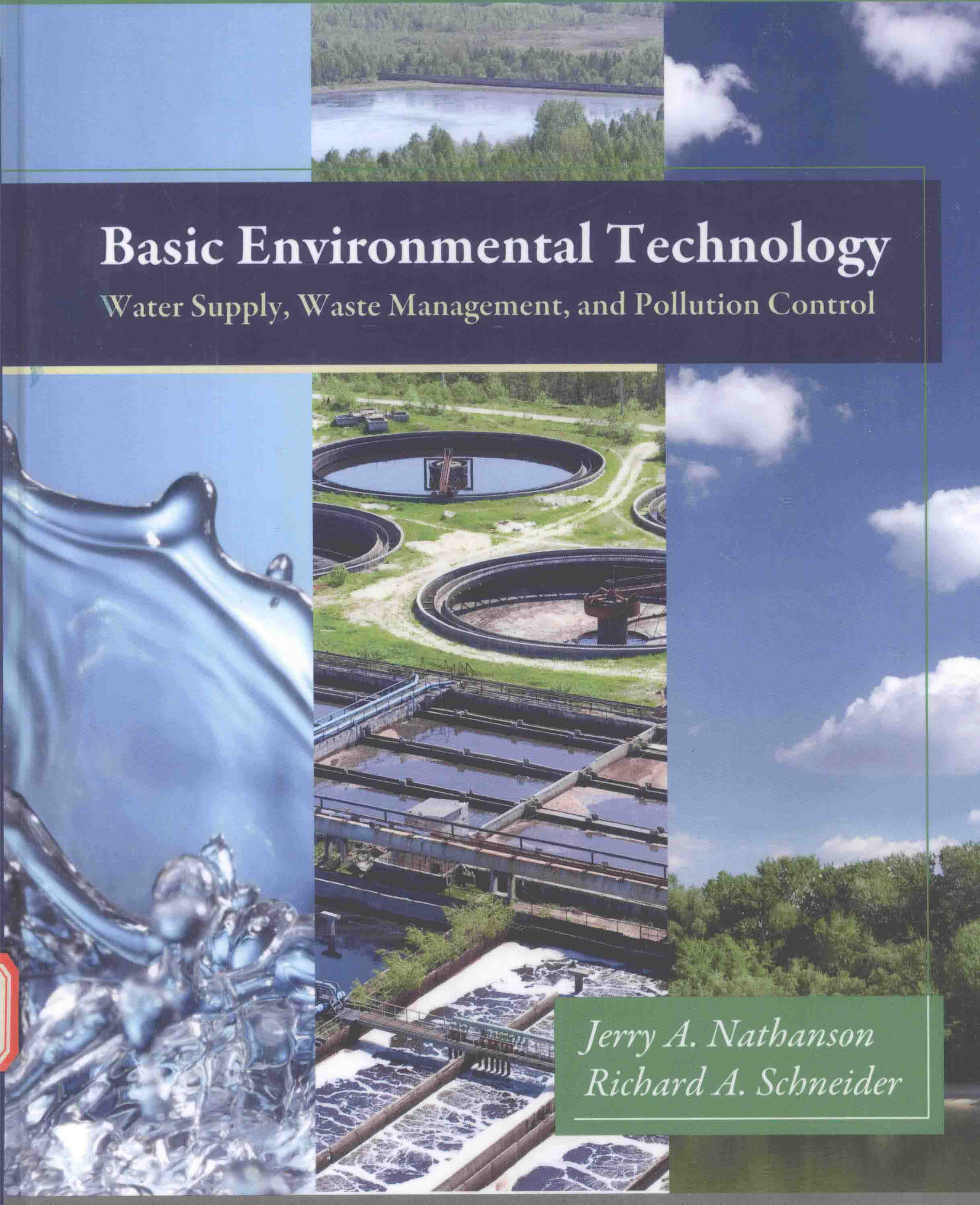
Sixth Edition

# Basic Environmental Technology

## Water Supply, Waste Management, and Pollution Control



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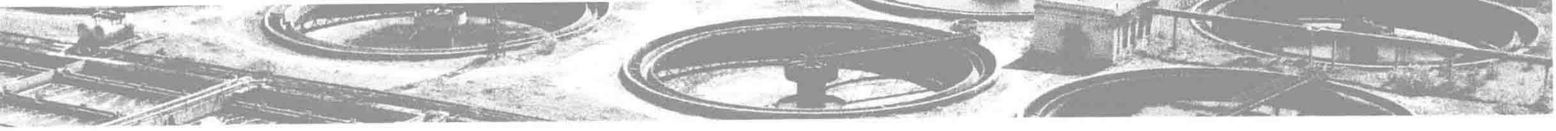

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## Water Supply, Waste Management, and Pollution Control

**SIXTH EDITION**


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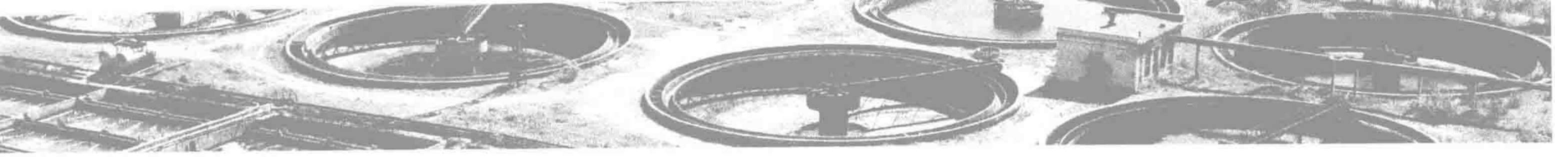
For Ginger and Adam and in Loving Memory of Sheila—Jerry

To Mom and Dad for Their Love and Support All These Years. To Stacy, Valentine, and Hannah for Their Patience and Understanding throughout All My Endeavors—Rich



# PREFACE

**B**asic Environmental Technology* offers a practical introduction to the topics of municipal water supply, waste management, and pollution control. The book is designed primarily for 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 broad but elementary course of study is desired, or for independent learning by individuals who want 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 sixth edition are its clear, easy-to-read style and its logical and systematic treatment of the subject. Because the field of environmental technology is multidisciplinary and extensive in scope, review or primer sections are included so 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 the numerical examples in the book, some knowledge of algebra and geometry will be useful.

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 F. Both SI metric and U.S. Customary units are used because students and practitioners in the United States must be familiar with these two systems. Online Instructor's Resources are available that include downloadable resources for lecture, modified classroom, and distance education. Chapter 1 provides an overview of environmental technology, including elements of public health, ecology, geology, and soils. The next nine chapters, that is, Chapters 2 to 10, 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 regarding environmental impact statements and audits; the education and employment of technicians, technologists, and engineers; green building project certification; basic mathematics; units and conversions; and an extensive glossary 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 may find it necessary to be selective in coverage of topics from the first 10 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 (e.g., hydraulics) and more time spent on the descriptive and qualitative aspects of environmental technology. Another option is to focus lectures on the first 10 chapters for most of the semester, and allow students to select topics of special interest from the last 4 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.

The original sequence of the chapters remains the same as in previous editions (although some instructors have suggested changes in this regard). It is not possible, however, to satisfy the different preferences of all instructors. Naturally, a course syllabus can readily designate a sequence of reading assignments that will meet particular course needs. In fact, one of the purposes of the extensive glossary in Appendix E is to provide brief definitions of terms that students may need to know and encounter for the first time, particularly if they read the chapters in a different sequence than that presented in the book.

This introductory textbook addresses a wide range of environmental topics, each of which is covered in greater depth and detail in other, more narrowly specialized and advanced texts. They are presented here in a form and at a level that is more readily accessible to students and others who are studying the subject for the first time. In writing and revising the book over six editions, decisions had to be made to include or exclude certain facts, details, examples, and illustrations, and some compromises were inevitable. 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 user-friendly and useful learning tool for all readers.

