大学环境教育丛书

影印版

Jerry A. Nathanson

Basic Environmental Technology

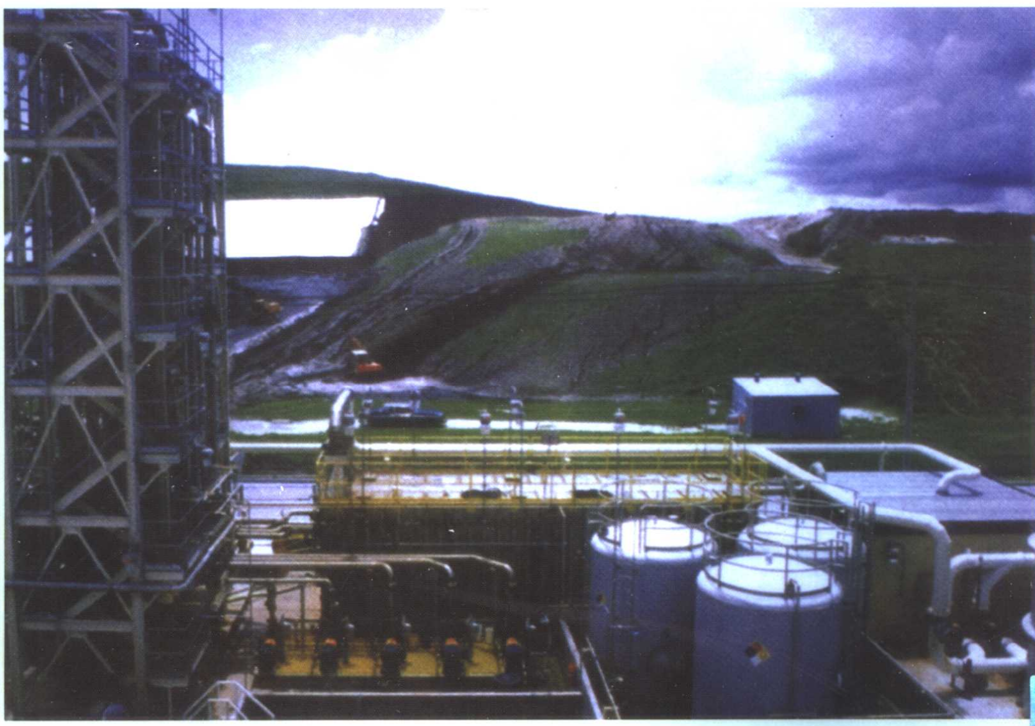
Water Supply, Waste Management, and Pollution Control

(Fourth Edition)

环境技术基础

供水、废物管理与污染控制

(第4版)



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出版前言

在 21 世纪初，面临各种环境问题，人类清醒地认识到要走可持续发展之路。而发展环境教育是解决环境问题和实施可持续发展战略的根本。高等学校的环境教育，是提高新世纪建设者的环境意识，并向社会输送环境保护专门人才的重要途径。为了反映国外环境类教材的最新内容和编写风格，同时也为了提高学生阅读专业文献和获取信息的能力，我们精选了一些国外优秀的环境类教材，组成大学环境教育丛书影印版和翻译版，本书即为其中的一册。所选教材均在国外被广泛采用，多数已再版，书中不仅介绍了有关概念、原理及技术方法，给出了丰富的数据，还反映了作者不同的学术观点。

我们希望这套丛书能对高等院校师生和广大科技人员有所帮助，同时为我国环境教育的发展作出贡献。

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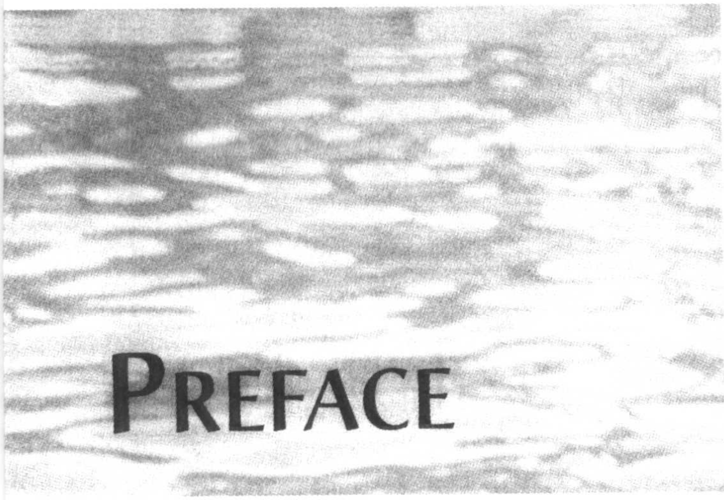
2003 年 7 月



PREFACE

Basic Environmental Technology offers a pragmatic introduction to the topics of municipal water supply, waste management, and pollution control. The book is designed primarily for use by students in civil/construction technology programs and related disciplines in community colleges and technical institutes. It can also be useful in baccalaureate engineering and technology programs when a practical but elementary course of study is desired, or for independent study by individuals who wish to explore the rudiments of environmental quality control and public health protection. Experienced technicians, engineers, scientists, and others in different disciplines who may become involved in environmental work for the first time will also find this book of value as an initial reference.

