Environmental ENGINEERING

PREVENTION and RESPONSE to Water-, Food-, Soil-, and Air-borne Disease and Illness

SIXTH EDITION

Nelson L. NEMEROW, Franklin J. AGARDY, Patrick SULLIVAN, and Joseph A. SALVATO

ENVIRONMENTAL ENGINEERING, SIXTH EDITION:

Prevention and Response to Water-, Food-, Soil-, And Air-Borne Disease and Illness

EDITED BY NELSON L. NEMEROW, FRANKLIN J. AGARDY, PATRICK SULLIVAN, AND JOSEPH A. SALVATO

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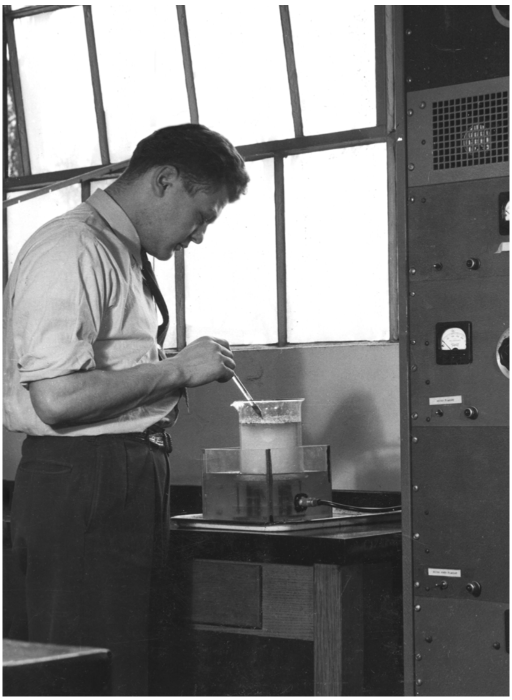
Doctors Agardy and Sullivan would like to dedicate this sixth edition of *Environmental Engineering* to Nelson L. Nemerow who passed away in December of 2006. Dr. Nemerow was born on April 16, 1923 and spent most of his productive years as a educator and prolific author. He spent many years teaching at Syracuse University, the University of Miami, North Carolina State, Florida International and Florida Atlantic University. He authored some 25 books dedicated to advancing the art of waste disposal and utilization. His passion was waste minimization and the title of one of his most recent publications, *Zero Pollution for Industry* summed up over fifty years of teaching and consulting. A devoted husband and father, he divided his time between residences in Florida and Southern California. Nelson served in the United States Merchant Marine during World War Two. His committment to excellence was second to none.



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PREFACE

The pressure placed on the environment as the global population approaches seven billion people has brought about the proliferation and spread of diseases associated with air, water and food. The pressure of population, especially in urban areas, has placed a great burden on public health agencies in attempting to deal with these problems. Many diseases which were thought to have been eliminated by prior public health efforts have not only rebounded but are often difficult if not impossible to treat.

Recognition must also be given to the fact that developing countries, by definition, do not have the resources to address water treatment and pollution problems to the same degree that more advanced nations, with much larger budgets and technical skills, have accomplished. Where economic and technical constraints limit treatment options, taking care of basic needs and minimum levels of sanitation become the driving force underlying technological implementation.

Increasingly, the world is faced with a new set of challenges to the environment, namely the need to develop plans to address emergencies—in real time. Issues such as hazard analysis, security assessment, emergency training, response logistics and standby medical equipment have taken on new meaning. Increased population densities in urban areas and along coastlines puts many more lives at risk from environmental emergencies and requires increased levels of detail and response, not seen in the past.

These problems can and are being addressed and dealt with and it is hoped that this text will aid in putting the problems into the proper prospective and bring forward solutions which can be implemented.

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CHAPTER 1

DISEASE TRANSMISSION BY CONTAMINATED WATER

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INTRODUCTION

Water is traditionally viewed as the "universal solvent" which accounts for its vital support of all living things. The property of solvency is also responsible, in the main, for the chemical quality of natural water as pertains to the dissolution of naturally occurring minerals, atmospheric gases, and organic molecules present in plant and animal residues. Natural waters are also a vehicle for suspended matter, including microbial cells.

Fresh surface waters are collectively represented by streams, rivers, lakes, ponds, and reservoirs and constitute a major source of drinking water. Unless protected, they are prone to receiving anthropogenic discharges of domestic, industrial, and agricultural wastewaters. Such adulterations alter the natural water quality, and the severity of change is dependent on the rate, extent, and composition of the waste discharges. Groundwater (subsurface water) is the most plentiful form of available freshwater. However, owing to greater inaccessibility and higher cost, groundwaters are less utilized as a water supply than surface waters.

The consequences for utilizing polluted waters as a drinking water supply are well documented historically and will be dealt with in the section "Historical waterborne disease background." Natural water should be valued both as a commodity and a habitat for aquatic life. The former consideration pertains to public health issues and the latter deals with the ecological value of natural waters.

Surface waters can be rated according to best usage with respect to drinking, bathing, shellfish rearing, fishing, and navigation purposes. A set of minimum water-quality standards defines the best usage of a water body. Waters suitable for drinking-water supplies, recreational bathing, and shellfish rearing are monitored regularly for microbiological quality. The best usage of a water body such

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as a river may change along its course. Designation of a water according to best usage as a source of drinking water may imply high raw water quality but does not preclude the need for proper treatment of the water before release to consumers. Even then, faults in the water distribution system can permit access of disease-producing microbes to an otherwise-adequately treated water. Furthermore, drinking water sources and subsequent purification steps vary widely in quality among world nations. It cannot be assumed that water drawn from a faucet is totally safe to consume, especially, in lesser-developed countries and rural areas. During a visit to Canada in 1989, then-Czechoslovakian president Vaclav Havel remarked, “I was surprised to learn that I was drinking tap water. No one in Czechoslovakia would do that.”[1]

Only about 2.6 percent of the global content of water constitutes fresh water (atmospheric, and both surface and subsurface water bodies). Distribution of fresh-water supplies among countries of the world is uneven and without regard to population demands. Although water is a renewable resource, loss of usable drinking-water supplies through unfavorable natural and manmade environmental changes intensifies the challenge of providing adequate and safe drinking water worldwide in the coming years. There is the anticipation of major alterations in rainfall patterns and increased frequency of catastrophic floods owing to climate change, meteoric expansion of human populations, and the likelihood of increasingly unfavorable air, soil, and water quality in populous nations such as China and India, where the focus is on competitive economic development. Compromising environmental standards, especially with respect to drinking-water quality, heightens the potential for transmission of disease-producing agents within the population. Poor sanitation is unequivocally linked to the occurrence of high rates of communicable and noncommunicable diseases worldwide.

The title of this chapter is “Disease Transmission by Contaminated Water.” The classical concept of disease transmission by contaminated water is by the oral route. Other avenues of infection are possible, however. Gleeson and Gray[2] have denoted four categories of infectious behavior in humans through contact with contaminated water or lack of water:

1. *Waterborne disease*. Sickness or ailment results from ingestion of water that is harboring a pathogen.
2. *Water-washed disease*. Sickness or ailment is spread by the fecal-oral route or person-to person contact and facilitated by the lack of adequate water for personal hygiene,
3. *Water-based infection*. Sickness or ailment is caused by infection arising through ingestion of a pathogenic agent (e.g., guinea worm larvae) or invasion of the body through water contact (e.g., schistosome and other trematode larvae able to penetrate the skin of individuals in contact with water).
4. *Water-related diseases*. Sickness or ailment is facilitated by insect vectors that breed in waters (e.g., malaria mosquitoes and filariasis arthropods that carry viruses responsible for dengue ad yellow fever).

To these may be added three more:

5. *Inhalation of water aerosols contaminated by a pathogenic agent*. This could include *Legionella pneumophila*, the etiologic agent of legionellosis and Pontiac fever.
6. *Consumption of water-based foods derived from contaminated water*. Sickness might be related, for example, to ingestion of raw shellfish containing *Vibrio vulnificus* or *V. parahemolyticus*, both causative agents of diarrheal diseases.
7. *Consumption of foods that have had contact with contaminated water at some stage of production*. Sickness results from microbial contamination during production/preparation (e.g., irrigation, washing, and preservation) of food such as leafy vegetables.

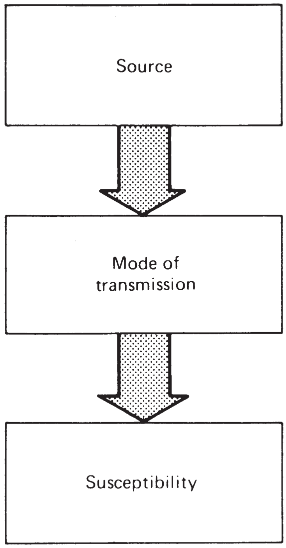
Many disease-producing viruses and bacteria have been identified in this connection, and the protozoan, *Cyclospora cayetanensis*, etiologic agent of a diarrheal disease, cyclosporiasis, with pathology resembling that of cryptosporidiosis, has been identified in imported raspberries and lettuce from South American countries.[3]

At this juncture, it is recommended that the reader consult the definition of terms in Chapter 2 in order to appreciate textural issues. Most definitions of the phrase "communicable disease" emphasize the involvement of an identifiable pathogenic agent. With any communicable disease, there is the need to transmit or communicate an infectious agent to a host by means of a vector or vehicle or person-to-person contact. Continuous propagation of the communicable disease within members of a population requires that the infectious agent be able to exit the diseased individual and find access to a healthy person. One definition of communicable disease appears in the list of definitions given in Chapter 3 and includes "toxic products" of infectious agents as an instrument of communicable diseases. Biological-based toxins alone have rarely been found to be the cause of a water-transmitted disease. However, such toxins are a potential weapon for terrorists and, notwithstanding the minimal chance of success, are an anticipated threat to water supplies.

Ingestion of chemical contaminants in water may cause acute and chronic forms of toxicity leading to the development of noncommunicable diseases in individuals. Biological agents are the cause of infectious (communicable) diseases that may or may not be contagious.

Control of Source (Agent Factors)

Certain sources of disease agents are noted in Figure 1.1. Gerstman[4] defines an agent as a biological, chemical, or physical factor whose presence or absence in varying amounts is required for the occurrence of a disease; a form of necessary factor. Gerstman identified several types of factors of varying essentiality in the propagation of a communicable disease. The agent is a necessary factor, that is, its presence in the host is required to produce a disease although its presence



Source (agent factors-physical, chemical biologic): food and infected or infested animals; poisonous plants and animals; parasites; toxic solid, liquid, and gaseous substances and natural deposits; genetic and inherited materials; ionizing and nonionizing radiations; noise.

Mode of transmission or contributing factors (environmental factors): environmental pollutants; contact; animals; personal behavior; level of hygiene, sanitation, standard of living; work, recreation, travel,home, climate.

Susceptibility (host factors): all animals or susceptibles, resulting in acute, chronic, or delayed effects, depending on portal of entry, dose, and virulence or toxicity of the agent; natural and acquired resistance of the host, and lifestyle.

Animals include humans and arthropods. *Arthropods* include insects, arachnids, crustaceans, and myriapods. *Environmental pollutants* may be transmitted by air, water, food, or contact. *Personal behavior* may involve cigarette smoking, drug use, poor nutrition, stress, lack of exercise, cultural habits, and obesity. *Physical agents* may be heat, cold, precipitation, and causes of accidents. *Biologic agents* include arthropods, helminthes, protozoa, fungi, bacteria, rickettsiae, and viruses. Chemical agents include inorganic and organic chemicals.

FIGURE 1.1 Spread of communicable and noninfectious diseases.

does not guarantee that the disease may be expressed. There is ample evidence that individuals may be carriers of a pathogenic agent (necessary factor) but not become clinically ill. The kinds of factors proposed by Gerstman are addressed elsewhere in the chapter. Elimination or control of the source and environmental exposure to disease agents or vectors is a primary step to be carried out to the extent feasible. Individuals frequently are not aware that they are being exposed to a potential source of disease, particularly when it is a minute, insidious, and cumulative substance, such as certain chemicals in the air, water, and food. An additional complication arises on the biological front when the disease agent is transmissible by more than one route. For example, many of the viral and bacterial agents of disease can be transmitted through both contaminated food and water.

In many instances, control at the source is not only possible but also practical. Measures that might be taken to reduce or eliminate the appearance of toxic substances in waters are:

1. Change the raw material or industrial process to eliminate or adequately minimize the offending substance. For example, terminate the production

of a chemical such as polychlorinated byphenyl (PCB). The U.S. Environmental Protection Agency (EPA) "zero-discharge" *goal* is a step in this direction.

2. Select the cleanest available source of drinking water, as free as possible from microbiological and toxic organic and inorganic chemicals.
3. Make available water with optimum mineral content, such as through fluoridation and water hardness control.
4. Prohibit taking of fish and shellfish from contaminated (e.g., pathogen, methylmercury, PCB) waters.
5. Regulate food production, processing, and service to ensure freedom from toxic substances and pathogens and to assure food of good nutritional content.
6. Provide decent housing in a suitable living environment.
7. Provide a safe and healthful work and recreational environment.
8. Promote recycling, reuse, and zero discharge of hazardous wastes.
9. Eliminate disease vectors (arthropods and other animals, including rodents) at the source. Practice integrated pest management.
10. Isolate infected persons and animals from others during their period of communicability and provide medical treatment to eliminate disease reservoir.
11. Educate polluters, legislators, and the public to the need for regulation and funding where indicated.
12. Adopt and enforce sound standards.
13. Support comprehensive environmental health, engineering, and sanitation planning, surveillance, and regulation programs at the state and local levels.

See also "Control of Susceptibles (Host Factors)" in this chapter.

Control of Mode of Transmission

Several types of factors may be brought into any discussion of disease expression and transmission. An environmental factor, in the context of disease transmission, would be any external physical, biological, or chemical condition, other than the agent, that contributes to the disease process.[4] As an example, several environmental factors, including high humidity, high temperature, neutral to slightly alkaline soils, presence of organic matter, variety of animal reservoirs, and infected cattle herds, appear to contribute to the high endemic rate of leptospirosis in certain tropical countries.[5] Several species of *Leptospira* are pathogenic. The causative agent of Weil's disease is the pathogenic spirochete, *Leptospira interrogans* serovar Icterohemmoragiae. The disease is one of the leading zoonoses worldwide and, while the incidence is infrequently encountered in the temperate climates (0.1 to 1 case per 100,000 individuals per year), it is more prevalent in tropical areas of high rainfall (10 to 100 cases per 100,000 individuals per year).[6] Although this chapter has the focus of water involvement within the scope of illness transmission in the environment, it is well to adopt an interconnective attitude toward the control of environmental disease transmission in general. It is necessary to continually ask the question, “Can a known pathogen or toxic substance be exposed to a susceptible population by more than one route?” Again, leptospirosis may be used to address the question. Leptospires may be found in the urine of those suffering from leptospirosis. Vehicles of transmission for this disease are urine-contaminated water, food, and direct bodily contact with contaminated materials, such as through cuts and abrasions of the skin and mucous membranes. In addition, many animals, especially rodents, are reservoirs of the leptospires. It can be appreciated, therefore, that spread of the pathogens is open to many routes of transmission.

Prevention of disease requires the continual application of control procedures such as the following 10 measures and elimination of the human element to the extent feasible:

1. Prevent the travel of disease vectors and control disease carriers.
2. Assure that all drinking water is at all times safe to drink and adequate for drinking, culinary, laundry, and bathing purposes.
3. Provide adequate spatial separation between sources of disease (and pollution) and receptors.
4. Assure that food processing, distribution, preparation, and service do not cause disease.
5. Control air, land, and water pollution, hazardous wastes, accidents, carcinogens, and toxics.
6. Prevent access to disease sources—polluted bathing waters and disease vector–infested areas.
7. Adopt and enforce environmental standards—air, water, land, noise, land use, housing.
8. Educate polluters, legislators, media, and the public to the need for regulation and funding where indicated.
9. Support comprehensive environmental health, engineering, and sanitation planning, protection, surveillance, and regulation programs at the state and local levels.
10. Adjust personal behavior to counteract cigarette smoking, poor nutrition, stress, overeating, and lack of exercise. Promote personal hygiene and handwashing to prevent person-to-person transmission of pathogenic or toxic agents.

Control of Susceptibles (Host Factors)

Host factors are personal characteristics and behaviors, genetic predispositions, and immunologic and other susceptibility-related factors that increase or decrease the likelihood of disease and may be as sufficient factors.[4] A sufficient factor is a causal factor that, in concert with a necessary factor, is "sufficient" to ensure that a disease will develop.[4] A necessary factor is a type of causal factor that is essential to, but not solely sufficient to, ensure the expression of a disease.[4] To facilitate the understanding of these factors collectively, consider the fate of an immunocompromised person who drank contaminated tap water containing the oocysts of *Cryptosporidium hominis*, an etiologic agent of the disease, cryptosporidiosis. After about 10 days, the individual begins to express symptoms of the disease. The afflicted person would be referred to as a case. A host factor and, in this instance also a sufficient factor, is the immunocompromised state of the individual. The necessary factor was the presence of the infectious material (oocysts) in the drinking water.

Individuals most susceptible to infectious diseases, especially the illnesses responsible to opportunistic pathogens, are the very young, the elderly, those with cardiovascular and respiratory disease, the immunocompromised, those occupationally exposed to airborne and other pollutants, those who smoke heavily, the obese, and those who underexercise. There are many diseases to which all persons are considered to be generally susceptible. Among these are measles, streptococcal diseases caused by group A streptococci, the common cold, ascariasis, chickenpox, amebic dysentery, bacillary dysentery, cholera, malaria, trichinosis, and typhoid fever. There are other diseases, such as influenza, meningococcus meningitis, pneumonia, human brucellosis (undulant fever), and certain water- and foodborne illnesses, to which some people apparently have an immunity or resistance. To these should be added the noninfectious diseases such as diseases of the heart, malignant neoplasms, and cerebrovascular diseases.

In order to reduce the number of persons who may be susceptible to a disease at any one time, certain fundamental disease-prevention principles should be followed to improve the general health of the public. This may be accomplished through educational programs on personal hygiene and immunization; avoidance of smoking; maintenance of proper weight; minimal liquor consumption; and conserving or improving the general resistance of individuals to disease by a balanced diet and nutritious food, fresh air, moderate exercise, sufficient sleep, rest periods, and the avoidance of stress, fatigue, and exposure. In addition, all individuals should be educated and motivated to protect themselves to the extent feasible from biological, physical, chemical, and radiation hazards and environmental pollutants.

Immunization can be carried out by the injection of vaccines, toxoids, or other immunizing substances to prevent or lessen the severity of specific diseases. Typhoid and paratyphoid fevers, poliomyelitis, and tetanus are some of the diseases against which the armed forces are routinely immunized. Children are generally immunized against diphtheria, tetanus, pertussis (whooping cough), poliomyelitis, rubeola (measles), mumps, and rubella (German measles). Revaccination of students and others born after January 1, 1957, against measles is recommended and may be required prior to school admission. It is now possible to discontinue smallpox vaccination as a routine measure in view of the global eradication of smallpox.[7]

Typhoid bacilli may be found in the feces and urine of cases and carriers. Typhoid immunization is reported to be about 70 to 90 percent effective, depending on degree of exposure,[8,9] and then only against small infectious doses. Routine typhoid vaccination is indicated only when a person is in intimate contact with a known carrier or travels in areas where there is a recognized risk of exposure, but precautions should still be taken with water and food. Routine vaccination of sewage sanitation workers is warranted only in areas with endemic typhoid fever. There is no reason to use typhoid vaccine for persons in areas of natural disaster such as floods or for persons attending rural summer camps.[8,9] There are currently two typhoid vaccines available in the United States, an oral live-attenuated vaccine (Vivotif Berna) and an injected capsular polysaccharide vaccine (Typhim Vi). Both vaccines have been shown to protect 50 to 80 percent of recipients. Boosters are required, every five years for the oral vaccine and every two years for the injected form.[10] Before choosing to forgo typhoid vaccination, travelers should be advised that a marked increase in antibiotic resistance by *S. typhi* has been documented in recent years and that the geographic location of the more resistant strains may be related to the frequency of antibiotic use.[11]

Cholera vaccine is not available in the United States. It has not been recommended for travelers because of the brief and incomplete immunity it offers. Currently, this issue is somewhat controversial; however, it is generally agreed that effective deployment of vaccines for cholera should take place in areas or countries of high endemic level of cholera, and 50 to 70 percent of the susceptible population must be immunized. Antibiotic resistance to tetracycline has been found in some *V. cholerae* isolates. However, widespread acquisition of antibiotic resistance has not been reported as in the case of *S. typhi*. No cholera vaccination requirements exist for entry or exit of any country. Yellow fever vaccine offers protection for at least 10 years and possibly up to 35 years. A certificate of vaccination is required for entry into some countries.[10] The WHO is recommending the use of five antihelminthic agents—albendazole, mebendazole, diethylcarbamazine, ivermectin, and praziquantel—to control parasitic worm infections that affect over 25 percent of the world's population.[12]

Good housing, sanitation (water, sewerage, solid wastes, and vermin control), and personal hygiene provide long-term protection against many diseases whereas an immunization protects only against a specific disease and must be repeated to remain effective. Individual and community performance, environmental hygiene, and economic levels are also improved,[13] in addition to the quality of life. This is not to minimize the importance of immunization against the childhood diseases and epidemic control where indicated.

Typical Epidemic Control

Outbreaks of illnesses such as influenza, measles, dysentery, poliomyelitis, and other diseases can still occur. At such times, the people become apprehensive and look to the health department for guidance, assurance, and information to calm their fears.

An example of the form health department assistance can take is illustrated in the precautions released June 1, 1951, in the *Illinois Health Messenger* for the control of poliomyelitis. These recommendations predate the 1955 availability of the Salk vaccine; hence, they portray a sense of urgency. For this reason, they are instructive and are generally applicable to outbreaks of other diseases. Even though poliomyelitis is under control in the United States, experience dictates that if the vaccination program is allowed to lapse, a resurgence of the disease is apt to follow.[14]

General Precautions during Outbreaks

1. The Illinois Department of Public Health will inform physicians and the general public as to the prevalence or increase in the incidence of the disease. *Note:* Incidence and prevalence are not synonyms. Incidence refers to the number of new cases occurring in a certain population *during* a defined time period. Prevalence is the number of cases of a disease *in* a defined population at a particular point in time. The terms are illustrated later in this chapter in the section "Epidemiology and Risk."
2. *Early diagnosis* is extremely important. Common early signs of polio are headache, nausea, vomiting, muscle soreness or stiffness, stiff neck, fever, nasal voice, and difficulty in swallowing, with regurgitation of liquids through the nose. Some of these symptoms may be present in several other diseases, but in the polio season they must be regarded with suspicion.
3. All children with any of these symptoms should be isolated in bed, pending diagnosis. Early medical care is extremely important.
4. Avoid undue fatigue and exertion during the polio season.
5. Avoid unnecessary travel and visiting in areas where polio is known to be prevalent.
6. Pay special attention to the practices of good personal hygiene and sanitation:
   a. Wash hands before eating.
   b. Keep flies and other insects from food.
   c. Cover mouth and nose when sneezing or coughing.

Surgical Procedures

Nose, throat, or dental operations, unless required as an emergency, should not be done in the presence of an increased incidence of poliomyelitis in the community.

General Sanitation (Including Fly Control)

1. Although there has been no positive evidence presented for the spread of poliomyelitis by water, sewage, food, or insects, certain facts derived from research indicate that they might be involved in the spread:

a. *Water*. Drinking water supplies can become contaminated by sewage containing poliomyelitis virus. Although no outbreaks have been conclusively traced to drinking water supplies, only water from an assuredly safe source should be used to prevent any possible hazards that might exist.

b. *Sewage*. Poliomyelitis virus can be found for considerable periods of time in bowel discharges of infected persons and carriers and in sewage containing such bowel discharges. Proper collection and disposal facilities for human wastes are essential to eliminate the potential hazard of transmission through this means.

c. *Food*. The infection of experimental animals by their eating of foods deliberately contaminated with poliomyelitis virus has been demonstrated in the laboratory, but no satisfactory evidence has ever been presented to incriminate food or milk in human outbreaks. Proper handling and preparation of food and pasteurization of milk supplies should reduce the potential hazard from this source.

d. *Insects*. Of all the insects studied, only blowflies and houseflies have shown the presence of the poliomyelitis virus. This indicates that these flies might transmit poliomyelitis. It does not show how frequently this might happen; it does not exclude other means of transmission; nor does it indicate how important fly transmission might be in comparison with other means of transmission.

2. Fly eradication is an extremely important activity in maintaining proper sanitation in every community.
3. Attempts to eradicate flies by spraying effective insecticides have not shown any special effect on the incidence of polio in areas where it has been tried. Airplane spraying is not considered a practical and effective means in reducing the number of flies in a city. The best way to control flies and prevent them from spreading any disease is to eliminate fly-breeding places. Eradicate flies by:

   a. Proper spreading or spraying of manure to destroy fly-breeding places.

   b. Proper storage, collection, and disposal of garbage and other organic waste.

   c. Construction of all privies with fly- and rodent-proof pits.

   Proper sanitation should be supplemented by use of effective insecticide around garbage cans, manure piles, privies, and so on. Use effective insecticide spray around houses or porches or paint on screen to kill adult flies.

Swimming Pools

1. Unsatisfactorily constructed or operated swimming pools should be closed, whether or not there is poliomyelitis in the community.
2. On the basis of available scientific information, the State Department of Public Health has no reason to expect that closure of properly equipped

and operated swimming pools will have any effect on the occurrence of occasional cases of poliomyelitis in communities.

3. In communities where a case of poliomyelitis has been associated with the use of a swimming pool, that pool and its recirculation equipment should be drained and thoroughly cleaned. (The State Department of Public Health should be consulted about specific cleansing procedures.) After the cleaning job is accomplished, the pool is ready for reopening.
4. Excessive exertion and fatigue should be avoided in the use of the pool.
5. Swimming in creeks, ponds, and other natural waters should be prohibited if there is any possibility of contamination by sewage or too many bathers.

Summer Camps

Summer camps present a special problem. The continued operation of such camps is contingent on adequate sanitation, the extent of crowding in quarters, the prevalence of the disease in the community, and the availability of medical supervision. Full information is available from the Illinois Department of Public Health to camp operators and should be requested by the latter:

1. Children should not be admitted from areas where outbreaks of the disease are occurring.
2. Children who are direct contacts to cases of polio should not be admitted.
3. The retention of children in camps where poliomyelitis exists has not been shown to increase the risk of illness with polio. Furthermore, return of infected children to their homes may introduce the infection to that community if it is not already infected. Similarly, there will be no introduction of new contacts to the camp and supervised curtailment of activity will be carried out, a situation unduplicated in the home. This retention is predicated upon adequate medical supervision.
4. If poliomyelitis occurs in a camp, it is advisable that children and staff remain there (with the exception of the patient, who may be removed with consent of the proper health authorities). If they do remain:
   a. Provide daily medical inspection for all children for two weeks from occurrence of last case.
   b. Curtail activity on a supervised basis to prevent overexertion.
   c. Isolate all children with fever or any suspicious signs or symptoms.
   d. Do not admit new children.

Schools

1. Public and private schools should not be closed during an outbreak of poliomyelitis, nor their opening delayed except under extenuating circumstances, and then only upon recommendation of the Illinois Department of Health.

2. Children in school are restricted in activity and subject to scrutiny for any signs of illness. Such children would immediately be excluded, and parents would be urged to seek medical attention.
3. Closing of schools leads to unorganized, unrestricted, and excessive neighborhood play. Symptoms of illness under such circumstances frequently remain unobserved until greater spread of the infection has occurred.
4. If poliomyelitis occurs or is suspected in a school:
   a. Any child affected should immediately be sent home, with advice to the parents to seek medical aid, and the health authority notified.
   b. Classroom contacts should be inspected daily for any signs or symptoms of illness and excluded if these are found.

Hospitals

1. There is no reason for exclusion of poliomyelitis cases from general hospitals if isolation is exercised; rather, such admissions are necessary because of the need for adequate medical care of the patient.
2. Patients should be isolated individually or with other cases of poliomyelitis in wards.
3. Suspect cases should be segregated from known cases until diagnosis is established.
4. The importance of cases to hospitals in a community where poliomyelitis is not prevalent has not been demonstrated to affect the incidence of the disease in the hospital community.

Recreational Facilities

1. Properly operated facilities for recreation should not be closed during outbreaks of poliomyelitis.
2. Supervised play is usually more conducive to restriction of physical activities in the face of an outbreak.
3. Playground supervisors should regulate activities so that overexertion and fatigue are avoided.

WATERBORNE DISEASES

General

Disease agents spread by water and food have in common the capability to incapacitate large groups of people and sometimes result in serious disability and death. The World Health Organization estimates that 80 percent of all diseases are attributable to inadequate water or sanitation and that 50 percent of hospital beds worldwide were occupied by people afflicted with water-related diseases.[15] During the period 1920 to 2000, there were 1,836 waterborne outbreaks representing 882,592 cases of illness in the United States.[16] The number of deaths recorded for the period was well under 1 percent, however. Most waterborne disease fatalities occurred before 1940 and were attributable to typhoid fever.[17] The finding probably reflects the unavailability of antibiotics during the early time frame. Diseases of a waterborne nature appear when disregard of known fundamental sanitary principles occurs, hence, in most cases are preventable. As often occurs, very young, elderly, immunocompromised, and critically ill persons with some other illness succumb with the added strain of a water- or foodborne illness. These groups of disease-sensitive people are thought to make up 20 to 25 percent of the population of the United States.[18]

Water- and foodborne diseases are sometimes referred to as the intestinal or filth diseases because they are frequently transmitted by food or water contaminated with excreta. Raw drinking water and improperly protected and treated surface and groundwater supplies may be polluted by excreta or sewage, which is almost certain to contain pathogenic microorganisms with potential to cause illness in consumers. In the United States, community waterborne outbreaks during the period 1981 to 1990 predominantly associated with inadequately treated surface water and deficiencies in the distribution system whereas untreated groundwaters were the major source of waterborne diseases for persons utilizing private water sources.[19]

Survival of Pathogens

Survival periods for selected pathogens in surface and groundwater are given in Table 1.1. The survival of pathogens is quite variable and affected by the type of organism, the presence of other antagonistic organisms, the soil characteristics, temperature, moisture, nutrients, pH, and sunlight. Table 1.1 is intended only as a comparative measure of survivability among pathogens. The amount of clay and organic matter in the soil affect the movement of pathogens, but porous soils, cracks, fissures, and channels in rocks permit pollution to travel long distances.

Some organisms are more resistant than others. Soil moisture of about 10 to 20 percent of saturation appears to be best for survival of pathogens; drier conditions increase die-off.

Nutrients may increase survival of some organisms, although elevated metabolism in vegetative cells and the germination of spores may produce the opposite effect. Typically, pH is not a major factor. As would be expected, survival of some pathogenic bacteria at very low pH (e.g., pH 2.5–3) is poor in certain media.[20,21] When pH values are below the isoelectric point of both bacteria and viruses, surface charge will be positive and, although controversial, may promote aggregation and adsorption of cells to predominantly negatively charged particulate matter and produce a protective effect against the potentially harmful effects of high hydrogen ion. In addition, hydrogen ion may effect the solubilization of nutrients. Viruses appear stable over the pH range of 3 to 9. Exposure to sunlight increases the death rate. Low temperatures favor survival.[22,23] The survival of pathogens in soil, on foods, and following various wastewater unit treatment processes, as reported by various investigators, is summarized by Bryan[24] and others.[25] Most

TABLE 1.1 Survival of Certain Pathogens in Water

	Survival Time[a]	
	In Surface water	In Groundwater
Coliform bacteria	—	7–8 days[b]
Cryptosporidium spp. oocyst	18+ months at 4°C	2–6 months, moist[c]
Excherichia coli	—	10–45 days[b]
Entamoeba histolytica	1 month[d]	
Enteroviruses	63–91+ days[e]	
Giardia lamblia cyst	1–2 months, up to 4[f]	
Leptospira interrogans serovar Ichterohemorrhagiae	3–9 days[g]	
Franciscella tularensis	1–6 months[g]	
Rotaviruses and reoviruses	30 days–1+ years[e]	
Salmonella faecalis	—	15–50 days[b]
Salmonella paratyphi	—	60–70 days[b]
Salmonella typhi	1 day–2 months[g]	8–23 days[b]
Salmonella typhimuriun	—	140–275 days[b]
Shigella	1–24 months[g]	10–35 days[b]
Vibrio cholerae	5–16 days[g] 34 days at 4°C[g] 21+ days frozen[g] 21 days in seawater[d]	
Viruses (polio, hepatitis, other enteroviruses)	—	16–140 days[b]
Enteroviuses[h]	38 days in extended aeration sludges at 5°C, pH 6–8; 17 days in oxidation ditch sludges at 5°C, pH 6–8	
Hepatitis A[i]	1+ years at 4°C in mineral water, 300+ days at room temperature	
Poliovirus[i]	1+ years at 4°C in mineral water, not detected at room temperature	

[a] Approximate.
[b] Guidelines for Delineation of Wellhead Protection Areas, Office of Ground-Water Protection, U.S. Environmental Protection Agency, Washington, DC, June 22, 1987, pp. 2–18. *Source:* Matthess et al., 1985. G. Matthess, S.S.D. Foster and A.Ch. Skinner, Theoretical background, hydrogeology and practice of groundwater protection zones, IAH International Contributions to Hydrogeology 6 (1985).
[c] A. S. Benenson (Ed.), *Control of Communicable Diseases in Man*, 15th ed., American Public Health Association, Washington, DC, 1990, p. 113.
[d] B. K. Boutin, J. G. Bradshaw, and W. H. Stroup, "Heat Processing of Oysters Naturally Contaminated with *Vibrio cholerae*, Serotype 01," *J. Food Protection*, **45**, 2 (February 1982): 169–171.
[e] G. Joyce and H. H. Weiser, *J. Am. Water Works Assoc.* (April 1967): 491–501 (at 26°C and 8° C).
[f] S. D. Lin, "*Giardia lambia* and Water Supply," *J. Am Water Works Assoc.* (February 1985): 40–47.
[g] A. P. Miller, *Water and Man's Health*, U. S. Administration for International Development, Washington, DC, 1961, reprinted 1967.
[h] G. Berg et al., "Low-Temperature Stability of Viruses in Sludges," *Appl. Environ. Microbiol.*, **54**, 839 (1988); *J. Water Pollut. Control Fed.* (June 1989): 1104.
[i] E. Biziagos et al., "Long-Term Survival of Hepatitis A Virus and Poliovirus Type 1 in Mineral Water," *Appl. Environ. Microbiol.*, **54**, 2705 (1988); *J. Water Pollut. Control Fed.* (June 1989): 1104.

enteroviruses pass through sewage treatment plants, survive in surface waters, and may pass through water treatment plants providing conventional treatment. According to WHO, water treatment plants maintaining a free residual chlorine in the distribution system of at least 0.5 mg/l for at least 30 minutes and low turbidity [less than 1 nephelometric turbidity unit (NTU)] in the finished water can achieve satisfactory virus inactivation. Other approved disinfection treatment (e.g., ozonation) can accomplish satisfactory virus destruction.

Substance Dose to Cause Illness

The development of illness is dependent on the toxicity or virulence of a substance or pathogen, the amount of the substance or pathogen ingested (at one time or intermittently), and the resistance or susceptibility of the individual. The result may be an acute or long-term illness. Sometimes two or more substances may be involved to produce a synergistic, additive, or antagonistic effect. The microbial modes of disease transmission include ingestion of a pathogen or toxin in contaminated water or food, contact with an infected person or animal, or exposure to an aerosol containing the viable pathogen.

If the dose of a chemical substance administered to a series of animals is plotted against the effect produced, such as illness, and increased doses produce no increases in illnesses, the substance is said to cause "no effect." If increased doses cause increasing illnesses, the substance has "no threshold." If increased doses cause no apparent increases in illnesses at first but then continuing increased doses show increasing illnesses, the dose at which illnesses begin to increase is referred to as the substance "threshold." Below that dose is the "no-observed-effect" range. Variations between and within animal species must be considered.

Table 1.2 contains a list various microorganisms and the approximate infectious dose required to cause disease. Bryan[24] has summarized the work of numerous investigators giving the clinical response of adult humans to varying challenge doses of enteric pathogens. For example, a dose of 10^9 *Streptococcus faecalis* was required to cause illness in 1 to 25 percent of the volunteers, 10^8 *Clostridium perfringens* type A (heat resistant) to cause illness in 26 to 50 percent of the volunteers, and 10^9 *C. perfringens* type A (heat sensitive) to cause illness in 76 to 100 percent of the volunteers.

If one were to consume 16 ounces of water containing a pathogen having a high infectious dose value (pathogen A) and the same amount of water containing a pathogen of low infectious dose value, it might be concluded that illness would be less likely through infection with pathogen A than pathogen B. Such thinking contains several fallacies, however. Pathogen infectious dose data should be used only as a guide and must be tempered in the knowledge that many variables influence the host-parasite relationship.[26] In any specific situation, virulence of the pathogen, physiological state of the pathogen, distribution of the infective units (pathogen) in a unit volume (in this case water), susceptibility of the host (infant, young, old, healthy, sick, immunocompromised), and route of infective

TABLE 1.2 Substance Dose to Cause Illness

Microorganism	Approximate Number of Organisms (Dose) Required to Cause Disease
Campylobacter jejuni[a]	10^2 or less
Coxiella burneti[b]	10^7
Cryptosporidium[c]	10^1–10^2 oocysts
Dracunculus, Ascaris, Schistosoma	1 cyst, egg, or larva
Entamoeba histolytica[d]	10–20 cysts, one in a susceptible host
Escherichia coli[b]	10^8
Giardia lamblia[c–f]	5–10^2 cysts
Salmonella typhi[b,g]	10^5–10^6
Salmonella typhimurium[g]	10^3–10^4
Shigella[b,g]	10^1–10^2
Staphylococcus aureus[b]	10^6–10^7 viable enterotoxin-producing cells per gram of food or milliliter of milk
Vibrio cholerae[b,g]	10^6–10^9
Virus, pathogenic	1 plaque-forming unit (PFU) or more

[a] Robert V. Tauxe et al., "*Campylobacter* Isolates in the United States, 1982–1986," *MMWR CDC Surveillance Summaries* (June 1988): 9.
[b] H. L. Dupont and R. B. Hornick, "Infectious Disease from Food," in *Environmental Problems in Medicine*, W. C. McKee (Ed.), Charles C. Thomas, Springfield, IL, 1974.
[c] R. M. Clark et al., "Analysis of Inactivation of *Giardia lamblia* by Chlorine," *J. Environ. Eng*. (February 1989): 80–90.
[d] *Guidelines for Drinking Water Quality*, Vol. 2, World Health Organization, Geneva, 1984, p. 44.
[e] Up to 10 cysts from beaver to human and 1 to 10 cysts to cause human to human infection.
[f] R. C. Rendtorff, "Experimental Transmission of *Giardia lamblia*," *Am. J. Hyg*., **59**, 209 (1954).
[g] Eugene J. Gangarosa, "The Epidemiologic Basis of Cholera Control," *Bull. Pan Am. Health Org*., **8**, 3 (1974).

contact (ingestion, inhalation, cutaneous) influence the inception of disease. The experimental conditions pertinent to the determination of infectious dose levels is important. The nature of the host subjects (human volunteers, monkeys, mice, or other), health status of the host subjects, protocol for introducing the pathogen dose to the subjects (oral, injection, aerosolization), and frequency of exposure of the host subjects to the pathogen challenge are all important to the interpretation of infectious dose values.

The low infectious dose for pathogenic viruses and protozoa would appear to suggest that viral infections ought be readily spread through drinking water, food, shellfish, and water-contact recreational activities. Fortunately, the tremendous dilution that wastewater containing viruses usually receive on discharge to a watercourse and the treatment given drinking water greatly reduce the probability of an individual receiving an infectious dose. However, some viruses do survive and present a hazard to the exposed population. Not all viruses are pathogenic in the sense that their obligate destruction of host cells to sustain replication and release of new virus particles may not trigger clinical symptoms of disesase in the host. Nonetheless, heretofore unknown insidious relationships between viruses and their effects on hosts are becoming better understood, resulting in recognition of the pathogenicity of viruses thought to be innocuous.

Data on infectious doses for many important environmentally transmitted diseases are lacking. Obtaining estimates of infectious doses is time consuming, animal or human subject intensive, and costly. An indication of the difficulty involved may be imagined in economics of testing for the effect of chemicals as given by Kennedy:[27] "A typical chronic toxicology test on compound X, done to meet a regulatory requirement with an adequate number of animals and an appropriate test protocol, costs $250,000 to 300,000" and requires 2 to 3 or more years to complete.

Information concerning the *acute* effect of ingestion of toxic substances is available in toxicology texts.[28]

Summary of Characteristics and Control of Water- and Foodborne Diseases

In view of the fact that water- and foodborne diseases result in discomfort, disability, or even death, a better understanding of their source, method of transmission, control, and prevention is desirable. Although not mutually inclusive throughout, several of the infections transmitted by contaminated food and water are caused by the same pathogenic agents. The primary focus of attack is the gastrointestinal tract.

Special attention should be paid the subject of gastroenteritis. It is a vaguely understood disease with a complex epidemiology, often without a known causal pathogen or chemical instigator. Three types of gastroenteritis may be distinguished by the pathological response to the presence of an infectious agent: (1) noninflammatory, (2) inflammatory, and (3) invasive (Table 1.3).[29] Yet, different forms of gastroenteritis typically display common symptoms such as watery diarrhea, vomiting, intestinal and stomach cramps, and muscular aches, all of which create a nausea in the victim. The purging of the gastrointestinal tract that takes place removes or inactivates the normal barriers to infection and changes the unshielded epithelium that alters the host defenses, causing malabsorption and nutrient loss. The severity of the symptoms somewhat characterizes the nature of its etiology as do the complications that accompany protracted illnesses.

There are acute and chronic forms of gastrointestinal diseases. The number of cases worldwide of gastrointestinal illnesses are estimated to be from 6 billion to 60 billion of which over 2 million directly result in death.[30] Acute forms of gastroenteritis outbreaks in countries of the world have a storied history, some of which are noted elsewhere in this chapter. The symptoms of gastroenteritis appear frequently among diseases associated with different source pathogens. This is borne out in Table 1.4, which contains a comprehensive grouping and summary of the characteristics and control of a number of these diseases for easy reference.

Although comprehensive, the body of information should not be considered exhaustive or terminally complete, rather the table should serve as an orientation

TABLE 1.3 Forms of Gastroenteritis, Symptoms, and Causative Agents

Gastroenteritis	Symptoms	Responsible Organisms
Noninflammatory gastroenteritis	Diarrhea and/or vomiting, no fecal leukocytes, no blood in stool, usually no fever.	Bacteria: *Staphylococcus aureus*,[a] *Bacillus cereus*,[a] *Clostridium perfringens*,[a] *Clostridium botulinum*[a] Viruses: noroviruses Protozoa: *Giardia lamblia (intestinalis), Cryptosporidium parvum* Algae: *Pfiesteria* spp[a].
Inflammatory gastroenteritis	Diarrhea and/or vomiting, fecal leukocytes present, usually severe fever, no blood in stool.	Bacteria: *Vibrio cholerae*,[b] enteropathogenic *Escherichia coli* (EPEC), enteroaggregative *E. coli* (EAggEC), *Clostridium difficile, Shigella* spp, enterotoxigenic *E. coli* (ETEC) Viruses: rotavirus, Caliciviruses[b] Protozoa: *Entamoeba dispar*
Invasive gastroenteritis	Invasion past epithelial layer of Gl tract, may not have any diarrhea or vomiting, dysentery may be present (mucus containing bloody feces), fecal leukocytes present, fever: may not have any Gl tract problems but instead severe systemic problems.	Bacteria. *Salmonella* spp., *Campylobacter jejuni*, enteroinvasive *E. coli* (EIEC), enterohemorrhagic *E. coli* (EHEC), *Vibrio vulnificus, Yersinia* spp., *Franciscella tularensis, Bacillus anthracis, Helicobacter pylori* Viruses: unknown Protozoa: *Entamoeba histolytica*

Source: MWH, *Water Treatment: Principles and Design*, 2nd ed., John Wiley & Sons, Hoboken, NJ, 2005.

[a]These microorganisms grow on food or in the environment and produce toxins that, when ingested, cause gastroenteritis a few hours later (only *Pfiesteria* spp. is of concern to drinking water).

[b]Often cited as not causing a fever.

to a complex field requiring much further study. There are likely many bacterial toxins, bacteria, viruses, protozoa, helminths, chemicals, and other agents that are not suspected or that are not examined for or discovered by available laboratory methods. Emerging infectious diseases worldwide are becoming recognized, particularly among the viruses, and will undoubtedly expand the list.

The primary bacterial pathogens, which have been historically linked to waterborne disease, are well known. However, a less-recognized occurrence in the

TABLE 1.4 Characteristics and Control of Water- and Foodborne Diseases

	Disease	Specific Agent	Reservoir	Common Vehicle	Symptoms in Brief	Incubation Period	Prevention and Control
Bacterial Toxins	Botulism food poisoning	*Clostridium botulinum* and *C. parabotulinum* that produce toxin	Soil, dust, fruits, vegetables, foods, mud, fish, animal and human feces	Improperly processed canned and bottled foods containing the toxin, also other foods	Gastrointestinal pain, diarrhea or constipation, prostration, difficulty in swallowing, double vision, difficulty in respiration	2 hr–8 days, usually 12–36 hr	Boil home canned nonacid food 5 min; thoroughly cook meats, fish, foods held over. Do not taste suspected food. Store fish at ≤38°F.
	Staphylococcus food poisoning	Staphylococci that produce entero-toxin, *Staphylococcus aureus*. (Toxin is stable at boiling temperature.)	Skin, mucous membranes, pus, dust, air, sputum, and throat	Contaminated custard pastries, cooked or processed meats, poultry, dairy products, hollandaise sauce, salads, milk	Acute nausea, vomiting, and prostration; diarrhea, abdominal cramps. Usually explosive in nature, followed by rapid recovery of those afflicted.	1–6 hr or longer, average 2–4 hr	Refrigerate promptly prepared food in shallow containers at a temperature below 45°F. Discard leftover food. Avoid handling food. Educate foodhandlers in personal hygiene and sanitation.
	Clostridium perfringens food poisoning	*Clostridium perfringens* (*C. welchi*), a sporeformer. (Certain spores are heat resistant.)	Soil, gastrointestinal tract of man and animals, cattle, poultry, pigs, vermin, and wastes	Contaminated food, inadequately heated meats, including roasts, stews, beef, poultry, gravies, improperly held or cooled food	Sudden abdominal pain, then diarrhea and nausea Ingestion of large numbers of vegetative cells that grow in intestine and form spores. Cast off cell releases toxin causing symptoms.	8–22 hr, usually 10–12 hr	Cook foods thoroughly, cool rapidly, and refrigerate promptly foods not consumed. Cool foods in shallow containers, cut up large pieces. Reheat thoroughly to 165°F before reserving. Educate cooks.

TABLE 1.4 ***(continued)***

	Disease	Specific Agent	Reservoir	Common Vehicle	Symptoms in Brief	Incubation Period	Prevention and Control
	Bacillus cereus food poisoning—diarrheal type	*Bacillus cereus*, toxin heat labile	Spores found in wide variety of cereals, spices, vegetables, and milk	Inadequately refrigerated cooked foods and subsequently inadequately reheated	Diarrhea, cramps; vomiting sometimes	6–16 hr	Prevent food contamination. Cool food rapidly in shallow containers, reheat rapidly.
	Bacillus cereus food poisoning—vomiting type	*Bacillus cereus*, toxin heat stable	Same as diarrheal	Boiled and fried rice	Vomiting, diarrhea, nausea, sometimes	1–6 hr	Same as diarrhea. Some spores, if present in large numbers may survive Ultra high temperture (UHT) and High temperature-short time (HTST) pasteurization.
	Gastroenteritis, dermatitis, central nervous system disorders	Cyano-bacteria	Nutrient-rich surface waters, aquatic sediments, soils	Ingestion and body contact involving waters containing dense cyanobacterial cell mass	Tremors, hypersalivation, ataxia, diarrhea (ingestion); rash, eye irritation, asthma (skin contact)	7–14 days	Water treatment may involve microscreening, coagulation, filtration; distribution system should be monitored for accumulation of cell residues and flushed
Bacteria	Salmonellosis (*Salmonella* infection)	*Salmonella typhimurium, S. newport, S. enteritidis, S. montevideo*, others	Hogs, cattle, and other livestock, poultry, pets, eggs, carriers, powdered eggs, turtles, animal feed, and rodents	Contaminated sliced cooked meat, salads, uncooked meats, equipment, warmed-over foods, milk and milk products, water, eggs	Abdominal pain, diarrhea (persists several days), chills, fever, vomiting, and nausea	6–48 hr, usually 12–24 hr	Protect storage of food. Thoroughly cook food. Eliminate rodents, pets, and carriers. Similar measures as in *Straphylococcus*, Poultry, water, and meat sanitation. Do not eat raw eggs or ground beef, Refrigerate foods.

Bacteria	Typhoid fever	Typhoid bacillus, *Salmonella typhi*	Feces and urine of typhoid carrier or patient	Contaminated water, milk and milk products, shellfish, and foods; flies	General infection characterized by continued fever, usually rose spots on the trunk, diarrheal disturbances	Average 14 days, usually 7–21 days	Protect and purify water supply. Pasteurize milk and milk products. Sanitary sewage disposal. Educate food-handlers. Food, fly, shellfish control. Supervise carriers. Personal hygiene. Isolate patients.
	Paratyphoid fever	*Salmonella paratyphi* A, *S. schott mulleri* B. *S. hirschfeldii* C	Feces and urine of carrier or patient	Contaminated water, milk and milk products, shellfish, and foods; flies	General infection characterized by continued fever, diarrheal disturbances, sometimes rose spots on trunk, other symptoms	1–10 days for gastroenteritis; 1–3 weeks for enteric fever	Similar preventive and control measures as in typhoid fever and salmonellosis
	Shigellosis (Bacillary dystentery)	Genus, *Shigella*, i.e., *flexneri, sonnei, boydii, dysenteriae*	Feces of carriers and infected persons	Contaminated water or foods, milk and milk products, flies, person-to-person	Acute onset with diarrhea, fever, tenesmus, frequent stools containing blood and mucus	1–7 days, usually less than 4 days	Food, water, sewage sanitation as in typhoid. Pasteurize milk (boil for infants). Control flies; supervise carriers. Personal hygiene.
	Cholera	*Vibrio comma*	Feces, vomitus; carriers	Contaminated water, raw foods, flies, shellfish	Diarrhea, rice-water stools, vomiting, thirst, pain, coma	A few hours-5 days, usually 3 days	Similar to typhoid. Quarantine. Isolate patients. Vaccine of limited value.

(*continues*)

TABLE 1.4 ***(continued)***

	Disease	Specific Agent	Reservoir	Common Vehicle	Symptoms in Brief	Incubation Period	Prevention and Control
Bacteria	Melioidosis	*Pseudomonas pseudomallei*	Rats, guinea pigs, cats, rabbits, dogs, horses	Contact with or ingestion of contaminated excreta, soil, or water	Acute diarrhea, vomiting, high fever, delirium, mania	Less than 2 days or longer	Destroy rats. Protect food. Thoroughly cook food. Control biting insects. Personal hygiene.
	Brucellosis (Undulant fever)	*Brucella melitensis*-goat, *B. abortus*-cow, *Br. suis*-pig	Tissues, blood, milk, urine, infected animals	Raw milk from infected cows or goats; also contact with infected animals	Insidious onset, irregular fever, sweating, chills, pains in joints and muscles	5–21 days or longer	Pasteurize all milk. Eliminate infected animals. Handle infected carcasses with care.
	Streptococcal infections	*Streptococcus pyogenes*	Nose, throat, mouth secretions	Contaminated salads or milk products	Sore throat and fever, sudden in onset, vomiting	1–3 days	Pasteurize all milk. Inspect contacts. Same as staphylococcus
	Diphtheria	*Coryne-bacterium diphtheriae*	Respiratory tract, patient, carrier	Contact and milk or milk products	Acute febrile infection of tonsils, throat, and nose	2–5 days or longer	Pasteurize all milk. Disinfect utensils. Inspect contacts. Immunize.
	Tuberculosis	*Mycobacterium tuberculosis (M. tuberculosis and M. bovis)*	Respiratory tract of man, rarely cattle	Contact, also eating and drinking utensils, food, and milk	Cough, fever, fatigue, pleurisy	4–6 weeks	Pasteurize all milk, eradicate TB from cattle. Skin test. Control contacts and infected persons. Selective use of BCG.

Bacteria	Tularemia	Francisella	Rodents, rabbits, horseflies, wood ticks, dogs, foxes, hogs	Meat of infected rabbit, contaminated water, handling wild animals	Sudden onset, with pains and fever, prostration	1–10 days, average of 3	Thoroughly cook meat of wild rabbits. Purify drinking water. Use rubber gloves (care in dressing wild animals).
	Campylobacter enteritis	*Campylobacter jejuni*	Chickens, swine, dogs, cats, man, raw milk, contaminated water	Undercooked beef, chicken, also pork Raw milk, contaminated water	Watery diarrhea, abdominal pain, fever, chills, nausea, vomiting, blood in stool	1–10 days 2–5 days average	Thoroughly cook chicken and pork and properly refrigerate. Treat water. Prevent cross-contamination.
	Vibrio para-haemolyticus gastroenteritis	*Vibrio para-haemolyticus*	Marine fish, shell-fish, mud, sediment, salt water, brackish and fresh water	Raw seafoods or seafood products; inadequately cooked seafoods, and cross-contamination between raw and cooked products and sea water	Nausea, headache, chills, fever, vomiting, severe abdominal cramps, watery diarrhea, sometimes with blood	2–48 hr, usually 12–24 hr	Properly cook all seafood (shrimp 7 to 10 min). Avoid cross-contamination or contact with sea water or preparation surfaces used for uncooked foods. Refrigerate prepared seafoods promptly if not immediately served.
	Diarrhea enteropath-ogenic (Traveler's diarrhea)	Enteropath-ogenic *Escherichia coli* invasive and entero-toxigenic strains	Infected persons	Food, water, and fomites contaminated with feces, raw or under-cooked meat	Fever, mucoid, occasionally bloody diarrhea; or watery diarrhea, cramps, acidosis, dehydration	12–72 hr	See Typhoid. Scrupulous hygiene and formula sanitation in hospital nursery. Food sanitation, thorough cooking.

(*continues*)

TABLE 1.4 ***(continued)***

	Disease	Specific Agent	Reservoir	Common Vehicle	Symptoms in Brief	Incubation Period	Prevention and Control
Bacteria	Yersiniosis	*Yersinia entercolitica, Yersinia pseudotuberculosis*	Wild and domestic animals, birds, man, surface water	Raw milk and milk products, seafoods, raw and rare meats, infected food-handlers, contaminated water	Diarrhea, cramps, fever, headache, vomiting, skin rash, pseudo-appendicitis	3–7 days, usually 2–3 days	Sanitary disposal of human, dog, and cat feces. Safe water. Pasteurize milk. Food sanitation. Wash hands. Organism grows at 40°F. Thoroughly cook food.
	Listeriosis	*Listeria monocytogenes*	Goats, cattle, man, fowl, soil, water, sewage	Raw milk, contaminated pasteurized milk and milk products, contaminated vegetables	Fever, headache, nausea, vomiting, meningeal symptoms	Probably a few days-3 weeks	Avoid contact with infected persons and aborted animal fetuses, raw milk and meats. Listeria grows at 37° to 113°F.
	Vibrio vulnificus gastroenteritis	*Vibrio vulnificus*	Oysters, sea water, sediment, plankton	Raw or lightly cooked seafood, i.e., oysters	Fever, chills, vomiting, nausea, diarrhea	16 hr	Same as *Vibrio parahaemolyticus* gastroenterits.
Rickettsias	Q Fever	*Coxiella burneti*	Dairy cattle, sheep, goats, ticks	Slaughterhouse, dairy employees, handling infected cattle: raw cow and goat milk, dust and aerosols from urine and feces	Heavy perspiration and chills, headache, malaise	2–3 weeks, average 20 days	Pasteurize milk and dairy products. Eliminate infected animal reservoir. Clean slaughterhouse and dairies. Keep down dust from dried wastes.

Viruses	Chorio-meningitis, lymphocytic	*choriomeningitis* virus (LCMV)	House mice urine, feces, secretions	Contaminated food	Fever, grippe, severe headache, stiff neck, vomiting, somnolence	8–13 days	Eliminate or reduce mice. General cleanliness. Sanitation.
	Infectious hepatitis	Hepatitis A virus	Feces from infected persons	Water, food, milk, oyster, clams, contacts, person-to-person, fecal-oral	Fever, nausea, loss of appetite; possibly vomiting, fatigue, headache, jaundice	10–50 days, average 30–35 days	Sanitary sewage disposal, food sanitation, personal hygiene. Coagulate and filter water supply, and plus 0.6 mg/l free Cl_2. Obtain shellfish from certified dealers. Steam clams 4 to 6 min. Exclude ill workers.
	Gastroenteritis, viral	Rotaviruses, Nor-virus agent, echo- and coxsackie-viruses, and others	Man, feces from infected foodhandler or sewage	Water, food including milk, possibly fecal-oral or fecal-respiratory route, ice, clams	Nausea, vomiting, diarrhea, abdominal pain, low fever	24–72 hr, 24–48 hr, 3–15 days	Same as hepatitis A.
	Amebiasis (Amebic dysentery)	*Entamoeba histolytica*	Bowel discharges of carrier, and infected person; possibly also rats	Cysts, contaminated water, foods, raw vegetables and fruits, flies, cockroaches	Insidious and undetermined onset, diarrhea or constipation, or neither; loss of appetite, abdominal discomfort; blood, mucus in stool	5 days or longer, average 2–4 weeks	Same as Shigellosis. Boil water or coagulate, set, filter through diatomite 5 gpm/ft^2, Cl_2. Usual Cl_2 and high-rate filtration not 100% effective. Slow sand filtration plus Cl_2, or conventional RSF OK. Pressure sand filtration ineffective. Also sanitation and personal hygiene.

(*continues*)

TABLE 1.4 ***(continued)***

	Disease	Specific Agent	Reservoir	Common Vehicle	Symptoms in Brief	Incubation Period	Prevention and Control
Portozoa	Giardiasis	*Giardia lamblia*	Bowel discharges of carrier and infected persons; dog, beaver	Cysts, contaminated water, food, raw fruits; also hand-to-mouth route	Prolonged diarrhea, abdominal cramps, severe weight loss, fatigue, nausea, gas; fever is unusual.	6–22 days, average 9 days	Same as amebiasis.
	Cryptos-poridiosis	*Cryptos-poridium* spp	Farm animals, man, fowl, cats, dogs, mice	Contaminated water, food, fecal-oral, person-to-person	Mild flulike symptoms, diarrhea, vomiting, nausea, stomach pain	2–21 days, average 2–10 days	Avoid untreated water, also ice, unpasteurized milk, salads in areas of poor hygiene.
	Balantidiasis	*Balantidium coli*	Swine, man, and other animals	Ingestion of cysts in infected feces	Mild diarrhea, nausea, dysentery, vomiting	Unknown, a few days	Same as cryptosporidiosis, and Shigellosis.
	Primary amebic meningoen-cephalitis (PAM)	*Naegleria fowleri*	Warm freshwater bodies and swimming pools	Nasal tissue contact with water through inhalation during swimming and diving in surface waters and swimming pools	Sudden headache, vomiting, fever, nausea, pharyngitis; late stages include confusion, lethargy, neck stiffness, coma	3–7 days	Drinking water supplies may be disinfected with chlorine or ultraviolet irradiation at proper dosage. Swimming pool water may be sand filtered and disinfected.

	Granulomatous amebic encephalitis (GME), acanthamoeba keratitis	*Acanthamoeba*	Soils, dusts, all forms of natural waters; swimming pools, spas, air conditioners	Abrasions, skin cuts, nasal passages, eyes	Eye pain, redness, blurred vision (keratitis); see symptoms for PAM (GME)	>10 days to weeks	Similar to protection against *Naegleria* spp.
Bacteria	Leptospirosis (Weil's disease)	*Leptospira* interrogans with 27 serovars	Urine and feces of rats, swine, dogs, cats, mice, foxes, sheep	Food, water, soil contaminated with excreta or urine of infected animal, contact	Fever, rigors, headaches, nausea, muscular pains, vomiting, thirst, prostration, jaundice	4–19 days, average 9 to 10 days	Destroy rats. Protect food. Avoid polluted water. Treat abrasion of hands and arms. Disinfect utensils, treat infected dogs.
	Trichinosis (Trichiniasis)	*Trichinella spiralis*	Pigs, bears, wild boars, rats, foxes, wolves	Infected pork and pork products, bear and wild boar meat	Nausea, vomiting, diarrhea, muscle pain, swelling of face and eyelids, difficulty in swallowing	2–28 days, usually 9 days	Thoroughly cook pork (150°F), pork products, bear and wild boar meat. Destroy rats. Feed hogs boiled garbage or discontinue feeding. Store meat 20 days at 5°F or 10 days at −10°F.

(*continues*)

TABLE 1.4 ***(continued)***

	Disease	Specific Agent	Reservoir	Common Vehicle	Symptoms in Brief	Incubation Period	Prevention and Control
Helminths	Schistosomiasis (Bilharziasis)[a] (blood flukes)	*Schistosoma haematobium, S. mansoni, S. japonicum, S. intercalatum*	Venous circulation of man; urine, feces, dogs, cats, pigs, cattle, horses, field mice, wild rats, water buffalo	Cercariae-infested drinking and bathing water (lakes and coastal sea waters)	Dysenteric or urinary symptoms, rigors, itching on skin, dermatitis; carrier state 1 to 2 years and up to 25 years. Swimmer's itch schistosomes do not mature in man.	4–6 weeks or longer	Avoid infested water for drinking or bathing; coagulation, sedimentation, and filtration plus Cl_2 1 mg/l; boil water; impound water 48 hr, Cl_2. Slow sand filtration plus Cl_2. 1 mg/l $CuSO_4$ to kill cercariae and 20 mg/l to kill snails. Drug treatment available.
	Ascariasis (intestinal roundworm)	*Ascaris lumbricoides*	Small intestine of man, gorilla, ape	Contaminated food, water; sewage	Worm in stool, abdominal pain, skin rash, protuberant abdomen, nausea, large appetite	About 2 months	Personal hygiene, sanitation.[b] Boil drinking water in endemic areas. Sanitary excreta disposal.
	Echinococcosis (Hydatidosis)	*Echinococcus granulosus*, dog tapeworm	Dogs, sheep, wolves, dingoes, swine, horses, monkeys	Contaminated food and drink; hand to mouth; contact with infected dogs	Cysts in tissues: liver, lung, kidney, pelvis, may give no symptoms, may cause death	Variable, months to several years	Keep dogs out of abattoir and do not feed raw meat. Mass treatment of dogs. Educate children and adults in the dangers of close association with dogs.

Helminths	Taeniasis (pork tapeworm) (beef tapeworm)	*Taenia solium* (pork tapeworm), *T. saginata* (beef tapeworm)	Man, cattle, pigs, buffalo, possibly rats, mice	Infected meats eaten raw, food contaminated with feces of man, rats, or mice	Abdominal pain, diarrhea, convulsions, insomnia, excessive appetite	8–10 weeks	Thoroughly cook meat. Control flies. Properly dispose of excreta. Foodhandler hygiene. Use only inspected meat. Store meat as for trichinosis.
	Fish Tapeworm (broad tapeworm)	*Diphyllo-bothrium latum*, other	Man, frogs, dogs, cats, bears	Infected freshwater fish eaten raw	Abdominal pain, loss of weight, weakness, anemia	3–6 weeks	Thoroughly cook fish, roe, (caviar). Proper excreta disposal.
	Dracontiasis (Guinea worm disease)	*Dracunculus medinensis*, a nematode worm	Man	Water contaminated with copepods-*Cyclops*; larvae from infected persons	Blistering of feet, legs, and burning and itching of skin; fever, nausea, vomiting, diarrhea; worms from skin	About 12 months	Use only filtered or boiled water in endemic areas for drinking, or a safe well-water supply. Treat water from unsafe source with temephos, Abate®. Health education.
	Paragonimiasis (lung flukes)	*Paragonimus ringeri, P. westermani, P. kellicotti*	Respiratory and intestinal tract of man, cats, dogs, pigs, rats, wolves	Contaminated water, freshwater crabs or crayfish	Chronic cough, clubbed fingers, dull pains, diarrhea	Variable	Boil drinking water in endemic areas. Thoroughly cook freshwater crabs and crayfish.[b]
	Clonorchiasis[a] (liver flukes)	*C. sinensis, Opisthorchis felineus*	Liver of man, cats, dogs, pigs	Contaminated freshwater fish	Chronic diarrhea, night blindness	Variable	Boil drinking water in endemic areas. Thoroughly cook fish.[b]
	Fascioliasis (sheep liver flukes)	*Fasciola hepatica*	Liver of sheep	Sheep liver eaten raw	Irregular fever, pain, diarrhea	Several months	Thoroughly cook sheep liver.[b]

(*continues*)

TABLE 1.4 ***(continued)***

	Disease	Specific Agent	Reservoir	Common Vehicle	Symptoms in Brief	Incubation Period	Prevention and Control
Helminths	Trichuriasis (whipworm)	*Trichuris trichiura*	Large intestine of man	Contaminated food, soil	No special symptoms, possibly stomach pain	Long and indefinite	Sanitation, boil water, cook food well, properly dispose feces.[b]
	Oxyuriasis (pinworm, threadworm, or enterobiasis)	*Oxyuris vermicularis*, or *Enterobius vermicularis*	Large intestine of man, particularly children	Fingers, ova-laden dust, contaminated food, water, sewage; clothing, bedding	Nasal and anal itching, diarrhea	3–6 weeks; months	Wash hands after defecation. Keep fingernails short. Sleep in cotton underwear. Sanitation.
	Fasciolopsias[a] (intestinal flukes)	*Fasciolopsis buski*	Small intestine of man, dogs, pigs	Raw freshwater plants, water, food	Stomach pain, diarrhea, greenish stools, constipation, edema	6–8 weeks	Cook or dip in boiling water roots of lotus, bamboo, water chestnut, caltrop.
	Dwarf tapeworm (rat tapeworm)	*Hymenolepis nana* (*diminuta*)	Man and rodents	Food contaminated with ova, direct contact	Diarrhea or stomach pain, irritation of intestine	1 month	Sanitary excreta disposal, personal hygiene, food sanitation, rodent control. Treat cases.
	Anisakiasis	Nematodes of Anisakides family	Marine mammals and fish: rockfish, salmon, cod, tuna	Contaminated fish eaten raw or under-cooked	Stomach pain, nausea, vomiting, confused with appendicitis	Hours	Do not eat raw fish. Cook fish to 140°F or freeze to −4°F for 60 hr to kill larvae.

Poisonous Plants and Animals	Ergotism[c]	Ergot, a parasitic fungus (*Claviceps purpurea*)	Fungus of rye and occasionally other grains	Ergot-fungus contaminated meal or bread	Gangrene involving extremities, fingers, and toes; or weakness and drowsiness, headache, giddiness, painful cramps in limbs	Gradual, after prolonged use of diseased rye in food	Do not use discolored or spoiled grain (fungus grows in the grain). Meal is grayish, possibly with violet-colored specks.
	Rhubarb poisoning	Probably oxalic acid	Rhubarb	Rhubarb leaves	Intermittent cramplike pains, vomiting, convulsions, coma	2–12 hr	Do not use rhubarb leaves for food.
	Mushroom poisoning	Phalloidine and other alkaloids: also other poisons in mushroom	Mushrooms—*Amanita phalloides* and other Amanita	Poisonous mushrooms (*Amanita phalloides, Amanita muscaria*, others)	Severe abdominal pain, intense thirst, retching, vomiting, profuse watery evacuations	6–15 hr or 15 min–6 hr with muscaria	Do not eat wild mushrooms; warn others. *Amanita* are very poisonous, both when raw or cooked.
	Favism[a]	Poison from *Vicia faba* bean, pollen	*Vicia faba* Plant and bean	The bean when eaten raw, also pollen	Acute febrile anemia with jaundice, passage of blood in urine	1–24 hr	Avoid eating bean, particularly when green, or inhalation of pollen. Toxin not destroyed by cooking.
	Fish poisoning	Poison in fish, ovaries and testes, roe (heat stable)	Fish: pike, carp, sturgeon roe in breeding season	Fish: tedrodon, meletta, clupea, pickerel eggs, mukimuki	Painful cramps, dyspnea, cold sweats, dilated pupils, difficulty in swallowing and breathing	30 min–2 hr or longer	Avoid eating roe during breading season. Heed local warnings concerning edible fish.

(*continues*)

TABLE 1.4 *(continued)*

	Disease	Specific Agent	Reservoir	Common Vehicle	Symptoms in Brief	Incubation Period	Prevention and Control
Poisonous Plants and Animals	Ciguatera poisoning	Toxin concentrated in tropical reef fish flesh, possibly from toxic dinoflagellate; also roe	Warm-water fish, possibly barracuda, snapper, grouper, amberjack, sea bass	Warm-water fish caught near shore from Pacific and Caribbean, coral reef fish	Progressive numbness, tetanuslike spasms, heavy tongue; facial stiffness; also nausea, vomiting, diarrhea, dryness of the mouth, abdominal cramps	1–8 hr, usually 3–5 hr	Avoid warm-water fish caught near shore in Pacific and Caribbean. The toxin ciguatera is not destroyed by cooking; toxin is not poisonous to fish.
	Shellfish poisoning (Paralytic)	Neurotoxin produced by *Gonyaulax catenella* and *G. tamarensis*	Clams and mussels feeding on specific dinoflagellates	Mussels and clams, associated with so-called "red tides"	Respiratory paralysis: in milder form, trembling about lips to loss of control of the extremities and neck. Fish kills and mass deaths in seabirds.	5–30 min and longer, up to 12 hr	Obtain shellfish from certified dealers and from approved areas. Monitor plankton in coastal waters. Toxin not destroyed by routine cooking.
	Scombroid fish poisoning	Scombrotoxin (histamine-like toxin)	Scombridea family primarily tuna, bluefish, amberjack	Fish that have been held at room temperature forming toxic histamine in muscle	Headache, burning mouth, nausea, vomiting, diarrhea, tingling of fingers, fever, cramps	Several minutes to 1 hr	Gut fish immediately after catch and refrigerate at 32°F or on ice. Toxin heat stable.
	Snakeroot poisoning	Trematol in snakeroot (*Eupatorium urticaefolium*)	White snakeroot jimmy weed	Milk from cows pastured on snakeroot	Weakness or prostration, vomiting, severe constipation and pain, thirst; temperature normal	Variable, repeated with use of the milk	Prevent cows from pasturing in wooded areas where snakeroot exists.

	Potato poisoning	*Solanum tuberosum*; other *Solanum*	Sprouted green potatoes	Possibly green sprouted potatoes	Vomiting, diarrhea, headache, abdominal pains, prostration	A few hours	Do not use sprouts or peel of sprouted green potatoes.
	Water-hemlock poisoning	Cicutoxin or resin from hemlock (*Cicuta maculata*)	Water hemlock	Leaves and roots of water hemlock	Nausea, vomiting, convulsions, pain in stomach, diarrhea	1–2 hr	Do not eat roots, leaves, or flowers of water hemlock.
Chemical Poisons	Antimony poisoning	Antimony	Gray-enameled cooking utensils	Foods cooked in cheap enameled pans	Vomiting, paralysis of arms	5 min–1 hour	Avoid purchase and use of poor-quality gray-enameled, chipped enamel utensils.
	Arsenic poisoning	Arsenic	Arsenic compounds	Arsenic-contaminated food or water	Vomiting, diarrhea, painful tenesmus (a cumulative poison)	10 min and longer	Keep arsenic sprays, etc., locked; wash fruits, vegetables. Avoid substances with concentrations greater than 0.05 mg/l.
	Cadmium poisoning	Cadmium	Cadmium-plated utensils	Acid food prepared in cadmium utensils	Nausea, vomiting, cramps, diarrhea	15–30 min	Watch for cadmium-plated utensils, racks, and destroy. Inform manufacturer.
	Cyanide poisoning	Cyanide, sodium	Cyanide silver polish	Cyanide-polished silver	Dizziness, giddiness, dyspnea, palpitation, unconsciousness	Rapid	Select silver polish of known composition. Prohibit sale of poisonous polish.

(*continues*)

TABLE 1.4 ***(continued)***

	Disease	Specific Agent	Reservoir	Common Vehicle	Symptoms in Brief	Incubation Period	Prevention and Control
Chemical Poisons	Fluoride or sodium fluoride poisoning	Fluoride or sodium fluoride	Roach powder	Sodium fluoride taken for baking powder, soda, flour	Acute poisoning, vomiting, abdominal pain, convulsions; paresis of eye, face, finger muscles, and lower extremities; diarrhea	Few minutes-2 hr	Keep roach powder under lock and key; mark "Poison"; color the powder, apply with care, if use is permitted.
	Lead poisoning	Lead	Lead pipe, sprays, oxides, and utensils, lead-base paints	Lead-contaminated food or acid drinks; toys, fumes, paints, drinking water	Abdominal pain, vomiting, and diarrhea (a cumulative poison), mental retardation, birth defects, fatigue, anemia	30 min and longer	Do not use lead pipe; Pb < 0.015 mg/l. Wash fruits. Label plants. Avoid using unglazed pottery. Test imported pottery. Screen child. Remove lead paint.
	Mercury poisoning	Mercury—methyl mercury and other alkyl-mercury compounds	Contaminated silt, water, aquatic life	Mercury-contaminated food, fish	Fatigue, mouth numbness, loss of vision, poor coordination and gait, tremors of hands, blindness, paralysis	2–30 min or longer	Keep mercuric compound under lock and key. Do not consume: fish with concentrations of mercury more than 0.5 ppm, water with more than 0.002 ppm, food with more than 0.05 ppm. Eliminate discharges to the environment.

Chemical Poisons	Methyl chloride poisoning	Methyl chloride	Refrigerant, methyl chloride	Food stored in refrigerator having leaking unit	Progressive drowsiness, stupor, weakness, nausea, vomiting, pain in abdomen, convulsions	Variable	Use nontoxic refrigerant, or ice, water, brine, dry ice.
	Selenium poisoning	Selenium	Selenium-bearing vegetation	Wheat from soil containing selenium, also other plants and water	Gastrointestinal, nervous, and mental disorders; dermatitis in sunlight	Variable	Avoid semiarid selenium-bearing soil for growing of wheat, or water with more than 0.05 mg/l Se.
	Zinc poisoning	Zinc	Galvanized iron	Acid food made in galvanized iron pots and utensils	Pain in mouth, throat, and abdomen followed by diarrhea	Variable, short	Do not use galvanized utensils in preparation of foods or drink, or water with more than 5.0 mg/l zinc.
	Methemo-globinemia	Nitrate nitrogen, plus nitrite	Groundwater; shallow dug wells, also drilled wells	Drinking water from wells high in nitrates	Vomiting, diarrhea, and cyanosis in infants	2–3 days	Use water with less than 45 mg/l NO_3 for drinking water and in infant formula. Properly develop and locate wells.
	Sodium nitrite poisoning	Sodium nitrite	Impure sodium nitrate and nitrite	Sodium nitrate taken for salt, cured meats	Dizziness, weakness, stomach cramps, diarrhea, vomiting, blue skin	5–30 min	Use USP sodium nitrate in curing meat. Nitrite is poisonous, keep locked.

(*continues*)

TABLE 1.4 ***(continued)***

	Disease	Specific Agent	Reservoir	Common Vehicle	Symptoms in Brief	Incubation Period	Prevention and Control
Chemical Poisons	Copper poisoning	Copper	Copper pipes and utensils	Carbonated beverages and acid foods in prolonged contact with copper	Vomiting, weakness, diarrhea	1 hr or less	Do not prepare or store acid foods or liquids or carbonated beverages in copper containers. Cu should not exceed 0.3 mg/l. Prevent CO_2 backflow into copper lines in soft drink machines.
	Reference: Material safety data sheets-Infectious substances. 2001. Public Health Agency of Canada (available at: http://www.phac-aspc.gc.ca/msds-ftss/msds106e.html); Centers for Disease Control and Prevention. 2007. Acanthamoeba infection, Department of Health and Human Services (available at http://www.cdc.gov/NCIDOD/DPD/parasites/acanthamoeba/factsht_acanthamoeba.htm); Martinez, A. J. Free-living amebas: *Naeglaria, Acanthamoeba*, and *Balamuthia*, Medmicro chapter 81 (available at http://www.gsbs.utmb.edu/microbook/ch081.htm)						

Source: This figure represents a summary of information selected from: I. G. M. Dack, *Food Poisoning*, 251 pp., University of Chicago Press, 1956. 2. C. E. Dolman, "Bacterial Food Poisoning," 46 pp., *Canad. Pub. Health J. Assoc*., 1943. 3. V. A. Getting, "Epidemiologic Aspects of Food-Borne Disease," 75 pp., *New Eng. J. Med*., 1943. 4. F. A. Korff, "Food Establishment Sanitation in a Municipality," *Am. J. Pub. Health* **32**, 740 (1952). 5. P. Manson-Bahr, *Synopsis of Tropical Medicine*, 224 pp., Williams & Wilkins Co., Baltimore, 1943. 6. New York State Department of Health, *Health News*. 7. Miscellaneous military and civilian texts and reports. 8. R. P. Strong, *Stitt's Diagnosis, Prevention and Treatment of Tropical Diseases*, 2 vols., Blakiston Co., Philadelphia, 1942. 9. *The Control of Communicable Diseases in Man*, American Public Health Association, Washington, D.C., (Sept. 1944, Revised May 1945, 1946, 1952, 1971, 1980, 1990.) Copyright 1946, Joseph A. Salvato, Jr., MCE.) More complete characteristics, preventive and control measures, and modes of transmission, other than food and water, have been omitted for brevity as has been the statement "epidemiological study" and "education of the public" opposite each disease under the heading "Prevention and Control." Milk and milk products are considered foods. Under "Specific Agent" and "Common Vehicle" above, only the more common agents are listed.

[a] Does not originate in the U.S.

[b] Take same precautions with drinking, culinary, and bathing water as in Schistosomiasis.

[c] Many other fungi that produce toxin are associated with food and feedstuffs. The mycotoxins cause illness in humans and animals; see text. For more information see F. L. Bryan, *Diseases Transmitted by Foods*. DHEW, PHS, Atlanta, Ga., 1971, 58 p., *Procedure for the Investigation of Foodborne Disease Outbreaks*, and *Procedures to Investigate Waterborne Illness*, International Association of Milk, Food, and Environmental Sanitarians, P.O. Box 701, Ames, Ia. 50010, 1988, and Morbidity and Mortality Weekly Report(s), U.S. DHHS, PHS, CDC, Atlanta, Ga.

present-day human population is the increasing number of infections caused by bacteria not normally considered highly virulent. These organisms, sometimes considered secondary pathogens, are opportunistic bacteria that, under certain conditions, can cause infections through contact in some way with water.[31] Certain groups of people notably, infants, elderly, immunocompromised, transplant recipients, and convalescents, are at greatest risk of susceptibility to infection by these organisms. A summary of some important opportunistic bacterial pathogens appears in Table 1.5. Several of the bacterial species listed in the table are relatively newly discovered and responsible for specific pathological problems. Two such organisms are *Helicobacter pylori* and *Legionella pneumophila*.

Gastrointestinal disturbances are so commonplace in the human experience in wealthy countries that they are essentially an accepted fact of life, hence, usually receive little medical attention and go unreported. However, in undeveloped lands, gastrointestinal diseases are a ravishing scourge that accounts for numerous deaths, especially, among children. Of an estimated 2.2 million deaths from diarrheal-type diseases, 1.8 million of these involve children under five years of age.[32] To grasp the importance of safe drinking water on reduction of child mortality in various countries of the world, examine the comparative data in Figure 1.2.[33] The occurrence of a large number of diarrheal cases indicates that there has been a breakdown in hygiene or in the sanitary control of water or food and may forewarn impending cases of salmonellosis, typhoid fever, dysentery, or other illness.

Bacteria are prokaryotic, microscopic organisms, typically unicellular with morphologies described as coccoidal (ovoid), bacillary (rodlike), spiral (vibroid or helical), and filamentous. Typical eubacterial single-cell dimensions average 0.5 to 1 μm in diameter by 1 to 5 μm in length. Bacterial physiologies are more varied among the species than those of any group of microorganisms that supports the notion that plant and animal life on earth as we know it would not be possible without the bacteria. Unfortunately, the typical notoriety that bacteria in general have among the uninformed is that bacteria are "germs" and, therefore, are synonymous with disease. *Rickettsias* are obligate, intracellular parasitic bacteria not cultivatable outside host cells. Unlike viruses, they are retained by the Berkefield filter.[34] Their sizes average 0.3 to 0.7 μm by 1 to 2 μm.

Viruses are submicroscopic, genetic parasitic elements consisting of a nucleic acid (DNA or RNA) core surrounded by a protein coat, fall in the size range of 10 to 100 nm, pass through filters that retain bacteria, are visible only with the aid of an electron microscope, and can replicate only following invasion of living (host) cells. Viruses responsible for diseases transmitted by the water route are all RNA viruses, and most are geometrically icosahedral (ovoid) and small (about 30 nm) in size. Virus particles (virions) maintain infectiousness outside the host. Although all viruses require a host for sustaining replication of virions, expression of a clinical disease does not always take place. Animal enteric viruses do not appear to be readily transmissible to humans, although hepatitis A virus has been shown to pass from chimpanzees to humans. There are more than 100 types of human enteric viruses excreted in large numbers from the gastrointestinal tract.

TABLE 1.5 Opportunistic and "Modern" Bacterial Pathogens Transmitted by the Water Route

Disease and /or Conditions	Specific Agent	Reservoir	Common Vehicle	Symptoms	Incubation Period	Prevention and Control
Varied infections (urinary, eye) and abscesses (lung, brain), septicemia	*Acinetobacter* spp.: *calcoaceticus-baumannii* complex	Soil, seawater, freshwater, estuarine water, wastewater, contaminated food	Finished waters withhigh bacterial levels and low disinfectant residuals	Multifactorial according to body site affected	6-12 days	Adequate water treatment; maintain chlorine residual in distribution system
Gastrointestinal maladies; septicemia	*Aeromonas* spp.: *hydrophila, sobria, caviae*	Freshwater, marine water, estuarine water, wastewater, sludges, sediments	Finished waters with high bacterial levels	Diarrhea, vomiting	1-2 days	Adequate water treatment; maintain chlorine residual in distribution system
Gastroenteritis	*Campylobacter* spp.: *jejuni, coli, upsaliensis*	Contaminated water, wastewater, wastewater effluent	Contaminated water facilitating a zoonosis especially involving poultry consumption	Diarrhea, fever, cramps, tiredness, occasional vomiting	2-5 days	Disinfect water to effectively minimize residual *E. coli* numbers
Septicemia, pneumonia, infant meningitis, endocarditis	*Flavobacterium* spp.: *meningosep-ticum, breve, odoratum*	Soil, natural and finished waters, plumbing systems, hospital water fixtures	Water supply by ingestion or bodily contact	Unavailable	Unavailable	Tight control of finished water quality and provide well maintained distribution system

Gastritis, peptic and duodenal ulcer disease, stomach adeno-carcinoma	*Helicobacter* sp.: *pylori*	Uncertain presence in water distribution system	Possible contaminated food and water	Chronic indigestion, heartburn	5-10 days	Maintain adequate disinfectant residual in finished water
Enterocolitis, urinary and respiratory infections including hypersensitivity pneumonitis	*Klebsiella* spp.: *pneumoniae, oxytoca, rhinoscleromatis, planticola, ozaenae terrigena*	Certain industrial wastes, especially of paper-making and sugar refining; fruits and vegetables, plant matter	Surface water and unprotected ground water; water filters	Diarrhea, abdominal cramps; fever, dry cough, bloody sputum	1-3 days (chronic respiratory disease)	Maintain adequate disinfectant residual in distribution system and conduct periodic flushing to eliminate biofilms
Central nervous system, bone, soft tissue infections; endocarditis (HIV/AIDS patients highly susceptible	*Mycobacterium avium* complex (*M. avium* and *M. intracell-ulare*)	All environments (soil, clean and polluted waters), animals	Water and soil by ingestion, inhalation of aerosols	Abdominal pain, fatigue, diarrhea, anemia	Typically very long and dependent on health status	Water treatment coagulation and filtration for suspended matter removal, maintain effective disinfectant residuals

(*continues*)

TABLE 1.5 ***(continued)***

Disease and /or Conditions	Specific Agent	Reservoir	Common Vehicle	Symptoms	Incubation Period	Prevention and Control
Infant diarrhea, bacteremia, eye infections, cystic fibrosis, folli- colitis, osteo- myelitis, malig- nant external otitis	*Pseudomonas* sp.: *aeruginosa*	Surface water, groundwater, bottled water, distilled water, seawater, soils, vegetation	Water and food by ingestion, bodily contact in bathing waters and spas, hospital environments	Multifactorial; coughing, chest pain, fatigue (cystic fibrosis); pimply rash; ear ache	1-10 days (infections and rashes)	Control growth of *Pseudomonas* spp. in all phases of water treatment and in the distribution system maintaining chlorine residual of 0.5 mg/l throughout
Legionellosis, Pontiac fever	*Legionella* sp.: *pneumophila*	Surface water, cooling water towers, evaporative condensers, whirlpools, hot water tanks, fountains, water distribution systems	Inhalation of water mists emanating from cooling waters, condensers, spas	Pneumonia, anorexia, malaise, headache (legionellosis); influenza-like symptoms (Pontiac fever)	2-10 days (legionellosis); 1.5-3 days (Pontiac fever)	Clean sediments from hot water tanks and cooling towers; hold temperature range of 71–77°C in hot water tanks; maintain steady disinfectant levels in whirlpools and cooling towers

Cystitis, septicemia, central nervous system infections	*Serratia* spp.:*marcescens, odorifera, rubidaea* subgroup *liquefaciens*	Surface water, groundwater, soil, decaying vegetation, insects, decaying meat, sour milk	Hospital sump water, medical solutions, dialysis effluents	Fever, urinary discomfort; vomiting, headache	Not clearly defined; 1-7 days (dose related septicemia	Maintain adequate disinfectant residuals and reduce sediment accumulation in pipes and storage reservoirs
Skin infections, bacteremia, urinary tract infections, nosocomial infections	*Staphylococcus* spp.: *epidermis saprophyticus*	Warm-blooded animal surfaces, wastewater, stormwater	Contaminated bathing water in contact with open skin lesions, eyes, and ears	Sudden vomiting (poisoning); inflammation, boils (dermal)	1-6 hours (poisoning); 5-10 days (dermal)	Distribution system maintenance in the manner required for minimizing conditions favorable to any of the opportunistic pathogens
Gastroenteritis	*Plesiomonas* sp.: *shigelloides*	Domestic animals, fish, amphibians	Contaminated drinking and recreational water	Fever, chills, diarrhea, nausea, vomiting	1 day	Effective water disinfectant residual; proper food handling

Source: Information presented in Table 1.5 was retrieved from chapters 5, 6, 11–16, 18, 20 in ref. 30; ref. 28; R. Webber, Communicable Disease Epidemiology and *Control*, CAB International, Wallingford, UK, 1996. and Internet sources.

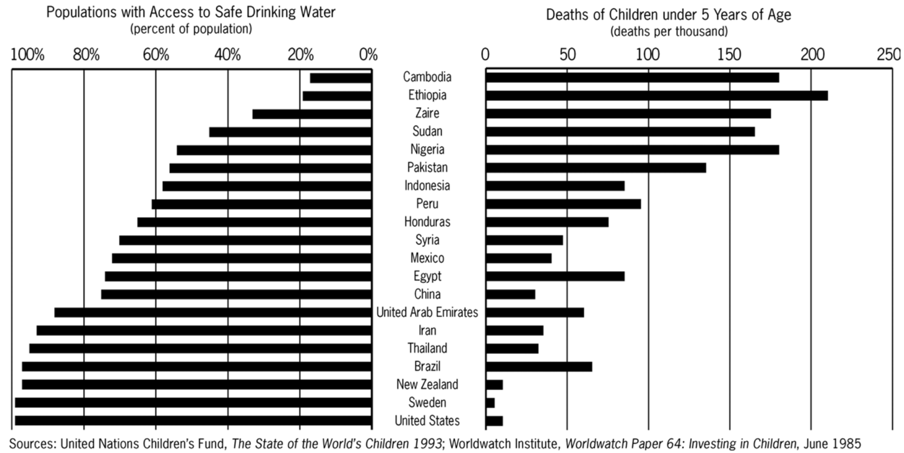


FIGURE 1.2 Relationship between availability of safe drinking water and mortality of children below age five. (*Source*: T. E. Ford and R. R. Colwell, A Global Decline in Microbiological Safety of Water: A Call for Action, American Academy of Microbiology, 1996. Washington, DC.)

The following groups of enteric viruses have been implicated or suspected to be transmitted by contaminated water: enteroviruses (including polioviruses and four subsets of enterovirus [A, B, C, D]), coxsackievirus A viruses, parechoviruses [1-3], hepatitis A (HAV) virus, hepatitis E (HEV) virus, caliciviruses (Noroviruses and Sapoviruses), rotaviruses, adenoviruses, and astroviruses.

Algae are chlorophyllous microorganisms ranging from microscopic unicellular to "seaweed"-size multicellular forms. Their oxygenic capability in performing the light reaction in photosynthesis is the major source of atmospheric oxygen. Various types of algae serve as sources of food and pharmaceutical agents. Although pathogenic algae are relatively rare, certain of the marine dinoflagellates (e.g., *Gonyaulax* spp.) are producers of saxitoxin and gonyautoxin, two of the most virulent nonprotein neurotoxins of record. *Gambierdiscus toxicus* is a tropical marine, benthic dinoflagellate, that synthesizes ciguatoxin, a polycyclic ether compound that creates imbalance in sodium concentration in the axons and nerve terminals causing influx of water and swelling. Ciguatera is a foodborne illness in humans caused by eating marine species that have accumulated cells of G. toxicus by ingestion.[35]

Protozoa are aerobic or anaerobic protists having a true nucleus (eukaryotic). They reproduce usually by fission. They are classically described as simple, unicellular microorganisms, some of which feed on particulate organic matter, including bacteria, and others that utilize soluble organic matter. Motility may be by protoplasmic streaming (amoeba), flagellation, or the synchronize thrashing of cilia. Free-living forms may utilize soluble nutrients or ingest particulate matter (e.g., bacteria). Several pathogenic forms exist such as *Giardia* sp. and *Cryptosporidium* sp. species, that are responsible for waterborne, communicable diseases. Protozoa range in size from approximately 5 to 100 μm in size. Giardia cysts are 8 to 18 μm in length and 5 to 12 μm in width and Cryptosporidium 3 to 5 μm in size.

Fungi are principally aerobic, achlorophyllous microorganisms represented by single and multicellular forms. Most notable of the multicellular fungi are the filamentous varieties known as molds. Filaments (hyphae) are typically on the order of 5 to 10 μm in diameter and many millimeters in length. Molds are important as degraders of complex animal and vegetative matter in nature but become a nuisance in food spoilage and as producers of allergens via sporulation. Many fungi cause diseases in both plants and animals. Certain of the higher fungi, notably the edible mushrooms, are important foodstuffs, as are the yeasts used in bread making and the brewing of alcoholic beverages. Some of the most valuable antibiotics used for medical therapy are synthesized by fungi.

Helminths include intestinal worms and wormlike parasites: the roundworms (nematodes), tapeworms (cestodes), and flatworms or flukes (trematodes). The eggs are about 40 μm or larger in size.

Poisonous plants contain toxic substances that may cause illness or even death when consumed by humans or other animals. Poisonous animals include fish whose flesh is poisonous when eaten in a fresh and sometimes cooked state. (Poisonous flesh is not to be confused with decomposed food.) Acute toxins, such as paralytic shellfish neurotoxins, pose the threat of severe illness or, in rare occasions, death when consumed along with shellfish meats by humans, especially children and the immunocompromised, and by other animals. As already noted, the toxic substance (e.g., saxitoxin) present in some poisonous shellfish flesh results from the filtration of toxigenic marine dinoflagellates, Gonyaulax spp., and appears to be heat stable. Inorganic chemical elements of greatest concern as a seafood hazard appear to be cadmium, lead, and mercury. The long-term effects are nephropathy, anemia and central nervous system disorders, and retardation; the latter two effects associated with lead and mercury are especially dangerous to the human fetus and neonatal stages.[36] Organic contaminants of fish flesh of particular concern are polychlorinated biphenyls, doxins, chlorinated insecticides, and furans as pertains to their potential as carcinogens and teratogens.

Illnesses associated with the consumption of poisonous plants and animals, chemical poisons, and poisonous fungi are not strictly communicable diseases but more properly noninfectious or noncommunicable diseases.

Vehicle or Means by Which Waterborne Diseases Are Spread

The means by which waterborne disease agents are transmitted to individuals include drinking, bathing in swimming pools and recreational waters, showering (mists), natural aerosols, contaminated hand towels and wash cloths, contaminated water (fish and shellfish), produce irrigated or washed with contaminated water, contact with water containing invasive parasites, and bites of insects that spend at least a part of the life cycle in water. The lack of potable water for bathing, household cleanliness, and food preparation also contributes to poor personal hygiene and sanitation and to the spread of disease. In addition, contagious diseases of individuals, originally produced by contact with contaminated water, may then be passed to another person. The discussions that follow will cover the role of water as a source of disease-producing organisms and poisonous substances.

The reporting of waterborne illnesses has, with rare exceptions, been very incomplete. Various estimates have been made in the past, indicating that the number reported represented only 10 to 20 percent of the actual number.