An important factor in deciding what to include is the prescribed limit to the total size of the book, and we have necessarily resisted the temptation (and requests by some instructors) to add even more topics and details. From our experience, a good textbook is one that provides a broad, solid foundation on which experienced instructors can (and should) build and provide additional information and explication to satisfy the needs of their students. We hope this updated textbook provides that basic foundation for student learning, and that it helps motivate and prepare readers to study environmental technology or engineering at a more advanced level.

A plethora of information related to environmental topics is, of course, now available on the World Wide Web. There is so much information and so many links among the profusion of Web pages that it is easy for beginners to be quickly overwhelmed. It is best to start exploring environmental topics on the Web gradually, after using a textbook such as this, in which the information is organized and presented so that students can understand the underlying concepts before delving online into the details of specific environmental technology subjects.

As the topics in this book are studied and mastered, students will be much better prepared to mine the wealth of environmental information in cyberspace. Lists of relevant website URLs are intentionally not presented because they are so numerous and, in many cases, transitory. Users of this book can, at their convenience, quickly search the World Wide Web for more specific online information using appropriate keywords and topic headings.

## NEW TO THE SIXTH EDITION

- Discussions related to environmental sustainability, integrated water management, low impact development, and green building design are included throughout the relevant sections of the text.
- A section on water resources augmentation using advanced wastewater treatment and recycling, including expanded description of membrane filtration technology for advanced water purification.
- Discussions of new topics, including dual water systems, new pipeline materials, environmental impacts of hydraulic fracturing (fracking), constructed wetlands, single stream municipal solid waste recycling, and plasma gasification of solid and hazardous waste.
- Updated water and air quality standards and regulations, including the recent acknowledgment by the EPA that carbon dioxide is an air pollutant that can harm public health and welfare by causing global warming and climate change.
- Expanded glossary and list of acronyms; expanded discussion of environmental education, certification, and employment; new section introducing LEED green building project certification.
- Expanded online Instructor's Resources materials, including worked-out solutions to all practice problems and text-page references for answers to review questions; supplemental problems, 100 + multiple-choice test questions (and answers), and additional test problems and student project assignments; photos; descriptions of selected URLs of environmental websites for each chapter; suggested references and video materials; and so on.

## SUPPLEMENTS

To access supplementary materials online, instructors need to request an instructor access code. Go to www.pearsonhighered.com/irc to register for an instructor access code. Within 48 hours of registering, you will receive a confirming e-mail including an instructor access code. Once you have received your code, locate your text in the online catalog and click on the Instructor Resources button on the left side of the catalog product page. Select a supplement, and a login page will appear. Once you have logged in, you can access instructor material for all Pearson textbooks. If you have any difficulties accessing the site or downloading a supplement, please contact Customer Service at http://247pearsoned.custhelp.com/.

## ACKNOWLEDGMENTS

The helpful comments, suggestions, and contributions from the many people (too numerous to list here) who used and reviewed the book as it developed over the first five editions are gratefully acknowledged. We would also like to thank Kenneth R. Leitch, PhD, PE, West Texas A&M University; Dr. Brian Matthews, NC State University, Raleigh, NC; and Tom Spendlove, Baker College of Flint, who took the time to review the previous edition of this book and offer useful suggestions. And last, but certainly not least, we thank the exemplary editorial, design, production, and marketing team who, at Pearson Education, continue to make this book a reality.

We have made every attempt to keep errors and inaccuracies in this textbook to a minimum. Nevertheless, we remain fully responsible for any mistakes that may be found herein, and welcome constructive comments and suggestions for the book's improvement from those who use it.