The qualities that continue to distinguish this book in its fourth edition are its clear, easy-to-read style and its logical and systematic treatment of the subject. Since the field of environmental technology is multidisciplinary and very broad in scope, review or primer sections are included so that readers with little or no experience in biology, chemistry, geology, and hydraulics can comprehend and use the book. Mathematical topics are presented at a relatively basic level; to understand all the numerical examples in the book, some knowledge of algebra and geometry will be useful.

Hundreds of example problems, diagrams, and photographs are used throughout to illustrate and clarify important topics. Numerous review questions and practice problems follow each chapter; answers to the practice problems are presented in Appendix G. SI metric as well as U.S. Customary units are used, since students and practitioners in the United States must still be familiar with both systems. A separate Instructor's Manual is available with worked-out solutions for the end-of-chapter practice problems and with supplementary problems that can be used for additional homework assignments or test questions.

The first chapter of the book provides an overview of environmental technology, including elements of public health, ecology, geology, and soils. The next nine chapters focus on water and wastewater topics, including hydraulics and hydrology, water quality and water pollution, drinking water treatment and distribution, sewage collection, sewage treatment and disposal, and stormwater management. Municipal solid waste, hazardous waste, air pollution, and noise pollution are covered in Chapters 11 through 14. Finally, appendixes covering environmental impact statements and audits; the employment of technicians; technologists, and engineers; basic mathematics; units and conversions; selected references; an extensive glossary; and a color photo insert (at the back of the book) are included.

There is more than ample material in this book for a typical one-semester course. Chapters 1 through 10 should suffice for introductory courses that focus mostly on water and wastewater topics. In courses where air quality, solid and hazardous waste, and noise pollution are also part of the syllabus, the instructor will probably find it necessary to be selective in coverage of topics from the first ten chapters to allow time for discussion and study of the last four chapters. In such circumstances, less time could be spent on the quantitative parts of the text (for example, hydraulics) and more time spent on the descriptive and qualitative aspects of environmental technology. Another option could be to focus in lectures on the first ten chapters for most of the semester, and allow students to select topics of special interest to them from those among the last four chapters for a term paper and/or oral presentation to the whole class. In this way, students get some exposure to those topics as well as practice in communication skills.

In this fourth edition, the text has been updated where necessary and some new topics have been added. These topics include nonuniform open channel flow, the rainfall severity index, mass balance, sewer plan and profile details, Geographic Information System (GIS) applications, description of software applications such as EPANET and HydroCAD, best management practices for stormwater quality control, and new water/wastewater treatment technologies. The book now includes a primer of basic mathematics as well as an expanded discussion of units and unit conversions in Appendix C. The number of case studies has been increased by about 50 percent, the number of relevant Web sites has been increased by about 30 percent, and many new terms have been added to the glossary in Appendix E.

This textbook addresses a wide range of environmental subjects. Every effort has been made to maintain a balance between thoroughness and practicality in covering the material to ensure that the book will continue to be a useful learning tool for students. The topics included here are covered in greater depth and detail in other, more narrowly specialized and advanced texts; they are presented here in a form that is more readily accessible to undergraduates and others who may have occasion to use the book. It is hoped that this book will motivate as well as prepare readers to study the discipline of environmental engineering or technology at a more advanced level.

ACKNOWLEDGMENTS

For reviewing the manuscript of this fourth edition and for offering many helpful suggestions for its improvement, I would like to thank the following people: Alan B. Chace, Mohawk Valley Community College; Francis J. Hopcroft, Wentworth Institute of Technology; Jim Callison, Utah Valley State College; Douglas P. Macdonald, Florence–Darlington Technical College; and Ron Newton, Chemeketa Community College. I also would like to thank Robert St. Amand, Union County College, for his many helpful suggestions regarding the sections on fundamental concepts in chemistry and chemical parameters of water quality.

I am also indebted to many people for reviewing the manuscripts of one or more of the previous three editions of this book and for offering many helpful comments and suggestions regarding its content. I would like to thank them all here: Louis Chanin, United Water Resources; Leo Ebel, Washington University; Jerry Haimowitz, Boro of North Plainfield; Keith Hancock, Larimer County Vocational–Technical Center; Gayle Huges, Nashville State Technical Institute; Paul Klopping, Environmental Training Consultants, Inc.; Paul Mazur, Columbus Technical Institute; Andrew Potter, Monroe Community College; Karl Schnelle, Jr., Vanderbilt University; Paul Trotta, Northern Arizona University; Paul Cheremisinoff, New Jersey Institute of Technology; Roger Hlavek, Indiana University; Charles Ballou, Jr., Mohawk Valley Community College; Francis Hopcroft, Wentworth Institute of Technology; and Douglas Macdonald, Florence–Darlington Technical College.

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I have tried to keep errors and inaccuracies in the text to a minimum. Of course, I remain fully responsible for any mistakes that may be found, and I welcome constructive comments and suggestions for the book's improvement from those who use it.

