditions. Any condition that is less than optimal can potentially interfere with the ability of a unit to conduct its mission. Commanders are responsible for planning for unit field sanitation efforts before deployment (eg, training, acquiring and maintaining equipment, developing standard operating procedures) and implementing field sanitation practices when deployed. Army doctrine[62] requires commanders of a company or similarly sized field unit (ie, Table of Organization and Equipment units) to appoint and train a Field Sanitation Team (FST) to perform specific environmental health monitoring, testing, and training. This team will consist of a minimum of two soldiers and at least one should be a noncommissioned officer; generally, this is an additional duty.

Typically, unit FSTs are trained by environmental health or preventive medicine professionals from a Division Preventive Medicine Section or a Corps- or theater-level preventive medicine organization. Other medical personnel assigned to unit aid stations (eg, physician assistants and medical corpsman) or other medical units also may provide training. Several of the references listed in Exhibit 20-8 provide the technical information that the FST should be taught. The Field Manual *Unit Field Sanitation Team*[65] contains guidance for training FSTs in aspects of maintaining safe drinking water (eg, evaluating the container, chlorinating, testing chlorine residual), field food service sanitation, arthropod and rodent control, waste disposal, heat and cold injury prevention, and personal hygiene.

The unit FST is an essential line of defense against disease and preventable injury and therefore should continually advise the commander concerning sanitation indicators. Many of the activities that the FST monitors have been discussed earlier in this chapter (eg, field drinking water, field food service sanitation) or elsewhere in this text. Exhibit 20-9 lists some examples of the FST's functions.

Improvised Field Sanitation Devices

As is shown in Exhibit 20-9, the unit FST may recommend the types of and monitor the construction of waste disposal, shower, and handwashing facilities. If the area of operations is in a town or city and the tactical situation permits, an existing infrastructure may supply the necessary facilities. If there are no or limited facilities or the tactical situation does not allow access to existing facilities, however, field sanitation devices must be fabricated. The devices selected for use depend on a variety of conditions, such as the tactical scenario (eg, smoke from a burn-out latrine or from burning trash may give away a unit's location), the amount of time the unit will remain in a particular location, and the environmental conditions (eg, digging holes for sewage and solid waste disposal may not be possible if the ground is frozen or has a shallow rock layer).

The complexity of an improvised sanitation de-

EXHIBIT 20-8

SELECTED MILITARY FIELD SANITATION REFERENCES

Regulations

Immunizations and Chemoprophylaxis (AR 40-562, AFJI 161-13, BUMEDINST 6230.15, CGCOMDINST M6230.4E)
Pest Management (AR 420-76)
Preparation for Oversea Movement of Units (POM) (AR 220-10)
Preparation of Replacements for Oversea Movement (POR) (AR 612-2)
Preventive Dentistry (AR 40-35)
Preventive Medicine (AR 40-5)
Veterinary/Medical Food Inspection and Laboratory Service (AR 40-657)

Field Manuals

Army Food Service Operations (FM 10-23)
Brigade and Division Surgeons' Handbook (FM 8-10-5)
Combat Stress Control in a Theater of Operations (FM 8-51)
Control of Communicable Diseases Manual (FM 8-33)
Field Hygiene and Sanitation (FM 21-10)
Food Sanitation for the Supervisor (FM 8-34)
Management of Skin Diseases in the Tropics at Unit Level (FM 8-40)
Preventive Medicine Technician (FM 8-250)
Unit Field Sanitation Team (FM 21-10-1)
Water Supply in Theaters of Operations (FM 10-52)
Combat Health Support in Stability Operations/Support Operations (FM 8-42)
Planning for Health Services Support (FM 8-55)

Technical Bulletins—Medical

Cold Injury (TB Med 81)
Food Service Sanitation (TB Med 530)
Medical Problems of Man at High Terrestrial Elevations (TB Med 288)
Prevention, Treatment, and Control of Heat Injury (TB Med 507)
Sanitary Control and Surveillance of Field Water Supplies (TB Med 577)

Other Publications and Resources

Commander's Guide to Combat Health Support (DA Pam 40-19)
Disease and Environmental Alert Reports (Armed Forces Medical Intelligence Center, Fort Detrick, Md)
Disease Occurrence—Worldwide (Armed Forces Medical Intelligence Center, Fort Detrick, Md)
Manual of Naval Preventive Medicine (NAVMED P-5010, Bureau of Medicine and Surgery, Washington, DC)
Personal Protective Techniques Against Insects and Other Arthropods of Military Significance (US Army Environmental Hygiene Agency Technical Guide 174, Aberdeen Proving Ground, Md)
Soldier's Handbook for Individual Operations and Survival in Cold-Weather Areas (Department of the Army Training Circular 21-3)
Armed Forces Medical Intelligence Center Medical Environmental Disease Intelligence and Countermeasures CD-ROM (Armed Forces Medical Intelligence Center, Fort Detrick, Md)

Adapted with permission from Withers BJ, Erickson RL, Petruccelli BP, Hanson RK, Kadlec RP. Preventing disease and nonbattle injury in deployed units. *Mil Med.* 1994;159:39–43.