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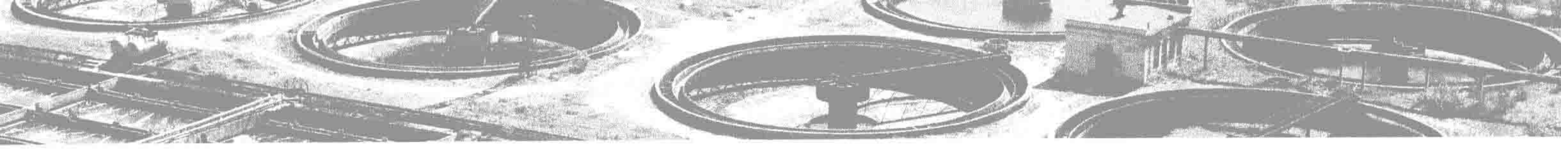

# CONTENTS

CHAPTER ONE

# BASIC CONCEPTS

Chapter Outline



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

- Drinking water treatment and distribution
- Sewage treatment and water pollution control
- Stormwater drainage and runoff 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 humans.
2. *Environmental health protection* to preserve the quality of our natural surroundings, including air, land, and water.

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 engineering technology is part of the broader field of *civil engineering*. It has had a variety of names, including *sanitary engineering, public health engineering, pollution control engineering,* and *environmental health engineering*. The phrase "green engineering" is also used now (in a broader sense), referring to design, construction, and manufacturing activities that focus on environmental sustainability and on energy and natural resource conservation. Low impact (land) development and green building design are also part of the modern-day civil and environmental engineering lexicon.

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 specific principles and applications of environmental technology.

## 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 may include residential and commercial centers. Whether the project owner is a governmental agency or a private company, a wide spectrum of environmental issues will have to be considered before construction of the new community can begin. Usually, the owner hires and retains the engineering services of an independent environmental consulting firm to address these issues. Various project reviews are also performed, and permits issued, by local, state, and federal agencies prior to project implementation. (An example of a "master-planned" community project is described on page 4.)

### Water Supply

One of the first tasks 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 drinking water standards? (Water from a river or a lake usually requires more extensive treatment than does groundwater, 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 the California law (implemented in October 2001) that 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 waste, 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. 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 should the system be designed to handle without *surcharging*, or overflowing?
3. Do local municipal land-use ordinances call for facilities that keep post-construction runoff rates equal to or less than the amount of runoff from the undeveloped land? If so,
4. What are the "best management practices" (BMPs) for reducing the peak runoff flows and protecting 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). However, 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 the second half of the 20th century, a significant number of water supply wells were found to be contaminated with synthetic organic chemicals, many of which are now known to cause cancer and other illnesses in humans. Improper disposal of these hazardous materials, usually by illegal burial in the ground (or "midnight dumping"), has been the main 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 (e.g., 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 an 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.

## Development of a Master-Planned Community[1]

Anthem Community Park in Maricopa County, Arizona, is an example of a large master-planned community, one that exemplifies many of the environmental issues discussed above. Beginning around 2000, this community has gradually been developed on approximately 2400 hectares (ha) [5800 acres (ac)]. Zoning densities on the property allowed for the construction of approximately 14,000 residential units, with about 240 ha (600 ac) set aside for mixed commercial uses. The initial 2001 population of 2500 residents increased to 25,000 in 2010; the ultimate design population is 30,000 residents.

Planned features for the growing Anthem community included school sites, a community center, two golf courses, a water park, single family and multifamily housing, as well as mixed commercial uses. Although the Anthem community is a good example of a project for which the developer must consider a wide range of environmental factors, as mentioned above, the discussion here will focus mainly on water supply and wastewater disposal issues.

As part of the engineering work for this project, the developer hired a consulting engineering firm to create computer programs (also called computer models) of the community's water supply and wastewater disposal networks. The initial purpose of the computer models was to establish design parameters and construction phasing for the planned infrastructure. They have also served to maintain, operate, and update the system on an ongoing basis. (Computer applications are discussed in more detail in later chapters.)

As it developed, the Anthem community had to 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 could not be used as the sole source of water in the Phoenix Active Management Area in which the project is located, due to overpumping of the aquifers within the area. Wells could 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 in 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 treatment and distribution topics are discussed in Chapters 6 and 7.)

[1]Adapted from an article that originally appeared in the June 2001 issue of Public Works®, published by Public Works Journal Corporation, 200 South Broad Street, Ridgewood, NJ 07450. © 2001 Public Works Journal Corporation.