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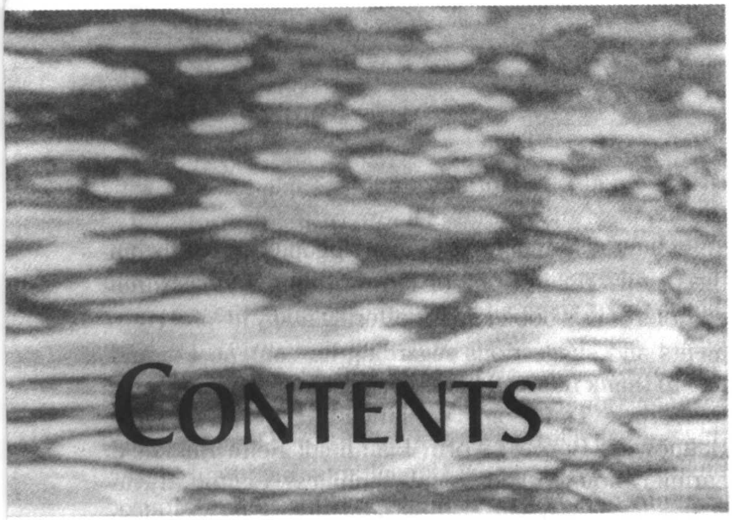

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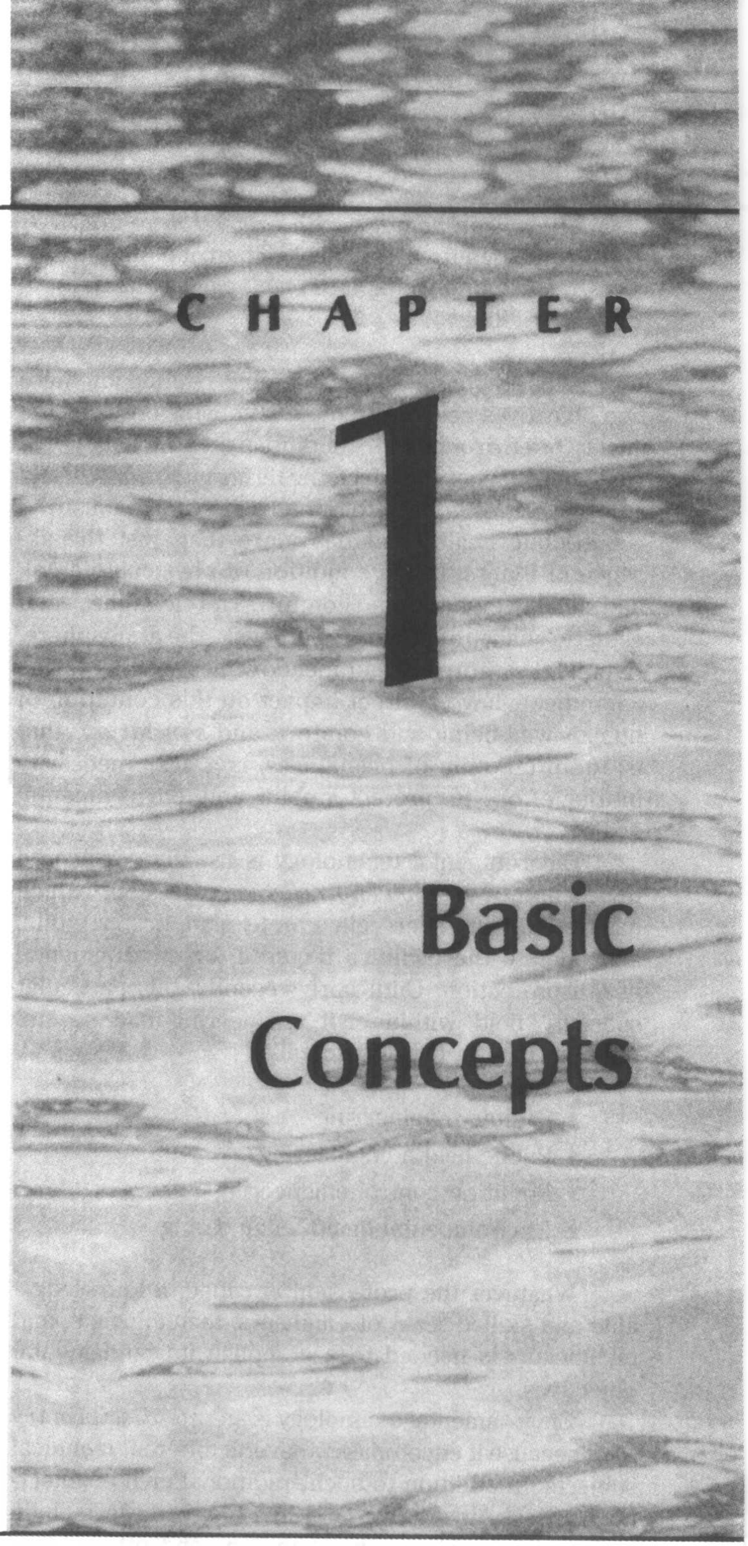

CHAPTER 1

Basic Concepts

Chapter Outline

Environmental technology involves the application of engineering principles to the *planning*, *design*, *construction*, and *operation* of the following systems:

- Drinking water treatment and distribution
- Sewage disposal and water pollution control
- Stormwater drainage and control
- Solid and hazardous waste management
- Air and noise pollution control
- General community sanitation

The structures and facilities that serve these functions, including pipelines, pumping stations, treatment plants, and waste disposal sites, make up a major portion of society's *infrastructure*—the public and private works that allow human communities to thrive and function productively.

The practice of environmental technology encompasses two fundamental objectives:

1. *Public health protection* to help prevent the transmission of diseases among human beings.