Hauschild and Bryan,[37] in an attempt to establish a better basis for estimating the number of people affected, compared the number of cases initially reported with either the number of cases identified by thorough epidemiologic investigations or the number estimated. They found that for 51 outbreaks of bacterial, viral, and parasitic disease (excluding milk), the median ratio of estimated cases to cases initially reported to the local health authority, or cases known at the time an investigating team arrived on the scene, was 25 to 1. On this basis and other data, the annual food- and waterborne disease cases for 1974 to 1975 were estimated to be 1,400,000 to 3,400,000 in the United States and 150,000 to 300,000 in Canada. The annual estimate for the United States for 1967 to 1976 was 1,100,000 to 2,600,000.[37] The authors acknowledge that the method used to arrive at the estimates is open to criticism. However, it is believed that the estimates come closer to reality than the present CDC reporting would indicate, particularly to the nonprofessional. The estimates would also serve as a truer basis for justifying regulatory and industry program expenditures for waterborne illness prevention, including research and quality control.

Historical Waterborne Disease Background

Prior to the mid-1800s, understanding the connection between routes of disease transmission and the causes of illness was greatly hampered by the ignorance of mankind concerning the existence and role of pathogenic agents. Two centuries separated the seminal discoveries of the basic biological cell, including the existence of microbial beings, and the demonstration that certain microorganisms were at the root of disease formation and decay. Prior to the formative years of the field of microbiology, civilization regarded the onset of infections as the curse of some undefined phenomenon of fouled air (miasma), and treatments of the sick were largely relegated to the practice of quarantine or administering of harsh chemical potions. Pollution of water sources was rampant. Some chose to intuitively avoid contact with such waters, not because of any knowledge of the presence of disease-producing agents, but because of the intolerable offensive odors. Indeed, such philosophy was espounded by Dr. John Sutherland, a Scottish physician, when asked in 1854 to comment on the origins of the London Asiatic cholera epidemic of 1853 to 1854: “There is no sufficient proof that water in this state [of impurity] acts specifically in generating cholera” [but] “use of water containing organic matter in a state of decomposition is one predisposing cause of cholera.[38]

Diseases such as cholera, typhoid, typhus, and dysentery were common in the United States, Europe, and other parts of the world prior to the 20th century. Three classical waterborne disease outbreaks are summarized next.

Asiatic cholera produced two epidemics in London in the years 1849 and 1853, both of which were investigated by John Snow, a physician in the twilight of his life, who came to believe that the feces of cholera patients were the source of the disease.[28] It was the Italian physician, Filippo Pacini of Florence,[39] however, who actually observed the cholera vibrio in the intestinal tissue specimens of a deceased victim with the aid of a microscope and deduced the relationship between the bacteria and the disease. Snow noted that the Broad Street well in the SoHo district of London—specifically, St. James Parish, Westminster—served an area where 616 people had died during a 15-week period, and the death rate for St. James Parish was 220 per 10,000, compared to 9 and 33 per 10,000 in adjoining subdistricts.

Snow found that a brewery on Broad Street employing 70 workmen had no deaths. The brewery had its own well, and all the workers had a daily allotment of malt liquor. It can be reasonably assumed that these workers did not drink any water. In contrast, at a factory at 38 Broad Street, where only water from the Broad Street well was available, 18 of 200 workers died (900 per 10,000). But in a nearby workhouse, which had its own water supply in addition to the city supply, there were only 5 deaths among 535 inmates.

Snow's investigation included a follow-up on each death. He spotted the location of each on a map with relation to the Broad Street well and inquired of the work and activities of each person, their habits and customs, and source of drinking water. The one common factor was consumption of water from the Broad Street well. With this information in hand, he convinced the Board of Guardians of St. James Parish to have the handle of the pump removed, and the epidemic was brought under control.

A survey was made to determine the cause and source of the epidemic. The house at 40 Broad Street nearest the well was suspected as the source; there had been four fatal cases of cholera at the house. A privy emptying into a cesspool, which served more like a tank, overflowed to a drain passing close to the well.

On further investigation, including excavations, it was found that the Broad Street well was a brick-lined dug well with a domed brick top 3 feet, 6 inches below the street. The well was 28 feet, 10 inches deep and 6 feet in diameter, and contained 7 feet, 6 inches of water. The house drain, 12 inches wide with brick sides 12 inches high and stone slab top and bottom, passed within 2 feet, 8 inches of the brick lining of the well. The drain, on a very flat grade, was 9 feet, 2 inches above the water level in the well and led to a sewer. The mortar joints of the well lining and the drain were completely disintegrated. It was found on inspection after excavation that the drain was like a "sieve and through which house drainage water must have percolated for a considerable period" into the well, as indicated by black deposits and washout of fine sand. The drain received wastewater from 40 Broad Street in addition to the overflow from a cesspool in the basement, over which there was a privy.[40]

In another study in 1854, Snow found that a low incidence (37 per 10,000 residences) of cholera fatalities occurred in one part of London supplied by the Lamberth Company with water from the River Lea, a tributary of the River Thames, with an intake more than 38 miles upstream from London. People supplied by the Southwark & Vauxhall Company received water taken from the heavily wastewater-polluted Thames River, opposite the location of Parliament, with a very high incidence of cholera and a death rate of 315 per 10,000 residences. Snow compared the income, living conditions, work, and other characteristics of the people in the two areas and found that source of water was the main variable and, hence, the cause of the illness. The study involved approximately 300,000 people and laid the basis for future epidemiologic studies.

Today, John Snow is considered the epidemiological giant of his time. However, his views on the transmission of cholera did not go unchallenged during his active investigations. William Farr, a professional epidemiologist, was lukewarm to Snow's findings of 1849 and, although he accepted that an association existed between cholera illness and the south district water supply of London, clung to the view that the cholera epidemic of 1849 was responsible to "spread by atmospheric vapours" and the consequences of the lower elevation of water pipes in the soil carrying water from the lower Thames as opposed to that of the upstream region.[41] Farr also contended that the cholera agent was heavier than water and, therefore, would be expected to be of higher concentration in pipes of lower elevation than those of higher elevation. Interestingly, in 1866 a cholera epidemic occurred in the Whitechapel area of London that was traced to water supplied by the East London Water Company whose source was the River Lea. William Farr pronounced, "Only a very robust scientific witness would have dared to drink a glass of the waters of the [river] Lea," on which note Farr's notions that air, not water, was the cause of London's infamous cholera epidemics came to an end.[42] Snow was immersed in the study of anesthesiaology in his final days and died from complications of a stroke at the age of 45; quite possibly brought on by his self-committed experimentation with chloroform, ether, and other noxious agents in the quest for useful anesthetics. Epidemics of cholera persisted in London after Snow's death. The poor water quality of the Thames is evident from the account of a large pleasure craft that capsized on a Sunday afternoon in the mid 1800s with its passengers thrown into the river; no one drowned, but most died of cholera within a few weeks, thereafter.[43]

In still another instance, Robert Koch (1843–1910), an eminent German physician, unaware of Pacini's earlier discovery, observed the cholera bacillus under similar pathological conditions in Alexandria, Egypt, in 1883.[44] In 1884, Koch succeeded in isolating and culturing the organism from the stools of advanced cholera patients in Calcutta, India. Closer to home in 1892, Koch investigated the incidence of cholera in two adjacent cities in Germany that pumped drinking water out of the Elbe River. Hamburg pumped water from a point upstream and Altona, a suburb, took water downstream from the city sewer outfalls, but the outbreak occurred in Hamburg upstream. However, the water in Altona was filtered through a slow sand filter, whereas the water in Hamburg was not. Koch isolated *Vibrio cholerae* from the polluted Elbe River, proving the relationship between polluted water and disease. There were 8,605 deaths in Hamburg, a death rate of 1,342 per 100,000. The death rate in Altona was 234 per 100,000.

Water treatment, specifically the application of a disinfectant, notably chlorine, has practically eliminated cholera, typhoid, and dysentery in developed areas of the world. The conquest of these and other waterborne diseases parallels the development of microbiology and sanitary engineering, as well as immunization; water treatment, including chlorination, proper excreta, and wastewater disposal; and education in hygiene and public health. However, waterborne diseases still occur with viral gastroenteritis (nonspecific gastroenteritis being more common), infectious hepatitis A, giardiasis, and cryptosporidiosis. As noted elsewhere, absence of potable water and latrines is associated with high diarrheal illness and mortality rates among children under five in developing countries. The major concerns in developed countries today are the chronic and degenerative diseases, including those associated with the ingestion of trace amounts of toxic organic and inorganic chemicals, but it is also essential that the safeguards found effective in preventing waterborne diseases be maintained and strengthened to prevent their recurrence.

Waterborne Disease Outbreaks Given the vulnerability of surface waters to pollution, it may be surprising to learn that in every decade since 1920, contaminated groundwaters in the United States have been responsible for more waterborne outbreaks than contaminated surface waters, and that during the period 1971 to 2000, waterborne outbreaks have declined in untreated ground waters, whereas disinfected groundwaters have accounted for 38 percent of the groundwater-related waterborne outbreaks during that time frame.[16] Most recently, however, a waterborne outbreak suspected to involve a *Salmonella* sp. was believed to be linked to the undisinfected, deep-well, groundwater system serving Alamosa County, Colorado, in the United States. On March 19, 2008, at least 33 confirmed cases of salmonella infections were recorded, and the Colorado Department of Health issued a "bottled water" advisory. The source of the contamination was unknown, but a cross-connection with a wastewater line or a violated storage water tank was suspected. The following day, the number of confirmed and suspected salmonella cases rose to 79. Two days later, 139 people were reported ill from salmonella infections, and the city declared a state of emergency. By Sunday, March 28, the suspected case load had reached 276, with 10 people hospitalized. Laboratory-confirmed-cases numbered 72 and a candidate pathogen, *Salmonella enterica* serotype Typhimurium, was isolated from the stools of confirmed victims.[45] The "boil order" was lifted on April 11, 2008 and Alamosa likely will be required to comply with U.S. EPA Groundwater Disinfection Rule as published in the Federal Register on November 8, 2006 concerning disinfection of groundwater public drinking water supplies. It was reported on April 20, 2008 that 411 salmonella cases, of which 112 were confirmed and 18 hospitalized, included one death not proven responsible to infection by salmonella.[46]

Waterborne outbreaks occur more frequently in noncommunity water systems than in community water systems; however, the number of cases associated with community water systems is usually larger than in noncommunity water systems. In the period 1991 to 2000, the annual average of waterborne outbreaks in noncommunity water systems was approximately eight compared to six outbreaks for community water systems. The median number of illness cases associated with the noncommunity and community outbreaks was 112 and 498, respectively.[16] Although waterborne diseases account for only a very small percentage of all human illness in the United States and other industrialized countries, this advantage can only be maintained by the continued reduction in biological and chemical pollution of our surface and groundwaters and by complete and competent treatment of drinking water. A case in point is the cryptosporidiosis outbreak that occurred in Milwaukee, Wisconsin, in 1993, resulting in an estimated 403,000 cases of watery diarrhea.[47] Although in excess of 100 deaths have been stated in various media sources, 54 deaths were *officially* reported in the 4-year post-outbreak period, of which 85 percent involved AIDS patients;[48] testimony to the ravishing effect of infectious diseases on immunocompromised individuals. The magnitude of the Milwaukee incident is such that it represented 93 percent of the total 173 waterborne disease outbreaks during the period 1991 to 2000. The total cost of the Milwaukee outbreak was estimated to be $96.2 million (1993 U.S. dollars), with about $31.7 million in medical expenses and about $64.6 million in productivity losses.[49]

Between 1946 and 1980, a total of 672 waterborne disease outbreaks were reported, with 150,475 cases. Contaminated untreated groundwater accounted for 35.3 percent of the 672 outbreaks, inadequate or interrupted treatment for 27.2 percent, distribution or network problems for 20.8 percent, contaminated untreated surface water for 8.3 percent, and miscellaneous for 8.3 percent. Forty-four percent of the outbreaks involved noncommunity water systems and accounted for 19 percent of the cases.[50]

Weibel et al.[51] studied the incidence of waterborne disease in the United States from 1946 to 1960. They reported 22 outbreaks (10 percent) with 826 cases due to use of untreated surface waters; 95 outbreaks (42 percent) with 8,811 cases due to untreated groundwaters; 3 outbreaks (1 percent) with 189 cases due to contamination of reservoirs or cisterns; 35 outbreaks (15 percent) with 10,770 cases due to inadequate control of treatment; 38 outbreaks (17 percent) with 3,344 cases due to contamination of distribution system; 7 outbreaks (3 percent) with 1,194 cases due to contamination of collection or conduit system; and 28 outbreaks (12 percent) with 850 cases due to miscellaneous causes, representing a total of 228 outbreaks with 25,984 cases.

Weibel et al.[51] reported the greatest number of outbreaks and cases in communities of 10,000 population or less. Wolman and Gorman stated that the greatest number of waterborne diseases occurred among population groups of 1,000 and under and among groups from 1,000 to 5,000—that is, predominantly in the rural communities.[52] Between 1971 and 1978, 58 percent of the outbreaks occurred at small, noncommunity water systems. The need for emphasis on water supply control and sewage treatment at small existing and new communities, as well as at institutions, resorts, and rural places, is apparent and was again confirmed in the 1970 PHS study,[53] a 1978 summary,[54] and others.[50] From 1971 to 1982, a total of 399 waterborne outbreaks with 86,050 cases of illness were reported to the U.S. Public Health Service. Forty percent of the outbreaks occurred at community water systems, 48 percent at noncommunity systems, and 12 percent at individual systems. Thirty-one percent involved groundwater systems serving motels, hotels, camps, parks, resorts, restaurants, country clubs, schools, day care centers, churches, factories, offices, and stores. Thirty-one percent of the total waterborne outbreaks were caused by use of contaminated untreated groundwater (wells and springs); 20 percent by inadequate or interrupted disinfection of groundwater (wells and springs); 16 percent by distribution system deficiencies (cross-connection, storage facilities, and contamination of mains and through household plumbing); 14 percent by inadequate or interrupted disinfection of surface water; 8 percent by use of contaminated untreated surface water; 4 percent by inadequate filtration, pretreatment, or chemical feed; and 7 percent by miscellaneous deficiencies.[55] In another analysis of 484 waterborne outbreaks with 110,359 cases between 1971 and 1985, the agent was bacterial in 59, parasitic in 90, viral in 40, chemical in 51, and acute gastrointestinal in 244. Community systems, noncommunity systems, and individual systems experienced 209, 217, and 58 outbreaks, respectively. Untreated groundwater and treatment deficiencies were the major causes.[56]

Drinking water contaminated with sewage is the principal cause of waterborne diseases. The diseases that usually come to mind in this connection are bacterial and viral gastroenteritis, giardiasis, hepatitis A, shigellosis, and typhoid and paratyphoid fevers. However, nearly one-half of outbreaks involving drinking water in the United States between the years 1971 to 2002 were described as gastroenteritis of unknown origin.[18] Protozoa, bacteria, and viruses were the causative agents in 19, 14, and 8 percent of outbreaks, respectively, and chemicals were responsible for 12 percent percent. A breakdown of the various diseases of drinking water for eight decades in the United States can be found in Table 1.6.[16]

Modern day globalization presents a concern for the monitoring and control of infectious diseases. Human transport and interaction on an international scale along with transport of animals and food items enhances the threat of disease transmission. The United States must be vigilant in recognizing the risk for its citizens in contracting infectious diseases or becoming carriers as a result of travel to countries having lower standards of environmental health. [57]

Because of the supervision given public water supplies and control over a lessening number of typhoid carriers, the incidence of typhoid fever has been reduced to a low residual level. Occasional outbreaks, due mostly to carriers, remind us that the disease is still a potential threat. During the period 1967–1972, *Salmonella typhi* was isolated from 3661 individuals in the United States and, coincidentally, the number of travel-associated cases of typhoid fever rose yearly by 270%; a phenomenon believed connected in some way to Mexico.[57] Although the incidence of typhoid fever cases has decreased from approximately 1.9 per million to 1.3 per million travelers to Mexico between 1985 and 1994, of all states reporting cases of typhoid fever to the Typhoid Fever Surveillance System for the period between 1985 and 1994, California and Texas ranked one and two, respectively, with California accounting for 44% of the 2443 cases recorded.[58] United States residents with Hispanic names were found to be at higher risk of contracting typhoid fever than were others in the population.[57] In effect, globalization is likely to influence the level of endemic infectious diseases in the United States and, as noted by Mermin et al[58], will be interconnected to the incidence of infectious diseases in other countries of the world, thus underscoring the importance of achieving high standards of environmental hygiene worldwide.

The outbreaks reported below are also instructive. In 1940 some 35,000 cases of gastroenteritis and 6 cases of typhoid fever resulted when about 5 million gallons of untreated, grossly polluted Genesee River water were accidentally pumped into the Rochester, New York, public water supply distribution system. A valved cross-connection between the public water supply and the polluted Genesee River firefighting supply had been unintentionally opened. In order to maintain the proper high pressure in the fire supply, the fire pumps were placed in operation and hence river water entered the potable public water supply system. The check valve was also inoperative.

TABLE 1.6 Causes of Drinking Water Outbreaks in the United States, 1920-2000. Calderon, and M. F. Craun. 2006

	Survival Time[a]	
Organism	In Surface Water	In Groundwater
Coliform bacteria	—	7–8 days[b]
Cryptosporidium spp. oocyst	18 + months at 4°C	2–6 months, moist[c]
Escherichia coli	—	10–45 days[b]
Entamoeba histolytica	1 month[d]	
Enteroviruses	63–91 + days[e]	
Giardia lamblia cyst	1–2 months, up to 4[f]	
Leptospira interrogans	3–9 days[g]	
Pasteurella tularensis	1–6 months[g]	
Rotaviruses and reoviruses	30 days–1 + years[e]	
Salmonella faecalis	—	15–50 days[b]
Salmonella paratyphi	—	60–70 days[b]
Salmonella typhi	1 day–2 months[g]	8–23 days[b]
Salmonella typhimurium	—	140–275 days[b]
Shigella	1–24 months[g]	10–35 days[b]
Vibrio cholerae	5–16 days[g] 34 days at 4°C[g] 21 + days frozen[g] 21 days in seawater[d]	
Viruses (polio, hepatitis, entero)	—	16–140 days[b]
Enteroviruses[h]	38 days in extended aeration sludges at 5°C, pH 6–8; 17 days in oxidation ditch sludges at 5°C, pH 6–8	
Hepatitis *A*[i]	1 + years at 4°C in mineral water, 300 + days at room temperature	
Poliovirus[i]	1 + years at 4°C in mineral water, not detected at room temperature	

[a] Approximate. See also refs. 27–30.

[b] *Guidelines for Delineation of Wellhead Protection Areas*, Office of Ground-Water Protection, U.S. Environmental Protection Agency, Washington, DC, June 22, 1987, pp. 2–18. *Source:* Matthess et al., 1985.

[c] A. S. Benenson (Ed.), *Control of Communicable Diseases in Man*, 15th ed., American Public Health Association, Washington, DC, 1990, p. 113.

[d] B. K. Boutin, J. G. Bradshaw, and W. H. Stroup, "Heat Processing of Oysters Naturally Contaminated with *Vibrio cholerae*, Serotype 01," *J. Food Protection*, **45**(2), 169–171 (February 1982).

[e] G. Joyce and H. H. Weiser, *J. Am. Water Works Assoc*., April 1967, pp. 491–501 (at 26°C and 8°C).

[f] S. D. Lin, "*Giardia lamblia* and Water Supply," *J. Am Water Works Assoc*., February 1985, pp. 40–47.

[g] A. P. Miller, *Water and Man's Health*, U. S. Administration for International Development, Washington, DC, 1961, reprinted 1967.

[h] G. Berg et al., "Low-Temperature Stability of Viruses in Sludges," *Appl. Environ. Microbiol*., **54**, 839 (1988); *J. Water Pollut. Control Fed*., June 1989, p. 1104.

[i] E. Biziagos et al., "Long-Term Survival of Hepatitis A Virus and Poliovirus Type 1 in Mineral Water," *Appl. Environ. Microbiol*., **54**, 2705 (1988); *J. Water Pollut. Control Fed*., June 1989, p. 1104.

At Manteno State Hospital in Illinois, 453 cases of typhoid fever were reported, resulting in 60 deaths in 1939.[59] It was demonstrated by dye and salt tests that sewage from the leaking vitrified clay tile hospital sewer line passing within a few feet of the drilled well-water supply seeped into the well. The hospital water supply consisted of four wells drilled in creviced limestone. The state sanitary engineer had previously called the hospital administrator's attention to the dangerously close location of the well to the sewer and made several very strong recommendations over a period of eight years, but his warning went unheeded until after the outbreak. Indictment was brought against three officials, but only the director of the Department of Public Welfare was brought to trial. Although the county court found the director guilty of omission of duty, the Illinois Supreme Court later reversed the decision.

An explosive epidemic of infectious hepatitis in Delhi, India, started during the first week of December 1955 and lasted about six weeks. About 29,300 cases of jaundice had developed in a total population of 1,700,000 people. (The authorities estimated the total number of infections at 1,000,000.) No undue incidence of typhoid or dysentery occurred. Water was treated in a conventional rapid sand filtration plant; however, raw water may have contained as much as 50 percent sewage. Inadequate chlorination (combined chlorine), apathetic operation control, and poor administration apparently contributed to the cause of the outbreak, although the treated water was reported to be well clarified and bacteriologically satisfactory.[60]

Waterborne salmonellosis in the United States is usually confined to small water systems and private wells.[61] However, an outbreak of gastroenteritis in Riverside, California, in 1965 affected an estimated 18,000 persons in a population of 130,000. Epidemiologic investigation showed that all cases harbored *Salmonella typhimurium*, serological type B and phage type II, which was isolated from the deep-well groundwater supply. There was no evidence of coliform bacteria in the distribution system, although 5 of 75 water samples were found positive for *S. typhimurium*, type B, phage II. The cause was not found in spite of an extensive investigation.[62]

Of potential for causing protozoal infections in humans are the species *Entamoeba histolytica, Giardia lamblia, Cryptosporidium parvum* and *C. hominis, Cyclospora cayetanensis, Enterocytozoon bieneusi, Isopora belli* and *I. hominis*, and *Balantidium coli*.[63] *E. histolytica, G. lamblia, C. parvum* and *C. hominis*, and *C. cayetanensis* have all been implicated in diseases of the water route. The remaining organisms stated above are intestinal parasites so there is potential for their transmission by contaminated water. Nonetheless, present-day concerns center on three genera, namely *Giardia, Cryptosporidium*, and *Cyclospora*. Also of interest are the free-living amoebae, *Naegleria* spp., especially, *N. fowleri*, the etiologic agent of an explosive disease of the central nervous system termed primary *amebic meningoencephalitis (PAM)* and *Acanthamoeba* spp., which are also free-living amoebae and causative agents of *granulomatous amebic encephalitis (GAE)* and *acanthamoeba keratitis* (see Table 1.4).

In 1974 to 1975, a waterborne outbreak of giardiasis occurred in Rome, New York.[64] About 5,357 persons out of a population of 46,000 were affected. The source of water was an upland surface supply receiving only chlorine–ammonia treatment, which confirmed the inadequacy of such treatment to inactivate the Giardia cyst. The coliform history was generally satisfactory. Other early giardiasis outbreaks in the United States occurred in Grand County (1973, 1974, 1976)[65] and near Estes Park (1976)[65], Colorado; Camas, Washington (1976) [66,67]; Portland, Oregon(presumptive, 1954-55)[68]; Unita Mountains, Utah(1974)[69]; Berlin, New Hampshire (1976)[70]; and in areas of California and Pennsylvania.[71] Between 1969 and 1976 a total of 18 outbreaks with 6,198 cases were reported. An additional 5 outbreaks with approximately 1,000 cases were reported in 1977. There were 42 outbreaks reported with 19,728 cases between 1965 and 1980.[72] A total of more than 90 outbreaks occurred through 1984. Acceptable turbidity and coliform tests are important for routine water quality control, but they do not ensure the absence of *Giardia* or enteric viruses; complete water treatment is necessary.

The reporting of outbreaks of waterborne giardiasis has become more common in the United States, Canada, and other countries of the world. The source of the *G. lamblia* cyst is humans, and possibly the beaver, muskrat, and other wild and domestic animals, probably infected from our waste. The *Giardia* stool positive rate may range from 1 to 30 percent, depending on age and the indigenous level of personal hygiene and sanitation, with the higher rate in day care centers and institutions.[73] Infected individuals may shed 10^6 cysts per gram of stool for many years. The cyst is resistant to normal chlorination, similar to the cyst of *E. histolytica*. Conventional rapid sand filtration of surface water—including coagulation, flocculation, and sedimentation, slow sand filtration, and diatomaceous earth filtration followed by disinfection—is considered effective in removing the *Giardia* cyst.[74] Prolonged protected sedimentation and a filter press using special cellulose sheets (reverse osmosis) to remove 1-μm-size particles is also reported to be effective.[75] Pressure sand filtration is not reliable and should not be used, as the cyst penetrates the filter. Experimental results show that 2.5 mg/l (free) chlorine for 10 minutes killed all cysts at pH 6 at a water temperature of 60°F (15°C), but 60 minutes was required at pH 7 and 8, and 1.5 mg/l at 77°F (25°C) in 10 minutes at pH 6, 7, and 8; at 42°F (5°C), 2 mg/l killed or inactivated all cysts in 10 minutes at pH 7 and in 30 minutes at pH 8. [76] A total chlorine residual of 6.2 mg/l after 30 minutes at pH 7.9 and 37°F (3°C) also inactivated *G. lamblia*. A temperature of 131°F (55°C) will destroy the cyst, but boiling is advised.

Cryptosporidium parvum (Type 1) and *C. hominis*, are both infectious apicoplexan protozoan parasites of humans. The first human cases of the disease were reported in 1976. [77] Infection occurs by the ingestion of oocysts that have been excreted in the feces and the disease, cryptosporidiosis, is usually spread by the fecal-oral route, but has also been implicated as the cause of food- and waterborne illness.[78] The incubation period is in the range of 2 to 14 days.[78] It is still often overlooked or not identified, contributing to the problem of underreporting of the disease. However, new molecular and clinical diagnostic tests are in use. The organism is found in the fecal discharges of humans and many wild and domestic animals, including cattle, deer, muskrats, raccoons, foxes, squirrels, turkeys, pigs, goats, lambs, cats, and dogs and zoonotic transmission to humans has been documented. The oocyst, 3 to 6 μm in diameter, survives 18 months or longer at 39°F (4°C), however, inactivation can be exacted at 45°C (20 minutes), 64.2°C (5 minutes), 72.4°C (1 minute), and –20°C (3 days).

Conventional rapid sand filtration, including coagulation, should remove 90 to 100 percent of the *Cryptosporidium*. The oocysts may be inactivated in the presence of a free chlorine residual of 2 mg/l (two days) at 20°C; 2 mg/l (one day) at 30°C, and 10 mg/l (less than six hours) at either temperature under chlorine-demand free conditions.[79] Circumstances contributing to the resistance of oocysts to chlorine in real-world conditions include presence of chlorine-consuming organic matter, protection of oocysts by clumping, and protection of oocysts by adsorption to particulate matter. Other chemicals, such as hydrogen peroxide (6 to 7.5 percent) and ammonia (5 percent), can be effective. Ultraviolet irradiation presents the interesting effect of being able to curtail infective capability in oocysts irradiated at low dosage (99 percent at 1 mWs/cm^2 at 20°C), however, prevention of excystation required 230 mWs/cm^2 at 20°C.[80] Cyclosporiasis is a diarrheal disease with symptoms closely resembling cryptosporidiosis, including watery diarrhea without blood, which may last for an extended period of up to 40 days. Other symptoms are anorexia, nausea, vomiting, pronounced flatulence, stomach cramps, and abdominal bloating. The incubation period is similar to that of cryptosporidiosis. The causative agent is *Cyclospora cayetanensis*—an intestinal parasite with many of the characteristics of *Cryptosporidium* spp. and viewed as an emerging, opportunistic waterborne pathogen.

In this vein, increased numbers of immunocompromised people in the population since the AIDS epidemic appears to be a root to the upwelling of disease incidence by organisms such as *Cyclospora* sp. and the collection of intracellular parasites making up the Microsporididea.[81] The oocysts of *C. cayetanensis* are larger (8–10 μm in diameter and approximately the size of *Giardia* spp. cysts) than those of *Cryptosporidium* spp. However, this feature has not deterred much past misdiagnosis of diseases caused by the misinterpretation of *Cyclospora* sp. for *Cryptosporidium* spp. One important difference between the cycle of cryptosporidiosis and cyclosporiasis is that the latter is not transmitted person to person, owing to the need for oocysts of *Cyclospora* sp. to spend an extended amount of time outside the human host in order to sporulate; a condition essential for the oocysts to become infectious upon transfer to another human. Detection of *Cyclospora* sp. oocysts, which autofluoresce a bright blue by epifluorescence microscopy, involves laboratory techniques similar to those described for *Cryptosporidium* spp.[82] Inactivation of the oocysts of *Cyclospora* sp. is difficult. Organisms die quickly at –70°C; at –20° and –15°C, survival is one day and two days, respectively.

Information on the effect of chemical disinfectants on the oocysts of *Cyclospora* sp. is little known. On the one hand, there is the general belief that oxidants such as chlorine are ineffective, at least at the concentrations employed in water and wastewater treatment. On the other hand, disinfection combined with secondary wastewater treatment may be sufficient to remove *Cyclospora* sp.[83] At present, there is the tendency to infer that inactivation steps effective for containment of *Cryptosporidium* spp. ought to prevail with *Cyclospora* sp. Incidence of cyclosporiasis in the United States up to the present is rare, and, when suspected, is often without the presence of the tell-tale oocysts.

Legionnaires' disease is caused by *Legionella pneumophila*. Another form is Pontiac fever, which typically has a shorter incubation period and results in mild, influenzalike symptoms. The organism has been readily isolated from surface waters and adjacent soils. Other sources are cooling towers and evaporative condensers, hospital hot-water systems, whirlpools, showerheads, domestic hot-water tanks, hot- and cold-water distribution systems, humidifiers, and open water-storage tanks. The organism is primarily spread by aerosols and, to a much lesser extent, water ingestion. It is a major problem in hospitals. Person-to-person spread has not been documented.[84] A water temperature of 68° to 114°F (20° to 45°C) or 104° to 122°F (40°to 50°C)[85] appears to be most favorable for organism survival. The critical temperature is believed to be 97°F (36°C). The organism has been found in hot-water tanks maintained at 86° to 129°F (30° to 54°C) but not at 160° to 172°F (71° to 77°C).[86] The FDA recommends a minimum temperature of 166°F (75°C).

Suggested *Legionella* control measures include 1 to 2 ppm free residual chlorine at water outlets, including daily testing; maintenance of continuous chlorination and hot water temperature; annual cleaning and disinfection of the cold-water system.[87,88] Consensus data suggests that 140°F (60°C) is the minimal temperature for thermal disinfection of hot water plumbing systems and that this temperature should be used in flushing outlets, faucets, and shower heads for a period in excess of 30 minutes and maintained to prevent reestablishment of L. *pneumophila*.[89] It should be noted that scalding is a potential hazard at the recommended thermal inactivation temperature. It has been suggested that 4 to 6 mg/l residual chlorine, maintained in the facility for 6 hours, is sufficient for disinfection, however, this level of disinfectant is difficult to maintain in hot water and may cause problems with patients having transplant surgery.[90] In view of the different findings, laboratory monitoring of the water in the distribution system for *L. pneumophila* is also suggested.

Control and Prevention of Waterborne Diseases

Many health departments, particularly on a local level, are placing greater emphasis on water quality and food protection at food-processing establishments, catering places, schools, restaurants, institutions, and the home and on the training of food management and staff personnel. An educated and observant public, a systematic inspection program with established management responsibility, coupled with a selective water- and food-quality laboratory surveillance system and program evaluation, can help greatly in making health department food protection programs more effective. It is necessary to remain continually alert because waterborne diseases have not been eliminated and other diseases, previously considered not typically transmissible or thought to be transmissible by the water route, are being discovered.

In the general sense, Lashley[91] outlines preventive measures to be taken to control waterborne disease, including the safeguard of drinking water, recreational water, and more stringent actions for the protection of immunocompromised persons. Immunocompromised individuals should not rely on tap waters without additional home treatment such as boiling for one minute or treatment with certain filters. The CDC AIDS Hotline (1-800-342-2437) is available for additional information on this subject. Immunocompromised persons should be especially careful about exposure to fecal matter, young animals—which are more apt to be carriers of infectious disease organisms that are especially difficult (e.g., *Cryptosporidium* and *Cyclospora* agents)—and travel to countries with low-grade sanitation.

Prevention of Waterborne Diseases

A primary requisite for the prevention of waterborne disease at the community level is the ready availability of an adequate supply of water that is of satisfactory sanitary quality for meeting microbiological, chemical, physical, and radiological standards. The prevailing scheme in the water treatment industry for the establishment of a reliable water purification system is the multiple-barrier concept.[92] The multiple-barrier plan for the treatment of water is, in effect, a fail-safe program for ensuring the safety of the consumer of finished water, should a step in the overall process fail. The barriers thus proposed are (1) source water protection, (2) water treatment plant processes, (3) disinfection practices, (4) distribution systems, (5) security, and (6) education. Protection of source water deals with the selection and developing of the raw water supply and safeguarding the watershed from infiltration of pollution. Water treatment plant processes entails the appropriate and proper unit operations and the necessary measures to maintain plant functions. Disinfection practices assume the maintenance of an adequate disinfectant residual throughout the distribution system for destruction of pathogenic agents arising from the untreated source water and faults within the distribution system. The distribution system includes inspection and remediation of piping and inline storage facilities. Security involves the physical watch on the treatment system against the possibility of unlawful entry, with the intent to disrupt or compromise treatment operations and goal of producing quality water. Education embraces the training of water treatment personnel and informing public officials and the public at large of any emergency measures required, owing to interruptions in operations that may affect water quality and quantity. Publicly owned water companies are preferred because they usually provide water of satisfactory quality and quantity and are under competent supervision. It is important that the finished water be convenient, attractive, and palatable to inspire public confidence in the product and dissuade alternate choices of expensive bottled waters or the selection of some other source water, such as a nearby well or spring of doubtful quality. Although excellent water service, especially in municipalities, is generally available in the United States and in many developed areas of the world, consumers and public officials must not have tended to become complacent. Many of the older water treatment facilities have distribution systems in dire need of replacement. The American Society of Civil Engineers in 2001 acknowledged the need for replacement of aged facilities in 54,000 water treatment plants in the United States at a cost of $11 billion, not including the additional cost to meet new drinking water standards.[93] Compounding the problem is the shrinking availability of revenues within the tax structure of communities such that, in some instances, funds may have to be diverted from maintenance, operation, and upgrading of the water supply system in order to cover other expenses. It is also sometimes forgotten that in developing areas of the world, a convenient, safe, and adequate water supply, in addition to affording protection against waterborne diseases, makes possible good personal hygiene, including hand washing, sanitation, household cleanliness, and clean food preparation. In addition, it obviates the need to wade in schistosome-snail-infested streams to undertake the laborious and time-consuming task of transporting water (see the section "Schistosomiasis," later in this chapter). An interesting sidelight is the controversy that emerged over the construction of the Aswan High Dam in the early 1960s. A large impoundment was formed on the Nile River to serve both as a water supply and flood control. It had been argued that the dam lowered the downstream level of the Nile River and, combined with large-scale irrigation, brought increased incidence of schistosomiasis. This may not be the case. With the improved level of sanitation, clean water, and medical facilities, schistosomiasis has actually been reduced from over 40 percent in predam years to 10.7 percent in 1991.[94]

Adequate drinking water statutes and regulations and surveillance of public water supply systems are necessary for their regulatory control. This is usually a state responsibility, which may be shared with local health or environmental regulatory agencies. The EPA recommendations for a minimum state program include [95]:

1. A drinking-water statute should define the scope of state authority and responsibility with specific statutory regulations and compliance requirements. Regulations should be adopted for drinking-water quality standards; water-supply facility design and construction criteria; submission, review, and approval of preliminary engineering studies and detailed plans and specifications; approval of a water-supply source and treatment requirements; establishment of a well construction and pump installation code; operator certification; provision for state laboratory services; and cross-connection and plumbing control regulations.
2. The surveillance of public water-supply systems should involve water quality sampling—bacteriological, chemical, and radiological, also turbidity and residual chlorine; supervision of operation, maintenance, and use of approved state, utility, and private laboratory services; cross-connection control; and bottled and bulk water safety.

3. Surveillance and disease prevention are recommended with periodic, onsite fact finding as part of a comprehensive sanitary survey of each public water-supply system, from the source to the consumer's tap, made by a qualified person to evaluate the ability of the water supply system to *continuously* produce an adequate supply of water of satisfactory sanitary quality. The qualified person may be a professionally trained public health, sanitary, or environmental engineer, or a sanitarian, to make sanitary surveys of the less complex water systems such as well-water supplies. The EPA suggests that the sanitary survey, as a minimum, cover quality and quantity of the source; protection of the source (including the watershed and wellhead drainage area); adequacy of the treatment facilities; adequacy of operation and operator certification; distribution storage; distribution system pressure; chlorine residual in the distribution system; water quality control tests and records; cross-connection control; and plans to supply water in an emergency. The WHO has similar suggestions.[96]

Details concerning water supply quality and quantity, source protection, design, and treatment are given in Chapters 1 and 2 of the water and wastewater volume *of Environmental Engineering*, *Sixth* Edition (Wiley, 2009).

Schistosomiasis

Schistosomiasis is a largely endemic disease in parts of Africa but also occurs in areas of Asia and South America. If known preventive precautions are not taken, the global prevalence of schistosomiasis, spread by freshwater snails and estimated at 300 million or more cases, is expected to increase as new impoundments and irrigation canal systems are built. Cooperation in the planning through the construction phases in endemic areas, or potentially endemic areas, between the health and water resources agencies can help reverse this trend. Water contact through swimming, wading, laundering, bathing, and collecting infested water and poor sanitation and hygiene are the major causes for the persistence and spread of schistosomiasis. Individuals who have or had schistosomiasis (bilharziasis) are more likely to have a urinary infection. Long-term schistosomiasis control would involve an appropriate combination of chemotherapy; mollusciciding; basic sanitation, including biological intervention and the supply of potable water at the village level; and socioeconomic development.[97] Mollusciciding is impractical where the water is used as a direct source of drinking water or where the water body and its tributaries are inaccessible or beyond control. In such cases, chemotherapy is considered the most cost-effective control *when* coupled with safe drinking water and sanitation facilities to minimize indiscriminate urination and defecation. In any case, education to prevent reinfection is necessary.[98,99] Heating water to 122°F (50°C) for 5 minutes or treating with chlorine or iodine as in drinking water and filtration through tightly woven cloth or paper (coffee) filter will remove the cercaria. Settling water for 3 days is also effective, as cercaria survives only 48 hours, but reinfestation must be prevented.

BIOTERRORISM

Bioterrorism is a disruptive and health-threating event directed at an individual, group of individuals, a community, or at-large population within a nation and is facilitated by the intentional release of a highly virulent biological agent. In this context, the term *biological agent* includes a microorganism or a biologically synthesized toxin that causes disease in man, plants, or animals or causes deteoriation of materials.[100] The use of pathogenic elements to subvert and disrupt the normal life style of innocent people has a long history.[101] As far back as the fourth century, Scythian warriors coated the tips of their arrows with human feces as a means of infecting their enemies. This is testimony to the very early suspicions about the noxious properties of excreta. In 1346, the Mongols used catapults to hurl the corpses of their dead soldiers, riddled with plague, over the walls in Kaffa, currently Theodosia. The practice of spreading infectious disease by exposure to the dead continued in the siege of the Bohemian castle at Karlstein in 1422 and the attack of the Swedes by Russians in 1710, whereupon corpses were catapulted over the city walls of Reval (Tallinn).

The selection of an agent to be used in an act of terrorism should satisfy the following properties: (1) be readily available, (2) be easy to produce on large scale, (3) be highly virulent for lethal or incapacitation purposes, (4) be of appropriate size for distribution by aerosolization and uptake by victims (penetrate defense mechanisms of the upper respiratory tract), (5) be easy to disseminate by available means, (6) be environmentally stable, and (7) be dispersible in a way that targeted individuals, but not the terrorists, suffer intended effects.[102] A list of candidate biological agents and biologically produced toxins for application in bioterroristic attacks is given in Table 1.7. The categories mainly reflect high level of priority for prepardness (category A), need for improved awareness, surveillance measures, and laboratory diagnosis (category B), and need for continued review of potential threat to the public (category C). Many of the typical vehicles and vectors of infectious disease transmission may be deployed in acts of terrorism. Several of the prominent bacterial agents high on the list of potential bioweapons are the cause of zoonotic infections.

An interesting approach has been made to quantitatively evaluate the usefulness of a biological agent as a weapon of bioterror by calculation of the agent's weapon potential (WP):

$$WP = [V_{\mathrm{BW}}SC/T] \times XD$$

where: V_{BW} = virulence of a bioweapons derived from F_{SI}/I where F_{SI} is the fraction of symptomatic infections for a given inoculum, I.

S = stability of biological agent when released

C = communicability by host to host transfer

T = time

X = terror modifier based on judgment that the agent could cause panic and social disruption

TABLE 1.7 Biological Agents Categorized According to Level of Concern as Threats to Human Welfare.

Biologic Agent	Disease(s)
Category A Agents	
Variola virus	Smallpox
Bacillus anthracis	Anthrax
Yersinia pestis	Plague
Clostridium botulinum toxin	Botulism
Francisella tularensis	Tularemia
Ebola virus	Ebola hemorrhagic fever
Marburg virus	Marburg hemorrhagic fever
Lassa virus	Lassa fever
Junin virus	Argentine hemorrhagic fever
Other arenaviruses	
Category B Agents	
Coxiella burnetti	Q fever
Brucella species	Brucellosis
Burkholderia mallei	Glanders
Venezuelan equine encephalitis virus	Venezuelan encephalomyelitis
Eastern equine encephalitis virus	Eastern equine encephalomyelitis
Western equine encephalitis virus	Western equine encephalomyelitis
Others include:	
Ricin toxin from *Ricinus communis*	*Salmonella* species
Epsilon toxin of *Clostridium perfringens*	*Shigella dysenteriae*
	Escherichia coli O157:H7
Staphylococcus enterotoxin B	*Vibrio cholerae*
	Cryptosporidium parvum (now *hominis*)
Category C Agents • Nipah virus • Hantaviruses • Tickborne hemorrhagic fever viruses • Tickborne encephalitis viruses • Yellow fever • Multidrug-resistant tuberculosis	

Source: Centers for Disease Control and Prevention, 2000a, pp. 5–6.
M. Cohen, "Bioterrorism in the Context of Infectious Diseases," in F. R. Lashley and J. D. Durham (Eds.), *Emerging Infectious Diseases—Trends and Issues*, Springer Publishing Company, New York, 2007, pp. 415–442

$D =$ deliverability of the agent that is a function of technical capabilities of the user and biological characteristics of the agent

Currently, availability of essential data and the necessity to make assumptions for terms in the equation limit the applicability of the equation for its intended purpose.[103]

Natural pathogens and even normally nonpathogenic agents, earmarked as potential terror weapons, may be genetically altered to improve virulence, nullify protection of the individuals that may have been immunized against terror agent, resist chemotherapy (antibiotic or antiviral treatments) applied to attack victims, and, possibly, alter the bodily regulatory functions of victims.[103]

Following the attacks in New York and Washington on September 11, 2001, letters containing *Bacillus anthracis* (anthrax) spores were mailed to various locations in the United States. This led to 11 inhalation and 7 cutaneous cases of anthrax, resulting in the death of 5 individuals due to inhalation anthrax. DNA sequencing of the anthrax DNA has led to the conclusion that the origin of the infectious material contained in the letters was a U.S. military laboratory.As such, the possibility existed that an employee of the laboratory was involved and that the laboratory harboring anthrax was in violation of the Biologic and Toxin Weapons Convention.[104] It remains to be determined whether these terrorist attacks were related and to identify the perpetrators. As of early 2008, 9,100 persons were interviewed and the Department of Justice had not named any suspects.[105] More recently, four suspects were placed under watch by the FBI, and the source of the anthrax used in the letters of 2001 was narrowed to the U.S. Army's biological weapons research facility at Ft. Detrik, Maryland. On August 6, 2008, it was concluded by the Justice Department, based on documents provided by federal investigators, that a mentally disturbed microbiologist employed at the U.S. Army biological weapons laboratory and who committed suicide one week earlier, acted alone in the 2001 anthrax letter attacks.

Critical microbiological agents in the United States are endemic but of low incidence in disease manifestation, and each new case reported should serve as an alert for investigation, especially in areas were the disease is nonendemic.[106] Several of the major agents will be briefly discussed next. Due to the significant pathogenicity of each of these agents, individuals seeking to employ their use, especially in large amounts, would require substantial knowledge, expertise, and laboratory equipment as well as protection against accidental exposure (e.g., vaccination or antibiotics).

Smallpox

Smallpox, a disease that has killed approximately 300 million people worldwide in the twentieth century alone, and is now globally nonexistent, may have been one of the first microbial agents to be used as a weapon. During the 1800s, North American Indians were deliberately given blankets contaminated with the virus[107] by European settlers. Smallpox virus comprises two strains: variola major, a highly virulent form that produces a high mortality among cases of the disease and variola minor, which causes a milder form of the disease resulting in under 1 percent fatalities among cases. The only remaining stocks of the variola virus are currently being held in secure locations in the United States and Russia. The WHO voted to postpone a decision on the remaining variola stocks until 2002, raising the possibility of their misappropriation and use as weapons.[108] The scientific community has requested that the available virus stocks be maintained and no further action on the part of WHO has been taken. Some have questioned the grounds for maintaining smallpox stocks. The likelihood of a rebirth of a vaccination program is minimal leading to the conviction that the only purpose the stocks could serve is for bioweapons research. This raises the question of accidental release, improper disposal of hazardous materials, and laboratory mishandling.[104] Variola virus satisfies a number of the prerequisites for an ideal bioterror agent. Since immunization against smallpox was halted in 1976, following a successful worldwide eradication program that saw the last known case of smallpox in 1977, a significant number of the U.S. population would be at risk from a bioterrorism attack. Although individuals vaccinated prior to 1976 may retain immunity to smallpox, the level of protection is currently unknown. Smallpox is generally fatal in about 30 percent of infections of unvaccinated individuals.[109]

Given these uncertainties and the significant health risk of smallpox, the United States and other countries are currently increasing the production of smallpox vaccine. In the wake of concerns for the deployment of variola virus in a bioterror attack, The Advisory Committee on Immunization Practices formulated an interim smallpox release plan, guidelines and a revision of vaccine recommendations in 2001 and reiterated recommendations in 2003.[102] However, approximately 1 in 1 million people exhibit serious and potentially fatal complications following vaccination. Thus, if the entire U.S. population were to be vaccinated, we might expect 100 to 300 deaths from the vaccine. To avoid this situation, one strategy that is being considered for a bioterrorism attack is to limit vaccination to individuals who have come in contact with the initial (index case) infected individual. Vaccination and training of primary health care workers and physicians who are most likely to see the first cases in an attack will also be an important aspect for countering the use of viruses and bacteria as weapons.

Anthrax

Anthrax is a zoonotic disease caused by *Bacillus anthracis*, the facultatively anaerobic, gram positive, nonmotile, endospore-forming bacillus isolated by Robert Koch in 1877 and used by Koch to demonstrate for the first time the relationship between an infectious agent and the etiology of disease. Many domestic and wild animal species have been demonstrated to harbor the anthrax bacillus. Three forms of the disease may be expressed and each is related to the points of entry of the bacterial spores into the body: cutaneous, gastrointestinal, and pulmonary.[102] Cutaneous anthrax in humans occurs through handling of infected animal meat or hides. Anthrax spores gain entry through skin abrasions or cuts. In fact, the term *anthrax* derives from the Greek word for "coal" and reflects the blackened nature of advanced skin lesions produced by infected individuals. It is far less fatal (under 1 percent) than the gastrointestinal and pulmonary form, which may exceed 50 percent. Gastrointestinal anthrax results from the ingestion of spores and if the disease reaches the septicemia stage, fatality rates are as high as 90 percent. Pulmonary anthrax, while normally rare, poses the greatest risk to humans that have inhaled the spores. Initiating the disease requires a high infectious dose, however, the incubation period is short (on the order of two days) followed by rapidly progressing symptoms culminating in cardiovascular arrest. Fortunately, *B. anthracis* responds readily to antibiotic therapy, most notably, penicillin. Antibiotics such as amoxicillin, ciprofloxacin, and doxycycline are effective against the inhalation form of anthrax; however, they must be administered prior to spore germination, which can occur within 48 to 72 hours following exposure and must be continued for several months.

The level of naturally occurring, human anthrax in the United States is nearly nil, having fallen steadily from about 130 cases in 1920. The last reported incidence of naturally occurring anthrax was a cutaneous case in 1989; however, in 2006, a pulmonary case developed in New York City.

As already noted, anthrax poses a major concern for use in bioterrorism. The endospore stage of the organism confers longevity for the organisms in the environment and represents an advantage to its use as a bioweapon. In fact, it is believed that during World War I, Germany intentionally infected sheep to be shipped to Russia for the purpose of infecting the Russian military. Gastrointestinal anthrax has been reported in the former Soviet Union, but never in the United States. Inhalation of anthrax spores, resulting in the full-blown pulmonary disease, is highly fatal when untreated—and sometimes even with treatment. Of the 18 cases of pulmonary anthrax recorded in the United States for the entire twentieth century, greater than 75 percent of them were fatal. The anthrax bacillus synthesizes four major virulence factors: a antiphagocytic polysaccharide capsule and three separate proteins (exotoxins) that act to induce an endema in the infected localities of the body and cause macrophages to elicit tumor necrosis factor and interleukin 1, which promotes sudden death in the pulmonary disease. An anthrax vaccine is available and is generally effective, although it is currently in limited supply (and mostly dedicated to military rather than civilian use). It has also been observed to cause side effects. Animal vaccines are available, also, however, disease incidence in herds has been so meager that farmers are reluctant to have their animals vaccinated.

It will be important to be able to rapidly monitor and analyze the genetic properties of different anthrax strains and to develop new antibiotics. Another promising avenue stems from the recent identification of the receptor for anthrax lethal factor toxin[110] as well as high-resolution structural determination of lethal factor[111] and edema factor.[112] These molecules represent potential targets for rational drug design of new antibacterial compounds to combat this disease.

Plague

The etiologic agent of plague is the gram negative, facultatively anaerobic, non-motile, coccobacillus, *Yersinia pestis*. Plague is a vectorborne disease that manifests itself in three clinical forms; bubonic, septicemic, and pneumonic. Bubonic plague has the greatest notoriety, having been the cause of great historic pandemics, such as the sixth-century pandemic that killed 100 million people and the fourteenth-century "Black Death" pandemic that claimed 40 million people.[113,102] The bubonic form of plague has a 75 percent fatality rate. No bacterial disease in history has been more devastating. *Y. pestis* is a zoonotic pathogen, and the reservoirs of *Y. pestis* are various rodents. Infected rodents transmit the pathogen to other animals, most notably domestic rats, through the bite of fleas. Domestic rats are susceptible to the plague and will die. In areas of poor sanitation and living conditions, as characterized much of Europe and Asia in the Dark and Middle Ages, domestic rat populations abounded among human squalor. As domestic rat populations dwindled, owing to loss of members to the plague, fleas carrying *Y. pestis* infected humans. The flea carries a high density of *Y. pestis* following a blood meal on an infected rat and can deposit the bacteria at the site of a human bite, both by regurgitation and fecal deposition.

The term *bubonic* comes from the word "bubo," which refers to the enlarged nodule that forms as a result of *Y. pestis* growth in lymph nodes. The human (host) defense system, through the action of polymorphonuclear leucocytes and macrophages, attack the infectious bacteria. Bacteria phagocytized by macrophages produce toxins that spare them from enzymatic destruction. Other bacteria (e.g., *Legionella pneumophila*) have similar defense strategies. The bacteria contained in the macrophages survive and grow and are delivered to lymph nodes and various organs of the body by the macrophages in the bloodstream. The hemorrhaging (gangrene) that occurs beneath the skin over various parts of the body appears dark—hence the term *Black Death* (recall a similar visible effect to the lesions developed in anthrax infections). More fatal than the bubonic form of plague is pneumonic plague; a manifestation of the disease caused by the migration of the infectious bacteria to the lungs. Untreated pneumonic plague is 100 percent fatal. Septicemic plague, which results either upon inoculation of the bacteria directly into the blood stream or as secondary complications from bubonic or pneumonic forms, progresses from the multiplication of the infectious bacteria in the bloodstream and is essentially always fatal.

As a bioweapon, it is likely that an attack would involve dissemination of the infectious bacteria in aerosol form. The respiratory consequences of inhalation would be expressed as pneumonic plague, which is the most contagious form of plague. *Assuming* the availability of swift medical attention and effective hospital care, the fatality rate from such an attack might be held to 25 percent of the infected portion of the population. First indications of an attack would be a burst in incidence of the disease, especially in places free of animal reservoirs such as a metropolitan area. The incubation period of the disease would be short, likely in the range of two to four days. Despite the high fatality rate and contagious nature of *Y. pestis*, the organism has a relatively short-lived existence in the free state, disfavoring its use as a terror agent for causing widespread panic.

Tularemia

Like *Y. pestis*, the etiologic agent of tularemia, *Franciscella tularensis*, is a gram negative, nonendospore-forming, coccobacillus. It is a strict aerobe and nonmotile, having many natural arthropod and animal reservoirs and not limited to a particular group of related species. Transmission of the infectious bacterium may occur by several routes:

- Insect bite
- Contaminated aerosols
- Contact with infected animal carcasses, hides, or fluids
- Contaminated water, food, or soil

It is not contagious; person-to-person transmission has not been demonstrated. Virulence of the organism varies among the subspecies, and type A, the North American variety, is the most virulent. There are six clinical manifestations of the disease, of which three are described here: ulceroglandular, pneumonic, and typhoidal. Ulceroglandular infection results from the bite of an insect, often a tick, or a scratch from an animal. The infectious bacteria initiate ulcer formation at the point of entry to the body and in various organs accessed through travel in the bloodstream. The pneumonic form of the disease results from inhalation of the infectious bacteria during handling of infected animals. Advanced symptoms include fatigue, malaise, atypical pneumonia signs, and, possibly respiratory failure. Pneumonic tularemia can develop in any of the other forms of tularemia. Typhoidal tularemia results from ingestion of the infectious bacteria and the symptoms resemble gastroenteritis-type diseases (i.e., vomiting, diarrhea, and abdominal pain). Typhoidal tularemia usually follows in pneumonic cases and is the most fatal form of the disease, with fatality rates as high as 35 percent in untreated cases.

The attractiveness of *F. tularensis* as a bioterror agent is its high rate of infectivity, high virulence, low infectious dose (25 to 50 percent rate of infection in exposed individuals when 10 organisms are presented by the respiratory route), and ease of dissemination by aerosolization. Incubation periods vary from 3 to 15 days, however, clinical symptoms typically appear in 3 to 5 days. There is ample evidence of the interest in *F. tularensis* as a bioweapon, having been studied by both the Japanese and United States during World War II and the Soviet Union into the 1990s.[29]

Glanders

Glanders is a disease occurring mostly in horses and rarely encountered in the United States. The disease in humans is very rare; however, one case was reported in the United States in 2000. The etioloigic agent of the disease is *Burkholderia mallei*, a gram negative, strictly aerobic, nonmotile bacillus, previously assigned to the Genus *Pseudomonas*. Several *Burkholderia* species are responsible for respiratory-type diseases including melioidosis (see Table 1.4). Glanders infection can be by the cutaneous (skin lesion), inhalation (upper respiratory and pulmonary), or bloodstream (septicemic) routes. Cutaneous infection produces swelling and sores at the site of inoculation within 1 to 5 days. Upper pulmonary invasion induces such symptoms as development of mucus and discharges from the nose and eyes. Pulmonary infection affects the lungs and the symptoms are edema, abscesses, and pneumonia. The incubation period is 10 to 14 days. Septicemia results in fevers, chills, sweating, chest pain, diarrhea, and fatigue, culminating in death within 7 to 10 days. Fatality rates as high as 95 percent occur in untreated events. Therapeutic measures are not well developed, owing to inexperience with the disease, but some recommendations on antibiotic therapy have been made. Several antibiotics are effective against the organism in vitro. Transmission by person to person is rare; however, there are documented cases of sexual transmission. Susceptible animals contract the disease through contaminated water.

Aerosolization of the bacterium is the anticipated form of bioweaponry. The glanders organism was deployed successfully by the Germans in World War I to infect enemy horses and mules. The Japanese intentionally infected both horses and humans in China during World War II.[114,115]

Botulism

The disease derives mainly from ingestion of foods containing an extremely potent neurotoxin produced by the strictly anaerobic, gram positive, endospore-forming, bacillus *Clostridium botulinum*. Spores of *C. botulinum* may gain entry to the body through wounds, ingestion, and inhalation. In these cases, neurotoxin formation would occur *in vivo* during and following spore germination. Intestinal botulism occurs in infants and adults. Inhalation is the mode of infection by intentionally dispersed, aerosolized spores, and by the snorting of spore-containing cocaine. Several forms of the toxin exist, assigned class A status by the CDC. The toxin consists of light (some number of peptides) and heavy (large quantity of proteins) chains. The mode of action of the botulinum toxin begins with the attachment of the heavy toxin chain to axon terminals. Briefly, toxin gains access to the neuron and the light chain penetrates synaptic cells. Through proteolytic action on a protein required for release of acetylcholine, muscle contraction is inhibited. Clinical manifestations of botulism may initially involve interruption in bowel functions, blurred vision, and dry mouth proceeding in advanced stages to paralysis of voluntary muscles, including those controlling the diaphragm. Respiratory arrest follows.

The lethal dose of the toxin to a 150-pound adult human being is approximately 0.15 μg, which explains its appeal as a bioweapon. It is deliverable in particulate form. Botulinum toxin is very unstable, however. In fact, several bacterial toxins are labile and would be short-lived upon release to the natural environment. Hence, if selected to inflict intentional harm to humans, the preferred delivery vehicle would be food rather than water. Although use of the toxin intentionally on mass scale is rare, such attempts by the cult Aum Shinrikyo took place in Tokyo, Japan, and at U.S. military sites in 1990 and 1995. Fortunately, the group lacked microbiological and technological expertise to deliver the bioweapon successfully.[116]

Tetanus or Lockjaw

This disease develops upon contamination of a wound or burn with soil, street dust, or animal excreta containing endospores of the bacterium, *Clostridium tetani*. Morphological characteristics of the organism are essentially similar to those of *C. botulinum*. The bacillus lives in the intestines of domestic animals. Gardens that are fertilized with manure, barnyards, farm equipment, and pastures are particular sources of danger owing to presence of endospores. The tetanus toxins are tetanolysin and tetanospasmin; the latter a neurotoxin and the known active participant in the pathology of the disease. The toxin is slightly less potent than botulinum toxin, requiring about 0.175 μg to be fatal to a 150-pound adult, but is still a powerful inhibitor of the nervous system. Fatality rates in the United States range from 18 to 25 percent; however, in lands where treatment is less effective, fatality can be 50 percent. There is a tetanus antitoxin that can be used after infection, however, preventative vaccination is much more effective. Older adults (over 50) especially should be revaccinated against tetanus.

Tetanospamin is taken up at the nerve axon, as in the case of botulinum toxin, but is delivered across the synapses to points directly on the central nervous system, as opposed to peripheral regions in the case of botulinum toxin. The effect of the toxin is to interfere with the release of neurotransmitters resulting in muscle contractions and spasms. The incubation period is 1 to 3 weeks.

In summary, use of pathogens as weapons is no longer theoretical. Strategies to counteract their use and defend against their presence are currently in place or under discussion. Research involving the synthesis of a reporter protein for use in a toxin detection system is underway at the Lawrence Livermore National Laboratories in California. Continued efforts in this arena will likely stimulate the development of improved treatments for many known and little understood infectious diseases that will likely plague mankind for the foreseeable future.

NONINFECTIOUS AND NONCOMMUNICABLE DISEASES AND CONDITIONS ASSOCIATED WITH THE WATER ENVIRONMENT

Background

The terms *noncommunicable* and *noninfectious* are used interchangeably. The noncommunicable diseases are the major causes of death in developed areas of the world, whereas the communicable diseases are the major causes of death in the developing areas of the world. The major noncommunicable disease deaths in the United States in 1988 were due to diseases of the heart, malignant neoplasms, cerebrovascular diseases, accidents, atheriosclerosis, diabetes mellitus, and chronic liver disease and cirrhosis (accounting for 73 percent of all deaths). An analysis of mortality due to noncommunicable diseases in five subregions of the Americas in 1980 showed 75 percent of the total mortality attributed to noncommunicable diseases in North America (United States and Canada); 60 percent in Temperate South American countries (Argentina, Chile, and Uruguay); 57 percent in the Caribbean area (including Cuba, the Dominican Republic, and Haiti); 45 percent in Tropical South America (including the Andean countries, Brazil, French Guiana, Guyana, Paraguay, and Suriname); and 28 percent in Continental Middle America (Central America, Mexico, and Panama).[117] The mortality can be expected to shift more to noncommunicable causes in the developing countries as social and economic conditions improve and communicable diseases are brought under control. Major diseases of developing countries are gastrointestinal, schistosomiasis, malaria, trachoma, and malnutrition.

Treatment of the environment supplements treatment of the individual but requires more effort and knowledge. The total environment is *the most important determinant of health*. A review of more than 10 years of research conducted in Buffalo, New York, showed that the overall death rate for people living in heavily polluted areas was twice as high, and the death rates for tuberculosis and stomach cancer three times as high, as the rates in less polluted areas.[118] Rene Dubos points out that "many of man's medical problems have their origin in the biological and mental adaptive responses that allowed him earlier in life to cope with environmental threats. All too often, the wisdom of the body is a shortsighted wisdom."[119]

Whereas microbiological causes of most communicable diseases are known and are under control or being brought under control in many parts of the world (with some possible exceptions such as malaria and schistosomiasis), the physiologic and toxicologic effects on human health of the presence or absence of certain chemicals in air, water, and food in trace amounts have not yet been clearly demonstrated. The cumulative body burden of all deleterious substances, especially organic and inorganic chemicals, gaining access to the body must be examined both individually and in combination. The synergistic, additive, and neutralizing effects must be learned in order that the most effective preventive measures may be applied. As noted earlier, chemicals contributed to 12 percent of drinking water outbreaks during the period 1971 to 2002, which is greater than the fraction attributed to viruses.[18] Some elements, such as fluorine for the control of tooth decay, iodine to control goiter, and iron to control iron deficiency anemia, have been recognized as being beneficial in proper amounts. But the action of trace amounts ingested individually and in combination of the pollutants shown in Figure 1.3 and other inorganic and organic chemicals is often insidious. Their probable carcinogenic, mutagenic, and teratogenic effects are extended in time, perhaps for 10, 20, or 30 years, to the point where direct causal relationships with

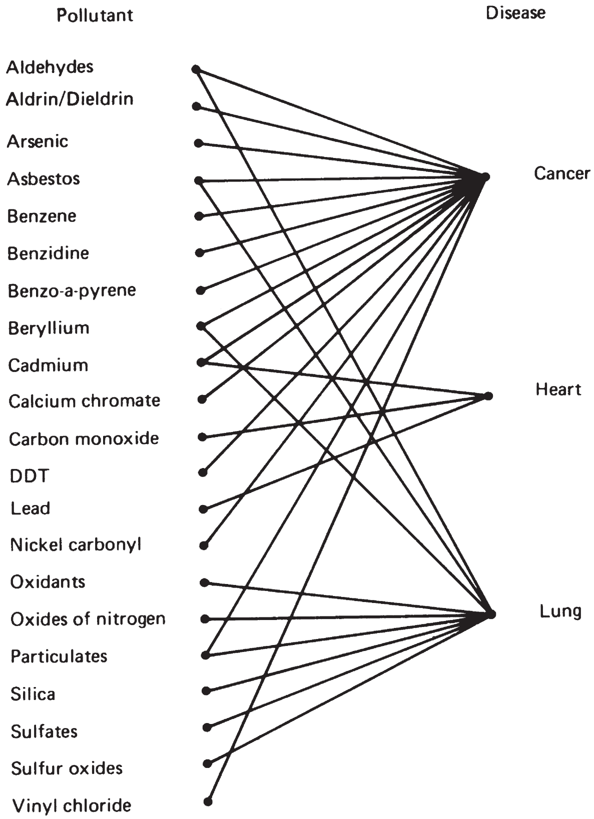


FIGURE 1.3 Known or suspected links between selected pollutants and disease. (*Source*: First Annual Report by the Task Force on Environmental Cancer and Heart and Lung Disease, Printing Management Office, U.S. Environmental Protection Agency, Washington, DC, August 7, 1978.)

morbidity and mortality are difficult, if not impossible, to conclusively prove in view of the many possible intervening and confusing factors.

There are an estimated 2 million recognized chemical compounds and more than 60,000 chemical substances in past or present commercial uses. Approximately 600 to 700 new chemicals are introduced each year, but only about 15,000 have been animal tested with published reports. Limited trained personnel and laboratory facilities for carcinogenesis testing in the United States by government and industry will permit testing of no more than 500 chemicals per year. Each animal experiment requires 3 to 6 years and a cost of more than $300,000.[120] Another estimate is $500,000 just to establish the carcinogenicity of one compound with the National Cancer Institute test protocol, requiring at least two species of rodents and 3 years' time.[121] A full toxicologic test, including those for carcinogenicity, can take five years and cost in excess of $1.25 million for each compound. The chemicals are viewed by Harmison[122] as falling into four groups: (1) halogenated hydrocarbons and other organics, (2) heavy metals, (3) nonmetallic inorganics, and (4) biological contaminants, animal and human drugs, and food additives.

In group 1 may be polychlorinated biphenyls (PCBs); chlorinated organic pesticides such as DDT, Kepone, Mirex, and endrin; polybrominated biphenyls (PBBs); fluorocarbons; chloroform; and vinyl chloride. These chemicals are persistent, often bioaccumulate in food organisms, and may in small quantities cause cancer, nervous disorders, kidney and brain damage, and toxic reactions. A recently recognized undesirable role for pharmaceuticals, herbicides, and pesticides in natural waterways is as endocrine disruptors.[123] The extraordinary production and use of these compounds, coupled with their persistence through wastewater treatment processes, has resulted in long residence times of such materials in the environment. Aquatic life have been impacted through the ability of endocrine disruptor-active compounds to mimic hormonal control of reproductive systems, organ development, and sensory functions. There is concern that contaminants falling into the category of endocrine disruptors may exist in finished drinking waters. The route by which herbicides and pesticides may gain entry to natural waters is through agricultural runoff. PCBs are no longer manufactured, but their residues are still present in aquatic sediments and the tissues of aquatic vertebrates and invertebrates. Other chlorinated compounds may appear in soils and waters from leaking storage drums, uncontained industrial lagoons, and accidental landfill leachates.

Another group of nine chlorinated compounds that may appear in drinking water as a consequence of the use of chlorine as a post water treatment disinfectant is the haloacetic acids or disinfection byproducts (DBP). Trihalomethanes are a subset of the haloacetic acids that are regarded as the major carcinogens among DBP in relation to colon and rectal cancers[124] and reproductive disorders including spontaneous abortions, fetal deaths, miscarriages, and birth defects.[119] Precursors to the formation of DBP are naturally occurring organic molecules present in raw water supplies. Unlike the plethora of organic substances referred to in the AP report, DBP are regulated in the drinking water standards. However, only five of the nine DPB compounds are monitored.

Group 2 includes heavy metals such as lead, mercury, cadmium, barium, nickel, vanadium, selenium, beryllium. These metals do not degrade; they are very toxic and may build up in exposed vegetation, animals, fish, and shellfish. Some of them (e.g., lead, mercury, cadmium, and beryllium) have no role in human metabolism and are inhibitors of enzymes at very low concentrations. As poisons, they can affect the functions of various organs (e.g., kidney, liver, brain) and damage the central nervous system, cardiovascular system, and gastrointestinal tract. Children and pregnant women are especially vulnerable. The levels of heavy metals in drinking water are highly regulated. Heavy metals variably appear in many manufactured products, including metal goods and electronic devices, as well as naturally occurring minerals and coal deposits. Hence, there is ample opportunity for contamination of natural waters through runoff from insecure toxic waste containment sites, improper disposal and storage, and anthropogenic discharges such as power plant emissions.

Group 3 represents nonmetallic inorganics such as arsenic (metalloid) and asbestos, which are carcinogens.

Group 4 includes biological contaminants such as aflatoxins and pathogenic microorganisms; animal and human drugs such as diethylstilbestrol (DES) and other synthetic hormones; and food additives such as red dye No. 2. An Associated Press report released March 9, 2008 (available at http://www.metrowestdailynews.com/homepage/x1574803402), outlined the appearance of antibiotics, hormonal preparations, personal care chemicals, antidepressants, cholesterol control and cardiovascular medications, and pain relievers in ultra-small concentrations (ppb and ppt) in drinking-water samples from 24 of 28 metropolitan areas of the United States. All of these chemical substances are undetectable by the human senses.

Evaluation of the toxicity of existing and new chemicals on workers, users, and the environment and their release for use represent a monumental task, as already noted. Monitoring the total effect of a chemical pollutant on humans requires environmental monitoring and medical surveillance to determine exposure and the amount absorbed by the body. The sophisticated analytical equipment available can detect chemical contaminants in the parts-per-billion or parts-per-trillion range. Mere detection does not mean that the chemical substance is automatically toxic or hazardous. But detection does alert the observer to trends and the possible need for preventive measures. Short-term testing of chemicals, such as the microbial Ames test, is valuable to screen inexpensively for carcinogens and mutagens. The Ames test determines the mutagenic potential of a chemical based on the mutation rate of bacteria that are exposed to the chemical. However, positive results suggest the need for further testing, and negative results do not establish the safety of the agent. Other tests use mammalian cell cultures and cell transformation to determine mutagenicity.

Prevention and Control

Prevention of the major causes of death, such as diseases of the heart, malignant neoplasms, cerebrovascular disease, accidents, and other noninfectious chronic and degenerative diseases, should now receive high priority. Prevention calls for control of the source, mode of transmission, and/or susceptibles as appropriate and as noted in Figure 1.1.

The prevention and control of environmental pollutants generally involves the following three procedures:

1. *Eliminate or control of the pollutant at the source*. Minimize or prevent production and sale; substitute nontoxic or less toxic chemical; materials and process control and changes; recover and reuse; waste treatment, separation, concentration, incineration, detoxification, and neutralization.
2. *Intercept the travel or transmission of the pollutant*. Control air and water pollution and prevent leachate travel.

3. *Protect humans by eliminating or minimizing the effects of the pollutant*. This affects water treatment, air conditioning, land-use planning, and occupational protection.

At the same time, the air, sources of drinking water, food, aquatic plants, fish and other wildlife, surface runoff, leachates, precipitation, surface waters, and humans should be monitored. This should be done for potentially toxic and deleterious chemicals, as indicated by specific situations. Table 1.4 also lists characteristics of noninfectious diseases due to the ingestion of poisonous plants and animals and chemical poisons in contaminated water or food.

INVESTIGATION OF A WATER DISEASE OUTBREAK

General

The successful outcome in the investigation of any disease outbreak, no matter the source, depends on expedient execution of a preplanned process. Extensive investigations are economically burdensome to all parties involved, and the target of the study (e.g., a municipal water supply) in the end is faced with a public-relations problem in winning back the confidence of the community concerning the safety of the drinking water.

Hunter[125] delineated a nine-step "cradle to grave" program for the conduct of a waterborne outbreak study (Figure 1.4).

Each of the steps in the chronology of an investigation is elaborated on in the following sections. Although investigation of a waterborne incident is described here, the steps put forth would be applicable to a foodborne outbreak, also. Details on foodborne outbreaks are presented in Chapter 3.

Preparation Requisite to the investigation of an elevated incidence of disease, there must be in place a team of individuals having the collective expertise to handle all phases of the study. Ideally, this would include an epidemiologist, field engineer, preferably trained in matters of public health, and assistants. Each of the individuals must have an assigned role to play in the team effort to characterize an outbreak and provide suggestions to solve the problem. Responsible leadership, typically under direction of an epidemiologist, must be established in order to monitor and coordinate team activities and seek approval of the plan from pertinent pubic officials.

Detection The first stage of a potential outbreak event is the unusual level of sick individuals in the population requiring medical attention within a short time frame. Similarity in patient symptoms and results of laboratory examinations of specimens may provide preliminary evidence of the possibility of an outbreak. However, it is imperative that prompt reporting of laboratory data to public health authorities take place in order that there be an evaluation and dispensing of information to appropriate individuals to confirm the existence of an outbreak.

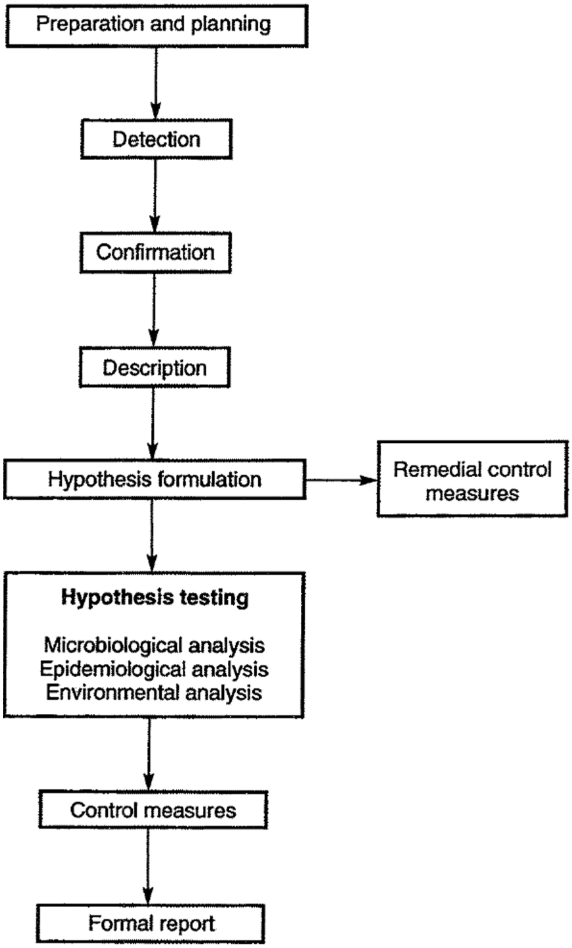


FIGURE 1.4 Flow diagram depicting the incremental steps in the investigation of a waterborne outbreak. *Source: P. R. Hunter, Waterborne Disease-Epidemiology and Ecology, John Wiley & Sons, New York, 1997*.

Hunter[125] cautions that many variables contribute to the inefficiency of identifying the existence of a waterborne disease, including difficulty in assembling patient data, proper diagnosis and laboratory testing for etiologic agents of prospective diseases, and underestimates of the number of afflicted people. For these and other reasons, much time and effort can be lost between the onset of illness in the population and the resolution of an outbreak.

Confirmation A redoubling of the effort on the part of authorities to substantiate from all information received that, indeed, an outbreak has occurred. This will involve a review of physician and laboratory records and ensuring that proper reporting of data to public health bureaus has taken place.

Description Upon confirmation that an outbreak has occurred, the investigating team should be activated and initial steps undertaken. It is not a simple matter to quickly determine the cause of illness due to water, food, or other vehicle, but a preliminary study of the symptoms, incubation periods, food and water consumed, housing, bathing area, and sanitary conditions may provide early clues and form a basis for formulating a quick response control action.

What is to be considered an outbreak case? The answer will require a preliminary set of parameters with which to define the case (e.g., limits of time regarding onset of the illness, symptoms of the illness, geographical boundaries of the affected area, and microbiological description of the disease etiology). The more rigid the definitions of parameters, the more likely it is that fewer cases will qualify for inclusion in the outbreak. However, parameter definitions should be flexible in relation to the availability of new information over time.

Following agreement on definition of a case, quantitative accounting of the number of cases involved is in order. Reliability of physician diagnoses and the collection of completed questionnaires of the type presented in Figure 1.5 are important. The information gathered from questionnaires contributes to the medical survey. If it appears that the number of completed questionnaires is insufficient, similar kinds of information can be collected and tabulated in the field when assistance is available. The tabulation horizontal headings would include the following seven categories:

1. Names of persons served food and/or water;
2. Age(s);
3. Ill—yes or no;
4. Day and time ill;
5. Incubation period in hours (time between consumption of ingestibles and first signs of illness);
6. Foods and water served at suspected meals—previous 12 to 72 hours (foods eaten are checked)
7. Symptoms—nausea, vomiting, diarrhea, blood in stool, fever, thirst, constipation, stomach ache, sweating, sore throat, headache, dizziness, cough, chills, pain in chest, weakness, cramps, other

Other analyses may include a summary of persons showing a particular symptom such as vomiting, diarrhea, and nausea, as shown in Figure 1.5, or those using a specific facility for calculation of incidence rates. For complete investigation details, consult references as appropriate.[126–129]

A common method of determining the probable offending water is a tabulation as shown in Figure 1.6, which is made from the illness questionnaire provided in Figure 1.5 or similar version. Comparison of the attack rates for each water will usually implicate or absolve a particular water. The water implicated is that showing the highest percentage difference between those who ate the specified water and became ill and those who did not eat the specified water and

Please answer the questions below to the best of your ability. This information is desired by the health department to determine the cause of the recent sickness and to prevent its recurrence. Leave this sheet, after you have completed it, at the desk on your way out. (If mailed, enclose self-addressed and stamped envelope and request return of completed questionnarie as soon as possible.)

1. Check any of the following conditions that you have had:

Nausea	Fever	Sore throat	Cough	Chills
Vomiting	Constipation	Headache	Pain in chest	Weakness
Diarrhea	Stomach ache	Dizziness	Laryngitis	Cramps
Thirst	Sweating	Paralysis	Bloody stool	Other

2. Were you ill? .... Yes ....No.
3. If ill, first became sick on: Date.............Hour............. A.M. / P.M.
4. How long did the sickness last ? ....
5. Check below (✓) the food eaten at each meal and (×) the food not eaten. Answer even though you may not have been ill.

Meal	Tuesday	Wednesday	Thursday
Breakfast	Apple juice, Corn flakes, oatmeal, fried eggs, bread, coffee, milk, water	Orange, pancakes, wheaties, syrup, coffee, milk, water	Grapefruit, Wheatina, shredded wheat, boiled egg, coffee, milk, water
Lunch	Baked salmon, creamed potatoes, corn, apple pie, lemonade, water	Roast pork, baked potatoes, peas, rice pudding, milk, water, chef salad	Swiss steak, home fried potatoes, turnips, spinach, chocolate pudding, orange drink, milk, water
Dinner	Gravy, hamburger steak, mashed potatoes, salmon salad, cookies, pears, cocoa, water	Roast veal rice, beets, peas, jello, coffee, water	Fruit cup, meatballs, spaghetti, string beans, pickled beets, sliced pineapple, tea, coffee, milk

6. Did you eat food or drink water outside? .... If so, where and when?
....
7. Name... Tel........................ Age .... Sex...............
8. Remarks (Physician's name, hospital)...
.... Investigator ....

FIGURE 1.5 Questionnaire for illness from food, milk, or water.

became ill (Figure 1.6). The sanitary survey is important to the interpretation of an environmental sample and determining a sound course of action and should include a study of all environmental factors that might be the cause or may be contributing to the cause of the disease outbreak. These should include water supply, food, housing, sewage disposal, bathing, insects, rodents, pesticide use, food handlers and other workers, practices, procedures, and any other relevant factors. Each should be considered responsible for the illness until definitely ruled

DEPARTMENT OF
HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
CENTERS FOR DISEASE CONTROL
CENTER FOR INFECTIOUS DISEASES
ATLANTA, GEORGIA 30333

INVESTIGATION OF A WATERBORNE OUTBREAK

Form Approved
OMB No. 920-0004

1. Where did the outbreak occur?
______________________(1-2) City or Town _______________ Country _________

2. Date of outbreak : (Date of onset of 1st case)
___________________________________ (3-8)

3. Indicate actual (a) or estimated (a) numbers :

Persons exposed _______ (9-11)
Persons ill _____________ (12-14)
Hospitalized __________ (15-16)
Fatal cases ____________ (17)

4. History of exposed persons :

No., histories obtained _______________ (18-20)
No. persons with symptoms ___________ (21-23)
Nauses _______ (24-26) Diarrhea______ (33-35)
Vomiting ______ (27-29) Fever ________ (36-38)
Cramps _______ (30-32)
Other, specify (39) ________________________

5. Incubation period (hours):

Shortest ____ (40-42) Longest ____ (43-45)
Median _______ (46-48)

Shortest ____ (49-51) Longest ____ (52-54)
Median _______ (55-57)

7. Epidemiologic date (e.g., attack rates (number ill / number exposed) for persons who did not eat or drink specific food items or water, attack rate by quantity of water consumed, anacdotal information) * (58)

ITEMS SERVED	NUMBER OF PERSONS WHO ATE OR DRANK SPECIFIED FOOD OR WATER				NUMBER WHO DID NOT EAT OR DRINK SPECIFIED FOOD OR WATER			
	ILL	NOT ILL	TOTAL	PERCENT ILL	ILL	NOT ILL	TOTAL	PERCENT ILL

8. Vehicle responsible (item incriminated by epidemiologic evidence) : (59-60) ______________________________

9. Water supply characteristics

(A) Type of water supply** (61)
☐ Municipal or community supply (Name ___________________)
☐ Individual household supply
☐ Semi-public water supply
☐ Institution, school, church
☐ Camp, recreational area
☐ Other, ____
☐ Botteled water

(B) Water source (*check all applicable*):

☐ Well a b c d
☐ Spring a b c d
☐ Lake, pond a b c d
☐ River, stream a b c d

(C) Treatment provided (*circle treatment of each source checked in B*):

a. no treatment
b. disinfection only
c. purification plant - coagulation, settling, filtration, disinfection (*circle those applicable*)
d. other ____

10. Point where contamination occurred: (66)
☐ Raw water source ☐ Treatment plant ☐ Distribution system

*See CDC 52.13 (Formerly 4.245) Investigation of a Foodborne Outbreak, Item 7.
**Municipal or community water supplies are public or investor owned utilites, Individual water supplies are wells or springs used by single residences. Semipublic water systems are individual-type water supplies serving a group of residences or locations where the general public is likely to have access to drinking water. These locations include schools, camps, parks, resorts, hotels, industries, subdivisions, trailer parks, etc., that do not obtain water from a municipal water system but have developed and maintain their own water supply.

CDC 52.12 (f. 4.461)
Rev. 7-81

This report is authorized by law (Public Health Service Act, 42 USC 241)
While your response is voluntary, your cooperation is necessary for the understanding and control of the disease.

FIGURE 1.6 Investigation of waterborne outbreak.

11. Water specimens examined: (67)
(*Specify by "X" wheather water examined was original (drunk at time of outbreak) or check-up (collected before or after outbreak occurred*)

ITEM	ORIGINAL	CHECK UP	DATE	FINDINGS		BACTERIOLOGIC TECHNIQUE (e.g., fermentation tube, membrane filter)
				Quantitative	Quantitative	
Examples: Tap water	X		6/12/74	10 focal coliforms per 100ml.		
Raw water		X	6/2/74	23 total coliforms per 100 ml.		

12. Treatment records: (*Indicate method used to determine chlorine residual*):
Example: Chlorine residual – One sample from treatment plant effluent on 6/11/74 – trace of free chlorine
Three samples from distribution system on 6/12/74 - no residual found

13. Specimens from patients examined (stool, vomitus, etc.) (68)

SPECIMEN	NO. PERSONS	FINDINGS
Example: Stool	11	8 *Salmonella typhi*
		3 negative

14. Unusual occurrence of events :
Example: Repair of water main 6/11/74; pit contaminated with sewage, no main disinfection. Turbid water reported by consumers 6/12/74.

15. Factors contributing to outbreak (*check all applicable*):

- ☐ Overflow of sewage
- ☐ Seepage of sewage
- ☐ Flooding, heavy rains
- ☐ Use of untreated water
- ☐ Use of supplementary source
- ☐ Water inadequately treated
- ☐ Interruption of disinfection
- ☐ Inadequate disinfection
- ☐ Deficiencies in other treatment processes
- ☐ Cross-connection
- ☐ Back-siphonage
- ☐ Contamination of mains during construction or repair
- ☐ Improper construction, location of well/spring
- ☐ Use of water not intended for drinking
- ☐ Contamination of storage facility
- ☐ Contamination through creviced limestone of fissured rock
- ☐ Other (specify)

16. Etiology: (69-70)

		(71)
Pathogen	Suspected	1
Chemical	Confirmed	2 (*Circle one*)
Other	Unknown	3

17. Remarks: *Briefly describe aspects of the investigation not covered above, such as unusual age or sex distribution; unusual circumstances leading to contamination of water; epidemic curve; control measures implemented; etc. (Attack additional page if necassary)*

Name of reporting agency: (72)

Investigating Official: | Date of investigation:

Note: Epidemic and Laboratory assistance for the investigation of a waterborne outbreak is available upon request by the State Health Department to the Centers for Disease Control, Atlanta, Georgia 30333.

To improve national surveillance, please send a copy of this report to: Centers for Disease Control
Attn: Enteric Disease Branch, Bacterial Diseases Division
Center for Infectious Diseases
Atlanta, Georgia 30333

Submitted copies should include as much information as possible, but the completion of every item is not required.

CDC 52.12 (f. 4.461) (BACK)
7-81

FIGURE 1.6 (*continued*)

out. Other chapters in this book dealing with water and wastewater treatment, residential housing, food protection, recreational areas, and so on may be useful. Table 1.4 should be referred to for guidance and possible specific contributing causes to an outbreak and their correction.

A form for use in an environmental field investigation is presented in Figure 1.7. Water system, food service, housing, and swimming-pool sanitary survey report forms are usually available from the state or local health

Date .... Investigator ....
Name of place .... Owner ....
Population .... Manager ....
Onsets—day and hours .... Incubation period ....
Number afflicted .... Number hospitalized .... Number deaths ....
Outbreak: explosive .... gradual .... undetermined ....
Samples collected ....

Underline symptoms most commonly reported:

Diarrhea, constipation, abdominal pains, stomach cramps, muscular cramps, prostration, high temperature, painful straining at stool or in urination, sore throat, chills, thirst, sweating, vomiting, nausea, swelling of face and eyelids, laryngitis, cough, pain in chest, enlarged tonsils or adenoids, pains in joints, eye movement difficult, swallowing difficult, headache, dizziness, other ....

Water

1. Water sources and treatment ....
2. Method of serving water ....
3. Interconnections: toilet .... washbasin .... bath tubs .... tubs .... other ....
4. Recent repairs ....
5. Cross-connections, with other supplies ....
6. Changes in water taste .... color .... odor ....

Milk and food

7. Source of milk (pasteurized) ....
8. Method of handling milk ....
9. Use of leftover foods ....
10. Source of fowl, meats, ice cream, shellfish, pastries ....
11. Food refrigeration and storage ....
12. Food handling and preparation ....
13. Ice source and handling ....
14. Thawing foods protected ....
15. Dressings, sauces, etc. ....

Food handlers

16. Recent illness in food handlers ....
17. Hand-washing facilities ....
18. No. pyogenic skin infections ....
19. Personal hygiene ....

Kitchen and dining hall

20. Storage and use of insecticides .... rat poison .... roach powder .... water paint .... silver polish ....
21. Garbage storage and disposal ....
22. Prevalence of rodents and insects ....
23. Fly breeding controlled ....
24. Dish cleansing and disinfection ....
25. Premises and equipment clean ....
26. Food service well organized ....

Other

27. Housing overcrowding ....
28. Bathing beach or swimming pool operation, water source ....
29. Medical and nursing care ....
30. Other ....

Remarks (Comment on unsatisfactory items and probable cause, general impressions, etc.):

FIGURE 1.7 Outbreak investigation field summary.

department to assist in making a complete epidemiologic investigation. A WHO publication also has a water system reporting form[130,131] and the EPA has an evaluation manual.[132]

Laboratory results are the key to confirming the cause of disease cases. It may be necessary to ask physicians to obtain specimens from patients considered to be presumptive cases where such sampling had not been done. Also, a reexamination of physician records may be warranted against the possibility that certain patients were overlooked.

Once individuals are identified as cases, personal history of each of the cases must be obtained. In addition to the usual descriptors (e.g., name, age, sex, etc.), personal information relevant to the case definition is needed. Accessory data may be collected on cases (e.g., information about whereabouts and activities leading up to the occurrence of disease symptoms). Such information is useful to establish the incubation period for the disease and to compare the evaluation with published incubation periods for suspected etiologic agents. The medical survey should assist in developing a clinical picture to enable identification of the disease and its causative agent. Typical symptoms, date of onset of the first case, date of onset of last case, range of incubation periods, number of cases, number hospitalized, number of deaths, and number exposed are usually determined by the epidemiologist. To assemble this information and analyze it carefully, a questionnaire should be completed, by trained personnel if possible, for each person available or on a sufficient number of people to give reliable information (see Figure 1.5).

The importance of animal reservoirs of infection should not be overlooked where small-scale water systems are involved. Table 1.4 contains in condensed form symptoms and incubation periods of many diseases that, when compared to a typical clinical picture, may suggest the causative organism and the disease. A high attack rate, 60 to 80 percent, for example, would suggest a virus (Norovirus) as the cause of a foodborne outbreak.[133]

Finally, all data collected in the description phase of the investigation are analyzed and charted in various ways to obtain a picture of the outbreak. Visual aids will be areal maps, graphs displaying the chronology of case densities over time with subplots according to age, sex, ethnicity, and so on. A simple bar graph, with hours and days (possibly weeks) as the horizontal axis and number who are ill each hour or other suitable interval plotted on the vertical axis, can be made from the data. The time between exposure to or ingestion of water and illness or first symptoms or between peaks represents the incubation period. The average incubation period is the sum of the incubation periods of those ill (time elapsing between the initial exposure and the clinical onset of a disease), divided by the number of ill persons studied. The median, or middle, time may be preferable when incubation periods vary widely. The shape of the curve is useful in revealing the period of primary infection as may be due to point source infection vs. person-to-person contact. Extended case-time plots may be biomodal, indicating a point-source outbreak and a secondary person-to-person outbreak. Good data presentation adds to the strength of the investigation and the location of "hot spots" that may reveal points of interest in the drinking-water distribution system subject to possible contamination.

Hyothesis Formulation The data collected and analyzed in connection with the "Description" are used to formulate hypotheses concerning the events responsible for the outbreak and make preliminary recommendations for remedial control measures. More than one hypothesis is possible. The outbreak may be responsible to a point-source or person-to-person contact. Furthermore, if it is envisioned that a point-source is possible, it will be necessary to determine the point of access by disease-producing agents to the finished water. For example, an infectious agent believed responsible for a waterborne outbreak may be associated with a cross-connection somewhere in the distribution system or regrowth in an activated carbon filter at the treatment plant compounded by ineffective disinfectant residual in the finished water. Knowledge of past outbreaks and epidemiology of the suspected infectious agent, combined with the total of current data logs and analyses of the outbreak in question will serve to identify the hypothesis with greatest likelihood explaining the outbreak. Publications summarizing disease outbreak investigation procedures are very helpful.[134–137]

Remedial Control Measures During hypothesis formulation, implications as to the cause of the outbreak may emerge, justifying a simultaneous review of options for remedial control measures. Since the hypothesis advanced has not been proven at this point, any remedial actions called for must be directed at immediate protection of the public. Where a danger in the drinking water supply is envisioned, decisions are limited to disconnecting the purveyor from the users, issuing a boil order, or supplying an auxiliary source of safe drinking water. In the example of the Alamosa, Colorado, outbreak, residents were advised not to use tap water for potable uses on the day bacterial contamination was discovered and to bring large containers to obtain safe water from distribution centers located within the community. Bottled water was supplied mostly to schools. Main flushing following superchlorination took place in stages, beginning six days from the time the outbreak was announced and residents were asked to refrain from using tap water for drinking and cooking at that time. Water authorities should not be required to undertake expensive repair and retrofitting of the treatment system before it is definitely ascertained that there is a physical problem in need of attention. The mere enactment of precautionary measures will prescribe a liability, both in terms of monetary cost and public relations.

Hypothesis Testing This is the important "proof" step in the investigatory program. All parties affected and the rest of the community will anxiously await the final word on the cause of the outbreak. All evidence obtained during the investigation is evaluated in an acceptable plan for testing a particular hypothesis. The evidence presented is the sum total of microbiological, epidemiological, and environmental findings collected during the course of the investigation. The most definitive microbiological evidence is the unequivocal identification of the waterborne disease agent in case specimens and samples taken at the source of the outbreak, however, the latter may be difficult to accomplish. New methodologies are available to aid in rapid detection of suspected pathogenic agents in environmental samples including water. A brief description of the procedures is given in the following section. Epidemiological evidence arises from the results of retrospective studies conducted on known cases and randomly selected control subjects within the affected community. Environmental evidence pertains to results of a sanitary survey. The sanitary survey should cover all factors that may potentially impact on operational and quality control issues associated with the treatment and distribution of the community water supply. It is very helpful to have personnel knowledgeable about the water field involved in the environmental investigation. Upon obtaining positive identification of the etiologic agent of a communicable disease, the number of confirmed cases should be made known to the state health department and to the national Centers for Disease Control.

Control Measures These are the repairs and installation of facilities and equipment necessary to safeguard the water supply from repeated microbial violations of the system. Successful establishment of the cause and source of the waterborne outbreak pays dividends, not only in returning the community to normal use of its water supply but also easing the tensions of individuals upon which the onus for correcting defects and bearing the financial burden is leveled.