The task of providing water to the growing community was further complicated because 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 governmental entities has different engineering criteria for planning and design; the public infrastructure designed for Anthem must meet the design criteria for both jurisdictions. The computer model used for water and wastewater infrastructure ensures that minimum and maximum pressures are maintained under all water demand conditions, and that maximum flow velocities are not exceeded.

Anthem Community Park wastewater is collected and treated to allow the reuse of the effluent for irrigation of landscaping in roadway medians, parks, and golf courses. Treatment processes include rotary drum screens as well as biological purification and microfiltration. (Wastewater collection is discussed in Chapter 8, and sewage treatment processes are discussed in Chapter 10.) Treated sewage effluent in excess of irrigation needs is allowed to percolate or seep into the groundwater aquifer, using a network of recharge trenches—an example of indirect wastewater recycling. Raw CAP water, potable water, and treated effluent are monitored and managed using automated radio telemetry systems to optimize the 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.)

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 was 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. But it is very soluble in water and can contaminate water sources, largely as a result of leakage from underground 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. Its use in the United States started to decline in 2005 when more than two-dozen states banned the chemical.

As more is learned 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.

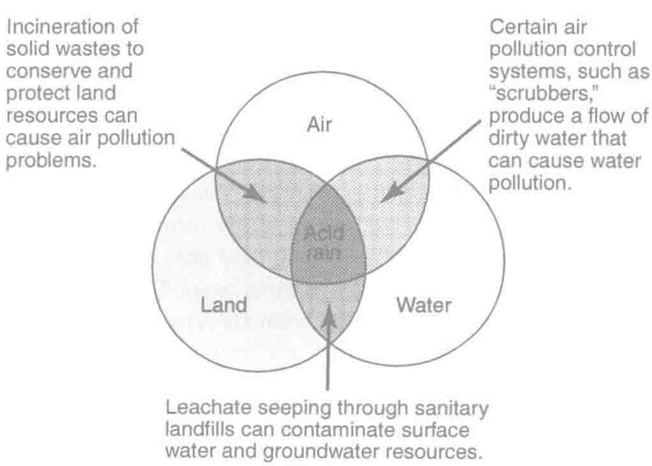


FIGURE 1-1 Most environmental problems pertaining to air, water, and land quality are interrelated. A problem called *acid rain*, for example, is caused by air pollution, and it damages both aquatic and terrestrial ecosystems.

## 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 remains a major problem for more than 2 billion people worldwide. Most medical professionals consider sanitation (i.e., the prevention of human contact with potentially harmful waste materials and other agents of disease) to be the most important aspect of disease prevention and public health protection.

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 (which 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*, **vectorborne**, and **vehicleborne**. 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 is discussed in Chapter 13.)

*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. Vectorborne disease can be controlled to some extent by proper sanitation measures.

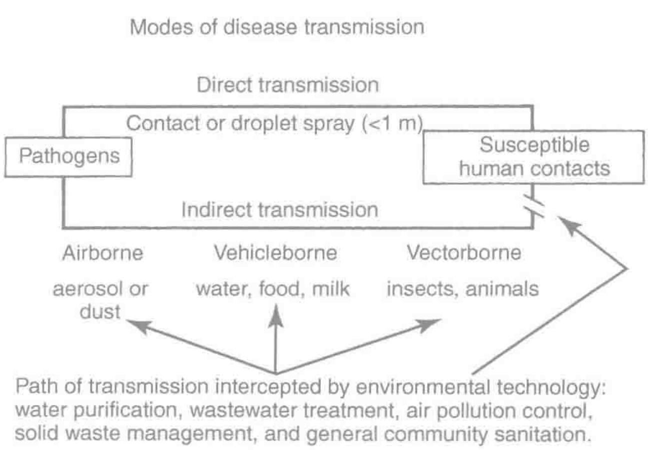


**FIGURE 1-2** Communicable diseases are spread in several ways, many of which can be controlled or intercepted by applications of modern environmental technology.

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. (Contaminated objects are also called *fomites*.)

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 foodborne diseases are perhaps the most preventable types of communicable diseases. The application of basic sanitary principles and environmental technology has virtually eliminated serious outbreaks of these diseases in technologically developed countries.