2. *Environmental health protection* to preserve the quality of our natural surroundings, including water, land, air, vegetation, and wildlife.

Actually, there is considerable overlap of these two objectives because of the relationship between the quality of environmental conditions and the health and well-being of people. In fact, the terms *public health* and *environmental health* are often used synonymously.

Public health includes more than just the absence of illness. It is a condition of physical, mental, and social well-being and comfort. The cleanliness and esthetic quality of our surroundings—the atmosphere, rivers, lakes, forests, and meadows, as well as towns and cities—have a direct impact on this condition of human well-being and comfort, and *sanitation*, that is, the promotion of cleanliness, is a basic necessity in the effort to protect public and environmental health.

Environmental technology is usually considered to be a part of the *civil engineering* profession,* which has traditionally been called on to plan, design, build, and operate the facilities required for environmental health protection. Until fairly recently, this particular specialty field within civil engineering had several different names. It was also called

- Sanitary engineering
- Public health engineering
- Pollution control engineering
- Environmental health engineering

Whatever the profession is called, a knowledgeable and skilled team of engineers, technologists, and technicians is needed to accomplish its fundamental objectives.

Environmental technology is an *interdisciplinary field* because it encompasses several different technical subjects. In addition to such traditional civil engineering topics as hydraulics and hydrology, these include biology, ecology, geology, chemistry, and others. This variety makes the field interesting and challenging.

Fortunately, it is not necessary to be an expert in all these subjects to understand and apply the basic principles of environmental technology. This particular text has been designed so that a student with little academic background in some or all of the supporting subjects can still use it productively.

This chapter is a review of basic and pertinent topics in public health, ecology, and geology. Practical hydraulics is covered in Chapter 2 and the fundamentals of hydrology are presented in Chapter 3. The essential concepts and terminology from chemistry and microbiology are presented in sections of Chapter 4, on water quality. The remaining chapters of the book build on these subjects by presenting principles and applications of environmental technology. Each chapter includes a list of relevant Web sites where the student can find additional and timely information.

1.1 OVERVIEW OF ENVIRONMENTAL TECHNOLOGY

Before beginning a study of the many different topics that make up environmental technology, it would be helpful to have an understanding of the overall goals, problems, and alternative solutions available to practitioners in this field.

To present an overview of such a broad subject, we can consider an engineering project involving the subdivision and development of a tract of land into a new community, which will include residential, commercial, and industrial centers. Whether the project owner is a governmental agency or a private developer, a wide spectrum of environmental problems will have to be considered and solved before construction of the new community can begin. Usually, the project owner retains the services of an independent environmental consulting firm to address these problems. (See Case Study on page 5.)

Water Supply

One of the first problems project developers and consultants must consider is the provision of a *potable* water supply, one that is clean, wholesome, safe to drink, and available in adequate quantities to meet the anticipated demand in the new community. Some of the questions that must be answered are as follows:

1. Is there an existing public water system nearby with the capacity to connect with and serve the new development? If not,
2. Is it best to build a new centralized treatment and distribution system for the whole community, or would it be better to use individual well supplies? If a centralized treatment facility is selected,
3. What types of water treatment processes will be required to meet federal and state

*Visit the Web site of the American Society of Civil Engineers at http://www.asce.org.

drinking water standards? (Water from a river or a lake usually requires more extensive treatment than groundwater does, to remove suspended particles and bacteria.) Once the source and treatment processes are selected,

4. What would be the optimum hydraulic design of the storage, pumping, and distribution network to ensure that sufficient quantities of water can be delivered to consumers at adequate pressures?

Illustrating the importance of water supply in new community development and environmental planning is a new California law (implemented in October 2001) which forces builders to prove that there will be adequate water to supply their new developments. This law imposes strict requirements for cities and counties when issuing permits for new subdivisions of 500 or more homes. The local water agencies must verify that water quantities are ample enough to serve the project for at least 20 years, including periods of drought. California is the first state to pass such strict legislation linking new development to water supply.

Sewage Disposal and Water Pollution Control

When running water is delivered into individual homes and businesses, there is an obvious need to provide for the disposal of the used water, or *sewage*. Sewage contains human wastes, wash water, and dishwater, as well as a variety of chemicals if it comes from an industrial or commercial area. It also carries microorganisms that may cause disease and organic material that can damage lakes and streams as it decomposes.

It will be necessary to provide the new community with a means for safely disposing of the sewage, to prevent water pollution and to protect public and environmental health. Some of the technical questions that will have to be addressed include the following:

1. Is there a nearby municipal sewerage system with the capacity to handle the additional flow from the new community? If not,
2. Are the local geological conditions suitable for on-site subsurface disposal of the wastewater (usually *septic systems*), or is it necessary to provide a centralized sewage treatment plant for the new community and to discharge the treated sewage to a nearby stream? If treatment and surface discharge are required,
3. What is the required degree or level of wastewater treatment to prevent water pollution? Will a *secondary* treatment level, which removes at least 85 percent of biodegradable pollutants, be adequate? Or will some form of advanced treatment be required to meet federal and state discharge standards and stream quality criteria? (Some advanced treatment facilities can remove more than 99 percent of the pollutants.)
4. Is the flow of industrial wastewater an important factor?
5. Is it possible to use some type of *land disposal* of the treated sewage, such as spray irrigation, instead of discharging the flow into a stream?
6. What methods will be used to treat and dispose of the *sludge*, or *biosolids*, that is removed from the wastewater?
7. What is the optimum layout and hydraulic design of a sewage collection system that will convey the wastewater to the central treatment facility with a minimum need for pumping?