Formal Report The published written report should chronicle the essentials of the waterborne outbreak. The report should be fully detailed and include the cause, laboratory findings, transmission, incidence, case by dates of onset, average incubation period and range, typical symptoms, length of illness, age and sex distribution, deaths, secondary attack rate, and recommendations for the prevention and control of the disease, so as to be of use to various professional, political, and technical members in the community workforce. Copies of the report should be sent to the state health department and the Public Health Service. The press should be carefully briefed to avoid misinterpretation and dissemination of misinformation to the community. Effort should be made to use the report as an instructional tool for the education of students in the community and geographically dispersed parties through scientific reporting.

Samples and Specimens

The prompt collection of samples and specimens for laboratory examinations is a necessary part of the investigation of any disease outbreaks. Although not often done, isolating the incriminating organism from the persons made ill and the alleged outbreak source, producing the characteristic symptoms in laboratory animals or human volunteers, and then isolating the same organisms from human volunteers or laboratory animals will confirm the field diagnosis and implicate the responsible vehicle. In the early stages of the field investigation, it is very difficult to determine just what samples to collect. It is customary, therefore, to routinely collect samples of water from representative places and available samples of all leftover milk, drinks, and food that had been consumed and place them under seal and refrigeration. Sterile spatulas or spoons boiled for 5 minutes can be used to collect samples. Sterile wide-mouth water bottles and petri dishes make suitable containers. In all cases, aseptic technique must be used. Since examination of all the food may be unnecessary, it is advisable, after studying the questionnaires and accumulated data, to select the suspicious foods for laboratory examination and set aside the remaining food in protected sterile containers under refrigeration at a temperature of less than 40°F (4°C) for possible future use. Laboratory procedures should be followed for collection, preservation, and shipment of all specimens and samples.

Samples of water should be collected directly from the source, storage tanks, high and low points of the distribution system at times of high and low pressure, kitchens, and taps near drinking fountains for chemical and bacterial examinations. It should be remembered that the time elapsing before symptoms appear is variable and depends on the causative agent and size of dose, the resistance of individuals, and the amount and kind of food or drink consumed. For example, an explosive outbreak with a very short incubation period of a few minutes to less than an hour would suggest a chemical poisoning. Antimony, arsenic, cadmium, cyanide, mercury, sodium fluoride, sodium nitrate, or perhaps shellfish poisoning, favism, fish poisoning, and zinc poisoning are possibilities. An explosive outbreak with an incubation period of several hours would suggest botulism or fish, mushroom, potato, rhubarb-leaf, shellfish, chemical, or staphylococcus food poisoning. An incubation period of 6 to 24 hours would suggest botulism, mushroom poisoning, rhubarb poisoning, salmonella infection, or streptococcus food poisoning. An incubation period of one to five days would suggest ascariasis, botulism, diphtheria, amebic dysentery, bacillary dysentery, leptospirosis, paratyphoid fever, salmonella infection, scarlet fever, streptococcal sore throat, or trichinosis. For other diseases with more extended incubation periods, refer to Table 1.4. The laboratory examinations might be biologic, toxicologic, microscopic, or chemical, depending on the symptoms and incubation period.

The CDC[138] classifies outbreaks of unknown etiology into four subgroups by incubation period of the illnesses: less than 1 hour (probable chemical poisoning), 1 to 7 hours (probable *Staphylococcus* food poisoning), 8 to 14 hours (probable *C. perfringens* food poisoning), and more than 14 hours (other infectious or toxic agents).

The sanitary and medical surveys may involve the swimming pool or bathing beach. In that case, samples should be collected at the peak and toward the end of the bathing period for examinations.

Laboratory analyses for water samples should include the standard plate count (heterotrophic plate count), in addition to the test for coliform bacteria, since large bacterial populations may suppress the growth of coliform organisms. Where large volumes of water are needed, use 2- to 5-gallon sterile containers and store at 41°F (5°C). Sampling for recovery of viruses and *Giardia or Entamoeba* cysts may require special on-site filters and equipment.[139]

It is customary to notify the laboratory in advance that an outbreak has occurred and that samples and specimens will be delivered as soon as possible. All should be carefully identified, dated, sealed, and refrigerated. A preliminary report with the samples and specimens, including the probable cause, number ill, age spread, symptoms, incubation period, and so on, will greatly assist the laboratory in its work.

Epidemiology and Risk

In the foregoing discussion, a scheme for dealing with the orderly investigation of a waterborne disease outbreak was presented. Central to the conduct of the investigation is the team of workers appropriately trained to perform specific roles. One such team member, if available, and a likely leader of the group, is the epidemiologist. *Epidemiology* literally translated is “study of epidemics.” In the broader sense, it is the science (with considerable art) of defining the causes of disease distribution within a population and the causal factors that made the disease possible. A causal factor is an event, condition, or characteristic that increases the likelihood of a disease.[4]

Environmental epidemiology is the study of environmental factors that influence the distribution and determinants of disease in human populations.[26] In the context of a waterborne outbreak, the epidemiologist is interested in learning the susceptibility of the population under the sphere of influence of a water transmitted disease, what regions or groups of people in the population are at the greatest risk, how the disease will manifest itself temporally and spatially in the population, commonalities, and differences among the individuals listed as having been symptomatically affected and not affected, and something of the risk to the population under the conditions of exposure to water.

During the course of the investigation of a waterborne outbreak, a descriptive epidemiologic study will be undertaken with the collection of data sets obtained from laboratory, hospital and physician, environmental, and residential records and field surveys. The emphasis will be put on establishing the veracity of the outbreak, containing the spread of the disease through emergency measures, and characterizing the event in support of formulating a hypothesis on the cause of the outbreak. A follow-up to the descriptive epidemiologic study would be an analytical epidemiologic exercise involving a case-control study to identify causal factors to the outbreak. A case-control study is an observational study in which a group of persons with a disease (cases) and a group of persons without the disease (controls) are identified without knowledge of prior exposure history and are compared with respect to exposure history.[140]

If the selection of control participants is truly random, some of the subjects selected to be controls may also have expressed the illness. Selection of individuals making up the control group is not a simple process and, as with the convening of any sample of people intended to be representative of a particular population, bias is inevitable. Bias impacts the strength of the study results. The object of the exercise is to analyze the behaviors of both groups prior to the outbreak so that a determination can be made about the importance of the water as a condition to developing the disease. For this, a simple approximation of the essentiality of the water to the infectious outcome is obtained by computing an odds ratio. A 2×2 square is constructed by pairing the number of people that consumed and did not consume water against the number of those people who became ill and did not become ill.

The following is a hypothetical example involving collected data on the population associated with the waterborne outbreak:

52 people drank contaminated water and became clinically ill. (a)
32 people drank contaminated water and did not become ill. (b)
21 people did not drink contaminated water and became ill. (c)
64 people did not drink contaminated water and did not become ill. (d)

The 2 × 2 table is constructed to display the data as given.

	Drank water	Did not drink water
Became ill	52	21
Did not become ill	32	64

$$\text{Calculation of the odds ratio (OR): } \frac{a/c}{b/d} = \frac{52/21}{32/64} = 4.95 = 5$$

The OR clearly establishes a strong connection between exposure (water) and the prevalence of disease.

In an actual study, there may be a number of possible sources for the disease agent including food, insects, and personal associations, to name a few. With the category of food, many subsets are possible, including salads, meats, breads, juices, milk, and so on. Each of the sources deserves consideration as a vehicle or vector, depending on the nature of the suspected disease agent. Case-control studies can be constructed to test any and all of the potential sources of the disease agent. The odds ratios can then be statistically analyzed to narrow the field of suspected sources. Usually, the statistical evaluation is performed at the 95 percent confidence level ($p < 0.05$).

In the previous example of a case-control study in connection with a waterborne outbreak, cases of the disease had been established. Now consider a situation where the town health officer released advance information to a population of people that a wastewater cross-connection was found to have leaked at some point in the distribution system. These conditions may provide the opportunity for a cohort study, which is an observational study in which two or more groups of persons who are free of disease and differ by extent of exposure to a potential cause of a disease are compared over time with respect to the incidence of the disease.[140] In our example, this would be a prospective investigation of a group (cohort) of healthy people known to have been exposed to contaminated water. The object of the study would be to follow the course of events to evaluate the appearance of illness in the exposed population and determine if consuming the contaminated drinking water posed a risk for illness. In the cohort study, it is of interest to determine the incidence of disease in the exposed group vs. the unexposed group. To do this, a 2 × 2 table is constructed as previously illustrated and a relative risk (RR) is determined. Relative risk cannot be established for a case-control study because members of the case-control population are not random samples of the *entire* community population.

To illustrate the calculation of RR, a hypothetical situation is presented below. The same data as for the case-control study was used for comparative purposes:

52 people drank contaminated water and became clinically ill. (a)
32 people drank contaminated water and did not become ill. (b)
21 people did not drink contaminated water and became ill. (c)
64 people did not drink contaminated water and did not become ill. (d)

The 2 × 2 table is constructed to display the data.

	Drank water	Did not drink water
Became ill	52	21
Did not become ill	32	64

Calculation of the RR value involves the ratio of the exposed group as a proportion of the population examined to the unexposed group as a proportion of the population examined:

$$\mathrm{RR} = \frac{a/(a+b)}{c/(c+d)} = \frac{52/(52+32)}{21/(21+64)} = \frac{0.62}{0.24} = 2.6$$

The RR establishes that the relative risk of becoming ill for the group of people exposed to contaminated water as opposed to the group of people not exposed to contaminated water is 2.6.

Two types of information regarding disease in a population that can be helpful to an epidemiological study are incidence rate and prevalence rate. Incidence rate is defined as the number of new cases per unit of person-time at risk. For example, suppose the waterborne outbreak used in the previous examples occurred in a stable community of 10,000 people. Following the outbreak, the number of new cases occurring over a five-year period was 30 per 10,000 people. These new cases might have nothing to do with consuming water, but the waterborne incident might have established some carriers of the disease within the population that could contribute to the infection of others. In this example, the incidence rate of the disease in the community would be 6 cases per 10,000 people-years; the expression *people-years* arriving from the normalization of the 30 disease cases over a five-year period.

Prevalence rate is something different from incidence rate because prevalence rate concerns the actual number of disease cases in a community. In the case of the waterborne outbreak, there were 73 cases of the disease. Supposing that secondary infections occurred among the population to add another 43 cases of the disease bringing the total to 116 cases of the disease for the year. In the community of 10,000 people, the prevalence rate of the disease for the year of the outbreak would be 1 percent.

The incidence rate can be determined for both the exposed and unexposed individuals identified with the waterborne outbreak above. Looking at the data, we find that 52 people became sick out of 84 people that drank water and 21 people became sick out of 85 people that did not drink water. The incidence rate for the two subgroups of individuals is 62 percent and 25 percent, respectively. From these data, an attributable risk can be determined by subtracting the incidence rate of nondrinkers from drinkers of the water, which would be 37 percent.

Incidence measures reflect the level of infectivity of the causative agent of the disease. They do not establish the virulence of the causative agent because virulence relates to the damage produced as a result of the infection. Damage resulting from infection of an individual can range from a few mild symptoms to life-threatening symptoms, depending on many contributing factors (e.g., health and nutrition status, age, infectious dose of the pathogen received, how the pathogen was received, genetic disposition and others). In the study of an outbreak, a case is defined not by the severity of the infection but by the fact that an infection occurred.

The subject of risk assessment has advanced considerably in the last 20 years. Mathematical models have been constructed to estimate the probability of infection using databases of human exposure. Before models could be formulated it was necessary to ascertain the variables of the infection process. In the case of microbial risk assessment, such variables might include etiologic disease agent identification, human health effects manifested through infection, dose-response data relating dose received and probability of infection/disease in the target population, physiology of host-parasite relations, and epidemiological data.[26]

Molecular Detection of Waterborne Pathogens

Water, especially drinking water, when under suspicion of the transmission of pathogens, requires laboratory examination for proof of contamination. Cultural methods may prove inadequate for the isolation of pathogens, may produce uncertain results, or may be too time-consuming to support ongoing epidemiological investigations. During the past three decades, environmental laboratories have exploited molecular-based protocols to gain insight into the presence of sundry infectious bacteria, viruses, and protozoa in aquatic environments and water supplies. These techniques can be useful to investigations of disease outbreak, especially, where no cultural evidence can be obtained to show the existence of an infectious agent. In fact, a fundamental challenge in proving the hypothesis that a disease outbreak has occurred is to establish conclusively that the suspected agent of disease existed at the suspected source of the disease. A broad range of sophisticated laboratory techniques, such as fluorescent antibody, enzyme-linked immunosorbent assay (ELISA), fluorescent *in situ* probe (FISH), flow cytometry, and the polymerase chain reaction (PCR), are available to provide answers not possible by classical measures. From these has emerged a branch of epidemiology called molecular epidemiology. Routine use of molecular tools is nonexistent in many health laboratories, however, owing to the requirement for relatively expensive equipment, need to employ technicians knowledgeable about molecular techniques, and the technical issues surrounding detection of specific genomes present in very low levels in water. Despite these apparent limitations to adopting molecular techniques for routine surveillance of pathogens in water-quality-control laboratories, molecular protocols have been used to detect a wide range of pathogenic agents in waters.

A brief introduction to molecular methods for microbiological investigation in the water environment is given based on descriptions by Rochelle and Schwab.[141]

Sample Collection Proper procedures for obtaining water samples are independent of the intended use of water. However, taking advantage of the sensitivity of molecular detection implies that the target organism is probably in very low in concentration, else it might be prudent to employ a cultural technique (assuming the target microorganism or virus is in a viable/recoverable state). Therefore, sample volumes earmarked for molecular applications are usually large and will require concentration of contents.

Sample Concentration Large water samples are processed by filtration procedures applicable to bacteria, protozoa, or viruses.

Nucleic Acid Extraction The material of interest to be assayed by molecular techniques is deoxyribonucleic acid (DNA) or ribonucleic acid (RNA). Extraction of nucleic acids from filtered/centrifuged biomass containing the target organism of interest may take place directly or following repeated elution and centrifugation steps (principally required for virus recovery). Ideally, the extraction step will be minimally time consuming, produce a high yield of intact nucleic acid, and preclude carryover of inhibitory substances inimical to the polymerase chain reaction (PCR) analysis. Special procedures can be introduced prior to nucleic acid extraction for removal of inhibitors. Published protocols and commercial kits may be used for postextraction purification of nucleic acids to eliminate inhibitors.

Methods of Detection The basic approach to assaying purified target nucleic acid is the application of PCR. The purpose of PCR is to amplify the nucleic acid of the target organism so that workable quantities of product become available for subsequent sequence analysis. It is important that the PCR procedure be sensitive and specific. PCR assays are typically operated in three cycles of temperature to accommodate three steps:

1. Denaturation of the double-stranded, target DNA (92°–94°C)
2. Annealing of specific primers to the single-strand form (denatured) of the target DNA at some prescribed or trial-and-error temperature (45°–55°C)

3. Complementary strand synthesis by primer extension of each of the single strands produced by step 1 at a temperature of 75°–80°C

The three-step procedure is repeated usually 30 to 40 times in order to obtain exponential copies of PCR product. The two important variables in successful use of PCR as a tool are primer synthesis or selection and PCR operating conditions. These two factors dictate the level of specificity and sensitivity that can be obtained by PCR and are instrumental in facilitating the detection of target nucleic acids at refined taxonomic levels.

Evaluation of PCR Products The purpose of amplifying target nucleic acids present in the environmental sample is to be able to subject a sufficient quantity of the representative material (PCR product) to a laboratory procedure for the determination of the microbial agent that it represents. Classic procedures for this purpose involve application of a series of concentrations of the PCR products to an agarose gel electrophoresis slab along with a molecular marker. Various amplified gene fragments migrate through the gels in proportion to their molecular weights. The separated gene fragments can then be confronted with an oligonucleotide probe specific for the organism of interest in relation to its possible presence in the original water sample. Oligonucleotide probes are conjugated with a reporter molecule (typically a fluorogenic compound) that under appropriate conditions (fluorescent lighting) signals hybridization with a complementary (target) nucleic acid fragment.

Two areas of interest in connection with molecular detection of specific microbial agents in environmental samples are robustness of the detection effort and the level or density of the target microbe in the representative environmental sample. In the former, since molecular detection is a gene-based exercise, it stands to reason that the more types of gene fragments that are available as probes, the more information that can be learned about the genome of the target organism. The technique that makes use of the multiple probe approach is the microarray. The microarray is a glass microscope slide that serves as a solid support for the spotting of literally thousands of genes or gene fragments—in this example, oligonucleotide probes—that serve to test hybridization potential with amplified gene fragments (PCR products) of unknown identity. The nucleotide sequence of the probe is known and representative of specific microbes. The location of each of the probes on the glass slide is carefully recorded, so when hybridization with unknown PCR products (amplicons) is indicated by reporter signals, the strain, species, and genus identity of the unknown amplicon can be learned.

Quantification of the target microbe in the environment with the aid of a PCR instrument must involve procedural modifications and special equipment in order to measure the level of production of PCR products. Fluorogenic probes and a fluorescence detection device are used to track the formation of PCR product formation. Quantitative PCR (qPCR) is still relatively new, and advances are being made to increase its utility. The following brief description is based on methodology described by Grove.[142] In the qPCR process, two fluorogenic probes anneal to the template nucleic acid between the primers. As the nucleic acid polymerase extends the primer, the probe is displaced, and the polymerase cleaves the fluorogenic dye. Released dye is freed from the quencher and a fluorescent signal is produced. The detection device consists of a multiwell thermal cycler connected to a laser and a charge-coupled optics system. A fiber optic inserted through a lens is positioned over each of the wells, and a laser beam is directed through the fiber to excite fluorochrome in the PCR fluid present in wells. Fluorescence emissions are sent through the fiber to the CCD camera, mathematically analyzed by the system software, and the data are computerized.

Obtaining quantitative data on the original sample requires construction of a calibration curve. This is done by preparing dilutions of a known quantity of nucleic acid and performing PCR. Emissions data are obtained for each dilution of the nucleic acid and plotted against thermal cycle numbers. A series of curves result, and a line is drawn through the curves parallel to the thermal cycle numbers (x axis) at a height just above the background fluorescence (Figure 1.8). Another line is drawn perpendicular to the thermal cycles (x axis) at the intersection of the parallel line and each of the curves representing the nucleic acid dilutions. The thermal cycle number corresponding to each curve is the threshold cycle (Ct). The calibration curve is a plot of each Ct value against the corresponding nucleic acid concentration in the dilution series. The Ct is inversely proportional to the copy number (concentration) of nucleic acids in the dilution series, so a straight line should result. The actual concentration of nucleic acid in the unknown sample is determined by obtaining a Ct value under identical conditions of PCR operation

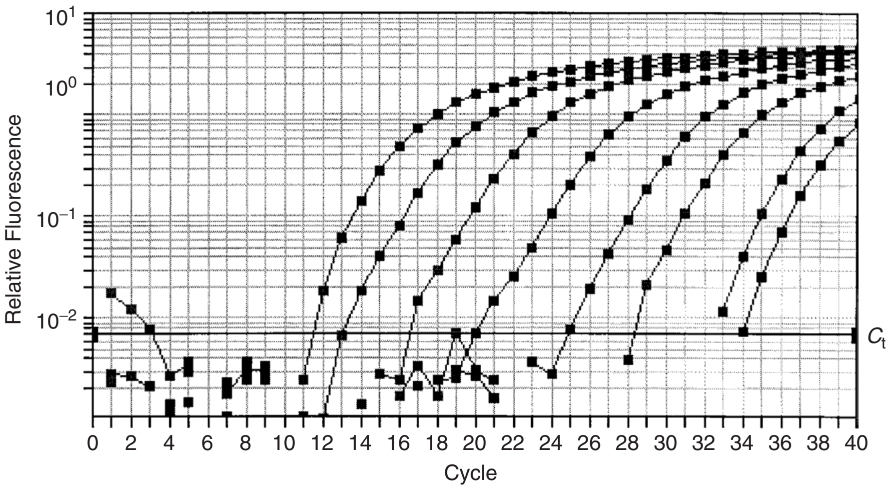


FIGURE 1.8 Family of fluorescence emission curves prepared from dilutions of nucleic acid for the determination of threshold cycle values. (*Source*: *D. S. Grove, "Quantitative Real-Time Polymerasae Chain Reaction for the Core Facility Using TaqMan and the Perkin-Elmer/Applied Biosystems Division 7700 Sequence Detector," J. Biomol. Tech, 10 (1999): 11–16.*)

as took place for the known dilution series and the nucleic acid concentration represented by the *C*t value is read from the calibration curve.

Quality control and assurance is uppermost in all phases of PCR methodology. Prospective analysts should be aware of the U.S. Environmental Protection Agency publication "Quality assurance/quality control guidance for laboratories performing PCR analyses on environmental samples," available at http://www.epa.gov/nerlc/cwww/qa_qc_pcr10_04.pdf.

Advances in molecular methods of detecting and quantifying microorganisms should be powerful assets to modern environmental epidemiology. The potential exists for analyzing samples for the presence of suspect pathogens in water supplies with far greater certainty than can occur by conventional methods.

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CHAPTER 2

CONTROL OF DISEASES OF THE AIR AND LAND

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COMMUNICABLE DISEASES

Background

Communicable diseases are illnesses due to a specific infectious agent or its toxic products. They arise through transmission of that agent or its products from an infected person, animal, or inanimate reservoir to a susceptible host, either directly or indirectly through an intermediate plant or animal host, vector, or the inanimate environment.[1] Illness may be caused by pathogenic bacteria, bacterial toxins, viruses, protozoa, spirochetes, parasitic worms (helminths), poisonous plants and animals, chemical poisons, prions (infectious proteinlike particles) rickettsias, and fungi, including yeasts and molds. In this text, vectorborne and airborne communicable diseases are discussed under arthropodborne diseases and respiratory diseases; noncommunicable diseases will also be discussed. This chapter concludes with a basic description of definitions and typical studies and measures used in epidemiology. The terms *communicable disease* and *infectious disease* are used interchangeably.

The communicable diseases (malaria, yellow fever, pneumonia, human immunodeficiency virus [HIV], tuberculosis, cholera, schistosomiasis, measles, onchocerciasis, intestinal parasites, and diarrheal diseases) and malnutrition have traditionally been considered the core health problems of developing countries, many of which are aggravated by contaminated drinking water, unhygienic housing, and poor sanitation. In developed countries, the chronic diseases (disease of the heart, cerebrovascular disease, cancer, diabetes) and injuries

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(motor vehicle accidents, suicide, poisonings) comprise the majority of causes of death. [2]

When a country shifts from predominately infectious disease mortality to chronic disease mortality, the country is said to have undergone the *epidemiologic transition*. Although this has been the view of disease burden for the latter half of the twentieth century, the burden of chronic diseases in developing countries has increased dramatically in the last two decades and has resulted in mixed patterns of mortality between different populations, even within the same country. For example, in developing countries relatively well-off urban dwellers will have a higher mortality due to chronic diseases, while poor rural residents may have greater burden of infectious disease. Therefore, it is important to remember that while communicable diseases are the focus of this chapter and the next, individuals with chronic health conditions will make up large proportions of infected populations; this has large implications for the severity of disease and managing clinical conditions, and it reiterates the importance of prevention for all.

A study by Clough[3] compares two investigations showing the impact of environmental factors on cancer mortality. The term *environment* has different meanings to the epidemiologist and to the general public. To the epidemiologist, "it refers to everything that humans encounter: everything that is eaten, drunk, and smoked; drugs, medicine, and occupational exposures; and air, water, and soil. In this context it means everything outside the body as distinct from a person's genetics."[3] Clough defined "environment" as the aggregate of all the external conditions and influences affecting the life and development of humans. Included is the air, water, land, and climate and the interrelationship that exists between them and all living things.

Social epidemiologists refer to different levels of human environment, terms that may be used differently than in other realms of environmental engineering. The *built environment* refers to manmade structures that are the setting for human activity, including buildings, bridges and planned open spaces. Influences of the built environment on mental health,[4,5] obesity,[6] nutrition,[7] sleep disturbances,[8] traffic accidents,[9] malaria-transmitting mosquitoes,[10] visceral leishmaniasis,[11] and other diseases and injuries have been documented. Although causal inference between these associations is difficult to make, we are just beginning to understand the health impact of the structures we live and work in. This is likely to be an expanding and exciting field of research in public health that can be translated into applications through environmental engineering.

Social factors not intuitively associated with health can also have significant influences. Of all the predictors of individual good health (diet, exercise, environmental factors, access to medical care, etc.), studies repeatedly show that educational attainment is highly important. More educated populations tend to be healthier, although the causal mechanism has not been clearly articulated. Although increasing the basic education level is not usually considered a public health intervention, it should be acknowledged that many of the broader societal trends that influence health are beyond the scope of any individual agency or organization. Collaborative efforts from different public welfare sectors are necessary to make meaningful improvements in public health.

It bears mentioning that many bacteria live in symbiosis (mutual benefit) with humans, with both deriving mutual benefits. The presence of natural "flora" of the intestinal tract and skin are normal and considered healthy under most circumstances; when the immune system becomes compromised (i.e., with age, HIV infection, breaks in the skin, chemotherapy, etc.) these organisms can cause pathological disease. The bacteria also provide protection against more damaging bacterial and viral organisms and can become depleted with the use of antibiotics. When we refer to "infectious diseases" for the rest of this chapter and the next, we specifically mean those infectious organisms that cause pathological disease in humans.

Life Expectancy and Mortality

The life expectancy at birth has varied with time, geography, and the extent to which available knowledge concerning disease prevention and control could be applied. Table 2.1 shows the trend in life expectancy through the ages. The gains in life expectancy in the United States between 1900 and 2000 shown in Table 2.2 have resulted in lower childhood mortality and longer life expectancy, and this is typical of the epidemiologic transition already mentioned. The life expectancy gains since 1900 are due primarily to better sanitation (water filtration and chlorination, sanitary excreta and sewage disposal, milk pasteurization, hygiene), improvements in nutrition, vaccination and the development of antibiotics, and improved medical care. These measures have led to a reduction in infant mortality, the conquest of epidemic and infectious diseases, and an improved quality of life. Many developing countries have achieved dramatic reductions in infectious disease mortality among upper and middle class populations; however, the joint burden of poverty and infectious disease remains entrenched in many areas, including in the United States. In many areas of the United States, including inner cities and Native American reservations, life expectancy is as low as in countries with much higher burdens of infectious disease. Future increase in life expectancy in the United States (and other developed countries) is dependent in part on our ability to identify the causes and control the chronic and degenerative noninfectious diseases such as cardiovascular diseases, malignant neoplasms, and cerebrovascular diseases, provided we maintain and strengthen existing barriers to infectious diseases as needed. In the United States, the top 10 causes of death in 2004 were diseases of the heart, cancer, stroke, chronic lower respiratory disease, unintentional accidents, diabetes, Alzheimer's, influenza and pneumonia, kidney disease, and septic bacterial infections.[12] See Table 2.3.

The prevention of deaths from a particular disease does not increase the life expectancy in direct proportion to its decreased mortality.[13] Keyfitz[14] gives an example showing that if a general cure for cancer were found, there would be nearly 350,000 fewer deaths per year (cancer deaths in 1970). It would seem, then, that the mortality would be lowered by one-sixth, since cancer deaths were

TABLE 2.1 Life Expectancy at Birth

Period of Year	Life Expectancy
Neanderthal (50,000 B.C.–35,000 B.C.)	29.4[a]
Upper Paleolithic (600,000 B.C.–15,000 B.C.)	32.4[a]
Mesolithic	31.5[a]
Neolithic Anatolia (12,000 B.C.–10,000 B.C.)	38.2[a]
Bronze Age, Austria	38[a]
Greek Classical (700 B.C.–460 B.C.)	35[a]
Roman Classical (700 B.C.–A.D. 200)	32[a]
Roman empire (27 B.C.–A.D. 395)	24
1000	32
England (1276)	48[a]
England (1376–1400)	38[a]
1690	33.5
1800	35
1850	40
1870	40
1880	45
1900	47.3[b]
1910	50.0[b]
1920	54.1[b]
1930	59.7[b]
1940	62.9[b]
1950	68.2[b]
1960	69.7[b]
1970	70.8[b]
1980	73.7[b]
1988	74.9[b]
1999	76.5[c]
2004	77.8[d]

Source: J. A. Salvato Jr., "Environmental Health," in *Encyclopedia of Environment Science and Engineering*, E. N. Ziegler and I. R. Pfafflin (Eds.), Gordon Breach Science, London, 1976, p. 286.

Note: The 1981–1982 average life expectancy for Japan was 77.0, Sweden 76.1, and Netherlands and Norway 76.0.

Life expectancy figures after 1690 are for the United States. The average life expectancy for the world) in 1984 was 61 years and for Africa in 1975 it was 45 years. The world population was reported by the United Nations as 4 billion in 1975 and projected to 6.25 billion in 2000. The U.S. Census Bureau in 1986 predicted 6.2 million.

[a]E. S. Deevy Jr., "The Human Population," *Sci. Am*., **203**, 3 (September 1960): 200.

[b]*Health United States 1989*, U.S. Department of Health and Human Services, Public Health Service, March 1990, p. 106.

[c]From ref. 12.

[d]National Center for Health Statistics, Centers for Disease Control and Prevention. *National Vital Statistics Report, Deaths: Final Data for 2004*, Vol. 55(9), August 2007.

TABLE 2.2 Increase in Life Expectancy between 1900 and 1990 at Selected Ages, U.S. Total Population

	Life Expectancy		
Age	1900[a]	2004[b]	Gain During 1900–2004
0	49.2	77.8	28.6
1	55.2	77.4	22.2
5	55.0	73.5	18.5
15	46.8	63.6	16.8
25	39.1	54.0	14.9
35	31.9	44.5	12.6
45	24.8	35.3	10.5
55	17.9	26.6	8.7
60	14.8	22.5	7.7
65	11.9	18.7	6.8
70	9.3	15.1	5.8
75	7.1	11.9	4.8
80	—	9.1	—
85	—	6.8	—

[a]Department of Commerce, U.S. Census Bureau, *United States Life Tables 1890, 1901, 1910, and 1901–1910*, by J. W. Glover, U.S. Government Printing Office, Washington, DC, 1921, pp. 52–53.
[b]National Center for Health Statistics, Centers for Disease Control and Prevention. *National Vital Statistics Report, Deaths: Final Data for 2004*, Vol. 55(9), August 2007.

one-sixth of all deaths, and the life expectancy increased by one-sixth. But this would hold true only for a population with homogeneous individual risks for cancer (ref. 13, p. 954): "Only in such a population would the reduction of the deaths and of the death rate by one-sixth extend the expectation of life by one-sixth. Only then could each of us expect to live 12 more years (assuming a life expectancy of 72 years) as a result of the discovery of a cure for cancer." But because the population is not homogeneous and the risk factors for cancer, and other diseases, vary with age [such as for a 20-year-old man (1: 10,000) compared to a 70-year-old man (1: 100)], the "universal elimination of cancer would increase life expectancy by only about 2 years—not the 12 years that would apply if the population were homogeneous" (ref. 13, p. 955). Keyfitz[14] goes on to say, "But even the gain so calculated (two years if cancer is eliminated) is almost certainly an overestimate of the benefit. For within any given age group, the people subject to any one ailment tend to have higher than average risks from other ailments" (p. 955). To extend average life expectancy beyond 70 years, Keyfitz feels it is necessary to focus on prevention of "deterioration and senescence of the cells of the human body" (p. 956).

Taeuber[15] estimates that the life expectancy of a 65-year-old man would be increased by 1.4 years if there were no cancer; 2.25 years would be added to the average life expectancy for 35-year-olds. Also, of the nearly 2 million deaths that

TABLE 2.3 Leading Causes of Death, 1990, 1960, and 2004 in the United States

Rank	Cause of Death	Deaths per 100,000 Population[a]	Percentage of All Deaths
	1900		
	All causes	1719	
1	Pneumonia and influenza	202.2	11.8
2	Tuberculosis (all forms)	194.4	11.3
3	Gastritis, etc.	142.7	8.3
4	Diseases of the heart	137.4	8.0
5	Vascular lesions affecting the central nervous system	106.9	6.2
6	Chronic nephritis	81.0	4.7
7	All accidents[b]	72.3	4.2
8	Malignant neoplasma (cancer)	64.0	3.7
9	Certain diseases of early infancy	62.5	3.6
10	Diphtheria	40.3	2.3
11	All other and ill-defined causes	615.3	36
	1960		
	All causes	955	
1	Diseases of the heart	366.4	38.7
2	Malignant neoplasms (cancer)	147.4	15.6
3	Vascular lesions affecting the central nervous system	107.3	11.3
4	All accidents[c]	51.9	5.5
5	Certain diseases of early infancy[d]	37.0	3.9
6	Pneumonia and influenza	36.0	3.5
7	General arteriosclerosis	20.3	2.1
8	Diabetes mellitus	17.1	1.8
9	Congenital malformations	12.0	1.3
10	Cirrhosis of the liver	11.2	1.2
11	All other and ill-defined causes	148.4	15
	2004		
	All causes	816.5	
1	Diseases of the heart	222.2	27.2
2	Malignant neoplasms	188.6	23.1
3	Cerebrovascular diseases	51.1	6.3
4	Chronic lower respiratory diseases	41.5	5.1
5	Accidents (unintentional injuries)	38.1	4.7
6	Diabetes mellitus	24.9	3.1
7	Influenza and pneumonia	22.5	2.8
8	Alzheimer's disease	20.3	2.5

(*continues*)

TABLE 2.3 (*continued*)

Rank	Cause of Death	Deaths per 100,000 Population[a]	Percentage of All Deaths
9	Nephritis, nephrotic syndrome, and nephrosis	14.5	1.8
10	Septicemia	11.4	1.4
11	All other and ill-defined causes		22.0

Sources: For 1960 data: *President's Science Advisory Committee Panel on Chemicals, Chemicals and Health*, U.S. Government Printing Office (GPO) Washington, DC, 1973, p. 152; DHEW, PHS, "Facts of Life and Death," DHEW Pub. No. (HRA) 74–1222, GPO, Washington, DC, 1974, p. 31. For 1900 and 2004 data: "National Center for Health Statistics, Centers for Disease Control and Prevention. *National Vital Statistics Report, Deaths: Final Data for 2004*, Vol. 55(9), August 2007. Cause of death is based on *International Classification of Diseases*, 10th rev. 1992, WHO, Geneva.

[a]Crude death rate. Cannot be compared among populations differing in relative age distribution. Does not reflect high percentage of older population dying of natural causes.

[b]Violence would add 1.4%; horse, vehicle, and railroad accidents provide 0.8%.

[c]Violence would add 1.5%; motor vehicle accidents provide 2.3%; railroad accidents provide less man 0.1%.

[d]Birth injuries, asphyxia, infections of newborn, ill-defined diseases, immaturity, etc.

occurred in 1973, 356,000 were attributed to cancer. Two-thirds of those saved lives, according to Taeuber, would have died of heart conditions or strokes.[15] It would seem, then, that a general improvement in the "quality of life" to slow down premature aging, together with prevention and control of the noninfectious as well as communicable diseases, will accomplish a greater increase in life expectancy than concentrating *solely* on elimination of the major causes of death; there will always be a list of the top then causes of death. This appears to be a sound approach since it is known that "mortality levels are determined by the complicated interplay of a variety of sociocultural, personal, biological, and medical factors" (ref. 14, p. 966). However, if the causes of a disease are also contributing factors to other diseases, then elimination of the cause of one disease may, at the same time, eliminate or reduce morbidity and mortality from other diseases, thereby resulting in an additional overall increase in life expectancy. For example, the ready availability of clean water can not only greatly reduce gastrointestinal diseases but also promote personal hygiene and cleanliness, prevent impetigo, reduce stress, and save time. Better nutrition can reduce mortality due to obesity, diabetes, and cardiovascular disease, but it would also improve resistance to certain infectious diseases, reduce birth defects, stunted physical growth, and subtle cognitive deficits, leading to a greater earning potential at the individual level and more productivity and economic security at the population level.

In developed countries, thousands of deaths due to preventable diseases occur each year. Some of these diseases are chronic in nature, and the incidence could be reduced through behavioral interventions (e.g., increased seat belt use, reduced cigarette smoking). Other preventable illnesses are due to infectious diseases such as influenza and pneumonia. There seems to be a consensus that further increase in life expectancy in developed countries is dependent primarily on the extent to which personal behavior will be changed—obesity, poor nutrition, lack of exercise, smoking, reduction of harm related to alcohol and drug consumption, stress—and environmental pollutants will be controlled—industrial and auto emissions, chemical discharges into our air and waters, use of pesticides and fertilizers, interaction of harmless substances forming hazardous compounds[16]—together with a reduction of accidental and violent deaths and an improvement in living and working conditions.

It must also be recognized that although life expectancy is a measure of health progress, it does not measure the morbidity levels and the quality of life.

FRAMEWORK FOR DISEASE TRANSMISSION

Sound factual information upon which to base programs for the prevention and control of morbidity and mortality is sometimes not adequate or available. Multiple causes of disease and delayed effects compound the uncertainties. Broadly speaking, interventions can be targeted at the individual level, the environment, and the infectious agent. Nevertheless, it is prudent to apply and update known health education measures, including screening for early disease detection and treatment, with the full knowledge of their limitations and without raising unreasonable expectations of the public. The environmental preventive measures for disease control are elaborated on here, but the importance of the other measures is not to be minimized.

The goal of environmental health programs is not only the prevention of disease, disability, and premature death but also the maintenance of an environment that is suited to humanity's efficient performance and the preservation of comfort and enjoyment of living today and in the future. The goal is the prevention of not only communicable diseases but also the noncommunicable diseases, the chronic and acute illnesses, and the hazards to life and health. This requires better identification and control of the contributing environmental factors in the air, water, and food at the home and the place of work and recreation, as well as changes in personal behavior and reduced individual assumption of risk. Lacking complete information, the best possible standards based on the available knowledge must be applied for the public good. Standards adoption and regulatory effort should be based on the risk that society or the individual is willing to assume and pay for, taking into consideration other risk factors and needs. At the same time, we must be conscious of limiting disruption to lifestyle and economic activity that could arise as unintended consequences of enacting disease control program. The more onerous a prevention program is, the less likely it is the many people will follow it.

The traditional epidemiologic triangle for infectious diseases has at its vertices three separate factors that influence disease transmission: host, environment, and

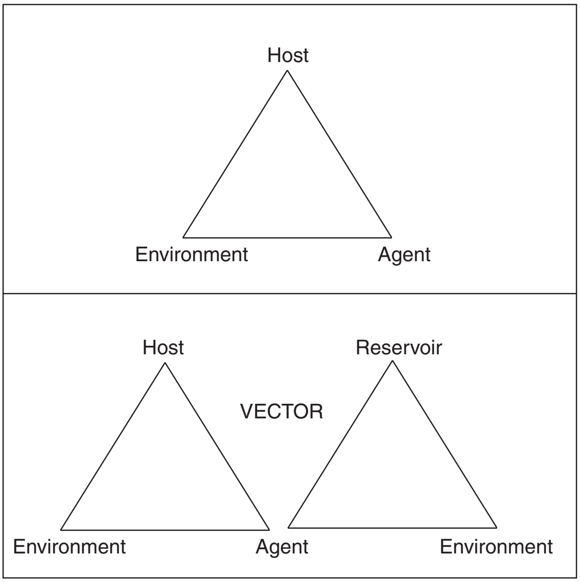

FIGURE 2.1 Epidemiologic triangle framework for infectious disease transmission. Top panel is for non–vectorborne diseases. Bottom panel shows interaction between insect and pathogen. The two "environment" vertices represent the separate milieu in which the host and reservoir reside. The vector participates in both triangles and serves as the bridge between them. Control measures should be targeted at all three/six legs for maximum effectiveness.

agent (Figure 2.1). For arthropodborne diseases, a second triangle is involved, representing the biological interactions between the vector (insect) and the environment. Host factors include genetic and behavioral susceptibility. The agent is the infectious organism. The environment is the setting in which the interaction occurs, and includes the social as well as biological environment. For most effective interruption of disease transmission, interventions must be targeted at all three legs of the triangle. More nuanced versions of this triangle or concept exist, but for our purposes, the three-point model will suffice.

Phelps called the interruption of disease at each of these three points the *principle of multiple barriers.*[17] It recognizes as axiomatic the fact that "all human efforts, no matter how well conceived or conscientiously applied, are imperfect and fallible" (ref. 16, p. 347). Sometimes it is only practical to control or break one link in the chain. Therefore, the number and type of barriers or interventions should be determined by the practicality and cost of providing the protection, the benefits to be derived, and the probable cost if the barriers are not provided. Cost is used not only in the sense of dollars but also in terms of human misery, loss of productiveness, ability to enjoy life, and loss of life. Here is a real opportunity to apply professional judgment to the problems at hand to obtain the maximum return for the effort expended.

REGULATORY AUTHORITIES IN HEALTH

Communicable and certain noninfectious diseases can usually be regulated or brought under control. In the United States, the local or municipal (often at the county level) health department is the fundamental unit of health intervention and surveillance. A health department having a complete and competent staff to prevent or control diseases that affect individuals and animals is usually established for this purpose. The preventive and control measures conducted by a municipal health department might include supervision of water supply, wastewater, and solid wastes; housing and the residential environment; milk and food production and distribution; stream pollution; recreational areas, including camps, swimming pools, and beaches; occupational health and accident prevention; insects and rodents; rural and resort sanitation; air pollution; noise; radiological hazards; hospitals, nursing homes, jails, schools, and other institutions; medical clinics, maternal and child health services, school health, dental clinics, nutrition, and medical rehabilitation; medical care; disease control, including immunizations, cancer, heart disease, tuberculosis, and venereal diseases; vital statistics; health education; epidemiology; and nursing services. In practice however, many local health departments are understaffed and not adequately funded.

The front line of emerging health concerns is often a private clinician's practice or hospital emergency department or poison centers. In the United States, health care providers and biological testing laboratories have mandatory reporting obligations for specified lists of infectious diseases. These data are to be sent to the state health department, usually within days of a presumptive diagnosis. Mandatory reporting is a prime form of disease surveillance, and has been bolstered in reaction of fears about bioterrorism. Large health care facilities, such as teaching hospitals, will have their own surveillance systems for infectious disease, and epidemiologists monitoring infections.

State health departments are involved in disease surveillance, priority setting for policy, and funding initiatives for alleviation of specific diseases. In some states, certain environmental and medical activities are combined with the activities of other agencies and vice versa, making the achievement of a comprehensive and coordinated preventive services program for environmental health more complicated. State health departments must interact closely with legislatures. Funding for disease prevention or health promotion programs can thus be tied to political considerations and public opinion.

At the federal level, the Centers for Disease Control and Prevention (CDC) has a broader mission, including but not limited to, setting national priorities, providing technical assistance, conducting multistate or rare disease outbreak investigations, and serving as an authority to policy makers and Congress. Parallel organizations fulfilling the same roles exist in all countries, with differing levels of capacity and resources. In the United States, the National Institutes of Health (NIH) fund research on diseases, the Food and Drug Administration (FDA) regulates foods, drugs, and cosmetics, the U.S. Department of Agriculture (USDA) sets standards for farming and animal husbandry, and the Environmental Protection Agency (EPA) sets standards for acceptable pollutant levels, funds research, and sets regulations for environmental exposures. Military involvement in outbreaks of infectious diseases with large-scale implications has increased over the last decade, due in part to increased fears of bioterrorism. Specialized offices for particular diseases also exist, such as for mental health and substance use and pandemic influenza. Public and private health financing agencies also have a strong interest in health promotion and may also be involved in interventions. Many infectious diseases have animal sources and veterinary regulatory agencies may also be involved in quelling an outbreak.

Also at the national level are commercial managed health care insurance organizations and public health financing authorities, such as Medicaid, Medicare and the Veterans' Administration (VA) system. These organizations exert influences on the types of diseases that are treated and what medications can be used. For example, a health plan may or may not reimburse for preventative malarial prophylaxis or particular vaccines. Insurance plans also dictate which antibiotics will be paid for, and the order in which they can be used in complicated cases. The medical records from these organizations can be a rich source of data for determining the incidence of infectious diseases that require medical attention, as well as afford details of the comorbid conditions that exist in those presenting with infectious diseases. These organizations also conduct regular review of causes of illness and can make convenient partners in disease investigations.

At the international level, the World Health Organization (WHO) is a technical organization that issues best-practice guidelines and assists member nations in disease prevention and eradication projects. The interactions between these levels of health organizations and regulators become of importance when multidimensional health interventions are proposed. Jurisdictional constraints may limit the reach a health promotion program has and will dictate which parties are involved.

EPIDEMIC CONTROL AT THE INDIVIDUAL LEVEL

Control of infections at the individual level is achieved primarily through three different measures: behavior modification, treatment with antibiotics and antivirals, and prevention through vaccination. We will describe these interventions at these three levels, followed by descriptions of environmental and infectious agent control. First, some basic terminology will be elaborated.

An infected individual goes through four basic stages: incubation period, carrier state, fulminate infection, and remission/immunity. The incubation period is the interval between exposure of a susceptible host to an agent and the establishment of the infection in the host. There are usually no clinical signs of disease in the host during this period. During this period, the person is not usually infectious to others. In the carrier state, the person or animal that harbors an infectious agent in the absence of discernible clinical disease and serves as a potential source of infection; this happens after the incubation period. The carrier state may exist in an individual with an infection that is outwardly unapparent throughout its course. The carrier state may be of short or long duration. During the third stage, fulminate infection (or convalescence), there are overt physical manifestations of disease pathology. Clinical diagnosis based on symptoms can occur at this phase.* Individuals may cycle through periods of clinically expressed disease and carrier state. This cycling can last days, weeks, months or even decades (e.g., herpes, chicken pox/shingles, tuberculosis), depending on the disease. In the fourth phase, remission (or post-convalescence), the individual will no longer express the signs of the disease, and is immune to reinfection. Immunity to reinfection is mediated by circulating antibodies, special protein-based complexes that can "remember" the identity of pathogens and serve to immediately neutralize (render harmless) an infectious organism when it reenters the body. However, in some cases, immunity can wane with age, and the individual may become susceptible to infection by the same organism again. The importance of understanding these four phases will become clear as interventions targeting all phases are discussed.

Behavioral Change

Behavioral interventions aim to control the actions of the individual. The most drastic of these measures, in a civil liberty-oriented society, is restriction of association, achieved through isolation of infected individuals showing signs of disease, quarantine of suspected carriers, and cancellation of school or mass gatherings. The basic idea is to limit the number of individuals who are exposed to the carrier or diseased persons. In order to sustain an infection in a population, a certain number of new individuals must be infected in a given time period. These numbers can be calculated and form the basis for ascertaining the length of the restriction period. Most countries have strict laws on isolation and quarantine, and these are some of the most powerful tools wielded by public health authorities. However, due to the severe interruption of lifestyle and livelihood resulting from these measures, they are rarely used. There has been a shift recently to develop protocols for more benign methods of limiting association, following a "snow day" model. In these instances, people would be encouraged (not forced) to stay home for a few days to prevent new infections.

Other forms of behavior modification for the prevention of infectious disease transmission are routinely employed. For example, in hospitals, frequent hand washing by health care professionals prevents the transmission of disease between patients.[18] Seatbelts, speed limits, driving age restrictions, and drunk driving

*For some infections, such as HIV, there may be an acute phase where mild symptoms are apparent, before progression into the carrier state. For HIV, this acute phase manifests as flulike symptoms and occurs in the week or two following infection. Not all individuals will experience this phase. After this acute phase, all outward signs of the disease subside and the person enters the carrier stage, during which he or she can be infectious (depending on the amount of circulating virus and integrity of the immune system). The acute phase infection has been used as an early surveillance system to identify those recently infected, weeks before traditional testing would have been able to detect the presence of the infection. It is hoped that early detection during the acute phase could be exploited to treat patients before the virus enters particular cell types, increasing the likelihood of clearing the infection.

prohibitions save thousands of lives each year.[19] Condom use and the availability of sterile syringes have been shown to reduce the incidence of HIV, hepatitis, and other sexually transmitted and injection-borne infections.[20] In order to reduce West Nile virus infection from mosquito bites, the use of personal insect repellent and staying indoors at dusk (when the disease carrying insects were active) is encouraged in epidemic areas.[21] Hand washing by foodservice staff also prevents transmission of foodborne diseases, as do industrial hygiene standards for food processing and inspections of facilities.[22] Protective masks are recommended for tuberculosis patients, and gain widespread public use during the outbreak of severe acute respiratory syndrome (SARS).[23]

The interventions described here involve the modification of human behaviors. In order to affect such changes, broad population-based educational campaigns are often used. Laws (such as for seatbelts) can also be enacted to require protective measures be taken for prevention or mortality and morbidity. Fear of sanction, as in the foodservice example, can also serve as a means for creating behavior change. In general, behavioral changes require a willingness on the part of the population to take protective measures to ensure the safety of themselves, but also of others. These types of interventions may take considerable public attention and concern to enact.

Antibiotics and Antivirals

Treatment of those who are showing symptoms of disease, and those who are believed to have been exposed, benefit the individual, but can also shorten the duration or severity of disease and thereby prevent infections in others.

The use of antibiotics and antivirals carry the risk of resistance developing in the infectious agent that could render the drugs useless. When these medications are used indiscriminately, bacteria and viruses that carry naturally occurring mutations that allow them to circumvent the mechanism of the drug's action will have an evolutionary advantage and are likely to become the dominant strain. Therefore, antibiotics and antivirals should be used judiciously and reserved for cases in which they are most likely to confer a medical benefit.

Every drug carries a risk of unintended side effects. In epidemic control, mass administration of antibiotics should be done carefully and limited to those who are most likely to have been exposed. It is an ethically difficult decision to give someone a medication when their level of exposure risk is unknown or low. In such cases, the antibiotic or antiviral serves little or no individual benefit, while the risks of their use to the individual remain. Therefore, mass administration of these medications should be limited to very specialized situations.

Vaccination (or Immunization)

A vaccine is a suspension of attenuated live or killed microorganisms (bacteria, viruses, or rickettsias), or purified protein or polysaccharide portions thereof, administered to induce immunity and thereby prevent infectious disease. Vaccines function by exposing the immune system to just enough of a pathogen to induce antibody formation. The important part of a vaccine is the signature proteins, which are normally expressed on the surface of bacteria or virus; these surface proteins are unique to each infectious agent and are duly recognized by immune system. Antibodies are formed that recognize these proteins, without the infection actually taking hold in the body. When the individual is subsequently exposed to the infectious agent, the antibodies neutralize the pathogen before it can enter cells and replicate. Pathogens coated with antibodies are recognized by immune system cells that destroy the virus or bacteria.

During the twentieth century, the burdens of many infectious diseases were drastically reduced due to widespread vaccination campaigns. Smallpox, the only infectious disease to have been actively eradicated by human beings, was vanquished due to diligent vaccination efforts by the World Health Organization.[24] Polio was also greatly reduced in a similar manner. Childhood vaccinations have made rare the incidence of measles, mumps, rubella, chickenpox, and other infectious diseases in all developed countries and many developing countries. Recently, a vaccine for human papilloma virus (HPV), the leading cause of cervical cancer, has been recommended for adolescent girls, with the hope of reducing mortality from this neoplasm.[25] Adult vaccines for hepatitis B, tetanus, and rabies are also routinely used. Some vaccines need to be administered repeatedly, such as tetanus, due to a decline in circulating antibodies with age. Other vaccines, such as for seasonal influenza must be administered every year since the genetic composition and signature proteins expressed on the surface of the virus changes from year to year.

Although vaccines have a storied and important place in the prevention of infectious disease, they are difficult to develop since they mimic a complex biological interaction. They have also traditionally taken decades to develop, although new advances in molecular biology are intended to reduce development time. Vaccines involve creating a less pathogenic (or "attenuated") form of the infectious agent, often by deleting genes and structures essential for replication. While the molecular mechanisms for creating vaccine strains are well developed, when these attenuated vaccines are used in humans, they may still be capable of producing some disease. Therefore, the same ethical problems as were discussed for mass administration of antibiotics and antivirals also apply to vaccination, namely balancing the benefit to the individual with the benefit to the population. Mass vaccination after release of a bioterrorism agent has been the focus of many studies in recent years, and remains a viable option.[26]

As previously mentioned, infectious diseases need to sustain a level of incidence over time in order to remain established (endemic) in a population. Vaccines do not prevent every case of disease in a population; they reduce the number of new infections so that the infectious agent cannot establish itself and replicate continuously in the population. When an infected (and infectious) individual is placed in a population with high vaccination rates, the chances that he or she will be able to pass along the infection is low. Not every person needs to be immunized, nor does the immunization need to be effective in creating protective antibodies in every person; however, the higher the rates of immunity in the population, the lower the chances that a newly introduced infectious person will infect enough people for the pathogen to be able to become endemic. This concept is called *herd immunity*.

The United States has enjoyed high levels of vaccine coverage for most childhood vaccine preventable diseases. However, there are and will always be subpopulations who are opposed to vaccination for moral and/or religious reasons. In 2005, an outbreak of polio was reported among unvaccinated Amish residents in remote Minnesota.[27] This group had eschewed vaccination on religious grounds, and U.S. law allows for such exemptions. When one member of the group traveled abroad (it is hypothesized), he was infected with polio (and became a carrier) and brought the disease back to the other susceptible members of his community. Since few people had been vaccinated, the virus was able to pass from human to human. Sanitary measures and emergency vaccination were used to control the outbreak, but not before considerable suffering in the small community.

In summary, vaccines play an integral role in protecting the public health. The use of vaccines is problematic due to ethical, biological, and social reasons. However, in the instances that they are available, they can be a crucial tool in breaking the cycle of transmission.

Control of Infectious Agents and Vectors

Arthropods involved in the transmission of human (and animal) disease are called *vectors*. Common vectorborne (or arthropodborne) include malaria, yellow fever, plague, dengue, West Nile virus, Japanese encephalitis, Lyme disease, Chagas disease, sleeping sickness, and leishmaniasis. These diseases combined are the most common infectious diseases in the world. The infectious agent is actually a bacteria or virus, and the insect serves as a vehicle for transmitting the agent to the human host. They are transmitted through bites (and other forms of inoculation) from mosquitoes, ticks, sand fleas, and other insects. The bacteria or virus have a complex biological relationship with the insect, as well as the host. In some cases, the bacterium will cause pathology in the insect. Arthropods serve as a site of maturation for the parasite, and passage through the insect is a crucial step in the natural life cycle of the infectious agent. Referring back to Figure 2.1, controlling arthropod populations can break the cycle of transmission between human and insect. Broadly speaking, this can be achieved through interruption of the parasite life cycle within the insect, or by limiting the reproduction of the insect itself. Vector control is an aspect of environmental engineering that has tremendous impact on infectious disease transmission. The most work has been done in controlling mosquito populations, and some of these interventions will be discussed in this chapter.

The *reservoir* is source of infection, often a nonhuman animal. Reservoirs are not adversely affected by the presence of the infectious agent, and interaction between humans and the reservoir introduce the pathogen into human populations. Wild animals and farm animals can be reservoirs for human disease.

To eliminate or reduce the incidence of insectbome diseases, it is necessary to control the environment and reservoirs and the vectors. This would include control of water and food, carriers of disease agents, and the protection of persons and domestic animals from the disease (immunization). Where possible and practical, the reservoirs and vectors of disease should be destroyed and the environment made unfavorable for their propagation. Theoretically, the destruction of one link in the chain of infection should be sufficient Actually, efforts should be exerted simultaneously toward elimination and control of all the links, since complete elimination of one link is rarely possible and protection against many diseases is difficult, if not impossible, even under ideal conditions. The amount of personnel, funds, and equipment available will frequently determine the action taken to secure the maximum results or return on the investment made.

In developing countries, insecticide-treated bed nets have been distributed and shown to effectively reduce malaria transmission. Including screens on windows in the design of buildings is a relatively simple means of preventing mosquito bites and disease transmission. In addition to such structural changes, preventative anti-malarial medications are sometimes given to individual travelers venturing from areas of no or low malarial endemnicity to areas of higher risk. However, this intervention is not an option in parts of the world where malaria is endemic, due to rapidly developing resistance to the drugs. In certain regions, a sleeping adult may be bitten hundreds of times a night by mosquitoes; if even a small proportion of the insects carry the malarial parasite, the risk of transmission is high. Therefore, reducing mosquito populations can result in a decrease in malarial transmission, as well as better quality of life.

Environmental Control of Infectious Diseases

Environmental interventions for preventing the spread of infectious diseases have long been a central component of public health, with a storied history starting long before the development of medications and vaccines. Malaria eradication in North America was achieved largely through environmental interventions, such as draining swamps and spraying insecticides. Large-scale engineering projects also require public health support. The Panama Canal could not have been built without research conducted by the military on protecting workers from yellow fever.[28]

Traditionally, clean drinking water (often referred to as *potable* water, water that is clean enough, in terms of microorganisms and chemicals, that it could be used for drinking), has been the primary concern of environmental and sanitary engineering, in the realm of infectious disease transmission. Related to this is proper treatment of sewage and other hazardous wastes. Water quality is covered in great detail in Chapter 4. However, there are other areas of environmental engineering that can play a crucial role in preventing the spread of infectious diseases.

The International Rice Research Institute (IRRI), based in the Philippines, has conducted extensive research into implementable environmentally oriented practices for reducing malaria transmission in developing countries. Since mosquitoes need still, nutrient-rich water to breed, rice paddies are a prime habitat for the insect; and, rice is a staple food in many mosquito endemic regions of the world. IRRI has proposed village layout plans that optimally increase the distance to mosquito-breeding grounds by relocating rice paddies to certain distances from homes. They have also developed strains of rise that are resistant to pestilence, resulting in less use of economic chemical poisons. Other projects include reducing methane and nitrous oxide emissions from burning of rice fields at the end of the harvest season,[29] strategies for managing water scarcity in rice producing areas,[30] and plans for increasing biodiversity in agricultural settings.[31]

Commercial air circulation systems have been implicated in the spread of infectious diseases. Legionnaires' disease is caused by the bacterium *Legionella*. It was discovered when attendees at a military veterans' conference staying in the same hotel came down with pneumonia. It was later found that the infectious agent was spread via exhaled droplets that traveled through the ventilation system.[32,33] Air filtration systems that are capable of sequestering airborne infectious organisms are routinely used in developed nations, but more can be done in developing countries to expand this prevention measure.

The spread of infectious diseases within a health care setting is called *nosocomial transmission*. Transmission of infectious diseases in clinical care settings is of grave concern because many hospitalized patients have compromised immune systems, due to medications they are receiving, advanced age, or immune system disorders. A large portion of nosocomial infections can be alleviated with frequent hand washing by health care providers and proper barrier protection. However, some factors influencing nosocomial spread can be alleviated through informed design of hospitals, including air and water filtration systems and proper waste disposal. For example, the shape of sinks in hospitals has been linked to transmission of *Pseudomonas aeruginosa*, a severe respiratory infection, often resistant to drugs, that preferentially infects hospitalized patients. One study found that faucets and taps were contaminated by the bacterium when water poured out from drinking glasses splashed upward.[34] In Europe, there were reports of transmission of smallpox from hospital workers breathing in aerosolized virus particles from dirty laundry.[35] In these cases, simple engineering and process control measures were enacted to end the outbreaks, alongside vaccination (when available and appropriate).

The Centers for Disease Control and Prevention have issued four guidelines for environmental infection control in health care facilities:[36]

1. Appropriate use of cleaners and disinfectants;
2. Appropriate maintenance of medical equipment (e.g., automated endoscope reprocessors or hydrotherapy equipment);
3. Adherence to water-quality standards for hemodialysis, and to ventilation standards for specialized care environments (e.g., airborne infection isolation rooms, protective environments, or operating rooms); and
4. Prompt management of water intrusion into the facility.

Routine environmental sampling is not usually advised, except for water quality determinations in hemodialysis settings and other situations where sampling is directed by epidemiologic principles, and results can be applied directly to infection-control decisions.

In summary, environmental measures for prevention of infectious diseases are a well-acknowledged component of public health. Since air and water are common vehicles for transmission of viruses and bacteria, the scope for increased participation of the environmental engineering community is vast.

Arthropodborne Diseases

Arthropod or insectborne diseases are an important class of diseases that affect millions of people worldwide. They have a long history of causing human suffering. The bubonic plague that devastated Europe in the late medieval period was transmitted via bites from a flea. Today, malaria is an archetype mosquitoborne disease for research.

The addition of an arthropod species to the transmission cycle results in a more dynamic and complex ecological to understand, but one which offers additional avenues for intervention. Again, multilevel responses have been shown to be most effective against vectorborne diseases, just as they have been for other infectious agents.

A *host* is a person or other living animal, including birds and arthropods, that provides subsistence or lodgment to an infectious agent under natural (as opposed to experimental) conditions. Some protozoa and helminths pass successive stages in alternate hosts of different species. Hosts in which the parasite attains maturity or passes its sexual stage are *primary* or *definitive hosts*; those in which the parasite is in a larval or asexual state are *secondary* or *intermediate hosts*. A *transport host* is a carrier in which the organism remains alive but does not undergo development.[1]

The infectious agent can be a virus, bacteria, or multicellular organism. We refer to the arthropod that delivers the infectious agent to humans as the *vector*. Vectors can involve simple mechanical carriage of the infectious agent by a crawling or flying insect through soiling of its feet or proboscis, or by passage of organisms or eggs through its gastrointestinal tract. This does not require multiplication or development of the infectious agent within the arthropod. The other type of vector-agent interaction involves a more complex biological process; the pathogen will undergo transitions in its life cycle while inside the insect. The transition is required before the arthropod can transmit the infective form of the agent to humans. The *extrinsic incubation period* is the time a pathogen requires to develop or multiply in the vector before it can be transmitted to another host. The infectious agent may be passed vertically to succeeding generations of arthropod (transovarian transmission); transstadial transmission indicates its passage from one stage of life cycle to another, as nymph to adult. Transmission may be by injection of salivary gland fluid during biting or by regurgitation, or deposition on the skin of feces or other material capable of penetrating through the bite wound or through an area of trauma from scratching or rubbing.[1]

Usually, mosquitoes, lice, ticks, and other blood-sucking insects spread disease from person to person, or animal to human by biting a person or animal carrying the disease-causing organisms. By taking blood containing the disease-producing organisms, the insect is in a position to transmit the disease organism when biting another person or animal. The complete elimination of rodents and arthropods associated with disease is a practical impossibility. Humans, arthropods, and rodents, therefore, offer ready foci for the spread of infection unless controlled.

Lately, insectborne diseases that had been confined to Africa or South America are showing up in the United States. A good example of this is West Nile Virus. This virus, a flavivirus, causes encephalitis in susceptible individuals. It was formerly found in Africa, Southeast Asia, and the Middle East, but how now been detected in the United States. It is spread by *Culex* mosquitoes, and usually is not spread from person to person. However, there are documented cases of people obtaining the virus from an organ donor.[37] The donor was apparently healthy before a fatal accident and the donor's organs were transplanted into four individuals who became ill with a febrile illness progressing to encephalitis 7 to 17 days posttransplantation. Their cerebral spinal fluid was tested and found positive for West Nile Virus. The donor's serum was also tested by a PCR test and found positive for West Nile Virus.[38] This indicates that transmission routes can change, and unusual transmissions should be considered when investigating the cause of insectborne diseases.

A list of insectborne diseases together with their important reservoirs is given in Table 2.4, Table 2.5, and Table 2.6. The list is not complete but includes some of the common as well as less-known diseases.

Since many diseases are known by more than one name, other nomenclature is given to avoid confusion. As time goes on and more information is assembled, there will undoubtedly be greater standardization of terminology. In some cases there is a distinction implied in the different names that are given to very similar diseases. The names by which the same or similar diseases are referred to are presented below.

Bartonellosis includes oroya fever, Carrion's disease, and verruga peruana. Dengue is also called dandy fever, breakbone fever, bouquet, solar, or sellar fever. Endemic typhus, fleaborne typhus, and murine typhus are synonymous. Epidemic typhus is louseborne typhus, also known as classical, European, and Old-World typhus. Brill's disease is probably epidemic typhus. Plague, black death, bubonic plague, and fleaborne pneumonic plague are the same. Filariasis or mumu are infestations of *Wuchereria bancrofti* that may cause obstruction of lymph channels and cause elephantiasis. Loa loa and loiasis are the same filarial infection. Cutaneous leishmaniasis, espundia, uta, bubas and forest yaws, Aleppo/Baghdad/Delhi boil, chiclero ulcer, and oriental sore are synonyms. Visceral leishmaniasis is also known as kala azar. Malaria, marsh miasma, remittent fever, intermittent fever, ague, and jungle fever are synonymous. Blackwater fever is believed to be associated with malaria. Onchocerciasis is also known as blinding filarial disease. Sandfly fever is the same as phlebotomus fever, three-day

TABLE 2.4 Characteristics of Some Insectborne Disease

Disease	Etiologic Agent	Reservoir	Transmission	Incubation Period	Control[a]
Endemic typhus (murine) (fleaborne)[b]	*Rickettsia typhi* (*R. mouserl*) also possibly *Ctenocephalides felis*	Infected rodents, *Rattus rattus* and *Rattus norvegicus*, also fleas, possibly opossums	Bite or feces of rat flea *Xenopsylla cheopis*; also possibly ingestion or inhalation of dust contaminated with flea feces or urine.	7–14 days, usually 12 days	First elimination of rat flea by insecticide applied to rat runs, burrows, and harborages, then rat control. Spray kennels, beds, floor cracks.
Epidemic typhus (louseborne)	*Rickettsia prowazeki*	Infected persons and infected lice	Crushing infected body lice *Pediculus humanus* or feces into bite, abrasions, or eyes. Possibly louse feces in dust.	7–14 days, usually 12 days	Insecticidal treatment of clothing and bedding; personal hygiene, bathing, elimination of overcrowding, Immunization. Delousing of individuals in outbreaks.
Bubonic plague	*Pasteurella pestis*, plague bacillus (*Yersinia pestis*)	Wild rodents and infected fleas	Bite of infective flea *X, cheopis*, scratching feces into skin, handling wild animals, occasionally bedbud and human flea; pneumonic plague spread person to person.	2–6 days	Immunization, Surveys in endemic areas. Chemical destruction of flea. Community hygiene and sanitation; rat control. (Plague in wild rodents called sylvatic plague.)

Q fever	*Coxiella burneti* (*Rickettsia burneti*)	Infected wild animals (bandicoots); cattle, sheep, goats, ticks, carcasses of infected animals	Airborne rickettsias in or near premises contaminated by placental tissues; raw milk from infected cows, direct contact with infected animals or meats	2–3 weeks	Immunization of persons in close contact with rickettsias or possibly infected animals. Pasteurization of all milk at 145°F for 30 min or 161°F for 15 sec.
Rocky Mountain spotted fever	*Rickettsia rickettsii*	Infected ticks, dog ticks, wood ticks, Lone Star ticks	Bite of infected tick or crushed tick blood or feces in scratch or wound.	3–10 days	Avoid tick-infested areas and crushing tick in removal; clear harborages; insecticides.
Colorado tick	Colorado tick fever virus	Infected ticks and small animals	Bite of infected tick, *Dermacentor andersoni*	4–5 days	See Rocky Mountain spotted fever.
Tularemia	*Franciscella tularensis* (*Posteurella tularensis*)	Wild animals, rabbits, muskrats; also wood ticks	Bite of infected flies or ticks, handling infected animals. Ingestion of contaminated water or insufficiently cooked rabbit meat.	1–10 days, usually 3 days	Avoid bites of ticks, flies. Use rubber gloves in dressing wild animals; avoid contaminated water; thoroughly cook rabbit meat.

(*continues*)

TABLE 2.4 (*continued*)

Disease	Etiologic Agent	Reservoir	Transmission	Incubation Period	Control[a]
Rickettsial-pox	*Rickettsia akari*	Infected house mice; possibly mites	Bite of infective rodent mites	10–24 days	Mouse and mite control. Apply miticides to infested areas; incinerators.
Scabies	*Sarcoptes scabiei*, a mite	Persons harboring itch mite; also found in dogs, horses, swine (called mange); not reproduced in skin of humans	Contact with persons harboring mite and use of infested garments or bedding; also during sexual contact	Several days or weeks	Personal hygiene, bathing, chemical treatment, clean laundry; machine laundering. Exclude children from school until treated. Prevent crowded living.
Trypanosomiasis, American	*Trypanosoma cruzi*	Infected persons, dogs, cats, wood rats, opossums	Fecal material of infected insect vectors, conenosed bugs in eye, nose, wounds in skin	5–14 days	Screen and rat proof dwellings; destroy vectors by insecticides and on infested domestic animals.
Scrub typhus	*Rickettsia tsutsugamushi*	Infected larval mites, wild rodents	Bite of infected larval mites	10–12 days	Eliminate rodents and mites; use repellents; clear brush.
Trypanosomiasis, African (sleeping sickness)[c]	*Trypanosoma gambiense*	Humans, wild game, and cattle	Bite of infected tsetse fly	2–3 weeks	Fly control; treatment of population; clear brush; education in prevention.

Lyme disease	*Borrella burgdorferi*	White-footed field mice in eastern United States and lizards and jack-rabbits in the West; ixodid tick feeds on and survives on white-tailed deer	Bite of infected deer tick nymph and adult	3–32 days, average 7 days	Identify and post infested areas and educate public to avoid ticks. Use repellent—deet or pemethrin. Inspect for presence of ticks, also cats and dogs, and remove without crushing. Early treatment if bitten.

Source: Various sources and ref. 3.

[a]Investigation and survey usually precede preventive and control measures.

[b]"The association of seropositive opossums with human cases of murine (endemic) typhus in southern California and the heavy infestation of the animals with *Ctenocephalides felis* which readily bite man, suggest that opossums and their ectoparasites are responsible for some of the sporadic cases of typhus in man." W. H. Adams, R. W. Emmons, and J. E. Brooks, "The Changing Ecology of Murine (Endemic) Typhus in Southern California," *Am. J. Trop. Med. Hyg*. (March 1970): 311–318.

[c]African trypansomiasis, or Chagas disease, affects 16–18 million people with 90 million at risk according to the WHO, *Nation's Health* (July 1990): 9.

TABLE 2.5 Mosquitoborne Diseases

Disease	Etiologic Agent	Reservoir	Transmission	Incubation Period	Control
Dengus or Breakbone fever[a]	Viruses of dengue fever	Infected vector mosquitoes, humans, and possibly animals, including the monkey	Bite of infected *Aedes aegypti, A. albopictus, A, scutellaris* complex	3–15 days, commonly 5–6 days.	Eliminate *Aedes* vectors and breeding places; screen rooms; use mosquito repellents.
Encephalitis, anthropodborne viral	Virus of Eastern equine, Western, St. Louis, Venezuelan equine, Japanese B, Murray Valley, West Nile, and others	Possibly wild and domestic birds and infected mosquitoes, ring-necked pheasants, rodents, bats, reptiles	Bite of infected mosquito, probably *Culiseta melanura* and *Aedes* for Eastern; *Culex tarsalis* for Western; *Culex tritaeniorhynchus* for Japanese; *Culex pipiens-quinquefasciatus* for St. Louis, also *Culex nigripalpus*	Usually 5–15 days	Destruction of larvae and breeding places of *Culex* vectors. Space spraying, screening of rooms; use mosquito bed-nets where disease present. Avoid exposure during biting hours or use repellents. Public education on control of disease. Vaccination of equines.
Filariasis[a] (elephantiasis after prolonged exposure)	Nematode worms, *Wuchereria bancrofti* and *W. malayi*	Blood of infected person bearing microfiliariae, mosquito vector	Bite of infected mosquito; *Culex fatigans, C. pipiens; Aedes polynesiensis* and several species of anopheles	3 months; microfilariae do not appear in blood until at least 9 months	Antimosquito measures. Determine insect vectors, locate breeding places, and eliminate. Spray buildings. Educate public in spread and control of disease.

Malaria[a]	*Plasmodium vivax, P. malariae, P. falciparum, P. ovale*	Humans and infected mosquitoes, found between 45° N and 45° S latitude and where average summer temperature is above 70°F or the average winter temperature is above 48°F or the average winter temperature is above 48°F	Bite of certain species of infected anopheles and injection or transfusion of blood of infected person	Average of 12 days for falciparum, 14 for vivax, 30 for malariae; sometimes delayed for 8–10 months	Resudual insecticide on inside walls and places where anopheles rests. Community spraying. Screen rooms and use bed-nets in edemic areas. Apply repellents to skin and clothing. Eliminate breeding places by drainage and filling; use larvicides; oil and Paris green. Suppressive drugs, treatment, health education. *Gambusia affinis* fish for larvae control.
Rift Valley fever[b]	Virus of Rift Valley fever	Sheep, cattle, goats, monkeys, rodents	Probably through bite of infected mosquito or other blood-sucking arthropod; laboratory infections and butchering	Usually 5–6 days	Precautions in handling infected animals. Protection against mosquitoes in endemic areas. Care in laboratory.

(*continues*)

TABLE 2.5 (*continued*)

Disease	Etiologic Agent	Reservoir	Transmission	Incubation Period	Control
Yellow fever[a]	Virus of yellow fever	Infected mosquitoes, persons, monkeys, marmosets, and probably marsupials	Bite of infected *A. aegypti*. In South Africa, forest mosquitoes, *Haemagogus spegazzinii*, and others; in East Africa, *Aedes simpsoni, A. africanus*, and others; in forests of South America, by bite of several species of *Naemagogus* and *Aedes leucoceldenus; Aedes albopictus* in Asia, Pacific, also southern United States and Brazil[b]	3–6 days	Control of *Aedes* breeding places in endemic areas. Intensive vaccination in South and East Africa. Immunization of all persons exposed because of residence or occupation. In epidemic area spray interior of all homes, apply larvicide to water containers; mass vaccination, evaluation surveys.

Source: Various sources and ref. 3.

[a]Normally not found in United States, The WHO estimates that 90 million people have lymphatic filariasis, with 900 million at risk: *The Nation's Health*, (July 1990): 8–9.

[b]*PAHO Bulletin*, **21**, 3 (1987): 314.

TABLE 2.6 Some Exotic Insectborne Diseases (Not Normally Found in the United States)

Disease	Incubation Period	Reservoir	Vector
Bartonellosis	16–22 days	Man	Sandflies (*Phlebotomus*)
Leishmaniasis			
cutaneous Visceral	Days to months 2–4 months	Animals, dogs Man, dogs, cats, wild rodents	Sandflies (*Phlebotomus*) Sandflies (*Phlebotomus*)
Loiasis (*Loa loa*)	Years	Man	Chrysops, blood-sucking flies
Sandfly fever	3–4 days	Man, sandfly	Sandfly (*Phlebotomus*)
Relapsing fever	5–15 days	Man, ticks, rodents	Lice, crushed in wound; ticks
Trench fever	7–30 days	Man	Lice, crushed in wound (*Pediculus humanus*)

Source: Ref. 3.

fever, and pappataci fever. Q fever is also known as nine-mile fever. Febris recurrens, spirochaetosis, spirillum fever, famine fever, and tick fever are terms used to designate relapsing fever. Rocky Mountain spotted fever, tick fever of the Rocky Mountains, tick typhus, black fever, and blue disease are the same. Tsutsugamushi disease, Japanese river fever, scrub typhus, and miteborne typhus are used synonymously. Trench fever is also known as five-day fever, Meuse fever, Wolhynian fever, and skin fever. Plaguelike diseases of rodents, deer-fly fever, and rabbit fever are some of the other terms used when referring to tularemia. Other forms of arthropodborne infectious encephalitis in the United States are the St. Louis type, the Eastern equine type, and the Western equine type; still other types are known. Nasal myiasis, aural myiasis, ocular myiasis or myiases, cutaneous myiases, and intestinal myiases are different forms of the same disease. Sleeping sickness, South American sleeping sickness, African sleeping sickness, Chagas' disease, and trypanosomiasis are similar diseases caused by different species of trypanosomes. Tick-bite fever is also known as Boutonneuse fever, Tobia fever, and Marseilles fever; Kenya typhus and South African tick fever are related. Scabies, "the itch," and the "seven-year itch" are the same disease.

Two vectorborne disease involving different types of vectors are detailed below to give the reader a sense of the different issues that arise in vector management: malaria and plague.

Malaria Nearly 40 percent of the world's population lives in regions at risk for malaria. The World Health Organization estimates that each year 500 million people become severely ill as a result of malaria.[39] The burden of disease falls disproportionately on some of the poorest countries, with most deaths due to malaria occurring in sub-Saharan Africa.

Malaria is a caused by parasites of the species *Plasmodium* that are spread from person to person through the bites of infected mosquitoes. The common first symptoms—fever, headache, chills, and vomiting—appear 10 to 15 days after a person is infected. If not treated promptly with effective medicines, malaria can cause severe illness that is often fatal. There are four types of human malaria—*Plasmodium falciparum*, *P. vivax*, *P. malariae*, and *P. ovale*. *P. falciparum* and *P. vivax* are the most common. *P. falciparum* is by far the most deadly type of malaria infection.[39]

Environmental factors directly influence malaria transmission. These include rainfall patterns, proximity of mosquito breeding sites to human settlements, the distribution and biting patterns of mosquito species, and mass application of commercial poisons. Changes in weather and climate, as well as natural disasters, can lead to epidemics of malaria, even in areas where few human cases have been reported. In the United States, most cases are a result of returning travelers from malaria-endemic areas. Cases of malaria transmitted through blood transfusions have also been reported in the United States.[40,41]

The WHO defines the main objective of malaria vector control as: "to significantly reduce both the number and rate of parasite infection and clinical malaria by controlling the malaria-bearing mosquito and thereby reducing and/or interrupting transmission".[39] The two main recommended strategies for limiting mosquito bites are indoor residual spraying of long-acting insecticide (IRS) and long-lasting insecticidal nets (LLINs). Larval control and environmental control of mosquito breeding locations is achieved through a process called Integrated Vector Management (IVM).

Plague Plague is a rare but frequently fatally zoonosis caused by the gram-negative bacterium *Yersinia pestis*. Humans are infected by the bites of infected rodent fleas, by handling infected animals, or rarely, by human-to-human transmission of pneumonic plague. Plague was first described in the United States in 1900 and is thought to have been introduced into San Francisco from plague-endemic regions of Asia.[42] Plague is now endemic in the western United States, where a median of seven human cases occur annually.[43] Plague is enzootic in wild rodent populations in rural areas of the Americas, Africa, and Asia, with occasional outbreaks among rats or other rodent hosts in villages and small towns. Wild rodent plague poses a real, although limited, risk to humans. When infection spreads to rats in urban or populated areas, persons are at markedly increased risk of exposure. In recent decades, urban outbreaks have been rare and limited in size.[44]

There are three principal clinical forms of plague: bubonic, septicemic, and pneumonic.[45] All three forms may be accompanied by fever and systemic manifestations of gram-negative sepsis and cause high mortality unless promptly diagnosed and treated. Patients with bubonic plague have a characteristic bubo (i.e. one or more enlarged, tender, regional lymph nodes, often auxiliary or inguinal). Septicemic plague may be primary when the bacteria invade and multiply in the bloodstream in the absence of an apparent bubo, or may occur secondarily to bubonic plague. Patients with pneumonic plague can have dyspnea, chest pain, and a cough that can produce bloody sputum.[46]

Plague is treatable in its early stages with appropriate antibiotics. Appropriate antibiotic treatment should be initiated immediately if plague is suspected. Drugs effective against plague include streptomycin, gentamicin, and the tetracyclines.[47] Fluroquinolone antibiotics are commonly used empirically to treat critically ill patients and have demonstrated activity against *Y. pestis in vitro, in vivo*, and in limited clinical use.[48] Penicillins and cephalosporins are not effective for plague treatment.

In the United States, most plague exposures occur in or around the home.[45,49] Plague can be prevented by year-rodent control, including rodent-proofing structures, elimination of food sources such as pet food and garage, and removal sources of rodent harborage. Additionally, persons residing in endemic areas should keep their dogs and cats free of fleas through regular use of flea treatments, and restrict pets from wandering. Persons who participate in outdoor recreational activities in areas of plague epizootic activity should use personal protective measures including use of insect repellents and protective clothing, and avoiding sick or dead animals. Public health officials should treat rodent habitats with effective insecticides and should conduct public education about plague prevention and control.[49]

Zoonoses and Their Spread

Zoonoses are infections that are transmitted from animals to humans. Many vectorborne disease are also capable of infecting other animals, with differing levels of severity. Zoonoses have garnered attention because it is recognized that many newly discovered or "emerging" infections in humans originated from animal sources. In addition, many infectious disease that were believed to be controlled or vanquished are making a resurgence as human interaction with wild animals has increased as a result of clearing and development previously uninhabited land. In this way, infectious diseases are directly linked to the environment and industrial development. Sensible environmental protection includes prevention of zoonoses.

The Pan-American Health Organization lists as the major zoonoses in the Americas encephalitis (arthropodborne), psittacosis, rabies, jungle yellow fever, Q fever, spotted fever (Rocky Mountain, Brazilian, Colombian), typhus fever, leishmaniasis, trypanosomiasis (Chagas' disease), anthrax, brucellosis, leptospirosis, plague, salmonellosis, tuberculosis (bovine), tularemia, hydatidosis, taeniasis (cysticercosis), and trichinosis. Others are ringworm, crytococcosis, toxoplasmosis, yersiniosis, cat scratch fever, tetanus, and tapeworm, hookworm, and roundworm infections;[50] as well as histoplasmosis, equine encephalitis, cryptosporidiosis, campylobacter infection, and Lyme disease. It will be recognized that some of these diseases are also classified with water-, food-, or insectborne diseases. A very comprehensive summary of zoonoses was prepared by Steele[50] and the Pan American Health Organization.[51]

The rodentborne diseases include rat-bite fever, Haverhill fever, leptospirosis, choriomeningitis, salmonellosis, tularemia, possibly amebiasis or amebic dysentery, rabies, trichinosis (indirectly), and tapeworm. Epidemic typhus, endemic or murine typhus, Rocky Mountain spotted fever, tsutsugamushi disease, hantavirus,[52] and others are sometimes included in this group. Although rodents are reservoirs of these diseases (typhus, spotted fever, etc.), the diseases themselves are actually spread by the bite of an infected flea, tick, or mite or the blood or feces of an infected flea or tick on broken skin, as previously discussed. Rats are also carriers of *S. aureus, E. coli, Y. enterocolitica*, and *Yersinia pseudotuberculosis*, as well as leptospirae and other pathogens.

Sodoku and Haverhill fevers are two types of rat-bite fever. The incubation period for both is 3 to 10 days. Contaminated milk has also been involved as the cause of Haverhill fever. The importance of controlling and destroying rats, particularly around dwellings and barns, is again emphasized.

The causative organism of leptospirosis, also known as Weil's disease, spirochetosis icterohemorrhagic, leptospiral jaundice, spirochaetal jaundice, hemorrhagic jaundice, canicola fever, mud fever, and swineherd's disease, is transmitted by the urine of infected rodents, cattle, dogs, swine, and wild animals. Direct contact or the consumption of contaminated food or water or direct contact with waters containing the leptospira may cause the infection after 4 to 19 days.

Dogs are carriers of many microorganisms and parasites that are discharged in the feces and urine and that may be transmitted to humans, particularly children. These include *G. lamblia* and *T. canis*, an ascarid roundworm (the larval stage in humans is called visceral larva migrans, a rare but serious disease if the larval stage lodges in the brain, eyes, heart, or liver). *Toxocara cati* and *Ancylostoma brazillense* are found in cats. *Ancylostoma caninum* is a canine hookworm that may affect humans. *Dipylidium caninum* and *Taenia pisiformis* are two common canine tapeworms; *Toxoplasma gondii*, a protozoa causing toxoplasmosis is also carried by cats, goats, pigs, rats, pigeons, and humans. Salmonella and campylobacter bacteria can also be transmitted to humans and from humans to dogs. Dogs are the reservoir of many other diseases. Stray and pet dogs are carriers of *Brucella canis*; stray dogs have a higher rate of infection (9 percent as compared to 1 percent for pet dogs).[53] A significant number of dogs and cats excrete the toxocara ova, and the hazard to human health is reported to be considerable.[54] General control measures include proper disposal of dog feces; avoidance of contact with the feces, such as in children's play areas; deworming of dogs; regulation of dogs in urban areas; and personal hygiene. In addition, there are the hazards associated with fleas, ticks, and rabies as well as play areas and street pollution from feces and urine. Pregnant women should exercise extreme sanitary precautions and avoid any contact.

The virus causing lymphocytic choriomeningitis (LCM) is found in the mouth and nasal secretions, urine, and feces of infected house mice, which, in turn, can infect guinea pigs and hamsters. The virus is probably spread by contact, bedding, or consumption of food contaminated by the discharges of an infected mouse. The disease occurs after an incubation period of 8 to 21 days. Precautions include destruction of infected mice, hamsters, and guinea pigs and burning their bodies and bedding. This is followed by cleansing all cages with water and detergent, disinfecting, rodent-proofing pet stores and animal rooms in laboratories and hospitals, and waiting a week before restocking with LCM-free animals

Tularemia may be transmitted by handling infected rodents with bruised or cut hands, particularly rabbits and muskrats, by the bite of infected deerflies, ticks, and other animals, and by drinking contaminated water. Freezing may not destroy the organism.

Anthrax, also known as woolsorter's disease, malignant pustule, and charbon, is an infectious disease principally of cattle, swine, sheep, and horses that is transmissible to humans (Table 2.7). Many other animals may be infected. In 2001, purified anthrax spores were implicated in an intentional release/bioterrorism event that resulted in deaths in five states, with documented transmission through postal mail sorting facilities[55,56].

Rabies is a disease of many domestic and wild animals and biting mammals, including bats. In 2001, 7,437 laboratory-confirmed cases were reported to the CDC in the United States and its territories. raccoons (37.2%; 2,767 cases), skunks (30.7%; 2,282), bats (17.2%; 1,281), foxes (5.9%; 437), cats (3.6%; 270), dogs (1.2%; 89), and cattle (1.1%; 82).[57] One human case was reported to CDC in 2001, and five in the previous year. Rabies virus is the only known infection to cause 100 percent mortality in humans.

Every sick-looking dog or other animal that becomes unusually friendly or ill-tempered and quarrelsome should be looked on with suspicion. One should not place one's hand in the mouth of a dog, cat, or cow that appears to be choking. A rabid animal may be furious or it may be listless; it may salivate heavily or have spasms, paralysis, and a hung jaw, depending on the form of the disease. A person bitten or scratched by a rabid animal, or an animal suspected of being rabid, should immediately wash and flush the wound and surrounding area thoroughly with soap and warm water, a mild detergent and water, or plain water if soap or detergent is not available and seek immediate medical attention. The physician will notify the health officer or health department of the existence of the suspected rabid animal and take the required action.

Airborne spread of the virus has been demonstrated in the laboratory and in the air of heavily bat-infested caves.

The animal (usually a pet) should be caged or tied up with a strong chain and isolated for 10 days; if any of the above symptoms appear, a veterinarian should evaluate the animal. An animal suspected of being rabid that has not been vaccinated will have to be confined for four months or be killed. A dog or cat bitten by or exposed to a rabid animal should be confined for 6 months and vaccinated 1 month before release or be destroyed. Consult the local health department. Any domestic animal that is bitten or scratched by a bat or a wild, carnivorous mammal that is not available for testing should be regarded as having been exposed to a rabid animal. A wild animal, if suspected, should be killed without unnecessary damage to the head. Gloves should be worn when handling the carcass of a suspected rabid animal, since rabies virus can be introduced

TABLE 2.7 Some Characteristics of Miscellaneous Disease

Disease	Etiologic Agent	Reservoir	Transmission	Incubation Period	Control
Ringworm of scalp (tinea capitis)	*Microsporum* and *Trichophyton*	Infected dogs, cats, cattle	Contact with contaminated barber clippers, toilet articles or clothing, dogs, cats, cattle, backs of seats in theaters, planes, and railroads	10–14 days	Survey of children with wood lamp; education about contact with dogs, cats, infected children; reporting to school and health authorities; treatment of infected children, pets, and farm animals; investigation of source.
Ringworm of body (tinea corporis)	*Epidermophyton floccosum, Microsporum, trichophyton*	Skin lesions of infected humans or animal	Direct contact with infected person or contaminated floors, shower stalls, benches, towels, etc.; lesions of infected persons or animals	4–14 days	Hot water laundering of towels; fungicidal treatment of floors, benches, mats, shower stalls with creosol or equal. exclusion of infected persons from pools and gyms. Treatment of infected persons, pets, and animals. Cleanliness, sunlight, dryness.
Ringworm of foot (tinea pedis) (athlete's foot)	*Trichophyton rubrum, T. mentagrophytes*	Skin lesions of infected humans	Contact with skin lesions of infected persons, contaminated floors, shower stalls, benches, mats, towels	Unknown	In addition to above, drying feet and between toes with individual paper towels; use of individual shower

					sandals, foot powder, and clean sterilized socks. Well-drained floors in bathhouses, pools, etc.
Ringworm of nails (tinea unguium)	Epidermophyton and *Trichophyton*	Skin or nails of infected persons, soil, animals	Probably from infected feet, contaminated floors, shower stalls	Unknown	Same as above.
Ancylostomiasis (hookworm disease)	*Necator americanus* and *Ancylostoma duodenale*	Feces of infected persons; soil containing infective larvae; cats and dogs	Larvae hatching from eggs in contaminated soil penetrate foot; larvae also swallowed	Weeks to months	Prevention of soil pollution; sanitary privies or sewage disposal systems; wearing shoes; education in method of spread; treatment of cases; sanitary water supply.
Rabies (hydrophobia)	Virus of rabies	Infected dogs, foxes, cats, squirrels, cattle, horses, swine, goats, wolves, bats, skunks, wild and domestic animals	Bite of rabid animal or its saliva on scratch or wound	2–8 weeks, as little as 5 days, or more than 1 year	Detention and observation for 10 days of animal suspected of rabies. Immediate destruction or 6 months detention of animal bitten by a rabid animal. Vaccination of cats and dogs, dogs on leashes; dogs at large confined. Education of public. Avoid killing animal; if necessary, save head intact. Reduce wildlife reservoir in cooperation with conservation agencies. If bitten, wash wound immediately and obtain medical attention.

(*continues*)

TABLE 2.7 (*continued*)

Disease	Etiologic Agent	Reservoir	Transmission	Incubation Period	Control
Tetanus	*Clostridium tetani*, tetanus bacillus	Soil, street dust, animal feces containing bacillus	Entrance of tetanus bacillus in wound, puncture wound, burn, or minor wound	3 days to 3 weeks, average of 10 days	Immunization with primary series of three doses of tetanus toxoid plus reinforcing dose and booster every 10 years. Allergic persons should carry record of sensitivity. Thorough cleansing of wounds. Safety program.
Anthrax	*Bacillus anthracis*	Cattle, sheep, goats, horses, swine, skins and hides of infected animals	Contaminated hair, wool, hides, shaving brushes, ingestion or contact with infected meats; inhalation of spores; flies possibly; laboratory accidents (Shaving brushes are under PHS regulations. Bristles soaked 4 hours in 10% formalin at a temperature of at least 110°F destroys anthrax spores.); intentional release/bioterrorism	7 days, usually less than 4 days	Isolation and treatment of suspected animals. Postmortem examination by veterinarian of animals suspected of anthrax and deep burial of carcass, blood, and contaminated soil at a depth of at least 6 feet or incineration. Spores survive a long time. Vaccination of workers handling animals, hair, hides, or meats; personal hygiene; prompt treatment of abrasions. Treatment of

					trade wastes. Disinfection of wool, hide, animal food. Dust control.
Myiasis	*Cochliomya hominivorax* fly larva (screwworm)	Humans and vertebrate animals	Fly (dipterous) infestation of humans and vertebrate animal tissue with fly larvae	Variable	Prevent fly larvae or egg infestation of wounds, skin, eye, ear, nasopharynx, food, and genitourinary tract. Manual removal of larvae. Personal hygiene, medical treatment. Release artificially sterilized male flies. Apply insecticide (dichlorvos).
Yaws	*Treponema pertenue*	Humans and possibly higher primates	Direct contact with exudates of early skin lesions of infected persons; also contamination from scratching and flies on open wounds	2 weeks to 3 months	Better sanitation, availability of clean water, personal hygiene, screening and mass treatment, including contacts.
Onchocerciasis[a] (river blindness)	*Onchocerca volvulus*, a nematode	Infected humans, gorillas rarely	Female black fly *Simulium* genus carrying *Onchocerca* bites human, causing infection with parasite: another fly bites victim	1 year or less, sometimes more	Protective clothing. Use repellent (DEET). Selected spraying of fast-flowing (oxygen) rivers harboring the larvae and treatment of individuals annually with drug invermectin,[b] which kills the microfilariae but not the worm.

(*continues*)

TABLE 2.7 (*continued*)

Disease	Etiologic Agent	Reservoir	Transmission	Incubation Period	Control
Trachoma	*Chlamydia trachomatis*	Tears, secretions, discharges of nasal mucous membranes of infected persons	Direct contact with infected persons and towels, fingers, handkerchiefs, clothing soiled with infective discharges	5–12 days	Routine inspections and examinations of school children. Elimination of common towels and toilet articles and using sanitary paper towels. Education in personal hygiene and keeping hands out of eyes.
Psittacosis (Ornithosis)	*Chlamydia psittaci*	Infected parrots, parakeets, love birds, canaries, pigeons, poultry, other birds	Contact with infected birds or inhalation of their desiccated wastes; agent is airborne	4–15 days	Importation of birds from psittacosis-free areas. Quarantine of pet shops having infected birds until thoroughly cleaned. Education of public to dangers of parrot illnesses.
Staphylococcal disease in the community	*Staphylococcus aureus*	Humans	Direct contact with infected skin lesions or articles by discharges	Usually 4–10 days	Personal hygiene, avoidance of common use of toilet articles; prompt recognition and treatment of illness. Inspection of children at camps, nurseries, institutions, schools. Frequent handwashing.