Water- and foodborne 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 foodborne diseases.

Although cholera and dysentery have not generally been a problem in the United States, they are prevalent diseases in Africa, India, and Pakistan and in many other developing countries in 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 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 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), which 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 less likely.

Insectborne 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.

In addition to insects, other vectors of disease transmission are vertebrate animals such as dogs and rats. Rabies is a familiar example of a disease spread by the bite of an infected dog or other mammal, but it is not generally related to environmental conditions. Rodent-borne diseases, such as *typhus* and *bubonic plague*, are more readily controlled by applications of environmental technology. Rat populations can be controlled by good community sanitation practices; rodent access to garbage and water should be prevented. Modern building codes include specifications for rodent-proof building construction.

## Noninfectious Diseases

It is a well-documented fact that the overall death rate for people residing in heavily polluted urban areas is significantly higher than the mortality rate in areas that are relatively pollution free. This is not necessarily because of the incidence of sewage pollution and the spread of infectious diseases. In fact, many current public health problems related to environmental pollution are considered to be the result of contamination of water, food, and air with toxic chemicals. The resulting diseases are noninfectious.

Some noninfectious illnesses associated with toxic chemical pollution have a relatively sudden and severe onset, and the acute or immediate health effects can be readily traced to a specific contaminant. A group of substances known as the **heavy metals** is particularly notorious in this regard. Other noninfectious diseases may take years to develop and can involve chronic or long-lasting health problems. Generally, various synthetic organic substances cause this type of problem, even in extremely small concentrations. Some organics are considered to be carcinogenic, having the potential to cause cancer in humans.

Lead is one of the heavy metals involved in noninfectious disease. The public health problems related to lead poisoning have long been associated primarily with ingestion by children of peeling lead-based paint. Lead poisoning can lead to blindness, kidney disease, and mental retardation (particularly in children).

The evidence against lead as a dangerous environmental pollutant is overwhelming. It is a cumulative poison; that is, it accumulates in human tissue and can build up to toxic levels over time. As a result, environmental agencies in Europe and the United States have banned the use of lead additives in gasoline.

Mercury is another heavy metal associated with environmental pollution and noninfectious illness. It was first noted as such when it afflicted large numbers of people living in the Minamata Bay region of Japan in the 1950s. Mercury compounds, discharged into the bay in wastewater from a local factory, were ingested by people who ate contaminated fish. A severe epidemic of disease, resulting in blindness, paralysis, and many deaths, was the result. Less severe symptoms included hand tremors, irritability, and depression.

At the time of the Minamata Bay incident, mercury vapor was known to be harmful, although metallic mercury itself was not considered hazardous (it has long been used in dental fillings). Research after the poisoning episode in Japan, however, led to the discovery that certain microorganisms can cause the metallic mercury to combine with other substances in the water, forming harmful mercury compounds, such as *methylmercury*. This substance was ingested by microscopic organisms in the water, called plankton, and entered the food chain. People who ate the contaminated fish were made ill by the methylmercury.

The episode of mercury poisoning in Japan is one example of a relatively sudden and acute illness related to environmental pollution. The concentration of the pollutant was relatively high, and the harmful effects were noticed within a short time. Questions remain as to the chronic or long-term effects of lower concentrations of mercury compounds. It is common to detect small amounts of mercury in fish and wildlife even in rivers and lakes far from industrial centers.

Discarded batteries and dry cells are a major source of mercury. This is becoming a very serious problem due to the difficulty in properly disposing of the many batteries generated by the growing electronics industry and the use of calculators, cameras, portable CD players, and watches.

Unfortunately, mercury and lead are not the only harmful chemical substances that become environmental pollutants when poorly managed or controlled. For example, the pesticide *Kepone* has seriously polluted the James River and Chesapeake Bay. The Hudson River is known to be contaminated with the toxic industrial chemical *PCB* (polychlorinated biphenyl) (see page 14). This oily substance was widely used in electrical transformer fluids, coolants, paints, and other products. It persists in the environment because it is nonbiodegradable; that is, it does not readily decompose and dissipate by natural processes. PCBs have accumulated in the bottom deposits of rivers, and many species of fish are contaminated with them.