Stormwater Management

The development of land for human occupancy and use tends to increase the volume and rate of stormwater runoff from rain or melting snow. Basically, this is due to the construction of roads, pavements, or other impervious surfaces, which prevent the water from seeping into the ground. The increase in surface runoff may cause flooding, soil erosion, and water pollution problems both on the site and downstream. The following are some of the questions the developer and consultant have to consider:

1. What is the optimum layout and hydraulic design of a surface drainage system that will prevent local flooding during wet weather periods?
2. What intensity and duration of storm would the system be designed to handle without *surcharging*, or overflowing?
3. Do local municipal land-use ordinances call for facilities that keep postconstruction runoff rates equal to or less than the amount of runoff from the undeveloped land? If so,
4. What are the "best management practices" (BMP) for reducing the peak runoff flows and protect water quality during wet weather periods?

5. What provisions can be made, during and after construction, to minimize problems related to soil erosion from runoff?
6. What is the best way to manage combined sewer overflows (CSOs) in older sewer systems?

Solid and Hazardous Waste Management

The development of a new community (or growth of an existing community) will certainly lead to the generation of more municipal refuse and industrial waste materials. Ordinarily, the collection and disposal of solid wastes is a responsibility of the local municipality. However, some of the wastes from industrial sources may be particularly dangerous, requiring special handling and disposal methods.

There is a definite relationship between public and environmental health and the proper handling and disposal of solid wastes. Improper garbage disposal practices can lead to the spread of diseases such as *typhus* and *plague* due to the breeding of rats and flies.

If municipal refuse is improperly disposed of on land in a "garbage dump," it is also very likely that surface and groundwater resources will be polluted with *leachate* (leachate is a contaminated liquid that seeps through the pile of refuse into nearby streams as well as into the ground). On the other hand, incineration of the refuse may cause significant air pollution problems if proper controls are not applied or are ineffective.

Hazardous wastes, such as poisonous or ignitable chemicals from industrial processes, must receive special attention with respect to storage, collection, transport, treatment, and final disposal. This is particularly necessary to protect the quality of groundwater, which is the source of water supply for about half the population in the United States. In recent years, an increasing number of water supply wells have been found to be contaminated with synthetic organic chemicals, many of which are thought to cause cancer and other illnesses in humans. Improper disposal of these hazardous materials, usually by illegal burial in the ground, is the cause of the contamination.

Some of the general questions related to the disposal of solid and hazardous wastes from the new community include the following:

1. Is there a *materials recycling facility* (MRF, or "murf") serving the area? What will be the waste storage, collection, and recycling requirements (for example, will source separation of household refuse be necessary)?
2. Will a waste processing facility (such as one that provides for shredding, pulverizing, baling, composting, or incineration) be needed to reduce the waste volume and improve its handling characteristics?
3. Is there a suitable *sanitary landfill* serving the area, and will it have sufficient capacity to handle the increased amounts of solid waste for a reasonable period of time? (Despite the best efforts to recycle solid waste or reduce its volume, some material will require final disposal in the ground in an environmentally sound manner.) If not,
4. Is there a suitable site for construction and operation of a new landfill to serve the area? (A modern sanitary landfill site must meet strict requirements with respect to topography, geology, hydrology, and other environmental conditions.)
5. Will commercial or industrial establishments be generating hazardous waste, and, if so, what provisions must be made to collect, transport, and process that material? Is there a *secure landfill* for final disposal available, or must a new one be constructed to serve the area?

Air and Noise Pollution Control

Major sources of air pollution include fuel combustion for power generation, certain industrial and manufacturing processes, and automotive traffic. Project developers can exercise the most control over traffic. Private industry will have to apply appropriate air pollution control technology at individual facilities to meet federal and state standards.

The volume of traffic in the area will obviously increase, leading to an increase in exhaust fumes from cars and other vehicles. Proper layout of roads and traffic-flow patterns, however, can minimize the amount of stop-and-go traffic, thus reducing the amount of air pollution in the development.

Usually, the developer's consultant will have to prepare an *environmental impact statement (EIS)*, which will describe the traffic plan and estimate the expected levels of air pollutants. It will have to be shown that air quality standards will not be violated, for the project to gain approval from regulatory agencies. (In addition to air pollution, the completed EIS will address all other environmental effects related to the proposed project.)

Noise can be considered to be a type of air pollution in the form of waste energy—sound vibrations. Noise pollution will result from the construction activity, causing a temporary or *short-term impact*. The builders may have to observe limitations on the types of construction equipment and the hours of operation to minimize this negative effect on the environment. A *long-term impact* with respect to the generation of noise will be caused by the increased amount of vehicular traffic. This is another environmental factor that the consultants will have to address in the EIS.

Other Environmental Factors

Not to be overlooked as an environmental factor in any land development project is the potential impact on local vegetation and wildlife. The destruction of woodlands and meadows to make room for new buildings and roads can lead to significant ecological problems, particularly if there are any rare or endangered species in the area. Cutting down trees and paving over meadows can cause short-term impacts related to soil erosion and stream sedimentation. On a long-term basis, it will cause the displacement of wildlife to other suitable habitats, presuming, of course, that such habitats are available nearby. Otherwise, several species may disappear from the area entirely.