Chancroid (soft chancre)	*Haemophilus ducreyi, Ducrey bacillus*	Discharges from open lesions and pus from buboes from infected persons	Sexual contact with open lesions and pus; direct contact with infectious discharges in sexual intercourse; transfusion of infected blood	3–5 days or longer	Character guidance, health and sex education, premarital and prenatal examinations. Improvement of social and economic conditions; elimination of slums, housing rehabilitation and conservation, new housing, neighborhood renewal. Suppression of commercialized prostitution, personal prophylaxis, facilities for early diagnosis and treatment, public education concerning symptoms, modes of spread, and prevention. Case finding, patient interview, contact-tracing and serologic examination of groups known to have a high incidence of venereal disease, with follow-up. Report to local health authority.
Gonorrhea (clap, dose)	*Neisseria gonorrhoeae*, gonococcus *C. trachomatis*	Infected persons, particularly females	Sexual intercourse; contact with open lesions of infected persons	2–7 days; sometimes longer, 3–30 days	Reduce number of partners within sexual network.

(*continues*)

TABLE 2.7 (*continued*)

Disease	Etiologic Agent	Reservoir	Transmission	Incubation Period	Control
Lymphogranuloma vencreum (tropical bubo) Syphilis (pox, lues)	*Treponema pallidum*	Exudates from lesions of skin, mucous membrane, body fluids, and secretions of infected persons; exudate from mucous membranes of infected persons	Sexual intercourse, contact with mucous membranes of infected persons	10 days to 10 weeks, usually 3 weeks	Use of condom., Prophylaxis of carriers. Reduce number of partners within sexual network.
Granuloma inguinale (tropical sore)	*Donovania granulomatis*, (presumed agent)	Infected persons	Presumably by sexual intercourse, direct contact with lesions	Unknown, probably 8 days to 12 weeks	

Other sexually transmitted diseases include chlamydial infections, nongonococcal urethritis, trichomoniasis, herpes simplex (genital herpes), genital warts, viral hepatitis B, human immunodeficiency virus (HIV) infection, and acquired immunodeficiency syndrome (AIDS). Control measures are similar to above.

[a]The WHO estimates that there are 17 million cases of onchocereciasis, or river blindness, mostly in Africa, and 326,000 people have been blinded by it, About 90 million are at risk. *Nation's Health* (July 1990): 8–9.

[b]E. Eckholm, "River Blindness, Conquering an Ancient Scourge," *New York Times* magazine, Jan. 8, 1989, p. 20. For further information the reader is referred to specialized sources such as ref. 3; P. N. Acha and B. Szyfres, *Zoonoses and Communicable Diseases Common to Man and Animals*, 2nd ed., Pan American Health Organization, WHO, Washington, DC, 1987; and "Guidelines for Prevention of Transmission of Human Immunodeficiency Virus and Hepatitis B Virus to Health-Care and Public-Safety Workers," U.S. Department of Health and Human Services, PHS, CDC, Atlanta, GA, February 1989, reprinted in *MMWR*, **38**, 25, (June 30, 1989): 446.

through saliva or a cut or scratch on the hands. The dead animal should be wrapped in newspaper or other covering and taken to a veterinarian or local health department. The head should be immediately delivered or packed in ice (not frozen) and shipped to the nearest equipped health department laboratory where the brain can be examined for evidence of rabies.

Several immunization products, vaccines and globulins, are available and used for postexposure prophylaxis. If treatment has been initiated and subsequent testing of the animal shows it to be negative, treatment can be discontinued. Preexposure prophylaxis is also practical for persons in high-risk groups. These include veterinarians, animal handlers, certain laboratory workers, and persons, especially children, living or visiting countries where rabies is a constant threat. Persons whose vocational or avocational pursuit brings them into contact with potentially rabid dogs, cats, foxes, skunks, or other species at risk of having rabies should also be considered for preexposure prophylaxis. The CDC and local and state health departments provide detailed recommendations for rabies prevention and treatment including pre- and post-prophylaxis.[58]

Vaccination of dogs and cats in affected areas, stray animal control, and public information are important for a good control program. In areas where rabies exists, mass immunization of at least 70 percent of the dog and cat population in the county or similar unit within a 2- or 3-week period is indicated. Where rabies exists or where it might be introduced, a good program should include vaccination of all dogs and cats at three months of age and older. Vaccines are available for dogs, cats, and cattle; special vaccines can be used in certain animals. A booster is recommended annually or triennially, depending on the vaccine used. All animal rabies vaccines should be administered by or under the supervision of a veterinarian.

Rabid bats have been reported from every state except Hawaii and have caused human rabies infections in the United States. The vampire bat (*Desmodus rotundus*) is a rabies carrier spreading death and disease among cattle and other livestock and endangering humans in Latin America from Mexico to northern Argentina. Annual livestock production losses are estimated at $250 million. The anticoagulant diphenadione is effective against the vampire bat species. The chemical may be injected directly in cattle and is then taken by the bat when it gets its blood meal or can be spread as a petroleum jelly mixture on captured bats, which, when released, spread the chemical by contact throughout a bat colony. In either case, the diphenadione enters the bloodstream and the bats bleed to death.

DDT formally was used as a control measure but has been banned since 1972. Currently, the most effective means of bat control is to screen all openings or build them out insofar as possible. Fiberglass insulation will keep bats out of spaces so insulated.

Any person bitten or scratched by a bat should receive antirabies therapy without delay unless the bat (head) is found negative by laboratory test. Any person who has handled a bat, dead or alive, may also have to undergo antirabies therapy, as the bat saliva, containing the rabies virus, may enter a patient's body through open cuts in the skin or mucous membranes.

Infectious Respiratory Diseases

Infectious diseases affecting the lungs and respiratory tract have special implications in public health. Bacteria and viruses responsible for these diseases are transmitted between humans via droplets that are expelled from the nose or mouth. Although direct transmission can occur (e.g., coughing or recirculated air), droplets on nonporous surfaces (e.g., door knobs) can also be involved in new infections. Environmental engineering can play a key role in ensuring the safety and quality of air, particularly in the design of institutional air supply systems, which have been implicated in the transmission of respiratory infections.

Control of transmission of respiratory dropletborne infections is achieved through interventions at the individual level (protective masks, hand washing, antibiotic treatment), the population level (restrictions on congregation and movement), and environmental levels (air filtration, institutional design).

In this chapter we describe two respiratory infections and their control mechanisms, of concern to developing and develop countries: tuberculosis and influenza. Table 2.8 summarizes the major respiratory illnesses.

Tuberculosis Tuberculosis (TB) is caused by *Mycobacterium tuberculosis*, *M. africanum* or *M. bovis*. Infection in the respiratory tract can lead to *pulmonary tuberculosis*, resulting in calcified nodules in the lungs, trachea, and bronchea. Infection with the mycobacterium at sites other than the lungs can happen, although much less frequently. Only 5 to 10 percent of those infected with TB will show clinical signs of disease or become infectious.[59] In 2005, the WHO estimates that there were 1.6 million deaths due to tuberculosis worldwide, making it one of the most common causes of human mortality on the planet.[59] Two developments in the last decade and half have made the spread of TB even more worrisome. First, the rapid increase in HIV infections has revealed that those infected with HIV are at much higher risk of acquiring TB. Second, the emergence of multiple-drug-resistant strains of tuberculosis (MDR-TB) have resulted from improper use of antibiotics; these strains can no longer be treated with the commonly available antibiotics and require expensive and intensive medical care. In addition, extremely drug resistant tuberculosis (XDR-TB) has also been reported, which is difficult to cure even with the most advanced forms of antibiotics available.

The World Health Organization has a large-scale program called Stop TB. These programs has the following six components[59]:

1. *Pursue high-quality DOTS expansion and enhancement*. The standard of care for tuberculosis is daily dosing of antibiotics that is observed by a health care worker. Direct observed therapy, short course (DOTS) was created in response to the realization that many TB patients were not completing the prescribed course of antibiotics, due to the number and size of the tablets that must be swallowed daily and the duration of therapy, which can be months to a year. Patients may not show outward signs of

TABLE 2.8 Respiratory Diseases

Disease[a]	Communicability (days)[b]	Incubation Period (days)
Chickenpox (v)	−2–6	14–21
Coccidioidomycosis (f)	No direct transmission	7–28
Common cold (v)	1–5	$\frac{1}{2}$–3
Diphtheria (b)	14	2–5
German (rubella) measles (v)	−7–4+	14–23
Histoplasmosis (f)	No direct transmission	5–18
Infectious mononucleosis (v)	Prolonged	28–42
Influenza (v)	3	2–3
Legionellosis (b)	None	2–10
Measles (rubeola) (v)	2–4	8–13
Meningococcal meningitis (b)	—	2–10
Mumps (v)	−6–9	14–21
Pertussis (whooping cough) (b)	Inflammation–21	7–10
Plague, pneumonic (b)	During illness	2–6
Pneumonia, pneumococcal (b)	—	1–3
Poliomyelitis (v)	Days before and after onset	7–14
Psittacosis (r)	In illness possibly	4–15
Q fever (r)	Transmission rare	14–21
Scarlet fever and streptococcal sore throat (b)	10–21	1–3
Smallpox (v)[c]	1–21	7–17
Tuberculosis (b)	Extended	28–84

[a] Abbreviations: b, bacteria; f, fungus; r, rickettsias, airborne; v, virus. For details, see A. S. Benenson, *The Control of Communicable Diseases in Man*, 15th ed., American Public Health Association, Washington, DC, 1990.
[b] Period from onset of symptoms. Onset of symptoms is considered day zero; negative numbers indicate days prior to clinical manifestation of the disease.
[c] Declared by WHO officially "eradicated" in 1978, if no new cases discovered.

TB infection (i.e., carrier state) and yet remain infectious. This component also includes public-private partnerships to create new medications for treatment of tuberculosis.

2. *Address TB/HIV, MDR-TB and other challenges*. Patients with co-occurring TB and HIV need special attention to ensure that medications do not interact with each other and that early signs of TB progression are detected. Addressing the role of TB in special populations is also important, such as among prisoners and low-income individuals, gender inequalities, and the implications of air travel.
3. *Contribute to health system strengthening*. National TB prevention programs must be integrated with other strategies to improve health care financing and delivery. Sharing of innovations among health care systems is encouraged, and adoption of new methods to stop TB is promoted.

4. *Engage all care providers*. Tuberculosis patients seek services from many different sectors of public and private healthcare providers. Training all health care workers to identify and handle patients with TB is important to ensuring that care can be delivered at a high quality at multiple levels.
5. *Empower people with TB, and communities*. Nonmedical communities can take responsibility of some aspects of TB care and prevention. Due to the large number of persons infected with tuberculosis, treating infected individuals with respect and civility is in the best interests of all parties. Networks of civil society and community organizations are crucial to promoting and sustaining political support for control programs.
6. *Enable and promote research*. New diagnostics, medications and prevention strategies will be needed in the coming decades to continue the fight against tuberculosis.

Although the WHO plan focuses on treatment, environmental engineers have played a role in the prevention of tuberculosis. For example, the Water and Environmental Engineering Research Group at the University of Leeds in the United Kingdom have created a system for ultraviolet inactivation of *mycobacterium tuberculosis* and other airborne pathogens in hospitals. Commercial airliner environmental control systems are also being developed to prevent transmission among air travel passengers.

Influenza *Seasonal influenza* occurs annually and is caused by a virus. It is an acute respiratory infection characterized by sore throat, fever, cough, headache, body pains, and prostration; it is spread via virus-laden droplets that are expectorated from the respiratory tract by infected patients. While influenza is usually self-limiting (naturally cleared by the body in 2 to 7 days), those with weakened immune systems, such as the elderly, are at risk of death.

The difficulty in controlling influenza stems from the genetic variability that is intrinsic to the family of viruses. Influenza is characterized by two main surface glycoproteins hemagglutinin (HA) and neuraminidase (NA). Dozens of variations in these glycoproteins are known; the swapping (or "reassortment") of the genes encoding these glycoproteins gives rise to strains of differing pathogenic quality. Showing the interconnectedness of human and animal health, much of the reassortment occurs in birds and pigs, from which humans are newly infected each year. The nomenclature of the viral strains specifies which numbered variant of hemagglutinin or neuraminidase is encoded; common strains include H1N1, H1N2, and H3N2 viruses, while more virulent strains are H7N7 and H5N1.

Seasonal influenza is preventable with a vaccine, but it must be administered every year due to the constantly mutating nature of the virus.[60] Vaccination rates can vary greatly, and the supply of vaccine has been hampered due to bacterial contamination during the production process. In the United States, there are thousands of deaths annually due to influenza, mostly among the oldest and youngest segments of the population.

Pandemic influenza arises when particularly virulent strains of the influenza virus emerge as a result of genetic recombination, resulting in widespread infections. Pandemics of influenza occurred in 1889, 1918, 1957, and 1968. During these pandemics, 20 percent of the general population and 50 percent of institutionalized populations (prison, college dormitories) were affected.[1] Although seasonal influenza deaths occur in the elderly, during the 1918 pandemic, most deaths were in young adults, for reasons that are unclear. Birds can be infected with influenza, and the pandemic strains from 1918, 1957 and 1968 bore genetic similarity to avian influenza viruses. This observation drives much of the fear and speculation about avian influenza and the likelihood of it morphing into the next human pandemic.

The specter of an influenza pandemic highlights many shortcomings in global health care. It is likely that the pandemic will begin in a developing country where there is close human and bird contact and veterinary surveillance is low, most likely on a farm or a food processing facility. Crowded living conditions will exacerbate the spread, and international air travel will move the virus to new regions of the world overnight. At that point, much will depend on the international cooperation in response to the perceived threat. If active control measures are put into place, there is the potential to reduce the severity, but most of the medical literature is imbued with a sense of inevitability. Whether the pessimism is warranted will be revealed with actual experience.

The availability of medical tools (respirators, vaccines, antivirals) has been the concern of much of pandemic influenza planning. Treating severe influenza is medical-resource intensive; respirators for those with impaired lung capacity are already in short supply, and must be regularly cleaned and patients monitored. Spread of influenza in health care facilities is likely, with the potential to infect health care staff. The potential volume of patients will overwhelm most hospitals, but other disruptions will occur due to absenteeism among employees needed to keep society functioning.

Airborne, or fine-droplet transmission, may also occur. In view of this, Standard Infection Control Principles and Droplet Precautions are the principal infection control strategies that should be rigorously followed. In certain circumstances, these control measures may need to be augmented with higher levels of respiratory protection. Scrupulous attention to handwashing and containment of respiratory secretions produced by coughing and sneezing are the cornerstones of effective infection control. Other key recommendations include separation or cohorting of patients with pandemic influenza from those who have other medical conditions; prompt identification of health care workers with pandemic influenza; restriction of ill workers and visitors from health care settings; and education of staff, visitors, and patients about the transmission and prevention of influenza that is understandable and applicable to their particular situation.[61]

BIOTERRORISM

In late 2001, letters containing *Bacillus anthracis* (anthrax) spores were mailed to various locations in the United States by yet unidentified individual(s) operating under unknown motive(s). This led to the deaths of at least five individuals due to inhalation anthrax and to several other cases of the less severe cutaneous form of the disease. While it remains to be determined whether these terrorist attacks were related and to identify the perpetrators, they signaled a new era of fear and awareness of biological agents.

It should be remembered that "bioterrorism" and "biological warfare" have long histories. Plague-infected corpses were catapulted by the Tartars during their siege of Kaffa (in Crimea), resulting in the collapse of the city population due to mortality from the mycobacterium. Smallpox-infected clothing and blankets were reported given to susceptible populations by Spanish conquistadors' during campaigns in South America, by the British during the French-Indian War, and by Confederate-sympathizing manufacturers during the U.S. Civil War. Plague outbreaks were created by the Japanese army after the intentional release of infected fleas over Chinese towns in 1941. The United States military tested biological weapons against unsuspecting U.S. residents by releasing relatively harmless bacteria that could be traced *Serratia marcescens* was released in San Francisco in 1950, and *Bacillus subtilis* was released into the New York City subway system in 1966. An accidental release of anthrax from a Soviet facility in April 1979 provides us with the only known "natural experiment" of aerosolized release of the bacteria; that accident resulted in hundreds of deaths and proved beyond a doubt that biological organisms could be weaponized with lethal consequences. On a smaller scale, in 1984 a group of politically motivated individuals intentionally contaminated salad bars in Oregon with *Salmonella typhimuium*, resulting in over 750 cases. A Japanese cult released the nerve gas sarin in the Tokyo subway system in 1995, resulting in 20 deaths and thousands of injuries.

The CDC and other federal agencies currently list *Bacillus anthracis* (anthrax), *Variola major* (smallpox), *C. botulinum* toxin (botulism), *Yersinia pestis* (plague), *Franciscella tularensis* (tularemia), and viral hemorrhagic fevers (Ebola virus, lassa virus) as category A agents—those that are the most likely to be used as potentially lethal weapons. This section will briefly discuss two of the major agents, smallpox and anthrax. Due to the significant pathogenicity of each of these agents, individuals seeking to employ their use, especially in large amounts, would require substantial knowledge, expertise, and laboratory equipment, as well as protection against accidental exposure (e.g., vaccination or antibiotics).

Smallpox

Smallpox, a disease that killed approximately 300 million people worldwide in the twentieth century alone, may have been one of the first microbial agents to be used as a weapon. The only remaining stocks of smallpox are currently being held in secure locations in the United States and Russia. The WHO has recently voted to delay destruction of the remaining smallpox stocks, raising the possibility of their misappropriation and use as weapons. Because immunization against smallpox was halted in 1976 following a successful worldwide eradication program, a significant number of the U.S. population would be at risk from a bioterrorism attack. Although individuals vaccinated prior to 1976 may retain immunity to smallpox, the level of protection is currently unknown. Smallpox is generally fatal in about 30 percent of infections of unvaccinated individuals. Given these uncertainties and the significant health risk of smallpox, the United States and other countries are currently increasing the production of smallpox vaccine. However, approximately 1 in 1 million people exhibit serious and potentially fatal complications following vaccination. Thus, if the entire U.S. population were to be vaccinated, we might expect 100 to 300 deaths from the vaccine. To avoid this situation, one strategy that is being considered for a bioterrorism attack is to limit vaccination to individuals that have come in contact with the initial (index case) infected individual. Vaccination and training of primary health care workers and physicians who are most likely to see the first cases in an attack will also be an important aspect for countering the use of viruses and bacteria as weapons.

Anthrax

As already noted, anthrax is a concern for use in bioterrorism. Inhalation of anthrax spores is fatal in approximately 75 percent of untreated cases. Anthrax consists of several major virulence factors: a polysaccharide capsule and three separate proteins (toxins) that act in concert to disrupt immune defense systems. An anthrax vaccine is available and is generally effective, although it is currently in limited supply (and mostly dedicated to military rather than civilian use). It has also been observed to cause side effects. Antibiotics such as amoxicillin, ciprofloxacin, and doxycycline are effective against the inhalation form of anthrax; however, they must be administered prior to spore germination, which can occur within 48 to 72 hours following exposure and must be continued for several months. One particular concern is that terrorists may genetically alter common strains of anthrax to encode antibiotic-resistance genes, a situation that could pose significant problems for current treatment protocols. Thus, it will be important to be able to rapidly monitor and analyze the genetic properties of different anthrax strains and to develop new antibiotics. Another promising avenue stems from the recent identification of the receptor for anthrax lethal factor toxin as well as high-resolution structural determination of lethal factor and edema factor. These molecules represent potential targets for rational drug design of new antibacterial compounds to combat this disease.

NONCOMMUNICABLE DISEASES AND CONDITIONS ASSOCIATED WITH THE ENVIRONMENT

Background

The terms *noncommunicable* and *noninfectious* are used interchangeably. The major noncommunicable disease deaths in the United States in 2000 were due to diseases of the heart, malignant neoplasms, cerebrovascular diseases, accidents, atherosclerosis, diabetes mellitus, and chronic liver disease and cirrhosis.

The mortality can be expected to shift more to noncommunicable causes in the developing countries as social and economic conditions improve and communicable diseases are brought under control. This section discusses some background issues, prevention and control, legislation, and types of noncommunicable diseases associated with the environment.

Treatment of the environment complements treatment of the individual but requires more effort and knowledge. The total environment is one of the most important determinants of health. A review of more than 10 years of research conducted in Buffalo, New York, showed that the overall death rate for people living in heavily polluted areas was twice as high, and the death rates for tuberculosis and stomach cancer three times as high, as the rates in less polluted areas.[62] Rene Dubos points out that "many of man's medical problems have their origin in the biological and mental adaptive responses that allowed him earlier in life to cope with environmental threats. All too often the wisdom of the body is a shortsighted wisdom."[63] In reference to air pollution, he adds that "while the inflammatory response is protective (adaptive) at the time it occurs, it may, if continuously called into play over long periods of time, result in chronic pathological states, such as emphysema, fibrosis, and otherwise aging phenomena."[63]

Human adjustment to environmental pollutants and emotional stresses due to crowding and other factors can result in later disease and misery with reduced potential for longevity and a productive life.[64]

In an address to the Sierra Club, EPA Administrator Barbara Blum stated[65]:

> Inner-city people—white, yellow, brown and back—suffer to an alarming degree from what are euphemistically known as diseases of adaptation. These are not healthy adaptations, but diseases and chronic conditions resulting from living with bad air, polluted water, excessive noise, and continual stress. Hypertension, heart disease, chronic bronchitis, emphysema, sight and hearing impairment, cancer, and congenital anomalies are all roughly 50 percent higher (for inner-city people) than the level for suburbanites. Behavioral, neurological and mental disorders are about double.

Whereas microbiological causes of most communicable diseases are known and are under control or being brought under control in many parts of the world (with some possible exceptions such as malaria and schistosomiasis), the physiologic and toxicologic effects on human health of the presence or absence of certain chemicals in air, water, and food in trace amounts have not yet been clearly demonstrated. The cumulative body burden of all deleterious substances, especially organic and inorganic chemicals, gaining access to the body must be examined both individually and in combination. The synergistic, additive, and neutralizing effects must be learned in order that the most effective preventive measures may be applied. Some elements, such as fluorine for the control of tooth decay, iodine to control goiter, and iron to control iron deficiency anemia, have been recognized as being beneficial in proper amounts. But the action of trace amounts ingested individually and in combination of the pollutants shown

> and other inorganic and organic chemicals is often insidious. Their probable carcinogenic, mutagenic, and teratogenic effects are extended in time, perhaps for 10, 20, or 30 years, to the point where direct causal relationships with morbidity and mortality are difficult if not impossible to conclusively prove in view of the many possible intervening and confusing factors. Nevertheless, sufficient information about many noninfectious diseases, including the chronic diseases, is available to make possible the mounting of an attack to prevent or at least minimize the debilitating effects. Some will say that we do not have sufficient preventive information and should devote our attention only to screening and treatment. Where would we be today if the same philosophy prevailed in our attack on the infectious diseases?

An interesting analysis was made by Dever[66] for use in policy analysis of health program needs. He selected 13 causes of mortality and allocated a percentage of the deaths, in terms of an epidemiologic model, to four primary divisions, namely, system of health care organization, lifestyle (self-created risks), environment, and human biology. He envisioned the environment as composed of a physical, social, and psychological component. Environmental factors were considered to be associated with 9 percent of the mortality due to diseases of the heart, with the rest due to causes associated with health care, life-style, or human biology. Similarly, environmental factors were considered the cause of 24 percent of the cancer deaths, 22 percent of the cerebrovascular deaths, and 24 percent of the respiratory system deaths.

Of added interest is Dever's analysis showing that environmental factors were considered to be the cause of 49 percent of all deaths due to accidents, 20 percent of the influenza and pneumonia deaths, 41 percent of the homicides, 15 percent of the deaths due to birth injuries and other diseases peculiar to early infancy, 6 percent of the deaths due to congenital anomalies, and 35 percent of the deaths due to suicides.

There are an estimated 2 million recognized chemical compounds with more than 60,000 chemical substances in past or present commercial uses. Approximately 600 to 700 new chemicals are introduced each year, but only about 15,000 have been animal tested with published reports. Limited trained personnel and laboratory facilities for carcinogenesis testing in the United States by government and industry will permit testing of no more than 500 chemicals per year. The chemicals are viewed by Harmison[67] as falling into four groups:

1. Halogenated hydrocarbons and other organics; polychlorinated biphenyls (PCBs); chlorinated organic pesticides such as DDT, Kepone, Mirex, and endrin; polybrominated biphenyls (PBBs); fluorocarbons; chloroform; and vinyl chloride. These chemicals are persistent, often accumulate in food organisms, and may in small quantities cause cancer, nervous disorders, and toxic reactions.
2. Heavy metals: lead, mercury, cadmium, barium, nickel, vanadium, selenium, beryllium. These metals do not degrade; they are very toxic and may build up in exposed vegetation, animals, fish, and shellfish.

3. Nonmetallic inorganics: arsenic and asbestos, for example, are carcinogens.
4. Biological contaminants such as aflatoxins and pathogenic microorganisms; animal and human drugs such as diethylstilbestrol (DES) and other synthetic hormones; and food additives such as red dye No. 2.

Evaluation of the toxicity of existing and new chemicals on workers, users, and the environment and their release for use represent a monumental task, as already noted. Monitoring the total effect of a chemical pollutant on humans requires environmental monitoring and medical surveillance to determine exposure and the amount absorbed by the body. The sophisticated analytical equipment available can detect chemical contaminants in the parts-per-billion or parts-per-trillion range. However, mere detection does not mean that the chemical substance is automatically toxic or hazardous. But detection does alert the observer to trends and the possible need for preventive measures. Short-term testing of chemicals, such as the microbial Ames test, is valuable to screen inexpensively for carcinogens and mutagens. The Ames test determines the mutagenic potential of a chemical based on the mutation rate of bacteria that are exposed to the chemical. However, positive results suggest the need for further testing, and negative results do not establish the safety of the agent. Other tests use mammalian cell cultures and cell transformation to determine mutagenicity.

Prevention and Control

Prevention of the major causes of death, such as diseases of the heart, malignant neoplasms, cerebrovascular disease, accidents, and other noninfectious chronic and degenerative diseases, should now receive high priority. Prevention calls for control of the source, mode of transmission, and/or susceptibles as appropriate.

The prevention and control of environmental pollutants generally involves the following:

1. *Eliminate or control the pollutant at the source*. Minimize or prevent production and sale; substitute nontoxic or less toxic chemical; materials and process control and changes; recover and reuse; waste treatment, separation, concentration, incineration, detoxification, and neutralization.
2. *Intercept the travel or transmission of the pollutant*. Control air and water pollution and prevent leachate travel.
3. *Protect humans to eliminate or minimize the effects of the pollutant*. This includes water treatment, air conditioning, land-use planning, and occupational protection.

At the same time the air, sources of drinking water, food, aquatic plants, fish and other wildlife, surface runoff, leachates, precipitation, surface waters, and humans should be monitored. Biosensor technology can assist in determining exposure to pollutants, however for the foreseeable future, epidemiological studies collecting blood and other biological specimens, astute clinical observation, emergency department and poison center surveillance will be the most likely tools of monitoring. This should be done for potentially toxic and deleterious chemicals as indicated by specific situations.

Environmental Control Legislation

Many of the laws establishing national standards and controls for the discharge of pollutants to the environment and consumer and worker protection are listed as follows:*

- *Asbestos Hazard Emergency Response Act of October 22, 1986* (Amends Toxic Substances Control Act (TSCA).] Requires the EPA to regulate the inspection of schools, identify asbestos-containing materials, monitor the development of asbestos management plans by schools, and oversee corrective measures. The Occupational Safety and Health Administration (OSHA) is to establish asbestos regulations in the workplace and for asbestos removal. The *Asbestos School Hazard Abatement Act of 1984* authorizes the EPA to provide grants and loans if justified.
- *Atomic Energy Act of 1954* PL. 83–703 (as amended). Regulates the discharge of radioactive waste into the environment. Gives the EPA authority to set standards for the disposal of radioactive materials to be implemented by the National Research Council (NRC).
- *Clean Air Act of 1970* P.L. 91–604 (as amended 1990, 1996, 1998, 1999). To improve the quality of the nation's air, the EPA is to establish national air quality standards to protect the public health and welfare from the harmful effects of air pollution and ensure that existing clean air is protected from significant deterioration by controlling stationary and mobile sources and preventing harmful substances from entering the ambient air; also to review and regulate hazardous and toxic air pollutants.
- *Coastal Zone Management Act of 1972* P.L. 92–583 (as amended). Requires consideration of environmental and economic factors in the planning and efficient development of coastal areas. State receives financial and technical assistance.
- *Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980* P.L. 96–510 (as amended) (Superfund). Establishes a trust fund financed by taxes on oil and certain chemical compounds and authorizes federal action in cleaning up hazardous waste sites (especially soil and water contaminated sites), responds to spills of hazardous substances that present danger to public health and welfare, and prepares guidelines for coordinating federal and state responses. Short-term response may include

*A very good resource for examining public laws is the Thomas search engine of the Library of Congress web site, www.loc.gov. This is a searchable database of all laws in Congress, whether passed or not, from the 93rd Congress (1973–1974) through the current one.

provision of bottled water and temporary evacuation. Sites are ranked for priority action.

- *Consumer Product Safety Act of 1972* P.L. 92–573. The Consumer Product Safety Commission (CPSC) is responsible for reducing injuries associated with consumer products, including the development of safety standards and the investigation of product-related morbidity and mortality.
- *Emergency Planning and Community Right-to-Know Act of 1986* Also called *Superfund Amendments and Reauthorization Act (SARA) Title III*. Employers must report and advise employees of hazardous substances handled and their potential effects. The act also requires that information about toxic chemicals stored or permitted to be released during operation of commercial and manufacturing facilities be made available to the public. State and local governments and facilities using or storing hazardous chemicals must have emergency plans for notification and response. Facilities must report annually the amount and characteristics of certain toxic chemicals on premises and released to the environment.
- *Federal Food, Drug, and Cosmetic Act of 1938* (as amended). The FDA is responsible for the safety and effectiveness of foods, drugs, medical devices, and cosmetics; it is also responsible for radiologic health and toxicologic research, enforces compliance with EPA-established allowable limits for pesticides on food and feed crops, and prohibits use of any carcinogenic additives.
- *Federal Insecticide, Fungicide, and Rodenticide Act of 1972* P.L. 92–516 (as amended). Requires that all pesticides be registered and used strictly in accordance with label instructions; gives government (EPA) authority to prohibit or restrict a pesticide to special uses for application only by a person trained in an approved program; extends control to intrastate products, container storage and disposal methods, and direct or indirect discharge of pesticides to surface waters and groundwaters; also requires proof that pesticides will cause no harm to people, wildlife, crops, or livestock when used as directed.
- *Federal Water Pollution Control Acts of 1971, 1972* P.L. 83–660, P.L. 92–500, and P.L. 95–217 (*Clean Water Act of 1977* as amended by the *Water Quality Act of 1987* and further amended in 2000). Controls water pollutants and other related factors to make surface waters fishable and swimmable. Intended to restore and maintain the chemical, physical, and biological integrity of the nation's surface and groundwaters. Also water quality planning, wetlands protection, research, and regulation of toxic water pollutants.
- *Food Security Act of 1985* (as amended by the 1990 Farm Bill). To control degradation of wildlife habitat, water quality, and inland waters due to cultivation of marginal farmlands; preservation of wetlands; minimizing of agricultural pollutant releases.

- *Hazardous Materials Transportation Act of 1974* PL. 93–633. U.S. Department of Transportation regulates the transportation in commerce of hazardous materials or hazardous wastes by all means of transportation.
- *Irrigation Mitigation and Restoration Partnership Act of 2000* PL 106–502. Directs the development and implementation of projects to mitigate impacts to fisheries resulting from the construction and operation of water diversions by local governmental entities in the Pacific Ocean drainage area (areas of Washington, Oregon, Montana, and Idaho from which water drains into the Pacific Ocean).
- *Lead Contamination Control Act of 1988* Requires that lead be removed from school and day-care center drinking water supplies, especially water coolers. The CDC is authorized to provide funds to states for screening of children and their treatment and to remove sources of lead. The CPSC is required to recall drinking water coolers that are not lead free, if not repaired or replaced.
- *Low Level Radioactive Waste Policy Act of 1980*. Declares that the disposal of low-level radioactive waste is a state responsibility. Permits states to make agreements for joint use of a site if approved by Congress.
- *Marine Protection, Research, and Sanctuaries Act of 1972* P.L. 92–532 (as amended). Controls the dumping of materials, including sewage sludge and toxic substances, into the oceans, and EPA responsibility.
- *Medical Waste Tracking Act of 1988*. The EPA is to establish requirements for medical and infectious waste management, including control of waste generators, transporters, and disposal facility operators. The CDC and OSHA are also involved.
- *National Environmental Policy Act of 1969* PL. 91–190 (as amended). Encourages productive and enjoyable harmony between human and environment; promotes efforts that will prevent or eliminate danger to the environment and biosphere and stimulates the health and welfare of humans; enriches the understanding of the ecologic systems and natural resources important to the nation; and establishes a Council on Environmental Quality.
- *National Flood Insurance Act of 1968* P.L. 90–448, PL. 93–234. A program administered by the Federal Emergency Management Agency for land management in flood-prone areas. Supplies funds to states for planning and regulation, restricting certain uses in flood-prone areas, with community participation.
- *National Gas Pipeline Safety Act of 1968* (as amended 1992, 1996). Requires federal pipeline safety standards to meet the need for protection of the environment and demands corrective action when any pipeline facility is hazardous to the environment.
- *National Invasive Species Act of 1996* P.L. 104–332. Orders the prevention of the introduction and spread of aquatic nuisance species into the Great Lakes and other U.S. waters through the discharge of ballast water.

- *Noise Control Act of 1972* P.L. 92–574 (as amended). Makes the federal government responsible for setting standards for noise detrimental to the human environment from a broad range of sources.
- *Nuclear Waste Policy Act of 1982*. Requires the Department of Energy (DOE) to prepare guidelines for and select a geologic site for the storage of high-level waste by 1998 and a second site at a later date. The DOE is also responsible for waste management, including interim storage and transportation.
- *Occupational Safety and Health Act of 1970* P.L. 91–956. Prevents occupational disease and accidents and establishes workplace standards as well as national standards for significant new pollution sources and for all facilities emitting hazardous substances.
- *Ports and Waterways Safety Act of 1972* PL. 92–340. Regulates, through the Coast Guard, the bulk of shipment of oil and hazardous materials by waters, also under the authority of the *Tanker Act* and the *Dangerous Cargo Act*.
- *Public Utility Regulatory Policy Act of 1979*. Requires utilities to purchase energy produced by small power generators at a set cost.
- *Radiation Control for Health and Safety Act of 1968*. Controls performance standards for electronic products and notification of defects, also repair or replacement.
- *Resource Conservation and Recovery Act of 1976* RL. 94–580 (as amended). (Revised by the Hazardous and Solid Waste Amendments of 1984, P.L. 98–616.) Requires a regulatory system for the generation, treatment, transport, storage, and disposal of hazardous wastes—that is, hazardous to human health or to the environment, including a manifest system, from the "cradle to the grave." This conserves natural resources directly and through resource recovery from wastes. It protects groundwater from contamination and controls landfills and underground storage tanks for hazardous materials and lagoons. Land disposal, landfilling, placement in salt domes, beds, or underground mines, and injection of hazardous wastes into or above underground drinking water source are banned. Small generators, transporters, and disposers are also regulated.
- *River and Harbor Act of 1899*. Prohibits discharge of refuse to navigable waters. Also *Oil Pollution Control Act of 1924*. U.S. Army Corps of Engineers is the responsible agency.
- *Safe Drinking Water Act of 1974* PL. 93–523 (as amended 1986). Authorizes the EPA to establish regulations for drinking water in public water systems, including microbiological, radiologic, organic and inorganic chemical standards, and turbidity levels in drinking water, to protect the public's health. Also controls underground injection of hazardous waste and lead in drinking water, permits sole-source aquifer designation, and provides for water supply source and wellhead protection.

- *Solid Waste Disposal Act of 1965* PL. 89–272 (as amended 1992, 1996). Initiates and accelerates a national research and development program for new and improved methods of proper and economic solid waste disposal and to provide technical and financial assistance to appropriate agencies in the planning, development, and conduct of solid waste disposal programs. The Secretary of Health, Education, and Welfare (program transferred to the EPA) was responsible for the administration of the act with respect to solid waste problems of communities and their environments, including those solid-waste residues that result from business, agricultural, and industrial activities. The Department of the Interior was responsible for solving industrial solid-waste problems within facilities engaged in extraction, processing, or utilization of minerals and fossil fuels.
- *Surface Mining Control and Reclamation Act of 1977* PL. 95–87. The U.S. Department of the Interior sets standards to control disturbance of the land from mining and to assure reclamation afterward. The act also deals comprehensively with specific types of pollution affecting ground-waters.
- *Toxic Substances Control Act of 1976* PL. 94–569. Grants the EPA authority to control manufacture, distribution, and use of new and existing chemical substances that present an unreasonable risk of injury to health or the environment, except for pesticides, foods, drugs, cosmetics, tobacco, liquor, and several additional categories of chemicals regulated under other federal laws; develop adequate data and knowledge on the effects of chemical substances and mixtures on health and the environment; establish an inventory and selectively act on those that appear to pose potential hazard; and devise a system to examine new chemicals before they reach the marketplace.
- *Uranium Mill Tailings Radiation Control Act of 1978* (as amended). Requires the cleanup of radioactive contamination, including ground-water, remaining from inactive processing sites.

Lead Poisoning

Lead is a cumulative poison ending up in the bones, blood, and tissue. Lead is also found in the urine. It is not readily excreted by children. It may cause mental retardation, blindness, chronic kidney diseases, fatigue, anemia, gastroenteritis, muscular paralysis, behavioral changes, high blood pressure, birth defects, and other impairments. Lead poisoning is commonly associated with children living in old and substandard housing built before 1950 who eat lead-based paint on woodwork and paint that peels or flakes from walls (both inside and outside of buildings), ceilings, and other surfaces. However, other sources of lead, as discussed below, may contribute to or be the major cause of high blood lead levels.

Removal of lead-based paint requires special precautions to protect children, adults, and workers from inhaling dust and fumes. Sanding causes the release of lead-laden dust, and open-flame burning or torching releases lead fumes. A heat gun is preferred. Precautions include enclosure of the work area to prevent spread of the dust to other apartments or public areas; protection of furnishings and clothing in the apartments; worker protection, including proper respirator and clothing; complete dust removal and collection using a vacuum with a high-efficiency particle air filter; and proper disposal of the dust and debris, all in accordance with building code, the Department of Housing and Urban Development (HUD), the EPA, and related regulations. The effectiveness of dust removal and cleanup should be determined by surface sampling (floors, walls, window sills) before and after paint removal. Encapsulating the lead-based paint may be a preferred and acceptable alternative to removal if approved by the regulatory agency. Easily accessible locations, such as window sills, should be given priority.

Lead was banned from housepaint in 1978. Food canners stopped using lead solder in the manufacture of tin cans in 1991, and lead in gasoline was phased out in 1995. Thus the number of children with potentially harmful levels of lead in the blood (>10 μg/dl) has dropped by 85 percent in the last 20 years. However, there are still many older homes with lead paint, which has further deteriorated and presents a great risk to children and adults who live in or near those homes. Lead is still in the soil, especially near major freeways and highways, at some worksites, and occasionally in drinking water, ceramics, and a number of other products.

Children two to three years old absorb 30 to 75 percent of their lead from ingesting substances, as compared to 11 percent for adults.[68] Adults excrete up to 95 percent of ingested lead, whereas children may absorb half of it. Other sources of lead are lead fumes and ashes produced in battery repair and burning lead battery casings, inadequately ventilated indoor firing ranges, emissions from industrial processes, soft corrosive water standing and flowing in lead pipe, pipe with lead-soldered joints, some bronze and brass faucets, and chrome-plated fixtures; natural or added lead in food and drink; lead in dust and soil; making lead type; handling lead scrap; lead in lead arsenate pesticides; radiator repair; pottery and ceramics manufacture; lead crystal decanters; lead-soldered cans; colored newsprint; household dust in urban areas; and lead in some household products, all of which contribute to the body burden.

On one hand, the phasing out of tetraethyl lead from gasoline has introduced a potential and unknown problem associated with manganese compounds used as a replacement for lead, which are emitted at low levels in various forms, including the toxic manganese tetroxide. On the other hand, a HUD study between 1970 and 1976 in New York City showed a drop in blood lead levels in children from 30 to 21 μg/100 ml (same as 30–21 μg/dl) of blood. The drop paralleled a recorded decrease of lead in the ambient air, suggesting a significant relationship.[69] A report from the National Center for Health Statistics found that 90 percent of all lead in the air came from leaded gasoline and that the blood lead level of the average U.S. resident between 1976 and 1980 dropped 38 percent, from 14.9 to 9.2 μg/100 ml, and continued through 1986.[70] This drop in blood lead level reinforces previous findings and the relationship to greater use of unleaded gasoline.

Serious illness and death have been attributed to the use of earthenware pottery with improperly heated lead-based glaze. Such glaze dissolves in fruit juice, acid salad dressing, tomato sauce, coffee, wine, soda pop, and other soft acid drinks. Most of the glaze applied to pottery contains lead. When pottery, dinnerware, and other ceramics are not fired long enough at the correct temperature or the glaze is not properly formulated, the glaze will not fuse and seal completely and its lead (and possibly cadmium) component can be leached or released. Moonshine whiskey made in stills containing lead has also been implicated. The FDA has set a limit of 0.5 ppm lead leachate for ceramics used to store acid liquids (including large bowls) and 7.0 ppm for ceramics used for liquids or food service (dishes), with 5.0 ppm for small bowls. Commercial laboratories can analyze dishes, bowls, pitchers, and cups for improper lead glaze.

Control of lead poisoning is approached through identification and removal of lead sources and through screening of children, workers and their families where exposure has occurred. This includes residents of neighborhoods with older homes that have not been kept up.

Additional controls include identification through selective systematic inspection of housing, mostly built before 1950 or 1960, and removal of lead-based paint containing more than 0.05 percent lead by weight; prohibition of sale of toys or baby furniture containing lead paint; removal of dust from floors by wet mop or vacuum; and promotion of hygiene and handwashing by children and adults; education of parents, social workers, public health professionals, health guides, owners of old buildings, and those occupationally exposed to the hazard and its control. The X-ray fluorescence lead paint analyzer has improved hazard identification. Paint analysis by a laboratory is necessary for lead concentrations below the fluorescence analyzer sensitivity. Building codes should prohibit the use of lead solder, pipe, and fittings. The sale of drinking water coolers with lead-lined tanks or piping is also prohibited. Lead water service lines should be replaced.

The national ambient air quality standard for airborne lead is 1.5 $\mu g/m^3$ of air averaged over a 3-month period. The OSHA permissible lead exposure level averaged over an 8-hour work day is 50 $\mu g/m^3$, but if the air-borne lead concentration averages 30 $\mu g/m^3$ during a work shift, a control program and medical surveillance are required. Persons who work in lead smelters, brass foundries, storage battery–manufacturing plants, and plastic-compounding factories and persons cutting through metal structures coated with lead-based paint or who remove such paints from tanks or other structures are at high risk for lead toxicity.

It is believed that lead poisoning contributed to the decline of the Roman Empire and the associated deaths, disease, and sterility. The poisoning was due to water distribution in lead pipes and the widespread practice of cooking in lead-based utensils (old pewter), particularly the cooking of a syrup used to preserve and enhance the taste of wine.

There is evidence that there is no acceptable level of lead in humans. Even low levels (below 25 $\mu g/dl$) may cause brain damage. It is theorized “that lead, as well as other toxic pollutants may interfere with calcium flow into neurons, thereby disrupting the learning process” in children.[71]

The CDC guideline for blood lead level has been lowered to 10 μg/dl. This will increase the number of children under age 6 at risk by 10 times according to CDC estimates.

Carbon Monoxide Poisoning

Carbon monoxide poisoning is sometimes confused with food poisoning, as nausea and vomiting are common to both. In carbon monoxide poisoning, the additional symptoms include headache, drowsiness, dizziness, flushed complexion, and general weakness, and carbon monoxide is found in the blood. Excessive exposure results in reduced oxygen availability to the heart, brain, and muscles, leading to weakness, loss of consciousness, and possible death. Persons with cardiovascular diseases are very sensitive to carbon monoxide in low concentrations.

Carbon monoxide combines readily with blood hemoglobin to form carboxyhemoglobin (COHb), thereby reducing the amount of hemoglobin available to carry oxygen to other parts of the body. Hemoglobin has a greater affinity for carbon monoxide than for oxygen—about 210 to 1. Fortunately, the formation of COHb is a reversible process. Death can occur when blood contains 60 to 80 percent COHb.

Carbon monoxide is an odorless, tasteless, and colorless gas. It is a product of incomplete combustion of carbonaceous fuels. Poisoning is caused by leaks in an automobile exhaust system; running a gasoline or diesel engine indoors or while parked; unvented or defective kerosene, gas,* fuel oil, coal, or wood-burning space or water heater, gas range-oven, or gas-fired floor furnace; use of charcoal grill indoors; clogged or leaking chimney or vent; inadequate ventilation and fresh air for complete combustion; improperly operating gas refrigerator; and incomplete combustion of liquefied petroleum gas in recreational and camping units. The indoor work environment (use of a fork lift or other motorized equipment) may also be a hazardous source of carbon monoxide.

Motor vehicle exhausts are the principal source of carbon monoxide air pollution; however, federal standards and emission controls on new automobiles are reducing the ambient-air carbon monoxide levels. Room space heaters are a major potential hazard indoors. Cigarette smoke is also a significant source of carbon monoxide to the smoker.

Education of the public and medical care personnel, standards for appliances, and housing code enforcement can reduce exposure and death from this poisoning. Homes in low-socioeconomic areas can be expected to have the highest carbon monoxide levels.

Concentrations of 70 to 100 ppm carbon monoxide are not unusual in city traffic. The federal ambient-air-quality standard maximum 8-hour concentration is 10 mg/m^3 (9 ppm); the maximum 1-hour concentration is 40 mg/m^3 (35 ppm).

*Including methane, butane, and propane.

These levels can reduce mental efficiency. The standard recommended by the National Institute for Occupational Safety and Health is (NIOSH) 55 mg/m^3 (50 ppm) 8-hour time-weighted average. Carbon monoxide levels of 200 to 400 ppm may cause headache and levels of 800 to 1600 ppm unconsciousness; even 50 ppm for 120 minutes has been shown to reduce exercise tolerance in subjects with angina. Persons with cardiovascular diseases are sensitive to concentrations of 35 ppm and as low as 10 ppm for extended periods.

Mercury Poisoning

Mercury poisoning in humans has been associated with the consumption of methylmercury-contaminated fish, shellfish, bread, and pork and, in wildlife, through the consumption of contaminated seed. Fish and shellfish poisoning occurred in Japan in the Minamata River and Bay region and at Niigata between 1953 and 1964. Bread poisoning occurred as a result of the use of wheat seed treated with a mercury fungicide to make bread in West Pakistan in 1961, Central Iraq in 1960 and 1965, and Panorama, Guatemala, in 1963 and 1964. Pork poisoning took place in Alamagordo, New Mexico, when methylmercury-treated seed was fed to hogs that were eaten by a family. In Sweden, the use of methylmercury as a seed fungicide was banned in 1966 in view of the drastic reduction in the wild bird population attributed to treated seed. In Yakima, Washington, early recognition of the hazard prevented illness when 16 members of an extended family were exposed to organic mercury poisoning in 1976 by the consumption of eggs from chickens fed mercurytreated seed grain. The grain contained 15,000 ppb total mercury, an egg 596 and 1902 ppb, respectively, of organic and inorganic mercury. Blood levels in the family ranged from 0.9 to 20.2 ppb in a man who ate eight eggs per day. A whole-blood level above 20 ppb may pose a mercury poisoning hazard.

It is also reported that crops grown from seed dressed with minimal amounts of methylmercury contain enough mercury to contribute to an accumulation in the food chain reaching humans. The discovery of moderate amounts of mercury in tuna and most freshwater fish and relatively large amounts in swordfish by many investigators in 1969 and 1970 tended to further dramatize the problem.

The organic methylmercury and other alkylmercury compounds are highly toxic. Depending on the concentration and intake, they can cause fever, chills, nausea, unusual weakness, fatigue, and apathy followed by neurologic disorders. Numbness around the mouth, loss of side vision, poor coordination in speech and gait, tremors of hands, irritability, and depression are additional symptoms leading possibly to blindness, paralysis, and death. Methylmercury also attacks vital organs such as the liver and kidney. It concentrates in the fetus and can cause birth defects.

Methylmercury has an estimated biological half-life of 70 to 74 days in humans, depending on such factors as age, size, and metabolism, and is excreted mostly in the feces at the rate of about 1 percent per day. Mercury persists in large fish such as pike from 1 to 2 years.

Elemental metallic mercury volatilizes on exposure to air, especially if heated, and in that state poses a distinct hazard. Mercury spills and the mercury from broken thermometers and barometers must be meticulously cleaned and the space ventilated and isolated until the mercury vapor level is no longer detectable by a "mercury sniffer" or similar device. Metallic mercury should never be incinerated; toxic gases would be released. Mercury should normally be stored and handled in an airtight enclosure with extreme care. Laboratory use must be carefully controlled and monitored. Certain compounds of mercury may be absorbed through the skin, gastrointestinal tract, and respiratory system (up to 98 percent), although elemental mercury and inorganic mercury compounds are not absorbed to any great extent* through the digestive tract because they do not remain in the body.

Mercury is ubiquitous in the environment. The sources are both natural and manmade. Natural sources are leachings, erosion, and volatilization from mercury-containing geologic formations. Carbonaceous shales average 400 to 500 ppb Hg, up to 0.8 ppm in soil. Manmade sources are waste discharges from chlor-alkali and paper pulp manufacturing plants, mining and extraction of mercury from cinnabar, chemical manufacture and formation, the manufacture of scientific instruments, mercury seals and controls, treated seeds, combustion of fossil fuels, atmospheric deposition, and surface runoff. The mercury ends up in lakes, streams, tidal water, and the bottom mud and sludge deposits.

Microorganisms and macroorganisms in water and bottom deposits can transform metallic mercury, inorganic divalent mercury, phenylmercury, and alkoxyalkylmercury into methylmercury. The methylmercury thus formed and perhaps other types, in addition to that discharged in wastewaters, are assimilated and accumulated by aquatic and marine life such as plankton, small fish, and large fish. Alkaline waters tend to favor production of the more volatile dimethylmercury, but acid waters are believed to favor retention of the dimethyl form in the bottom deposits. Under anaerobic conditions, the inorganic mercury ions are precipitated to insoluble mercury sulfide in the presence of hydrogen sulfide. The process of methylation will continue as long as organisms are present and have access to mercury. It is a very slow process, but exposure of bottom sediment such as at low tide permits aerobic action causing methylation of the inorganic mercury.

The form of mercury in fish has been found to be practically all methylmercury, and there are indications that a significant part of the mercury found in eggs and meat is in the form of methylmercury.

The concentration of mercury in fish and other aquatic animals and in wildlife is not unusual. Examination of preserved fish collected in 1927 and 1939 from Lake Ontario and Lake Champlain in New York has shown concentrations up to 1.3 ppm mercury (wet basis). Fish from remote ponds, lakes, and reservoirs have

*Seven to 8 percent from food and 15 percent or less from water (*Guidelines for Drinking Water Quality*, Vol. 2, World Health Organization, Geneva, 1984, p. 122).

shown 0.05 to 0.7 ppm or more mercury, with the larger and older fish showing the higher concentration.

There is no evidence to show that the mercury in the current daily dietary intake has caused any harm, although this does not rule out possible nondetectable effects on brain cells or other tissues. The general population should probably not eat more than one freshwater-fish meal per week.

Since mercury comes from manmade and natural sources, every effort must be made to eliminate mercury discharges into the environment. The general preventive and control measures applicable to chemical pollutants were summarized previously under "Background," but the goal should be "zero discharge."

Habashi[72] has summarized techniques for the removal of mercury at metallurgical plants in the United States, Europe, and Japan. The author reports that "the removal and recovery of traces of mercury from SO_2 gases or from sulfuric acid has been proved to be technically and economically feasible." Insofar as water supply is concerned, approximately 98 percent of inorganic mercury may be removed by coagulation and settling at a pH of 9.5 followed by filtration through a granular activated carbon filter.

Illnesses Associated with Air Pollution — Lung Diseases

The particulate and gaseous contaminants in polluted air may irritate the eyes and respiratory system or damage the clearance mechanism of the lungs, thereby increasing susceptibility to upper respiratory diseases and aggravating existing chronic illnesses. Diseases mentioned as *also* being associated with air pollution include bronchial asthma (restriction of the smaller airways or bronchioles and increase in mucous secretions), chronic bronchitis (excessive mucus and frequent cough), pulmonary emphysema (shortness of breath), lung cancer, heart diseases, and conjunctivitis (inflammation of the lids and coatings of the eyeballs) (also with lead and carbon monoxide poisoning as previously discussed). In an example of the built environment influencing health, one study found the higher prevalence of asthma in poor neighborhoods of Hartford, Connecticut, to be due in large part to a heavy burden of dust laden with cockroach antigen.[73]

A direct single cause-and-effect relationship is often difficult to prove because of the many other causative factors and variables usually involved. Nevertheless, the higher morbidity and mortality associated with higher levels of air pollution and reported episodes are believed to show a positive relationship.

Certain air contaminants, depending on the body burden, may produce systemic effects. These include arsenic, asbestos, cadmium, beryllium compounds, mercury, manganese compounds, carbon monoxide, fluorides, hydrocarbons, mercaptans, inorganic particulates, lead, radioactive isotopes, carcinogens, and insecticides. They require attention and are being given consideration in the development of air quality criteria.

Bronchial asthma affects susceptible sensitive individuals exposed to irritant air contaminants and aeroallergens. The aeroallergens include pollens, spores, rusts, and smuts. There also appears to be a good correlation between asthmatic attacks in children and adults and air pollution levels.

Chronic bronchitis has many contributing factors, including a low socioeconomic status, occupational exposure, and population density; smoking is a major factor. Air pollution resulting in smoke, particulates, and sulfur dioxide is an additional factor.

Emphysema mortality rates in U.S. urban areas are approximately twice the rural rates, indicating an association with air pollution levels (sulfur oxides). Asthma and bronchitis often precede emphysema.

Lung cancer rates are reported to be higher among the urban populations than the rural. The dominant factor in lung cancer is smoking. Air pollution plays a small but continuous role.

Some generalized effects of common air pollutants and their possible relationship to these diseases are of interest. Sulfur dioxide and sulfuric acid in low concentrations irritate the lungs, nose, and throat. This can cause the membrane lining of the bronchial tubes to become swollen and eroded, with resultant clotting in the small arteries and veins. Children are more susceptible to coughs, colds, asthma, bronchitis, and croup. Carbon monoxide can affect the cardiovascular system; in high concentrations, the heart, brain, and physical activity can be impaired. It can reach dangerous levels where there is heavy auto traffic and little wind. Smokers are at greater risk. Acute carbon monoxide poisoning causes a lowered concentration of oxygen in the blood and body tissues. (See the discussion on carbon monoxide poisoning earlier in this chapter.) Ozone and other organic oxidants, known as photochemical oxidants, are produced by the reaction of hydrocarbons and nitrogen oxides in sunlight. Ozone is believed to be responsible for a large portion of the health problems associated with photochemical oxidants.[74] Ozone and other chemicals formed in smog irritate the eyes and air passages, causing chest pain, coughing, shortness of breath, and nausea. Ozone can cause aging and severe damage to the lung tissues and interference with normal functioning of the lungs at levels of 0.12 ppm to greater than 0.20 ppm. Nitrogen dioxide in high concentrations can result in acute obstruction of the air passages and inflammation of the smaller bronchi. Nitrogen dioxide at low levels causes eye and bronchial irritation. In the presence of strong sunlight, nitrogen dioxide breaks down into nitric oxide and atomic oxygen, and this then combines with molecular oxygen in air to form ozone. Particulate matter can cause eye and throat irritation, bronchitis, lung damage, and impaired visibility.

Benzopyrene and related compounds are known to cause some types of cancer under laboratory conditions and have been incriminated as carcinogens. Olefins have an injurious effect on certain body cells and are apt to cause eye irritation. Beryllium concern relates primarily to lung disease, although it also affects the liver, spleen, kidneys, and lymph glands. Vinyl chloride is related to lung and liver cancer. Mercury may affect several areas of the brain as well as the kidneys and bowels. Lead is associated with retardation and brain damage, especially in children (see separate discussion earlier). The EPA National Emission Standards for Hazardous Air Pollutants identify vinyl chloride, lead, benzene, asbestos, beryllium, and mercury as hazardous. Considerable evidence has been assembled linking air pollution with adverse health effects.[225, 226]

Asbestos Diseases

Asbestosis is caused by fine silicate fibers retained in the lungs. There are six grades of asbestos. The most common are crocidolite (blue asbestos), amosite (brown asbestos), and chrysotile (white asbestos), which come from serpentine, and the less common are actinolite, tremolite, and anthrophyllite. Fibers are 0.1 to 10 μm in length, a size not generally visible. Positive identification requires laboratory analysis. The crocidolite fibers, the most hazardous, are straight and stiff (crocidolite has rarely been used since World War II), the amosite are less so; the chrysotile are curly. Fibers that are stiff and elongated lodge across the bronchi and eventually pass into the lung tissue and pleural cavity. Hence, more of the crocidolite is retained in the lungs and may be the cause of most asbestosis. However, chrysotile* is as likely as crocidolite and other fine silicate fibers to induce mesotheliomas after intrapleural entry and also as likely to induce lung neoplasms after inhalation exposures, although it is of less risk than crocidolite. The four most common diseases that might result from asbestos, usually after prolonged exposure, are listed here. The disease may appear 10 to 35 years after first exposure:

1. *Asbestosis*—a diffuse interstitial nonmalignant, scarring of the lungs
2. *Bronchogenic carcinoma*—a malignancy of the interior of the lungs
3. *Mesothelioma*—a diffuse malignancy of the lining of the chest cavity (pleural mesothelioma) or of the lining of the abdomen (peritoneal mesothelioma)
4. Cancer of the stomach, colon, and rectum

A potential health risk exists when asbestos fibers become airborne, as in the deterioration and exposure of asbestos in old asbestos paper-lined air distribution ducts, acoustic plaster ceilings, decorative and textured-spray finishes or paints and fire-retardant coatings on steel beams, and the demolition of old buildings. Spackling and other patching compounds may contain asbestos, which would be released to the ambient air in mixing and sanding to prepare the surface for painting. Fireplaces that simulate live embers and ash usually contain asbestos in an inhalable form. Other sources include furnace patching compounds, old steam pipe covers, floor materials, brake linings, paints, and certain domestic appliances. Asbestos is also found in some surface waters, urban stormwaters, and soils and generally in urban areas. However, occupational exposure is the major risk.

The EPA, under authority of the Toxic Substances Control Act of 1976, ruled on July 6, 1989, that all manufacture, import, or processing of felt products, asbestos–cement sheets, floor tiles, and clothing containing asbestos be ended by August 1990 and that distribution be ended in 1992; that disc brake linings

*Chrysotile fibers are estimated to make up 90 percent of all asbestos ("The asbestos dilema," *U.S. News & World Report*, January 14, 1990, pp. 57–58).

and gaskets be ended by August 1993 and their distribution by 1994; and that the manufacture, import, or processing of asbestos–containing paper products, brake blocks and pads, and asbestos-cement pipe and shingles be ended by August 1996 and distribution ended in 1997.* The CPSC has banned the use of sprayed-on asbestos insulation, spackling compound, and fireplace logs made with asbestos.

Airborne asbestos is potentially hazardous where asbestos-containing materials are loosely bound or deteriorating (friable, crumbly, or powdery when dry), including areas subject to vibration or abrasion, permitting fibers to be released. Control measures in buildings include removal, coating, or sealing (with butyl rubber in inaccessible locations) the surface; enclosure to prevent escape of fibers; surveillance; and affirmative action when the asbestos material begins to lose its integrity. *Existing asbestos that is sound is best left undisturbed*. Schools are required to be inspected to identify both deteriorating and solid asbestos. The coating or sealer used must be flame resistant, and must not release toxic gases or smoke when burned or contain asbestos. Coating or sealing must be considered an expedient requiring continual surveillance. Removal poses added risks to renovation, demolition, and other workers and occupants; it may also cause air pollution and dangers in handling (respirators, disposable garments, showering, complete enclosure of work area, and wetting down are needed) and disposal.

Malignant Neoplasms (Cancer)

Cancer is any malignant growth in the body. It is an uncontrolled multiplication of abnormal body cells. The cause of the various types of cancer is unknown, circumstantial, or unclear except for cigarette smoking and exposure to ionizing radiation. There does not appear to be a dosage or level of exposure to cigarette smoking or ionizing radiation below which there is *no* risk. Viruses, genetic background, poor health, and exposure to various agents in our air, water, food, drugs, and cosmetics are believed to contribute to the disease. Some environmental substances become carcinogenic only after metabolism within the body, and gene-environment interactions are believed to be crucial in determining an individual's risk to developing cancer from exposure to toxins.

Cardiovascular Diseases

The following are the major cardiovascular diseases.

- Ischemic heart disease (coronary heart disease)—a deficiency of the blood supply; the principal disease of the heart.

*The EPA ban on, e.g., pipe and pads was overturned by the U.S. Court of Appeals for the 5th Circuit in New Orleans. The ban on insulation, patching, and clothing remains in effect. (P. Zurer, *C&EN, October* 28, 1991, p. 5. Also, EPA Asbestos Materials Bans: Clarification May 18, 1999, EPA Office of Pollution Prevention and Toxics Web page, http://www.epa.gov/opptintr/opptintr/asbestos/help.htm#Roles. December 2001.)

- Cerebrovascular disease (stroke)—an occlusion or rupture of an artery to the brain.
- Arteriosclerosis—a thickening or hardening of the walls of the arteries, as in old age. Atheroselerosis is the most common form; fatty substances (containing cholesterol) deposited on the inner lining restrict the flow of blood in the arteries, causing coronary thrombosis (an occlusion of arteries supplying heart muscle). Hypertension (high blood pressure) and hypertensive heart disease. Rheumatic fever and rheumatic heart disease.

The risk factors associated with cardiovascular diseases include cigarette smoking, poor nutrition, socioeconomic status, age, sedentary way of life, family history, severe stress, personality type, and high blood pressure. Cardiovascular diseases have also been linked to high amounts of total fats, saturated fats, cholesterol, and sodium in the diet. Persons with cardiovascular diseases are more sensitive to carbon monoxide in low concentrations. Obesity and excessive alcohol intake are associated with hypertension.

The Council on Environmental Quality[75] confirmed reports showing that the death rates from cardiovascular diseases tend to decrease as the hardness of drinking water increases, but the factor is not considered to be hardness per se. The direct relationship between cardiovascular death rates and the degree of softness or acidity of water, according to Schroeder, points to cadmium as the suspect.[76] Large concentrations of cadmium may also be related to hypertension in addition to kidney damage, chronic bronchitis, and emphysema. Cadmium builds up in the human body. Low levels of magnesium in soft drinking water are also linked to sudden cardiac death. The indications are that the effects of soft water on cardiovascular diseases may be relatively small. Nevertheless, the water association deserves close attention since cardiovascular disease deaths account for about one-third of all deaths in the United States.

There is also evidence associating the ingestion of sodium with heart disease as well as with kidney disease and cirrhosis of the liver. Soft waters and reused waters generally contain higher concentrations of sodium than hard waters. Incidentally, diet drinks generally contain more sodium than regular soft drinks, as do sodium-containing dried milk preparations and cream substitutes. Home drinking water supplies softened by the ion exchange process (most home softeners) contain too much sodium for persons on sodium-restricted diets.* This can be avoided by having the cold-water line bypass the softener and using only the cold water for drinking and cooking. Other sources of sodium in drinking water are road salt contamination of surface and groundwater supplies; the sodium hydroxide, sodium carbonate, and sodium hypochlorite used in water treatment; sodium in distilled and bottled water; carbonated water in soft drinks; lime–soda ash and zeolite softened municipal water supplies; and natural minerals in sources of drinking water. The total body burden including that from food and drink must

*Each grain per gallon (17.1 mg/1) of hardness removed will add 8 mg/1 sodium to the treated water.

be considered. The crude death rate has decreased from 366.4 per 100,000 population in 1960 to 314.2 in 1988. The age-adjusted rate decreased from a peak of 307.4 in 1950 to 134.6 in 1996, an overall decline of 56 percent. This decline is due to a number of factors, including a decrease in the number of adults who smoke cigarettes, better control of hypertension, less ingestion of cholesterol and control of cholesterol levels, and improvements in medical care.

Methemoglobinemia

The presence of more than 45 mg/1 nitrates (10 mg/1 as N), the standard for drinking water, appears to be the cause of methemoglobinemia, or "blue baby." The disease is largely confined to infants less than three months old but may affect children up to age 6. It is caused by the bacterial conversion of the nitrate ion ingested in water, formula, and other food to nitrite. Nitrite then converts hemoglobin, the blood pigment that carries oxygen from the lungs to the tissues, to methemoglobin. Because the altered pigment no longer can transport oxygen, the physiologic effect is oxygen deprivation, or suffocation. Methemoglobinemia is not a problem in adults, as the stomach pH is normally less than 4, whereas the pH is generally higher in infants, allowing nitrate-reducing bacteria to survive.

Dental Caries

Fluoride deficiency is associated with dental caries and osteoporosis. [77] Water containing 0.8 to 1.7 mg/1 natural or artificially added fluoride is beneficial to children during the period they are developing permanent teeth. The incidence of dental cavities, or tooth decay, is reduced by about 60 percent. The maximum fluoride concentration permissible in drinking water is 4.0 mg/1. Optimum fluoride levels in drinking water for caries control, based on the annual average of the maximum daily air temperature for the location of the community water system, are as follows:

Temperature (°F)	Fluoride Level (mg/1)
53.7 and below	1.2
53.8–58.3	1.1
58.4–63.8	1.0
63.9–70.6	0.9
70.7–79.2	0.8
79.3–90.5	0.7

An alternate to community water fluoridation is a 1-minute mouth rinse by children once a week; it is reported to reduce tooth decay by about one-third or more. The mouth rinse also appears to be beneficial to adults in the prevention of dental caries. Other alternatives include fluoridation of school water supplies if there is an onsite water supply, use of fluoride toothpaste, drops and tablets, and topical application. Milk fluoridation has been shown to be effective in the prevention of dental caries, but to be clinically effective, it must be freshly prepared and consumed immediately. The use of table salt containing fluoride has been proposed by the Pan American Health Organization in areas lacking fluoridated community water supplies. Oral hygiene, including at least daily teeth brushing, consumption of fewer sweets, followed by water rinse or drink, is also basic to caries reduction.

Hypothermia

The maintenance of a normal body temperature at or near 98.4°F (37°C) is necessary for proper body function. When the body core temperature drops to 95°F (35°C) or below, the vital organs (brain, heart, lungs, kidneys) are affected, causing what is known as hypothermia. There were 7,450 deaths from hypothermia reported between 1976 and 1985. In 2001, Montana had a death rate from hypothermia of 1.08 per 100,000, which is nearly fives time greater than the overall U.S. rate.[78] Rectal temperature measurement is necessary to get a correct reading. Special "hypothermia thermometers" for accurate reading are available. Predisposing conditions for hypothermia include old age, poor housing, inadequate clothing, poverty, lack of fuel, illness, cold weather, alcohol, and drugs.

Proper body temperature requires a balance between body heat generated and heat loss. Bald people lose a great deal of heat; fat people are better insulated and lose less heat on a weight–body surface basis. Disease and drugs, including alcohol, affect heat loss. Wind and dampness increase coldness. The maintenance of warmth and comfort is related to the prevailing temperature, building design and construction, clothing, heating and cooling facilities, and food consumed and also to air movement, radiant heat, relative humidity, the tasks performed, and the age and health status of individuals. At greater risk are babies and the elderly, particularly those already suffering from an acute or chronic illness. Provision for heating and cooling above and below that temperature is recommended. Lack of adequate housing and acute alcohol intoxication are the principal causes of death, as well as advanced age and adverse social and economic circumstances (homelessness).

Signs of hypothermia are bloated face, pale and waxy skin or pinkish color, drowsiness, low blood pressure, irregular and slow heart beat, shallow very slow breathing, trembling of leg, arm, or side of body, and stiff muscles. People should stay indoors when the windchill index is −20°F (−29°C) and below.

High Environmental Temperatures

Heat waves have been associated with marked increases in morbidity and mortality in the United States, but these deaths are largely preventable. Heat disorders include heatstroke, heat exhaustion, heat cramps, and heat rash. Heatstroke, when one's core temperature exceeds 105°F (40.5°C), is the most serious. The measures that have been shown to be effective to reduce heat stress include the following:

1. Keep as cool as possible.
   a. Avoid direct sunlight.
   b. Stay in the coolest available location (it will usually be indoors).
   c. Use air conditioning, if available.
   d. Use electric fans to promote cooling.
   e. Place wet towels or ice bags on the body or dampen clothing.
   f. Take cool baths or showers.
2. Wear lightweight, loose-fitting clothing.
3. Avoid strenuous physical activity, particularly in the sun and during the hottest part of the day.
4. Increase intake of fluids, such as water and fruit or vegetable juices. Thirst is not always a good indicator of adequacy of fluid intake. Persons for whom salt or fluid is restricted should consult their physicians for instructions on appropriate fluid and salt intake.
5. Do not take salt tablets unless so instructed by a physician.
6. Avoid alcoholic beverages (beer, wine, and liquor).
7. Stay in at least daily contact with other people.

Special precautions should be taken for certain higher-risk groups, including those occupationally exposed. Safeguards may include increased efforts to keep cool and close observation by others for early signs of heat illness. The high-risk groups are infants and children less than 4 years of age, persons over 65 years of age, alcoholics, persons who are less able to care for themselves because of mental illness or dementia, persons with chronic diseases, especially cardiovascular or kidney disease, and those taking any of the three classes of medication that reduce the ability to sweat: diuretics (water pills), tranquilizers, and drugs used for the treatment of gastrointestinal disorders. Building insulation and ventilation help control indoor temperature. Temperatures of 85°F (29°C) or less are usually no cause for worry. High humidity and temperatures near 100°F (38°C) for several days could be dangerous. Strenuous activity should be suspended when the wet bulb temperature index is 90°F (32°C) and above.[79]

Skin Damage from Sunlight

The ultraviolet light in sunlight can injure the skin and cause skin cancer (melanoma), depending on the exposure. Melanoma appears as a pigmented mole or tumor that may or may not be malignant. Melanomas are almost always curable if detected early and can be usually removed by surgery or freezing with liquid nitrogen. Cataracts can also result from too much sun.

Anyone exposed to the sun should take precautions to avoid the most intense and most hazardous rays between 11 a.m. and 3 p.m. in the United States. A hat and clothing that covers the body are advised. Bathers should use an effective sunscreen lotion. The higher the sunscreen number, the higher the protection.

The number selected should be based on skin type and expected exposure time. Individuals with light skin are especially vulnerable.

Tap Water Scalds

Residential hot-water heaters with temperature settings above 120°F (48.9°C) are the principal cause of tap water scalds. Young children, the elderly, and the handicapped are most frequently involved. Showers are another potential hazard if capable of discharging water above 120°F. Hot-water heater thermostats should be lowered to 120°F to prevent scalding accidents.

Sporotrichosis

Conifer seedlings packed in sphagnum moss can cause papules or skin ulcers and inflammation on the hands and arms, which can then spread to other parts of the body. This disease is caused by a fungus, *Sporothrix schenckii*, found in moss, hay, soil, and decaying vegetation. Protective clothing, including gloves and long-sleeved shirts, should be worn when handling sphagnum moss or seedlings.

DEFINITIONS

Certain terms with which one should become familiar are frequently used in the discussion of communicable and noninfectious or noncommunicable diseases. Some common definitions are given here.

Antigen(s) Foreign substance(s) inducing the formation of antibodies. In some vaccines, the antigen is highly defined (e.g., pneumococcal polysaccharide, hepatitis B surface antigen, tetanus, or diphtheria toxoids); in others, it is complex or incompletely defined (e.g., killed pertussis bacteria; live, attenuated viruses).[1] Antibodies are specific substances formed by the body in response to stimulation by antigens.

Body burden The total effect on the body from ingestion or exposure to a toxic chemical in the air, water, or food. Can be determined by examination of samples of human hair, tissue, blood, urine, and milk, also by measurement of the amount in air, water, and food, and then the intake from these sources, including contact.

Contact A person or animal that has been in an association with an infected person or animal or a contaminated environment that might provide an opportunity to acquire the infective agent.[3]

Contamination The presence of an infectious agent on a body surface; also on or in clothes, bedding, toys, surgical instruments or dressings, or other inanimate articles or substances, including water and food. *Pollution* is distinct from contamination and implies the presence of offensive, but not necessarily infectious, matter in the environment. Contamination on a body surface does not imply a carrier state.[3]

Disinfection The application of microbicidal chemicals to materials (surfaces as well as water), which come into contact with or are ingested by humans and animals, for the purpose of killing pathogenic microorganisms. Disinfection may not be totally effective against all pathogens.

Disinfestation Any physical or chemical process serving to destroy or remove undesired small animal forms, particularly arthropods or rodents, present upon the person or the clothing, in the environment of an individual, or on domestic animals. Disinfestation includes delousing for infestation with *Pediculus humanus*, the body louse. Synonyms include the terms *disinsection* and *disinsectization* when only insects are involved.[3]

Endemic The constant presence of a disease or infectious agent within a given geographic area; may also refer to the usual prevalence of a given disease within such area. *Hyperendemic* expresses a persistent intense transmission and *holoendemic* a high level of infection, beginning early in life and affecting most of the population (e.g., malaria in some places).

Endotoxin The toxin produced by a microorganism that is retained within the cell but is liberated when the cell disintegrates (as in the intestine) causing pathologic damage to surrounding tissue. Most known varieties of these toxins withstand autoclaving.[6]

Enterotoxin A toxin produced by certain microorganisms that is secreted in the gastrointestinal tract. It is associated with the symptoms of food poisoning and is heat stable. Examples of bacteria know to secrete this type of toxin are: *Escherichia coli* O157: H7, *Clostridium perfringens*, *Vibrio cholerae*, *Staphylococcus aureus*, and *Yersinia enterocolitica*.

Epidemic/outbreak The occurrence in a community or region of cases of an illness in excess of what would be expected during the same time period. The number of cases indicating the presence of an epidemic will vary according to the infectious agent, size and type of population exposed, previous experience or lack of exposure to the disease, and time and place of occurrence; epidemicity is thus relative to usual frequency of the disease in the same area, among the specified population, at the same season of the year. A single case of a communicable disease long absent from a population or the first invasion by a disease not previously recognized in that area requires immediate reporting and epidemiologic investigation; two cases of such a disease associated in time and place are sufficient evidence of transmission to be considered an epidemic. The terms *outbreak* and *epidemic* can technically be used interchangeably; however, the public perception of the latter is more dramatic.

Exotoxin A toxin produced by a microorganism and secreted into the surrounding medium, usually the cellular cytoplasm, blood, or other bodily fluids. Exotoxins can operate on organs and tissues different from the site of infection and can bring about pathological manifestations that are separate from the initial infection, or within the infected cell itself. Genes encoding exotoxins can be acquired by microorganisms that would otherwise cause minor or less severe disease in humans. Some strains of the following bacteria have are common causes of disease associated with exotoxins: *E. coli*, *Staphylococcus aureus*, *Streptococcus pyogenes*, *Clostridium perfringens*, *Shigella* spp., and *Clostridium botulinum*.

LC_{50} The median lethal concentration of a substance in the air, causing death in 50 percent of the animals exposed by inhalation; a measure of acute toxicity.

LD_{50} The median lethal dose, causing death in 50 percent of the animals exposed by swallowing a substance; a measure of acute toxicity.

Neurotoxin A toxin that attacks nerve cells (e.g., botulism).

Noninfectious or noncommunicable disease The chronic, degenerative, and insidious disease that usually develops over an extended period and whose cause may not be entirely clear. In its broad sense, cancer, alcoholism, mental illnesses, tooth decay, ulcers, and lead poisoning are regarded as noncommunicable or noninfectious diseases. Also included are cardiovascular diseases, pulmonary diseases, diabetes, arthritis, nutritional deficiency diseases, malignant neoplasms, kidney diseases, injuries, and illnesses associated with toxic organic and inorganic chemicals and physical agents in air, water, and food. For the purposes of this text, discussion of noninfectious diseases emphasizes the environmental media or factors serving as the vehicle for transmission of the disease. The usual environmental media are air, food, water, and land (soil, flora, fauna); other factors leading to injuries and contact may also be involved.

In contrast to communicable diseases, *chronic diseases* may be caused by a variety or combination of factors that are difficult to identify, treat, and control. The resulting illness may cause protracted or intermittent pain and disability with lengthy hospitalization. A *degenerative condition* is the result of the deterioration or breaking down of a tissue or part of the body (aging).

Pathogen An infectious agent capable of causing disease.

Pathogenic The potential for producing disease, if the organism is sufficiently virulent to enter the body and overcome the defense mechanism of the host.

Prevention, primary Prevention of an etiologic agent, substance, or action from causing disease or injury in humans; intervention; regulation of exposure to environmental hazards that cause disease or injury to decrease morbidity and mortality. Action to promote health and prevent disease or injury. Includes immunization, adequate supply of safe water and basic sanitation, prevention education, food and nutrition, and maternal and child care.

Prevention, secondary Early detection and treatment to cure or control disease. Surveillance, screening, and monitoring the environment. Also measures to protect the public (e.g., treatment of public water supplies, fluoridation for dental control).

Prevention, tertiary Amelioration of a disease to reduce disability or dependence resulting from it. Conventional medical treatment and restoration of health and well-being to the extent possible. Voluntary action by the individual.

Primary health care Application of the principles of health education, nutrition, immunization, water and sanitation, maternal and child care and family planning, control of endemic diseases, treatment of common diseases, and provision of essential drugs [World Health Organization (WHO)].

Public health "Public health is the science and art of preventing disease, prolonging life, and promoting physical and mental health and efficiency through organized community efforts for the sanitation of the environment, the control of community infections, and education of the individual in principles of personal hygiene, the organization of medical and nursing services for the early diagnosis and preventive treatment of disease, and the development of the social machinery that will ensure every individual in the community a standard of living adequate for the maintenance of health."[80]

Sanitation The effective use of measures that create and maintain healthy environmental conditions. Among these measures are the safeguarding of food and water, proper sewage and excreta disposal, and the control of disease-carrying insects and animals.

Sanitize To reduce microorganism level to an acceptable level, usually by the continuous application of heat or chemicals at suitable concentrations and times.

Sterilization The process of killing all microorganisms, including spores.

Susceptible A person or animal presumably not possessing sufficient resistance against a particular pathogenic agent to prevent contracting infection or disease if or when exposed to the agent.[3]

Teratogen An agent (radiation, virus, drug, chemical) that acts during pregnancy to produce a physical or functional defect in the developing offspring. Substances that have caused defects are methylmercury and thalidomide. Some environmental pollutants may be both carcinogenic and teratogenic.

TLV (threshold limit value) The *average* 8-hour occupational exposure limit This means that the actual exposure level may sometimes be higher, sometimes lower, but the average must not exceed the TLV. TLVs are calculated to be safe exposures for a working lifetime.

Toxicity, acute condition Adverse effects occurring shortly after the administration or intake of a single or multiple dose of a substance (oral rat LD_{50}). Conditions classified as acute include viruses, colds, flu, and other respiratory conditions; headaches, gastrointestinal disorders, and other digestive conditions; accidental injuries; genitourinary disorders; diseases of the skin; and other acute conditions. A condition that has lasted less than three months and has involved either a physician visit (medical attention) or restricted activity.

Toxicity, chronic condition An injury that persists because it is irreversible or progressive or because the rate of injury is greater than the rate of repair during a prolonged exposure period (cancer or liver damage). Conditions classified as chronic include major categories of chronic illnesses such as heart disease, hypertension, arthritis, diabetes, ulcers, bronchitis, and emphysema. Any condition lasting three months or more or one of certain conditions classified as chronic regardless of their time of onset.

Toxin A poisonous substance of animal or plant origin.

YPLL Total years of potential life lost, a measure of premature mortality from all causes over the span from age 1 to 65 years based on age-specific death rates.

USEFUL INTERNET WEB SITES

Centers for Disease Control: http://www.cdc.gov. Site includes Emerging Infectious Disease, National Vital Statistics, *MMWR* (*Morbidity and Mortality Weekly*), National Center for Environmental Health, and FoodNet.

World Health Organization: http://www.who.int/.

Environmental Protection Agency: Including National Ambient Air Quality Standards, AIRNOW and Pollution Prevention.

U.S. Dept of Health and Human Services: http://www.dhhs.gov.

Food and Drug Administration: http://www.fda.gov. Including FDA Consumer Magazine and Center for Food Safety and Applied Nutrition.

Taber's Online: http://www.tabers.com. Medical definitions and periodicals.

American Journal of Public Health: http://www.ajph.org.

Library of Congress: http://www.loc.gov/ Thomas Search Engine, which searches the database of the *Congressional Record* for any law or piece of legislation from the 93rd Congress (1973–1974) to the present Congress.

Medline/PubMed: http://www.ncbi.nlm.nih.gov/pubmed.

Powerful search engine for biomedical science literature. Use the "limits" feature to narrow your search.

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CHAPTER 3

FOODBORNE DISEASES

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INTRODUCTION

Enteric infections are the second most common cause of mortality among children less than five years of age in developing countries.[1] Poverty is a fundamental cause of the high mortality associated with enteric infections in the developing world. Issues such as a lack of safe drinking water, crowded living conditions, lack of refrigeration, and inadequate sanitation all contribute to this problem. Additionally, because of a lack of access to health care, enteric infections are more often severe or fatal setting where there are barriers to adequate medical care. In contrast, there is little mortality from enteric infections in industrialized countries. Toward the beginning of the twentieth century, similar conditions were more prevalent in North America and Europe; economic development and improved living conditions are thought to have played a large role in the decrease in deaths from diarrheal diseases and pneumonia by the 1930s.[2]

Foodborne illnesses are estimated to cause 76 million illnesses, 325,000 hospitalizations, and 5,000 deaths in the United States each year.[3] Infectious agents spread by water and food cause both sporadic cases and large outbreaks. Symptoms of these illnesses range from mild gastroenteritis to potentially life-threatening conditions that may cause disability and death. In some instances, as among the very young, the very old, and the immunocompromised, the added strain of a water- or foodborne illness can be fatal. This chapter covers major food- and waterborne diseases of public health importance, including their epidemiology and prevention. Included in this chapter as foodborne diseases are also those caused by poisonous plants and animals used for food, toxins produced by bacteria, and foods accidentally contaminated with chemical poisons. These diseases are usually, but not always, characterized by

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diarrhea, vomiting, nausea, or fever. Additionally, this chapter addresses some related diseases and conditions, including nutritional deficiencies, as well as investigation and control of disease outbreaks.

SURVIVAL OF PATHOGENS

The survival of pathogens is affected by a number of factors, including the type of organism, temperature, moisture, nutrients, pH, and sunlight. Since these factors are quite variable, the survival data in Table 3.1 should be used only as a guide. For some waterborne pathogens, the amount of clay and organic matter in the soil may affect the movement of pathogens, but porous soils, cracks, fissures, and channels in rocks permit pollution to travel long distances.

Despite variations in environmental resistance among pathogens, some generalities can be made. Soil moisture of about 10 to 20 percent of saturation

TABLE 3.1 Survival of Certain Pathogens in Soil and on Plants

Organism	Media	Survival Time (days)
Ascaris ova	Soil	Up to 7 years
	Vegetables and fruits	27–35
Coliforms	Soil surface	38, greater in soil
	Vegetables	35
	Grass and clover	6–34
Cryptosporidium oocyst[a]	Moist environment	60–180
Entamoeba histolytica cysts	Soil	6–8
	Vegetables	1–3
	Water	8–40
Enteroviruses	Soil	8 or longer[b]
	Vegetables	4–6 or longer
Salmonella	Soil	1–120
	Vegetables and fruits	1–68
Salmonella typhosa	Peat soils	Up to 85, 2 years at 0°C
Shigella	Grass (raw wastewater)	42
	Vegetables	2–10
	Water containing humus	160
Tubercle bacilli	Soil	180
	Grass	10–49

Source: D. Parsons et al., "Health Aspects of Sewage Effluent Irrigation," Pollution Control Branch, British Columbia Water Resources Services, Victoria, 1975, cited by E. Epstein and R. L. Chancy, "Land Disposal of Toxic Substances and Water-Related Problems," *J. Water Pollut. Control Fed*. (August 1978): 2037–2042.

Note: The survival of pathogens can be quite variable. [a]A. S. Benenson (Ed.), *Control of Communicable Diseases in Man*, 15th ed., American Public Health Association, Washington, DC., 1990, p. 113.

[b]One or two years at 40°F (4°C).

appears to be best for survival of pathogens; drier conditions generally decrease the ability of a pathogen to survive. Nutrients increase survival. The pH is not a major factor. For most pathogens, exposure to sunlight acts as desiccant rate. Low temperatures favor survival.[4,5] The survival of pathogens in soil, on foods, and following various wastewater unit treatment processes as reported by various investigators, is summarized by Bryan and others.[6,7] Most enteroviruses pass through sewage treatment plants, survive in surface waters, and may pass through water treatment plants providing conventional treatment. Water treatment plants maintaining a free residual chlorine and low turbidity less than 1 nephelometric turbidity unit (NTU) in the finished water, as noted under Chlorine Treatment for Operation and Microbiological Control in Chapter 3, or using other approved disinfection treatment, can accomplish satisfactory virus destruction.

INFECTIOUS DOSE

The development of illness is dependent on three basic things: the toxicity or virulence of a substance, the amount of the substance or microorganisms ingested (at one time or additively over a specified period of time), and the susceptibility of the individual. The result may be an acute or a chronic illness. Exposure to two or more substances may produce a synergistic, additive, or antagonistic effect. Persons may be exposed to a microorganism by direct ingestion of a pathogen or toxin in contaminated water or food, contact with an infected person or animal, or exposure to an aerosol containing the pathogen.

When the dose of a chemical substance administered to a series of animals is plotted against the effect produced, such as illness, if increased doses produce no increases in illnesses, the substance is said to cause "no effect." If increased doses cause increasing illnesses, the substance has "no threshold." If increased doses cause no apparent increases in illnesses at first but then continuing increased doses show increasing illnesses, the dose at which illnesses begin to increase is referred to as the substance *threshold*. Below that dose is the "no-observed-effect" range. Variations between animal species must be considered.

Table 3.2 lists various microorganisms and the approximate number (infectious dose) of organisms required to cause disease. Bryan[6] has summarized the work of numerous investigators giving the clinical response of adult humans to varying challenge doses of enteric pathogens. For example, a dose of 10^9 *Streptococcus faecalis* was required to cause illness in 1 to 25 percent of healthy volunteers, 10^8 *Clostridium perfringens* type A (heat resistant) bacteria caused illness in 26 to 50 percent of the volunteers, and 10^9 *C. perfringens* type A (heat sensitive) bacteria caused illness in 76 to 100 percent of the volunteers.

For some viral infections, ingestion of as few as one viral particle can infect a susceptible host. In that case, it would appear that viral infections should be readily spread through drinking water, food, shellfish, and water-contact recreational activities. Fortunately, the tremendous dilution that wastewater containing viruses usually receives on discharge to a watercourse and the chemical treatment of drinking water greatly reduce the probability of an individual receiving

TABLE 3.2 Substance Dose to Cause Illness

Microorganism	Approximate Number of Organisms (Dose) Required to Cause Disease
Campylobacter jejuni[a]	10^2 or fewer
Coxiella burneti[b]	10^7
Cryptosporidium spp.[c]	10^1–10^2 oocysts
Dracunculus, Ascaris, Schistosoma	1 cyst, egg, or larva
Entamoeba histolytica[d]	10–20 cysts, one in a susceptible host
Escherichia coli[b]	10^8
Giardia lamblia[c–f]	5–10^2 cysts
Salmonella typhi[b,g]	10^5–10^6
Salmonella typhimurium[g]	10^3–10^4
Shigella spp.[b,g]	10^1–10^2
Staphylococcus aureus[b]	10^6–10^7 viable enterotoxin-producing cells per gram of food or milliliter of milk
Vibrio cholerae[b,g]	10^6–10^9

[a]Robert V. Tauxe et al., "*Campylobacter* Isolates in the United States, 1982–1986," *MMWR CDC Surveillance Summaries*, June 1988, p. 9.
[b]H. L. Dupont and R. B. Hornick, "Infectious Disease from Food," in *Environmental Problems in Medicine*, W. C. McKee (Ed.), Charles C. Thomas, Springfield, IL, 1974.
[c]R. M. Clark et al., "Analysis of Inactivation of *Giardia lamblia* by Chlorine," *J. Environ. Eng*. (February 1989): 80–90.
[d]*Guidelines for Drinking Water Quality*, Vol. 2, World Health Organization, Geneva, 1984, p. 44.
[e]Up to 10 cysts from beaver to human and one to 10 cysts to cause human to human infection.
[f]R. C. Rendtorff, "Experimental Transmission of *Giardia lamblia," Am. J. Hyg*., **59**, 209 (1954).
[g]Eugene J. Gangarosa, "The Epidemiologic Basis of Cholera Control," *Bull. Pan Am. Health Org*., **8**, 3 (1974).

an infectious dose. However, some viruses (and other microorganisms) do survive and present a hazard to the exposed population. Not all viruses are pathogenic. An indication of the difficulty involved in testing for the effect of chemicals is given by Kennedy[8] "A typical chronic toxicology test on compound X, done to meet a regulatory requirement with an adequate number of animals and an appropriate test protocol, costs $250,000 to 300,000," and requires two to three or more years to complete. Information concerning the *acute* effect of ingestion of toxic substances is available in toxicology texts.[9]

RESERVOIR OR SOURCE OF DISEASE AGENTS

Humans as Reservoirs

Contamination of food and drink may occur either directly with human or domestic animal feces or indirectly by contact with objects that have had contact with infected waste. Infected persons may serve as reservoirs for many of these diseases, and may shed infectious organisms in their feces. Urine is usually sterile, except for urinary schistosomiasis, typhoid, and leptospirosis carriers.[33] The prevalence of carriers differs by disease within an exposed population. For example, the prevalence of amebic dysentery varies between 10 and 25 percent and may be as high as 60 percent; shigellosis may be higher. Stoll has ventured to hazard a guess of the prevalence of helminthic infections in the world.[10] He estimates that at least 500 million persons harbor ascarids, 400 million other worms (helminthes). Actually, a person who is ill with a helminthic disease probably is infected with more than one parasite, since the conditions conducive to one infection would allow additional species to be present.

The World Health Organization (WHO) estimates that 600 million people are at risk and 300 million are afflicted by schistosomiasis (bilharziasis), usually spread by wading in cercariae-infested water[11] In addition, it is estimated that almost a quarter of the world's population suffers from one of four water-related diseases: gastroenteritis, malaria, river blindness (onchocerciasis), or schistosomiasis A survey of U.S., state, and territorial public health laboratories by the CDC in 1976 for frequency of diagnosis of intestinal parasitic infections in 414,820 stool specimens showed 15.6 percent contained one or more pathogenic or nonpathogenic intestinal parasites, 3.8 percent were positive for *Giardia lamblia*, 2.7 percent for *Trichuris trichiura*, 2.3 percent for *Ascaris lumbricoides*, 1.7 percent for *Enterobius vermicularis*, and 0.6 percent for *Entamoeba histolytica*.[12]

A study at a missionary college in east central China showed that 49 percent of the students harbored parasitic worms, and a survey in an elementary school in New Jersey found that 23 percent of the children were infected. In 1970, Lease reported on the study of day care and elementary school programs in four counties in South Carolina involving 884 children.[13] He found that 22.5 percent of black children harbored *Ascaris* intestinal roundworms and, of the 52 white children in the group, 13.5 percent had worms. Central sewage and water supply was lacking. Persons living in rural areas had higher infection rates; infected rural children also had twice the number of worms as infected children from urban areas. A study involving 203 children ranging in age from six months to six years in St. Lucia in the Caribbean showed that infection with *T. trichiura* was 84 percent, *A. lumbricoides* 62 percent, hookworm 7 percent, and *Toxocara canis* 86 percent.[14] Since parasitic infection plus poor diet may result in serious debility and perhaps death, preventive measures, including better sanitation and hygienic practices, are essential.

The mouth, nose, throat, respiratory tract, and skin of humans are also reservoirs of microorganisms that directly cause a large group of illnesses. *Staphylococci* that produce enterotoxin are also found on the skin and mucous membranes, in pus, feces, dust, and air, and in unsanitary food-processing plants. They are the principal causes of boils, pimples, and other skin infections, and are particularly abundant in the nose and throat of a person with a cold. It is no surprise, therefore, that *staphylococcus* food poisoning is one of the most common foodborne diseases. Scrupulous cleanliness in food-processing plants, in the kitchen, and among foodhandlers is essential if contamination of food with *salmonella* spp., *staphylococci*, *clostridia*, and other microorganisms is to be prevented.