EXHIBIT 20-9

SOME OF THE FUNCTIONS OF THE FIELD SANITATION TEAM

- Assists in the selection and layout of bivouac sites to avoid insect infestations and pollution sources
- Recommends the types of and monitors the construction of facilities for waste disposal, showering, and hand washing
- Monitors the disposal of liquid and putrescible wastes to prevent mosquito breeding and fly breeding (human waste, sometimes referred to as black water, should not be mixed with liquid waste from showers, handwashing stations, and food service facilities, referred to as gray water)
- Monitors drinking water acquisition and consumption; checks chlorine levels and disinfects if necessary
- Monitors the transport, storage, handling, preparation, and service of food to prevent contamination
- Issues iodine tablets
- Issues insect repellent and assists personnel in treating uniforms and bednetting with permethrin; encourages use of personal protection measures
- Issues powders, dusts, and uniform impregnants as appropriate
- Provides limited pest control for insects and rodents
- Trains unit members in aspects of personal hygiene and individual field sanitation measures

vice will depend on the availability of building materials and construction support. A decision matrix to select appropriate devices is shown in Exhibit 20-10. Examples of improvised field sanitation devices and some construction criteria are contained in Army field manuals for field hygiene and sanitation[59] and unit field sanitation teams.[65]

Personal Hygiene

In addition to the commander's responsibility and the duties of the FST, the individual service member is the first line of defense for combating disease and must perform certain personal functions to remain healthy in the field environment. The individual is responsible for his or her own personal hygiene and individual field sanitation measures. Some examples are:

- maintaining cleanliness by bathing and brushing and flossing teeth as frequently as possible,
- keeping the feet clean and dry and using foot powder,
- maintaining a clean living area,
- wearing clean clothes,
- wearing clothing properly to prevent heat and cold injuries, insect bites, and injury,
- using insect repellents,
- using bed netting and insect sprays,
- drinking water and eating properly, and
- maintaining proper immunizations.

Standards, Controls, and Monitoring

The environmental health topics in the other sections of this chapter have been presented in terms of applicable standards, controls, and monitoring. Field sanitation also can be discussed in this manner. For example, the Army's preventive medicine regulation,[64] field manual,[59] and field sanitation technical references (see Exhibit 20-8) can loosely be considered the "standards" for field sanitation even though they do not fit the criteria for standards as discussed in this chapter's introduction. Field sanitation practices, field sanitary devices, and FST equipment may be considered as controls. FST surveillance and inspections constitute operational monitoring and visits by division or other theater preventive medicine personnel may be considered health monitoring.

EXHIBIT 20-10

DECISION MATRIX TO DETERMINE FIELD DISPOSAL REQUIREMENTS

	Highly Mobile	Short Bivouac	Extended Bivouac
CAT-HOLE Cover with dirt after use	X		
STRADDLE TRENCH • Enough for 4% of males and 6% of females • Cover with dirt after each use		X	
DEEP PIT • Enough for 4% of males and 6% of females • Add urinals to protect seats			X
CHEMICAL TOILETS • Use where field sanitation devices are prohibited		X	X
GARBAGE PIT • Locate near dining facility, but not closer than 30 yards • One pit per 100 soldiers served per day • Cover with dirt after each meal, close daily		X	X
SOAKAGE PIT (Food Service) • Locate near dining facility alternate daily use • Fill with loose rocks • Add grease trap for dining facility waste		X	X
SOAKAGE PIT (Other) • Provide pit for urinals, shower, or other locations where water collects			X
MESS KIT LAUNDRY • Dig soakage pit to provide good drainage		X	X
HANDWASHING DEVICES • Dig shallow soakage pit • Collocate with latrine and food facilities		X	X
SHOWERS • Dig soakage pit			X
URINALS • Trough • Pipe • Urinoil			X

Adapted from US Department of the Army. *Field Hygiene and Sanitation*. Washington, DC: DA; 1988. Field Manual 21-10.