Human activity in wetland areas, including marshes and swamps, can be very damaging to the environment. Coastal wetlands are habitats for many different species of organisms, and the tremendous biological productivity of these wetland environments is a very important factor in the food chain for many animals. When wetlands are drained, filled in, or dredged for building and land development projects, the life cycle of many organisms is disrupted. Many species may be destroyed as a result of habitat loss or loss of a staple food source. Wetlands also play important roles in filtering and cleansing water and in serving as a reservoir for floodwaters. There is a definite need to control or restrict construction activities in wetland environments and to implement a nationwide wetlands protection program.

Environmental concerns related to general sanitation in a new community include food and beverage protection, insect and rodent control, radiological health protection, industrial hygiene and occupational safety, and the cleanliness of recreation areas such as public swimming pools. These concerns are generally the responsibility of local health departments.

CASE STUDY

Development of a Master-Planned Community

Anthem Community Park, one of the largest *master-planned communities* in Maricopa County, Arizona, is undergoing development on approximately 2400 hectares (ha) [5800 acres (ac)] located north of Phoenix. Zoning densities on the property allow for the construction of approximately 14,000 residential units, with about 240 ha (600 ac) set aside for mixed commercial uses. The year 2001 population of 2500 residents is expected to reach its ultimate design population of 30,000 residents in 10 years.

Existing and planned features for the expanding Anthem community include school sites, a community center, two golf courses, a water park, single family and multifamily housing, as well as mixed commercial uses. The planned Anthem community is a good example of a project for which the developer must consider a wide range of environmental factors; this case study will focus only on the water supply and wastewater effluent systems.

As part of the engineering plans for this project, a consulting engineering firm has been hired by the developer to construct computer models of Anthem's water supply and wastewater systems. The initial purpose of the computer models was to establish design parameters and construction phasing for the community's future infrastructure. However, in addition to use as a planning tool, the models also serve to maintain, operate, and update the existing system on an ongoing basis. The computer modeling software is used to analyze the existing water system (made up of over 550 pipes), predict future system characteristics, and design the most efficient layout to meet interim and future needs for the Anthem community. (Computer modeling software applications are discussed in more detail in later chapters.)

The growing Anthem community must meet the guidelines of the Arizona Department of Water Resources, which requires that surface water be used to provide for any new development and that a 100-year water supply be assured. Groundwater cannot be used as the sole source of water in the Phoenix Active Management Area in which the project is situated due to overpumping of the aquifers within the area. Wells can be used, but the volume of groundwater withdrawn must be equal to or less than the recharge volume. (Surface water, groundwater, and wells are topics covered in more detail in Chapter 3.) Since there is no permanent source of surface water supply at Anthem, it was necessary for the developer to obtain an assured 100-year supply from Lake Pleasant on the Central Arizona Project (CAP) canal, a long distance away. A 750-mm (30-in.)-diameter ductile iron pipeline more than 13 km (8 mi) long was built to transport CAP water to the Anthem community. (Water transmission and distribution topics are discussed in Chapter 7.)

The task of providing water to the growing community is further complicated by the fact that the Anthem property is located in two different governmental jurisdictions. On the west side, it is within the Phoenix city limits, and on the east, it is in Maricopa County. Each of these political entities has different engineering criteria for planning and design. The public infrastructure designed for Anthem must meet the design criteria for both jurisdictions.

The required fire flows vary in the community; a fire flow of 1500 gallons per minute (gpm) is required in residential areas and a fire flow of 3000 gpm is required in all commercial areas.

Minimum and maximum water pressures in the distribution system also vary. These and other variables are used in the computer model of the system, which is analyzed to ensure that the minimum and maximum pressures are maintained under all water demand scenarios, and that maximum flow velocities are not exceeded. Analyses are performed for average day, maximum day, and peak hour demand conditions. The system model is also analyzed for different fire flow alternatives. The ability to analyze many alternatives or scenarios with one hydraulic model is a key benefit provided by the computer software. (A *scenario* refers to a model run for a given set of water demand and system operating conditions, which are stored as various alternative datasets in the computer. The alternative datasets can be reused in many scenarios.)

Wastewater is collected and treated to allow the reuse of the effluent for irrigation of landscaping in roadway medians, community parks, and golf courses. Treatment processes include rotary drum screens as well as biological purification and microfiltration. (Wastewater treatment is discussed in Chapter 10.) Effluent (treated wastewater) in excess of irrigation needs will be allowed to percolate into the groundwater aquifer, using a network of recharge trenches. In the initial stages of the project, recycled wastewater quantities will not be sufficient to meet irrigation needs; CAP canal water will be purchased to meet the balance of those needs, and will also be stored for emergencies at the recharge facility. Raw CAP water, potable water, sewage, and treated effluent will be managed by using automated radio telemetry systems to optimize the eventual total reuse of treated wastewater in the planned community.

Environmental Interrelationships

In the preceding overview of environmental technology, we have briefly considered many factors that are very much interrelated and overlapping, as illustrated in Figure 1.1. In a textbook, it is necessary to organize these factors into chapters and sections. But this is only for academic convenience. The interrelationships should always be kept in mind. Water, land, and air pollution are part of a single problem.