Animals as Reservoirs

A number of animal species serve as reservoirs for diseases that may affect humans, including the following 13 diseases:

1. Brucellosis (undulant fever)
2. Clonorchiasis
3. Fascioliasis (intestinal fluke) and fasciolopsiasis
4. Leptospirosis
5. Paragonimiasis (lung fluke)
6. Salmonella infection (salmonellosis)
7. Schistosomiasis
8. Taeniasis (pork or beef tapeworm) and cysticercosis
9. Toxoplasmosis
10. Trichinosis (trichiniasis)
11. Trichuriasis (whipworm)
12. Tularemia
13. Yersiniosis

In 1948, the prevalence of trichinosis in grain-fed hogs was 0.95 percent and in garbage-fed hogs 5.7 percent.[15] Surveys in New England and the Mid-Atlantic States in 1985 found infection rates of 0.73 and 0.58 percent, respectively, in pigs, compared to an estimated national rate of 0.1 percent[16] Wild animals, including bears, boars, martens, wolverines, bobcats, and coyotes, are also carriers. Horsemeat has also been implicated as a source of infection.[17] The incidence of adult *Trichinella* infection in the United States has been declining, with only 129 cases reported in 1990[18] and 16 cases reported in 2005.[19]

Processed meats may be considered acceptable when stamped “U.S. inspected for wholesomeness,” but this is no guarantee that the product is absolutely safe; it signifies the product was processed in accordance with U.S. Department of Agriculture (USDA) specifications. This is also true of raw meat and poultry, which frequently contain *Salmonella* and other pathogenic organisms, even though stamped “inspected.” Raw meat products require hygienic handling and adequate cooking. Uncooked summer sausage (fresh ground pork, beef, and seasoning plus light smoking) and raw or partially cooked pork products should be avoided.[20]

Some organisms are excreted in the urine of mice and rats, including the following:

- Lymphocytic choriomeningitis virus
- *Escherichia coli*
- *Leptospira*
- *Salmonella*

- *Staphylococcus*
- *Yersinia*

Because of the practical difficulty of permanently eliminating all mice and rats, the threat of contaminating food with the organisms causing the foregoing diseases is ever present. This emphasizes the additional necessity of keeping all food covered and protected.

Dust, eggs, poultry, pigs, sheep, cattle and animal feed, rabbits, rats, cats, and dogs may harbor *salmonella* and other causative organisms. shelled eggs and egg powder may also contain *salmonella*. *Salmonella* food infection is common and routinely causes non-life-threatening in healthy individuals

FOOD SPOILAGE

When fresh foods are allowed to stand at room temperature, they begin to deteriorate. The changes in the composition of the food are brought about by the action of enzymes and microorganisms, including molds and yeasts. Factors such as oxygen, sunlight, warmth, dehydration, insects, and other vermin accelerate decomposition, contributing to the unpleasant appearance and taste of the food, the loss of freshness, and changes in the color and odor. Food that has been permitted to decompose loses much of its nutritive value. Atmospheric oxidation causes a reduction of the vitamin content and quality, a breakdown of the fats, then the proteins, to form hydrogen sulfide, ammonia, and other products of decay. Antioxidants are sometimes used to slow down food deterioration, rancidity, or discoloration due to oxidation. These include ascorbic acid, butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), citric acid, and phosphates. The Food and Drug Administration (FDA) requires that ingredient labels carry and list the antioxidants as well as their carriers.[21] Contamination, which almost always accompanies putrefaction, may be dangerous. In certain instances, the microbiological activity will produce a toxin (e.g *Staphylococcus aureus* toxin) that even ordinary cooking cannot destroy. Most bacteria associated with food spoilage will grow within a wide pH range, from 3.0 or 4.0 to 8.0 or 9.3. Yeasts and molds also grow within a very wide pH range, from 1.5 to 8.5 or 11.0. Foods with pH values below 4.5 are usually not easily spoiled by bacteria but are more susceptible to spoilage by yeasts and molds.[22]

Mycotoxins are secondary meabolites produced by several groups of fungi, including those in the genera *Aspergillus, Penicillium, and Fusarium*. Mycotoxins may contaminate human or animal food, resulting in a toxic response when ingested. The toxic effects of mycotoxin ingestion depend on several factors, including the amount and type of toxin ingested and the duration of exposure to the toxin. In addition to causing acute toxicity, some mycotoxins may have teratogenic and carcinogenic effects.

High humidity and water activity (a_w) favor mycotoxin production; the amounts vary with the product. Molds and most yeasts require oxygen to grow and grow over a very wide pH range. Mycotoxins may also be resistant to heat and dessication and can survive a range of temperatures from 14° to 131°F (−10° to 55°C). Ingestion of contaminated feed by farm animals may permit carryover of toxins into meat and milk. There are about 15 types of dangerous mycotoxins. One common type, aflatoxin, is a potential human carcinogen and is produced by the mold *Aspergillus flavus* and other *Aspergillus* species generally found in feeds and food. Aflatoxin-producing mold growths occur over a wide range of temperatures from 53° to 110°F (12° to 43°C), although 92°F (33°C) is optimum. *Aspergillus* mold has been detected in peanuts and peanut butter, corn, figs, cereals (wheat, barley, millet), cottonseed products, milk and milk products, and other foods that are not properly dried and stored, thereby favoring fungus contamination and growth on the food. The *Aspergillus* species may be airborne and inhaled, causing aspergillosis. Compost piles are common reservoirs and sources of infection. Fortunately, the mere presence of a mold does not automatically mean the presence of mycotoxins. Contamination may result also before harvest. Most fungal toxins, including aflatoxins, are not destroyed by boiling and autoclaving.[23] Oven roasting artificially contaminated peanuts for 30 minutes at 302°F (150°C) or microwave roasting for 8.5 minutes can destroy 30 to 45 percent of aflatoxin B_1.[24]Properly stored leftover foods may also be a source of aflatoxins. Aflatoxins fluoresce under long-wave ultraviolet light.

Aflatoxin causes cancer in rats and is suspected to be a cause of liver cancer in humans. Mycotoxins can also damage the liver, brain, bones, and nerves with resultant internal bleeding.

A concise summary of mycotoxins and some mycotoxicoses of humans and animals is found in a report of a WHO Expert Committee, with the participation of the Food and Agriculture Organization (FAO) of the United Nations,[25] a paper by Bullerman, and a paper by Scott.[26,27] Some compounds and substances may inhibit, stimulate, or have no effect on the growth of aflatoxins.[28]

Foods (vegetables, meats, fruits, and cheeses) with abnormal mold growth should be promptly and properly discarded.[29] The exception to this is cheese from which mold has been *properly* removed (including mold filaments deeply penetrating along the holes or eyes), which is considered safe to eat. For other foods, is not safe to scrape off the mold and eat the remaining food. Mycotoxins are not effectively destroyed by cooking. Freezing food will prevent mold growth, but mold grows at refrigerator temperature, although at a slower rate. The inside of refrigerators should be washed and dried regularly to prevent mold growths and musty odors; commercial deodorants are not a substitute for cleanliness. Some cheeses, such as Roquefort, Brie, Camembert, and Blue, are processed with special species of molds, similar to those from which penicillin is made, and have been consumed with safety for hundreds of years.[30] In addition, consuming certain dairy, fruit and vegetable delicacies (e.g., cheeses and cider) made with unpasteurized raw materials may also lead to illness.

BURDEN AND COST OF FOODBORNE ILLNESS

In 1999, Mead et al.[3] reported new estimates of foodborne illnesses in the United States. They found that there are several factors that complicate surveillance for foodborne infections. First is underreporting, especially of mild or asymptomatic cases, but also of severe cases. Second, they found that because many pathogens can be spread by means other than food, their role in foodborne illness is often obscured or unknown. For example, pathogens such as *E. coli*, which may be spread by food, can also be transmitted through contact with infected animals or other infected persons, and through contact with contaminated water. Third, some illnesses are caused by pathogens that have not yet been identified and so cannot be diagnosed. Many of the pathogens that are reported today, including *Campylobacter jejuni, Escherichia coli* O157:H7, *Listeria monocytogenes*, and *Cyclospora cayetanensis*, were not recognized as causes of foodborne illness only 25 years ago. In total, Mead et al. estimated that foodborne diseases cause approximately 76 million illnesses, 325,000 hospitalizations, and 5,000 deaths in the United States each year. Of these, infections caused by known pathogens account for an estimated 14 million illnesses, 60,000 hospitalizations, and 1,800 deaths each year. Clearly, further work is needed to identify the causes of these other foodborne illnesses. *Salmonella, Listeria*, and *Toxoplasma* cause more than 75 percent of deaths by known pathogens.

The total cost of a disease outbreak is often overlooked. For example, a typhoid fever outbreak in 80 restaurant patrons consuming food contaminated by a carrier was estimated to cost $351,920. This cost includes patient-related medical expenses and costs of loss of income or productivity.[31] One estimate of the annual economic impact of foodborne disease in the United States is $1 billion to $10 billion. If there are five million cases each year, the average cost per case would range from $200 to $2000.[32] The FDA estimated in 1985 that 21 to 81 million cases of diarrhea yearly are caused by foodborne pathogens. The out-of-pocket costs were estimated to be $560 million for the quarter million hospitalized and $690 million for those who saw a doctor.[33] More recently, the 2001 FDA Food Code estimates that the annual cost of foodborne illness is $10 billion to $83 billion annually.[34] This figure is calculated considering the increased estimation of foodborne illness by Mead et al.[3]

The reporting of water- and foodborne illnesses has, with rare exceptions, been very incomplete. Various estimates have been made in the past indicating that the number reported represented only 10 to 20 percent of the actual number. Reasons for underreporting include that many infected persons do not seek medical care, and that persons who seek medical care may not have a stool sample or other confirmatory test. Mead et al. estimated, for example, that *Salmonella* infections are underreported 38-fold, while *E. coli* infections are underestimated 20-fold.

For other, more severe infections such as *Listeria*, the degree of underreporting was estimated to be much lower.[3]

Hauschild and Bryan,[35] in an attempt to establish a better basis for estimating the number of people affected, compared the number of cases initially reported with either the number of cases identified by thorough epidemiologic investigations or the number estimated. They found that for 51 outbreaks of bacterial, viral, and parasitic disease (excluding milk), the median ratio of estimated cases to cases initially reported to the local health authority, or cases known at the time an investigating team arrived on the scene, was 25 to 1. On this basis and other data, the annual food- and waterborne disease cases for 1974 to 1975 were estimated to be 1,400,000 to 3,400,000 in the United States and 150,000 to 300,000 in Canada. The annual estimate for the United States for 1967 to 1976 was 1,100,000 to 2,600,000.[35] The authors acknowledge that the method used to arrive at the estimates is open to criticism. However, it is believed that the estimates come closer to reality than the present CDC reporting would indicate, particularly to the nonprofessional. The estimates would also serve as a truer basis for justifying regulatory and industry program expenditures for water- and foodborne illness prevention, including research and quality control. The total number of foodborne illnesses in the United States has been estimated at 5˜million, with a total cost of $1 billion to $10 billion per year.[32]

FOODBORNE DISEASE OUTBREAK SURVEILLANCE

Between 1938 and 1956, 4,647 foodborne outbreaks with 179,773 cases and 439 deaths were reported to the PHS CDC. In 1967, 273 outbreaks were reported, with 22,171 cases and 15 deaths.

Another analysis of foodborne illnesses based on 1969 and 1970 CDC/Department of Health, Education, and Welfare (DHEW) information reported 737 outbreaks with 52,011 cases. It was found that 33.0 percent of the outbreaks occurred at restaurants, cafeterias, and delicatessens; 39.1 percent at homes; 8.7 percent at schools; 5.2 percent at camps, churches, and picnics; and 14 percent at other places. However, 48 percent of the *cases* were at schools and 28 percent at restaurants, cafeterias, and delicatessens.[36]

Bryan, in a summary of foodborne diseases in the United States from 1969 to 1973, reported 1,665 outbreaks with 92,465 cases.[37] During this same period it was found that food service establishments accounted for 35.2 percent of the outbreaks; homes 16.5 percent; food-processing establishments 6.0 percent; and unknown places 42.1 percent.

In 1982, 656 foodborne outbreaks with 19,380 cases and 24 deaths were reported to the U.S. PHS CDC.[38] The most frequently isolated bacterial pathogens were *Salmonella*, *Staphylococcus aureus, Clostridium perfringens, Campylobacter jejuni, Clostridium botulinum*, hepatitis A virus, and Norwalk virus. The latter two viruses accounted for 21 outbreaks and 5,325 cases. The most common contributing factors were (1) improper holding temperature, (2) food from an unsafe source, (3) inadequate cooking, (4) poor personal hygiene on the part of foodhandlers, and (5) contaminated equipment.

An analysis of 1,586 foodborne outbreaks reported to the CDC from 1977 through 1984 most frequently implicated fish and shellfish in 24.8 percent of the outbreaks; beef and pork in 23.2 percent; turkeys and chickens in 9.8 percent; potato, chicken, and other salads in 8.8 percent; and other foods in 5 percent.[39]

In the most recent summary of foodborne outbreak surveillance in the United States, a total of 6,647 outbreaks were reported during 1998 to 2002, causing 128,370 persons to become ill.[40] Atlhough this was in increase in the number of outbreaks compared to previous summaries, enhanced surveillance was likely responsible for much of the increase. Bacterial pathogens caused 55 percent of both outbreaks and cases, with *Salmonella* serotype Enteritidis accounting for the largest number of outbreaks and outbreak-related cases. During this same time period, infection with *Listeria monocytogenes* caused the most deaths. Viral pathogens caused 33 percent of outbreaks and 41 percent of cases, and the proportion of outbreaks attributed to viruses increased 26 percent from 1998 to 2002.[40] The factors most commonly associated with these outbreaks were described as follows:

> The most commonly reported contamination factor that contributed to FBDOs foodborne disease outbreaks was “bare-handed contact by handler/worker/preparer.” For outbreaks caused by bacterial pathogens “raw product/ingredient contaminated by pathogens from animal or environment” was the most commonly reported contamination factor. The most commonly reported proliferation factor was “allowing foods to remain at room or warm outdoor temperature for several hours”; the most common survivability factor was “insufficient time and/or temperature during initial cooking/heat processing[40].”

Poultry

Campylobacter jejuni is a common contaminant in poultry-processing plants and is frequently found in conjunction with *Salmonella*. Contaminated chicken has been found to be the source or vehicle of over 50 percent of *C. jejuni* enteritis cases.[41] *Campylobacter* may also be also found in raw milk and contaminated water.

Salmonella outbreaks have been related to the use of raw or undercooked eggs.[42] The incidence of *Salmonella enterica* infection and the number of outbreaks has increased dramatically in the United States since the 1970s.[43] Shell eggs are the major vehicle for *Salmonella enterica* infection in humans; eggs are contaminated internally by transovarial transmission from the laying hen. The FDA now recommends that all products containing eggs are fully cooked or made with a pasteurized liquid egg product. Contaminated feed is believed to cause animal infection leading to contamination of meat and poultry products.

Between 1963 and 1975, there were 651 reported outbreaks of salmonellosis, with 38,811 cases in the United States. Poultry, meat (beef, pork), and eggs were the three most common vehicles. Eggs were not incriminated in

1974 and 1975, probably due to hygienic processing, pasteurization, and quality control,[44] but bulk and cracked eggs are a recurring problem as vehicles for foodborne salmonella.[42] Hauschild and Bryan found that for a total of 26 outbreaks of salmonellosis the median ratio of estimated cases to initial human isolations of salmonella was 29.5.[35] On this basis, the actual number of cases of human salmonellosis for the period 1969 to 1978 was estimated to be 740,000 in the United States and 150,000 in Canada annually.[35] Although estimates differ, they do show the seriousness of the problem and the need for more effective control methods. The overall national salmonellosis morbidity has remained relatively constant. The average number of isolates has actually increased since 1976 except for the years 1980 and 1984. Surveillance by the Foodborne Diseases Active Surveillance Network (FoodNet) has similarly found that despite decreases in the incidence of many foodborne pathogens, *Salmonella* infections have remained relatively constant over time. Of the six most common *Salmonella* serotypes, only one declined in 2006 from baseline levels.[45] Additionally, because *Salmonella* can be transmitted to human via many vehicles, including produce, eggs, poultry, meat, and contact with animals, efforts to control *Salmonella* must take into account many potential sources of infection. Several recent outbreaks of *Salmonella*, including one associated with peanut butter,[46] and one associated with tomatoes[47] underscore the diverse routes of infection and the need to more effectively prevent contamination of food products. Salmonellosis control involves use of salmonella-free feeds; strict hygiene in the handling and preparation of food for human consumption; education of managers, inspectors, and foodhandlers; time-temperature control in food preparation; and prohibition of antibiotics in animal feed (cattle, hogs, poultry), which may promote the growth of drug-resistant organisms that can spread to humans.

Milk and Other Dairy Products

Raw milk (including certified) or improperly pasteurized milk, poor milk-handling and processing practices, postpasteurization contamination, and improper refrigeration have been associated with outbreaks caused by contaminated milk. Soft cheeses and other dairy products have also been associated with a number of foodborne outbreaks. Raw milk and raw milk products have been associated with outbreaks of a number of pathogens, including *Salmonella* spp., *Camylobacter, Listeria, Staphylococcus aureus* (staphylococcus enterotoxin), *Streptococcus agalactiae, Mycobacterium tuberculosis, Listeria monocytogenes*, and *Yersinia enterocolitica*. A recent review found 46 raw-milk-associated outbreaks reported to CDC from 21 states during 1973 to 1992, including 57 percent caused by *Campylobacter* and 26 percent caused by *Salmonella*.[48] Several recent multistate outbreaks of *Salmonella* associated with the consumption of raw milk have been reported. [49,50]

The largest milkborne outbreak on record occurred in the Chicago area in March and April of 1985. Two brands of two percent low-fat pasteurized milk were implicated. *Salmonella typhimurium* was found in 16,284 culture-confirmed cases, resulting in at least two deaths and probably 12 related deaths. It was estimated that 183,000 or more persons were infected. The outbreak had been preceded by at least three smaller outbreaks. Evidence pointed to milk blending via a cross-connection between a pasteurized milk transfer line and a raw milk line. Other causes such as suction in a milk line that could draw raw milk past two valves could not be ruled out. The cross-connection was an in-plant modification. Outbreaks such as this emphasize the complexity of modern processing equipment, the importance of plan approval, the continual necessity for evaluation of plant piping systems and controls, education and training of personnel, and constant supervision and surveillance. According to a class-action suit reported in the *Baltimore Sun*, the milk company must offer 2,100 people who "represent about 15 percent of all those involved in the lawsuit . . . up to $1000 plus medical and employment compensation."[51]

Despite the ban on interstate sales of raw milk implemented in 1987, raw milk has continued to cause numberous outbreaks. In 1995, 54 percent of states permitted the intrastate sale of raw milk, although the estimated volume of raw milk in states where sales was legal was less than 1 percent of the total milk sold[48]. Of 46 raw-milk-associated outbreaks occurring from 1973 to 1992, 87 percent occurred in states where sales of raw milk were still legal at the time of the outbreak.[48]

Contamination of pasteurized milk has also been involved in several outbreaks, likely due to contamination of milk products after pasteurization. At least 12 outbreaks occurred in the United States during 1960 to 2000 associated with the consumption of pasteurized milk, including *Salmonella typhimurium* outbreaks in Arizona in 1978[97] and Pennsylvania in 2000.[52] One of the first outbreaks of yersiniosis associated with milk was reported in 1976, and was caused by milk to which chocolate syrup had been added after pasteurization. A *Yersinia* outbreak linked to postpasteurization contaminated milk affected 17,000 persons in Memphis in 1982.[53] Salmonellosis has also been associated with the consumption of nonfat powdered milk.[54]

In addition to outbreaks caused by raw milk, soft cheeses made from raw milk have been associated with *Listeria monocytogenes* infection.[55] *Listeria* grows at below refrigeration temperatures, making it hazardous in raw milk products (cheeses), unpasteurized milk, and pasteurized products that have been contaminated after pasteurization. A large outbreak, which included 142 cases with 48 deaths, occurred in California in 1985 and was linked to consumption of a Mexican-style cheese made with raw milk.[56] Victims filed damage claims for $100 million. The manufacturer of the cheese went out of business. A jury found the manufacturer responsible, but the supplier of raw milk was exonerated. The federal investigators could not determine whether the raw milk, improper pasteurization, or postpasteurization contamination was the cause.[57] *Listeria monocytogenes* has also been found in seafood and turkey franks. Other outbreaks have been reported in Canada, Massachusetts, Los Angeles, California, and Switzerland.

Fruits and Vegetables

A number of outbreaks of foodborne pathogens have been linked to consumption of contaminated fruits and vegetables. From 1973 to 1997, a total of 190 produce-associated outbreaks were reported in the United States and the proportion of outbreaks associated with a produce item increased from 0.7 percent to 6 percent.[58] Items frequently implicated in these outbreaks included salad, lettuce, juice, melon, sprouts, and berries. Of the 103 outbreaks with a known pathogen, 29 percent were caused by *Salmonella*.

Meat and Seafood

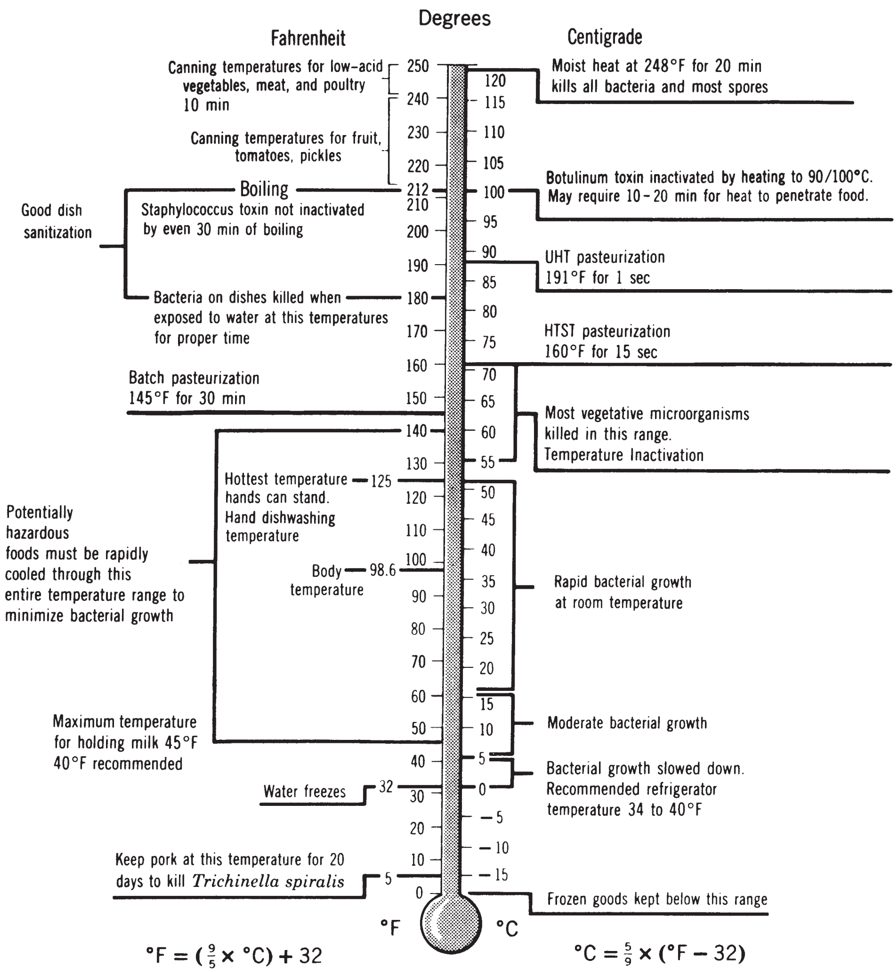
Seafood is implicated as the vehicle in 10 to 19 percent of foodborne illnesses in the United States[59] and more than 70 percent of foodborne illness in Japan.[60] In the United States, of those infections with known etiology, approximately half are caused by viruses. As with many other foodborne infections, persons with underlying immunocompromising conditions are more susceptible to infection and have worse outcomes. Consumption of raw or undercooked seafood is the factor most commonly associated with infection.[61] In one study, shellfish accounted for 64 percent of the seafood-associated outbreaks, and finfish were implicated in 31 percent.[59] Large outbreaks of norovirus have been associated with the consumption of raw oysters.[61] Oysters and other seafood are often contaminated by the discharge of human waste into harvest areas. *Vibrio* spp., including *V. parahaemolyticus* and *V vulnificus*, are also associated with human illness in the United States; consumption of oysters accounts for nearly 50 percent of *Vibrio* infections. During seasons of peak infection, as much as 100 percent of the oyster harvest may be contaminated with *Vibrio*.[62]

CONTROL AND PREVENTION OF FOODBORNE DISEASES

Many health departments, particularly on a local level, are placing greater emphasis on water quality and food protection at food-processing establishments, catering places, schools, restaurants, institutions, and the home and on the training of food management and staff personnel. An educated and observant public, a systematic inspection program with established management responsibility, coupled with a selective water and food quality laboratory surveillance system and program evaluation can help greatly in making health department food protection programs more effective. It is necessary to remain continually alert as water- and foodborne diseases have not been completely eliminated; we continue to find new ones. For a discussion of waterborne diseases, please refer to Chapter 1.

Prevention of Foodborne Diseases

The application of known and well-established microbiological and sanitary principles has been effective in keeping foodborne diseases under control, but it is apparent that more effective measures are needed. Refrigeration, hygienic practices including prevention of cross-contamination with raw foods or contaminated surfaces, food preparation planning, hot or cold holding of potentially hazardous food, identification and assurance of critical temperatures for proper cooking and reheating, and general sanitation are most important. These precautions apply also to prepared frozen dinners, reconstituted foods, and drinks. Leaving food at room temperature, inadequate cooking, and storing food in a large container account for many outbreaks. Continuous and competent surveillance is necessary to identify and eliminate procedures that might permit contamination of food or the growth of microorganisms or the accidental addition of toxic substances



Note: Increase boiling time 5 min for each 1000 ft above sea level.
H.T.S.T. = high temperature, short time. UHT = ultra high temperature.

FIGURE 3.1 Food sanitation temperature chart.

from the point of preparation to the point of consumption to prevent foodborne illnesses.

The approximate optimal temperature for growth of the principal organisms associated with foodborne illnesses are salmonella 99°F (37°C) (maximal 114°F), *Staphyhcoccus aureus* 99°F (maximal 114°F), *Clostridium perfringens* 115°F (46°C) (maximal 112°F), and enterococci (maximal 126°F). *Listeria*, in contrast, can grow at lower temperatures and is thus often associated with contaminated of refrigerated deli meats and soft cheeses.[63]

Salmonellae are widely distributed in nature and found in many raw food products, especially poultry, beef, and swine. Pets are also reservoirs of salmonellae, and outbreaks of *Salmonella* have also been associated with pet food.[64] Tables and surfaces used in preparing raw poultry and other meats can serve as vehicles for the spread of *Salmonella* and other pathogens unless they are thoroughly cleaned and sanitized between each use. *Clostridium perfringens, Campylobacter jejuni*, and *Staphylococcus aureus* are also frequently found in samples of raw beef and on workers' hands, knives, and cutting boards, as well as in soil, dust, and the intestinal tracts of humans and other warm-blooded animals. Raw meat and seafood should be separated from other food in the grocery cart or refrigerator; persons should always wash hands, cutting boards, and dishes with hot soapy water after coming in contact with raw meat, poultry, or seafood; one cutting board should be used for raw meat, poultry, and seafood and another for foods that are ready to eat; cooked food should never be place on a plate that previously held raw meat, poultry, or seafood.[63]

Salmonellae may survive up to 10 months in cheddar cheese. Aging of salmonella-infected cheese 60 days, manufactured from heat-treated (nonpasteurized) milk, is therefore ineffective to prevent human illness. The use of pasteurized milk can ensure the marketing of safe milk and milk products, including elimination of *Salmonella* spp., *Listeria, Yersinia, Campylobacter*, enterohemorrhagic *E. coli*, and other pathogens.[65] Thorough cooking 165°F (74°C) of raw shell eggs, raw meat and poultry, raw clams, and other foods of animal origin before consumption will prevent salmonellae infections, as will the use of pasteurized egg products in preparing eggnog, Caesar salad, hollandaise sauce, and homemade mayonnaise and ice cream. Eggs should not be used raw and should be cooked thoroughly before service. Flocks and eggs have been found infected.[66] Cross-contamination during food preparation should be avoided.

Fish that has been fried, baked, or broiled until it flakes when pried with a fork can be assumed to be free of viable parasites. Freezing fish at −4°F (−20°C) for three to five days will also kill most pathogens. Cooking fish to a temperature of 145°F (63°C) will kill parasites.[63]

Campylobacter jejuni is responsible for numerous foodborne outbreaks, many of which are not recognized. *Campylobacter* contamination of food products may begin during animal slaughtering and processing and may be increased by overconcentration of animals in feedlots and brooding houses. Poor food handling, storage, and sanitation facilitate *Campylobacter* transmission.

TABLE 3.3 Pathogen Time-Temperature Inactivation[a]

Organism	Temperature °C	Temperature °F	Time	Source
Ascaris lumbricoides eggs	50	122	60 min	2, 4
Brucella abortus	62–63	144–145	3 min	2
Brucella suis	61	142	3 min	3
Campylobacter jejuni	60	140	10 min	
Clostridium botulinum	100	212	5 hr	2
Spores	105	221	40 min	2
	110	230	15 min	2
	120	248	6 min	2
Toxin	70–73	158–163	10 min	2
	80	176	2 min	2
	72	162	10 min	2
	65	149	30 min	2
Clostridium burnetii				
In ice cream	66	150	30 min	5
In chocolate milk	74	165	15 sec	5
In milk	63	145	30 min	5
	72	161	15 sec	5
Clostridium perfringens				
Enterotoxin		140+	80 min	6
Spores	100	212	1 hr or more	6
Vegetative cells	65	150	A few seconds	
Corynebacteriun diphtheriae	55	131	45 min	3, 4
	60	140	20 min	2
Coxsackie viruses	71	160	15 sec	
	62	143	30 min	
Entamoeba histotytica	49	120	60 min	1
	45	113	A few minutes	4
	55	131	A few seconds	2
	68	154	10 min	3
Enteric viruses	63	145	60 min	1
	71	160	30 min	
Escherichia coli	60	140	15–20 min	3
	55	131	60 min	4
Giardia lamblia	55	131	A few minutes	
Micrococcus pyogenes var.	50	122	10 min	3, 4
Mycobacterium tuberculosis var. hominis	66	151	15–20 min	3
	60	140	20 min	2
	67	153	A few minutes	3, 4
Necator americanus	45	113	50 min	3
Salmonella spp.	60	140	15-20 min	3
	57	135	60 min	1
	55	131	60 min	4

(*continues*)

TABLE 3.3 (*continued*)

Organism	Temperature °C	Temperature °F	Time	Source
Salmonella typhosa	55–60	131–140	30 min	3, 4
	60	140	20 min	2
Shigella spp.	60	140	20 min	2
	55	131	60 min	3, 4
	58	136	60 min	1
Staphylococcus aureus	71	160	15 sec	
	60	140	30 min	
Streptococcus pyogenes	54	129	10 min	3
	60	140	5 min	2
Taenia saginata	55	131	A few minutes	2, 4
	71	160	5 min	3
	51	124	60 min	1
Toxoplasma gondii	70	158	A few seconds	
Trichinella spiralis larvae	55	131	A few minutes	2, 4
	60	140	A few seconds	2, 4
	62–70	144–158	10 min	3
Vibrio cholerae	45	113	60 min	1

Sources: 1. R. G. Feachem et al., *Sanitation and Disease: Health Aspects of Excreta and Wastewater Management*, World Bank Studies in Water Supply and Sanitation. No. 2, World Bank, Washington, DC, 1978.
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5. J. M. Last (Ed.), *Maxcy-Rosenau Public Health and Preventive Medicine*, 11th ed., Appleton-Century-Crofts, New York, 1980, p. 937.
6. H. S. Naik and C. L. Duncan, "Thermal Inactivation of *Clostridium perfringens* Enterotoxin," *J. Food Protection* (February 1978): 100–103.

[a]In the presence of moisture. To compensate for elevation, increase heating time 5 minutes for each 1000 ft above sea level. There is a lack of agreement among experts regarding some time—temperature relationships.

All cooked and precooked beef and beef roasts must be heated to a minimum internal temperature of 145°F (62.7°C) to comply with USDA regulations to ensure destruction of all salmonellae. At this temperature, it would not be possible to make available "rare" roast beef. However, the USDA permits other time–temperature relations for processing of water- or steam-cooked and dry-roasted beef.[67] Studies show that salmonella-free rare roast beef can be produced, for example, at internal time–temperatures ranging from 130°F (54.4°C) for 121 minutes to 136°F (58°C) for 32 minutes. The elimination of salmonella from the surface of dry oven-roasted beef (at least 10 lb. uncooked in size) requires a minimum internal temperature of 130°F (54.4°C) in an oven set at 250°F (121.0°C) or above.[63] It should be understood that these time-temperatures are under controlled laboratory conditions, which normally do not prevail in the average restaurant. The higher time–temperatures should be used in practice to prevent possible disease transmission and ensure heat penetration.

Adequate cooking of ground beef and other meats is essential to prevent infection with *E. coli* O157. Consumption of ground beef, particularly "pink" (indicating undercooked) meat, has been associated with both outbreaks and sporadic cases of *E. coli* infection.[68,69] USDA recommends cooking hamburgers and ground beef to 160°F on a meat thermometer.[63] Cooked beef roasts and turkeys, because of their size, are rarely rapidly cooled to 45°F (7°C) or less. If not consumed or sold immediately, they should be reheated as noted before use. Cooked roasts that have been rolled or punctured should be reheated to 160°F (71.1°C) (FDA recommends 165°F (73.9°C)). Cooked roasts that have been cut up into small pieces should be reheated to 165°F (73.9°C) because the handling introduces greater possibility of contamination. Cooked roasts that include solid muscle should be reheated to assure pasteurization of the surface of the roast.

There is a danger of cooking large masses of raw meat on the outside but leaving the interior of the food underdone, thereby permitting survival of salmonellae[70] spores introduced in handling, or those intrinsically present that can germinate and cause *C. perfringens* food poisoning. However, if the meat is cooked as already noted and eaten immediately after cooking, there is usually minimal risk of bacterial foodborne illness.

Incomplete cooking of stews, meats, gravies, and large cuts of meat that have been rolled or penetrated with skewers and failure to provide prompt and thorough refrigeration can lead to contamination with *C. perfringens*. *Clostridium perfringens* vegetative cells in food are destroyed by heat and thorough cooking, but spores are not completely destroyed by normal cooking. Therefore, foods contaminated with spores that are cooked and not promptly cooled can permit the germination of spores and the multiplication of vegetative cells with the danger of food poisoning on consumption. Heating *C. perfringens* enterotoxin at 140°F (60°C) in cooked turkey showed a gradual decrease in serologic activity with no detectable toxin being present after 80 minutes.[71]

Clostridium perfringens type A food poisoning is caused by the ingestion of foods containing large numbers of vegetative cells of enterotoxigenic strains. Many (not all) of these cells pass through the human stomach into the intestines where they are able to grow and eventually sporulate. During sporulation, the enterotoxin responsible for food-poisoning symptoms is synthesized and released. The toxin does not normally develop in the food, as in staphylococcus food poisoning and botulism, but rather, forms in the intestinal tract. Adequate cooking alone will not always prevent *C. perfringens* food poisoning because the spores are resistant to heat and may survive, multiply during slow cooling, and produce a toxin under anaerobic conditions, unless the food is eaten immediately or *promptly* cooled to 45°F (7°C) or less and reheated to 165°F (74°C) for safety to destroy the vegetative cells in the food.

The enterotoxin is produced in the intestinal tract after ingestion or in food under suitable temperatures 60° to 120°F (16° to 49°C), 110° to 117°F (43° to

47°C) for optimum growth in the absence of air. This enterotoxin is destroyed above 140°F (60°C). Bacteria in spore form are more difficult to destroy than when in vegetative form. The vegetative cell is killed at a temperature of 150°F (66°C); spores survive 212°F (100°C) for 1 hour or more. Spores are dormant, that is, inactive or not growing; they must germinate and become vegetative cells to grow. The term germination refers to the process involved when a spore changes into a vegetative cell.

Other bacterial toxins may also contaminate food, leading to food poisoning. Certain specific strains of staphylococcis (*S. aureus*) commonly found in skin infections, hands, feces, and discharges from the nose and throat are frequently associated with food poisoning. Staphylococci multiply under favorable temperature conditions, producing highly temperature and chemical resistant enterotoxins.. Common food vehicles associated with staphylococcal enterotoxins include contaminated ham, potato and chicken salads, sauces, poultry, and custard or cream-filled bakery products. Even after refrigeration and reheating, the consumption of food containing sufficient toxin, may cause food poisoning.

Botulism is caused by ingestion of a toxin produced by *Clostridium botulinum*. The *C. botulinum* in improperly canned or bottled low-acid food and in improperly cooled food will also produce a toxin (neurotoxin), but this poison is destroyed by boiling and cooking. *Clostridium botulinum* is rarely found in commercially canned foods but can be a risk in home-canned foods. During 1950 to -2005, CDC reported 405 events of foodborne botulism, of which 92 percent were linked to home-processed foods and 8 percent to commercially processed foods, including those prepared in restaurants.[72] Outbreaks associated with deficiencies in the commercial canning process are rare; in 2007, the outbreak associated with commercially canned chili sauce was the first such outbreak reported in the United States since 1974.[72] Botulism is also a hazard in prepared foods in which oxygen has been driven off in cooking and in which the food is shielded from oxygen and kept warm, permitting surviving spores to germinate and produce toxin, such as in potato salad, beef stew, meat pie, sautéed onions, and garlic in olive oil. *Clostridium botulinum* is reported not to grow at an a_w less than 0.93.

Intestinal or infant botulism can result from intraintestinal production and absorption of botulinum toxin, which is thought to result from the colonization of spores found in foods and dust and entering the gastrointestinal tract of the infant (2 to 38 weeks of age). Intestinal botulism is the most common form of human botulism in the United States (check reference list for this CDC. Botulism in the United States, 1899–1996: handbook for epidemiologists, clinicians, and laboratory workers. Atlanta, Georgia: U.S. Department of Health and Human Services, CDC, 1998), is a result of swallowing *C*. botulism spores. One source of these spores is honey. Honey should not be fed to infants less than 1 year of age.

The spread of diseases such as trichinosis, taeniasis, and salmonellosis associated with the consumption of foods of animal origin can be prevented by thorough cooking. Using only inspected meats, prohibiting the feeding of uncooked garbage or offal to hogs, and good sanitation will also help.

Storage of pork 10 days at −13°F (−25°C), or 20 days at −13°F if the meat is more than six inches thick, is adequate to kill trichina larvae. Cooking to an internal temperature of 150°F (66°C) is also adequate, although 165°F (74°C) is recommended for safety. The National Pork Producers Council recommends, and the USDA requires, that pork and pork products labeled ready to eat be frozen as noted or cooked to 170°F (76°C).[63] Fewer than 100 cases of trichinosis are being reported annually to CDC.[19] Cooking in a microwave oven does not ensure destruction of trichinae. Trichinae in polar bear meat remained viable after 24 months at 0°F (−18°C) and bear meat after 81 days at 0°.

The FDA requires that "fishery products that are not cooked throughout to 140°F (60°C) or above must have been or must, before service or sale in ready-to-eat form, be blast frozen to −31°F (−35°C) or below for 15 hours or regularly frozen to −10°F (−23°C) or below for 168 hours (7 days). Records that establish that fishery products were appropriately frozen on-site must be retained by the operator for 90 days." (FDA Code Interpretations, No. 2-403, August 21, 1987)These temperatures assure that tapeworms, roundworms, flukes, and other parasites are killed. Fish menu items that have not been fully cooked may harbor pathogenic bacteria or viruses. In summary, the 11 essential elements of health protection in food establishments are as follows:[63]

1. Cook to proper internal temperature (minimum): beef roasts 145°F (63°C), pork 165°F (74°C), eggs, fish, and lamb (145°F), poultry and all stuffed meats (165°F); holding of hot foods at 140°F (60°C), thorough reheating to 165°F of precooked or leftover (refrigerated) potentially hazardous foods, and holding potentially hazardous foods at or above 140°F or refrigerating at 45°F (7°C) or less in shallow pans (less than 4 inches food depth) until served; heating of custard and pastry filling to 165°F and cold holding at 45°F. Bring stock to a boil and keep at 140°F or above. Serve prepared foods promptly. Do not reuse leftover food that has been served. Microwave cooking of pork is not reliable, as microwave cooking can leave cold spots.
2. Ensure adequate refrigeration capacity and promptly and properly refrigerate at 45°F or less potentially hazardous leftover and prepared foods. Store in shallow pans, with food thickness or depth not greater than 4 inches. Cool foods to 45°F or less within 4 hours, but do not allow foods to remain at room temperature longer than 2 hours. A refrigeration temperature of 38 to 40°F (3° to 4°C) is recommended, and refrigerators should have indicating thermometers.
3. Plan food preparation to coincide as closely as possible with serving time. Serve food immediately after cooking.
4. Stress cleanliness and good personal hygiene habits of employees (who should be free of communicable disease or infection transmissible through food or food service). Wash hands before and after preparing each food; avoid or prevent handling of food; use utensils or plastic gloves to mix or serve food. Avoid cross-contamination; thoroughly clean and sanitize

cutting boards used for raw poultry, beef, pork, lamb, or fish before using for other foods; also clean meat grinders, knives, saws, and mixing bowls.

5. Use wholesome food and food ingredients; purchase and use of shellfish from approved safe sources. Discard swollen, leaking, deeply rusted, and seam-dented cans. Do not use raw or certified raw milk or home-canned foods. Use only pasteurized milk and milk products and commercially canned food.
6. Clean dishware, utensils, equipment, and surfaces used for food preparation; use adequate, properly constructed equipment that is easily cleaned and sanitized and is kept clean.
7. Have an adequate supply of potable water (hot and cold), detergents, and equipment for cleaning and sanitization of dishes and utensils; eliminate cross-connections or conditions that may permit backflow or back siphonage of polluted or questionable water into the water supply piping or equipment.
8. Properly store and dispose of all liquid and solid wastes.
9. Control rodents, flies, cockroaches, and other vermin, and proper use and store pesticides, sanitizers, detergents, solvents, and other toxic chemicals. Exclude dogs, cats, birds, and turtles from kitchen.
10. Protect dry food stores from flooding, sewage backup, drippage, and rodent and insect depredations. Store all foods at least 6 inches above the floor. Rotate stock—first in, first out.
11. Use structurally sound, clean facilities in good repair and adequately lighted and ventilated premises that can be properly cleaned.

According to *Food Code 2001*:

Potentially hazardous food means any food or ingredient, natural or synthetic, in a form capable of supporting (1) the rapid and progressive growth of infectious or toxigenic microorganisms or (2) the slower growth of *C. botulinum*. Included is any food of animal origin, either raw or heat-treated, and any food of plant origin which has been treated or which is raw, e.g. seed sprouts. Excluded are the following

- Air-dried hard-boiled eggs with shells intact the FDA has classified raw shell eggs as a potentially hazardous food;
- Foods with a water activity (a_w) value of 0.85 or less;
- Foods with a pH level of 4.6 or below;
- Foods, in unopened hermetically sealed containers, which have been commercially processed to achieve and maintain commercial sterility under conditions of unrefrigerated storage and distribution; and
- Foods for which laboratory evidence (acceptable to the regulatory authority) demonstrates that rapid and progressive growth of infectious and toxigenic microorganisms or the slower growth of *C. botulinum* cannot occur.[73]

Open self-service food counters, salad bars, or buffets require a physical barrier such as a canopy or guard that will effectively prevent or minimize contamination by persons assisting themselves to the displayed food. In any case, the potentially hazardous food should be held either at or above 140°F (60°C) or at or below 45°F (7°C) at all times. Displayed foods remaining should not be reused.

Since food service in private institutions, including churches and nonprofit and fraternal organizations, have been implicated in numerous foodborne outbreaks, special educational material should be developed incorporating the principles listed above and distributed to affected organizations. Caterers should be under special surveillance and permit.

Sandwiches containing potentially hazardous foods that remain unrefrigerated for more than 2 or 3 hours at room temperature can support the growth of bacteria that could lead to a foodborne disease outbreak. Prior refrigeration, or freezing where appropriate, and consumption within 4 hours will minimize the hazard. Cheese, peanut butter and jelly sandwiches, salami, bologna, and hard-boiled eggs will keep better. Canned meats and poultry also keep well. Commercial mayonnaise (pH below 4.1–4.6) will inhibit the surface growth of salmonellae and staphylococci on food, but the pH of all the ingredients or mass of the food, such as egg, meat, chicken, or potato salad, must be reduced to inhibit bacterial growth in the food. Vinegar and lemon juice can accomplish the same objective, provided the food ingredients do not neutralize the acidity of the mixture. The salads should be kept refrigerated. The guiding principles should be hygienic food preparation practices, proper cooking, and *prompt refrigeration* of potentially hazardous foods if the food is not immediately.

Mercury Poisoning

Mercury poisoning in humans has been associated with the consumption of methylmercury-contaminated fish, shellfish, bread, and pork and, in wildlife, through the consumption of contaminated seed. Exposure to mercury may also occur from household sources, including certain antique items such as clocks or thermometers.[74] Short-term exposure to high levels of mercury can cause lung damage, nausea, vomiting, diarrhea, increases in blood pressure or heart rate, skin rashes, and eye irritation. Exposures to mercury vapor at high levels can permanently damage the brain, kidneys, and developing fetuses. Mercury exposure is of particular concern for fetuses, infants, and children, and for persons with medical conditions that might be worsened by exposure to mercury, such as conditions of the nervous system, kidneys, or heart and vascular system.[74,75]

Fish and shellfish poisoning occurred in Japan in the Minamata River and Bay region and at Niigata between 1953 and 1964. Bread poisoning occurred as a result of the use of wheat seed treated with a mercury fungicide to make bread in West Pakistan in 1961, Central Iraq in 1960 and 1965, and Panorama, Guatemala, in 1963 and 1964. Pork poisoning took place in Alamagordo, New Mexico, when methylmercury-treated seed was fed to hogs that were eaten by a family. In Sweden, the use of methylmercury as a seed fungicide was banned in 1966 in view of the drastic reduction in the wild bird population attributed to treated seed. In Yakima, Washington, early recognition of the hazard prevented illness when 16 members of an extended family were exposed to organic mercury poisoning in 1976 by the consumption of eggs from chickens fed mercury-treated seed grain. The grain contained 15,000 ppb total mercury, an egg 596 and 1,902 ppb, respectively, of organic and inorganic mercury. Blood levels in the family ranged from 0.9 to 20.2 ppb in a man who ate eight eggs per day. A whole-blood level above 20 ppb may pose a mercury poisoning hazard.[66]

It is also reported that crops grown from seed dressed with minimal amounts of methylmercury contain enough mercury to contribute to an accumulation in the food chain reaching humans. The discovery of moderate amounts of mercury in tuna and most freshwater fish and relatively large amounts in swordfish by many investigators in 1969 and 1970 tended to further dramatize the problem.

Methylmercury has an estimated biological half-life of 70 to 74 days in humans, depending on such factors as age, body mass, and metabolism, and is excreted, mostly in the feces, at the rate of about 1 percent per day. Mercury persists in large fish such as pike for one to two years.

Elemental metallic mercury volatilizes on exposure to air, especially if heated, and in that state poses a distinct hazard. Mercury spills and the mercury from broken thermometers and barometers must be meticulously cleaned and the space ventilated and isolated until the mercury vapor level is no longer detectable by a “mercury sniffer” or similar device. Metallic mercury should never be incinerated; toxic gases would be released. Mercury should normally be stored and handled in an airtight enclosure with extreme care. Laboratory use must be carefully controlled and monitored.[66] Certain mercury compounds may be absorbed through the skin, gastrointestinal tract, and respiratory system (up to 98 percent), although elemental mercury and inorganic mercury compounds are not well absorbed through the digestive tract.

Mercury is ubiquitous in the environment from both natural and manmade sources. Natural sources include leachings, erosion, and volatilization from mercury-containing geologic formations. Carbonaceous shales average 400 to 500 ppb Hg, up to 0.8 ppm in soil. Manmade sources include waste discharges from chlor-alkali and paper pulp manufacturing plants, mining and extraction of mercury from cinnabar, chemical manufacture and formation, the manufacture of scientific instruments, mercury seals and controls, treated seeds, combustion of fossil fuels, atmospheric deposition, and surface runoff. As a result of these processes, mercury may end up in lakes, streams, tidal water, and the bottom mud and sludge deposits.

Microorganisms and macroorganisms in water and bottom deposits can transform metallic mercury, inorganic divalent mercury, phenylmercury, and alkoxyalkylmercury into methylmercury. The methylmercury thus formed and perhaps other types, in addition to that discharged in wastewaters, are assimilated and accumulated by aquatic and marine life such as plankton, small fish, and large fish. Alkaline waters tend to favor production of the more volatile dimethylmercury, but acid waters are believed to favor retention of the dimethyl form in the bottom deposits. Under anaerobic conditions, the inorganic mercury ions are precipitated to insoluble mercury sulfide in the presence of hydrogen sulfide. The process of methylation will continue as long as organisms are present and have access to mercury. It is a very slow process, but exposure of bottom sediment such as at low tide permits aerobic action causing methylation of the inorganic mercury.[76]

In fish, most mercury is in the form of methylmercury, and there are indications that a significant part of the mercury found in eggs and meat is also in the form of methylmercury.

The concentration of mercury in fish and other aquatic animals and in wildlife is not unusual. Examination of preserved fish collected in 1927 and 1939 from Lake Ontario and Lake Champlain in New York has shown concentrations up to 1.3 ppm mercury (wet basis). Fish from remote ponds, lakes, and reservoirs have shown 0.05 to 0.7 ppm or more mercury, with the larger and older fish showing the higher concentration.

In view of the potential hazards involved, steps have been taken to provide standards or guidelines for mercury. The maximum allowable concentration for 8-hour occupational exposure has been set at 0.05 mg metallic vapor and inorganic compounds of mercury per cubic meter of air. For organic mercury the threshold limit is 0.01 mg/m^3 of air. The suggested limit for fish is 0.5 ppm; for shellfish, it is 0.2 ppm. The primary standard for drinking water is 0.002 mg/1 (2 ppb) as total mercury. A standard of 0.05 ppm has been suggested for food.

A maximum ADI of 0.03 mg for a 70-kg (154-1b.) man would provide a safety factor of 10. If fish containing 0.5 ppm mercury were eaten daily, the limit of 0.03 mg would be reached by the daily consumption of 60 g (about 2 oz.) of fish. The safe levels would be 2 μg/100 ml for whole blood and 6 ppm for hair.

There is no evidence to show that the mercury in the current daily dietary intake has caused any harm, although this does not rule out possible nondetectable effects on brain cells or other tissues. The general population should probably not eat more than one freshwater-fish meal per week, with special concern for pregnant women.

Since mercury comes from manmade and natural sources, every effort must be made to eliminate mercury discharges into the environment.

Habashi has summarized techniques for the removal of mercury at metallurgical plants in the United States, Europe, and Japan.[77] The author reports that "the removal and recovery of traces of mercury from SO_2 gases or from sulfuric acid has been proved to be technically and economically feasible." Insofar as water supply is concerned, approximately 98 percent inorganic mercury may be removed by coagulation and settling at a pH of 9.5 followed by filtration through a granular activated carbon filter.

Methemoglobinemia

The presence of more than 45 mg/1 nitrates (10 mg/1 as N), the standard for drinking water, appears to be the cause of methemoglobinemia, or "blue baby" syndrome. The disease is largely confined to infants less than three months old but may affect children up to age six years of age. Methemoglobinemia is caused by the bacterial conversion of the nitrate ion ingested in water, formula, and other food to nitrite.[78] Nitrite then converts hemoglobin, the blood pigment that carries oxygen from the lungs to the tissues, to methemoglobin. The altered pigment no longer can transport oxygen, resulting in oxygen deprivation, or suffocation. Methemoglobinemia is not a problem in adults, as the stomach pH is normally less than four, whereas the pH is generally higher in infants, allowing nitrate-reducing bacteria to survive.

The boiling of water containing nitrates would cause the concentration of nitrates to be increased. Also, certain respiratory illnesses may in themselves cause an increase in methemoglobin levels in infants. A better epidemiologic basis for the standard is apparently needed. The inclusion of nitrite ion and nitrates ingested through food and air, in addition to those ingested through water, would give a more complete basis for evaluating dietary intake. Spinach, for example, is a high source of nitrate nitrogen.

Dental Caries

Fluoride deficiency is associated with dental caries and osteoporosis.[79] Water containing 0.8 to 1.7 mg/1 natural or artificially added fluoride is beneficial to children during the period they are developing permanent teeth. The incidence of dental cavities or tooth decay is reduced by about 60 percent. The maximum fluoride concentration permissible in drinking water is 4.0 mg/1. Optimum fluoride levels in drinking water for caries control, based on the annual average of the maximum daily air temperature for the location of the community water system, are as follows:

Temperature (°F)	Fluoride Level (mg/1)
53.7 and below	1.2
53.8–58.3	1.1
58.4–63.8	1.0
63.9–70.6	0.9
70.7–79.2	0.8
79.3–90.5	0.7

An alternate to community water fluoridation is a 1-minute mouth rinse by children once a week; it is reported to reduce tooth decay by about one-third or more. The mouth rinse also appears to be beneficial to adults in the prevention of dental caries. Other alternatives include fluoridation of school water supplies if there is an onsite water supply, use of fluoride toothpaste, drops and tablets, and topical application. Milk fluoridation has been shown to be effective in the prevention of dental caries, but to be clinically effective, it must be freshly prepared and consumed immediately.[80] The Pan American Health Organization has proposed adding fluoride to table salt in areas lacking fluoridated community water supplies.[81] Oral hygiene, including at least daily teeth brushing, consumption of fewer sweets, followed by a water rinse or drink, is also basic to caries reduction.

Studies have found that consumption of fluoridated water does not lead to adverse health effects. A federal study involving almost 1 million persons in 46 American cities showed virtually no difference in death rates, including from cancer, between 24 cities using fluoridated water and 22 without fluoridated water.[82]

The long-term consumption of water high in fluoride (8–20 mg/1) is reported to cause bone changes. On the one hand, an intake of 20 mg fluoride per day for 20 or more years may cause crippling fluorosis, and death can come from a single dose of 2,250 to 4,500 mg. On the other hand, optimal concentrations of fluoride in drinking water and food appear to be beneficial in preventing osteoporosis.

Sporotrichosis

Conifer seedlings packed in sphagnum moss can cause papules or skin ulcers and inflammation on the hands and arms, which can then spread to other parts of the body. This disease is caused by a fungus, *Sporothrix schenckii*, found in moss, hay, soil, and decaying vegetation. Protective clothing, including gloves and long-sleeved shirts, should be worn when handling sphagnum moss or seedlings.[83]

Nutritional Deficiency and Related Diseases

Severe examples of diseases caused by deficiencies in the diet are not common in the United States and other developed countries; however, they do occur.[84] These deficiencies are found much more often in less developed countries of the world. There are, however, many people whose diet is slightly deficient in one or more nutrients but who show no clinically detectable symptoms for many years. Most malnutrition takes the form of protein deficiency. Diarrheal diseases and resulting malabsorption may compound nutritional deficiencies; hence, basic environmental sanitation, including safe water, availability and use of latrines, clean food handling, hand washing, personal hygiene, and refrigeration of food, are essential elements of a comprehensive nutrition program. Deficiency of a nutrient does not by itself necessarily cause disease. Predisposing host and environmental factors as noted are also involved, and this must not be overlooked in the development of a control program.

Recommended daily dietary allowances for the maintenance of good nutrition, to be consumed in a variety of foods to provide other less defined required nutrients, are shown in Table 3.4.[85] Of the more than 60 mineral elements found in living things, nine are considered essential to human life. These are iron, iodine, fluoride, copper, manganese, zinc, selenium, chromium, and cobalt. The role of other minerals is not well established.

There has been a great deal of interest in the adoption of a balanced, healthy diet to help minimize deaths due to heart disease and cancer, which, together

TABLE 3.4 Food and Nutrition Board, National Academy of Sciences—National Research Council Recommended Dietary Allowances,[a] Revised 1989

							Fat-Soluble Vitamins			
Category	Age (years) or Condition	Weight[b] (kg)	(lb)	Height[b] (cm)	(in)	Protein (g)	Vitamin A (μg RE)[c]	Vitamin D (μg)[d]	Vitamin E (mg α-TE)[e]	Vitamin K (μg)
Infants	0.0–0.5	6	13	60	24	13	375	7.5	3	5
	0.5–1.0	9	20	71	28	14	375	10	4	10
Children	1–3	13	29	90	35	16	400	10	6	15
	4–6	20	44	112	44	24	500	10	7	20
	7–10	28	62	132	52	28	700	10	7	30
Males	11–14	45	99	157	62	45	1,000	10	10	45
	15–18	66	145	176	69	59	1,000	10	10	65
	19–24	72	160	177	70	58	1,000	10	10	70
	25–50	79	174	176	70	63	1,000	5	10	80
	51+	77	170	173	68	63	1,000	5	10	80
Females	11–14	46	101	157	62	46	800	10	8	45
	15–18	55	120	163	64	44	800	10	8	55
	19–24	58	128	164	65	46	800	10	8	60
	25–50	63	138	163	64	50	800	5	8	65
	51+	65	143	160	63	50	800	5	8	65
Pregnant						60	800	10	10	65
Lactating	1st 6 months					65	1,300	10	12	65
	2nd 6 months					62	1,200	10	11	65

Water-Soluble Vitamins							Minerals						
Vitamin C (mg)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg NE)[f]	Vitamin B_6 (mg)	Folate (μg)	Vitamin B_{17} (μg)	Calcium (mg)	Phosphorus (mg)	Magnesium (mg)	Iron (mg)	Zinc (mg)	Iodine (μg)	Selenium (μg)
30	0.3	0.4	5	0.3	25	0.3	400	300	40	6	5	40	10
35	0.4	0.5	6	0.6	3.5	0.5	600	500	60	10	5	50	15
40	0.7	0.8	9	1.0	50	0.7	800	800	80	10	10	70	20
45	0.9	1.1	12	1.1	75	1.0	800	800	120	10	10	90	20
45	1.0	1.2	13	1.4	100	1.4	800	800	170	10	10	120	30
50	1.3	1.5	17	1.7	150	2.0	1,200	1,200	270	12	15	150	40
60	1.5	1.8	20	2.0	200	2.0	1,200	1,200	400	12	15	150	50
60	1.5	1.7	19	2.0	200	2.0	1,200	1,200	350	10	15	150	70
60	1.5	1.7	19	2.0	200	2.0	800	800	350	10	15	150	70
60	1.2	1.4	15	2.0	200	2.0	800	800	350	10	15	150	70
50	1.1	1.3	15	1.4	150	2.0	1,200	1,200	280	15	12	150	45
60	1.1	1.3	15	1.5	180	2.0	1,200	1,200	300	15	12	150	50
60	1.1	1.3	15	1.6	180	2.0	1,200	1,200	280	15	12	150	55
60	1.1	1.3	15	1.6	180	2.0	800	800	280	15	12	150	55
60	1.0	1.2	13	1.6	180	2.0	800	800	280	10	12	150	55
70	1.5	1.6	17	2.2	400	2.2	1,200	1,200	320	30	15	175	65
95	1.6	1.8	20	2.1	280	2.6	1,200	1,200	355	15	19	200	75
90	1.6	1.7	20	2.1	260	2.6	1,200	1,200	340	15	16	200	75

[a] The allowances, expressed as average daily intakes over time, are intended to provide for individual variations among most normal persons as they live in the United States under usual environmental stresses. Diets should be based on a variety of common foods in order to provide other nutrients for which human requirements have been less well defined. See text for detailed discussion of allowances and of nutrients not tabulated.

[b] Weights and heights of Reference Adults are actual medians for the U.S. population of the designated age, as reported by NHANES II. The median weights and heights of those under 19 years of age were taken from P. V. Hamill, T. A. Drizd, C. L. Johnson, R. B. Reed, A. F. Roche, and W. M. Moore, "Physical Growth: National Center for Health Statistics Percentiles," *Am. J. Clinical Nutrition* (March 1979): 607–629 (see pp. 616–617). The use of these figures does not imply that the height-to-weight ratios are ideal.

[c] Retinol equivalents: 1 retinol equivalent = 1 μg retinol or 6 μg β-carotene. See text for calculation of vitamin A activity of diets as retinol equivalents.

[d] As cholecalciferol; 10 μg cholecalciferol = 400 IU of vitamin D.

[e] α-Tocopherol equivalents: 1 mg D-α-tocopherol = 1 α-TE. See text for variation in allowances and calculation of vitamin E activity of the diet as α-tocopherol equivalents.

[f] 1 NE (niacin equivalent) is equal to 1 mg of niacin or 60 mg of dietary trytophan.

with stroke, were the top three causes of death in the United States in 2004.[86] Diets high in saturated fat, sugar, and sodium may promote the development of these diseases. Recommendations include greater consumption of chicken and turkey (with skin removed), fish, pasta, whole-grain products, vegetables, fruits, and vegetable oils (not palm or coconut oils), and reduced consumption of meat, dairy products, and eggs.

Scurvy Scurvy is caused by a deficiency of vitamin C or ascorbic acid. Vitamin C is found in citrus fruit, fresh strawberries, tomatoes, raw peppers, broccoli, kale, potatoes, and raw cabbage. Common symptoms of scurvy include weakness, anemia, spongy and swollen gums that bleed easily, and tender joints. Vitamin C also strengthens body cells and blood vessels and aids in absorption of iron and in healing wounds and broken bones.[87]

Pellagra Pellagra is caused by a prolonged deficiency of niacin (nicotinic acid) or tryptophan (amino acid). Niacin is found in eggs, lean meats, liver, whole-grain cereals, milk, leafy green vegetables, fruits, and dried yeast. Recurring redness of the tongue or ulcerations in the mouth are primary symptoms, sometimes followed by digestive disturbances, headache, and psychiatric depressive disorders.[87]

Rickets Rickets is most common in children less than two years old and is caused by the absence of vitamin D, which is associated with proper utilization of calcium and phosphorus. Vitamin D is found in liver, fortified milk, butter, eggs, and fish of high-body-oil content such as sardines, salmon, and tuna. An inadequate supply of vitamin D in the diet will probably show in knock-knees or bowed legs, crooked arms, soft teeth, potbelly, and faulty bone growth. Sunshine is a good source of Vitamin D, as are vitamin D-fortified foods. Vitamin D helps build strong bones and teeth.[87]

Beriberi A prolonged deficiency of thiamin or vitamin B_1, found in whole-grain cereals, dried beans, peas, peanuts, pork, fish, poultry, and liver, may cause changes in the nervous system, muscle weakness, loss of appetite, and interference with digestion. Change from unpolished to polished rice in the diet can cause the disease in some countries where the diet is not varied.[87]

Ariboflavinosis This disease is due to a deficiency of riboflavin, known also as vitamin B_2 or G. Riboflavin is found in liver, milk, eggs, dried yeast, enriched white flour, and leafy green vegetables. An inadequate amount of this vitamin may cause greasy scales on the ear, forehead, and other parts of the body, drying of the skin, cracks in the corners of the mouth, anemia, and sometimes partial blindness. Riboflavin is essential for many enzyme systems.[88]

Vitamin A Deficiency A deficiency of Vitamin A causes night blindness, skin and mucous membrane changes, and dryness of the skin and eyes. It is believed to increase susceptibility to colds. In severe deficiencies, Vitamin A deficiency may lead to blindness and death. Vitamin A is also needed for bone growth. The diet should be adjusted to include foods rich in vitamin A or carotene, such as dry whole milk and cheese, butter, margarine, eggs, liver, carrots, dandelion, kale, and sweet potatoes.[89]

Iron Deficiency Anemia Lack of vitamin B_{12} or folic acid, repeated loss of blood, and increased iron need during pregnancy cause weakness, irritability, brittle fingernails, cuts and sores on the face at the mouth, and other debility. Prevention of blood loss and treatment with iron salts are suggested. Iron combines with protein to make the hemoglobin of the red blood cells that distribute oxygen from the lungs to body tissues. Consumption of liver, lean meats, poultry, shellfish, eggs, oysters, dried fruits, dark green leafy vegetables, iron-fortified flour, and cereal foods will contribute iron to the diet.[90]

Goiter Goiter is a thyroid disorder usually caused by deficient iodine content in food and water and inadequate iodine absorption. The WHO estimated that nearly 2 billion people worldwide have insufficient iodine intake, with the greatest burdens in Europe, the Middle East and Africa.[91] Widespread use of iodized salt in the Americas has led this region of the world to have the lowest prevalences of insufficient iodine intake. Seafood and ocean mist are good sources of iodine.[88]

Kwashiorkor Kwashiorkor is one of a group of diseases caused by protein deficiency and common among children less than six years of age living in underdeveloped areas of the world. Related diseases include marasmus and protein energy malnutrition (PEM). The term *kwashiorkor* means “the disease of the displaced child” and often occurs in children affected by manmade or natural disasters. Signs and symptoms include changes in the color and texture of the hair, diarrhea, and scaling sores. A diet rich in animal proteins, including dry skim milk, meat, eggs, fish, and cheese, and vegetables can control the disease. Because of the scarcity or lack of these foods in some developing countries, special formulations have been prepared to provide the necessary nutrients. These include Incaparina,[92] a mixture of cornmeal, ground sorghum, cottonseed flour, torula yeast, and leaf meal, blended and fortified with calcium and vitamins; WSDM, consisting of 41.5 percent sweet whey, 36.5 percent full-fat soy flour, 12.2 percent soybean oil, nine percent corn syrup, and vitamins and minerals; and CSM, corn soy-milk.

Marasmus Marasmus is a form of malnutrition that causes a progressive wasting of the body. Marasmus occurs primarily in young children and is associated with insufficient intake or malabsorption of food.[93] Marasmus is usually associated with diarrheal diseases and weight loss in young children. An inadequate diversified food intake can contribute to the problem. A gradual increase in food intake, including protein, carbohydrates, and fat, is the suggested treatment.

Dehydration Dehydration is the leading cause of diarrheal illness–associated morbidity and mortality. Oral rehydration therapy (ORT) with oral rehydration salts (ORS) began as the use of oral rehydration salt packets dissolved in water[94] on the basic premise that fluid replacement can be achieved by providing patients with diarrheal illness an oral supplement comprised of sugar, salt, and water. More recently, the term *ORT* has expanded to include the use of ORS, as well as recommend home fluids which are composed of NaC and a source of carbohydrate ranging from rice water to cereal-based solutions and traditional soups.[95] Newer formulations of oral rehydration salts under development will also help to promote intestinal healing. In order to be most effective, oral rehydration salts must be used early in the course of illness and maintained or replaced by early resumption of feeding.[96]

Important to note is that the use of ORT does not prevent recurrence of the diarrheal disease, and affected children may require ORT many times during their first five years. The causes must be removed. Safe drinking water, environmental sanitation, and hygiene are essential to provide long-term protection against the causes of diarrheal diseases. Safe drinking water will also promote sanitary food preparation, personal hygiene and household cleanliness, improved housing, a better quality of life, and more.[97]

Osteoporosis Osteoporosis is defined as a decrease in bone mass and bone density and an increased risk or incidence of fracture. In osteoporosis, bone is decalcified and becomes porous and brittle, particularly in women after menopause. Because estrogen has an important role in the maintenance of structure and calcification of bone, the drop in estrogen at menopause is, in part, responsible for osteoporosis, although lifestyle, nutritional, and environmental factors have also been found to play a role in the development of osteoporosis. Maintenance of an adequate level of calcium and vitamin D may help to offset the disease and fluorides in proper amounts in drinking water and food also appear to help prevent osteoporosis. Major dietary sources of calcium include milk, cheese, and other dairy products, and dark green leafy vegetables. The use of hormone replacement therapies to offset the decrease in estrogen has been used with some success, but because of the increased risk of certain cancers and heart disease, the use of hormone replacement therapy is generally not recommended.

Obesity *Overweight* is classified as having a body mass index (BMI is weight kg/height m^2) of ≥ 25.0, *obesity* is defined as having a BMI ≥ 30.0, and *extreme* (class III) *obesity* is defined as having a BMI $\geq 40.0\,kg/m^2$. Obesity is associated with increased risk for hypertension, dyslipidemia, type 2 diabetes, coronary heart disease, stroke, and certain cancers.[98] The prevalence of obesity has increased dramatically in the United States in the past decades. In 1999-2002, 65 percent of adults surveyed in the National Health and Nutrition Examination Survey (NHANES) were either overweight or obese, a 5 percent increase over the previous survey (NHANES III, 1988–1994). Of these, half (30% of total) were obese. In the 2003–2004 NHANES, the prevalence of obesity was 32.2 percent.[99]

Given the continued increases in the prevalence of obesity in the United States, there is a clear need for programs to educate and motivate persons to make healthier lifestyle choices and to establish environments which support these choices.[100] Effective public health programs to reduce obesity should combine policies, programs, and supportive environments created through the combined activities of health-care agencies, government, media, business and industry, communities, schools, families, and individuals.[100]

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CHAPTER 4

APPROPRIATE TECHNOLOGY FOR DEVELOPING COUNTRIES

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ABBREVIATIONS

AAEE	American Academy of Environmental Engineers
ADB	Asian Development Bank
AEESP	Association of Environmental Engineering and Science Professors
AESs	Appropriate environmental standards
APHA	American Public Health Association
ASCE	American Society of Civil Engineers
ASEP	Asian Society for Environmental Protection
AWWA	American Water Works Association
BMR	Bangkok Metropolitan Region
CC	Construction Contractor
CECI	Chief Environmental Construction Inspector
CP	Cleaner production
DC	Developing country
DIW	Department of Industrial Works
E1	Economics parameter
E1-c-E2 (E-c-E)	Economics-cum-Environmental
E2	Environment parameter
ED	Environmental degradation
EE	Environmental engineering
EIA	Environmental impact assessment
EMO	Environmental management office
EMP	Environmental management plan
EPM	Environmental protection measure
EPU	Economic Planning Unit (Malaysia)
ES	Executive summary

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ESA	Environmental study area
ET	Environmental technology
FCF	Fixed capital formation
FS	Feasibility study
GDP	Gross domestic product
HFL	Harvey F. Ludwig
HW	Hazardous waste
HWMP	Hazardous waste management project
IAA	International assistance agency
IC	Industrialized (developed) country
IEE	Initial environmental examination
IEEDP	Integrated Economic-cum-Environmental Development Planning
IT	Information technology
IUCN	International Union for Conservation of Nature
IWA	International Water Association
KIP	Kampung improvement project
KVEIP	Klang Valley Environmental Improvement Project
LACSD	Los Angeles County Sanitation Districts
LW	Liquid waste
MDB	Multilateral development bank
MSL	Municipal sanitary landfill
MSS	Municipal sewerage system
NEB	National Environment Board (Thailand)
NEcPA	National economic planning agency
NEnPA	National environmental protection agency
O&M	Operation and Maintenance
PB	Palmer-Bowlus (flumes)
PCD	Pollution Control Department (Thai government)
PEA	Project economic analysis
PrPr	Project proponent
R&D	Research and development
SEIs	Significant environmental issues
SLF	Sanitary landfill
STP	Sewage treatment plant
SW	Solid waste
TDS	Total dissolved solids
THMs	Trihalomethanes
TOR	Terms of reference
TT	Technology transfer
UNDP	United Nations Development Program
UNEP	UN Environment Program
USAID	U.S. Agency for International Development
USEM	Urban sewerage and excreta management
U.S. EPA	U.S. Environmental Protection Agency

USWM	Urban solid waste management
UWSS	Urban water supply system
VEO	Village Environmental Officer
WB	World Bank
WEF	Water Environment Federation
WHO	World Health Organization
WPC	Water pollution control
WQ	Water quality
WTO	World Trade Organization
WWF	World Wildlife Fund
YC	Young coyote

INTRODUCTION

Background

Examination of publications in the field of engineering shows that practically all of the technologies utilized for protecting environmental resources and preventing environmental degradation have been developed in the affluent industrialized countries (ICs) without significant contributions from the developing countries areas and regions of the world. This is because their advanced economic status has enabled the ICs to reach levels of understanding on the need for protecting environment, and has given them the funds to study and develop the feasible technologies needed for controlling environmental degradation and the funds to finance design/construction/operation of the protection control facilities.

History

By the mid-twentieth century, the ICs had progressed sufficiently to begin implementation of the desired control programs, especially in the basic sanitary engineering fields of urban water supply, wastewater management, and food sanitation, plus beginning efforts for tackling other key problems including solid wastage management, air pollution control, noise control, and radioactive emissions control. Then came the impact of World War II, which initiated a great increase in research and development (R&D) in all aspects of environmental engineering, so much so that of the total arena of information on environmental engineering technology, it is estimated that more than 90 percent has been generated in the second half of the twentieth century. Moreover, while this environmental technology developed by the ICs was relatively simple and labor-intensive before World War II, the emphasis of the subsequent R&D has focused on minimization of labor by replacing this with hi-tech equipment that is readily operated only by trained professionals. And the overall IC effort has included progressively improving programs for furnishing the needed training. In the U.S. the U.S. Environmental Protection Agency (U.S. EPA) established in the 1960s (built on the earlier federal environmental engineering program operated by the U.S. Public Health Service) had a leadership role in the "U.S. Environmental Movement" with a budget believed to exceed the governmental budgets of all other countries combined, and this remarkable effort has been further enhanced by very significant extra investments by U.S. state and local agencies and by the U.S. private sector. The result is, in the United States (and somewhat similarly in other ICs) the approach to resolving environmental degradation problems has become very hi-tech, with the level of technology continuing to increase.

Problem of Developing Countries

What is the situation in the DCs, as related to the context of environmental technology development in the ICs, keeping in mind that the bulk of the world's population, land area, and environmental resources are located in the DC regions? An important point here is that the IC developments were essentially focused as would be expected on IC problems, with little, if any, attention to the fate of environment in the DCs. However, development of the U.S. environmental movement in the years immediately following World War II (stemming from the new role of the United States as a truly rich country) led to the UN/Stockholm/1972 Conference, which established a global effort funded by the ICs for assisting the DCs for protecting DC environments, including establishment of UNEP, and led to establishment of National Environmental Protection Agencies (NEnPAs) in virtually all DCs, either as an environmental ministry or branch or affiliate of existing ministries, intended to function together with existing National Economic Planning Agencies (NEcPAs) (already established with World Bank assistance) to promote continuing assistance to DCs to promote economic development (E1 development), but without sufficient attention to protecting environmental resources (E2 protection) as needed to promote sustainable development.

Examination of what has actually happened to the DC environments since the beginning of the "International Global Environmental Movement" in 1972 shows that the expectations for protection of DC environmental resources have not happened. Indeed, as shown by the UN Brundtland Report of 1987[141], DC environmental degradation over the period 1972 to 1987 actually exceeded the total of all historically previous degradation. This was due to (1) rapid growth of population and industries in the ICs resulting in increasing demands for import timber and other environmental resources from the DCs, (2) rapid development of new technologies, making it increasingly much easier to extract and export these resources, and (3) matching realization by DC decision makers that allowing such rapid extraction and export furnished much money for their immediate goals of remaining in office[72,82,83]. In this context the newly established DC/NEnPAs found that achieving meaningful environmental protection could not be done in emulation of role models like U.S. EPA, because of lack of basic will by DC governments to resolve the degradation problem[58]. Hence, the NEnPAs had, compared to say, U.S. EPA, relatively very low budgets and staff without experience in how to proceed to protect environment under DC conditions. Moreover, their efforts were undermined by the lack of will by the governments to enforce the recommendation of the NEnPAs for environmental protection (e.g., the environmental protection measures specified in a project's Environmental Impact Assessment.

Summary of DC Problem

A summarization of the typical DC situation is given in the paper, "How Asian Development Bank can Improve Their Technology Transfer Operations for Water/Sanitation Projects in Developing Countries"[94], which is quoted here as follows

> (a) Require post-construction monitoring of performance of the systems which are built. This is basic standard engineering practice which together with periodic performance monitoring is routine in the ICs, to determine how effective the investment is, and what needs to be done to improve planning/design practices so the system will become more effective. Despite this fundamental fact, the MDBs have persistently refused to require performance monitoring, hence the MDB staff have not found out how to improve their practices in guiding DC project planning/design. Such monitoring will reveal deficiencies in design and in provisions for O&M, so that practices can be progressively improved[73].
>
> (b) For each type of sector investment (water supply, sewerage, air pollution control, etc.), discontinue common MDB practice of allowing systems to be designed which follow IC design criteria and matching environmental standards, and figure out for each sector for the particular DC what the appropriate/affordable environmental standards and matching design criteria should be, in recognition that the monies available to the DC will be only a fraction of that spent in the ICs for managing the same problem. This is crucial but cannot be done by "Environmental Generalists" or "Engineer Generalists" but can be done only by skilled sanitary engineers knowledgeable both in IC practices and how to modify these to suit DC conditions. Many of the MDB project staff with whom the author has worked have not had the needed skills in appropriate IC vs. DC practices.
>
> (c) Ensure that the recommended system is realistic with respect to the O&M limitations in the DCs. Most IAA projects have not done this but have pretended to do it. The Feasibility Study reports commonly include a chapter on O&M which simulates IC practices, even though the writers know the DCs cannot/will not implement it. This practice is not only counterproductive but is grossly unprofessional. The reason for the malfunctioning and wastage mentioned above sometimes is poor design, but even with good design the system often will not function effectively due to lack of adequate O&M. Usually the DC governments (and the IAA sponsors) are not aware of this because of the lack of performance monitoring. Sometimes the DC officials involved may insist on including components in the project which shouldn't be there (such as a highly mechanized sewage treatment plant). Never mind, their "money need" must be accommodated, but they take only a part of the total project budget. The goal is to see to it that the remaining money isn't frittered away but will produce a useful project. The existing syndrome is that "corruption" takes a sizeable slice, but the DC can live with that. The need is not to let the rest of the money get frittered away.

(d) The MDBs and other IAA sponsors have done a very poor job in technology transfer to DC personnel. The best/cheapest way to achieve effective TT (technology transfer) is to utilize the actual project for this purpose. But the way the MDBs et al. structure the budget, while the overall project team includes both expat experts and DC participants as assistants, the project budget has no funds for enabling the expat experts to use the project for TT purposes[45]. So the expats use the DC-ers to do tasks without explanation of the "why" of the tasks. The MDBs et al assume the TT will "rub off" on the DC participates in the project implementation process, but this doesn't happen—It's not that easy. The need is to increase the project budget for the expats by about 10 percent to enable the expat experts to have the time to utilize the project for training purposes.

(e) The MDBs should recognize that Environmental Technology has been developed primarily in the ICs, but in the DCs, because of the non-money making nature of most environmental/sanitary infrastructures, the DC governments/universities are generally not knowledgeable on appropriate sanitary engineering design technology. Often the practitioners and university professors have only academic backgrounds in affluent IC practices and are not at all capable of doing the judgment thinking needed for making the IC to DC changes. This applies also to most MDB/IAA staff and most DC staff because they have not had the needed apprenticeship[72]. The result is the poor design noted in Items (b)(c) above. How to correct this very basic problem? Several approaches are feasible:

(e.1) Incorporate technology transfer into the investment project program as noted in Item (d) above.

(e.2) Prepare textbooks or manuals on appropriate DC design criteria (and matching environmental standards), which can guide DC/IAA designers to produce a project which works, such as done by H. Ludwig et al. for the Municipal Sewerage Sector[105], which to the author's knowledge, is the only environmental engineering design textbook yet produced which is actually appropriate for DC application. As noted in its Preface, this Sewerage textbook is "just for starters," to illustrate this approach. Similar textbooks are needed for all sectors (municipal water supply, highways, ports, etc.) so that projects in all sectors will be economically-cum-environmentally sound.

(e.3) Established graduate training programs on IC versus DC design practices for all types of investment, to ensure appropriate design practices (and matching environmental standards) for all types of environmentally-sensitive projects, leading to university graduate degrees in Economic-cum-Environmental (E-c-E) Development in the DCs, to be attended by both DC and IAA personnel[99]. This approach is the most basic—to give attention to the need for E1-cum-E2 project design for all sector projects as part of the graduate education program. The MDBs should take the lead to establish at least one such university program, somewhere in a qualified university. No existing graduate university now does this, not even the Asian Institute of Technology in Bangkok nor the UN university program in Japan.

(e.4) Promote establishment of an Environmental Engineering Journal, i.e., a professional magazine in which each issue will feature projects that discuss specific examples or case studies of illustrative DC projects which explain how IC practices were modified to suit DC conditions.

(e.5) Furnish copies of selected IC textbooks/manuals, which, despite their IC origins, nevertheless can be very useful to DC practitioners (who with rare exceptions cannot afford to buy them), translated into the local DC language[163]. One example is the American text, "Standard Methods for Analysis of Water and Wastewaters"[2], which is a virtual "bible" on this subject, which is useful per se in both ICs and DCs. If done this simple stop alone should greatly improve water and wastewater management technology in the DCs, hence remarkably high benefits at low cost.

(e.6) Send DC staff for training, not "observing," with U.S./IC organizations. Most MDB-sponsored projects of this type amount to what may be called "observation junkets." What is needed (and the author has used this approach repeatedly) is to assign the DC individual to be an additional working team member in an organization doing what he wants to learn to do. For example, if the DC-er wants to learn about regulatory permit systems for WPC (water pollution control), assign him to be a temporary extra member of the WPC permit section staff of one of the California State Regional Water Quality Control Boards. This not only achieves real world training but doesn't require the organization to whom the individual is assigned to make any special preparations. The best agencies for this purpose in my view in the environmental engineering field are the California Regional Boards for regulation procedures, and the Los Angeles County Sanitation Districts for management of liquid and solid wastes.

(e.7) Plan Technology Transfer projects, not in the usual way as a single event operation, but spread this over a period of training series with enough time between to permit the student to absorb the lessons from each session[45]. The IAAs like the single-event approach because it "saves" travel costs, without realizing that their approach is not effective. Might as well cancel the project and save all of its cost.

(e.8) Use retired expat experts to give hands-on training, where a single expert, say in community water supply systems, visits each of say 10 systems every month. The big advantage of this approach is that the expert catches the DC-er at the moments when he has a serious problem, hence listens carefully to the expert's advice. This is far superior to use of academic classroom textures.

Make much more effective use of the Private Sector, both by means of turnkey projects and by use of contracts limited to O&M, especially for projects in water supply and sanitation. This subject is discussed in some detail in the section on Urban Water Supply Systems (UWSSs).

Purpose of This Chapter

This chapter is devoted to Item e.2, namely the furnishing of design guidelines, with matching environmental standards, which are appropriate for design of DC environmental engineering systems. Experience over the past several decades on many DC projects has shown[72] that the lack of such guidelines is often the major reason for failure of investments in DC environmental engineering systems. This experience shows that if the project is designed so that it is not suitable for DC/O&M, it is doomed to failure at the outset—and a large percentage of IAA-sponsored projects are in this category. However, if the project is designed to suit DC conditions, there is a good chance that it will actually be operated and effectively utilized, despite the many problems already noted. What the DC practitioner critically needs (the same for his IAA adviser) is a "cookbook" type of manual that can be copied (despite the practitioner's lack of training/experience), just as a novice cook can make an edible cake using a cookbook, and environmental lab technicians can do acceptable BOD testing of wastewaters even with limited training.

To sum up, the essential purpose of this chapter is to illustrate how the design information given in the other chapters, which is essentially IC-oriented, can be properly modified to be applicable for use in DCs. The objective is to enable DC (and IAA) practitioners to make valuable use of this sixth edition of *Environmental Engineering*. Note not only that almost all existing textbooks/manuals are intended for IC use, but also, the same applies to the articles in the magazines/journals published by professional organizations such as ASCE, AWWA, and WEF. The technologies described in these articles are much beyond the affordability of most DCs now and in the foreseeable future[112].

Specific Subjects Included in This Chapter

Of the various technological fields discussed in the sixth edition of *Environmental Engineering*, this chapter includes discussion of the major sanitary/environmental engineering fields of urban water supply, urban sewage management, industrial waste management, urban solid waste management, urban hazardous waste management, urban air pollution control, megacities, urban slums, urban sanitation, rural sanitation, public health, and water resources, together with discussion of the related subjects of environmental governance, environmental impact assessment, emergencies management, environmental technology transfer, development planning, global warming, and the future of global environmental issues.

Key Constraints in Environmental Engineering Practice in DCs The purpose of this section is to illustrate the key constraints involved in applying environmental engineering technology in DCs (as distinguished from ICs).

Limited DC Expertise in Environmental Technology This problem is illustrated in Figure 4.1, which shows that many, if not most, DC/ET professionals have limited actual apprenticeship experienced in working under the guidance of ET experts, and moreover their academic training is often IC-oriented[72]. This explains the need for "cookbook" versions of design textbooks/manuals for use by DC practitioners (and their counterparts in the IAAs).

Appropriate DC Design Criteria/Environmental Standards This problem is illustrated in Figures 4.2 and 4.3. Review of the development of environmental engineering design criteria (and matching environmental standards) in the ICs shows that these have steadily increased over the decades along with increasing

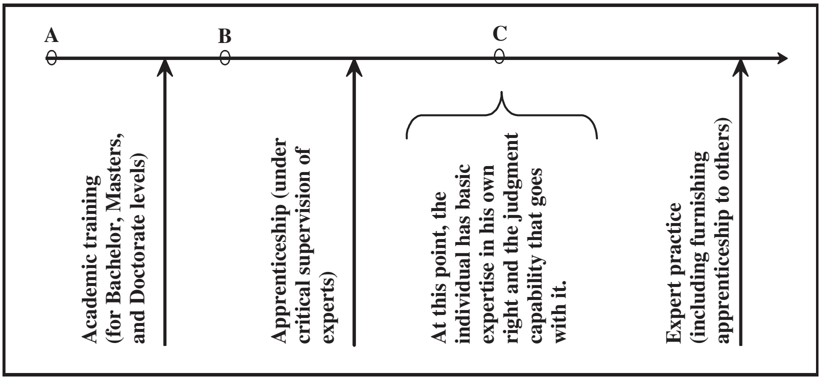


FIGURE 4.1 Role of apprenticeship in development of expertise[66].

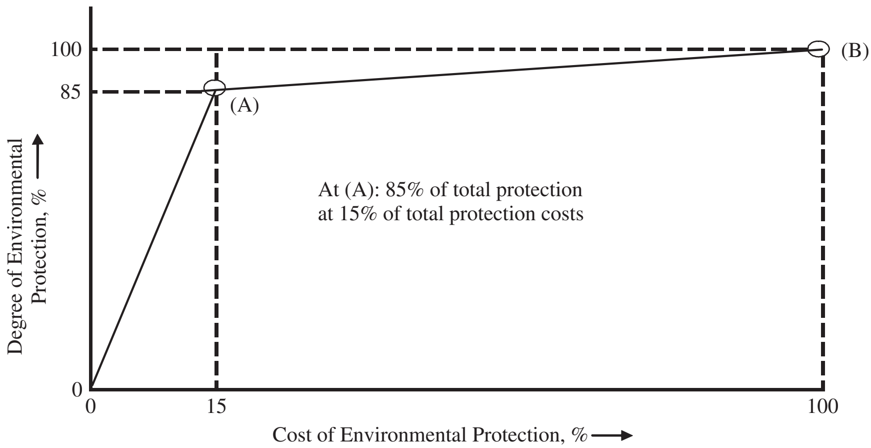


FIGURE 4.2 Appropriate project design criteria for DCs[82].

IC affluence. These criteria/standards are simply not affordable or appropriate for use in DCs; hence, the criteria/standards that are appropriate represent lesser levels as shown in the figures. However, as shown in Figure 4.2, even at a much lower percentage of cost, the bulk of the environmental protection can still be achieved. The problem is in modifying IC criteria/standards to reduce them to appropriate DC levels, which takes truly expert judgment. This is another reason for the need for "cookbook" textbooks/manuals.

(a) Figure 4.3 also illustrates the influence of costs in differentiating between IC and DC design criteria. While Point C represents the target in current U.S. practice, Point B is the appropriate target for DCs.

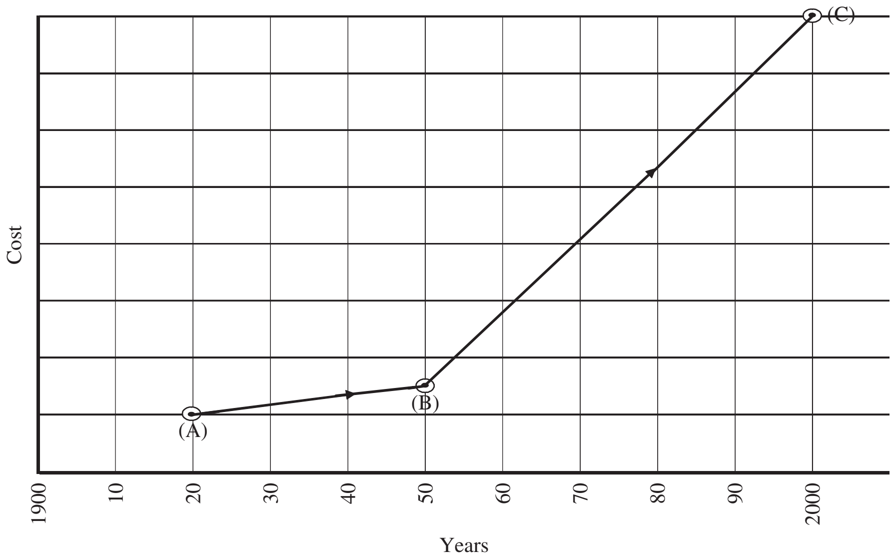


FIGURE 4.3 Levels of U.S. requirements for treatment of water supply and sewage. Source: H. Ludwig/2007.

Lack of Enforcement of Environmental Laws/Regulations This problem is illustrated in Figure 4.4. The ICs clearly understand that laws/regulations are not meaningful unless their requirements are enforced using monitoring to detect noncompliance with penalties for noncompliance sufficient to encourage compliance. Sad to say, no DC has as yet have applied this principle so that, while the DCs do often have excellent laws/regulations for environmental protection, including use of the EIA process, generally the monitoring of performance and use of serious penalties is low, which, of course, encourages evasion rather than compliance[82]. However, as noted earlier, experience in the DCs shows that if an EE facility is properly designed so it can be feasibly operated within the DC system, there is a good chance that the plant will be made to perform by its management despite the lack of monitoring/enforcement.

Use of Private Sector As already noted, much more effective use of the private sector is recommended, especially for water and sanitation systems. How to achieve this is discussed in the section on “Urban Water Supply.”

Protection of Precious Ecosystems A serious deficiency in conventional economic analyses of proposed development project is to ignore the real value of precious ecosystems that will be impaired by the project simply because of lack of mechanics for expressing this value in the money terms used for such analyses. This issue is discussed in the section on “Development Planning.”

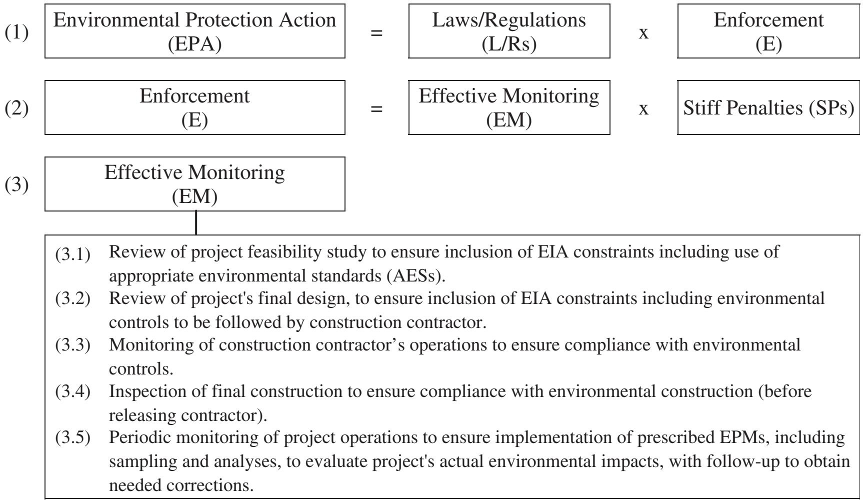


FIGURE 4.4 Environmental protection action versus enforcement.[120].

ENVIRONMENTAL GOVERNANCE

Introduction

The previous section on "Introduction" includes preliminary discussion of the issue of environmental governance in the DCs (i.e., the degree to which attention is given in the country by the government, by industries, and by environmental engineering practitioners to the needs for protecting environmental resources from unnecessary degradation). This section gives additional details.

Situation in DCs versus United States/ICs

As noted in Figure 4.4 the situation in environmental governance in the DCs is vastly different from that in the ICs, simply because the U.S./IC system embodies effective monitoring/enforcement to ensure that the project proponent for any proposed project, both public and private, will actually comply with the requirements for EPMs that are specified in the approved EIA (part of the feasibility study) in the subsequent project implementation stages of final design, construction, and operation. Usually, the administration of this process in the ICs involves use of the "permit system" in which the project regulating agency issues a permit to the project proponent that spells out all of the EIA's EPMs to be carried out by the proponent, including periodic self-monitoring with periodic reporting, with public surveillance visits to the regulating agency to check actual environmental performance (i.e., to check the reliability of the self-monitoring reports). The project proponent complies simply because the cost of compliance is less than the cost of penalties for noncompliance. This system has evolved in the ICs in recognition that effective monitoring/enforcement is essential to gain compliance.

Unfortunately, the situation in the DCs is vastly difference because none of the DCs has yet to establish effective monitoring/enforcement operations. Although the DCs do use the EIA process (with limited success), which do specify the needed EPMs, the follow-up provisions for monitoring/enforcement are generally so weak that it is much less costly to evade rather than to comply with the specified EPMs. It seems that the decision makers of the DCs have not wanted to implement effective monitoring/enforcement because this conflicts with their interest in immediate financial gains, rather than in optimal long-term economics (See section on "Environmental Economics and Financing").

What DC and IAA Practitioners Can Do to Correct This Problem

There are several approaches that can be utilized to encourage use by the DCs of effective monitoring/enforcement.