Like the pesticide DDT, PCB has been banned from manufacture and most uses in the United States, but because these substances are extremely persistent in the environment, they remain potential dangers to public health for many years after their initial discharge. Traces of DDT and PCB are still found in the body tissues of animals far removed from the sources of pollution. Both of these chemicals are considered potential human carcinogens.

Environmental pollution with harmful chemicals and the resulting incidences of noninfectious disease are part of a problem now commonly referred to as **hazardous waste** disposal. This is discussed in more detail in Chapter 12.

Perhaps one of the most publicized environmental disasters in the United States that was related to improper disposal of hazardous wastes occurred in the 1970s at Love Canal in Niagara Falls, New York. Waste chemicals in steel drums were buried in the unused canal over a period of several years. The land was sold and many homes were built on top of the site. Eventually, the chemicals leaked out of the drums and into the soil, water, and air in the vicinity of the old dump site. Soon it was evident that residents in the area of Love Canal were suffering from unusually high rates of cancer, miscarriage, birth defects, kidney disease, and other illnesses. Love Canal was the first polluted site to be put on the federal Superfund list (see Section 12-4). In 2004, the U.S. Environmental Protection Agency (EPA) announced that after more than two decades of cleanup work at the site, at a cost of about $400 million, the Love Canal site was clean enough to be taken off the list.

In incidents like Love Canal, it is difficult to tie a particular chemical to a specific health problem, but the fact that the noninfectious illnesses suffered by the residents of the area were associated with environmental contamination with chemical wastes is beyond question. Research is being conducted by many universities and governmental agencies to determine some of the long-term effects of heavy metals and synthetic organic chemicals on human health.

Finally, several noninfectious diseases are specifically associated with air pollution. Air pollution and its control are discussed in Chapter 13. Briefly, common diseases related to air pollution include *bronchial asthma, bronchitis,* and *emphysema. Lung cancer* also occurs more frequently among people who live in congested industrial and urban areas, and poor air quality is considered to play a role in this. Again, it is difficult to prove a direct cause-and-effect relationship between a specific pollutant and these illnesses, but the overall negative effect of dirty air on public health is obvious: The incidence of respiratory ailments and increased mortality rates are directly related to the severity of air pollution.

## 1-3 ECOLOGY

Ecology is the branch of biological science concerned with the relationships and interactions between living organisms and their physical surroundings or environment. Living organisms and the environment with which they exchange materials and energy together make up an *ecosystem*, which is the basic unit of ecology. An ecosystem includes *biotic components*—the living plants and animals—and *abiotic components*—the air, water, minerals, and soil that constitute the environment. A third and essential component of most natural ecosystems is *energy*, usually in the form of sunlight.

Familiar examples of land-based, or *terrestrial*, ecosystems include forests, deserts, jungles, and meadows. Water-based, or *aquatic*, ecosystems include streams, rivers, lakes, marshes, and estuaries. There is no specific limitation on the size or boundaries of an ecosystem. A small pond can be studied as a separate ecosystem, as can a desert comprising hundreds of square kilometers. Even the entire surface of Earth can be viewed as an ecosystem; the term "biosphere" is often used in this context.

If Earth is imagined to be about the size of an apple, then the layer of air that we breathe would not be much thicker than the skin of that apple. This thin envelope of air (called the troposphere) and the shallow crust of land and water just beneath it provide the abiotic components that support life in the biosphere. It is a *closed* ecosystem because there is essentially no transfer of material into or out of it. Only the constant flow of energy from the sun provides power to sustain the life cycles within the biosphere. Nutrients are continually recycled and reused.

The biosphere seems so big that it is sometimes difficult to believe that humans can affect or disrupt its natural balances. But global problems related to environmental pollution, such as **acid rain**, the ozone hole, and the *greenhouse effect*, are significant and must be controlled before irreversible environmental changes occur. These and other pollution problems are discussed later in the text.