Sometimes, due to unanticipated interrelationships and overlaps, a solution of one environmental problem inadvertently causes a different problem to arise. For example, the use of catalytic converters since the mid-1970s to reduce smog caused by automobile exhaust gases has been found to contribute to a different air pollution problem—*global warming* (or the "greenhouse effect"). Catalytic converters can form significant quantities of nitrous oxide ("laughing gas"), which is a potent gas that can trap heat energy and warm the atmosphere. (The greenhouse effect and atmospheric warming are discussed in more detail later, in Section 13.4, Global Air Pollution.)

Another example involves the contamination of groundwater and surface water in some cities by MTBE (methyl tertiary butyl ether), an organic chemical added to gasoline to reduce air pollution. MTBE has been used as a fuel additive since the early 1990s to increase gasoline octane levels and help reduce carbon monoxide and ozone concentrations in the air. It can contaminate water sources, largely as a result of leaking underground

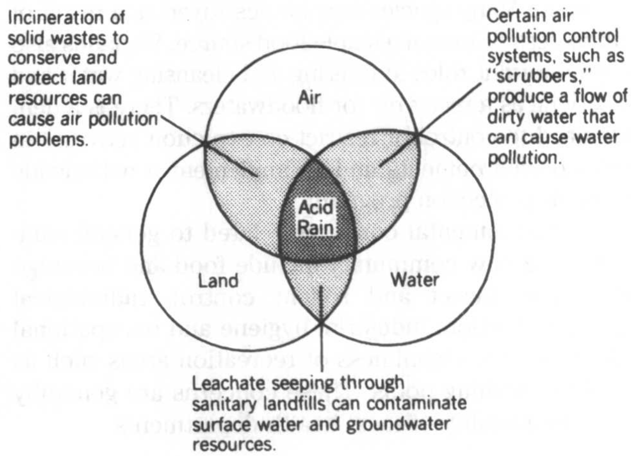

FIGURE 1.1
Most environmental problems pertaining to air, water, and land quality are interrelated. A problem called acid rain, ***for example, is caused by air pollution, and it damages both aquatic and terrestrial ecosystems.***

storage tanks (see Section 12.3) and the use of motorized watercraft on lakes and reservoirs. MTBE may be a *carcinogen* (cancer-causing agent), and it can give water a bad taste and odor even at low levels; scientific research is underway to further understand its adverse health effects and to find effective methods to remove it from contaminated water sources.

As more is learned in the future about the potential interrelationships among environmental phenomena, engineers and technologists will be better able to create pollution control systems that will not have any unexpected harmful effects on other components of the environment, and will be able to avoid situations like the foregoing.

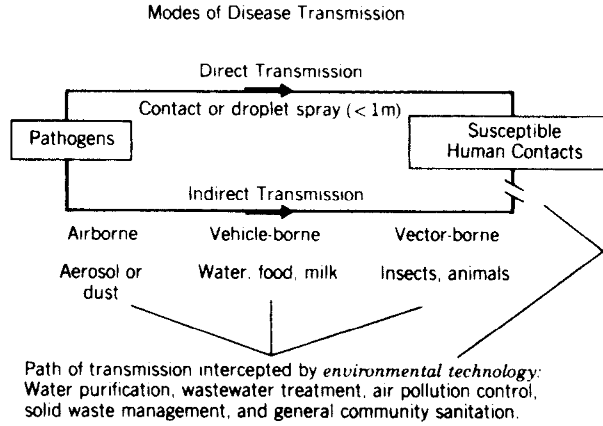

FIGURE 1.2
Communicable diseases are spread in several ways, many of which can be controlled or intercepted by applications of modern environmental technology.

1.2 PUBLIC HEALTH

Preventing the spread of disease and thereby protecting the health of human populations is a fundamental goal of environmental technology. Public health protection is, of course, a primary concern of doctors and other medical professionals. But engineering technology also plays a significant role in this effort. In fact, the high standard of health enjoyed by citizens of the United States and other developed nations is largely due to the construction and operation of modern water treatment and pollution control systems. The spread of diseases in countries with inadequate sanitary facilities is a major problem for millions of people.

Diseases are classified into two broad groups: *communicable diseases* and *noninfectious diseases.* Communicable diseases are those that can be transmitted from person to person, commonly referred to as being infectious or contagious. Noninfectious diseases, as the name implies, are not contagious; they cannot be transmitted from one person to another by any means. The kinds of noninfectious diseases of concern in environmental technology are associated with contaminated water, air, or food. The contaminants are usually toxic chemicals from industrial sources, although biological toxins can also cause disease.

Communicable Diseases

Communicable diseases are usually caused by *microbes.* These microscopic organisms include bacteria, protozoa, and viruses (see Section 4.4). Most microbes are essential components of our environment and do not cause disease. Those that do are called pathogenic organisms, or simply *pathogens.*

The ways in which diseases are spread from one person to another vary considerably. They are called *modes of transmission* of disease and are summarized in Figure 1.2. It is important to make distinctions among the various modes of transmission to be able to apply suitable methods of control. *Direct transmission* involves an immediate transfer of pathogens from a carrier (infected person) to a susceptible contact, that is, a person who has had direct contact with the carrier and is liable to acquire the disease. Clearly, control of this mode of transmission is not within the scope of environmental technology; it is in the province of personal hygiene and the medical profession (who provide immunization and quarantine infected persons).