World Bank and Other IAAs: Project Monitoring and Enforcement The best opportunity for improving DC environmental performance is the leverage available to the World Bank and other IAAs that help finance DC projects, for requiring project monitoring/enforcement as a loan codicil. There have been some projects where the loan codicil did include this requirement, including World Bank/Gunaratnam projects[81,161,162,163]. But these have been very few and, in general, the World Bank and others seem to have assiduously avoided this requirement. (They have preferred the "diplomatic approach," no doubt because such effective monitoring would clearly conflict with political wishes, including the very serious problem of wastage of project money by corruption.) Also, the monitoring would clearly indicate the wastage that takes place and which parties are the "culprits," and both the IAAs and DCs have preferred not to push this approach. Only in recent years has the World Bank begun overt evaluation of the corruption problem, and this is a major issue now facing new World Bank president appointed in 2007. The job of the IAAs is to get all parties involved in project investments to understand that only by competent monitoring can deficiencies in project performance be evaluated, leading to progressive improvement in planning/design criteria to get best results for these investments.

Guidelines Design Manuals Another boat missed by the IAAs is their lack of understanding of the need for producing guidelines manuals on how to design DC projects that will suit the DC system, which will actually produce the desired objectives. With very few exceptions, all manuals and virtually all university teaching (even at AIT in Bangkok) utilize the affluent IC approach, including design criteria and matching environmental standards. If the project planning/design practitioners (in both DCs and IAAs) had the proper manuals, they could greatly improve their performance. When projects are properly designed to match DC conditions, the chances that these will actually be built and operated will be greatly improved. See the section on "Technology Transfer" for details.

Role of the Private Sector

Private Consulting Firms that Design Projects, including EIA As already noted, if appropriate manuals were made available to these DC practitioners, their chances of preparing appropriate designs should be greatly improved.

Industry This same principle applies to the investments in pollution control systems by industries. Properly planned, many industry plant managers will operate the systems instead of practicing evasion. Industry plant managers are generally not anti-environmentalists, but they can hardly be expected to use funds for operating systems that cannot be operated with available local skills or that produce no significant environmental improvement.

Another promising governance role for industry is for several industries to form their own industry/environment associations that develop practices to be utilized by all association members[92]. Still another example of industry cooperation utilized in Thailand is the establishment of an effective joint enterprise for managing oil spills from oil tankers operating in the open seas and in harbors (See section on "Industrial Wastewater Management.")

URBAN WATER SUPPLY

Situation in United States/ICs

One of the greatest engineering achievements of the twentieth century, which is included in the listing of these achievements by the U.S. National Academy of Engineering (NAE), is the advent of chlorination of community water supplies early in the century, which by mid-century had become the well established practice of practically all U.S. cities, to chlorinate the water delivered to the distribution system, plus rechlorination along the way, to ensure that the water delivered at the household tap had a measurable chlorine residual. This chlorination, together with the provision of superior water supply distribution system piping to obtain "watertight" piping, plus pressures sufficient to maintain a significant positive pressure in the distribution system at all times, served to deliver water at the taps that was safe to drink at all times. And this, together with steadily improving management of excreta and other sanitary wastes, resulted in reduction in enteric disease rates from their high levels at the beginning of the century, to very low levels by mid-century, representing a great public health achievement, especially so for infants and preschool children, who are especially vulnerable to enteric diseases.

Following World War II, urban water supply practice in the United States and other ICs became increasingly more sophisticated in design and equipment and materials, particularly in relation to the hazards of other communicable diseases that can be transmitted by water, including those transmitted by cysts of *Cryptosporidium* and *Giardia*, which has resulted in a great deal of attention to utilization of other methods of disinfection including use of ozone and ultraviolet light. Moreover these alternative methods, while more expensive, have the added advantage of not generating trihalomethanes (THMs), which are a byproduct of chlorination and which, if ingested in drinking water over a period of decades, can result in some increase in THM-induced cancer. Hence, the international waterworks literature of today (which is IC-oriented) gives major of attention to use of these alternative disinfection methods.

Another important aspect of urban water supply systems in the United States is that in the earlier decades many of these systems were privately owned, but by the end of the twentieth century, most of these had shifted to municipal ownership. Even so, the municipally owned systems have been well designed and managed—and hence, profitable, including financing of return on investment plus O&M plus profit. A basic reason for this success is that the municipal and higher-level public health authorities had the real power to require effective monitoring for the safety of drinking of water delivered to the tap and to enforce the requirement that the routine testing of the tap water for coliforms meet the prescribed safety levels.

A key question here is, what do these progressive improvements in U.S. urban water supply systems (WSSs) mean for DCs?

Situation in Typical DCs

Sad to say, the urban municipal water supply systems for almost all cities in DCs, with the exception of the capital cities, very much resemble the situation in U.S. cities in the early 1900s. The typical DC systems maybe characterized as follows:

- Little if any attention to protecting the source of supply (the raw water supply) from pollution contamination.
- Focus of interest of WSS managers is on delivering an adequate quantity of water, with little, if any, attention paid to the safety of the water delivered to the tap for drinking. Some attention is given to selected water quality parameters including hardness or excessive color or turbidity, which would result in massive complaints from householders.
- Use of treatment plants (usually rapid sand filters) designed to suit IC conditions requiring sophisticated O&M. Hence, these plants (the most expensive component in the overall WSS) function poorly, commonly producing effluents with turbidities in the range of 5 to 10 ppm, which are hardly amendable to disinfection. This is due primarily to the fact that the plant design is by IAA engineers not familiar with DC needs, and to the fact that IC governments in their programs for helping DCs often try to do so by furnishing/selling them the type of design/equipment utilized in the ICs, without realizing the consequences.
- Although the treatment plant effluent is usually chlorinated, so the water is safe to drink when leaving the plant, the WSS managers rarely have training in sanitary engineering, so they often don't understand that the

key issue is safety of drinking water delivered at the household tap. Often, the distribution-system piping uses materials and equipment that do not result in watertight piping but have "holes" that tend to soak up excreta in the vicinity (which is often there do to lack of excreta management). This soaking up is intensified by the fact that many of the WSSs are not able to maintain pressures 24 hours day, resulting in marked pressure fluctuations.

- There is a lack of any monitoring of water safety for drinking at household taps, due primarily to the fact that most the DC health authorities, unlike those in the ICs, have thus far not given significant attention to this need.
- The sad fact that the people customers believe they should be furnished with water at low cost, and this practice has been going on for so long that the UWSSs are unable to collect enough tariffs to finance costs. Often, the total revenue is barely sufficient to pay for O&M costs, with nothing for return on investment (and nothing for profit).

In most DCs, the only city that does sometimes receive adequate attention with competent WSSs is the country capital city, which, because of its political importance, does receive special attention, including extraordinary financial assistance plus use of expat consultants. However, this kind of assistance is rarely ever furnished to secondary cities (most of which do not have sufficient taxing powers to afford this level of attention).

An example of a problem facing DCs relates to the Provincial Waterworks Authority (PWA) of Thailand, which has responsibility for all community UWSSs in the country except the capital (Bangkok), including use of rapid sand filter plants throughout the country, which commonly produce effluents with turbidities—not of 0.1 ppm as per the design, but in range of 5 to 10 ppm, because of the lack of adequate budgets for financing competent O&M operators. Although the IAAs have given many grants for funding programs for training of these operators, these programs do not deal with the "root" O&M problem, which is the low pay for these workers. Such training programs per se cannot correct this problem. In fact, such programs commonly result in causing the workers who have potential talents to leave their jobs to take better-paying jobs, which they are able to get because of the training. Use of the private sector has not been able to solve this problem, as has been the experience of many DCs including DCs in Latin America[30,32], because the private sector companies, to operate efficiently with profits, must charge much higher water use rates, which infuriates the public (so the governments tend to back down).

Suggested Approach for Improving IAA Assistance to DCs

What can be feasibly done in a typical DC to improve its UWSSs, taking into account the constraints already noted? The experience of the World Bank on projects in

China[161,165] indicates that the following measures are feasible (and can be made as requirements through codicils in the financing loan agreement):

(a) Insist on use of chlorination sufficient to produce a measurable residual at the household taps, including weekly monitoring of a selected number of taps (which is easily done using simple colorimetric instruments) (Measure coliforms much less frequently, say at 3-month intervals). To this end, promote use of elevated storage tanks in the UWSS for maintaining pressure in the distribution system, instead of pressure pumping, so that the storage tank can be used for easy chlorination of the supply, preferably by use of sodium hypochlorite powders. If gaseous chlorine must be used, utilize safety protection systems as specified in publications of the American Water Works Association, to prevent injury to O&M personnel.
   (a.1) People in some DCs, especially in Asia, commonly boil their drinking water; hence, the argument may be made that chlorine disinfection is not needed. It is nevertheless needed, especially because children, when away from the home, are prone to drink water from any available tap, regardless of instructions from parents.
   (a.2) Some UWSS officials are confused by the attention in the international media on THMs in chlorinated water and use of disinfection by methods other than chlorination. The reality in the DCs is quite different from that in the ICs. In the DCs, a person's chances for growing old will be greatly diminished if he or she drinks nondisinfected water, and the only disinfection method feasible for almost all DC cities is chlorination.
   (a.3) Encourage local organizations, like the Boy Scouts, to do the routine chlorine residual testing, as a public service, in recognition that most DC municipalities will be reluctant to fund this service.

(b) Insist on a salary level sufficient to attract and keep and a competent UWSS manager and furnish him with adequate staff and training materials and training opportunities, and require meaningful periodic reports on system performance (including management of complaints).

(c) Encourage use of quality materials and equipment in order to minimize "holes" in the distribution system.

(d) Try to achieve a design for the overall UWSS that will maintain positive pressures in the system at all times.

(e) Encourage addition to the UWSS staff of an engineer trained in sanitary/public health engineering as the most practical way for incorporating the sanitary/public health engineering parameter into the "mindset" of the UWSS organization, including establishment of a reliable water quality testing laboratory. The need and value for this is illustrated in the paper on this subject as presented in Box 4.1 in the Subsection, "Water Quality Analyses."

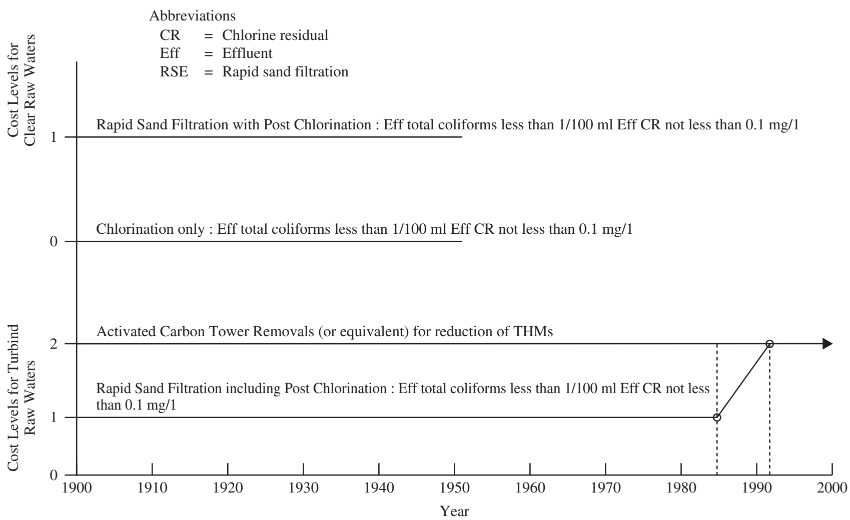
(f) Make effective use of private sector, either for turnkey projects or only for O&M, with feasible attention to use of water charge rates acceptable to public. This means the private company should start with a rate low enough to be acceptable, with subsidies from government to comply, with progressive increase in rates (with lesser subsidies) over a period of years.

Appropriate Water Quality Standards

Maintaining a measurable chlorine residual in the delivered tap water is the water quality parameter that should be given greatest attention in designing and operating DC/UWWSs. It is illustrated by Figure 4.5, taken from a report of the Asian Development Bank published in 1988[112].

Water and Sewer Pipes in Same Trench

Situation in ICs Many U.S. state health authorities have persistently prohibited placing water supply and sewers in the same trench, setting limits requiring specified distance between the two types of conduits. However, there



NOTES

U.S. Practices:

- Turbid raw water: "Zero health risk" syndrome will require activated carbon tower or equivalent treatment to remove THMs and other toxic substances.
- Clear raw waters (initial turbidity <10 units): whereas previously only chlorination required, now full-scale rapid sand filtration with post chlorination to be required.
- In addition to chlorination of filter effluent, it has been necessary in states like California to maintain a positive chlorine residual in the water supply distribution system, which sometimes requires rechlorinaization within the distribution system. Generally, DCs have no such requirement, and often there is no residual in the distribution system, but the DCs really need this (far more than ICs) because of leaky distribution systems, fluctuating pressures, and lack of sanitation.

RecommendationS for DCs:

- Clear waters: Chlorination only.
- Turbid water: RSF/Chlorination only, no activated carbon treatment. Maintain positive chlorine residual in distribution system.

Source: ADB[112]

FIGURE 4.5 Schematic drawing showing drinking water standards for U.S. chlorine residuals, coliforms, and THM toxicity parameters with recommendations for DCs.

are exceptions—for example, in Washington, D.C. In some Western Europe countries (e.g., Sweden), such dual use of the trench is permitted under specified conditions because of the resulting considerable savings in total trending costs.

Situation in DCs The DCs have followed the WHO guidelines, which do not permit dual use of the same trench following general U.S. practice. However, a study sponsored by USAID completed in 1984 at the request of the Jordan government evaluated dual use considering both economic and public health parameters[60]. The conclusions of this study (endorsed by Dr. Abel Wolman, then a chief consultant to WHO), are summarized as follows:

- A review of UWSS experience in the United States and elsewhere, which included consultation with the U.S. and international agencies carrying out evaluations and research on water supply contamination hazards, has clearly indicated that dual use of the trenches is regarded as an acceptable practice in many localities, without the use of special encasement of the sewer pipe and/or the use of pressure pipe for the sewer, provided (1) the sewer pipe is of first-class quality (can withstand low head pressures with rubber ring joints or the equivalent); (2) the vertical separation between the two pipes is at least 18 inches; and (3) the water main is located on a side-bench so that the sewer main may be repaired without disturbing the water main. This practice is commonly used in Western Europe, and in the United States, it is generally allowed whenever the physical or right-of-way constraints make it necessary to utilize a single trench for both mains. It is commonly used in Washington, D.C.
- In Amman, dual use of the trenches has resulted in a reduction in the cost of the water supply system of about 15 percent. Where excreta disposal depends on the use of subsurface leaching areas, as is the case in the urban areas of many developing countries, dual use on wide as well as narrow streets, would be a relatively cheap way of providing health protection. The alternative (i.e., the use of separate trenches) or of dual use with rigid sewer requirements (i.e., the use of pressure pipe and/or encasement), will often be too expensive for developing countries to afford. However, such dual use assumes that the quality of construction for both water and sewer pipes will meet minimum international standards, and the construction records of municipal agencies in many developing countries may show that they do not meet this requirement.
- This is one of the main reasons for recommending that the DC/USSS should establish a Division of Water Quality (DWQ), one of whose functions would be to monitor and exercise surveillance over the planning, design, and construction of future water supply and sewer mains, including dual use, to ensure that construction practice do in fact meet the minimum international standards. The DWQ would, of course, work closely with the Ministry of Health to keep the Ministry of Health appraised of its activities and progress. Assuming that this is done, it would be good practice to allow use in Jordan

and other DCs (1) where separate trenches are not feasible (due to physical constraints or right-of-way constraints), and (2) in wider streets where the savings would result in enhancing the overall health protection obtainable with limited funds.

Reuse of Treated Wastewater

Situation in ICs Ever since human activities reached levels that caused significant pollution of streams, urban water supply system (UWSSs) have, in effect, been producing the water supply delivered to the distribution system by treating polluted stream waters—representing a kind of reuse. In the 1940s, USPHS studies concluded the stream waters, to be suitable as raw water to be treated, must not be polluted beyond specified limits, but since then these limits have steadily risen as the removals achieved by rapid sand filtration progressively improved with the development of superior additives for improving the coagulation/flocculation/filtration processes included in rapid sand filtration plants—so much so that even badly polluted raw waters can be utilized. Despite this, U.S. public health officials have persisted in not being willing to authorize direct reuse of sewage for urban drinking water supply purposes (the treated sewage could be utilized for irrigation of selected types of crops). For urban water supply purposes, first the sewage must be released into a stream, then the raw water removed at a downstream location. As a result, the only systems acceptable to U.S. health authorities have been those where the wastewater, after treatment (conventional complete treatment followed by reverse osmosis if salinity must be reduced) is infiltrated into the ground to become part of the natural groundwater supply, then can be pumped out for acceptable use as raw water supply. This system was pioneered in Southern California in the 1950s to 1960s by the Los Angeles County Sanitation Districts and the Eastern Riverside Municipal Water District[34] and since has been utilized in many other communities in Southern California including the Orange County Water District[144]. However, the City of San Diego's Water District has since implemented partial direct reuse, approved by the health authorities, by which treated wastewater is mixed with natural fresh water in an impounding reservoir used for raw water supply.

Situation in DCs The current situation in the DCs resembles that in the United States prior to the interest in projects for direct reuse beginning in the 1950s. However, some initial studies are being made in recent years for exploring the potentials for recharging groundwater in desert type regions, as in Pakistan[151] and in regions with ample water in the rainy season but with negligible rainfall for the remainder of the year (prolonged dry season)—for example, in the Bangkok region of Thailand[138].

IAA-Sponsored Community Water Supply Programs

WHO/UN Program A primary effort of WHO has been the development of the UN's "Water and Sanitation Decade" program and follow-up efforts carried out in recent decades, with the objective of furnishing everybody in the DCs, including the poor, with clean water safe for drinking together with basic provisions for management of excreta. Although this program has achieved only partial success, it has done much good and the effort continues. An evaluation of the program's achievements made in 2004 by the *Economist* magazine[31] showed there have been many problems that have hampered progress in the UN program. One problem is that governments have persisted in delivering water at much too low charge rates, so those with taps in their homes (typically the better-off) have no incentive to conserve it. Because the UWSS has not been self-funding, it has not been extended to the poorest areas, so the poorest have ended up paying inflated prices to black-market water sellers.

In towns, private firms can work wonders if they are allowed to charge reasonable prices. In rural areas, where the poorest of the poor live, the most progress has been made by concentrating on small (and usually publicly funded) projects, such as boreholes, rather than trying to follow urban water supply practice. The locals should be trained to maintain their own boreholes. Pumps can be designed to double as children's round-abouts, so that children pump water as they play. Tanks to catch rain are simple and efficient. In one African village, for example, the poorest residents pay a few cents each week for water and a communal shower block. Better-off families pay extra for taps in their homes. The sums raised pay for an engineer to live in the village and fix its pipes.

U.S. Agency for International Development (USAID) Legislation was enacted ("Water for Poor Act") by the U.S. Congress in 2006 for authorizing USAID to establish a program for assisting DC populations to have access to clean water and basic sanitation, which is an example of efforts by bilateral countries to supplement the UN project[145]. But it remains to be seen whether the U.S. Congress will actually furnish funds to support this program.

Other Considerations

Desalinization Desalinization technology and costs have steadily decreased in the past several decades resulting in increasing use in the United States and other affluent countries like the oil-rich Middle East countries. But little use has been made of desalinization in the DCs because the costs are still beyond their means. There are only special exceptions, such as in Baja California, in Mexico, where use of "shelf" desalinization units has made it feasible to operate beach resorts catering to affluent visitors.

Dual Water Supply Distribution Systems Advocates of the use of dual urban water supply systems in the ICs, including Dan Okun[126], argue that (1) the established UWSS practice is to design the systems so then can accommodate the flows required for firefighting (which are very large compared to the needs for domestic and other municipal purposes), which results in large resident time in the distribution system piping leading to growth of biofilms on the pipe walls, which depreciate water quality, and (2) it would make much more sense, cost-wise and water-quality-wise, to switch to use of separate systems. This would permit use of much-smaller-diameter piping in the distribution system for delivering potable water, and resulting in much reduced residence time—hence much lesser organic growths—and making it feasible to utilize stainless steel for the drinking water piping, which would greatly reduce the problem of pipe leakage due to corrosion. It would also permit unrestricted use of reclaimed water for firefighting purposes. Despite these arguments, little interest in such systems has been expressed in the ICs and virtually none in the DCs. Some DC cities such as Calcutta still utilize dual systems, but, unfortunately, the water for the firefighting mains is untreated water drawn from the local river, which is replete with cholera virus, and these mains have been commonly tapped to furnish drinking water for the plentiful urban poor, who often have no place to sleep except on the city streets[146]. Hopefully, the recent ADB-sponsored project for improving this situation in Calcutta will ensure continuing disinfection of the water in the firefighting mains.

Overdrafting of Groundwater and Ground Subsidence Overpumping of groundwater is an all-too-common practice in many DCs where the UWSSs systems depend on use of groundwater as a major source and where the demands by increasing population and industry have resulted in very serious damages. This includes deterioration of the groundwater quality due to infiltration into the fresh groundwater basin from adjacent salinity groundwater basins, and very serious subsidence of ground levels. Outstanding examples are the situations in the Bangkok metropolitan area[17] and at Taiyuan in China[164]. The only solution is for the DC governments to sponsor much better use of the local freshwater plus importing freshwater, thus enabling elimination of groundwater overdrafting.

The situation of the "too little/too late" approach is the situation at Bangkok, where the seriousness of the subsidence become obvious in the 1970s, but even now the government's importation program has enabled closing of wells only in limited areas. Hence, subsidence (now more than 2 meters in some areas) continues in much larger (and heavily industrialized) areas. And at Taiyuan, the situation is almost comical in that the Chinese government, with World Bank support, recently completed an importation system (300 km of aqueducts, tunnels, pumping plants) that does bring in the needed extra water, but without provision of firm administrative mechanics (i.e., without establishing a local "water czar" with power to control all water uses in the municipal area, including wastewater treatment/reuse), and as a result, industries continue with more overdrafting to avoid paying the extra costs for buying the expensive imported water[166].

Water Hyacinths

Situation in ICs Water hyacinth growth in waterways has been a serious problem in virtually all tropical regions, including the tropical areas in the United

States such as southern Florida and Puerto Rico and the Virgin Islands in the Caribbean. Because of the seriousness if this problem in Florida, the U.S. Corps of Engineers has carried out a comprehensive studies on control of such growths, including use of physical, chemical, and biological methods of control, which show that mechanical cutting/removal is expensive and yet the most feasible control method[123].

Situation in DCs A study of this problem in southern Nigeria in 1988[157], where the problem is very serious, led to a review of other potentials for control, including a comprehensive review by the Asian Institute of Technology in 1984[133]. This again did not come up with any noncostly control methods, although some potential for harvesting hyacinths for making wood furniture which was followed by limited use of this method in Thailand[22] and in Japan for limited commercial making of fiber baskets[18]. Still another potential being tested in Argentina uses Amazonian flies as a means of biological control[123]. For reservoirs suffering from heavy hyacinth growth, it may be necessary to utilize log booms to prevent the hyacinths from entering water intakes.

The survival hardiness of this plant is well shown by observations of its growth in a major *klong* (waterway) in Bangkok, Klong Samrong, which in 1970 was relatively free of hyacinth, with the klong used for major boat traffic. However, progressive pollution by degradable organics resulted in such heavy growth that the boat traffic had to cease; then came pollution from toxics discharged by industries, which caused the growth to fade away. Another example is the experience in Laguna Lake in the Philippines, Manila[148] where little growth occurred when the lake, normally freshwater, was affected by serious periodic seawater intrusions; then building of a gate to minimize the intrusion resulted in great increase in the hyacinth prevalence.

Water Quality Analyses

Problem in DCs A very common problem with WQ testing by DC practitioners, both in the laboratory and in the field, is the lack of review of the test data by WQ testing experts to ensure its reliability. This is due, usually, to the common belief that the practitioner with a graduate degree is bound to be correct—hence, no need for such review[66]. As a result, much of the data are misleading and counterproductive. This problem is illustrated by Box 4.1, which reviews a practitioner's nonreviewed report to indicate errors with explanations[61]. The IAAs commonly give grants of testing equipment to the DCs but do not finance the training that is needed to enable good use of the equipment.

An additional example is the testing of well waters by the laboratory of the national water supply agency of the Philippines (very well furnished with donor grants, with ample equipment and ample staff with ample graduate training), with the laboratory reports showing that the well waters were negative by presumptive coliform (agar testing), but with positive coliform counts in the follow-up confirmation test[57]. In another situation at Bali (Indonesia), a Korean testing team headed by a doctorate engineer scientist reported that the river waters there were unfit for irrigation of rice because the soil would be clogged by the excessive sodium in the river waters, despite the fact that these waters had been successfully used for a thousand years without clogging[3]. The problem was that the reported sodium analysis concentration was 10 times too high (wrong decimal point).

Correction Measures As already noted, the IAAs should recognize the need for training in WQ monitoring, including distribution of free (or cheap) copies of Standard Methods (translated into the local language), as recommended in the section on "Water Resources Management." Another good measure is to advise the DC practitioners to use checking methods to check the validity of the laboratory results by using more than one laboratory to do the same testing, and by having the same laboratory do the testing for the same sample submitted as two separate samples (one say the actual water and the other, say a 50–50 mix with distilled water).

BOX 4.1 EXERCISE IN CHECKING VALIDITY AND RELIABILITY OF TYPICAL WATER QUALITY ANALYSIS FOR A NATURAL WATER, SEPTEMBER 1985

By Dr. H. F. Ludwig, Advisor to NEB

An exercise has been developed for training professional staff of NEB on the significance of quality control in making and reporting upon analyses for determining water quality. All too often the results of water analyses reported in developing countries, while they look to be adequate at first glance, actually contain numerous errors and omissions and scarcely give a competent picture of the water quality. The problem stems from lack of critical review of such reports, which are often accepted as submitted on the assumption, because these doing the analyses are presumably qualified, that no such review is necessary. Actually such reviewing is an essential element of quality control for all fields of environmental monitoring.

The exercise described here comprises three attachments. Exhibit A is a laboratory report on results of a mineral analysis for a natural water (in this case a surface water). Please review these data and prepare your comments on the validity and reliability of the data in this report. (There are at least 11 aspects of this report that are either incorrect "suspicious," or improperly stated.) When you have completed your comments, compare them with Exhibit B and C.

Exhibit A

Laboratory Report on Mineral Analysis for Surface Water

	Constituent	Unit	Value
(1)	pH	-	7.35
(2)	Total alkalinity (as $CaCO_3$)	mg/l	52.14
	(a) Carbonate alkalinity (as $CaCO_3$)	”	2.02
	(b) Bicarbonate alkalinity (as $CaCO_3$)	”	50.12
(3)	Bicarbonate (HCO_3)	”	82.24
(4)	Sulfate (SO_4)	”	32.33
(5)	Chloride (Cl)	”	35.05
(6)	Nitrate (NO_3)	”	17.14
(7)	Silica (SiO_2)	”	8.01
(8)	Sodium (Na)	”	15.27
(9)	Potassium (K)	”	8.13
(10)	Calcium (Ca)	”	30.19
(11)	Magnesium (Mg)	”	20.52
(12)	Hardness (as $CaCO_3$)	”	93.14
(13)	Silica (SiO_2)	”	16.67
(14)	Iron (Fe)	”	8.03
(15)	Manganese (Mn)	”	7.14
(16)	Boron (B)	”	3.56
(17)	Turbidity	ppm	15.36
(18)	Suspended Solids	mg/l	40.25
(19)	Total Dissolved Solids (TDS)	”	523.10
(20)	Electrical Conductivity	mm/cm	106.0

Exhibit B

Errors/Irregularities/Inadequacies in Report

Most of values shown in Exhibit A are not realistic in terms of significant figures. Most of these analyses are reproducible only within a few percent. Thus, to report the results to hundredths of a mg/l is actually silly. A suitable presentation of these values is shown in the revised tabulation, Exhibit C.

At pH of 7.35, no carbonate alkalinity is possible (to have carbonate alkalinity, (pH must be 8.3 or more).

If the bicarbonate alkalinity is 82.24 mg/l, then its equivalent in me/l would be 1.35 me/l or 67 mg/l as $CaCO_3$.

In terms of me/l, the total major cations must be approximately equal to the total major anions, which is not at all the case here. Hence, one or more of the major anion and major cation determinations must be in error.

The total of Ca plus Mg in me/l must equal the total hardness in me/l, which is not the case here (the total of Ca and MG is 3.22 me/l, whereas the total hardness is only 1.86 me/l, which is impossible).

An iron value of 8.0 mg/l would be extremely high if not impossible for a natural surface water, hence this value appears to be wrong. Maybe it was misrecorded and should be 0.8 or 0.08 mg/l. Also, surface water with this much iron would likely be highly colored (hence the color could not be 0.1 units as reported).

Manganese levels in natural waters are very low, rarely over 1 mg/l and usually much less. Values as high as 7.5 mg/l do not occur in natural waters (if they did, the water would be very red and the color (Item 21) would not be 0.1 units are recorded.)

Boron values over 2 mg/l are extremely rare.

If the turbidity is 15 ppm, then the suspended solids should be of the same magnitude, not three times as much.

The TDS of 523 mg/l is much too high, i.e., is not consistent with the reported values for major anions and cations (which indicate a TDS of about half as much).

It the TDS is 523 mg/l, the electrical conductivity would be in the range of 600, not 106.

Exhibit C

Revised Tabulation

	Constituent	Unit	Value	me/1[1/]
pH and Alkalinity (1, 2)				
(1)	pH	-	7.35	-
(2)	Total alkalinity (as $CaCO_3$)	mg/l	52.	1.04
	(a) Carbonate alkalinity (as $CaCO_3$)	"	2.0	-
	(b) Bicarbonate alkalinity (as $CaCO_3$)	"	50.1	1.00
Major Anions (3 to 7)				
(3)	Bicarbonate (HCO_3)	"	82.	1.34
(4)	Sulfate (SOV)	"	32.	0.67
(5)	Chloride (Cl)	"	35.	0.99
(6)	Nitrate (NO_3)	"	17.	0.54
(7)	Total major anions	-	-	3.54
Major Cations (8 to 12)				
(8)	Sodium (Na)	"	15.3	0.67
(9)	Potassium (K)	"	8.1	0.21
(10)	Calcium (Ca)	"	30.2	1.51
(11)	Magnesium	"	20.5	1.71
(12)	Total major cations	-	-	4.10

	Constituent	Unit	Value	me/1 1/
Other Parameters (13 to 22)				
(13)	Silica (SiO_2)	”	17.	-
(14)	Hardness (as $CaCO_3$)	”	93.	1.84
(15)	Iron (Fe)	”	8.0	-
(16)	Manganese (Mn)	”	0.07	-
(17)	Boron (B)	”	3.6	-
(18)	Turbidity	ppm	15.	-
(19)	Suspended Solids	mg/l	45.	-
(20)	Total dissolved solids (TDS)	”	520.	-
(21)	Electrical conductivity	mm/cm	106.	-
(22)	Color	color units	0.1	

Water Quality Monitoring

One of the most confusing issues for DC water quality (WQ) monitoring practicioners is selection of appropriate WQ monitoring parameters to suit the particular situation, and thus to spend money only to obtain valuable needed information and not to obtain information that is not needed. A common mistake in many DCs is to set up a monitoring system with a group of parameters deemed at the time to be needed, then to continue on with this same system year after year. The need is for critical review on an annual basis to (1) fill gaps for valuable data not being obtained, and (2) delete parameters where it is found that the data are not serving any useful purpose. In China, for example, the river basin agencies commonly set up monitoring problems to include a long list of parameters, as specified by national governmental guidelines (which include “everything in the book”), then continue this indefinitely (at no small expense) when a critical review would show than a sizable portion of the data do not contribute in any way to assisting river basin development planning[160].

Figure 4.6 is a matrix that indicates the appropriate parameters to use for various particular situations[163].

Role of Private Sector

As already mentioned, use of the private sector for receiving DC problems in UWSSs and USEMs has not yet been successful because, while the private sector firm has the necessary skills, the firm must make a profit. Thus, it must increase water use rates from the low rates commonly used in the DCs (which have commonly subsidized UWSSs believing that this is a government obligation) to

FUNCTION	PARAMETERS																										
	1. BOD/COD	2. Suspended Solids (inflow and outflow)	3. Floatables (including grease, oils) (in and out)	4. Settleable Solids (in and out)	5. Toxicity in effluent or stream	5.1 Gross toxicity (if applicable)	5.2 Toxic heavy metals (if applicable)	5.3 Toxic inorganics (if applicable)	5.4 Toxic synthetic organics (if applicable)	6. Ammonia in effluent	7. Total phosphorus (P) in (effluent) (if applicable)	8. Total nitrogen (N) in (effluent) (if applicable)	9. TDS and/or conductivity (effluent) or stream)	10. Major ions	10.1 Chlorides (Cl)	10.2 Bicarbonate (HCO_3)	10.3 Sulfate (SO_4)	10.4 Nitrates (NO_3)	10.5 Sodium	10.6 Potassium	10.7 Calcium	10.8 Magnesium	11. Bottom Salients (See note)	12. Temperature	13. Quality of flow when sampling	14. Turbidity
1. Sewage Treatment Plants (MSS/STPs) 1.1 Sewage treatment Plant design (for expected inflow including industrial wastes)	A	A	A																							
1.2 Sewage treatment plant operations (inflow, outflow)	D	D	D	D	M					W	M	M	M	M										D	D	
2. Industrial Wastewater Discharges: 2.1 Food/organics processing	D	D	D	D									W											D	D	
2.2 Industries using toxics	D	D	D	D	D								W											D	D	
2.3 Animal farms	D	D	D	D	W					W	W	W	W	W										W	W	
3. Anbient WQ Monitoring	W	W	W		M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	Y	M	M	M

NOTES:

1. A = Average, D = Daily, W = Weekly, Y= Annually, S = Sesonally
2. Nutrients (5,6) = When downstream eutrophication may be a problem. Not a single such situation to date in Asian DCs. (This is problem sometimes in U.S. and often in European Union)
3. Item (9): Total anions in me/1 must equal total cations in me/1.
4. Item (10): Includes toxic substances (toxic heavy metals, toxic synthetic organics, petroleum substances, and particle size distribution).
5. Samples for Items 1.2 and 2 to be composited (not grab) samples.
6. On Items 5: Select applicable parameters on situation. For example, mining operations involve toxic heavy metals and toxic inorganics but not toxic synthetic organics, and if put factory involve then toxic synthetic organics is pertinent.
7. Source: Ref. 163.

FIGURE 4.6 Water quality monitoring parameters.

markedly higher rates, resulting in massive public protests and consequent backing down of the government's commitment to permit the private firm to change proper rates. Examples are described in[32], which reviews the very unsuccessful experiences of the three major European private-sector firms in this field of business as of August 2006, and in[37], which reviews a similar recent experience in the city of Cochabamba in Bolivia.

The suggestion here is that the private-sector firms can be valuably utilized for filling the skills gap, both for turnkey projects, which may include financing as well as design/construction and for only O&M, but with provision for continuing subsidization by the government but at a level that progressively decreases over a period of years with a corresponding gradual increase in rates.

Integrated Economic-cum-Environmental Development Planning (IEEDP)

The programs already noted for making optimal use of water resources, valuable as those are, may be criticized for planning for effective water resource utilization independently of other precious environmental resources—"obviously" the best approach would be use of planning mechanics in which the target is optimum utilization of all precious environmental resources including freshwater resources. Information on how to do this is given later in this chapter on "Development Planning for DCs."

WATER RESOURCES MANAGEMENT

Circa mid-the twentieth century, it was still practical in most countries to design and build dams/reservoirs on streams for intended single-purpose uses such as UWSSs, but over the next half-century, it become increasingly necessary, because of increasing growth of population and industry, to design the reservoirs for multipurpose uses (i.e., for all beneficial water uses in the project's service area). But also by year 2000, water resources experts were beginning to realize that continuing further growth was resulting in serious water shortages conflicts between provinces (or states) of individual countries and between different countries. Hence, the problem now facing the world in water shortage regions is how to resolve these conflicts by (1) making much more effective use of the limited water resources, and (2) reaching agreements between countries utilizing the some limited resources on fair allocation of the limited resources. In the DC regions, initial steps are underway on how to reach agreements on fair allocation, including especially regions in the Middle East and in the semiarid regions in Asia (such as the region of India/Pakistan/Bangladesh). Excellent evaluation of this problem on a global scale includes surveys made by *Resources for the Future* in 1996[129], by *Economist* magazine in 2003[30], and by the *International Herald Tribune*[39]. The Asian

Development Bank has carried out a comprehensive survey limited to the Asian region[10].

Reducing Water Irrigation Requirement

Virtually all of the studies on how to make much more efficient use of the limited resources in water shortage regions, including those in California[85], show that the single most important inefficiency is in use of water for irrigation. Hence, a priority in both ICs and DCs is to develop practicable mechanics for resolving this problem. One approach is that used by Israel, where the severity of the problem has led to development of a new approach to agriculture called *drip irrigation*, in which the water is fed directly into the plant roots rather than into the soil around the plant. In due time, it is expected that many DCs will have to adapt to use of this approach.

China Studies Sponsored by World Bank

One of the most serious immediate water shortage problems for Asian DCs is the situation in the northern coastal provinces in China, where about half of the countries population and industry are located, and which is continuing to grow despite the fact that most of this region has been desperately short of fresh water for some 20 years, resulting in very severe impairment of both economics and public health, including increasing problems for industries to continue to operate efficiently, very severe water pollution, and massive land subsidence in many areas.

A comprehensive evaluation of this situation was conducted by the "Water Agenda Study for North China" sponsored by the World Bank together with AusAid. It was completed in 2000[163], and included detailed analyses of all water uses and of their relative efficiencies and importance for contributing to continuing economic-cum-environmental development, with recommendations for making marked changes in the existing water use system, in order to achieve maximum beneficial use of the limited local natural fresh water resources and hence to minimize the need for expensive importing of the plentiful water available in the Yangtze River in southern China to resolve the water crisis in the north. This massive water transfer program is being planned in detail, with its initial project, the Wanjiazhai Water Transfer Project[164], already constructed. When completed, the overall importation project will be by far the world's largest mass water transfer project, dwarfing even the existing mass massive transfer system in California.

The Water Agenda emphasized that efficient use of the limited local water can be achieved only by establishing River Basin Control Agencies, which (unlike existing river basin agencies) will have the needed real power to manage the limited resource. This means there will be changes in the existing system where power is divided (and hence not integrated and not effective) between the national and local governments. The study recommended that this new approach be demonstrated by first applying it to the Yellow River basin in north China, resulting in a follow-up World Bank sponsored study for this demonstration for the Yellow River basin completed in 2005[165]. This included provisions for authorizing this new basin agency for achieving effective water pollution control throughout the basin, following the same approach developed by U.S. EPA in the 1960s, which has been proven to be very successful. Actual achievement of the recommended effective river basin authorizes will, of course, not be easy for China to achieve, but this must be done because the existing ineffective system is no longer viable. And this same approach (use of real basin authorities) is critically needed in most DCs, including Indonesia[156].

Watershed Management

Watershed management represents a complex specialized technology in the field of environmental engineering, especially on the need for maintaining forest cover to prevent massive erosion runoff and loss of infiltration of rainwater into the soil to maintain groundwater that furnishes the dry weather flow of streams. Such management is most important in water shortage regions.

Particular references that discuss pertinent projects applicable to DC conditions include the following:

- "Supplemental EIA Manual for Watershed Projects," prepared for the Thailand National Environment Board in 1997[69].
- Ludwig, H., "Engineering-Cum-Environmentalism: Case Study of Tarim River Basin of China" (Region of the Silk Road), ASEP Newsletter, September 1992[76].
- Ludwig, H., and Castro, L., "Sharing of Project Benefits for Hydropower Projects in Upland Regions of Philippines," *ASEP Newsletter*, September 1992[103].
- Ludwig, H., "Wastewater Management and Water Quality Control, Experience in California as Applicable for Helping Resolve Water Shortage Problem for North China," for World Bank/Beijing, April 2001[85].
- World Bank, "Water Agenda Study for North China," D. Gunaratnam, 2000[163].

URBAN SEWERAGE AND EXCRETA MANAGEMENT (USEM)

Regarding urban (or municipal) sewage and excreta management (USEM), this is believed to be one of the very few subjects (if not the only subject) of environmental engineering technology for which a textbook has been written specifically for use by DC practitioners (and their IAA counterparts). This textbook, *Appropriate Sewerage Technology for Developing Countries* by H. Ludwig et al., was published in 2006[105]. Its Preface and Table of Contents are as shown in Box 4.2.

The textbook includes comprehensive coverage of all aspects of USEM in detail. This chapter, because of space limitations, includes only brief discussion of the most salient points.

Situation in ICs

Sewerage technology evolved essentially from the experiences of the Western European countries, then the United States, and this evolution developed in three stages:

1. Construction of sewers in the community to collect excreta and to export the collected wastewater for discharge into a nearby river or stream or drainage channel. This removes the excreta from the immediate community environment where, if unmanaged, it poses great hazards for transmission of enteric diseases. Although disposal of the untreated wastewater into the waterways involves some disease hazard, this is small compared to the hazard from the presence of unmanaged excreta in the community.
2. Treatment of the collected wastewater, primarily to protect stream ecology but also for public health protection purposes. The target is achievement of complete treatment (primary plus secondary) of the collected wastewater.
3. Use of advanced waste treatment methods for removal of nutrients, together with effective control of point sources for control of toxics.

The resulting situation is that the typical IC city does have an effective wastewater management system, including sewers, interceptors, transmission liens, pumping stations, and treatment facilities, together with point source control and effective use of on-site septic tank/leaching units for buildings not connected to the sewers, including effective periodic monitoring of overall system performance.

BOX 4.2 PREFACE OF TEXTBOOK OF APPROPRIATE SEWERAGE TECHNOLOGY FOR DEVELOPING COUNTRIES

H. Ludwig, B. Fennerty, S. K. Leng, and K. Mohit

"Practically all existing textbooks on planning/design of municipal sewerage systems (MSSs) are written by Westerners and tend to emulate the environmental standards and matching design criteria utilized in the affluent industrialized countries (ICs), and because these same standards and design criteria have been used for planning/design of MSSs in the developing countries (DCs), most of the MSSs built in the DCs have been dysfunctional and have not achieved their intended objectives. The new textbook is believed to be the first that is written to be appropriate for DC use, featuring use of simple rather than sophisticated approaches, thus greatly simplifying problems of O&M. The textbook of 400 pages covers all aspects of MSSs systems including institutional, economic, financing, and environmental as well as technical engineering aspects for both sanitary and industrial wastewaters. It also recognizes the need to give attention to not only the affluent urban sectors which case afford sanitary sewers but also to the problem of ensuring adequate management of excreta from buildings not connected to sewers but utilize individual on-site disposal units. It covers all components of MSSs, including the collection component (collecting sewers, interceptors, and pumping to collect and deliver the sewage to the treatment plants, plus treatment and disposal. Dr. Harvey F. Ludwig of Bangkok is Chief Author, assisted by the three co-authors. Their combined experience in MSS technology is estimated 60 man-years, about one-third in IC and two-thirds in DC systems. Dr. Ludwig is a member of the National Academy of Engineering of the U.S.

If you wish to purchase a book, please contact Mr. Kumar Vinod, South Asian Publishers at New Delhi, India. His e-mail address is <sapub@del2.vsnl.net.in>. Cost for persons in Industrialized Countries and International Agencies is US$32.00 (hardcover version) including surface mailing. Extra postage of US$3.00 required for airmail shipping, totaling US$35.00. A softcover version at lower price is applicable for nationals of Developing Countries. Postal address of South Asian Publishers is 50 Sidharth Enclave, P.O. Jangpura, New Delhi 110014, India."

The chapters included in this textbook is as follows:

Introduction
Urban Sewerage and Excreta Management
Sewage Characteristics and Flow Measurements
Sewerage System Collection Component
Onsite Sewage Disposal
Sewage Treatment and Disposal
Industrial Wastewater
Operation and Maintenance
Monitoring and Enforcement
Appropriate Standards
Environmental Impact Assessment
Sewerage Institutions
Sewerage Economics
Sewerage Financing
Other Considerations
Summary and Conclusions

Situation in Typical DCs

In contrast with the United States/ICs, the typical DC city, including even many capital cities, has yet to achieve satisfactory management of community excreta and other wastes posing public health/environmental hazards, including industrial wastewaters discharged to municipal sewers. However, in recent decades the IAAs have made many grants/loans intended to help the DCs to get a handle on this problem, but with generally ineffective results and wastage of investments. The first (and almost remarkable) finding in reviewing DC/USEM experience to date shows a lack of understanding of the three components of a comprehensive municipal sewerage system as previously described. It especially fails to recognize that the most important component is use of sewers to collect/export the sewage, not the subsequent treatment. A large number of IAA-sponsored projects of the past several decades have been formulated on the assumption that provision of treatment per se is the answer to the problem, without recognition that treatment plants are not effective without sewers to collect and transport the waste to the treatment plant.

The most comprehensive analysis of the USEM problem in the DCs known to the author is the study on "Sewerage Prioritization" in Thailand completed in 1995[135]. This evaluated the ongoing situation in all of the larger cities in the country (more than 100), with the key findings. These who plan/design/manage urban sewerage systems must recognize that the DC approach must be quite different from the IC approach, as follows:

- A common notion (already noted) in both the IAAs and the DCs is that urban sewage problems can be solved simply by building a treatment plant, which receives only a portion of the area's excreta, with much of the remainder reaching the waterway without adequate treatment, without recognizing that such plants may do little good for protecting either public health or receiving water quality.
- In the ICs, virtually all buildings in the sewerage service areas are served by sanitary or combined sewers. When the public sewer system is built, all buildings connect up and existing on-site units are abandoned. Generally in the DCs, only the affluent areas (which can afford them) are served and the bulk of the population continues to depend on on-site units. Many of these on-site units do not function satisfactorily due to inadequate design and lack of periodic servicing, resulting in frequent excreta overflows into the community environment, which pose very serious disease transmission risk hazards, not only to the nonaffluent subareas but to the entire service area. Hence, the argument that is often made by IAAs that improving service to the affluent subareas can be justified in terms of protecting overall community health is hardly correct. If the planners are really interested in overall community public health protection, the project plan must include "equal attention" to the nonaffluent subareas (the same is true for provisions of improved urban water supply) if these are to be justified in terms of public health).

- Another common misconception is that treatment plants can be operated and maintained with a very low O&M budget, usually about one-third of the minimum need[51], so that, even if well designed, the plant cannot be expected to function. Monitoring and acting on this problem, which is mandatory in the ICs, does not exist in the DCs. DC officials and practitioners have paid such little attention to O&M because of lack of performance monitoring and because the project feasibility studies often do not include adequate allowance in the economic analysis for O&M costs.
- A typical example is the proposed expansion in 1992 of the municipal sewage treatment plant of Chittagong (Bangladesh)[8], justified on the basis of public health protection and of correcting water pollution in the river receiving the plant effluent. An evaluation showed that (1) the plant, even when enlarged, would not receive the bulk of the city's excreta, (2) the existing plant (built earlier by the British) had long since ceased to be operated properly, and, hence, was doing little if any good, and this problem was scarcely recognized in the project feasibility study, and (3) even if the old and new plants were to be properly operated, the resulting benefit both to public health and water pollution control would likely not be very meaningful. All such proposed projects need to include an EIA, which will call attention to such deficiencies and misconceptions.
- An additional finding from the USEM experience in the DCs so far is the need for standardization in design of facilities for the USEM system, to standardize practices for all system components, but especially for treatment plants. As it has been, individual designers use a variety of treatment systems that are in the same ballpark in terms of costs[135] but that, because of their differences in terms of parts replacement, go unrepaired for months or even years. Replacement parts often takes months or even a year or two to get, and finding people who are trained to make the repairs is another problem. With standardization, parts replacement can be readily managed and training requirements greatly simplified. Unfortunately, few if any DCs have as yet adopted such standardization and, accordingly, O&M is usually very inadequate.
- Infiltration into sewers in the ICs used to be a serious problem but this has been virtually eliminated over the past half-century by use of new pipe jointing methodology. But jointing in existing DC sewers is often old-style (bell and spigot pipes), which can result in significant infiltration, which must be taken into account in the design.
- Selection of treatment/disposal design criteria depends on the environmental standards to be met, and the appropriate standards suited to the DC use may be quite different from the IC standards. Care must be given to selecting treatment levels that are appropriate/affordable.
- Attention must be given in the project feasibility study to the institutional and financial aspects—that is, the relationship between the central, provincial, and local governments and their relative responsibilities. Common

practice in many DCs has been for the central government to build the plant, then "abandon" it to the local government to be managed without provision for funding of O&M. The ADB study of 1990[7] on "Economic Policies for Sustainable Development" stresses the need to decentralize so that the local governments have both responsibility and authority for planning/building/operating, with ability to raise their own funds, with the central government in an assisting role.

- The role of the EIA in the project feasibility report is very important for helping ensure attention to all of the issues already noted. The manual on EIA for USEM prepared for use in Thailand in 1997[6] serves this need and, as such, can be very helpful to all parties concerned including project proponents, regulatory officials, and design engineers.

Brief discussions some of the problems already noted are given next. Details are given in[135].

Sewerage-cum-Sanitation Systems for 100 Percent Excreta Management

The first effort to plan and implement a comprehensive USEM system that provides for management of all excreta in the study area, so that its public health protection target will actually be achieved, is the World Bank–sponsored Jakarta Sewerage and Sanitation Project, which was constructed in the 1980s[152]. It covers one selected area in the overall Jakarta region. The project includes both (1) a system for collecting and treating sewage from those portions of the area capable of paying for this service (the affluent portion), with the interceptors planned for ready expansion eventually to cover all areas, and (2) provisions for satisfactory use of on-site disposal units for buildings not connected to the sewerage system.

The recommended on-site disposal is provided by use of dual leaching pits, which receive the discharges from pour-flush toilets, including establishment by the municipality of a special pit desludging service dedicated to servicing only these nonaffluent areas, with use of special desludging trucks designed to be narrow enough to enable access to buildings on narrow streets/lanes, with long desludging hoses. These units give satisfactory service for most of the premises for which the ground permeability and groundwater levels enable them to function as designed, and for these desludging is needed only every several years, with the premise owner paying for this service. For the relatively small percentage of the houses/buildings where permeability is not adequate and/or groundwater levels are too high, more frequent desludging is needed, with these extra costs subsidized by the municipality.

Sewage Treatment Systems

Evaluation of the accumulated experience in numerous DCs showed that the tendency is for each municipal system to be designed on its own, employing a wide variety of treatment systems, each costing about the same to construct but each posing separate needs for parts replacement (which may take many months in many cases) and for O&M training. The economic answer is for each DC to standardize the design of treatment units so that one of several parts depots can readily service all plants in the country and so that O&M training is greatly simplified. The recommended procedure is to utilize a system of four types of plants, proceeding from the first to the fourth progressively as land prices increase, as shown in Figure 4.7. Note that three options (A, B, C) are indicated for System (i) and 2 options (A, B) for System (iii). The selection depends on the particular situation. For example, for System (iii), Option B will often be adequate for very small plants, as for schools in rural areas and for large plants discharging to open (unconfined) ocean water. See[105] for details on the selection process.

Experience indicates that the IAAs will generally be quite willing to give grants to international DCs who wish to follow these guidelines to prepare a national sewerage system plan, including provisions for collection as well as treatment, to be progressively implemented as the country's urbanization and industrialization continue to grow and land prices correspondingly increase. The same study can also examine potentials for achieving regional pollution control systems for protecting affected waterways.

Sewage Collection (Including Interceptors, Pumping, Transmission)

The most important design consideration here is to recognize that many DC municipalities will not be able to afford immediate construction of sanitary sewers for servicing the entire community area, which will have to be achieved progressively with a series of stages, so that use is made of the existing storm drainage conduits for the collection role on an interim basis. Again, the national agency responsible for sewerage facilities should standardize use of materials and equipment for simplifying parts replacement and O&M training, including sewer-cleaning equipment.

Pumping Stations An especially difficult problem is design of pumping plants (which have always been a headache in sewerage history everywhere), but fortunately a design manual produced by Robert Sanks et al.[130] is available that is invaluable for helping the designer with this problem. Another important design aspect for collecting sewers is to utilize not the old-fashioned bell and spigot pipe lengths, which generally result in entry into the sewers of large amounts of unwanted groundwater, but instead the modern type of joint (now generally available) using rubber rings, which virtually eliminate groundwater infiltration.

Curved Sewers Another valuable change in design of sewers applicable to both ICs and DCs was development in the United States following World War II of curvilinear sewer alignments, thus greatly reducing sewer construction costs,

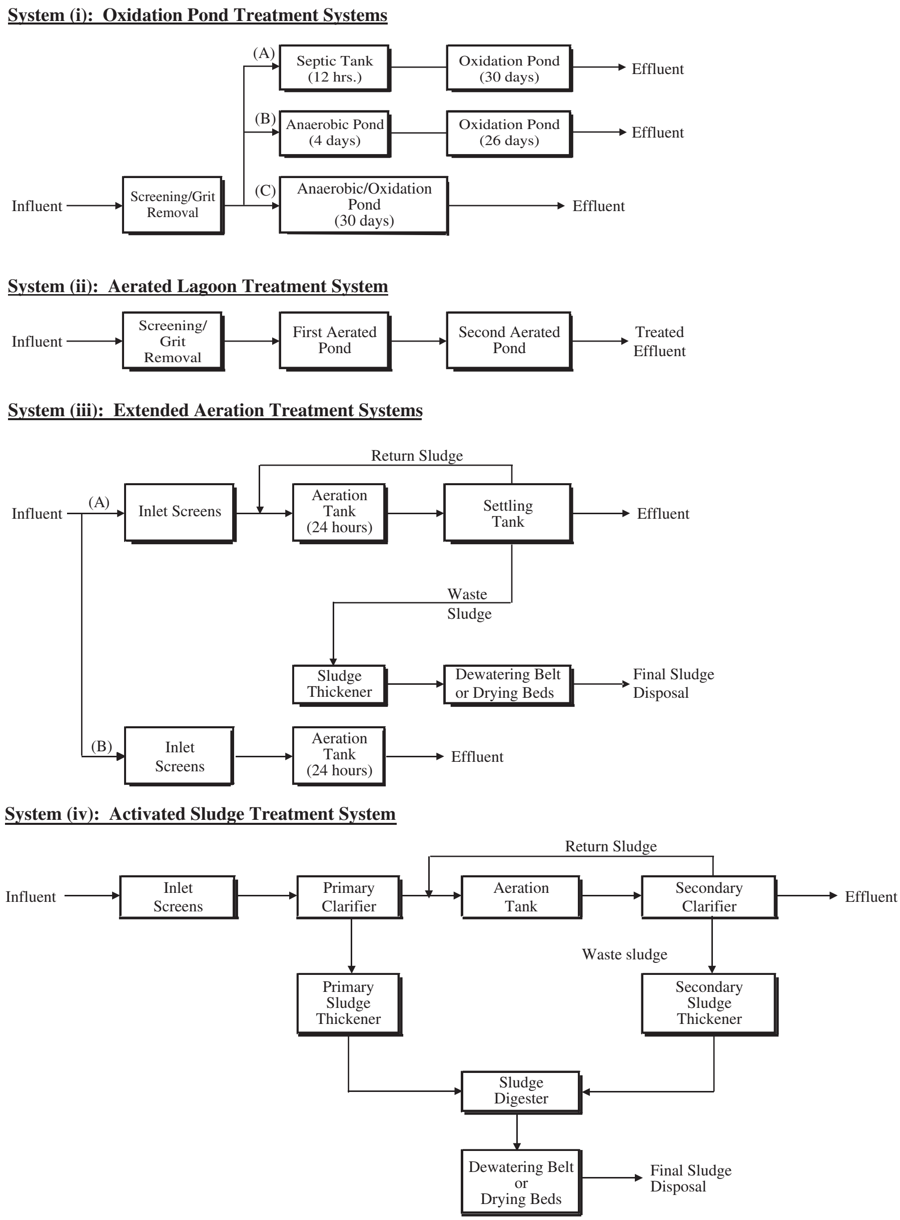


FIGURE 4.7 Recommended standard sewage treatment systems[105].

which became practical because of availability of sewer cleaning equipment which can readily clean curved sewers. Previously, standard practice was to allow only straight sewer alignments, requiring a much larger number of costly manholes[105].

Sewage Characteristics and Needs for Treatment and Point Source Control

Unfortunately, the international literature on sewage treatment places such emphasis on removal of BOD that many design engineers tend to forget which are the parameters that are most important for design of sewage treatment systems:

- Floatable materials, which, if not removed, form surface mats on receiving waters
- Settleable solids, which, if not removal, form sludge banks in receiving waters
- BOD (together with suspended solids), which if not removed, will be harmful to stream ecology (as well as making it more costly to use the river waters as raw water supply)
- Nutrients, which, if not removed, can induce eutrophication
- Toxics and other hazardous substances, which, if not removed, can disturb biological treatment processes and harm aquatic ecology (and impair raw water quality for community water supply)

Primary treatment will remove floatable materials and settleable solids, and complete treatment (primary plus secondary) is required to removal of BOD. Advanced treatment is required for removal of nutrients, and point source control is needed for control of toxics and other hazardous substances. For many DC communities, primary treatment will suffice for the foreseeable future, but for others, complete treatment should be the target. Rarely in DCs will there be need for removal of nutrients. Thus far, many DCs have not made sufficient progress on point source control due to weakness in the enforcement mechanics of most DC governments.

Sewage Flow Measurement

Measurement of sewage flows used to be a difficult problem, but the development of the Palmer-Bowlus ("PB") flume[105] greatly simplifies the problem by use of the PB flume placed in the sewer, which does not restrict the sewage flow. Beginning in the 1960s, such flumes became commercially available as shelf items. They can be readily fitted into a sewer of specified size.

Unfortunately, many DC practitioners are not familiar with the use of these "PB" meters.

Appropriate Standards

As shown in Figure 4.3, the target for DC sewage systems should be not the IC target of point C, but point B. This is all that is needed for environmental protection in the DCs, and it will require several decades to achieve this. Unfortunately, the international media releases nowadays feature point C concerns, leading to confusion rather than help to DC practitioners.

A few years ago the IWA sponsored a major international conference at Bangkok on the subject of controlling eutrophication in rivers and lakes and other waterways in DCs by removal of nutrients. But this is quite expensive and hardly ever needed in DCs, where problems of eutrophication are scarcely a priority issue.

Some examples relating to appropriate standards for sewage treatment developed by ADB[112] are included here as Figures 4.8, 4.9, and 4.10.

Marine Sewage Disposal

As indicated by Figure 4.10, treatment/disposal of municipal sewage for discharge to marine waters can be categorized into two types, (1) disposal to confined marine waters (bays, shallow nearshore waters) for which DO is the controlling parameter, hence treatment requirements are the same as for inland waterways, and (2) disposal to open ocean waters, which requires use of a submarine outfall extending far enough offshore to reach unconfined open ocean water, for which removal only of floatables is really required, together with point source controls to prevent discharge of toxics/hazardous substances into sewer systems.

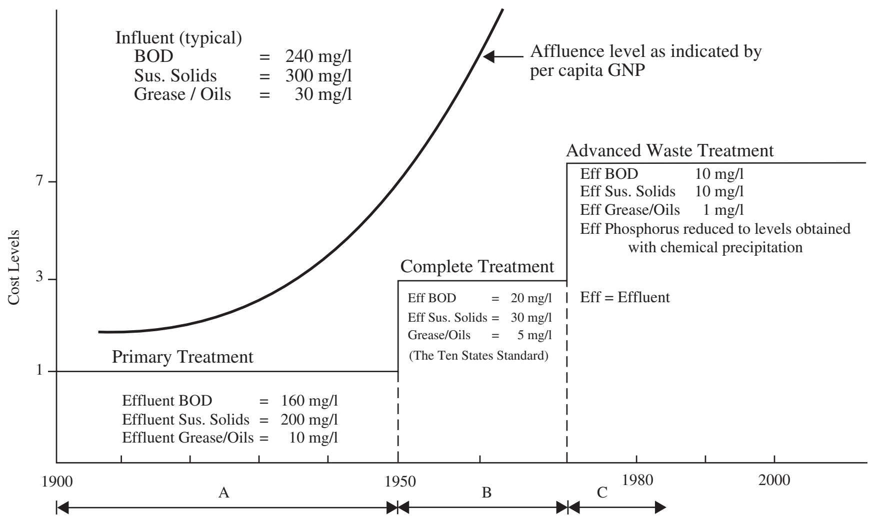


FIGURE 4.8 Drawing showing effluent standards requirements for disposal of municipal sewage to receiving waters where DO is a salient ambient parameter (inland waters and confined coastal waters including estuaries and semi-enclosed bays).

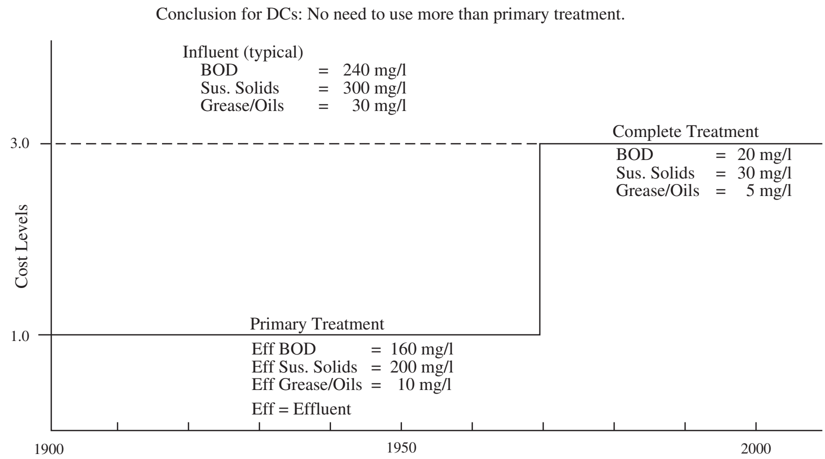


FIGURE 4.9 Schematic drawing showing effluent standards requirements for disposal of municipal sewage to inland/confined coastal waters where DO is not and significant ambient parameter.

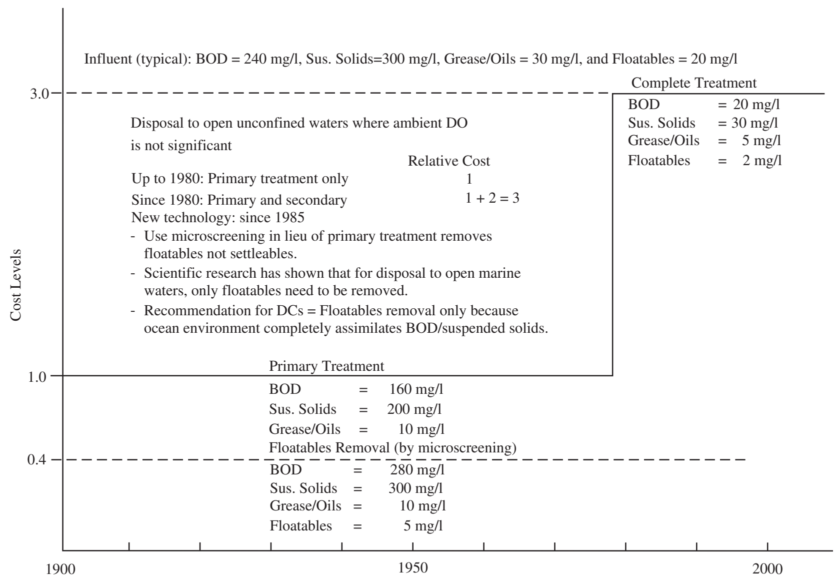


FIGURE 4.10 Schematic drawing showing effluent standards requirements for disposal of municipal sewage to unconfined marine waters (where access to open ocean is feasible and DO is not a significant parameter).

An economic analysis is needed to compare costs for the submarine outfall plus floatables removal, versus a short outfall with complete treatment.

Disposal to open ocean waters also can greatly simplify disposal of industrial wastewaters, which may contain numerous substance (such as salt, degradable organics, inorganic chemicals, etc.) that cannot be discharged to inland waterways without treatment to remove substances that impair confined water quality but that need not be removed for disposal to open seawater[105].

Buffer Area Requirements around Treatment/Pumping Plants

Recommendations that are considered appropriate for DCs are given in a paper by R. Bradley[24]. His recommendations are summarized in Figure 4.11.

Regional Water Pollution Control

Few DCs have yet developed regional water pollution control systems, which can cover the needs for a group of municipalities, but beginning efforts to do this are the Samutprakarn regional system in Thailand[107], the proposed regional plan for Abidjan in the Ivory Coast[67], and the regional systems for the coastal provinces in north China[163].

INDUSTRIAL WASTEWATER MANAGEMENT

Situation in ICs versus DCs

Management of industrial wastewaters is a very complex subject because of the great variety (ever increasing) of pollutant constituents contained in these wastewaters. One way or another, by treatment, by use of cleaner production technology, or by point source control, the levels of these pollutants must be controlled to reduce concentration to levels acceptable to receiving waters. Fortunately, U.S. EPA, with its ample financial resources, has been able to produce a series of excellent manuals, one for each type of industry (now available on the Internet), which give excellent basic data for each industry including quantification of all raw materials utilized, the steps involved in manufacture, and the various types of wastes produced by each step, including needs for treatment of these either singularly or combined. The online manuals include illustrative schematic drawings. These basic data are equally useful for IC and DC purposes. The U.S. EPA manuals include a final chapter which includes environmental standards applicable in the U.S. together with the matching treatment requirements. Unfortunately, these manuals do not include an additional chapter on standards and matching treatment requirements that are appropriate for DCs. It would be greatly helpful to the DCs if U.S. EPA would do this.

The job of the DC designer is to devise environmental standards and matching treatment requirements that are appropriate for the particular DC. The target for DCs should be point B in Figure 4.3 of the Introduction section, not the point C

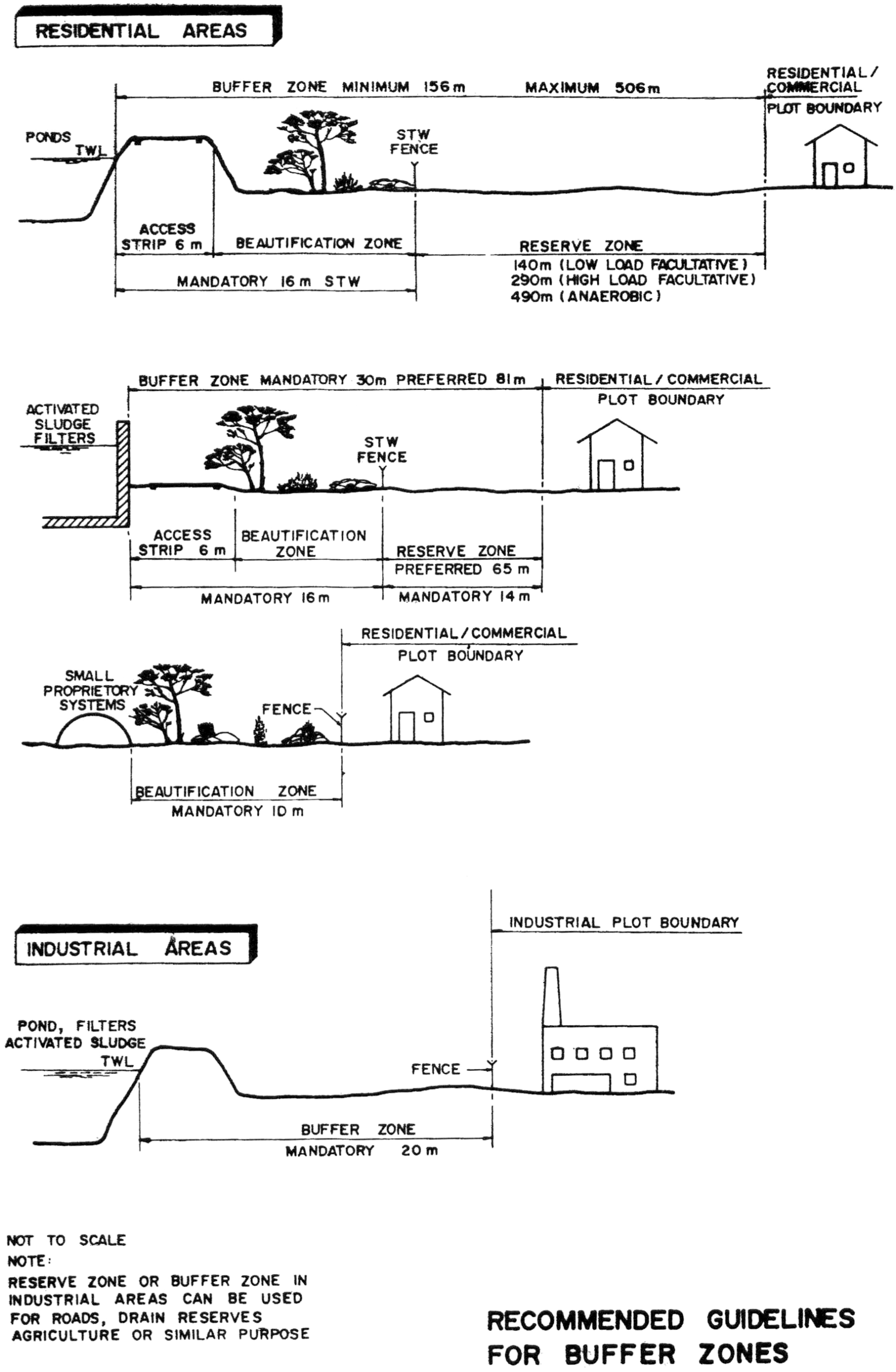


FIGURE 4.11 Recommended guidelines for buffer zones.

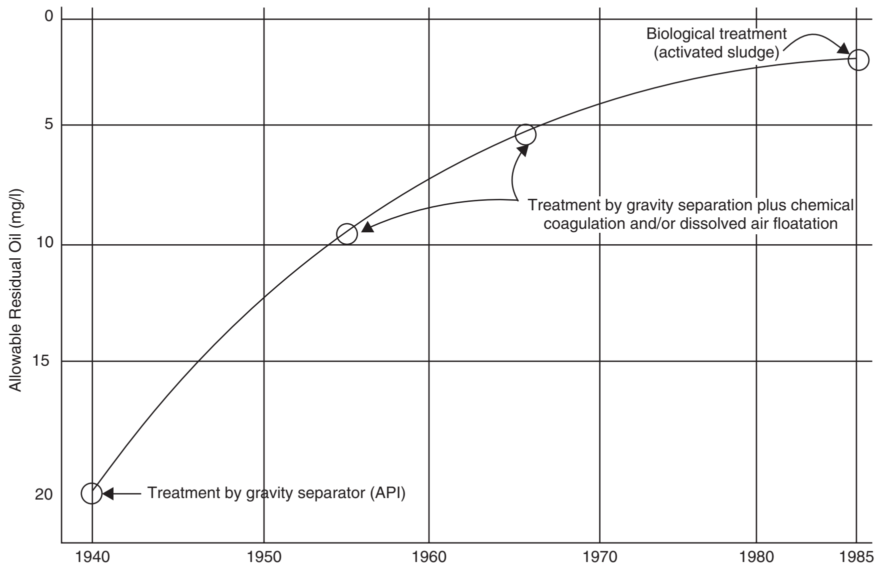


FIGURE 4.12 Schematic drawing illustrating requirements in U.S. over Past 50 years for removal of oil from refinery effluents.

target used in the ICs. An example of this approach is illustrated here from ADB sources[112] for petroleum refinery wastewaters, as shown here in Figures 4.12 and 4.13. Figures 4.14 show recommendations for control of industrial wastes disposal of by infiltration into groundwaters for the parameter of total dissolved solids (TDS).

Discharge into Municipal Sewerage Systems (MSSs)

Box 4.3 describes preparation of a municipal ordinance that encourages industries to make use of the MSS (municipal sewerage system), which can greatly assist in financing the overall MSS, but with a system of controls that protects the MSS and the receiving water environment. The salient control items are the following:

- Restrictions to prohibit discharge into the MSS of any industrial wastewaters that cannot be received by the municipal system because of hazards of damage to the system, or to receiving waters or land areas to which the STP effluent is discharged
- In-house pretreatment by industries for removing unacceptable constituents from industrial wastewaters so effluents will be acceptable for discharge to MSS (or directly to the environment)

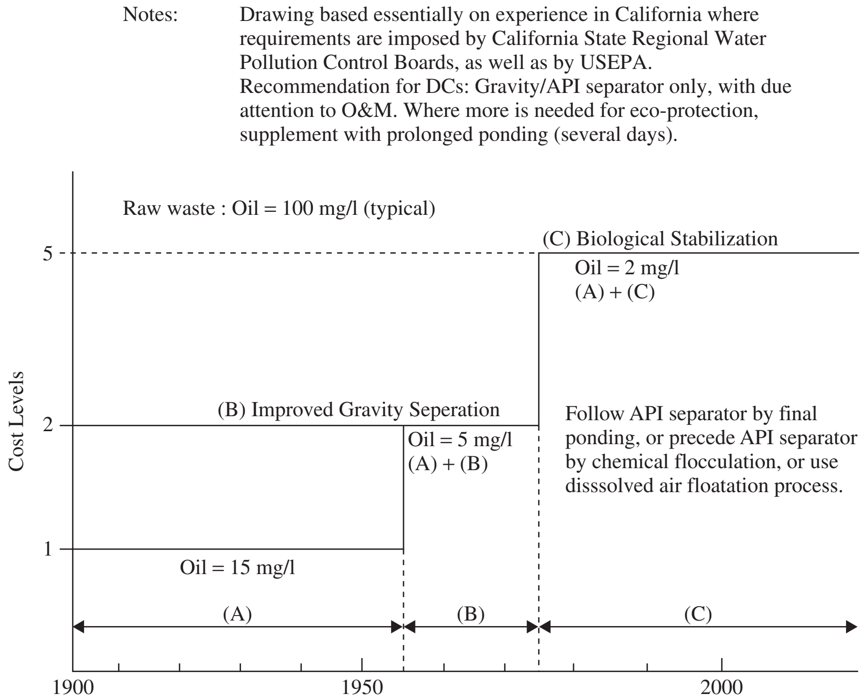


FIGURE 4.13 Schematic drawing showing effluent standards removal of oil from petroleum refinery waste.

- Permit system to be established by MSS that authorizes industries to discharge into MSS, including provisions for fees to be paid by the participating industry

Note that this recommended system is patterned after that used by the Los Angeles Country Satiation Districts (LACSD) circa 1970, which is considered to be practicable for DC use. The current system utilized by LACSD, as now required by the U.S. EPA, is much too sophisticated/expensive for DC use[105].

Discharge Directly to Environment

These discharges must be controlled in the DCs by use of the permit system already described, administered by the local authority with this power (which may be the MSS for industries within the municipal boundaries). In most DCs, the permit system is administered by the NEnPA, which requires preparation by the industry of an approved EIA before the Ministry of Industry can issue its permit that allows the industry to be built and operated. The EPMs specified in the approved EIA are included in the Ministry of Industry permit.

Notes: Based essentially on experience in California as regulated by California State Regional Water Quality Control Boards for area where economy is dependent on use of imported water as well as of groundwaters.
TDS removals are required to prevent salt build-up in groundwaters.

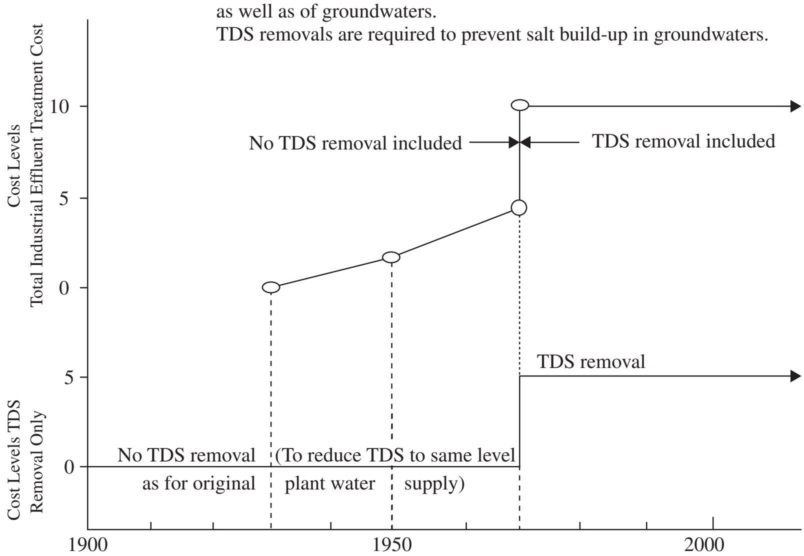


FIGURE 4.14 Schematic drawing showing effluent standards requirement for disposal of industrial wastes by soil infiltration affecting valuable groundwaters in semi-arid regions for parameter of total dissolved solids (TDs).

The weakness in this system is the lack of firm monitoring of actual industry performance and lack of fines for nonperformance, which are sufficiently high to encourage performance.

Appropriate Standards

As already noted, the U.S. EPA point source publications, which are available for almost all types of industries, are excellent sources of background information needed for designing the appropriate wastewater management system for a particular industry. But in using these manuals, care must be taken (as already noted) to adjust the control system to be practical for use in the DC (if not, performance will be evaded)—that is, to utilize appropriate environmental standards. This adjustment requires skilled expertise and virtually all DCs need IAA assistance for this task.

Some examples of use of appropriate environmental standards are given in Figures 4.12, 4.13, and 4.14.

Cleaner Production (CP)

In the 1990s, the IAAs initiated a program for getting DC industries to utilize cleaner production technologies developed in the ICs for minimizing production of wastewater pollutants by modifying the various process steps utilized by industries, thus not only simplifying treatment needs but also saving raw materials, making the industrial operation more economic. The experience thus far in DCs[108] indicates three things:

1. The NEnPAs/industry ministries have not established sufficient regulatory mechanics to enforce use of CP; hence, use of CP to date has been limited because of the required upfront investment in reorienting the industrial processing methods, and the time required (3 years or more) before these costs can be recovered, together with the pressures prevailing in most DCs for realizing immediate financial gains, and the continuing lack of regulatory enforcement for controlling pollution discharge requirements.
2. The best success in use of CP in the DCs has been in industries that are branches of international companies that can afford the upfront investments and, moreover, have the goal of increasing overall long-term profits.
3. The best approach is for the DC to gain support from the country's industrial/trade associations to encourage industries to use CP[87].

Industrial Estates

Usually, the most practical approach for controlling industrial pollution in DCs is the use of industrial estates where polluting industries are required to locate, as illustrated by the Industrial Estates Authority of Thailand. These estates offer economic advantages in furnishing a central treatment plant for managing pollutants treatable by the central plant, and with the estate administering the permit system including performance monitoring and enforcement. The administrative costs of proper control of pollutants with these estates are vastly simpler and inexpensive compared to the situation when the industries are in separate locations.

Marine Disposal

As noted in the section on "Urban Sewerage and Excreta Management," when disposal to unconfined offshore ocean waters is feasible, the costs for treatment/disposal can be greatly reduced because of open ocean's virtually unlimited supply of oxygen for stabilizing BOD, and because the ocean waters can receive many types of inorganic compounds without damage which cannot be accepted by confined receiving waters. Selenium, for example, is a serious toxic substance for receiving waters used for irrigation but of no special significance when discharged to the open seas.

Figure 4.15 illustrates this capability of the open seas for accepting many types of inorganic compounds. One example of this advantage of open ocean disposal is the World Bank's project for metropolitan sewerage planning at Abidjan (Ivory Coast), where such disposal is vastly less costly and much more practical than a previous proposal, which attempted to require in-house treatment by the many industries in the metropolitan region[157]. Another is the recommendation

TREAEMENT PARAMETER / INDUSTRY		pH	Acidity/Alkalinity	TSS	TDS	BOD	COD	TOC	Temperature	Color	Grease/Oil	Phosphorus	Nitrogen	Surfactants	Chromium	Lead	Copper	Mercury	Arsenic	Manganese	Zinc	Potassium	Aluminium	Heavy Metals	Cyanide	Phenols	Fluoride	Sulfate	Coliforms (Fecal)
Inorganic Chemicals		●		●			●	●							●	●		●							●				
Organic Chemicals		●	●	●	●	●	●	●		●	●	●	●												●	●			
	Bauxite Refining	●	●	●	●																							●	
Aluminium	Primary Smelting	●		●																							●		
	Secondary Smelting	●		●			●						●				●						●				●		
Feedlots				●	●	●	●					●	●																●
Fruit/Vegetable Canning		●		●		●																							●
Plywood		●	●	●	●	●	●		●		●	●	●		●		●		●		●						●		
Iron Smelting		●		●											●					●					●	●			
Cement		●	●	●	●				●													●						●	
Asbestos Building Materials		●		●	●	●	●	●	●			●	●											●		●			
Cane Sugar Refining		●	●	●	●	●	●		●			●	●																
Fiberglass Insulation		●		●	●	●	●		●	●	●		●														●		
Meat Processing		●	●	●	●	●	●		●		●	●	●																●
Grain Processing		●	●	●	●	●	●		●			●	●																
Soap and Detergents		●	●	●		●	●				●			●															
Synthetic Resins		●			●	●	●					●			●						●								
Steam Power									●																				
Pulp and Paper		●		●		●	●			●																			
Brewery				●		●																							
Copper Wire		●		●	●										●		●				●								

FIGURE 4.15 Significant parameters for treating wastewaters from various industries for discharge to confined waters (but not significant for discharge to open ocean waters) (after point source publications of U.S. EPA).

for disposing of huge amounts of polluting coal dust from power generation in India by discharge to the open seas[131].

See section on "Emergencies Management" for discussion of Thailand's system for managing oil spills.

BOX 4.3 GUIDELINES FOR PREPARATION OF ORDINANCES FOR REGULATING AND INDUSTRIAL WASTE DISCHARGES FOR MUNICIPALITIES IN INDONESIA

by H. Ludwig for UNDP/UNOTC, 1978[44]

Abstract

Interest in environmental protection in Indonesia, including protection of the quality of the water resources of the country, has progressed greatly over the past decade. There is now considerable interest in formulating and establishing a national program for protecting the quality of these water resources, including rivers, lakes, estuaries, and marine waters.

An important aspect of a national water quality control program relates to the management of public sewerage systems in urban areas, so that the system will fulfil its primary objective of collecting and disposing of sanitary wastes, while at the same type furnishing reasonable service for receiving and disposing of industrial wastes. Thus, a municipality having a public sewerage system needs to enact ordinances which will provide for the proper controls for protecting both (1) the public sewerage system including treatment plants, and (2) the environment in waterways that received the treated wastewater.

A preliminary step toward formulation of such guidelines for municipal sewerage systems was carried out as part of the Jakarta Sewerage and Sanitation Project completed in 1978 by the Ministry of Public works in cooperation with the United Nations Development Program and the World Health Organization. The Jakarta Project report includes sections, prepared by Dr. Harvey F. Ludwig as the Project's Consultant on Environmental Technology, on a recommended municipal ordinance for control of industrial wastes discharged to municipal sewers, which were adapted from the requirements utilized by the Los Angeles County Sanitation Districts circa 1970.

The information in the current report includes the salient aspects of municipal ordinances that are needed to control discharges to the public sewerage system, both for sanitary and industrial wastes. A glossary is also included to define the technical terms and abbreviations used in the report. Although the information presented in this report was initially prepared for consideration for use at Jakarta, it has been edited to make it generally useful by all municipalities in Indonesia.

URBAN SOLID WASTE MANAGEMENT

Situation in United States versus DCs

Solid waste disposal in the United States has mostly made use of landfills. Pursuant to U.S. EPA regulations, design and operation of urban solid waste landfills is now a highly sophistical hi-tech business, which, while expensive is affordable in the United States and desirable to protect environment, particularly to prevent pollution of groundwaters[142]. In most DCs, however, most solid wastes continue to be disposed of by piling into open dumps, resulting in serious environmental hazards including (1) exposure of workers and other site visitors to disease hazards from flies and rodents that are attracted to the site, (2) production of odor and smoke nuisances from uncontrolled burning, (3) hazard of polluting groundwater, and (4) hazard of polluting nearby areas by flood runoff. In addition the systems for collection and transport of the wastes to the site are generally not protected and often are contacted by children.

The history of urban solid waste management (USWM) in the United States has involved three stages: (1) use of open dumps, (2) use of sanitary landfills beginning in the 1930s, then (3) improvement of landfilling technology to its current hi-tech state. The costs for Stage 3 are prohibitively expensive for DCs; in fact, the Stage 3 costs for performance monitoring alone may exceed the funds available in many DCs for the entire landfilling system. The realistic target for DCs at this time is to aim for switching from open dumping to use of sanitary landfilling as practiced in the United States prior to U.S. EPA involvement (Stage 2).

Over the past two decades, the DCs with IAA assistance, have begun the process of utilizing sanitary landfill in selected cities, so the technology for designing and operating these to suit the criteria is gradually being developed.

It should be noted that many DC/USWM practitioners are not aware that solid wastes typically are replete with disease pathogens (much like sanitary sewage); hence the need for attention to collection/handling/disposal practices to protect people from exposure/contact with the wastes.

Practical Sanitary Landfilling Technology for DCs

As already noted, the target for DC/SWMSs is use of sanitary land-filling technology as used in the United States up to mid-twentieth century, without use of plastic liners/recirculation of waters seeping through the fill and without elaborate monitoring, but with adequate attention to (1) use of storage collection containers and/or storage areas which are protected from access by children, (2) use of collection trucks that can transport the wastes without spilling, and (3) locating the landfill site at places with little if any potential for polluting groundwater (no groundwater or deep groundwater aquifers that are covered with deep layers of impermeable clays), (4) protection against flood runoff from the site, and (5) provision of buffer areas around the landfill sufficient to prevent complaints from neighbors (see section on "Urban Sewerage and Excreta Management," subsection on "Buffer Area").

Following these guidelines, an ADB-sponsored project in 1997 produced and EIA manual on the requirements for designing and operating an acceptable DC sanitary landfill[136].

Experience in Asian DCs

Thailand Most Thailand cities are located in the flat lowland regions where the major groundwater resources are at deep depths covered by deep layers of impermeable clays, so it is feasible to find sites where use of expensive liners is not necessary. In about 1990, there were only a few municipal sanitary landfills (MSLs) in the country, and these came about at local initiative (usually by city officials who happened to observe SLF operations in the United States). Beginning in the 1990s, Thailand's Pollution Control Department (branch of the country's environmental ministry), in response to development of serious SWM problems in several municipal areas, undertook studies to plan SLF operations on a provincial basis so that a single MSL could provide economic service to several municipalities in its region. However, while these plans appear excellent from the technical/economic points of view, progress in implementing these schemes has been slow because it has been difficult to obtain political approval from the municipalities involved[134].

Malaysia Solid waste disposal problems in cities in the Klang Valley region the country's primary population/industrial region with a number of cities (including the capital city of Kuala Lumpur) had become especially serious by about 1970, due to the legal situation where each city is responsible for managing its own disposal, but usable disposal sites within the city boundaries had become all used up, and the cities had no authority to utilize areas outside their boundaries. As part of an ADB-sponsored project for improving economic-cum-environmental development in the region, called the "Klang Valley Environmental Improvement Project"[5], a plan was prepared in 1987 for a single regional SWL system serving all these cities, including trucks for picking up the wastes collected by each city, hauling these to the SWL site (using transfer stations as needed along the way), with the SLF well located for economic hauling form the cities to be serviced. The essence of this plan is shown in Figure 4.16. At the same time, the capital city of Kuala Lumpur had proposed to proceed with an incineration plan that would cost seven times as much per ton of solid waste incinerated, compared to the regional plan, and even the incineration scheme would dispose of only 80 percent of the waste with 20 percent remaining as residue to be disposed of by hauling to a landfill.

Philippines In most DCs, a serious public health hazard is the practice of the urban poor to find employment by visiting SLF sites to pick them over to recover plastics and other resalable. In the Philippines, the Ministry of Human

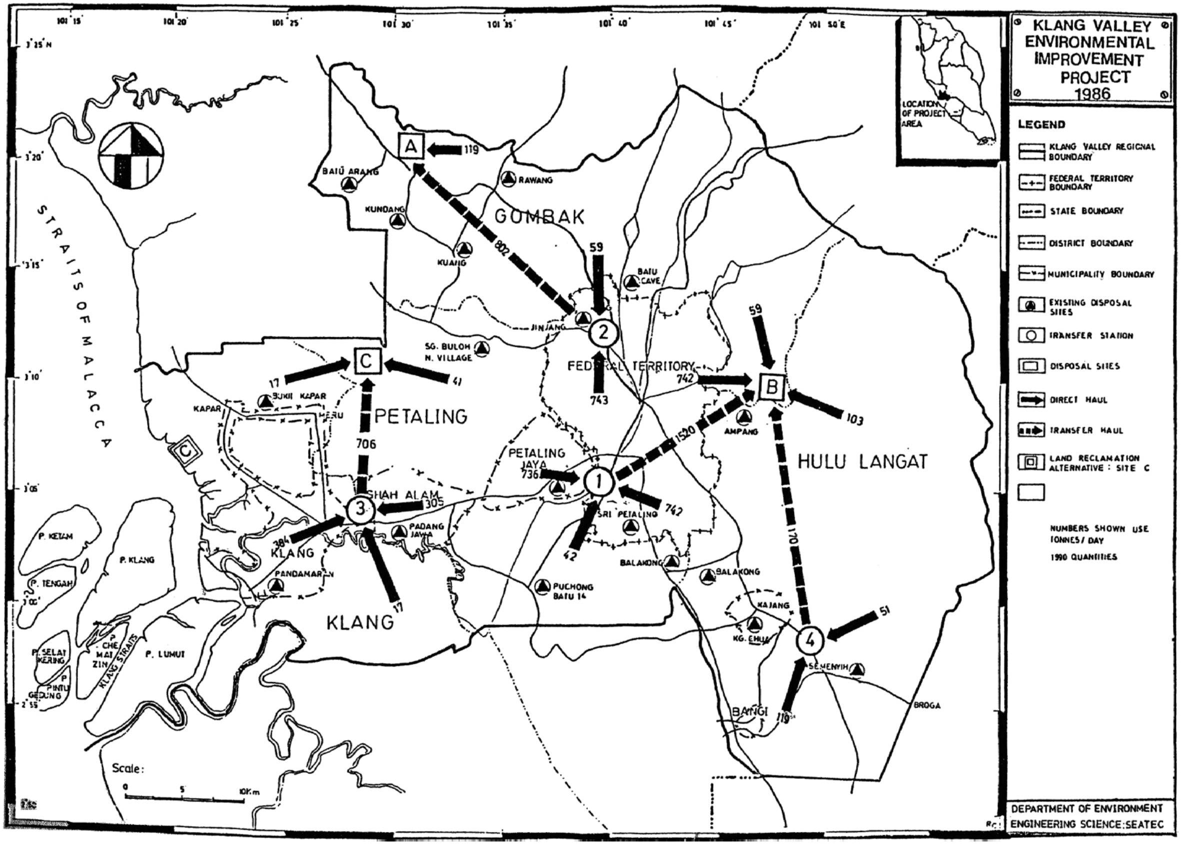


FIGURE 4.16 Recommended plan for solid waste management in Klang Valley.

Settlements in 1980 attempted to "sanitize" the landfill recovery operations in the Metro Manila region with public employees doing the picking over, using protective clothing and picking gear, but it was found that the costs of this was greater than the value of the recovered materials[49].

Indonesia A World Bank–sponsored project in the 1980s[150] developed a plan for markedly increasing the life of the available SLF sites by use of equipment for compacting the waste into bales before disposal, thus greatly decreasing the waste disposal volume.

China The World Bank's project for resettlement for the major Xiaolanddi dam/reservoir project on the Yellow River included provisions for adequate SWM in the resettlement cities, including use of appropriate vehicles for picking up and hauling wastes to transfer stations fenced off to prevent access by children, then hauling to SLF sites including fencing off of the sites to prevent public access[160]. Hence, these resettlement cities are blessed with USWM facilities much better than those in the cities in which the resettlers previously lived.

Alternative Disposal Methods

The DCs cannot consider use of incineration because of the unaffordable high costs. Several attempts have been made for use of composting (as practiced in Europe), including construction in Bangkok in the 1960s of several major composting plants presumed to be useful as a general disposal alternative. These have been abandoned except for one plant, which produces only a small amount of compost sold to nearby fruit orchard farmers[46].

Reclamation of Swamp Lowlands by Refuse Landfilling

Project Concept It was observed in the Jakarta region of Indonesia in the 1970s[150] that valuable land was being reclaimed from uninhabited swamp areas by filling of the swamps with solid wastes by private-sector operators. This practice would be prohibited by U.S. health authorities, but examination of this practice in Jakarta indicated that it was essentially sound.

The solid waste materials, under water-saturated conditions, quickly consolidated and degraded to form good land. This led to a World Bank–sponsored R&D project conducted at Bangkok for evaluating the feasibility of reclaiming swamp areas by filling with refuse[104]. The study examined core samples in Bangkok areas that had been filled by refuse. Half of the city of Bangkok is built on former swampland filled with refuse, but the other half on areas filled with dirt or sand.