SPECIAL TOPICS

Indoor Air

Ambient air quality was discussed earlier in this chapter, but indoor air quality (to include the air in office buildings) and workplace air quality (ie, atmospheres generated by typical industrial work activities, such as welding fumes and solvents) are also important issues.[68–72] Common indoor air agents include gases (eg, nitrogen dioxide, carbon monoxide, and sulfur dioxide from gas stoves and heaters or garaged-vehicle exhaust), volatile organics (eg, formaldehyde from tobacco smoke and glues), reactive chemicals (eg, isocyanates from paints and structural supports), and biological particulates (eg, allergens from dust mites, animal dander, fungi, toxins).[66] In industrial workplaces, contaminants are identified as those substances that are regulated under the Occupational Safety and Health Act (29 CFR 1910) and include a variety of vapors, gases, and particulates that have permissible exposure limits (PELs). The American Conference of Governmental Industrial Hygienists (ACGIH) also recommends exposure limits for hazardous workplace air contaminants.[67] Some military systems generate air contaminants (eg, vehicles and weapons systems) that can cause both acute and chronic effects if excessive exposure occurs.

Confined Space

In both civilian and military settings, confined spaces can be deadly, so precautions and safe practices must be followed to prevent fatal events. Confined spaces are defined as spaces that by design have limited openings for entry and exit and unfavorable natural ventilation that could contain or produce dangerous air contaminants; they are not intended for continuous employee occupancy.[73] Examples include but are not limited to storage tanks, ship compartments, process vessels, pits, silos, vats, degreasers, reaction vessels, boilers, ventilation and exhaust ducts, sewers, tunnels, underground utility vaults, and pipelines. The military preventive medicine or environmental health practitioner should be especially vigilant of such areas at military field, installation, and depot maintenance operations. Examples of other places of military interest include railheads, marine terminals, and ports.

Hazards that may exist in a confined space include oxygen deficiency due to displacement by simple asphyxiants (eg, carbon dioxide, nitrogen) or oxidation reactions (eg, welding, rusting); hazardous atmospheres (eg, flammable, explosive, irritant, or corrosive gases, vapors, fumes, or particulates); and engulfment from fill materials, (eg, grain or stones in a rail car, hopper, or silo).

Federal regulations (OSHA; 29 CFR Part 1910.126) require workplaces to identify confined spaces and institute specific practices to minimize or preclude accidental injury, illness, or death associated with such areas. These spaces must be tested and monitored before and during occupancy, and specific safety and health precautions must be followed to preclude accidental injury or death. Examples of these precautions include sampling the atmosphere, dilution ventilation, use of personal protective equipment (eg, respirators, harnesses), training, and positioning a trained worker outside of the workspace in sight of the person inside.[74,75]

There is another category of similar spaces that also could be harmful. These, identified as enclosed spaces, would normally not be considered confined spaces. During certain conditions (eg, during maintenance and repair work), though, they warrant an evaluation to determine if precautions for entry into confined space are required.[75] Examples of military enclosed spaces include mobile vans, shelters, crew compartments, and vehicle cabs.

Global Issues and Department of Defense Environmental Activities

The environmental health issues presented in this chapter primarily draw on experiences in the United States, with some emphasis on the impact to US military forces. Outside of the United States, however, some issues may have to be looked at from a different perspective because of different social, economic, and political dynamics. For example, in the United States the emphasis in drinking water quality is on controlling chemical contaminants, especially carcinogens. In lesser-developed countries, though, the emphasis on microbial control is greater,[76] presumably because infectious diseases are more prevalent than in the United States. Adverse environmental conditions and subsequent effects on human health can lead to destabilization and cause social, economic, and political unrest in a country. Such conditions may affect how countries interact with each other and lead to regional and global conflicts. Conflicts may be avoided if environmental conditions are sustained in a manner that supports and enhances human health. Thus, if the United States assists other nations in resolving environmental problems, then the possibility of conflicts may be reduced. This concept was addressed by Secretary of Defense William J. Perry in 1997, who described it as "Preventive Defense" which "creates the conditions which support peace, making war less likely and deterrence unnecessary."[77(pW-13)] This also is one of the goals of the Department of Defense's thrust in international environmental activities.[78]

SUMMARY

We strive to interact with the environment in ways that are not harmful to our health but enhance our lives. Environmental health is a public health specialty that promotes a healthy relationship between people and their environment. This chapter presents several perspectives for medical and public health professionals, particularly those in the military, to consider concerning environmental health. Environmental factors need to be anticipated, recognized, evaluated, and controlled to prevent adverse health effects. The critical functions performed in the practice of environmental health—standards, controls, monitoring, and policy—can be applied to specific subjects that occur during and can affect deployments. The subjects introduced in the chapter—drinking water, military field water, swimming pools and bathing areas, wastewater management, managing hazardous materials, managing waste, food safety and sanitation, ambient air quality and pollution, field sanitation—are as important to the health and efficiency of military personnel on deployment as they are on permanent installations in the United States.

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