Environmental technology can be applied to intercept many of the modes of *indirect transmission.* The three indirect modes of disease transmission are *airborne, vector-borne,* and *vehicle-borne.* Airborne transmission involves the spread of microbes from carrier to contact in contaminated mists or dust particles suspended in air. It is the least common of the indirect modes. (This should not be confused with the noninfectious public health problems associated with chemical air pollution, which will be discussed later.)

Vectors of disease include insects, rodents, and other animals that can transport pathogens to susceptible human contacts. The animals that carry the pathogenic microbes are also called *intermediate hosts* if the microbes have to develop and grow in the vector's body before becoming infective to humans. Vector-borne disease can be controlled to some extent by proper sanitation measures.

A *vehicle* of disease transmission is any nonliving object or substance that is contaminated with pathogens. For example, forks and spoons, handkerchiefs, soiled clothes, or even children's toys are potential vehicles of transmission. They can physically transport and transfer the pathogens from carrier to contact.

Water, food, and milk are also potential vehicles of disease transmission; these are perhaps the most significant with regard to environmental technology and sanitation. Water, in particular, plays a major role in the transmission of communicable diseases, but it is most amenable to engineering and technological controls. Water and wastewater treatment facilities effectively block the pathway of waterborne diseases.

Types of Communicable Diseases

Waterborne and food-borne diseases are perhaps the most preventable types of communicable diseases. The application of basic sanitary principles and environmental technology have virtually eliminated serious outbreaks of these diseases in technologically developed countries.

Water- and food-borne diseases are also called *intestinal diseases* because they affect the intestinal tract of humans. The pathogens are excreted in the feces of infected people. If these pathogens are inadvertently ingested by others in contaminated food or water, the cycle of disease can continue, possibly in *epidemic* proportions, that is, when the number of occurrences of a disease in a community is far above normal.

Symptoms of intestinal disease include diarrhea, vomiting, nausea, and fever. Intestinal diseases can incapacitate large numbers of people in an epidemic and sometimes result in the deaths of many infected individuals. Water contaminated with untreated sewage (domestic wastewater) is generally the most common cause of this type of disease.

The most prevalent waterborne diseases include *typhoid fever*, *dysentery*, *cholera*, *infectious hepatitis*, and *gastroenteritis* (common diarrhea and cramps). These can also be transmitted by contaminated food or milk products. Diseases caused by bacterial toxins include *botulism* and *Staphylococcus* food poisoning. Refrigeration, as well as proper cooking and sanitation at food-processing facilities and restaurants, are important for control of these food-borne diseases.

Although cholera and dysentery have not generally been a problem in the United States, they are prevalent diseases in India and Pakistan and in many of the technologically underdeveloped countries of southeast Asia. In fact, they are considered to be *endemic* (habitually present) in these areas. Typhoid fever is more common in occurrence than cholera or dysentery. Until the beginning of the 1900s, typhoid mortality rates in some urban areas of the United States were as high as 650 deaths per 100,000 population. The beginning of modern water purification technology at about that time helped to lower the typhoid death rate to considerably less than 1 per 100,000 people per year. (Immunization and improvements in food and milk sanitation also played a role in reducing the incidence of typhoid.)

Amoebic dysentery, caused by a single-cell microscopic animal called an amoeba, occurred in epidemic proportions in Chicago during the early 1930s. About 100 of the approximately 1000 people who contracted the disease died from it. The cause of this epidemic was traced to sewage that contaminated the water supplies of two hotels in the city. Although epidemics of intestinal disease like this one are not at all common in the United States, when they do occur they are usually very localized and can be traced to contaminated water supplies in hotels, restaurants, schools, or camps. Generally, the contamination is caused by *cross-connections* in the water distribution system, which may allow backflow of wastewater into the drinking water supply.

Giardiasis and *cryptosporidosis* are two waterborne diseases that can cause gastrointestinal illness and serious public health problems. They are both caused by single-celled microscopic animals called *protozoa* (see Section 4.4 for a discussion of microorganisms) that can contaminate drinking water supplies. A very large outbreak of cryptosporidosis, for example, occurred in Milwaukee, Wisconsin, in 1993. The city's water supply comes from Lake Michigan. An unusual combination of circumstances during a period of heavy rainfall and runoff allowed the protozoan *Cryptosporidium* to pass through the water treatment plant. More than 40,000 people became ill, about 4000 people were hospitalized, and more than 50 deaths were attributed to this outbreak. The original source of the contamination is uncertain. Since that incident, improved water quality standards and treatment rules make a repetition of this type of outbreak unlikely.

Insect-borne diseases include those transmitted by the bites of mosquitoes, lice, and ticks. *Malaria*, *yellow fever*, and *encephalitis* are typical diseases spread by certain species of mosquitoes. Flies also transmit disease, but not by biting; the contact of their germ-laden bodies, wings, and legs with food consumed by humans spreads diseases such as typhoid fever and gastroenteritis.

The elimination of the breeding places of insects is one of the most important control measures. Proper garbage disposal reduces fly breeding places, and elimination of standing water is one of the methods available for eliminating mosquito breeding areas. Chemical control with insecticides is usually a last resort because of the environmental and potential health problems associated with the use of toxic substances.