Stabilization Phenomena The study evaluated the available literature on research studies of landfilling with solid wastes, on gas production and degree of stabilization of the fill materials, to obtain appropriate guidelines or criteria

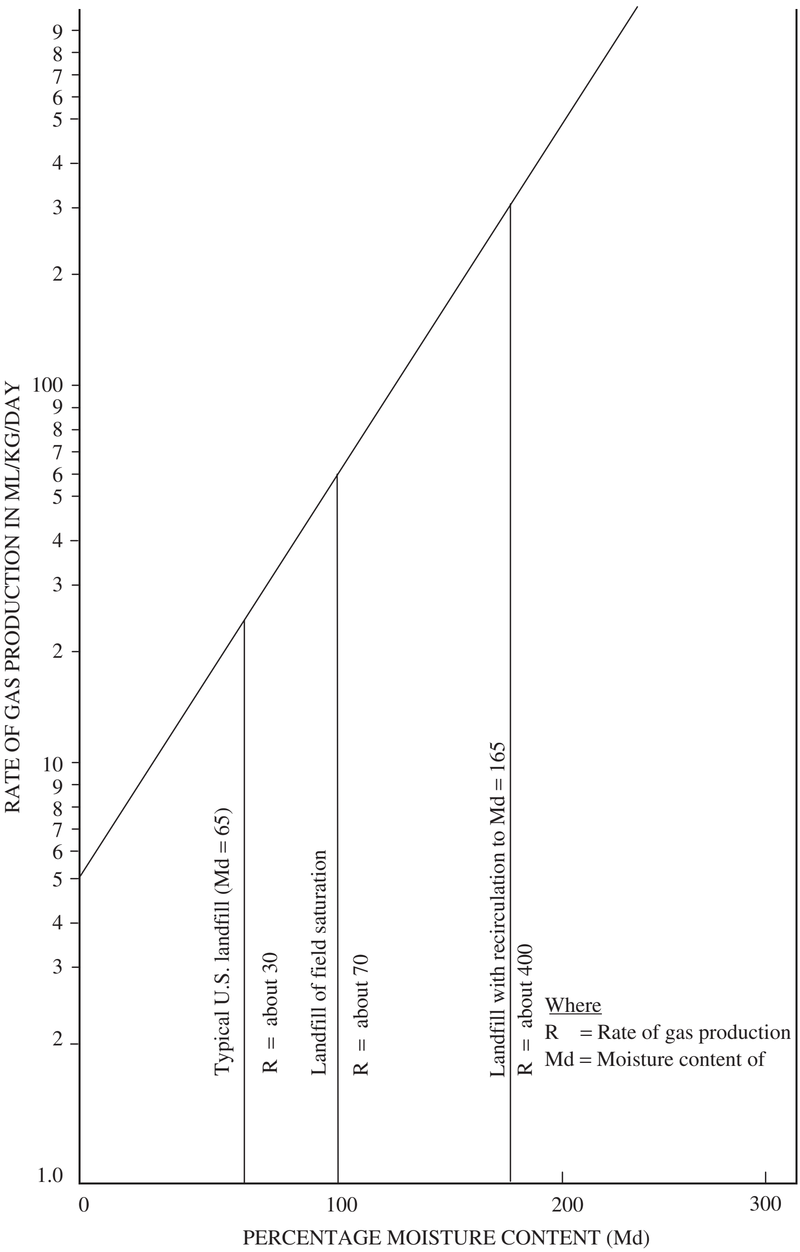


FIGURE 4.17 Illustrates this relationship between rate of gas production and percentage moisture content in landfills for different sets of conditions.

that could be used for estimating the degree of stabilization obtained within fills under the saturated or submerged conditions prevalent at Bangkok during the six-month rainy season Figure 4.17 illustrates the relationship between the rate of gas production and the percentage moisture content in landfills. Information was also gathered on problems in utilizing completed fill sites as related to degree of stabilization and/or compaction. To supplement the review and literature available at Bangkok, a canvass was made of past and ongoing research on refuse landfilling stabilization phenomena. The results of the review are as follows:

- There are several types of stabilization/gas production phenomena going on in a fill including aerobic, facultative, and anaerobic, with the anaerobic phase representing the main mechanics for achieving gas-production (both methane and carbon dioxide) and hence stabilization. These various phenomena into be classified in five stages: (1) initial adjustment, (2) transition, (3) acid formation, (4) methane fermentation, and (5) final maturation[127].
- In a typical U.S. fill, a total of about 600 days is required to complete stabilization under usual conditions in practice. However, various studies show that the stabilization can be speeded up by increased temperature (up to 41°C), and especially by increasing moisture content, because the unsaturated portions of the fill tend to remain within the acid formation phase, whereas when the materials become saturated, methogenesis develops very rapidly. Under Bangkok conditions, saturation would be the norm during the rainy season (about 6 months).
- While the data are limited, the available data indicate that the rate of gas production (total gas) may be roughly expressed by the equation:

$$\log R = 0.0125\text{Md} + 0.5$$

where R = gas production in ml/kg/day and M_d is the moisture content of the fill on a dry weight basis.

Study Conclusions Because of the fact that practically all research studies on refuse landfilling have been conducted in the Western countries, there is a well-meaning tendency in the Western technology against the concept of depositing organic refuse at ground elevations below groundwater levels. Western technology requires that all filling be at levels above groundwater, and moreover, a great deal of research and development over the past two decades has been focused on developing practicable methods for preventing leachate percolating from fills downward into the groundwater strata. The objectives are to protect the groundwater quality from pollution because, in many situations, the groundwater, including strata near the surface, are used as a source of water supply for community and industrial purposes. In other words, under normal conditions, without use of planned refuse filling, the groundwater is not generally polluted and it is desired to keep it clean.

The situation in urbanizing swamp (formerly paddy) areas in tropical monsoon countries is entirely different. Under these conditions, the normal situation involves routine deposition of community refuse into the vacant lands by householders all year around, because the municipal refuse collecting system gives only partial service. Thus, a great deal of refuse is disposed of by the householders, commercial establishments, and others on a local basis, by throwing it into the swamp/paddy area or by trucking it there (usually done during the night hours so the operations are not observed by most people). As a result, the swamp areas are routinely very heavily polluted with these materials. The groundwater level during the rainy season is above the surface and often close to the surface during the dry season. In other words, the surface and shallow groundwaters in these urbanizing areas are routinely polluted to a high degree by uncontrolled deposition of refuse.

In addition, excreta also heavily pollute the surface and shallow groundwaters because excreta disposal is generally by use of subsurface leaching pits, or by septic tanks with subsurface leaching systems. At Bangkok, because the soils are generally tight clays, the subsurface leaching systems hardly leach at all; hence their effluents tend to ooze to the ground surface. At Jakarta, many of them in the northern city area function poorly because of either tight soils or high ground water. The result is that even under normal conditions, the surface and shallow ground waters are very heavily polluted. This situation continues until the low-lying areas become filled. Usually, this requires a period of years, ranging from a few years to much longer periods of a decade or several decades. There is little prospect in the foreseeable future that this situation will change. Even when the municipal refuse collection system can expand its services, new areas of building development spring up in the fringe areas on the city outskirts.

Because of the situation just described, the first conclusion, in making the environmental analysis, is that the "Western rules" are inappropriate for evaluating the situation on refuse landfilling in low-lying tropical monsoon regions, and that the analysis, to be appropriate, must be based on the actual local situation.

Parameters for Analysis Review of the literature on refuse filling practices in developing countries indicates that the significant parameters involved in evaluating the environmental effects of the proposed scheme for systematic swamp reclamation by refuse landfilling are: (1) sanitation/public health, (2) community aesthetics, and (3) economics including savings in reclaiming land by the proposed method (with credits for its value for waste disposal) and suitability of the completed fill for building purposes. Other meaningful considerations applicable at Bangkok include the impact on local flooding and on the local refuse scavenger industry.

Sanitation/Public Health/Aesthetics Under current conditions, the swamp areas in urbanizing zones arc characterized by very heavy pollution of the shallow groundwater, and of surface waters existing during the rainy season, due to uncontrolled dumping of refuse into these areas and due to excreta waste residuals from subsurface disposal units, which are unable to function effectively.

These problems persist so long as the areas are undergoing filling, which may take many years or even decades.

The only practicable solution to the problem is to fill these areas as promptly as possible, because there is little hope in the foreseeable future that waste management practices will be much improved. The proposed refuse landfilling reclamation scheme will achieve the objective of prompt filling. This will include planned filling of sites so that the refuse hauling distances will be decreased. In these selected areas filling will be as rapid as possible (as permitted by biological degradation and consolidation constraints), thus minimizing the period of unacceptable sanitation/public health/aesthetic conditions.

Structural Suitability of Completed Fill Much of the literature on sanitary landfilling in the industrialized countries is concerned with the suitability of the completed fill for use for sites for buildings. Such use has involved serious problems because methane gas generation in the fill results in explosion hazards beneath the building, with settling of the building due to settling/consolidation of the fill, and with the difficulties in driving structural piling through the completed fill.

In the proposed refuse landfilling reclamation scheme for DCs, the problems of methane gas and of fill settling appear to be eliminated due to the virtually total biological degradation and total physical consolidation taking place in the reclamation period because of the wetted condition in the fill during the rainy seasons.

With respect to driving of piles, this should pose no significant problem because of the limited depth of the fill, usually less than 2 meters. In addition, where footings are used for foundations, because the fills are shallow, usually it should be possible to place the footings to rest on the natural soil underlying the fill.

No problems of the types described here arc known to have been reported in Bangkok, despite the fact that much of the city (all built on former swamp/paddy areas) has been filled with refuse to a depth of about 1.5 meters.

Overall Study Conclusions The conclusions on economics are as follows:

- The stabilized waste is suitable for fill material, which will be used for developments such as parks, playing fields, light surface improvements, one-story buildings with footings in soil below the fill, or structures on piles. This is based on the study soils laboratory analyses that show that the decomposed solid waste is similar in nature to inert fill material used in Bangkok and based on experiences in Thailand and elsewhere where swamps reclaimed with solid waste have been widely utilized for decades for building development, with no known reported settling or structural damage.
- Degradation of solid wastes deposited in low-lying areas with tropical monsoon climatic conditions probably occurs within two rainy seasons, and

maybe even more rapidly if swamp conditions prevail year-round. Problems of methane gas and fill settling are believed to be eliminated through virtually total biological degradation and total physical consolidation due to the wetted conditions.

- The proposed scheme of refuse filling should be quite beneficial in terms of environmental impacts, primarily because the only known way to solve "sanitation mess" problems in low-lying areas is to fill them in, and use of refuse is often the only affordable approach.
- The solid waste disposal/swamp reclamation scheme could reduce overall municipal solid waste management costs by a significant reduction in hauling costs and reduction in expansion requirements for the existing series of landfill operations.

URBAN AIR POLLUTION CONTROL

Background

In the United States, the regulatory control system established by U.S. EPA for point source control (industries) is effective because its regulations are enforced, so it is cheaper to comply than to evade, and the major remaining problem is control of pollution emission from vehicles. The regulations for vehicles (use of exhaust emission controls, requirements for better mileage) have made significant progress, but the eventual solution will probably be switching the fuel from gasoline to hydrogen.

The problem in most DCs is relatively very poor; hence, many of the major DC cities suffer from severe air pollution. The DCs have appropriate laws/regulations, but enforcement is generally very weak, and in addition to the major sources from industries and vehicles, uncontrolled burning of forests, especially in Indonesia, now is a major pollutant. The pollution from the annual burning in Indonesia now causes prolonged pollution every year in the nearby countries of Singapore and Malaysia, and despite a major effort by ADB to help the Indonesian government to resolve this problem, significant progress has not been made.

Air pollution is now horribly severe in many of the major cities of China, due primarily to China's dependence on burning of coal as the primary energy source, and it seems unlikely that China will get around to use of sequestering of CO_2 from coal burning in the foreseeable future. And this problem, already so severe, is now being compounded by the recent great increase in vehicle traffic in China cities now underway.

Thailand: General Situation

One of the better (less bad) situations on air pollution control in Asian DCs is that in Thailand where the government's Pollution Control Department has achieved significant reductions in reducing vehicle pollution by enforcement for reducing emission with periodic inspections, ban on use of leaded gasoline, and requirements for switching from two-stroke to three-stroke motorcycle engines. The control program of the Ministry of Industry's Department of Industrial Works, which has jurisdiction for industry control suffers from inadequate enforcement measures, and tends to enforce correction measures only in situations with very severe public complaints. The worst single major air pollution problem in Thai history resulted in massive emissions of SO_2 from a major power generating facility (Mae Moh) in northern Thailand, which generates power by burning of peat with high sulfur content, resulting in a major control effort by the Pollution Control Department (assisted by U.S. EPA), but even with this, plentiful public complaints continue. This record has given fossil fuel power production in Thailand a very bad image, and made it difficult to gain acceptance of proposed new plants, even for plants burning clean coal with proper controls. It is the public's belief that these will be "more Mae Mohs."

Thailand: Sharing of Controls for Multiple Industries

Study Objectives The Department of Industrial Works (DIW) sponsored a study completed in 2001[139] for evaluating the situation in industrial zones where emissions come from multiple industries, to develop a system that can fairly distribute/divide responsibility for controls among the various industries.

Study Work Plan and Strategy Figure 4.18 shows the Work Plan tasks, and Figure 4.19 shows the study strategy for evaluating the pertinent collected data.

Organization of Study Report The report consists of seven chapters and appendices as follows:

- Chapter 1: Introduction.
- Chapter 2: Industrial area management. This section contains reviewing of related documents and data, summary of necessary data, industrial area management data in Thailand and related international experience.
- Chapter 3: Methodology for conducting assimilative capacity both overall, detailed for each step, including limitations.
- Chapter 4: Detailed applications of assimilative capacity evaluation method and appropriate management methods for the two main industrial study zones.
- Chapter 5: Environmental management conditions and implementing organization, which present detailed environmental management conditions for the project developers.
- Chapter 6: Training, meetings, and seminars for project outcome presentations.
- Chapter 7: Conclusions and recommendations.
- Appendices: References and detailed related information, which are grouped for each chapter for convenient use.

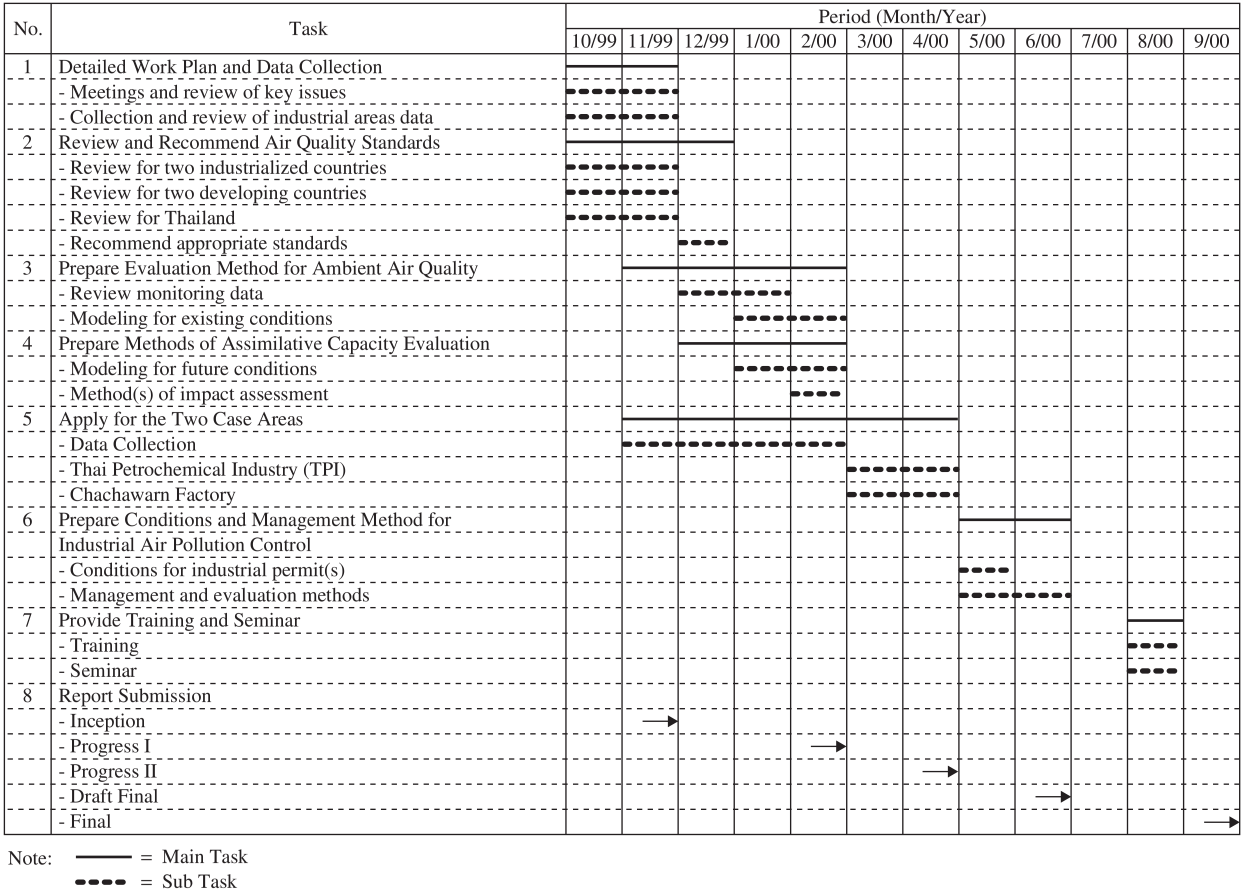


FIGURE 4.18 Work plan for study for controlling air pollution in zones receiving emissions from multiple industries.

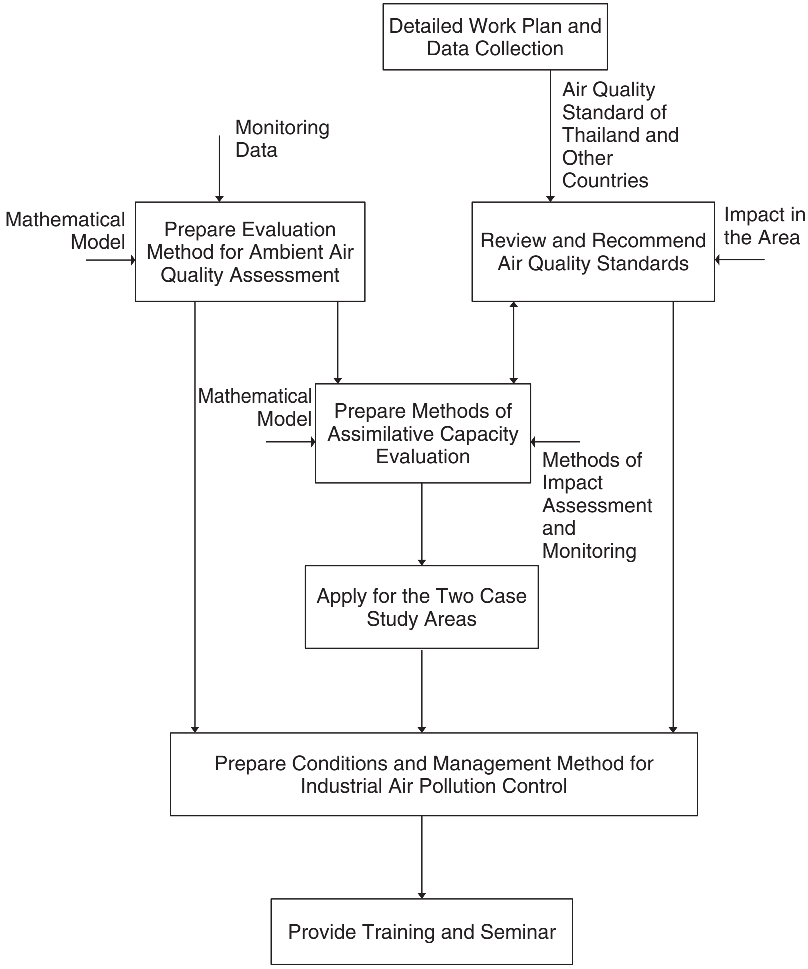


FIGURE 4.19 Assimilative capacity evaluation of air pollution.

Conclusions and Recommendations A mathematical modeling procedure is presented that enables determination of the reductions to be required for each industry operating in dense industrial zones where the ambient conditions exceed prescribed standards. The essential aspect of the recommended procedure is to require continuing competent monitoring of key parameters and reporting of the monitoring data, in sufficient frequency and detail as needed for proper modeling purposes

Air Pollution Control Experience in India

This summarizes information on a review of air pollution control experience in India reported in 2003[1].

Standards and Procedures for Industrial Air Pollution Control

- *Ambient air quality standards:* These standards for India are shown in Table 4.1. These differentiate between air quality requirements for industrial areas, residential areas, and "sensitive" areas. Sensitive areas are intended to include health resorts, national parks, bio-reserves, sanctuaries, declared archaeological monuments (e.g., Taj Mahal, Ajanta, Khajuraho) and other declared sensitive areas. However, industrial and residential areas are often mixed and overlapping, and because there are large differences between the limits for the two uses, this often creates a lot of confusion and controversy. Obviously in all such circumstances the more stringent value should prevail. To utilize relaxed requirements, strict land-use zoning would be necessary, which is hardly possible in most developing countries, including India. Also, due to lack of recording/monitoring instrumentation, regular frequent monitoring, and long-term data collection, annual average values are used, but these have only limited relevance. Pollution control based on 24-hour values seems to be easily complied with at almost all places for all pollutants, except for particulates.
- *Emission standards:* Prescribed emission limits for a few selected categories of industries are given in the report. The limits are essentially based on what is expected to be achieved by the best available/practical technology

TABLE 4.1 Ambient Air Quality Standards (National) In India

Pollutants	Time Weighted Average	Concentration in Ambient Air		
		Sensitive Areas	Industrial Areas	Residential Areas
1	2	3	4	5
Sulphur dioxide (SO_2)	Annual average[a]	15 mg/m^3 30 mg/m^3	20 mg/m^3 120 mg/m^3	60 mg/m^3 80 mg/m^3
Oxide of nitrogen as NO_2	24 hours[b]	15 mg/m^3 30 mg/m^3	80 mg/m^3 120 mg/m^3	15 mg/m^3 80 mg/m^3
Suspended particulate matter (SPM)	Annual[a] 24 hours[b]	70 mg/m^3 100 mg/m^3	360 mg/m^3 500 mg/m^3	140 mg/m^3 200 mg/m^3
Suspended particulate matter (SPM) size less than 10m	Annual[a] 24 hours[b]	50 mg/m^3 75 mg/m^3	120 mg/m^3 150 mg/m^3	60 mg/m^3 100 mg/m^3
Lead (Pb)	Annual[a] 24 hours[b]	0.50 mg/m^3 0.75 mg/m^3	1.0 mg/m^3 1.5 mg/m^3	0.75 mg/m^3 1.0 mg/m^3
Carbon monoxide (CO)				

[a]*Annual arithmetic mean of minimum of 104 measurements in a year taken twice a week 24 hours at uniform interval.
[b]24 hours/8 hourly values should be met 98 percent of the time in a year. However, 2 percent of the time, it may exceed but not on two consecutive days.

and not on any relationship to ambient air quality on assimilative capacity of the atmosphere. In the absence of recording instruments for emission monitoring, limits specifying pollutant loads per unit of production have little meaning. Concentration monitoring is on grab samples and is rather infrequent, and hence, enforcement is rather lax.

- *Assimilative capacity of atmosphere:* Prediction of expected increments in pollutant concentrations due to proposed major industries, using modeling dispersions of the likely emissions, has become an integrated part of EIAs and environmental clearances for the last 15 years. However, this does not appear to have contributed very much to air quality management due to doubtful meteorological data and models that have never been validated for local conditions. Modeling is done on a case-by-case basis, and in the absence of firm meteorological or background air quality data; there is unlimited scope to manipulate to get projects cleared. A few regional EIA studies (or what are called "carrying capacity" studies) have been carried out (e.g., for Doon Valley, National Capital Region at Delhi, and the Jamshedpur Region), but so far, these have not been used for planning or granting clearance for industrial units. Thus, assimilative capacity of the atmosphere is a new concept and the greatest difficulty in its use is the lack of appropriate meteorological data. The first competent effort in this field appears to be that underway at Patna in Bihar State since August 1999 by Envirotech Instruments Pvt. Ltd. of New Delhi, which is collecting primary meteorological data at the site (including wind and temperature profiles and mixing heights).
- *Pollution load trading:* This concept has so far not arrived in India, and each project is treated as an individual case. In the highly dusty and politicized Indian scenario, pollutant load trading may not be easy, even in years to come.

Evaluation of Performance It is wrong to say that there have been no significant improvements in the air quality scenario in India during the previous 10 years. The most noticeable improvements have been in the levels of SO_2 in urban areas, primarily due to a switch from using sulphur-free liquid petroleum gas instead of other locally available fossil fuels. A recent reduction in sulphur content of diesel (from around 1 percent to below 0.1 percent) is bound to further improve the situation. The introduction of lead-free gasoline and of catalytic converters on all new cars has drastically brought down concentrations of lead in ambient air of the metro cities. However, the levels of particulates have not abated, and concentrations of nitrogen oxides are rising. All these changes have essentially resulted from reductions in vehicular and other nonindustrial emissions under court directions. Although a lot of emission control systems have been installed and commissioned in industries, and industrial units and regulatory agencies claim large improvements in compliance of emission standards, it would be a rare case that reports even the slightest improvement in the ambient air quality due to the better management of industrial emissions. The situation in all such pockets suffering air quality deterioration due to industrial emissions, especially particulates, continues to be as bad as ever. Compliance with emission limits has been easier to manage in cases of large industries, especially multinational and/or private sector units. Much greater attention needs to be given to regulating the emissions from medium and small-scale units, which often cause much greater adverse impacts due to their location in or near densely populated or other sensitive and critical areas.

Lessons Learned from Indian Experience

- *Experience to date:* The Indian experience shows that people's support and pressure, either overt or at least covert, is necessary to obtain any level of significant success in pollution control. Shortcomings in enforcement mechanisms may render the efforts of regulatory agencies ineffective unless public concern and public activism enter into the picture to require improved regulatory action. Public agitations and public interest litigation can activate and energize even weak/corrupt/inefficient bureaucratic machinery. People's concern and interest are much more easily roused when impacts of the environmental pollution are easily seen, such as loss of crops, health damage, offensive odors or visibility loss, or risks to sensitive structures like the Taj Mahal. Subtle and distant impacts such as greenhouse effect or climate change are not readily perceived and do not attract public pressure without long and arduous mass-education and sensitization. Proper selection of siting and technology for new industrial units appears to be the most cost-effective method for industrial air pollution control, together with requirements for continuing self-monitoring. These requirements should be the responsibility of the government's industry control agency, as part of its permit system.
- *Future:* The government's environmental agency should reinforce the role of the industry agency by the effective use of the EIA process, which should spell out in detail the requirements for emissions control as already noted, including routine periodic monitoring to be done by the industry as a prerequisite for application for a permit from the industry agency. Also, the environmental agency should conduct its own periodic monitoring of industrial emissions as a check to ensure that the industry agency's requirements are being observed.

It should be noted that while affluent Western industrialized countries understand that effective regulatory monitoring with enforcement is essential for achieving successful performance by emitters, and do practice such monitoring/enforcement effectively, the authors (who have worked in more than 40 developing countries) do not know of any developing country where this has yet happened—no doubt because of the traditional "top-down" nature of the governments. However, the situation is gradually changing in most developing countries (like India and Thailand) due to the continuing efforts of dedicated working-level professionals who persistently push for establishing meaningful monitoring and enforcement. Meaningful monitoring/enforcement is expected to be introduced in many developing countries within the next few decades, and the lessons learned in India should be valuable in helping guide for such introduction.

HAZARDOUS WASTES MANAGEMENT

Background

Attention to management of hazardous wastes/substances in the DCs has been woefully lacking. The main problems have been (1) lack of adequate point source control at factories that produce these wastes, including both wastewaters and solid wastes, and (2) inadequate attention to this problem in the design of wastewaters management systems (insufficient attention to excluding intakes of these materials), (3) use of open dumps for solid waste disposal that accept delivery of anything and everything, and (4) inattention to management of hazardous substances that enter the country.

The first three problems are discussed in the sections on "Urban Sewage and Excreta Management" and "Urban Solid Waste Management." Especially serious is the common practice of accepting used batteries and electronic gear, which include plentiful amounts of toxic metals/substances that will be released sooner or later to contaminate groundwaters—for example, the use of such a landfill in Tonga located above the groundwater, which is the country's only freshwater source[48].

A typical example of the fourth problem is the experience in Thailand in the 1990s, when dangerous radioactive cobalt materials were found along public streets[21]. Investigation of this problem showed that the Thai government's agency responsible for keeping track of imports of radioactive materials had a very inadequate budget, with staff not sufficiently trained for their jobs.

The answer is that the IAAs who guide the DCs need to get a much better handle on this problem. Moreover, the attention must be "DC-oriented," not the publication and distribution to the DCs of manuals for control, which are essentially IC-oriented (as has often been the general practice of UNIDO). The manuals must suit the guidelines shown in Figure 4.2 of the section on "Introduction."

Guidelines Manual for DCs

An ADB project for strengthening EIA practice in Thailand[11] produced a series of guideline manuals, including one on management of hazardous wastes/substances[12]. Boxes 4.4 and 4.5 give the table of contents and the text for this manual, without its numerous annexes.

BOX 4.4 SUPPLEMENTAL EIA SECTOR MANUAL FOR HAZARDOUS WASTE MANAGEMENT PROJECTS (HWMPS)

Table of Contents

BOX 4.5 SUPPLEMENTAL EIA SECTOR MANUAL FOR HAZARDOUS WASTE MANAGEMENT PROJECTS (HWMPS)

1. Introduction

1.1 Purpose of Present Manual The purpose of the present manual of guidelines is to advise participants in the EIA process on the specific requirements for EIA for projects in the Hazardous Waste Management Sector. Figures 1.1-1 is a drawing showing the group of manuals utilized by DEIE, including (a) the Primary EIA Process Manual (and supplements to this), which applies to all types of projects, and (b) EIA Sector Manuals for particular categories or types of projects. The present document is the sector manual for Hazardous Waste Management Projects (HWMPs).

The EIA for HWMP projects is to comply with the requirements specified in the Primary Process Manual and in the present HWMPs sector manual. An EIA for a HWMP project must comply with the requirements of both manuals.

1.2 Types of HWMPs This manual classifies HWMPs in two categories, (i) LWs (Liquid wastes) and SWs (Solid wastes). HWMP/SWs are assumed to utilize landfills. Hospital wastes are covered in the Sector Manual for Large Buildings.

1.3 Toxic Wastes For purpose of the present manual, the term HWs includes toxic wastes which are in liquid or solid form.

1.4 Steps in Applying EIA Process The initial step for the EIA team is to carry put an IEE which will prepare the detailed TOR the follow-up EIA, including identification of Significant Environmental Issues (SEIs) and their prioritization, as specified in Chapter 2 of the Primary Manual. Following approval of the IEE, when a follow-up full-scale EIA is needed, the EIA team is to proceed to prepare the full-scale EIA report.

1.5 Reference Utilized Annex I list of references utilized in preparing the present manual. The primary reference utilized for LWs is Reference 1, "Preliminary Data Summary for the Hazardous Waste Treatment Industry," U.S. EPA, Sept. 1989, and Reference 2, "Requirements for Hazardous Waste

Landfill Design, Construction, and Closure." This information has been adapted to suit present conditions in Thailand.

1.6 Laws and Regulations Pertinent laws and regulations are discussed in Annex II.

2. IEE for HWMPs

2.1 Importance of IEE Any HWMP, if not properly designed and operated, can result in very significant adverse environmental impacts, even for very small projects employing only a few people. Hence, submittal of an IEE is required for all commercial HWMPs projects, regardless of size. Assuming full-scale will be needed, the IEE should include preparation of the Work Plan for the full-scale EIA including the tentative detailed Table of Contents for the final EIA report.

2.2 Basic Planning Requirements Basic guidelines for planning and conducting the IEE for a project are given in the Primary Manual. For HWMP/EIA, the SEIs will usually include the following:

(i) Delineation and quantification of wastes can be expected to be discharged from the project, both for (a) conditions assuming the project control plan is properly designed and operated, and (b) conditions in event of breakdown in operation of the control facilities.

(ii) Delineation and quantification of all beneficial uses of land/water/air in the project vicinity which could be affected by the plant discharges under conditions as noted in (i), and delineation of these in an appropriate Environmental Base Map.

(iii) Need for design of an effective control system with matching O&M skills.

(iv) Need for incorporating into the project provisions for ensuring delivery of HW inputs to the plant (no dumping elsewhere to avoid costs), and evaluation of affordability of charges to the interested customers.

(v) Preparation of an effective Environmental Management Plan (EMP) and Environmental Management Office (EMO) including implementation of competent monitoring, especially of the plant operations phase and for corrections of any inadequacies discovered by the monitoring.

3. Full-Scale EIA Tasks for HWMP/LWs

3.1 Project Description

3.1.1 General Description Annex III.1 gives information on the nature and scope of HWMP/LWs, which will be useful for preparing parts of Task 2.

3.1.2 Waste Characteristics and Treatment Annex III.2 gives background information on waste characterization and Annex III.3 on feasible methods for treating and disposing of the wastes. This will be useful for Task 2.2.

As noted in Annex III.3, the types of LHWs (liquid HWs) include three general categories, corresponding to ongoing practices in the U.S.

Recently a new approach has been under development at the University of Texas (Austin) for treatment and disposal of LHWs by "supercritical water oxidation" which sues very high temperature/pressures which break the HW substances down into harmless simple substances (Reference 6 and Annex III.5). It is anticipated that this type of treatment will come into commercial use within the next few years.

3.1.3 Project Alternatives Because of the "not in my backyard" feeling of most of public, it is important to present a convincing case for the proposed selected location, together with adequate attention to Public Participation (See Item 3.5).

3.2 Environmental Study Area (ESA) The ESA must be very carefully delineated and explained (See Comment 2.2/ii).

3.3 Environmental Impacts and EPMs Information from the Reference 1 and Reference 2 sources is summarized in Annex III and IV.

3.4 Environmental Monitoring Because of the sensitivity of all HWMP operations, preparation of the Environmental Monitoring programs is essential, especially for the Operations stage. This is to cover all items noted in Comment 2.2 and Annex III.4.

3.5 Public Participation Because of the "not in my backyard" feeling of many people, they will tend to oppose any waste treatment/ disposal facility to be located in their neighborhood, no matter how well it may be planned, because of apprehensions that the system will not be properly designed/operated/monitored. For this reason a public participation program, including provision of amenities, will usually be very important, to convince the localities that they will be properly protected. T his may include provisions for allowing local representatives to participate in the project planning and especially in the continuing project monitoring, with agreement that the system will be shutdown if not giving satisfactory performance. This approach has been very successfully utilized for example, by the Los Angeles County Sanitation Districts in gaining neighborhood acceptance of proposals for new waste landfilling operations. For further details please refer to DEIE's Supplemental Process Manual on Public Participation.

Reference 8 is an example of such public concern for a proposed HWMP in Thailand.

3.6 Compliance with Environmental Laws The pertinent laws and regulations are discussed in Annex II.

4. Full-Scale EIA Tasks for HWMP/SWs

4.1 Introduction Sections 3.1.1, 3.1.3, 3.2, 3.4, 3.5, and 3.6 for LWs also apply to SW systems.

4.2 Use of Reference 2 As already noted, reference 2 from U.S. EPA, "Requirements for Hazardous Waste Landfill Design, Construction, and Closure," which is available in the DEIE Library. This presents the basic information for planning and monitoring HWMP/SW systems. Included here in Annex IV is the Table of Contents of Reference 2 and section 1 which summarizes the salient findings of this publication.

Information of Task 4 (SEIs and treatment methodology) is given in Annex IV section 2 to 9, including closure systems and provision for emergency response in event of spills/failures. Information on monitoring is given in Annex IV, sections 4, 6, 7, 9, 10.

4.3 Special Situation on Clays in BMR In the BMR, much of the area is covered with very thick layers of very tight impermeable clay layers of thickness of 100 meters or more, and the usable groundwater resources are below this layer. Where this is the case, this greatly simplifies the design of landfill systems both for solid wastes (including solid hazardous wastes), especially use of liners. Linear technology has been developed primarily in the United States where the soils are permeable and where leakage from the fill can contaminate valuable groundwater. In BMR (and similar coastal areas of Thailand) the clay layers are often impermeable so that leachate hazards are minimized, and if sufficiently impermeable the liners may not be needed. This potential in BMR is reviewed in Reference 10.

5. Summary and Conclusions

The technology on management of HWs as its won specialty is relatively new, beginning essentially in the 1980s as part of U.S. EPA's focusing on this issue including its Superfund program. The technology is still evolving and it is estimated that about another decade will be required before this specialized field becomes conventional and standardized.

Annex I: References

1. "Preliminary Data Summary of Hazardous Waste Treatment Industry," Document EIA-440/1-89/100, U.S. EPA, Sept. 1989.
2. "Requirements for Hazardous Waste Landfill Design, Construction, and Closure," Publication EPA/625/4-89/622, U.S. EPA, Cincinnati, Ohio, 1989.

3. "Manual for Preventing Spills of Hazardous Substances at Fixed Facilities," Document EPA/600/52-87/068, U.S. EPA, Feb. 1988.
4. "Quality Assurance for Hazardous Waste Projects," N. Shashidhara Civil Engineering (ASCE), Dec. 1994.
5. "Redefining Hazardous Waste," P. Puglionesi, Environmental Engineer (American Academy of Environmental Engineers), 1996.
6. "Integrated Approaches to Management of Toxic Chemicals and Hazardous Waste," J. Hay and N. Thom, University of Auckland, New Zealand, 1996.
7. "Supercritical Water Oxidation and Related Processes." Consulting Engineering Studies, University of Texas (Austin), 1996 (Annex III.5).
8. "Traffic Disrupts As Villagers Protect Plant," Nation Newspaper, Oct. 1996.
9. "Laws and Standards on Pollution Control in Thailand, 3rd Edition," PCD, Sept. 1994.
10. Techniques for Assessing Industrial Hazards," by Technica for World Bank, 1990.

MEGACITIES: RURAL TO URBAN MIGRATION

Background

One of the major development of the past several decades is the accelerating migration from the rural areas to urban cities (and even to urban cities in other countries), due to realization by rural farmers for the first time in history, resulting from the new IT technologies, that the cities offer opportunities for a better quality of life[9,25,29,124]. In 1950 two-thirds of the world's population lived in rural areas, but by 2030 an estimated two-thirds will be urbanites. From 1975 to 2015, the number of world megacities (over 10 million people) will have grown from 5 to an estimated 26, all but 4 in the DCs, which are the least prepared to provide the essential services of transportation, housing, water supply, sewerage, and drainage systems. This corresponds to the equivalent of a new Bangkok every 2 months. And everybody agrees that this migration in unstoppable, and there is no precedent in history for this phenomenon.

Economic Policies for Sustainable Development (ADB)

Primary Study The UN/Brundtland report of 1987 emphasized the need for studying the mass immigration phenomenon in order to gain information fro guiding Asian DCs on how to proceed to get better prepared for accepting the massive immigration. In response to this the ADB, together with financial assistance from the Scandinavian countries, carried out a major in-depth evaluation in seven selected Asian DCs (Indonesia, Malaysia, Nepal, Pakistan, Philippines, Sri Lanka, and South Korea), completed in 1990[7]. The findings of the study, with respect to need in megacities for environmental infrastructure, are evaluated in a follow-up paper[111] presented at a WEF-sponsored seminar at Singapore in 1993.

Existing Situation in the DCs

Infrastructure In all six DCs (excluding South Korea as a semi-industrialized country), the existing urban infrastructure and housing are severely overtaxed, and this will get progressively worse unless, somehow, a marked increase in investment funding can be realized. Even South Korea is suffering from similar problems. The primary sector problems are as follows:

- *Water supply:* Quantity of supply is usually "Acceptable," but generally the water as delivered to house taps is not safe, and generally there are very high unaccounted-for water losses. Also, major cities like Jakarta, Surabaya, and Manila (and Bangkok) are having increasing difficulty in obtaining raw water supplies sufficient to keep up with increasing urban/industrial growth due to the lack of coordinated river basin planning and control needed to achieve a proper balance in water use, and especially to reduce large wastages in traditional irrigation practices.
- *Sewerage and excreta management:* Service generally is not bad in affluent urban areas in the six DCs, either by sewers or by on-site subsurface disposal; but the excreta in nonaffluent areas including slums, except for some urban areas in Indonesia, is more or less uncontrollable, resulting in very serious enteric communicable disease hazards. South Korea, following the Japanese pattern, is proceeding to provide sewers to all urban areas (South Korea now has the affluence to afford this).
- *Sewage treatment for water pollution control:* There has been little if any meaningful investment in most urban cities in the six DCs, except for Malaysia, where municipal sewerage practices introduced by the British are still followed to a limited extent, no doubt because of the relatively favorable position of Malaysia municipalities with respect to local financing. The resulting massive river and coastal water pollution in most DC urban areas, and of course uncontrolled industrial wastes, intensify this problem. South Korea, with its new affluence, is just now embarking on a massive national sewage treatment program covering 100 major cities.
- *Flooding and drainage:* This is a serious problem in all six DCs in the poor people areas, which are generally located at the lowest elevations. It has not received much attention precisely because it is the poor people who are suffering. This problem is increasingly intensified by the development of more infrastructure (like highways), which results in increasing flood runoff into the low areas, without regard by the planners for this impact.

- *Solid wastes:* In most of the DCs the problem is already very serious, with adequate collection services generally limited to affluent areas, and lesser and quite unsatisfactory collection services elsewhere, and generally with disposal from all areas by dumping, resulting in plenty of land and water pollution. It also poses serious public health hazards, since municipal garbage is almost as replete with pathogens as is municipal sewage. In Malaysia, disposal previously had been managed fairly well using landfilling by individual cities, but in heavily urbanizing and industrializing regions like the Klang Valley, no more land is available for individual city use because of prohibitive haul distances, and hence the need is for regional solid waste management systems.
- *Slum improvements:* Of the six DCs, only Indonesia has given meaningful attention to this problem through its "KIP" (Kampung Improvement Program) for upgrading the slum area infrastructure (leaving the homes alone), which has been remarkably successful[155]. This is a massive problem in the other five DCs, except in Nepal where it is expected to develop soon, and in three of them (Malaysia, Pakistan Philippines) the governments continue to insist that the slum inhabitants (mostly illegal squatters) do not belong there, and hence can be neglected despite the huge hazard to public health thus imposed on the entire community. Attempts to solve the problem by use of public housing in the city and by relocation to condominiums out in the country have failed due to the high expense, and due to the relative scarcity of jobs in the country. The Indonesian KIP program represents an innovative practicable solution. It is slum infrastructure upgrading, including legalization of squatters. One of the innovative findings of the Indonesian KIP experience is that on-site leaching pits for excreta disposal, considered by most as not suited for concentrated urban areas because of failure of some of the units (posing health hazards to all), can be made to give overall acceptable service simply by furnishing special subsidized desludging service for the poorly functioning units, which are usually a small percentage of the total. Another interesting finding is that, where piped water service is not feasible, many slum homes utilize shallow tube wells for domestic water supply, and while this water is invariably polluted, the people diligently boil all water before drinking. This boiling practice is used even in affluent areas of Jakarta, where the main municipal water treatment plant has never been operated "as designed" and routinely produces unsafe water.

Institutional Aspects

- *Laws and regulations:* There are ample laws, but they are generally uncoordinated and overlapping in all seven countries, and in the six DCs there is little meaningful enforcement. The study of the Klang Valley region in Malaysia, where the capital of Kuala Lumpur is located, indicated about 20 to 30 percent enforcement, and Malaysia is relatively quite advanced in enforcement compared to the other DCs. The need is for each country to prepare a consolidated law with clear delineation of responsibilities, which is enforceable, and to enforce it.

- *Central versus municipal government roles:* In practically all of the DCs to some extent, the central government agencies have practically all the authority, expertise, and control of funds (limited as they are); while the municipal governments are assigned the bulk of the responsibilities but have very little authority, expertise, and funds.
- *Status of national policies, strategies and planning:* In all six DCs there is negligible or little attention to formulating or implementing a coordinated policy/strategy/planning so that the limited funds available for municipal infrastructure can be wisely used. The pattern continues to be a piecemeal process, with each implementing agency operating as its own "fiefdom." There is little if any attention in most of the DCs to formulating appropriate standards of minimum acceptable infrastructure/services to serve as the basis for optimal cost effectiveness for future investment, and many projects continue to incorporate Western practices, which are often inappropriate for DC use. South Korea is now planning to implement a massive national sewerage program.
- *Better use of informal and private sectors:* The findings here are that (1) the informal sector can create jobs at greatly reduce investment capital per job created, hence attention should be give to planned and systematic use of this potential, and (2) the private sector potentials need to be utilized in a systematic way to assist not only in financing but in furnishing skills that the government sector can hardly do because of salary constraints, such as for operating and maintaining water supply and sewerage systems.
- *Dearth of planning:* There is a great dearth of meaningful national/subnational planning on needs for E-c-E infrastructure services in all the DCs, which is essential for guiding continuing investment and to get away from the syndrome of uncoordinated piecemeal investments (often with inappropriate components). A carefully thought-through strategy/plan is needed so that the limited funds can get optima1 returns, with decent attention to the urban poor, including use of appropriate design technologies to reduce ineffectiveness and to reduce needs for sophisticated O&M skills. This is an overriding highest priority need in all the DCs.
- *IAA involvement:* All of the poor DCs stress the need for increased assistance from the IAAs, both for funding and for expert guidance on planning and on appropriate use of the EIA process.

Urban Growth Management/Action Strategy

National Strategy The critical need in all six DCs is to prepare a national industrial expansion plan, based on E-c-E principles, to furnish the needed employment in the urban sector, including selective use of the subnational E-c-E planning process that can produce detailed guidelines on how to meet minimal infrastructure requirements in the most cost-effective manner for accommodating continuing urban/industrial development. This would include (1) establishing a reliable matching economic/environmental database, (2) establishing appropriate standards for urban infrastructure, with attention to the urban poor and urban slums (poorest of the poor) as well as the urban affluent, for guiding development of matching infrastructure design technologies, (3) fair distribution of total infrastructure investment funds, both within the individual urban areas and between the capital region and other urban areas, and (4) clear delineation of urbanizing/industrializing areas versus rural areas. Some beginning efforts in this direction have been made in South Korea and the partially industrialized DCs.

Local Municipal Planning The critical need everywhere is to replace the conventional discoordinated piecemeal approach, carried out by essentially independent local government "fiefdoms," with integrated planning that achieves optimal cost-effective progress within the constraint of limited funds, including use of appropriate standards/technologies and including fair distribution of benefits between urban affluent/urban poor/urban slum areas, and including effective use of the EIA and subcountry E-c-E planning processes.

River Basin Planning In the partially industrialized DCs (as well as South Korea), it is becoming recognized that sooner or later, it will be necessary to establish River Basin Authorities to solve the increasingly severe problem of managing the water resources in a river basin, so this limited resource can be optimally used with minimum wastage to meet all development needs (rural and urban). Although worldwide experience in the ICs has shown this to be the only practicable solution, it is never easy to make the change because of conflict with established government authorities. However, it must be done, and both the national governments and the IAAs should give persistent effort to achieve this in basins where the problem is acute. From the urban development point of view, the problem is becoming more and more serious in that the capital and other major cities are usually coastal cities with their surface water river supplies being "dried up" by upstream irrigation development using excessive amounts of water.

Decentralization/Taxation In virtually all DCs, the message is clear that the only feasible solution to the problem of obtaining the needed additional funding for urban infrastructure must come from municipal property taxes and service charges, and moreover, that the taxing power must be decentralized so that the municipalities will not only have responsibility for municipal infrastructure but will also have the authority/funds resources to manage this. This would encourage local authorities to give attention to problems of environmental degradation through effective use of EIA and Regional E-c-E planning as valuable planning tools. Also, the IAAs need to contribute their influences for helping to achieve this transition.

Slum/Squatter Areas As already noted, in all the seven countries these areas must be given a fair share of the total municipal infrastructural/services investment, and in addition the planning of all municipal infrastructure/services projects must be reoriented, through use of EIA process, so that these projects give due attention to poor people problems. Virtually all conventional (Western) infrastructure/service design criteria, which were developed for use in essentially urban affluent areas, are not applicable to DCs in that the resulting projects almost invariably advantage the affluent and disadvantage the poor (for example, urban highways invariably create serious poor people severance problems that are only partially offset, and they compound poor people/low area drainage problems with no offsetting).

There is increasing recognition by most DCs that the only practical solution to the squatter areas (instead of doing away with them because they are "illegal") is by upgrading the slum community infrastructure/services and letting the individual householder attend to his housing, which is a far cheaper solution than public housing or relocation to remote condominiums. Indonesia has made impressive progress in this, and South Korea, Pakistan, and Sri Lanka are beginning to believe it. The trend is certainly in this direction.

Better Use of Informal and Private Sectors There is increasing recognition in the DCs of the need to make much more effective use of the informal sector for helping to create jobs (at relatively very low capital investment cost per job), of the private sector for helping solve infrastructure/services problems, not only through financing taking on O&M assignments which can hardly be handled by government agencies because of low salaries, and of NGOs for aiding/abetting the government agencies to get action on urgent critical problems.

Economic Instruments As already noted, while NEcPAs have tended to ignore environmental degradation in the past (i.e., to give it only a kind of add-on-attention), there is beginning recognition in all DCs that deregulation alone can hardly be expected to solve problems of environmental degradation. Rather, the need is for optimal use of reoriented economic policies. This includes adjustments not only in investment policy but in virtually all economic policies involved in DC development, including trade policies, energy policies, access to resource policies, and so on. There is urgent need, also, for preparation of a new "Manual of Appropriate Economic Analysis for DC Project Development," for use both by DCs and IAAs to ensure due consideration of the sustainable/E-c-E approach in future project planning.

Effective Control of Environmental Degradation

The NEcPAs must give No. 1 priority to seeing to it that E-c-E principles become an integral part of all governmental operations, including its own operations, including giving guidance/support to the NEnPA and NEcPA to enable them to develop and work effectively, including establishment of meaningful environmental units in the planning divisions of the major governmental implementing agencies, including insistence on appropriate use of the EIA to be an integral project feasibility planning, and selected use of the subcountry E-c-E planning process. Without strong NEcPA support, the NEnPA cannot be successful.

Strengthen the NEnPA (at least in its components relating to urban development, looking at this from the urban point of view) so that the NEnPA capabilities/resources are sufficient to do a meaningful job, which has not been yet the case in any of the seven countries. In the poorer DCs, the situation is pathetic, but some meaningful progress is now being made in Indonesia, which is now launching an innovative large-scale program including establishing of an "NEnPA affiliate" for proceeding with local action on such issues as industrial pollution control and pollution cleanup in river basins experiencing heavy growth. In Thailand, a similar approach is envisioned under a new environmental law, by delegating environmental responsibilities to the provincial governors, together with resources to enable them to act.

In general, the budget resources available to the NEnPAs are very low compared to the situation in the United States (and extremely low in the poorer DCs); hence, a critical study is needed for developing guidelines on minimum "bottom 1ine" budget/staffing levels appropriate for DCs. This does not suggest matching U.S. levels, but certainly more than one percent or a few percentages of U.S. levels.

Follow-up Evaluation of ADB Study

Purpose of Study The report on "Economic Policies for Sustainable Development," published by the Asian Development Bank in September 1990, was based on detailed case studies of national development problems in seven selected Asian countries, namely Indonesia, Malaysia, Philippines, Pakistan, Sri Lanka, Nepal, and South Korea. The country reports considered the present and projected future conditions involved in continuing economic development of the countries, considering all environmental sectors, especially as related to the problem of relentless population growth and accelerating rural to urban migration. A follow-up study was carried out by the ADB in 1993[111] to make an analysis of the detailed information in the country reports with respect to the mushrooming needs for urban infrastructure and services. This appears to be perhaps the paramount environmental problem to be faced up to by the DCs over the next several decades.

Methodology Based on preliminary review of the country reports, a "standard format" (four pages) was prepared that lists the various items discussed in the reports in a systematic manner, as related to urban environmental development. The main items of this listing (each of which has a number of sublistings) are the following:

- Urban Growth Management Existing Situation
  - Urban population growth
  - Employment and incomes
  - Poverty and slums

Infrastructure/housing facilities
Infrastructure/institutional aspects
Extent of environmental degradation (ED)
Control of environmental degradation
Urban Growth Management Proposed Action Strategy
Planning
Decentralization
Greater policy focus on poor people
Better use of nongovernmental sectors
Financing
Establish meaningful EPC in near future
Industrial Growth Management Existing Situation
Background
Economic aspects affecting ED
Adverse environmental effects
Adequacy of waste management
Planning needs
Industrial Growth Management/Proposed Environmental Action Strategy
Planning
Economic policies reorientation
Establishing effective regulatory control of pollution

Results of Study The detailed study findings are summarized in a series of matrices, including each of the items just listed, each with various subheadings, and a judgment evaluation for each of the seven countries the seriousness of the problem.

Conclusions The inevitable acceleration of urbanization and industrialization in the DCs poses unprecedented problems to the DC governments, not only in nature but in magnitude, and the No. 1 task facing the governments is to change their economic development behavioral patterns, and to do this promptly, in order (1) to create the needed jobs to support the massive population influx, (2) to furnish urban the infrastructure/housing to accommodate the growth needs, including obtaining a much higher level of financing for this purpose by use of taxation and service charges and including innovative use of planning so that the available funds can be wisely invested in an integrated urban development approach, including decentralization of authority/resources for urban infrastructure/housing problems to the municipal level where it belongs, and (3) to accomplish this in an E-c-E manner that reduces urban environmental degradation problems to acceptable levels.

To accomplish this, a huge increase in technical assistance investment is needed for developing the needed appropriate technology for guiding future planning and project implementation. For example, it is clear that manuals of appropriate technology are urgently needed, as follows:

- For setting appropriate minimum acceptable standards for urban infrastructure/services, for all categories of developments, with "equal attention" to affluent, poor, and poorest municipal areas
- For design of urban infrastructure systems (including water supply and waste management) that are appropriate (which give acceptable levels of service at affordable cost), with special attention to ensuring adequate O&M, for all categories of development
- For conducting EIAs, including follow-up monitoring for all categories of urban/industrial projects, in sufficient detail to facilitate wide-scale use and application of the EIA process (similar to engineering design handbooks)
- For planning and conducting appropriate environmental monitoring programs, including all aspects of community environment including quality-of-life and socioeconomic aspects, including institutional and financing aspects, including periodic evaluation of the monitoring data for use in planning needed improvements, and including establishment of an appropriate national environmental database adequate for assessing environmental quality in quantified terms suitable for use by both environmentalists and economists

Essay on Urban Population Growth in DCs

The rural to urban influx is increasing not only because of the economic pressure but also because of the impact of modern communications (especially TV, the internet, and cell phone) in alerting the rural people to realize that life in the urban sector, even if one has no job, will generally be much better than in the rural in terms of both earnings and quality of life. A World Bank officer who worked in Calcutta (India) in the 1960s remarked that the homeless people who slept on the streets (a million at least) were actually "bankable" people. By doing odd jobs, their income was much higher than their rural cousins, and the sidewalk-urbanites were sending appreciable monies to their rural relatives every month.

The term *quality life* reminds me of the author's work in the Belgian Congo (now the Congo Republic) in the 1950s, to assist the Congo's chief engineer and deputy governor general, on urban sanitary engineering planning. He noted one day that the black natives who made up most of the population of the capital (then Leopoldville, now Kinshasa) had immigrated to the city from the "bush" (the rural areas), attracted by the urban employment opportunities, and that to his knowledge, not a single one had since returned to the bush. Once the native tasted the "Wine, Women, and Song" readily available in the urban sector (and almost nonexistent in the bush), nobody ever left. Later on, working with a Belgian who was chief engineer for Katanga Province, a visit was made to the province's maximum-security prison (for hardened criminals) to observe pipe manufacturing with prison labor. The prison guards were mostly asleep, and the chief engineer noted that nobody ever tried to escape because life in prison was far better than in the bush. Nowadays, the rural peasant almost everywhere can see on TV that his urban cousin is enjoying a much higher quality of life, and the ruralite often abandons the farm (even if his situation there is viable) to head for the city.

One illustration of this situation is experience in East Java in Indonesia on a World Bank irrigation project in the 1980s[152], namely, a Sunday tour to talk to typical farmers. It was found that while most farmers worked essentially to grow rice, a few had invested in chicken raising to produce eggs to sell to the provincial capital market at Surabaya and thus realize some cash income all year round. Only a few had the investment resources to do this. One of these explained, when asked if he/his family ever ate any of the eggs, that the eggs were much too expensive for them to consume, but his two younger brothers, who had been forced off the farm to become urbanites (typical family of three sons, but only enough land for one), and who had become taxi drivers, yes, they often ate eggs.

Another final illustration of the rural to urban scenario is a TV cartoon movie, which features a young coyote ("YC") who lives in the uninhabited open bush areas of eastern Riverside Country in Southern California (one drives through this region in going from Los Angeles to Las Vegas). He's happy there, including working at hunting 10 to 12 hours per day (mostly chasing rabbits) to get enough to eat. It's all he knows. One day, while chasing a rabbit in the northern part of his hunting territory, which borders on the highway, it happened that a big truck/van stopped there, and the driver opened the back to take out a package for delivery to a local gas station, leaving the door open. The rabbit ran in, the YC after him, and the driver returned, closed the door, and took off. When the truck stopped and the door was opened, the YC got out and found himself in the foothills residential area of Hollywood/Beverly Hills (populated mainly by very wealthy people). He promptly ran up into the mountainous hills that overlook the L.A. basin, where he soon found a pack of coyotes who took him in. These guys were living in the lap of luxury. They spent less than an hour per day having a banquet, in the early morning, by feeding on a deluxe variety of delicious foods contained in the house garbage cans that they overturned. Instead of eating only rabbits all the time, and not very much of that, he enjoyed choices of beef, pork, veal, whatnot, even rabbit, plus all sorts of desserts. Our YC soon became sleek (no longer skinny) and with his ample time soon found a girlfriend and had endless recreational fun with her, howling together especially in the evenings. It was too good to be true, for long. The women organizations of Los Angeles County, who believed that the "Hollywood Way of Life" was not good for the coyotes and that they should be caught and returned to wilderness areas, forced the county to set up a governmental unit to do this. Yes, our YC got caught, and it happened he was returned to the very place where he had come from. At first, he was very glad to be "home," to see his friends again; however, after a few weeks of all work and no recreation, the story ends when the YC stations himself near the highway, waiting for another truck to stop and leave the rear open. It happens; the YC runs in, the driver returns, closes the door, and drives off.

URBAN SLUMS

Background

As noted in the section on "Megacities," a massive immigration of rural farmers to urban cities has been underway for several decades, which is "unstoppable," and the existing cities being enlarged have been able to furnish the infrastructure and housing sufficient to accommodate only part of the immigrants, leading to formation of large slum areas with very inadequate housing and community facilities including environmental infrastructure/facilities (water supply, excreta management, solid waste management, drainage, roads/access lanes). This section on Urban Slums describes the experience and findings of two major slum management studies/projects, one in Indonesia and the other in Malaysia.

Indonesia Kampung Improvement Projects (KIPs)

New Approach to Slum Management In the 1990s, the governor of Jakarta "invented" a new approach to handling the urban slum problem in which abandoned than the conventional approach of tearing down slum housing and moving the families to new housing outside the city, which hardly solved the problem because of lack of employment in the new housing areas, requiring the workers to travel back to the city to be employed, through wasting both time and travel costs. In the new approach the city furnished these facilities to the slum areas with the expectation (which did happen) that the families would then upgrade their homes to match their new environmental situation. An evaluation of this in 1976 for a WHO sponsored project for planning a metropolitan sewerage system for Jakarta, showed that the governor's project, to be really effective, needed improvements, and these were subsequently planned and implemented with World Bank support[43]. The success of this effort led to expansion of the "KIP" (kampung improvement program) approach to many other cities throughout Indonesia.

The sanitation facilities furnished in this program[154] included provisions for (1) piped water supply including delivery to homes that could afford individual house connection changes, with public taps (operated by a paid tap manager) for other users, (2) use of pour-flush toilets with excreta disposal using dual leaching pits, (3) periodic pickup of refuse, (4) pathways for enabling access to homes above flood levels, (5) adequate drainage (with the KIP dwellers themselves furnishing the labor to keep the drains clean and functioning), and (6) public centers with toilets, washing facilities, and bathing facilities, including payment by users at low charge levels.

The dual pit leaching system for disposal recognized the need for (1) two pits so that one would be in use while the other was being desludged, (2) a special desludging unit of the municipal government for desludging service to the homes designed to work effectively in narrow access[154].

A very important aspect of the KIP program was recognition that, while many if not most of the slum residents were squatters who had come to the cities "illegally," hence previously not considered eligible for assistance, but in fact these people were citizens who were there to stay hence deserving of assistance.

Quantification of Impacts of Jakarta KIP A paper prepared for presentation at a UNEP conference on slum management at Bangkok in 1976[43] evaluated the information derived from the KIP projects in Indonesia cities with the objective of quantifying the actual impact of the water supply and sanitation improvements furnished by the KIP projects. The Jakarta KIP in 1969 to 1972 covered 88 villages with 2 million people. Some key findings are the following:

1. *Definition of KIP sanitation component:* This was defined as including the following components:

   Water supply: Facilities for making water of acceptable (good and safe) quality and of sufficient quantity available to village residents.

   Public hygiene: Facilities for enhancing use of this water for promotion of community sanitation, especially toilets, plus washing and bathing facilities, usually in the form of "MCK's" (public hygiene stations located at strategic points in the village), available at low rates (costs partially subsidized by government).

   Excreta management: Sanitary sewerage system when affordable. For homes not connected to sewers, use of pour-flush toilets with dual leaching pits, with availability of a community pit desludging service with affordable service rates.

   Surface drainage: Provision of minimum surface drains to maintain a reasonably dry community environment most of the time.

   Access ways: These are pathways high enough to enable villagers to reach their homes form the roads in the rainy season without traveling in water.

   Solid wastes: Minimum facilities for collection, hauling, storage, and disposal of solid wastes.

2. *Water supply* The basic problem is the cost for individual homes to afford individual house connections. One solution is to permit on several houses to be served together as a single unit (up to 10 houses), with a single meter and single connection fee, and moreover to permit this fee to be paid in easy monthly installments rather than requiring payment in advance. It is estimated this reduces the average per house cost for installing connections to houses by about 50 percent. Where public taps are used, the key problem is to ensure it is properly operated/maintained. The usual solution is to assign management rights to the individual homeowner who allows a portion of his land to be used for the tap, with authority to charge for the water at established rates.

Expansion of KIP Program to Cover Entire Country The success of the initial Jakarta project, including the World Bank sponsored improvements to the original Jakarta KIP implemented by Jakarta on its own, resulted in subsequent expansion of the program to include many major secondary cities throughout the country.

A significant “political” problem occurred at Jakarta where some of the tap franchise holders built water storage tanks plus pumping to enable them to “suck up” the water supply in the surrounding distribution system (their authority legally permitted them to serve only a fixed number of families); thus, enabling them to go into business on their own, due to the lack of adequate governmental controls, stemming mostly from the diverse ethnic groups in the city. No such problem occurred with the KIP project at Surabaya where the city has no ethic divisions and the city government did establish effective controls.

Urban Slum Sanitation Planning Manual The Jakarta KIP experience led to a project for preparing a World Bank design manual on how to plan/design KIP facilities including provisions for management, financing, and O&M[154]. This manual is one of the Bank’s “Kalbermattan” series of manuals on Low Cost Sanitation Manuals for use by DCs prepared in the 1980s. Home sewage disposal utilizes pour-flush toilets with dual leaching pits, with special desludging service operated by the municipal government, which is equipped with special trucks, and pumping to gain access to homes located on narrow lanes.

Klang Valley Environmental Improvement Project (KVEIP) An ADB sponsored project, the “Klang Valley Environmental Improvement Project” (KVEIP) completed in 1987[5], prepared a master plan for recommended environmental improvement in the Klang Valley region of Malaysia, which includes the capital (Kuala Lumpur) and many other cities and is the major industrial region in the country. And, of course, this region had been a “magnet” for attracting immigration from rural areas, resulting in formation of large-scale slum areas in the region. One of the components of the overall environmental planning was the task on what to do about these slum areas, mostly inhabited by “illegal” people who entered the region without government permit to change their place of residence. Hence, they were legally classified as “squatters” without any obligation by the government to provide for them.

Because of their legal policy, the government established a governmental unit, equipped with bulldozers, with the job of destroying the squatter homes. At the time, the costs of housing had increased to levels no longer affordable even to some nonsquatter people, and some of these moved to live in the illegal but cheap slum housing, including the chief of the slum bulldozing operations. Discussions with him showed that the home destruction approach was not working because the squatters promptly rebuilt the homes within a period of days.

The problems of the slum areas were very similar to those of the kampungs in Indonesia. Based on the success of the Indonesia KIP experience, the KVEIP study prepared a recommended project following the same KIP approach, including provision of a project for upgrading the community service facilities in these slum areas following the KIP guidelines. This included an economic analysis that showed that if these areas were upgraded as proposed, the value of the land in the surrounding neighborhood would be increased more than enough to offset the cost of the slum improvements. However, while ADB welcomed this proposal, Malaysia's Economic Planning Unit (EPU) (the NEcPA of Malaysia), which was in top-level charge of the KVEIP project, vetoed the proposal in apprehension that this would further increase the illegal immigration problem.

URBAN SANITATION

Although many aspects of urban sanitation are discussed in other sections of this chapter, some additional information on selected subjects is provided here.

Ports and Harbors

A common problem in DCs is that design of ports and harbors generally pays little attention to furnishing adequate provisions for sanitation/water pollution control. Guidelines for helping resolve this problem were prepared for use in Thailand in 1980[50].

One of the findings of the major programs in water pollution control in the industrialized countries over the past two decades is that ports/harbors, as conventionally designed, built, and operated, tend to become "sanitation messes," with much lower sanitation levels than the rest of the urbanizing zone in which the port/harbor is located. It was found that this occurred because sanitation facilities in port/harbor areas had been planned the same as for urbanizing areas in general, without recognizing that special provisions must be made in the design of the port/harbor complex if acceptable sanitation conditions are to be maintained. In addition, it was found that it is relatively inexpensive to solve this problem for new ports/harbors if appropriate special sanitation measures are incorporated into the system from the outset, and that if this not done, it will be very expensive (and perhaps unaffordable) to correct the situation later.

The evaluations made of actual sanitation mess situations in the United States and elsewhere have shown that the following measures must be incorporated into the planning/design of the port/harbor complex in both ICs and DCs if it is expected to be able to maintain an acceptable level of sanitation in the port/harbor area, including consideration both of shipping and of shore installations:

1. Provision of an adequate water supply distribution system recognizing the extraordinary water supply demands in port/harbour complexes (usually considerably higher than for other urban zones), including pier installations for hose connections for furnishing fresh water to ships.
2. Provision of an adequate sewage collection, treatment, and disposal system serving the entire complex, including a shoreline interceptor for receiving liquid wastes from all shoreline installations. (In conventional practice such an interceptor is usually not provided because it is expected that slips will discharge treated sewage directly into the harbor waters.)

3. This includes provision of special hose connections so ships can readily connect to them and discharge their sewage, bilge water, and other liquid wastes into the sewage collection system. (Without these, it can be expected that most ships will discharge raw sewage and bilge waters directly into the harbor waters.)
4. Provision of a comprehensive solid waste management system for the entire complex including provisions so that ships can readily be serviced by the system, otherwise the ships will likely dump the wastes into the harbor.
5. Where the port/harbor is to be used for importing or exporting petroleum oil or products from refining of oil, additional special measures must be provided to control the hazard of oil spills.

Coastal City of Chonburi in Thailand

Many of the homes in the coastal area of this city are built on stilts over shallow coastal water areas that, in earlier years, were regularly cleaned by tidal flushing, but because of coastal development the sewage discharged from the homes remains under them—hence, these areas are a "sanitation mess." A study done in 1984[132] recommended that the city correct this problem by filling the space under the homes with city refuse, which will promptly be consolidated and stabilized because of its water content (see section "Urban Solid Waste Management"). The initial work would be done by the city with no cost to the homeowner. The work would involve filling the sites with refuse in a systematic manner up to the desired ground elevation, covering if with a thin layer of soil to eliminate problems from rats, odors, and so on, and periodically continuing the process as the refuse degrades and settles until a stable fill to the desired depth is achieved. Once the homeowners are confident that the filling enhances sanitation and increases property values, it is anticipated they will want and even demand the service and may be willing to pay for it.

Public Water Supply Taps

While public water supply taps are widely used for improving environment in urban slum areas, these are also valuable for use in other municipal areas where house connections are generally unaffordable. A review of this usage on Asian DCs, made for the World Bank in the 1980s[71], resulted in the following eight findings:

1. While the construction cost of the public tap varies widely (in the range of \$100 to \$1,000), the indicated usual cost is about \$400 for an installation sufficient to serve about 30 families (average of seven persons) with an average consumption of about 30 lcd (or about 6 m^3/d per tap). The price of water delivered to the tap (paid to the municipal water agency) is in the order of US\$0.10, or 10 cents/m^3, and the price to the family getting water directly from the tap is about 40 cents/m^3. Where vendors are used, the price to the public is usually three times as much.

2. The cost for one house connection in the same slum area is about 0.3 of that for a public tap, or as much as $120. Consumption is much higher, around 150 lcd or five times as much, with the price to the householder about the same per m^3 as paid by the public tap manager. Thus, the investment cost per family for the house connection is more than 10 times as much as for using a public tap. However, the unit water charge is considerably higher for public tap water in order to gain sufficient revenues to pay for tap management, including operation and maintenance.
3. The percentage of homes in a slum area that use public taps varies widely. The average is about 50 percent each for use of public taps and for use of house connections (including sharing of one house connection by several families). This indicates that most urban slum areas are populated by families of diverse income ranges.
4. Most public taps installed are being utilized more-or-less as planned, but little feedback information is available to permit reorientation of the planning/design criteria to obtain a much higher percentage of success. Very few urban slum improvement projects include budgets for post-construction usage monitoring which would furnish the needed feedback. This represents a gap in the planning of urban tap systems that, hopefully, International Assistance Agencies will take into account in the future. Moreover, periodic usage monitoring can be effectively combined with monitoring for evaluating O&M needs, another serious gap in conventional public tap planning.
5. Continuing tap management is essential if the facility is to remain intact and be wisely operated with efficient use of water. For the reason, taps may best be located on private home property, with an agreement with the homeowner to be responsible for tap security and management, including collection of fees established by mutual agreement between the homeowner and the municipality.
6. A typical slum area includes a wide range of family incomes. The source of supply varies accordingly, from (1) individual home wells (using a hand pump), to (2) public taps with self-service, to (3) public taps with vendor service, (4) shared house connections, and (5) individual house connections. The tendency is to progress upward in the series as family income increases.
7. With effective tap management, the municipal water authority can be reasonably reimbursed for its actual costs for furnishing water to public taps. Where the municipal agency cannot exercise controls, some of the taps are likely to be converted to local private-sector water supply businesses, with only a part of the delivered water being paid for. Hence, arranging for competent management is essential for a financially viable program.
8. The results of this study indicate that it should be very worthwhile for an interested International Assistance Agency to sponsor a project to obtain much more detailed information on experiences in using public taps in urban poor people areas; to analyze these data; and to prepare a manual of guidelines to assist in planning public tap programs in DCs. The proposed

study should include consideration of all parameters that significantly affect the planning and implementation of public tap projects, including (1) technical design criteria, (2) institutional aspects, including procurement of land, and provisions for management, (3) operation and maintenance, (4) financial aspects, (5) economic and socioeconomic aspects, and (6) provisions for continuing monitoring and feedback.

RURAL SANITATION

Very Low Priority for Attention

Rural sanitation is a major problem in most DCs because of the simple fact that governments are very sensitive to the urban centers (which have the potential for serious revolts) and are generally quite insensitive to rural areas (which have little such potential and are "out-of-sight, out-of-mind"). A typical situation is government responsibility for provision of rural town water supply in Thailand, which used to be the responsibility of the Public Health Ministry, where it received little attention for the reason already noted. Then in the 1980s, this was transferred to the Provincial Waterworks Authority in order to have water supply responsibility for all communities in the country (excepting the capital city of Bangkok) in a single agency, where it seems to be again receiving very little attention for the same reason[159].

WHO Manuals

WHO has produced a series of manuals covering virtually all aspects of rural sanitation, and these contain a great deal of pertinent basic sanitation. However, it is good to keep in mind that the standards utilized by these manuals sometimes are a bit too idealistic and too expensive for use in DCs, so some adjustments may need to be made. In the 1970s to 1980s, the World Bank decided to produce its own series of rural sanitation manuals titled "Low Cost Sanitation Manuals" (the "John Kalbermatten series"), which were planned to suit poor DC financing limitations. An example is[154] on use of pour flush toilets with leaching pits at Jakarta (Indonesia).

Xiaolangdi Resettlement

Sanitation Improvements The World Bank project for resettlement of families displaced by the major Xiaolangdi dam on the Yellow River completed in year 2001[160] gave careful attention to provisions of (1) use of wells for water supply, with protection from surface contamination, for all homes in the more than 60 resettlement villages, together with use of elevated water storage tanks, which served the very useful purpose of enabling ready disinfection of the supply using hypochlorite powder, plus periodic monitoring of chlorine residuals in selected house/public building taps, (2) provisions for handwashing by students leaving toilets (See see “School Sanitation”), (3) managing solid wastes from houses by furnishing routine pickup, storage in protected storage sites (to prevent public access, especially by children), transfer to landfill sites using sanitary landfill techniques, again fenced off from the public, (4) careful attention to provision of adequate town drainage plus planning for discharge of the drainage outside the town without flooding downstream areas. Unfortunately, the Chinese resettlement authority opted for use of dry toilets in the homes, instead of use of pour-flush toilets (to enable washing on exit), which could have been used, considering that all homes received piped water supply. Otherwise, these homes actually had sanitation facilities at the “semiurban” level, far better than those in the towns that the resettlers come from.

Household Excreta Management The World Bank project of the late 1990s for resettling villagers displaced by the Xiaolangdi dam on the Yellow River[160] included an estimate of the relative values of household excreta management systems for protecting public health, which is summarized in Figure 4.20. This compares the performance of (1) dry latrine toilet systems,

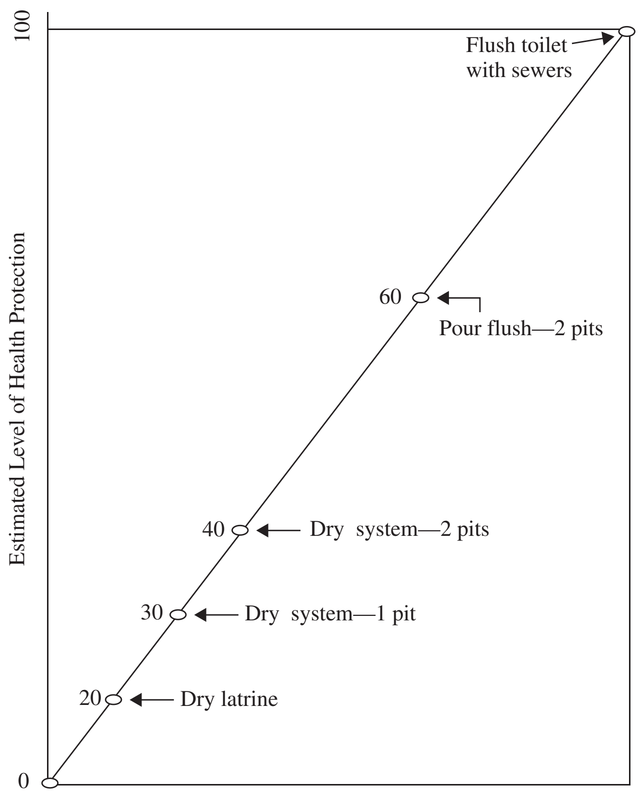


FIGURE 4.20 Health Protection Levels for Different Methods of Excreta Management.

(2) dry toilets with one receiving pit, (3) dry toilets with two pits, and (4) pour-flush toilets with two receiving pits, and shows that the pour-flush systems should be utilized whenever feasible. The pour-flush/two-pit systems not only permits washing before leaving the toilet, but also the water content in the receiving pit greatly speeds up sludge stabilization, so that the sludge removed (usually taken for use as fertilizer for crops), is very much safer for handling than dry pit sludge.

Village Environmental Officers (VEOs) The overall environmental program already noted for Xiaolandgi resettlement towns included attention not only to the water/sanitation facilities but also attention to all other significant village environmental issues including adequacy of roads, electricity service, clinics, and even the need for planting of trees to furnish aesthetically attractive green areas. To ensure continuing adequate attention to all of these the local governments for all of the resettlement towns, at the World Bank's recommendation, appointed a village environmental officer (VEO) for continuing monitoring of all the various environmental protection activities, with monthly reporting following a standardized format including recommendations to the resettlement program's director on needed improvements[81]. These officers are included in the upper echelon of the village governmental hierarchy and are paid for their services. An interesting finding is that all of the village chiefs expressed real enthusiasm for using the VEO, and at time of completion of the resettlement construction program, the VEO program was going very well.

Farm Animal Manures

The World Bank–sponsored Water Agenda study for north China's coastal provinces[163] found the bulk of river pollution caused by animal farms was due to drainage of unmanaged animal manures, and that this problem could readily be solved by requiring the farmers to utilize simple stabilization ponds with retention periods of 20 or more days. These ponds remove about 90 percent of the BOD.

Handwashing

The importance of handwashing can scarcely be overemphasized. Studies by the London School of Hygiene and Tropical Medicine reported in 2002[28] indicate that diarrhea alone kills more children than malaria, and the most effective preventive measure is to persuading people to wash their hands with soap after going to the toilet, cleaning a dirty baby, and so on, which will reduce disease incidence in their children by some 43 percent. The problem is to get DC governments together with private-sector soap companies to develop programs suited to particular countries. The World Bank has initiated a program in Ghana with plans to extend it to many other DCs.

School Sanitation

Review of design of school facilities in DCs showed that these designs often need improvement in two important aspects:

1. Provision of a handwashing basin at the exit from the school toilets, especially when dry latrine–type toilets are used, arranged (with monitoring supervision by a school staff member) so that the exiting students must pass this basin and use it to wash their hands, so that their excreta is not passed on to others, especially during periods of recess playing[160].
2. Location of school toilets as far as possible from school dining rooms. In the Philippines in the 1980s, it was found that school design manuals often placed dry latrine toilets next to the dining areas[49].

Hazard of Flies

The *Bangkok Post* newspaper published on article on February 2, 1991[19] that has proven to be of value in getting DC officials to understand the need for control of flies. The article reads as follows:

> Our Gulf war correspondent faxed us an ad for a pest control firm published in an English-language newspaper in Saudi Arabia. It says: “This is what happens when a fly lands on your food. Flies can’t eat solid food, so to soften it up they vomit on it. Then they stamp the vomit in until it’s a liquid, usually stamping in a few germs for good measure. Then when its’ good and runny they suck it all back again, probably dropping some excrement at the same time. And then, when they’ve finished eating, it’s your turn. Had your breakfast yet?”

Septic Tanks for Coastal Homes on Stilts

A common pollution problem in DCs with homes built on stilts over nearshore coastal waters (e.g., in Malaysia) is how to manage pollution from sewage discharged from these homes. The recommended solution is to install a septic tank under the home, with a 24-hour retention period, which removes the waste components that if discharged are really objectionable, namely floatable and settleable materials[35]. The net discharge contains only soluble/colloidal pollutants, which generally are readily absorbed by the coastal waters. Provision must be made for a desludging service to be available for periodic tank dislodging (average about every 10 years).

Water Treatment for Homes Using Surface Waters

One of the suggestions prepared for assisting the National Environment Board of Thailand in the 1970s for improving the health of villagers who take their water supply from ponds or klongs (canals), which is common practice for many rural villages in the country, is for distribution to these homes (free or at low prices) of pill packages, containing sodium hypochlorite powder and alum, with instructions to the villager to flocculate the raw water in large jars, allow the flocs to settle, then add the hypochlorite powder, to be done in the evening, and by the following morning the supernatant water is safe for drinking.

PUBLIC HEALTH

Many of the other sections in this chapter deal with public health issues, especially the sections on urban and rural sanitation. In addition, an important parameter in evaluating public health benefits is the ongoing market value of a human life. This is discussed in the section "Environmental Economics and Financing."

Assessment by Asian Development Bank

A good summary of public health conditions in Asian DCs is given in ADB's 1999 report, "Policy for the Health Sector"[13]. This shows that health conditions in Asian DCs have much improved over the previous 3 decades for the general population, but of course the level of improvement has been much less in the poverty poor social sector. The IAA projects have focused on furnishing primary care clinics in the rural villages. However, the book *The White Man's Burden* by W. Easterly (2006)[27] shows that the poor sector is disadvantaged in the IAA-sponsored health improvement programs for the usual reasons, for example, the situation on malaria control in Africa where more than 300 million people per year are infected with malaria, with more than 70 million deaths per year, mostly infants and preschool children. Insecticide- treated mosquito nets, which cost a few dollars, can prevent most infections and another few dollars for medicine give effective treatment. Easterly notes that when the IAA projects handed out free mosquito nets in poor DCs, many of the nets are diverted to the black market and wind up being used as fishing nets or wedding veils, and a similar story for the medicines.

Water Supply and Sanitation

"The Truth about Public Health Protection and Community Water Supply/Sewerage in DCs" (2003), reviewed the author's experience on this subject[115]. This paper notes that since the establishment by the affluent ICs of the "Global System" for assisting the developing countries following World War II, the affluent ICs, operating through various IAAs, have carried out a vast array of assistance projects, including both technical assistance grants and attractive loans. In practically, all cases the control of the planning and design of these projects have been in the hands of the IAAs using planners and engineers who are experts in planning and design of facilities that suit the needs of the affluent ICs, but unfortunately, only a few of these officials are competent in understanding that the DCs cannot afford such systems because their state of economic development requires management of the problems with budgets that are only a fraction of those available in the ICs. The resulting systems that are built are often not suitable for DC use; hence, they do not function adequately, and the losses are very large. Unfortunately, the IAAs have chosen not to invest in post-construction monitoring of actual project performance (because it is much easier to assume satisfactory performance, and to collect facts to the contrary would be politically disturbing), and none of the DC governments have as yet invested in meaningful performance monitoring (such monitoring is routine in the ICs, but as yet is absent in the DCs).

With respect to the projects for sewerage and excreta management and for community water supply, the true picture is very unsatisfactory, particularly due to the utilization of IC designs/standards, which depend on skilled operation and maintenance (when it is known in advance that these will not be available). The result is that the investments furnish only a small fraction of the services and health protection that are assumed, with these assumptions are used to justify the investments. About the only beneficiaries from the projects are the community's affluent: "The rich get richer."

It is time to recognize this reality. What is needed is a project (financed, say, by the Global Environment Fund) that will make a critical evaluation of the actual performance of these water supply and sanitation systems, and then reorient the planning procedures to be realistic. This will include manuals of design and of operation and maintenance that match the DC realities, using systems that require the simplest levels of operation and maintenance skills, recognizing that the existing texts and manuals, with only a very few exceptions, represent use of conventional IC systems. Use of the private sector for operation and maintenance is another feasible option.

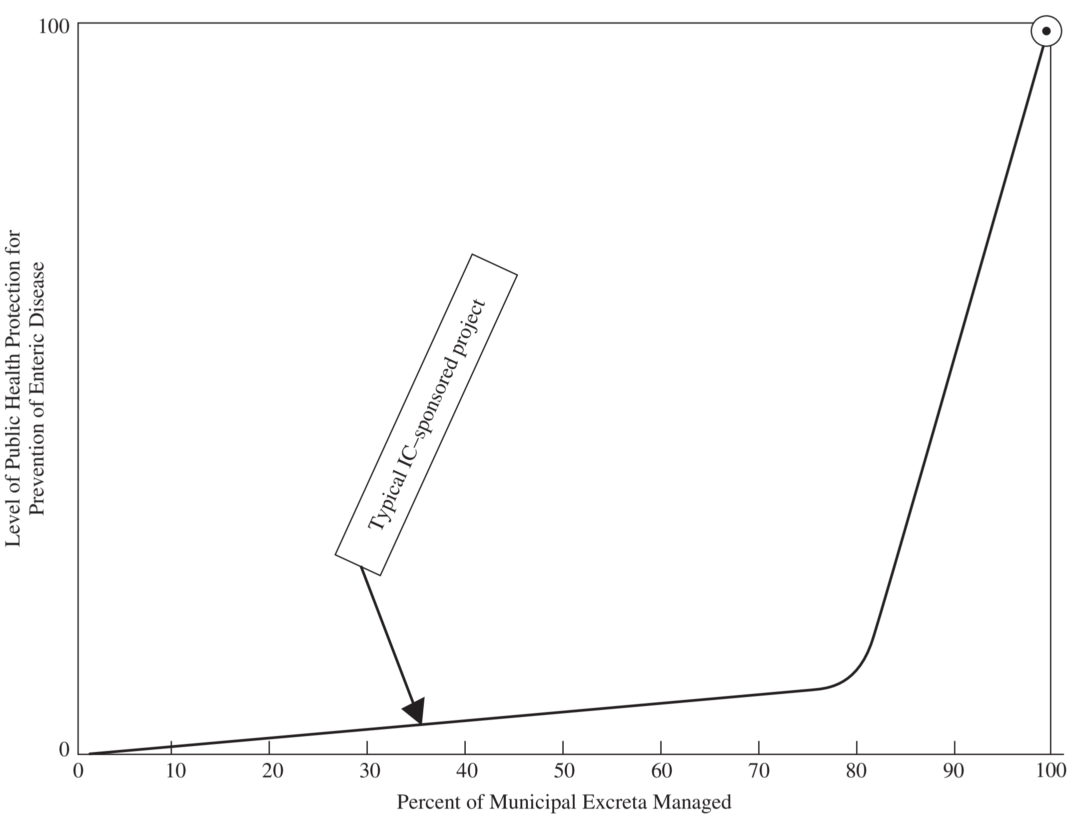
Figure 4.21 shows the author's estimate of the relationship of percent of excreta managed versus degree of community public health protection provided.

To summarize the United States/IC versus DC current situations on control of water-related diseases, the ICs have reduced the major diseases (cholera, typhoid, etc.) to negligible levels, and their emphasis today is on control of relatively minor water-related disease such as control of "crypto" and reduction/elimination of THMs in urban water supply systems, whereas these issues are hardly pertinent in the DCs, which have yet to achieve control of the major diseases. It is the author's estimate that current U.S. expenditures on the nonmajor diseases probably exceed the total expenditures of all DCs on the major diseases.

Disease Reporting

Philippines Reporting of disease cases is usually poorly managed in the DCs due to low budgets for this function. A study of this problem in the Philippines[57] in 1983 showed that the data reported by provinces varied a lot from the information in the annual reports of the Ministry of Health, and discussions with the responsible reporting doctors in the provinces showed they were employed only on a part-time basis with inadequate time for this task.

Resettlement Villages in China It was found, as part of the resettlement program for China's Yellow River Xiaolangdi dam, in most Chinese rural villages



Notes:

1. Even if only 10% of excreta is left unmanaged, the overall hazard is not much reduced.
2. Most municipal sewerage projects pronoted by World Bank, ADB, USAID, UNEP, etc. manage sewage only for affluent city areas. Hence, they provide little public health protection, yet these projects are often *justified* as overall community health protection projects.
3. In U.S., *everybody* in service area is sewererd.
4. In DC cities, only the affluent areas are sewered. Other areas use individual building on-site subsurface disposal units, which often function very inadequately.
5. To get real public health protection, need 100% excreta management = sewers for affluent areas *plus effective* sub surface disposal systems individual systems for each nonsewered areas.

FIGURE 4.21 Estimate of protection against enteric disease furnished by excreta management in urban areas in developing countries.

in the Yellow River basin the local pharmacies not only sell medicines but keep a careful record of the names/addresses of the villagers who buy them[160]. Every village had at least one pharmacy, all with competent pharmacists, who kept detailed daily records of names/addresses of all persons who purchased pills/drugs, including which kinds were bought and how much. These pharmacists' records clearly showed that the sale of pills/drugs relating to various diseases sometimes increased to much higher levels for a period of time, indicating an outbreak of a related disease. However, most of these illnesses were never reported to the local health offices. The project recommended that these data could be utilized as a very valuable supplement to the health officer's official records on disease morbidities, so the health officers could be on the alert whenever they notice any marked increase in the use of pills/drugs.

Jordan: Cholera Outbreak During the author's assignment on a USAID project in Jordan in 1984[60], the water resources ministry noted that, when a cholera outbreak had occurred in one of the country's cities, the government responded by putting the city's sewage treatment plant operator in jail—an indication of their level of knowledge on enteric disease epidemiology at the time.

Syria: Endemic Cholera at Damascus A WHO-sponsored project for planning of sewage treatment at Damascus in 1980 had the target of solving the existing problem of endemic cholera due to discharge of raw sewage into the river running through the city which was subsequently used for irrigating vegetable crops below the city, with the vegetables (with the cholera virus) then sold for consumption in the city[149]. The study proposed intercepting the raw sewage discharges on both sides of the river, treating the intercepting flows at a station below the city, then pumping the treated flow back for return to the river at a point above the city (to maintain steady river flow).

India: Enteric Cholera at Calcutta A WHO-sponsored project for improving water supply waste management, and drainage at Calcutta in the 1960s[146] included provision for chlorinating the river water that was used, separately from the city's drinking water system, for the city's firefighting mains, but this river water was also used as drinking water by about one million illegal squatters living in the city, as the logical and practical step to resolving the endemic cholera problem. However, after several years of such chlorination, the city council discontinued this chlorination with the argument that public health savings applied mostly to the illegal squatters who were not entitled to this expenditure.

ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

Difficulties in Application of EIA Process to DCs

The advent of the EIA process in the United States in the late 1960s (called the Environmental Impact Statement) was the initial step leading to the UN/Stockholm/1972

Conference that established UNEP and led to establishment of National Environmental Protection Agencies (NEnPAs) in the DCs around the world. This was a moment of great expectations, when it was generally assumed that the DC/NEnPAs would be able, like the U.S. EPA (the role model at the time), to make effective use of the EIA process to achieve control of all proposed development projects (as well as existing projects) so that their potentials for causing significant environmental damage would be brought under control. However, by the end of the 1970s and early 1980s, it became apparent that the DC/NEnPAs were not able to achieve effective control, primarily because of the lack of governmental will to permit this, including (1) lack of provision of effective monitoring/enforcement mechanics for ensuring project compliance for implementing the environmental protection measures specified in the project's EIA report, and (2) insufficient budgets for the NEnPAs to attract, train, and keep personnel skilled in administering the EIA process. This problem became painfully recognized in 1987 with publication of the UN/Brundtland report, which made a comprehension evaluation of environmental resource degradation in the DCs. It showed that the DC degradation that occurred in the 15-year period 1972 to 1987 actually exceeded all known historical degradation up to 1972[141].

For the reason already noted, the EIA has not yet been effectively utilized by the DCs, despite numerous IAA-sponsored training projects to try to help, but that didn't help much because of the low budget problem already noted and because many of the IAA/EIA trainers were not themselves knowledgeable in how to adapt the IC-oriented approaches to suit DC conditions. An important breakthrough on this problem was the publication by the Asian Development Bank in 1988 of a series of EIA guideline manuals, one for some 12 different types of developed projects, which were the first such manuals designed to suit DC conditions[6]. This series became an ADB best seller and was widely distributed and used by DC practitioners. These manuals were especially valuable in enabling DC/EIA practitioners, including both NEnPA staff and the private sector and other agencies doing EIA studies, to produce EIAs that are realistic in specifying environmental protection measures (EPMs) that are suited to DC conditions and thus have a realistic chance for actually being implemented.

Effective Use of EIA Process in DCs

The most effective use of the EIA process for DC projects has been (1) for projects built by major international private-sector companies to require preparation of a competent EIA and competent implementation of the EPMs specified in the EIA as a matter of the environmental protection policy set by the company headquarters, and (2) for projects with financing by IAAs such as the World Bank similar EIA requirements in order to get IAA project approval. Example of such World Bank projects are given in[160,162,164]. An important step by the World Bank, followed by the other MDBs, was the Bank's requirement that the Executive Summary of the EIA for a proposed project be made available to the public 6 months prior to the time for the Bank's loan approval, thereby giving NGOs and others interested an invitation to submit comments to be considered. This procedure is illustrated in Box 4.6, "Recommended DC/EIA Report Table of Contents".

BOX 4.6 RECOMMENDED DC/EIA REPORT TABLE OF CONTENTS

PREFACE

General Table of Contents
Abbreviations Utilized in Report

EXECUTIVE SUMMARY (ES)

CHAPTERS

1. INTRODUCTION
   - 1.1. Project Background
   - 1.2. Purpose of EIA Report
   - 1.3. EIA Methodology
   - 1.4. Environmental Study Area (ESA)
   - 1.5. Relation to Project Feasibility Study
   - 1.6. EIA Team
   - 1.7. Pertinent Reference
   - 1.8. Work Plan/Tesks
   - 1.9. Task Scheduling
   - 1.10. Report Preparation
   - 1.11. Summary
2. PROJECT DESCRIPTION
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   - 2.2. Project Production Components
   - 2.3. Environmental Production Components
   - 2.4. Project Time Frame
   - 2.5. Required Permits from Governmental Agencies
   - 2.6. Due Diligence
   - 2.7. Training Program
   - 2.8. Use of Local Personal
   - 2.9. Special Amenities
   - 2.10. Summary

3. ENVIRONMENTAL SETING
    3.1. Environmental Study Area (ESA)
    3.2. Environmental Resources in ESA
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4. INSTITUTIONAL SETTING
    4.1. Environmental Lews/Regulations
    4.2. Country Agencies for Managing Environmental Protection
    4.3. Environmental Standards
    4.4. Permits
    4.5. Summary
5. ENVIRONMENTAL IMPACTS AND RECOMMENDED EPMs
    5.1. Introduction
    5.2. Identification of Significant SEIs
    5.3. Management of SEIs
    5.4. Constraints for Contract for CCs
    5.5. Summary
6. ENVIRONMENTAL MONITORING
    6.1. Introduction
    6.2. Monitoring for Individual EMPs
    6.3. Consolidated Monitoring Programs
    6.4. Summary
7. OTHER SIGNIFICANT ISSUES
    7.1. Public Participation
    7.2. Compliance with Environmental Lews
    7.3. Attention to Poverty Poor
    7.4. Risk Management
    7.5. Training
    7.6. Summary
8. ENVIRONMENTAL MANAGEMENT PLAN (EMP) AND ENVIRONMENTAL MANAGEMENT OFFICE (EMO)
    8.1. Introduction
    8.2. Compilation of EPMs
    8.3. Functions of EMO
    8.4. EMO Organization/Staffing/Budget
    8.5. Reporting
    8.6. Surveillance by Government
    8.7. Summary

The EIA reports sponsored by the international companies and by the MDBs have proven to be very valuable for training of DC/EIA practitioners, who prepare the reports with supervision by consulting experts furnished by the IAA. Each such report has been, in effect, valuable as a demonstration on how to understand the essence of the EIA concept and, accordingly, to prepare a competent EIA report. Preparation of the reports has been especially valuable in developing *team mechanics* by which the various expert disciplines included in the IEA team, including environmental engineers, economists, ecologists, and sociologists, learn how to function together to produce an integrated EIA report.

The methodology for using the EIA process in the DCs has evolved to maximize its usefulness, especially the development of the requirement beginning in the 1990s for a final chapter in the EIA report, which requires established of an Environmental Management Office (staffing/offices/equipment/budget) by the project owner as a part of the overall project management system[140]. Experience had shown that establishment of the EMO is essential if it is to be expected that the EPMs specified in the EIA report will actually be implemented.

Recommended EIA Report Components

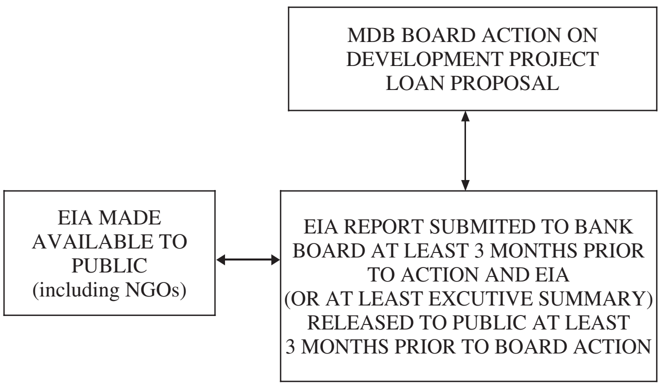
For DE/EIA reports, the recommended EIA report TOR, designed to meet World Bank, ADB, and other IAA requirements, is shown in Box 4.7, "Procedure for Approval of EIA Reports for New Projects to be Financed by Multilateral Development Books"[110]. Explanatory notes are as follows:

- *Summaries:* Each chapter's final section is a summary of the findings and conclusions of the chapter. The Executive Summary is readily prepared by combining these summaries.
- *Item 2.6 (Due Diligence):* This is to ensure that there are no "hidden" aspects that could be later found to the detriment of the project. The primary concern is whether the project site soils contain toxic/hazardous substances from previous uses of the site.
- *Item 7.1 (Public Participation):* This has become a major requirement beginning in the 1990s. It requires (1) consultations with concerned governmental agencies (all levels) and with local "people leaders" and NGOs, and (2) making the EIA report draft available for public inspection at selected local libraries, to obtain public comments (with radio/television announcements on where to find the draft).
- *Item 7.3 (Poverty Poor):* The intention here is to ensure that the project gives fair consideration to the needs of the general public and, especially, the poverty poor.
- *Item 2.8 (Use of Local Staff):* Provisions for use of local people for project staffing (including training) (to extent feasible).
- *Item 2.9 (Special Amenities):* To gain local approval, it may be necessary for the project to furnish some special amenities (e.g., schools, water wells, roads, etc.) to the affected communities.

- *Item 3.1 (ESA):* This includes the project area, plus all surrounding areas that may be significantly affected by the project.
- *Item 3.2 (Environmental Resources in ESA):* Detailed description of physical, biological, economic, and quality-of-life resources in ESA.
- *Item 8.2 (Compilation of EPMs):* This compilation represents the Environmental Management Plan.

BOX 4.7

PROCEDURE FOR APPROVAL OF EIA REPORTS FOR LOANS FOR NEW PROJECTS TO BE FINANCED BY MULTILATERAL DEVELOPMENT BANKS (Effective 19 Dec. 1991 for World Bank)



NOTES: PREVIOUSLY, THE EIA REPORTS WERE AVAILABLE TO MDBs AND TO THE GOVERNMENT, BUT THERE WAS NO REQUIREMENT FOR RELEASE OF THE EIA TO THE PUBLIC. THE SIGNIFICANCE OF THIS CHANGE IS THAT BOARD MEMBERS GIVE MUCH GREATER ATTENTION TO EIAs THAN PREVIOUSLY

Source: HFL/1992.

Constraints for Construction Contractors

Experience in use of the EIA process in DCs has shown that the EIA must include special detailed provisions to ensure that the EPMs specified in the approved EIA will be actually observed by the construction contractors (CCs) who build the project. While the CCs agree in their contracts to comply with the EIA/EPMs assigned to the CC, the CC commonly does not intend to do so. Therefore, the CC does not include in his bid price the cost for proper compliance because his own experience has shown that the usual project has no provisions for forcing compliance. A good example is the experience of the World Bank with the major Xiaolangdi Dam Project on the Yellow River in China[160], which was built by three international contractors who had signed contracts for compliance without intending to do so.The Bank's loan codicils provided for routine monitoring/enforcement, but it was not easy to get the CCs to understand they would have to set up their own competent EMOs. Under Bank pressure, they all came around to satisfactory compliance, including preparation of detailed monthly reports giving compliance details including management of all complaints by people and agencies affected.

Box 4.8 "Illustration of Requirements to be included in Construction Contracts to Ensure Compliance by Construction Contractor for Implementing Environmental Protection Measures Specified in Approved EIA" illustrates the types of requirements that need to be included in the CC's contract, including specific details for each EPM so the CC understands clearly what must be done to gain performance approval. Note that a special system is needed for management of the monitoring of the CC's performance on EPMs, which is carried out by a chief environmental construction inspector, but this inspector must work through and in collaboration with the project's chief supervisor of construction, because it is essential that the CC will report only to a single construction supervisor boss.

BOX 4.8 ILLUSTRATION OF REQUIREMENTS TO BE INCLUDED IN CONSTRUCTION CONTRACTS TO ENSURE COMPLIANCE BY CONSTRUCTION CONTRACTOR (CC) FOR IMPLEMENTING ENVIRONMENTAL PROTECTION MEASURES SPECIFIED IN APPROVED EIA

Purpose of These Instructions to CCs
Environmental Responsibilities of CCs

Monthly and Yearly Reports

Areas Involved in CC's Reporting

Base Drawings

Specific Issues Involved and to be Reported Upon by CC

- Water Supply
- Sanitary Sewage Management
- Industrial Wastewater Management
- Housing for Chinese Villages/Camps
- Solid Waste Management
- Drainage
- Erosion Control

- Air Pollution Control
- Noise Control
- Occupation Health and Safety in Construction Zones
- Communicable Disease Control
- Cultural Relics
- Natural Resources Protection
- Other Issues Relating to Environment Protection

Format for CC Reporting

Work by Chief Environmental Construction Inspector (CECI)

Work and Reporting by CECI
Environmental Supervision Daily Log Book
Monthly Environmental Supervision Report
Six-Monthly Environmental Supervision Report

Notes

1. Only main headings are given here.
2. Source: [160].

Need for Effective Training

A primary lesson in DC use of the EIA process is that the NEnPAs could make much better utilization of the process if the training efforts sponsored by IAAs were planned to be much more realistic. EIA technology and its adaptation to suit DC conditions is a complex subject[110], and most of the IAA-sponsored projects have made the mistake in assuming that the needed technology can be effectively transferred to the DC practitioner in a short-term period—say, for one year, and often the trainer himself is not "DC-oriented." The need is for a different approach where consulting EIA expertise is furnished to the NEnPA on a continuing basis over a period of, say, 5 to 10 years. This can be part time, so the same expert can give service to more than a single EIA agency—say, 1 week per month to each of four agencies[51,110].

Another way for improving EIA technology transfer is for the IAAs to modify their plan for financing of technical assistance to DC projects, which virtually always includes financing only for expat experts to carry out their work, assisted by DC staff assigned to them, without provision for meetings with the staff to explain their "thinking" for carrying out the project. The expert uses the assistants, but without explaining to them the "why" of what they are doing.[45] details the author's experience in this, for an EIA report prepared by an expat expert for a major World Bank dam/reservoir project in Indonesia, with assistance of professionals from the Government's Institute of Water Resources Research. For this purpose, an extra work session was scheduled for 4 hours on Saturday mornings, during which the expert did the necessary explanations, but this was "freebee" work by both the expert and the trainees.

ENVIRONMENTAL ECONOMICS AND FINANCING

Inclusion of Environmental Values in Project Economic Analysis (PEA)

Prior to use of EIA, PEAs commonly were limited to values of interest to the Project Proponent (PrPr). The "Economic Study Area" was often considered to exclude the *project externalities*, meaning that these are not to be considered in the economic analysis. Examples include (1) downstream flooding damages due to deforestation in timber logging projects, (2) flooding damages due to hydrology changes by highway projects, (3) loss of capture fisheries due to hydrology changes, and so on. A proper "economic study area" must include all areas that are significantly affected by the project, with attention given to all environmental values that are impaired (and to any gains that may occur)[136].

Another aspect of this issue is the value assigned to existing natural resources that are utilized for economic gain, such as trees that are logged for timber. The fair value would seem to be its replacement values (cost for regrowing)[9].

Effect of EPMs on Project Economic and Financial Analyses

The EIA should evaluate the impact of including EPMs on the PEA (i.e., to compare the benefit/cost and financing both with and without the EPMs). This may be needed to offset arguments that the costs of EPMs will ruin the project economics. These evaluations invariably show that provision of EPMs will actually increase overall benefit/cost in the project's life term, and that for some of the amenities that may be included, the benefit/cost ratio may be much greater than for the main project production objective.

Unfortunately, however, the DC decision makers, for political reasons, were more interested in immediate financial gains[88], and the use of the EPMs requires provision of significantly more upfront financing money, which conflicts with the immediate gains goal. This *immediate gains goal* is the primary reason why so many DC projects do not achieve their intended objectives and are very wasteful.

Human Greed Parameter

The *human greed parameter* has a very considerable effect on project development. This is well explained in "Radical Birthday Thoughts" featured in the June 28, 2003 issue of the *Economist* on the occasion of this magazine's 160^{th} birthday[168]. This includes a statement by Alan Greenspan that man hasn't become more greedy; rather, the new technologies including IT have made it possible for the same greed-level to steal much more (e.g., Enron et al.).

Application of this principle to the field of environment gives a gloomy picture. Although the new technologies have created enormous new wealth, so it's much more feasible now to care for the poor and to protect environmental values—the money is there—there seems to be little hope for environment because human greed will continue to give its primary attention to using the technologies to making the rich richer, with environment going down the drain. The world will wake up to the environmental problem and face up to it only when the "roof falls in." However, even then it may not be too late; for example, even it jillions of species are lost, Man may well be able to do very well with what's left in terms of tending to human economy (health and welfare), using ever new technologies to fill the gaps.

Economic-cum-Environmental Development Planning

The need to incorporate the environmental (E2) parameter into economic (E1) development planning, as the only way for the DC to affair sustainable development, has been long recognized, but an acceptable methodology for this is now available as discussed in the section "Development Planning."

Value of Human Life

A key parameter to be taken into account when modifying IC environmental design criteria and matching standards is the DC's situation on the value of a human life. The author moved from the United States to live in Bangkok in 1973, and at that time had a public liability policy for auto driving that included provision of $1 million in case of causing accidental death (today this is many times higher). He asked his Bangkok insurance agent to furnish a similar policy for Bangkok. The provision for accidental death was only $10,000, and this because the author was a foreigner—The normal Thai policy amount was $1,000. This, of course, doesn't mean that an American life is worth 1,000 times more than a Thai life, but it does mean that the actual market value of a life must be taken into account in modifying IC design criteria to suit DC conditions.

At that same time, the author's brother's firm engaged in heavy engineering construction. He noted that the cost in the United States for building a dam, which in 1950 was, say, $100 million, by 1970 had increased to $200 million due to stiffer safety construction regulations which reduced the average construction death rate from three to one—at a cost of $50 million per person. Obviously, most DCs can hardly afford the original $100 million. The same problem applies to modifying construction requires for setting design criteria for protection against earthquakes for dams and superhighways.

Protecting Precious Eco-Resources

Another need for economic analyses DC project planning is to assign some appropriate money values representing the value for sustainable development of preserving precious Eco-Resources. This is discussed in the section, "Development Planning."

EMERGENCIES MANAGEMENT

Little progress has been made in most DCs in formulating for management of environmental emergencies, with only a few exceptions. The recent huge tsunami in Asia made the DCs painfully aware of the need for establishing a competent Asian regional emergency warning system for tsunamis, which likely will bring about expansion of the existing tsunami warning center in Honolulu in order to fill this role for the entire Asia-Pacific region. Even so, each DC involved needs to improve its own tsunami warning service to receive and give attention to warnings from Honolulu. At present, most DC meteorological agencies do give good warnings on impending flooding hazards. In most DCs, about the only agency able to offer prompt assistance for assisting the DC people/properties affected by emergencies (including damages from earthquakes, floods, hurricanes, landslides, oil spills, etc.) is the military. A World Conference on National Disaster Reduction was held in Japan at Yokohama in May 1944, which indicated the need for each DC to establish its own National Emergency Management Agency. The recent earthquakes in china and massive flooding in Myanmar also emphasize this need.

An example of a rare exception-to-the-rule is the system established in Thailand in the 1970s by a consortium of the country's major petroleum companies, for managing major oil spills from tankers or other sources, including a standing management committee (with the director rotated among the participating companies)[77,128]. This includes (1) enforcement of regulations to prohibit illegal discharge of oil laden wastes both at sea and in harbors, (2) provision of standby equipment ready to get into action when needed for managing the spills, including use of log booms, mechanical removal of the oil, and use of chemicals for negating oil damage, (3) planning for use of equipment in emergencies, and (4) actual emergency operations. This is operated under the jurisdiction of the Thai government, and has proven quite effective for handling the several major spills that have occurred. Some efforts were made to expand this operation into a joint operation of the Southeast Asian countries in the same region (Thailand, Malaysia, Singapore, Indonesia), but with no success as yet.

TECHNOLOGY TRANSFER (TT)

Problem

All IAAs recognize the need for transfer of environmental technology to DC practitioners; hence, there have been hundreds of IAA sponsored project since the 1970s for such TT to assist them in their planning efforts. Many, if not most, of these projects have not been successful for a variety of reasons that are summarized as follows:

- Lack of experience by many IAA staff actually working/living in DCs such that they understand the DC problem. For example, the World Bank staff at

Bangkok work in what is essentially a branch of World Bank/Washington, a luxury office with luxury equipment, and the World Bank staff contacts are mostly with high-level country officials. Rarely are these staff exposed to actual working-level conditions in the country. Yet these are the persons who plan the TT projects.

- Lack of understanding that almost all environmental protection technology has been developed in the affluent ICs and is not directly applicable to DCs but must be modified to suit DC conditions (see Figure 4.3), and lack of sufficient training in how to make the modifications.
- Use of consultants for conducting TT projects who have the same backgrounds and the same deficiencies as just noted.
- Assumption that TT can be achieved with "slug type" projects (e.g., assignment of an EIA technology expert or a team of experts to the country for one year). But TT/EIA is not that easy. What is needed is for continuing expat inputs (can be on a part-time basis) for a prolonged period. For EIA/TT, the best approach is for continuing inputs over a period of several years. For one of the author's projects to train the staff of the Institute of Water Resources Development of the Ministry of Public Works of Indonesia at Bandung on environmental technology, the original plan of the sponsoring agency (UNDP) was for the expert to spend 3 months at Bandung full-time, but the UNDP agreed at the author's suggestion to change the plan to four visits each of 3 weeks, covering a period of a year. This kind of teaching is like university teaching, where a typical approach includes a number of lectures (usually 20) spread over a period of one half-year semester. Trying to achieve the TT on a slug basis is not the way, but the IAAs almost always use it because it "saves" travel time. For the case under discussion, the author advised the UNDP that its original plan would not be successful—hence, UNDP should use the "prolonged approach" or cancel the entire project and save all the money[45,94].
- Planning the TT course must be DC oriented, using appropriate standards affordable in the DCs. One of the IAA/TT projects in Thailand for protecting marine beaches utilized experts from California to do the teaching. Their lectures were about the state of California's program for beach protection, where the standards for protection are hugely high and not affordable in DCs. The lectures were all about the California practices[82].
- Another nonproductive approach in IAA planning of TT projects is that the project target is production of training manuals by the expat experts, and for such a project for the Provincial Waterworks Authority (PWA) in Thailand sponsored by World Bank, the manuals produced were actually appropriate, but the project budget did not permit the expert team to produce the manuals in close association with the PWA staff, or to explain them to the PWA staff. Therefore, the manuals were rarely "accepted" and used by the PWA staff[159].

- For many training needs, the best approach is not provision of an academic type course, but to include in the planning of a major development project sufficient budget to enable the expat team to give lecturers as the project continues for explaining to the DC team members the "why and how" of the tasks being managed by the expats[94]. But this is almost never done. The IAAs still haven't grasped this basic concept; they still think the TT occurs simply by "rub-off."
- Another good approach for O&M training, for example, for water supply and/or sewage treatment plants, is to use experts on O&M from the ICs who make periodic visits (like a circuit judges in early Western U.S. history) to a number of plants. Retired IC experts are often willing to accept these assignments. This system is much more effective than academic training because, when the expat arrives at the plant, the plant O&M manager is very happy to get guidance from the expat on immediate urgent O&M problems. At that time, he the manager is keenly interested in learning, but at an academic course (where the manager has no immediate urgent problems), he often is not very keen to learn.

Recommendation

The author's recommendations are discussed in the 2006 publication, "How the Asian Development Bank Can Improve Their Technology Transfer Operations fro Water/Sanitation Projects in Developing Countries"[93]. These recommendations are summarized in this chapter in the section on "Introduction" (and also in the section on "Urban Water Supply").

DEVELOPMENT PLANNING FOR DCS

This section summarizes efforts by the IAA/DC practitioners for regional development planning in the DCs, with the goal of selecting development projects that can best contribute to continuing DC sustainable development. The section includes subsections on (1) the need to give much more attention to providing for the rural poverty poor, (2) the need to assign money values to represent (in project economic analyses) the intrinsic value of precious eco-resources, (3) development of a practical methodology for achieving integrated economic-cum-environmental planning methodology so that project investments will best contribute to sustainable development, and (4) role of women for alleviating poverty.

Social Parameters: Attention to Rural Poverty Poor

Background Over the last decade, the affluent ICs, represented by the Group of 8, and the IAAs, including the U.N., have increasingly recognized that, while new technologies are improving the overall economics of DCs, nevertheless the gap between family income for urbanites and ruralites has generally been steadily increasing, and the IAAs (including WTO) and some DC are now undertaking numerous projects/programs to try to help resolve this problem, but as yet without much improvement. It is proving to be very difficult to close this gap.

ADB's report of 1990 on "Economic Policies for Sustainable Development"[7] represents ADB's initial recognition of the seriousness of rural poverty and outlines development policies, which need to be followed, including giving the rural sector its fair share of attention in the country's overall investment program, especially for provision of rural town amenities and development of local agro-industries. The report's Executive Summary stresses the urgency of this need.

ADB's report of 2000, "The Environment Program, Recent Achievements and a New Agenda for the Poor"[14] was prepared in response to new and emerging directions in ADB's overall operation. ADB has recently embarked on a reformulation of its environment program. In particular, the adoption of poverty reduction as ADB's overarching objective in November 1999 offers challenges and opportunities for ADB to adjust the focus of its assistance in sustainable management of environmental resources to improve the plight of Asia's rural and urban poor.

All of the studies/projects already noted concur that attention to the rural poverty sector is a major urgent problem in most DCs. Feasible ways for resolving the problem include the following:

- Provision of decent amenities (facilities), including water supply and sanitation, primary health care facilities, and schools
- Land distribution so the "landless poor" have opportunity to manage farming to help themselves
- Promotion of local handicraft industries
- Promotion of local factories using trained local labor to produce items for sale to global manufacturers
- Promotion of off-farm job opportunities

Illustrative Projects Two of the ADB projects over the past several years, which were designed with the twin objectives of environmental protection and poverty reduction, are the following:

1. Sulawesi Rainfed Agriculture Development, Indonesia ($34 million project loan), is directly benefiting about 50,000 households scattered over 235 villages and representing about 10 percent of the total population. The project has increased the productivity and farm incomes of rainfed farmers; protected and improved the fragile environment; created employment in the rural areas; reduced poverty; and improved the socioeconomic condition of women beneficiaries.
2. The Philippines received a $35.2 million loan for fisheries resource management, aiming to reverse the trend of fisheries resources depletion in

municipal waters. It will achieve this objective by implementing three components: (1) fisheries data management, and coastal resource management and planning; (2) income diversification; and (3) capacity building for relevant public agencies. By controlling destructive fishing, reducing overfishing, and rehabilitating fish habitats, the project will benefit municipal fisherfolk in about 100 municipalities in 18 of the country's 6 priority bays.

Role of Women Virtually all socioeconomic analyses of development on the DC have shown that the potentials for utilization of the talents of women have generally been given very inadequate attention in development project planning. That is, the traditional role of women in DC socioeconomic should be reoriented to make much better efficient use of these talents. Guidelines for achieving this in project planning developed in recent years have been prepared by the World Bank and ADB and other IAAs.[83], A guide to "womenomics,[168]" from the April 25, 2006 issue of the Economist magazine, gives a good summary of this subject. It notes, "The future world economy lies increasingly in female hands."

Eco-Resources Protection

Problem in DCs A major problem in DCs has been the lack of environmental engineering expertise needed for planning projects for protecting natural eco-resources (and modifying the planning of projects which utilize natural resources), especially forests, eco-swamps, river aquatic life, and aquatic life in nearshore marine waters, due to increasing encroachment into the eco-areas by cities, industries, and agriculture, extraction of the resources for export for the DCs, and lack of government monitoring/enforcement needed to protect established national parks and other eco-resources areas from poaching of animals and "looting" of precious plants and animals for sale in urban markets. In the author's view, this is a major problem of the World Wildlife Fund and International Union for Conservation of Nature, which are staffed essentially by wildlife scientists (foresters, fisheries, etc.) are seriously lacking in environmental engineers[52].

Protection of National Parks/Eco-Resource Areas A key problem has been the inability of DC governments to protect national/eco-resource areas so there is actual protection. Many DCs have officially established many such parks/resources, but very few are actually protected, so the official proclamations amount to delineating these areas on a map and pretending their bio-resources are indeed being protected. The most serious single problem of natural resources destruction in the DCs is the loss of natural forests, which has reached unprecedented high rates in the past several decades. It seems that this degradation will continue with little forest left by mid-twenty-first century because of inability of DCs governments to impose controls. This results in very serious problems of loss of wildlife habitat, and in watershed areas heavy loss of soils by rain runoff and seriously diminished water infiltration to sustain the groundwater levels that furnish the dry season flow in streams. The author's recommendation for saving the world's tropical rainforests are given in Box 4.9.

One approach that appears to be feasible and meaningful for DC/forestry protection agencies was developed in preparing the EIA for a proposal hydroelectric plant in Ecuador to be located in the Amazon portion of the country[53]. The study made three findings:

1. The national environmental protection agency of the government, located at Quito, near the Pacific Ocean, had very limited budget hence was not able to protect its proclaimed national resources even in the western region of the country, let alone for the Amazon portion on the other side of the Andes.
2. One of the most precious wildlife regions in the country was located next to the hydropower operations area.
3. Financial resources of the hydropower protect were very large compared to those of the NEnPA.

The recommendation (to which the hydropower agency expressed interest) was for the NEnPA to arrange for the hydropower agency to protect/manage the precious habitat region as part of its overall project tasks, which the hydropower agency could do readily as a contribution to helping preserve the nation's eco-resources (as well as using these areas for hydropower generation).

Segara Anakarn Lagoon Preservation in Indonesia Studies sponsored by the ADB for promoting irrigation in the huge Citanduy River basin in Java, beginning in 1990[90], included attention to what should be done about protecting the lower end of the basin where the Citanduy River discharges (along with some smaller rivers) into the Segara Anakarn lagoon, located just next to and discharging to the sea (like Jamaica Bay in New York City). This wonderful eco-swamp, the last remaining large eco-swamp in Java, has over the past several decades been filling up with silt runoff resulting from continuing development in the Citanduy River basin. This attracted the interest of environmentalists in developing a feasible plan for saving the swamp while a major portion of it still exists. A number of studies concluded that the best feasible plan would be to reroute the Citanduy River to discharge directly into the sea (bypass the lagoon), and ADB offered a loan for doing this, but this plan is yet to be implemented, apparently due to differences between the bureaucracies of the two provinces in which the lagoon location is shared.

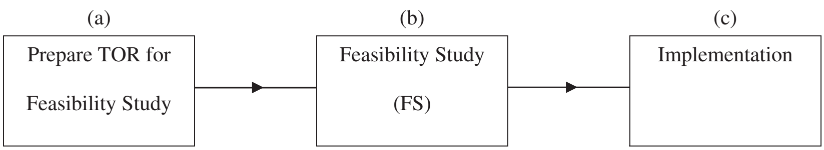
Assigning Money Values for DC Eco-Resources The Segara Anakarn project brought out need for recognizing that saving precious eco-resources (like Segara Anakarn)deserves to be assigned money values representing the economic-cum-environmental development value of these resources, and for revising conventional project economic evaluations to include these money values[97]. The conventional methodology gives zero money value for eco-resources in the area/region affected by a proposed project. The argument is that ICs spent very large amounts of real money for this purpose, for many projects—for example, restoring the eco-systems of the Florida Everglades in Florida. The proposal recognizes that DCs cannot afford the IC approach, but notes that even so, the eco-resources do have some intrinsic value for sound development value in the DCs. The proposed approach is to evaluate the budgets spent for the many cases of eco-preservation in the United States (and other ICs) in order to devise a “formula” for quantifying these values, then to have these IC values reduced to match, say, the relative GDPs of the ICs versus the DCs, with the value for a particular eco-resource set by a high-level DC committee comprising both distinguished economists and environmentalists in the country.

Recommendations A basic recommendation is for the WWF, IUCN, and other interested IAAs is to give much more attention to this problem, and in doing so to do a much better job in adapting or modifying protection technologies developed in the United States (much to expensive for DC use), including use of the engineering approach for planning of proposed eco-protection projects, including use of the methodology discussed in subsection “Economic-cum-Environmental Development Planning.” The author’s review of the IUCN’s proposed plan for protecting Thailand’s wildlife habitat in 1980[52] is an example of the need for environmental engineering expertise in developing such plans, including development and use of the methodology already noted for assigning many values for precious DC eco-systems.

Another critical need is for preparing the tropical forests preservation plan shown in Box 4.9.

BOX 4.9 RECOMMENDED PROGRAM FOR SAVING WORLD’S TROPICAL RAIN FORESTS

by H. Ludwig[94]



(a) This cost estimated at two professional man-months = about \$50,000 to \$100,000. Report will describe FS job, its components, FS team, schedule, costs, and proposed financing plan.

(b) This will evaluate all remaining precious tropical rainforests in the world and delineate the described minimum combination of pieces/components which are to be purchased and protected, including (1) skills and support needed for implementing plan, (2) estimated costs for acquisition and for true protection (total and annual over period of, say, 50 years), (3) financing plan, (4) management plan, with each component area to be established as International Treaty Organization Nature Reserve (ITONR), and (5) overall global management system. Estimated cost of FS is about $20 million.

(c) Present implementation program, to be spelled out in FS, is in the range of about $1 trillion (to be spread out over period of 50 years). The FS will include such cost estimating and suggested financing (to be paid by ICs).

Affordability of Environmental Improvements

Prior to the 1990s, it was common practice, in project economic analysis (PEA), to look upon proposed environmental improvement projects as a kind of "add on" to economic development, and economic decision makers expressed willingness to approve proposal environmental improvements, provided these were a small percentage of all project investments. Figure 4.22 is a typical situation for ADB's 1987 proposed Klang Valley Improvement Project for Malaysia[5]. This shows the capital cost of the proposed environmental improvement represents from one to three percent from about 2 percent of total fixed capital formation (FCF). This represents approximately 0.4 percent of the Klang Valley GDP.

Integrated Economic-cum-Environmental Development Planning (IEEDP)

Sustainable Development The term *sustainable development* means a development program that takes care of society's current needs, by utilization-cum-protection of environmental resources (natural and human) so that sufficient resources will be maintained so that future societies can take care of their needs.

IEEDP Methodology Most development planning in the DCs has not been able to focus on sustainable development per se because of lack of a suitable planning methodology. As shown in Figure 4.23, the need for developing a practical IEEDP methodology began to be recognized in the 1990s. An ADB-sponsored project carried out by Dr. Daniel G. Gunaratnam in 2000 did produce a practicable methodology for IEEDP for the region of northeast Thailand[15]. This has been followed up by a second ADB-sponsored project for preparation by Dr. Gunaratnam of a textbook/guidelines manual to be released in 2008, for use by IAA/DC practitioners for general application for any DC or sub-DC region or for regions that include areas in two or more adjoining DCs[16].

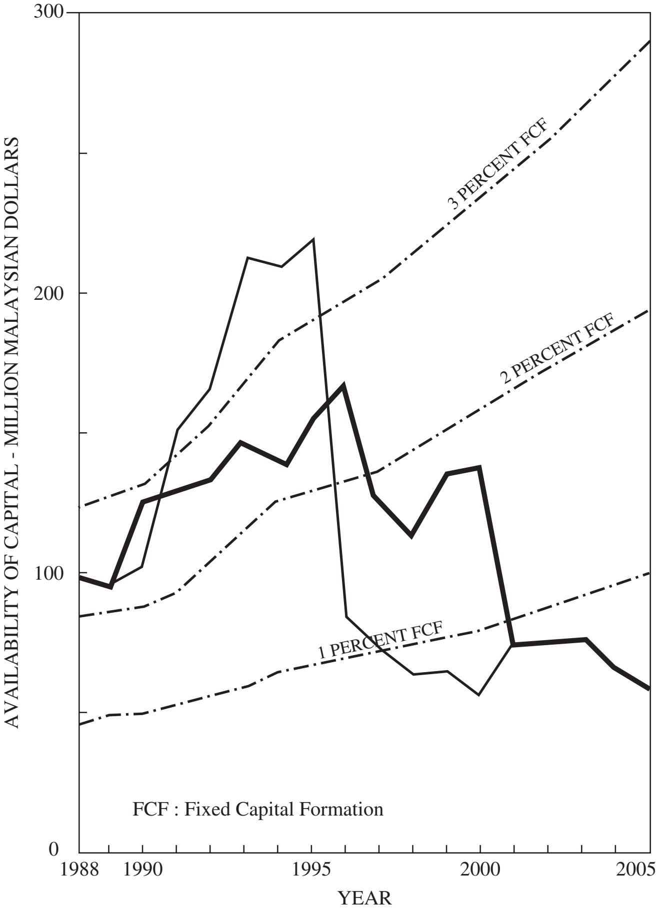


FIGURE 4.22 Comparison of in capital requirements to capital availability for environmental improvement Klang Valley.

GLOBAL WARMING

Problem

Most climate scientists believe that serious global warming due to man-induced emissions of CO_2 and methane gases is underway and that, if this is not soon controlled, it can be expected there will be dire consequences throughout the world, including flooding of coastal areas and of low-lying islands. Agricultural changes will also take place, in that crop choices will need to be shifted to correspond with the new climatic patterns. It is also recognized that while the damages will be felt globally, the greatest damages will be in the DCs, which can least afford to cope with them. While the United States and China are now is in the lead in contributing emissions, India is expected also to become

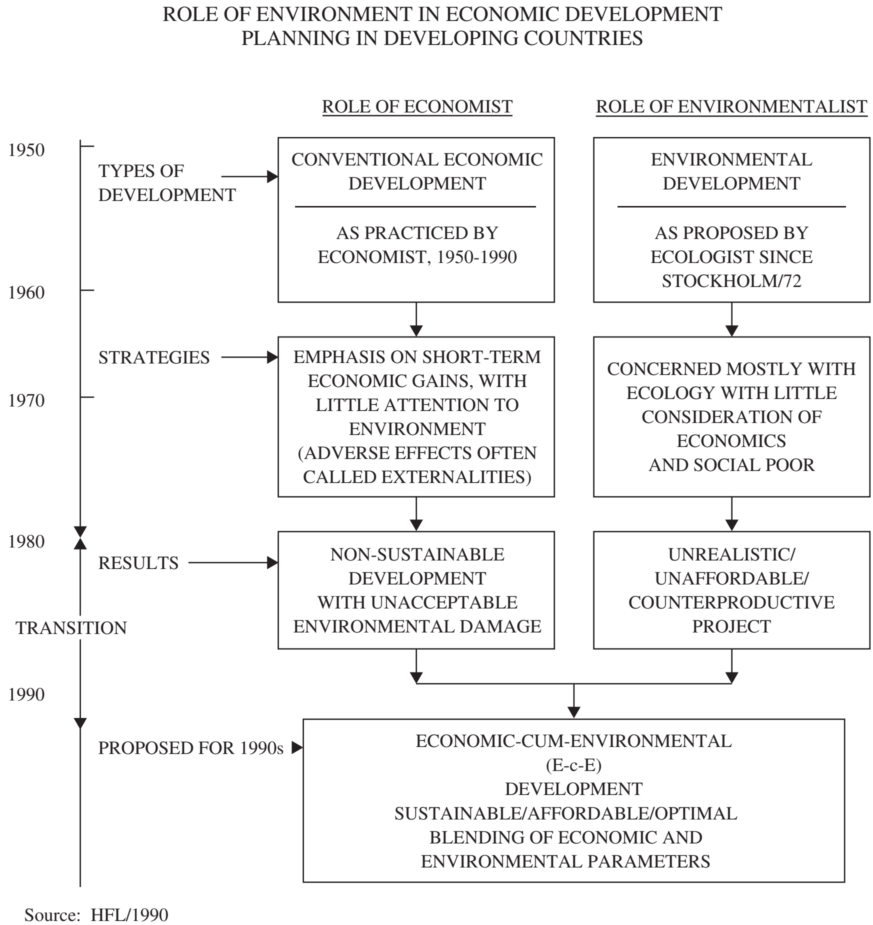


FIGURE 4.23 Role of environment in economic development planning in developing countries.

"one of the big three." The protocols now being proposed, to replace Kyoto, even if totally implemented, seem far "too little too late," and the cost of achieving adequate global control will be hugely expensive. It will be very difficult to get the key countries to agree on a comprehensive plan of corrective action.

What seems not to be sufficiently recognized is that the timeframe for achieving sufficient emissions reductions is very short, probably only a few decades, which further increases the problem of reaching agreement on an effective global action plan. The basic problem is lack of any definitive proposal so far as to the specifics on what needs to be done together with the applicable timeframe, task assignments for each country, and how to finance the costs. Without this, country leaders do not have a good picture on what their country should do.

Efforts have been made to prepare a feasibility study for climate warming control which would furnish the answers needed by country division makers, but it has not yet been possible to do this because of a multitude of complexities. Even if a proper comprehensive global correction program could be formulated, it's very unlikely China and India (2 of the 3 major "culprits") would be willing to participate. What is clear is that the most appropriate approach at this time is (a) to reduce energy wastage, and (b) to development energy sources as alternatives to burning of fossil fuels.

FUTURE OF ENVIRONMENT IN DEVELOPING COUNTRIES

Problem of DCs

The world's ICs with their power/financial resources have had the role of formulating the program of the ICs for assisting the DCs on how to protect (as well as use) environmental resources as needed for sustainable development in the DCs. The global assistance program started with the UN/Stockholm/1972 Conference, with great expectations at the time that the new NEnPAs being established by the DCs, with assistance from the ICs (via the IAAs including MDBs, UN agencies, bilaterals, others), would be able to simulate the progress made in the United States with establishment of U.S. EPA. Unfortunately for the DCs, this target has not been achieved, because (1) it is the ICs themselves who are the primary problem by getting the DCs to export their raw resource materials (export of timber for making pulp and paper in the DCs is a classic example) to meet rapidly increasing IC demand for these materials, (2) the DC capabilities for developing skills/procedures for environmental management had been quite limited, and very dependent on IAA assistance to help the DCs develop the needed expertise, and (3) the interest of the ICs has been focused on how to make money by utilizing the DC resources, with quite limited interest in helping the DCs to develop their own capabilities, hence the assistance programs of the IAA have not been very effective.

However, the past several years have witnessed growing discontent by people of both ICs and DCs in the way the IC-assistance system has failed to bring about the needed results in the DCs including both protection of human resources, that is meeting the needs of the several billion DC peoples living with incomes at one dollar per day per person or less, and reducing the high ongoing rates of degradation of natural resources in the DCs, including forests, eco-swamps, nearshore marine areas, and so on.

Changes in Environmental Policy in the ICs

A promising sign in recent years is numerous media items showing a distinct change in IC policy makers in both the public and private sectors, and also in individual persons, resulting in many improvement in environmental performance—for example, in design of big buildings and in conduct of business operations[33]. However, little of this has taken place in the DCs.

Glimpse of Future

The present indicators are that the affluent ICs will be able to maintain fairly good environments in their countries. They have the money and the popular will to require public and private agencies to do this. But the situation in the DCs, which have the major share of land, environmental resources, and people in the world, does not look good. Most DCs have neither the needed financial resources nor the will to manage even the ongoing problems of environmental pollution and accommodating the massive immigration of people from the rural sector. The situation will be intensified by global warming and, again, the DCs have much lower capabilities for coping. Hopefully, the ICs will give much more attention to helping resolve the environmental problems of the DCs, as is happening now—for example, by the 2007 pledge of the Group of 8 for increased major reduction of poverty in Africa.

Recommendations

Some of the author's recommendations for consideration by the IAAs are given in[94], "How the Asian Development Bank Can Improve Their Technology Transfer Operations for Water/Sanitation Projects in Developing Countries" (2005). These recommendations are summarized in the sections on "Introduction" and on the "Urban Water Supply." Hopefully the IAAs will come around to giving serious attention to these recommendations.

As noted in the subsection on "Eco-Resources Protection," in the section on "Development Planning for DCs," the most serious single problem of natural resources destruction in the DCs is their losses of natural forests, which has reached unprecedented high levels in the past several decades, and it seems that this degradation will continue, with little forest left by the mid-twenty-first century, because of the inability of DC governments to impose controls. The author's recommendations for saving the world's tropical forests are given in Box 4.9. As for the problem on how to control global warming, the indicated best approach is to reduce wastage of energy and to develop alternative energy sources not dependent on the use of fossil fuels.

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CHAPTER 5

ENVIRONMENTAL EMERGENCIES AND EMERGENCY PREPAREDNESS

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INTRODUCTION

The objective of this chapter is to present the basic concepts associated with emergency preparedness and the preparation of emergency response plans for industrial contingencies, which can result in toxic releases of contaminants in air, water and soil, as well as, more generally, in other industrial emergency situations such as fire and explosions. Emergency preparedness is not only limited to the prevention, contingency planning, and emergency activities within the boundary of an industrial facility, but it may extend to the federal government, state and local officials, as well as local communities, especially if the release of hazardous materials is involved, or if it involves transportation emergencies. Therefore, the scope of this chapter is to examine the main aspects of emergency preparedness first at the facility level (i.e., concerning the industrial plant) and then at the local level (i.e., within the community but outside the facilities).

The impact of the release of hazardous and toxic materials may be different depending not only on the type and physical state of the material being released, but also on the medium in which the material is released. In general, toxic gaseous or vapor emissions have the potential for causing more acute, and possibly catastrophic, effects, especially on humans and animal populations, but are typically less severe on the environment. If the materials being released as well as the receiving medium are denser (e.g., an oil spill in a waterway or in soil), the consequences are typically less potentially lethal for human populations, because

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of the limited risk for acute toxic exposure, but the immediate and especially long-term consequences, especially for the environment, can be more severe. In all cases, the basic approach to contingency planning and emergency preparedness is similar, although the remedial actions may not be. Therefore, in this chapter a unified approach was used to discuss emergency preparedness, planning, and response in general, without distinctions between different emergency scenarios.

Currently, and for the foreseeable future, the focus of emergency preparedness and industrial emergencies will likely be in two areas: protecting public health and safety as well as environmental media from the potential effects of releases of hazardous substances and protecting vital services from possible terrorist attacks, natural disasters or similar catastrophic events.

Before the toxic release catastrophe of Bhopal, India, in 1984, emergency planning was the exception rather than the rule for facilities, organizations, and agencies other than those associated with the nuclear industry, since there was no regulatory incentive for them to do otherwise. However, the federal government had already begun to legislate as early as 1968 on emergency preparedness, primarily for those events associated with the release of petroleum hydrocarbons (oil spills). The impetus for this action at the federal level originated from another calamitous incident, i.e., massive oil spill from the oil tanker *Torrey Canyon* off the coast of England in 1967. More than 37 million gallons of crude oil spilled into the water, causing extensive environmental damage. To avoid the problems faced by response officials involved in this incident, U.S. officials developed a coordinated approach to cope with potential spills in U.S. waters. This resulted in the National Oil and Hazardous Substances Pollution Contingency Plan, more commonly called the National Contingency Plan or NCP, which was promulgated in 1968. The NCP is the federal government's blueprint for responding to both oil spills and hazardous substance releases. The 1968 plan provided the first comprehensive system of emergency event reporting, spill containment, and cleanup, and it established response headquarters, a national reaction team, and regional reaction teams.

Initially, the NCP's focus was primarily on emergency response to oil spills. Since 1968, Congress has broadened the scope of the NCP. This first amendment came in 1973 in response to the Clean Water Act of 1972. This revision provided the framework for responding to hazardous substance spills in addition to oil discharges. In 1980, the NCP was again revised in response to the Superfund legislation. This revision broadened the NCP to include response and clean-up of hazardous waste sites in the form of emergency removal actions. The current version of the NCP was revised in 1994 to reflect oil spill provisions of the Oil Pollution Act of 1990 (CFR Title 40, Volume 20, Parts 300 to 390). The NCP establishes the fundamental aspects of the federal government's organizational structure and procedures for preparing for, and responding to, discharges of oil and hazardous substances, pollutants, and contaminants. It includes provision for the development of response teams, the definition of the role of the federal on-scene coordinators (OSC), National Response Center (NRC), the coordination among federal agencies, the preparation of Federal Contingency Plans. The NCP also establishes the authority of the federal government to initiate removal actions at hazardous waste sites.

When the Bhopal disaster occurred in India in 1984, and some 3,800 people died as a result of the toxic release of methyl isocyanate gas, it became quickly apparent that no contingency plans existed in the United States to deal with similar emergencies, and that this type of extreme events involving an industrial toxic gas release had not been not considered in the NCP at the time. In the wake of the Bhopal tragedy and other accidental chemical releases, public concern escalated dramatically. This became even more acute with the advent of environmental regulations that sought to identify the magnitude of the release of hazardous substances to the environment. As a result, the public continued to demand protection, and the Emergency Planning and Community Right-to-Know Act (EPCRA), Title III of the Superfund Amendments and Reauthorization Act (SARA) of October 1986, was the outcome.[1] The onus of Title III is on states and local communities to develop plans for responding to hazardous materials emergencies. Although legislation such as EPCRA is intended to protect the public, others are focused on the protection of workers in the workplace. The Occupational Safety and Health Administration's (OSHA) Hazard Communication Standard, or Worker Right-to-Know, became fully effective in May 1986 and amended as of February 13, 1996.[2] Its purpose is to ensure that employees are aware of hazards in the workplace. Additional federal regulation, that is, OSHA 1910.120–Hazardous Waste Operations and Emergency Response, often referred to as HAZWOPER, became effective in March 1990.[3] It mandates emergency response and preparedness programs for industry, including required interface activities with off-site agencies and prompt notification to them of an emergency situation. It also requires health and safety training for all individuals involved with emergency response and investigation and remediation of hazardous waste sites and spills. HAZWOPER applies to five distinct groups of employees and their employers, which are clean-up operations, corrective actions at RCRA facilities, voluntary clean-up at any site covered by a federal, state, or local environmental action, operations involved with treatment, storage, and disposal of hazardous waste, and emergency response actions. Companies must have a written emergency action plan in place to comply with 29 CFR 1910.38,[4] and an employee alarm plan per 29 CFR 1910.165.[5]

Some states have even more prescriptive regulations. New Jersey's and Delaware's Toxic Catastrophe Prevention Acts (TCPA)[6] are examples. In addition to the sudden release of a substance, environmental emergencies can take on other forms. The discovery of a leaking underground tank or a number of buried drums requires a response that seeks to protect human health or the environment, particularly when the release threatens a water supply or a fragile ecosystem. The response to these situations involves equally important planning activities among federal, state, and local groups.

The planning process is the key to successful emergency preparedness. Relationships among the plant, local government, and the community are often complex. Planning promotes interaction among participants. The planners become aware of one another's strengths and weaknesses, which are factored into the response mechanism. Therefore, the planning process should not be circumvented by reworking a document prepared by others because this diminishes the importance of the planning process and the interaction of those responsible for implementing it.

The planning process can take many forms. Normally, emergency response planning is thought of as being undertaken for unpredictable but anticipated sudden events, such as a spill or gas release. However, planning is critical to the response to any environmental event as well. For example, a concern about the indoor air quality at a school or office building requires detailed planning with regard to sample collection, instrumentation, and analytical procedures if the data are to be meaningful and useful to design a remedial approach.

Normally, one of the most important outcomes of the planning process is the preparation of an Emergency Response Plan. This document covers the many different aspects of emergency response, from establishing procedures for mobilizing resources and communicating with site specific first responders and off-site emergency response personnel to describing levels of emergency situations and providing a description of the conditions associated with each level. The plan is designed to promote effective response with minimal confusion and disruption to site activities. It also defines responsibilities and establishes priorities for essential activities.

The following sections describe the two basic aspects of emergency action response. The first is associated with emergency planning at industrial facilities, and the other is related to emergency response at the community level. It is well known that industrial facilities use and manufacture a wide variety of hazardous chemicals contained in vessels, tanks, pipelines, and other storage containers. All industrial facilities need some form of emergency response planning that establishes the procedures and actions that the facility will follow in the case of emergency. The section on industrial facilities discusses a number of the key aspects associated with emergency preparedness at the facility level, such as the planning process, emergency action levels, the facility response organization, the resources needed to cope with the most probable emergency events, the establishment of an emergency operations center, how to interact with the media, communication equipment and alarm systems needed, personnel protective equipment and protectiveness levels, spill/vapor release control equipment, medical facilities, security and access control, environmental media sampling and testing, recovery and reentry, and training exercises.

The emergency response at the local level is covered in the second part of this chapter, where emergency management and leadership commitment, the community planning team, interaction between various levels of government, local hazard analysis, resources needed on the local level, development of a basic community emergency response plan and the development and distribution of public information and education are discussed.

EMERGENCY PLANNING FOR INDUSTRIAL FACILITIES

One of the reasons for having an emergency preparedness plan is that the stress induced by a crisis severely limits cognitive ability. In plain language, when people become frightened or anxious, their ability to process information and make judgments appropriate to the circumstances is severely degraded. This happens to everyone to some degree. By planning for emergencies, one can make decisions while in a calm state, unaffected by stress, and outline rational response activities commensurate with the events that have been defined and prepared for in advance.

Initially, the emergency planning process focuses on analysis of the situation. Members of the planning team use analytical skills to approach the problem. They will, for example, analyze the hazards associated with the facility, assess the resources currently available to control a potential emergency event, determine the facility command structure, determine what external resources exist, collect information on applicable codes and regulations, and analyze existing plans and assess their validity.

Once this initial work has been completed and relevant material has been collected, emphasis switches toward the preparation of the actual plan document. This includes allocation of the resources needed to control emergency events, procedures to raise the alarm and assess the severity of the situation, establishment of a chain of command and emergency response structure and definition of response strategies to protect people, the environment, and property while mitigating an event. These activities lead to synthesis of the previously accumulated information into a cohesive emergency response organization and structure.

An effective emergency response plan should include the following:

- Pre-emergency planning and off-site coordination
- Identification of roles and responsibilities of assigned personnel
- Training programs
- Communication structure
- Emergency recognition and prevention
- Identification of safe distances
- Places of refuge and evacuation routes
- Decontamination procedures
- Emergency medical treatment and first-aid training
- Locations, emergency alerting and response procedures
- Identification of personal protective equipment (PPE), and emergency equipment

RESOURCES

Facility response teams typically comprise specially trained personnel normally operating the plant itself and therefore familiar with it and its hazards. However, as part of the planning process, a resource assessment should be performed. Figure 5.1 presents a sample format for performing a resource assessment. The list is not necessarily totally exhaustive, but facilities should nevertheless select only those resources appropriate for their anticipated response activities.

The resource assessment should consider not only facility resources but also those available in local municipalities and at neighboring industrial facilities. The local fire department, however, may be trained to cope only with the most common emergencies, such as structural fires and rescue, or perhaps for hazardous material transportation accidents. Thus, they may only support the primary response actions that plant personnel must implement in a serious emergency. Local resources will, however, become essential if the emergency spreads beyond the plant boundary or is the result of a transportation accident.

Resource Assessment			
Resources	*Current*	*Required*	*To Be Acquired (Acquisition Date)*
Emergency Control/Operations Center			
Media Center			
Site Notification System			
Offsite Notification System			
Communications Equipment			
Personal Protective Equipment			
Meteorological Equipment			
Firefighting Equipment			
Spill Control Equipment			
Monitoring Equipment			
First Aid Capability			
Security and Access Control Equipment			
Auxiliary Power			
Trained Employees			

FIGURE 5.1 Resource assessment chart.

Emergency Operations Centers (EOCs)

An EOC is the physical location where a predefined team of responders assembles and operates from during an emergency to coordinate response and recovery actions and resources. These centers may alternatively be called command centers, situation rooms, war rooms, crisis management centers, or other similar terms. Regardless of the term, this is where the coordination of information and resources takes place. The EOC is not an incident command post; rather, it is the operations center where coordination and management decisions are facilitated.[7]

All but very small plants should establish an EOC from which response activities can be directed and coordinated whenever a major emergency is declared or anticipated. Upon declaration of an emergency, the emergency management staff, including the highest-ranking person in charge of the operation, will activate the EOC. The EOC should be equipped with adequate communication systems such as telephones, radios, and other equipment to allow unhampered communication with the site response teams, external agencies, and other response organizations.

A properly designed EOC should serve as an effective and efficient facility for coordinating emergency response efforts. An EOC may serve a number of uses, including operations, training, and meetings. The EOC can optimize communication and coordination by effective information management and presentation.

The EOC should be located where the risk of exposure to accidental releases is minimal. When possible, it should also be located close to routes easily reached by response personnel. Only a limited and prearranged number of people should be admitted to the EOC. This eliminates unnecessary interference and reduces confusion.

The EOC should be designed to protect its occupants against releases, especially against infiltration of toxic vapors. A small meteorological station (or at least a wind sock) should be located nearby to monitor wind direction and velocity. The EOC should have an uninterruptible power supply or at least backup power for lighting and electric communication system operation. The EOC should always be ready for operation. It need not be a single-purpose room; a conference room can be easily adapted for this purpose, provided it is maintained for EOC operations as well.

Media Center

A media center is a designated room located on or near plant property where representatives of the various news media would be admitted during an emergency. This center should be located near the plant entrance and be the only area accessible to news reporters. This limits access to the facility for all nonessential personnel.

The public affairs officer should ensure that the necessary media material is stored at or near the media center. Such material should include a fact sheet on the facility describing the number of employees, annual payroll, taxes paid to the community, a simple description of the plant processes, consumer products that are produced either at the facility or ultimately from its operations, and a facility map.

Communication Equipment and Alarm Systems

Communication equipment and alarm systems are essential to notify plant personnel, to notify external agencies, and to coordinate response operations. Initial notification equipment and procedures are especially important because their effectiveness determines how rapidly the response actions can be initiated. Communication equipment must be available to each function within the response organization to prevent communication breakdowns.

Horns, Sirens, and Public Address Systems Audible alarm systems are commonly used in many industrial facilities. Horns and sirens rely on different types and lengths of tones to convey messages. An alarm should not just warn but also instruct people to perform specific assignments. However, horns and sirens can convey only a very few simple messages. Public address systems are limited in areas of excess external noise. In high-noise areas, it is appropriate to install a visual signal (e.g., a flashing light) as well as an audible alarm system. Systems that use belt-worn vibrators as alarm signals are also used.

Telephones Telephones are often the preferred means of communication for reporting emergencies and for communicating between different areas of the plant. The EOC should be equipped with enough telephone lines to enable all the members of the response teams to communicate effectively. Some lines should be equipped for outgoing-only capability. Cellular phones are also very useful in emergencies. They can be used to notify response personnel who are away from the plant, by emergency management to direct operations while on the way to the site, and even to coordinate the entire response effort.

Portable Radios Radios are most effective for communicating with emergency response teams operating in the field. In addition, they can be a backup system in case of telephone communication breakdown. Emergency response radios should operate on a frequency dedicated for emergency communications only.

Mobile Phone/Text Messaging/Email In recent years, new technology has allowed the contact of many people simultaneously. Computer command centers based at EOCs can now distribute, with just a few commands on a computer, messages to people via phone, pager, fax, e-mail, and text message. Contact information is inserted in a computer calling system. Messages can then be distributed to a predetermined list of personnel based on the alert level and complexity of the event. To reach a wider group, text messages can now be sent to cell phones over a broad-based contact system. Personnel must register to receive the messages and agree to follow emergency response protocol.

Personal Protective Equipment (PPE) The main function of PPE is to protect personnel from a hazard while performing rescue or emergency control operations. Protective clothing for protection against heat radiation or those having high resistance to chemical assault (acid suits) are typically used by response personnel. The most important pieces of protective equipment in both fire and toxic release events are the self-contained breathing apparatus (SCBA).

Personnel performing tasks that require prolonged exposure to a toxic environment such as smoke or toxic vapors typically use SCBA. The use of SCBA requires training. It is also important to remember that personnel performing any such containment or control operations must be trained in accordance with the appropriate levels of emergency response mandated by 29 CFR 1910.120 (q).[3] The PPE and SCBA should be stored in strategic locations throughout the plant, for example in control rooms, EOCs, the firehouse, special plant units, and the emergency supply storage area. A compressor is required for refilling the cylinders. The SCBA should be inspected and serviced periodically through a preventive maintenance program.

In addition to protective clothing, there are a variety of instruments available to monitor the conditions surrounding emergency response personnel. Portable gas detectors that are intrinsically safe for service in hazardous environments are available. These devices can be supplied with sensors that can monitor methane, lower explosive limits, toxic gases, chlorine gas, hydrogen sulfide, carbon monoxide, oxygen deficiency and other hazardous concentrations. Also, portable gas chromatographs are available that can provide compound-specific data on the concentrations of gases in the breathing zone as well as preliminary information on contaminated soil or water.

Other important PPE items are personnel respirators and escape hoods. Both can selectively reduce exposure to toxic gases or particles. All require training to be properly used. There are several different types of respirators and escape hoods, including the following:

- Escape respirators for quickly leaving a dangerous area to a safe one
- Particulate respirators that only protect against particles but not against gases or vapors
- Chemical cartridge or air purifying respirators that trap chemical gases and possibly particles from the breath air
- Powered air purifying respirators use a fan to blow air through the filter to the user

There are some important questions one should ask about any respirator or escape hood:8

- What protection (which chemicals and particles, and at what levels) does the respirator or escape hood provide?
- Is there more than one size?

- How does one know if the gas mask or escape hood will fit the user?
- What type of training is needed?
- Has the respirator or escape hood been tested against claims for protection such as biological agents, chemical warfare agents, toxic industrial chemicals, and radioactive dust particles?
- Who performed the testing, what were the tested levels, and test durations?
- Is the respirator or escape hood certified by an independent laboratory or government agency?
- Are there any special maintenance or storage conditions?
- Will the user be able to talk while wearing the respirator?
- Does the hood restrict vision or head movement in any way?
- Can one carry the device in the trunk of an automobile?
- Is a training respirator available?
- Can one use the same device more than one time?
- Can children wear the respirator or escape hood and get the expected protection?

Finally, EPA identifies four levels of PPE ensembles for responding to chemical spills:[8]

- **Level A** protection is used when contaminants are present that require the highest possible degree of both respiratory and skin protection. Includes the use of an atmosphere supplying respirator such as a self-contained breathing apparatus (SCBA) and a totally encapsulating chemical protective (TECP) suit.
- **Level B** is used when contaminants are present that require the same degree of respiratory protection as Level A, but require a lesser degree of skin protection, such as a splash suit that is not totally encapsulating or gas tight.
- **Level C** involves the same degree of skin protection as Level B, but a lesser degree of respiratory protection. Oxygen levels and chemical concentration levels must be known in order to use the air-purifying respirators in the Level C ensemble.
- **Level D** provides protection only against "normal" workplace hazards and is not designed to protect against chemical hazards. Includes safety glasses, hard hats, steel-toe boots, and leather work gloves.

Firefighting Facilities, Equipment, and Supplies

Medium-sized and large plants usually have some type of firefighting capability. Fire pumper trucks are the most important units. National Fire Protection Association (NFPA) standards provide details on the equipment to be carried on pumpers and on ladder trucks. For example, NFPA provides guidelines for the use, maintenance, and service testing of fire department ground ladders.[9] A firewater distribution system is common to many industrial facilities. Arrangements should be made to access water tank trucks to supply additional water if the need arises.

Specialized firefighting equipment is often necessary at industrial sites because of the unusual chemical process. For example, dry chemical units carrying large quantities of dry extinguishing material such as potassium bicarbonate (purple K) may be necessary where water cannot be used as extinguishing agent.[10] Fire-extinguishing foam is probably the most frequently used nonaqueous medium.

New innovations are assisting firefighters in responding to chemical fires and complex situations. Thermal imaging equipment is now available that allows firefighters to “see” in areas with dense smoke. GPS equipment allows firefighters to locate one another in complex situations where multiple activities are occurring.

Spill and Vapor Release Control Equipment

Few methods are available to control a vapor release after it has occurred. Fixed abatement systems (e.g., water curtains) spraying an absorbent such as water into the dispersed cloud of a soluble vapor such as ammonia and hydrogen chloride or fluoride are occasionally used.[11,12] Sometimes, dispersion of gases in air below their flammability point can be achieved using water streams.

Special tools may be required to perform some response operations to control the leak or vapor release, such as plugging a leak or shutting off jammed isolation valves. Equipment for stopping and containing a liquid spill is also necessary. Emergency containment systems for liquid spills, such as booms and portable dikes, can be built to limit the leaching of spilled material into the ground and to nearby sensitive areas. Quick-setting foams can be applied to create an impermeable barrier to limit leaching of spills into the ground. These foams can also be used to temporarily plug a leak.[13] Also, emergency spill containment barriers designed for rapid deployment are available. These units are manufactured from chemical-resistant flexible membranes and have self-supporting perimeter chambers. Vacuum trucks are another useful type of spill response equipment. These trucks can quickly collect surface liquids for transport to appropriate disposal facility.

Many facilities have spill containment trailers equipped with a variety of spill control equipment and supplies. Usually these trailers are outfitted with sorbent products, acid neutralizers, spill containment berm, pumps and tanks, and various types of PPE. Universal sorbents are available that can control pesticides, acids, hydrocarbons, and chlorinated compounds. Also available are products that rapidly neutralize and solidify low pH fluids such as hydrochloric acid, nitric acid, and sulfuric acid.

Medical Facilities, Equipment, and Supplies

Most industrial facilities have a medical center. This facility should be equipped to deal with the most likely medical emergencies at the particular site and contain a file of material data safety sheets (MSDSs) on site-specific chemicals. Additionally, the plant response team personnel should be trained in cardiopulmonary resuscitation and should be equipped with the most common types of rescue equipment.

Meteorological Equipment

During toxic gaseous release emergencies, meteorological conditions greatly affect migration speed and direction. The most important of these parameters are wind direction and speed. A facility should have one or more meteorological stations where this key information is constantly monitored. The station needs not be complex. Care should be taken to avoid locations where the presence of buildings and other structures may result in faulty readings. In addition to mounting windsocks on the highest point for optimum visibility, windsocks should also be located close to the ground so that people leaving a building in an emergency know in which direction to run to avoid a toxic plume.

Security and Access Control Equipment

In an emergency, it is likely that traffic flow around the plant may have to be redirected, especially if toxic material has contaminated nearby areas. Equipment such as flares, emergency lighting, road barriers, reflective vests, reflective tape, and traffic control cones should be available to security personnel.

Environmental Testing Systems

Although initially the emphasis of the emergency response will focus on containment and control of the situation, it will quickly shift to evaluation of the potential impacts to the environment. Thus, planning should also include methods to quickly assess the degree of potential environmental impacts. While it is not normal for a facility to own a drill rig or soil-testing apparatus, planning should include mechanisms to acquire these services rapidly, if needed. By quickly assessing the magnitude of potential impacts, an effective remedial response that will control potential threats can be developed. Hydraulic push soil-sampling machines are very useful to collect near surface soil and groundwater samples, and a variety of instruments are available to do field analysis of the samples. Also, arrangements should be made with a nearby environmental testing laboratory to provide rapid turnaround analysis of samples.

Mobile laboratories and field test kits for various types of chemicals are available. For example, portable GC/MS units are available that can provide high quality chemical testing in the field on a fast turnaround basis. The ability to have field-based testing is critical when trying to assess the magnitude of the impact and the extent of threats to human health and the environment. GPS systems are available that allow real-time location and plotting of sample locations so that the finding from rapid testing equipment can be interpreted in a dynamic fashion. This allows managers to determine the next sampling locations as the investigation unfolds.

EMERGENCY ACTION LEVELS

A practical way to classify the seriousness of an incident and quickly convey this information to other personnel is to use emergency action levels (EALs), which may be designated by code names or numbers associated with situations of different intensities. The higher the number, the more serious the problem. A four-level classification system is typically adequate:[14]

Level 1: Minor building incident. This can be resolved by the responding service unit. No other entities are involved.

Level 2: Building incident. This can be resolved with existing facility resources or limited outside help. These incidents are usually one-dimensional events having a limited duration and little impact, except those using the space/building in which the incident occurs.

Level 3: Major emergency impacting a sizable portion of the facility and/or outside community. Level 3 emergencies may be single or multihazard situations, and often require considerable coordination, both within and outside the facility. These emergencies include projected events on the facility or in the general community that may develop into a major crisis or a full disaster.

Level 4: Catastrophic emergency involving the entire facility and surrounding community. Immediate resolution of the disaster, generally multihazard, is beyond the emergency response capabilities of the facility and local resources.

The use of EALs has the advantage of standardizing response to different classes of events in terms of the resources mobilized to cope with the emergency. It also improves communications during critical times.

EMERGENCY RESPONSE ORGANIZATION

A major objective of contingency planning is the creation of a response organization structure capable of being deployed in the shortest time possible during an emergency. For this purpose, the following questions must be answered:

- What will be the command structure and who will be in command of emergency operations?
- Will the command structure change as more response personnel reach the event site?
- How will the command structure evolve if the emergency worsens?
- Who will decide what company resources to allocate to mitigate the consequences of the event?
- Who maintains communication with whom during an emergency?

- Which emergency functions (e.g., firefighting, engineering, medical) should be deployed?
- Who will be in charge of each specific emergency response function?
- Where should the command post(s) be located?
- Who decides which protective actions to recommend?
- Will environmental testing be required?
- Who decides when the emergency is over?
- Who is responsible for recovery operations?

A response organization, complete with command structure, should be developed. One method of arriving at this is to first develop a responsibility matrix of emergency organization functions versus the departments or positions that will have primary and support responsibilities for performing them. An example of such a matrix is presented in Figure 5.2.

Initial-Response Organization

The timely implementation of appropriate initial response actions may significantly mitigate the consequences of an emergency. One person should be designated to be in charge of the initial response. Usually, responsibility for coordinating these early emergency response actions is assigned to the shift supervisor. The shift supervisor assumes the function of emergency director and assesses the level of severity of the emergency event using the emergency action

Function **Department/ Individual**										

FIGURE 5.2 Emergency responsibility matrix.

level classification system; notifies the appropriate personnel, departments and agencies; and directs the response activities.

Other plant personnel are also assigned the task of covering the other key functions in the initial emergency response organization until the predestinated personnel arrive to relieve them. Initially, the production or operations manager, who could also act as the field operations coordinator, takes the post of response operations coordinator. Alternatively, the production supervisor of the unit where the emergency occurs could take the latter position. These two coordinators are in charge of organizing response activities and directing response operations at the actual emergency scene.

Full Emergency Response Organization

The deployment of the full emergency organization is required only in the case of severe emergencies. An example of a full emergency organization chart is given in Figure 5.3. Multiple personnel are assigned to all emergency functions in the event that the principal person is unavailable to cover that position. The personnel assigned to each of the different functions shown in Figure 5.3 play key roles in implementing the decisions made by the emergency director. They decide what appropriate response actions to take, such as shutting down the plant, fighting fires, evacuating plant personnel, recommending that the public be evacuated from certain areas, carrying out emergency repair work, arranging for supplies or equipment, and coordinating actions with local off-site agencies.

Emergency Director (Site Emergency Coordinator)

The emergency director responsibility includes those actions necessary to bring the emergency under control and the overall supervision of the protective actions recommended for the public, employees, and the environment. It is recommended to the degree possible that the same hierarchical structure used during normal operation should be maintained during an emergency. Thus, the plant manager should be assigned the emergency director position, if possible.

Response Operations Coordinator

The response operations coordinator operates in the EOC and is responsible for coordinating the activities. The response operations coordinator performs the following functions:[14]

- Assists the emergency director in organizing and directing emergency activities
- Formulates strategies on actions to be taken to mitigate consequences of the event
- Maintains direct communication with the on-scene incident commander
- Establishes a journal/log for recording activities
- Evaluate operational information and determines priorities
- Requests additional personnel and equipment resources

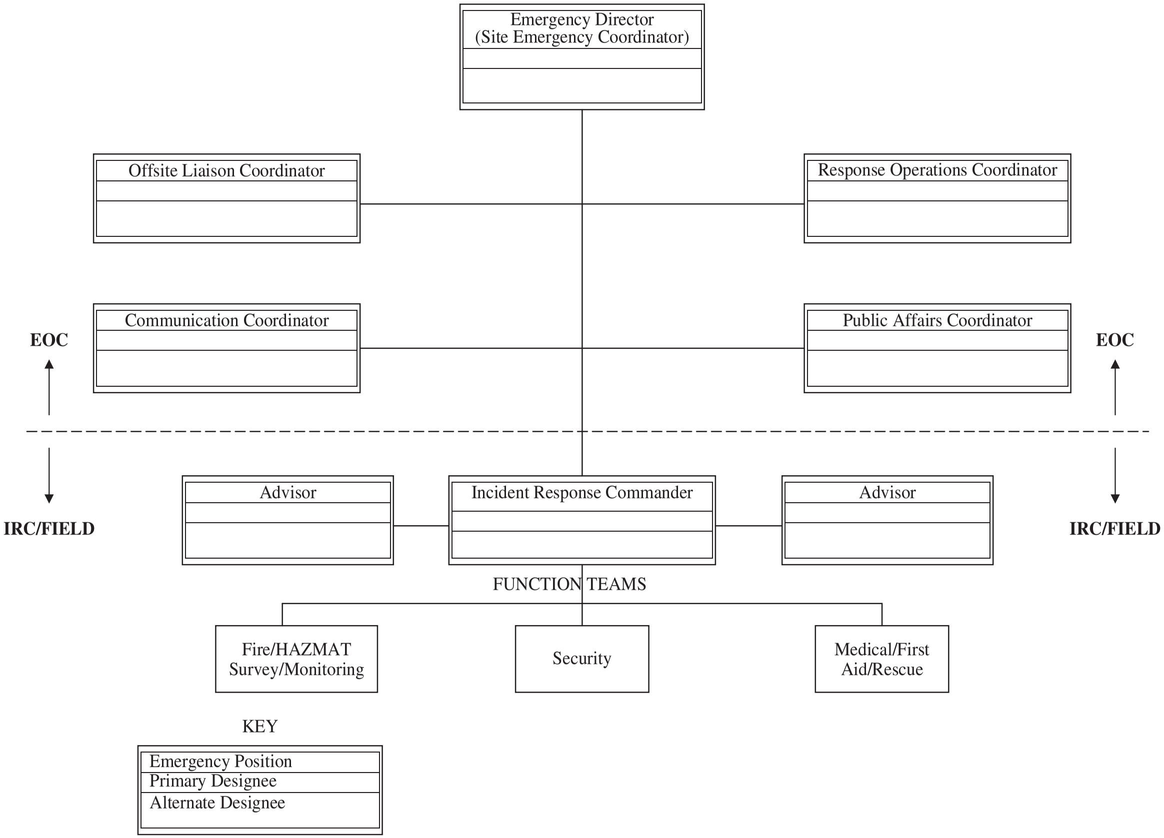

FIGURE 5.3 Emergency response organization.

The response operations coordinator should be very knowledgeable of the plant and its response plan and organization. In small plants, this position may coincide with the emergency director function. In other cases, the plant manager may assume the emergency director function, mainly because of the responsibilities associated with this role and his or her overall responsibility for the safety of the facility. The response operations coordinator may perform the bulk of the coordination activities.

Incident Response Commander (IRC, Field Operations Coordinator)

The incident response commander or field operations coordinator is the highest ranking officer at the scene of an emergency event. The command post from which that person directs the emergency response should be located as close as possible to the emergency field operations. The main responsibilities associated with this position are as follows:

- Direction and coordination of all field operations
- Assessment of severity of the incident
- Recommendation of on-site protective actions
- Implementation of response actions at the scene of the event
- Coordination of these actions with the emergency preparedness coordinator

The incident response commander must also be very familiar with the facility and have solid technical expertise.

Incident Response Team

These are the group of persons directly involved, and prepared for, an emergency event. Typically, there are two types of teams: specific member teams and volunteer or ad-hoc teams.

Specific member teams are trained and are on standby all the time during scheduled hours. They are normally paid by the state or local municipality or agency and therefore outside the facility operations. Sometimes, plants are large enough to support a specific member team. They are usually organized by rank and have a clearly defined chain of command and response structure. Examples are SWAT and municipal fire department HAZMAT response teams.

Volunteer or ad-hoc teams are composed of willing volunteers who get special training focused on emergency response. These teams undergo specialized training for various aspects of the response and are prepared to fulfill the roles required by the specific situation. They normally have unrelated jobs at the facility, but in an emergency respond as a member of the team. Example would be a member of the engineering department trained in confined space emergency response.

EMERGENCY FUNCTIONS

Implementation of an emergency response plan relies on a number of functions that deal with different aspects of the emergency. The most important emergency functions are as follows:

- *Communications*. Ensures that the flow of communications among the response personnel within the on-site response is effective and uninterrupted.
- *Fire and rescue*. Most facilities have an emergency response team, primarily trained to handle fires and rescue operations and typically composed of personnel from the different plant units or departments. These teams usually have some basic training in the handling of other types of emergencies (such as spills) to control the situation before more specialized teams arrive at the scene. Team members are trained in comprehensive first aid, search-and-rescue procedures, and emergency equipment handling.
- *Special hazard (HAZMAT) or spill control*. This function is associated with personnel specially trained in dealing with any emergency caused by the presence of special hazards such as releases of toxic or hazardous materials. The handling of these emergencies depends on the physical state of the material released, type of hazardous material (e.g., poisonous gas, explosive, flammable liquid), type of facility from which the material is released (e.g., storage tank or reactor), and type of event (e.g., vessel rupture, overfilling, spill, fire, toxic vapor release).
- *Process/utilities*. Controls the process during the emergency and ensures that the necessary facility units are shut down. This function is also responsible for generating the necessary utilities during the emergency and isolating the impacted portions of the manufacturing process.
- *Engineering/technical assistance*. Provides the technical support for strategies to isolate damaged process equipment, designs emergency transfer of materials to safe vessels, and is responsible for all other process-related emergency management.
- *Environmental and field survey*. This function is responsible for reducing the impact of an emergency on the environment. This function develops programs to monitor potential migration of the release and assesses impacts.
- *Medical*. This function is responsible for providing first aid to the victims and arranging for their prompt transportation to an appropriate hospital and also for providing information on the nature and properties of the chemical and identifies the most appropriate emergency treatment of injured or exposed personnel.
- *Security*. This function is responsible for ensuring that plant security is maintained, making sure that unauthorized persons are not admitted to the plant, and controlling the entry and exit of contractor and other appropriate response personnel.

- *Off-site liaison*. This function coordinates actions between the on-site response organization and the various external response teams, departments, local representatives, agencies, and neighboring industries.
- *Public affairs/legal counsel*. The function is responsible for providing news releases and legal counsel during an emergency.
- *Resources/supplies* This function ensures that the necessary supplies are available to the emergency response teams and organizes and maintains the staging area where emergency material and equipment is temporarily stored.

All the persons in charge of each of these functions report to the emergency director or to the incident response commander. A team is established, the size and composition of which depends on the task to be performed and the size of the facility. This team operates according to instructions provided by the emergency director's staff and utilizes preformatted, written procedures to accomplish their tasks.

EMERGENCY RESPONSE ACTIONS

One critical aspect of emergency preparedness is the identification of the actions to be implemented by the various response functions. Although the emergency response plan includes generic descriptions of the functions, specific details are incorporated in the annexes to the plan. For simplicity and user friendliness, these are best formatted as checklists.

Concept of Operations

An outline of the response sequence should be included in the emergency plan. This plan should include a brief description of the following points:

- Brief description of plant operations and chemicals handled
- Warning upon discovery of an abnormal event
- Event evaluation and classification
- Emergency declaration and response team activation
- Notification of off-site response teams
- Implementation of on-site response actions
- Identification of protective actions
- Coordination of response actions with external resources
- Completion of the response and plant reentry

Emergency Response Implementing Procedures

Emergency response organization implementation is organized according to the type of hazard. Different manufacturing facilities use varying types of chemicals in their processes, which require customizing the response to the situation. For each hazard, a set of procedures is developed, which includes checklists of detailed steps, to be followed by the response teams for the release situation.

Environmental Considerations

An environmental emergency such as a hazardous substance spill or gas release requires not only notification and mobilization of containment and control response teams but also an understanding of the potential migration pattern of the material in the environment. Basic site information, such as geology, soil types, proximity to water bodies, and general meteorological conditions, needs to be available so that this information can be used to design a sampling program. It is important to quickly obtain data on soil, air, or water impacts in order to assess risk and define the magnitude of the affected area. For example, if a facility has a shallow water table, a surface spill could impact groundwater quality. This situation would require groundwater as well as soil sampling. Conversely, if the water table is deep or separated from the surface by a low permeable layer, then groundwater sampling may not be necessary and the focus of sampling may be toward soil and surface-water impacts.

Another important need for sampling media at the time of the emergency is to establish a database that can be used to protect the responsible party from unjustified damage claims. Environmental damage lawsuits are common in today's world and in many cases are driven by emotional issues. Hard data, acquired at the time of the incident, can be very useful in controlling damage claims and establishing a factual representation of the impacts from the event.

Finally, it is important to understand the local, state, and federal regulatory community. A spill or other emergency event that causes a release of a chemical to the environment will involve reporting this incident to the appropriate regulators. They will want to understand the extent of the impacts and whether any human health or sensitive environmental systems are threatened. Usually, any sampling data generated by studying the effects of the event will need to be submitted to the regulators. In some cases, an environmental consultant or engineer will needed to be hired to oversee the investigation and determine if clean-up is necessary and to what degree. He/she would also be responsible for preparing a report of clean-up. It is useful to document activities taken to minimize environmental impact in light of the sensitivity of this issue and the public concern.

Recovery, Reentry, and Restoration

One area typically neglected in the emergency plan is postemergency activities. Specific procedures for recovering from an emergency and reentering a facility must be determined on a case-by-case basis. However, guidelines for response team activities following termination should be included.

Once the critical phase of the emergency is concluded, an inspection team appointed by the emergency director should enter the damaged area and ensure that it is safe for recovery operations.

The impact of an emergency event may be felt throughout the plant even if only a relatively minor emergency has occurred. If toxic or flammable materials have been involved in the event, the area must be decontaminated and the procedures used should be discussed in the plan. It will be important to collect samples of the impacted area after clean up in order to document the restored condition and provide evidence of a clean work space. The main objective of the recovery phase is to restore the plant to its initial condition so that normal plant operating conditions can be established as quickly as possible. After the emergency is concluded, the emergency response should be reviewed and the plan adjusted accordingly.

TRAINING, EXERCISES, AND PLAN MAINTENANCE

An emergency plan, no matter how carefully prepared, cannot be effective unless accompanied by a training program. The objectives of training and drills are to accomplish the following:

- Familiarize personnel with the content of the plan
- Train new or existing personnel
- Train specific response personnel in certain special skills
- Introduce personnel to new equipment and techniques
- Keep personnel informed of changes
- Test the preparedness of response personnel
- Test the validity, effectiveness, and timing of the plan
- Test emergency equipment preparedness
- Maintain cooperative capability with other response organizations

Anyone assigned to a position within the emergency response organization needs initial training. Members of off-site emergency response organizations should participate in training exercises because it strengthens the cooperation among response groups and improves communication procedures. Drills and exercises are vital to emergency preparedness. Both involve enactment of the implementation of the response actions performed during an emergency.

There are three types of training: tabletop drills, functional drills, and full-scale exercises. Tabletop drills are useful for orientation purposes, while functional drills are designed to test a limited aspect of the response capability (e.g., a fire drill). Full-scale exercises are more comprehensive and test the entire response organization up to and including communication with off-site response organizations. An important benefit of training exercises is that the response plan is reviewed during these activities, a process referred to as *plan maintenance*.

The two main benefits of the training are individual training and system improvement. Individual training exercises enable people to practice their roles and gain experience in these roles, while the exercises improve the organizations system for managing incidents and emergencies. Exercises only have value when they lead to improvement.

EMERGENCY PLANNING AT THE LOCAL LEVEL

Regulatory requirements exist under OSHA and the Environmental Protection Agency (EPA) for interaction with local, state, and, in some cases, federal agencies[1,2,3] and require the development of hazardous materials emergency response plans for local communities. For communities to develop these plans, they need to be aware of the hazards presented by facilities within their planning district. Those facilities that fall within the planning district must, by law, provide a representative to assist the community with its planning.

Emergency Management

Effective emergency planning at the local level provides assurance to a community as to how citizens and the environment will be protected in a disaster. Emergency response plans on the local level have the following objectives:

- Create an ensured level of preparedness
- Ensure an orderly and timely decision-making process
- Ensure the availability of necessary services, equipment, supplies, and personnel
- Ensure a consistent, preplanned response

The optimum emergency management plan delineates actions that may be required for any hazard.[14] Such broadly applicable functions as direction and control, warning, communications, and public protective actions are generic to the management of events.

A multihazard emergency operations or contingency plan consists of a basic plan, generic functional annexes, and hazard-specific appendices.[15] The basic plan provides an overview of the local entities' approach to emergency management, while the generic functional annexes address the specific activities required in all emergency response on the local level. Hazard-specific appendices provide response direction for special problems identified during the hazards analysis process. They detail the tasks to be performed by preassigned organizational elements at projected places under specific circumstances, based on plan-defined objectives and a realistic assessment of response capabilities.

Leadership Commitment

Management commitment to emergency preparedness is essential to an effective response at the local level. The motivation for leadership commitment to effective emergency preparedness comes from the concerns of the citizens in the community. Citizen awareness of the potential threats to safety, health, and the environment from hazardous materials is growing. Local government officials have the authority and access to resources necessary to develop the plan that will allay their fears. They also have the credibility to interact effectively with industry leaders and other government jurisdictions.

Management of a crisis and authority to direct the response must be vested in an individual who is responsible and accountable. At the local level, this is usually the elected chief official. Alternates should be named for each defined position in the local emergency organization. Alternates must have the same responsibility and accountability. The question of direction and control must be confronted directly before an emergency occurs because it is impossible to establish a line of command and control while a crisis is in progress. The chain of command needs to be clearly laid down and accepted within an organization long before an incident occurs.

This is particularly important with regard to the interaction between the local level officials and others within the state, county and federal government. The planning document should address the different levels of government and their roles and responsibilities during emergency response. Local jurisdictions have the primary duty to save lives, protect property, protect the economic base of the community, and preserve the environment. However, there will come a time when an emergency requires resources beyond those available at the local level, and additional agencies and departments need to assist. The interaction between all these parties must be prearranged in order to allow for the effective command structure. Normally, federal resources in the form of FEMA have to be acquired through a formal request made by the governor of the affected state.

The chief executive of a community is charged with coordinating the functions of the local fire and police departments and any other agencies involved in aspects of local emergency response. These groups may have differing views about their roles in managing an incident. It is up to the community leader to resolve these differences before an emergency situation arises. It is important to note that the responsibility for assuring proper local incident response is assigned to the appropriate office and not the individual. Ideally, there should be written agreements in place that define the roles and responsibilities of all the appropriate entities before the emergency. These agreements can be obtained through the planning process.

Planning Team

Successful planning requires community involvement and support throughout the process. When a community participates in the planning process, then it will accept the plan. Cooperative interaction among responders and the community begins with the planning process. Most important in the development a community emergency preparedness plan is a leader who has the respect of the organizations involved in the local emergency response. Management and communication skills are essential for gaining the cooperation of all concerned parties.

The team should be staffed with individuals with expertise in many areas. Representatives of industrial facilities in the community that could be potential sources of hazardous substance releases should be included, as well as knowledgeable officials from transportation, community resources, and utilities.

The group should represent all elements of the community and be able to work cooperatively.

A component of the community emergency response planning is the Local Emergency Planning Committee, or LEPC. This is a voluntary organization established to meet the requirements of the federal Emergency Planning arid Community Right-to-Know Act (EPCRA), also known as the Superfund Amendment and Reauthorization Act (SARA Title III), for emergency response planning. EPCRA contains four major provisions:

1. Emergency planning
2. Emergency release notification
3. Hazardous chemical storage reporting requirements
4. Toxic chemical release inventory

Each one of these components is associated with specific reporting requirements, which will not be discussed here. Instead, the following sections briefly touch upon the planning process, the key steps in the development of the response plan, the content of the plan and procedures, and the integration of the plan with other response plans.

PLANNING PROCESS

As discussed in previous sections, the planning process is the key to success. Agreeing to use a document prepared by others substantially reduces the value of the planning process and diminishes the commitment of those who must prepare the plan. The relationships of the industry, government, and the local community are often fragile. The process itself provides an opportunity to interact with the participants so they become aware of their strengths and weaknesses.

Hazards Analysis

The planning team is responsible for several key components. Hazards identification, vulnerability analysis, and risk analysis together make up the hazards analysis task. Help with this process is available. The EPA has developed a publication jointly with the Federal Emergency Management Agency (FEMA) and U.S. Department of Transportation (DOT) to assess the hazards related to potential airborne releases of extremely hazardous substances [“Technical Guidance for Hazards Analysis” (“Green Book”)]. Information on this and other relevant publications is available elsewhere.[16]

Hazards Identification Identification of the hazards determines whether a plan is really needed. High-priority hazards should be addressed first. For facilities or transportation routes where the identified hazard is toxic or flammable material, the identity, location, and quantity must be precisely determined. The facility that manufactures, processes, stores, or uses such material is the logical source of this information.

Vulnerability Analysis The vulnerability analysis, sometimes called a consequence analysis, involves determination of the areas, populations, and facilities that may be at risk if a release occurs. A list summarizing those critical facilities in the county or municipal area whose loss would severely hamper emergency operations or increase the potential for loss of life or property should be included in the plan.

Risk Analysis The purpose of the risk analysis task is to determine the potential and severity of a possible incident. Methodologies are available for calculating estimates of the quantity of a release, the rate of dispersion, and possible concentrations that could affect human health. The previously identified EPA document[16] lists a number of publications and computer programs available from federal agencies, such as the *Handbook of Chemical Hazards Analysis Procedure* ("Brown Book"), which provide fairly detailed information useful for estimating the size of zones considered vulnerable to toxic effects from accidental releases. These documents give additional information on suggested levels of concern. When completed, a local risk and vulnerability analysis should provide the following:

- Geographic description of the areas deemed vulnerable to the identified hazard
- Size and type of populations expected to be in the defined vulnerable zones
- Property and essential utilities services that may be affected
- Environmental media that may be affected

Examples of emergency planning information that result from this process include needs for facilities and equipment; identification of safe zones for conducting response coordination and the type of equipment needed for event mitigation, emergency worker protection, and spill clean-up. Also, criteria for determining the extent of emergency response required can be established.

Additional information that should be included in the risk analysis is identification of important community resources. Sources of water are particularly vulnerable to environmental emergencies. Groundwater supply wells or surface-water reservoirs should be located on maps. Water supply distribution systems, important transportation routes, electrical supply substations, and wastewater treatment plants are examples of community resources that should be factored into risk analysis. Recently, geographic information systems (GISs)—computer systems capable of assembling, storing, manipulating, and displaying geographically referenced information—have become widely used to electronically map community resources, thus enabling risk planners who must respond to emergency situations to have access to relevant data identified according to their geographic locations, such as population densities, wetlands, groundwater resources, or critical conservation areas.[17]

Emergency action levels (EALs) or an incident classification system should be included in the planning process because they are preestablished conditions that can be used to trigger a desired response. The definition of EALs during the planning removes the ambiguity of uncertainty attitude when a problem emerges.

Damage Assessment and Recovery Operations

During the early phase of an event, the initial damage is only estimated. Plans should include procedures for conducting more detailed surveys. The procedures should include safety concerns, structural damage, clean-up activities, reentry controls, and hazard assessment. Recovery operations include informing and briefing local officials, issuing public information releases, restoring medical and government functions, removing debris, restoring utilities, providing emergency shelter, and providing building and public safety inspections.

Resources

Resources, in terms of people as well as facilities and equipment, are necessary for the contingency plan to work. Questionnaires should be developed in order to identify available resources. The questionnaires should be provided to the sources of identified hazards (facilities, transporters) and to local response and government agencies. The National Response Team's *Hazardous Materials Planning Guide* (NRT-1, 2001 update) contains a list of questions.[18]

Personnel The people available to implement the contingency plan must be identified. The specific community points of contact should be identified by position and title, along with their areas of responsibility. A list of the individuals who hold these positions and their alternates should be developed separately. Since positions stay constant, the plan should identify position titles only, with names of responsible individuals and 24-hour phone numbers in a separate, easily updated document. Once the personnel resources and areas of responsibility are identified, a matrix of groups versus functions is readily constructed.

Facilities In most cases, local governments already have facilities in place to handle the types of emergency situations they are likely to face. To the degree possible, the facilities should be integrated into the plan and augmented as necessary for industrial emergency response. In order to develop mutual understanding, letters of agreement or memoranda of understanding must be executed between government leaders and the organizations responsible for buildings that may be needed during an emergency. Normally a section of the town hall or police or fire department headquarters is established to store the equipment necessary to set up a center from which to direct emergency response.

The public receives most of its information about emergency situations through the media. For this reason, a media center should be available, staffed by spokespersons from industry as well as from local government and response agencies. Other facilities that may be needed in local response to an emergency depend on what has been identified during the hazards analysis phase. A government inventory survey (GIS) can be very useful in quickly identifying available resources. For example, if emergency response personnel may be exposed to toxic or radioactive materials, a decontamination center may be required. Portable, inflatable tents have been designed for this purpose. Whatever means are employed, procedures should be in place for their use. Additional consideration should also be given to the possible need for vehicle decontamination. For example, some commercial car washes recycle their wastewater, and agreements could be made with them.

The planning team should make arrangements assuring that emergency medical treatment will be available. The plan should consider the placement of a triage area near the scene of an event. Agreements should be established with local ambulance companies who will be directed to this area to transport the severely injured to area hospitals or treatment centers. The planning team should ensure that medical personnel at the designated centers are aware of the potential health hazards.

Sheltering in place is the most desirable mode of public protection in fast-moving industrial emergency events. However, evacuation of areas near the scene may be necessary. The planning team should develop an evacuation plan that describes optimal routes and identifies relocation centers. Public schools are often designated as relocation centers because they have cafeterias, adequate sanitary facilities, and large open gymnasiums.

Equipment The equipment needed for emergency operations at the local level is, to some degree, generic, yet also hazard specific. Emergency operations centers are equipped to handle any kind of major emergency. Communications equipment will be essentially the same in all cases, as will public warning systems and notification methods, traffic and access control, public works, law enforcement, and health and medical services. Computers connected to the Internet and copy and fax equipment should be available for electronic/hard-copy transmission and reception of data and messages.

Large-scale maps of the planning area should be prominently displayed in the local EOC. Major transportation and evacuation routes, as well as identified hazard locations with their vulnerable zones, are provided on the base map. Airborne dispersion plume projection overlays or templates are useful additions, especially for transportation accidents involving toxic releases or spills, with known wind speed and direction and populations at risk identified promptly for protective action. Specialized equipment for response to industrial plant emergencies depends on the nature of the identified hazards. Much of this necessary planning information comes from the hazards analysis process. Here, again, a GIS is useful because it allows a large amount of information to be stored electronically and then integrated with other relevant information to evaluate relationships.

Content of the Plan and Procedures

The best local-level contingency plan attempts to consider all potential hazards and is adaptable enough to accommodate those identified in the future. However, it is overly optimistic to consider that all hazards can be planned for; thus, a better term for the plan is a multihazard emergency operations plan (EOP). The EOP includes (1) a basic plan, an overview of the general approach to emergency management; (2) functional annexes in support of the basic plan to address specific activities critical to emergency response and recovery; and (3) hazard-specific appendices to the plan that address specified emergency situations. Dealing with the aspects common to all hazards first and then examining hazard-specific characteristics unique to the planning district is both efficient and economical.

Basic Plan The basic EOP is an umbrella plan that contains a substantial amount of the generally applicable organizational and operational detail. The basic plan cites the legal authority for the plan, summarizes the situations addressed, explains the concept of operations, and describes the organization and responsibilities for emergency planning and operations. The basic plan should also include maps, organization charts, and the emergency responsibility matrix. The plan should also identify critical environmental resources and environmentally vulnerable areas within the planning area.

Functional Annexes The generic functional annexes define and describe the policies, procedures, roles, and responsibilities that are inherent in the functions before, during, and after an emergency. These should include standard operating procedures, which are user friendly, checklist-type instructions for the various segments of the emergency response organization to execute the functions defined in the annexes. A telephone roster listing the names and phone numbers of key members of the emergency response organization (and their alternates) should be provided. Additional information that should be contained in the annexes is local environmental data. This would include critical habitat areas, water supply information, groundwater resources, and potentially sensitive receptors such as hospitals and schools.

One area too often overlooked in the local planning process is the step taken to return to normal conditions following an emergency. It is suggested that the planning team visit a community where an emergency event has previously occurred to learn from them what recovery problems they faced and how they resolved them.

Hazard-Specific Appendices The unique characteristics of hazards identified specific to the local planning district are included as appendices to the functional plan. A single appendix should address all response function requirements related to a particular hazard.

Plan Integration

Coordination of contingency planning between industry and community is necessary to develop mutually acceptable solutions to anticipated events. Should an actual emergency response be necessary, cooperation and commitment supply the means for orderly, timely decision making. It takes time to lay the groundwork among the members to establish an approach to cooperative problem solving. Industry should provide personnel to local planning teams and community planners should be invited to industry planning meetings.

PUBLIC INFORMATION

Public information has two roles in contingency planning: education about the plan itself and notification of an emergency condition. The first is a public relations function and the second a necessary part of the plan itself.

Public Education

Residents and businesses in industrial areas are increasingly aware of potential threats to their well being from industrial and transportation emergencies. The more information citizens have about environmental conditions and potential threats in their communities, the better equipped they are to participate in measures for their own protection. The hazards in a community and what both industry and the jurisdiction are doing to minimize the risks must be made known clearly and explicitly to the public. Perception and truth can be the same in the public eye.

People react differently to the same risk, depending on their backgrounds and their level of risk acceptance. Voluntary risks such as smoking and not wearing a seat belt are usually accepted, whereas the involuntary risks of exposure to asbestos, contaminated drinking water, or a toxic plume are not. Health risks, especially long term, are of primary concern to those who resent risks not of their own choosing. While risk comparisons may be valid, it is better to focus discussion on preventive measures, emergency preparedness, and containment and remediation procedures. The public gets most of its information through the media, which can sometimes oversimplify complex situations. The key is to present essential factual information in readily understandable terms.

When the first round of planning is complete and the plan is initially approved by the planning committee, a familiarization program should be undertaken so that citizens will understand their expected actions. Presentations to community groups are good, but they may not reach all that could be affected. Experience has shown that readily accessible emergency information presented positively and in an attractive format is remembered and used. For example, one possible method is the creation of an attractive calendar distributed annually to households and commercial establishments that contains simple instructions for citizens to follow. Another option is to provide the information on one- or two-page inserts in local telephone directories. Public confidence is enhanced when citizens have the factual information needed to make intelligent decisions.

Public Emergency Notification

When an emergency does occur, the local emergency response team must be promptly notified, and a public warning must be issued to all who may be affected. A standardized notification message form should be available to both sender and receiver of the initial information. How the media are treated while an emergency is in progress determines, to a large extent, public perception and reaction. Establishment of a media-briefing center or public information center is important. Here the local designated spokesperson can coordinate the timely provision of accurate, detailed, and meaningful information to media representatives.

CONCLUSION

Industrial emergencies are a byproduct of many of the technologies that permeate any industrialized society. Since the risk associated with them, like the risk associated with any other human activity, can never be completely reduced to zero, society has to learn to live with the finite possibility that industrial emergency situations can occur if it wants to benefit from the technologies that can generate them. What one can do, however, is to learn how to reduce the frequency with which such events can occur, learn how to cope with them, and minimize their consequences on people, environment, and property once they have occurred. Emergency preparedness and emergency planning are the tools that can be effectively used to do just that.

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