大学环境教育丛书

PEARSON

影印版

Jerry A. Nathanson

Basic Environmental Technology
Water Supply, Waste Management, and Pollution Control
(Fifth Edition)

环境技术基础
供水、废物管理与污染控制
（第5版）

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出版前言

在21世纪之初，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，我们精选了国外一些优秀的环境类教材，加以影印或翻译，组成大学环境教育丛书。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，也反映了作者不同的学术观点。

我们希望这套丛书的出版能对高等院校师生和广大科技人员有所帮助，并为我国的环境教育事业作出贡献。

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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 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 fifth 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 broad 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. 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 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 4 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 is to focus in lectures on the first 10 chapters for most of the semester, and allow students to select topics of special interest to them 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.

In this fifth edition, the text has been updated where necessary, and some new topics have been added. A section on alternative wastewater collection systems is now included in Chapter 8, reflecting the U.S. Environmental Protection Agency's (EPA's) recommendation that both alternative and conventional (gravity) collection systems now be considered during project planning stages for all communities with populations between 3500 to 10,000 people.

In addition, the section covering onsite wastewater disposal in Chapter 10 has been rewritten and expanded. In growing communities, the use of onsite disposal systems has long been considered to be just a temporary means of sewage disposal, only to be replaced by a centralized municipal treatment facility as soon as possible. But it is now generally recognized that when properly designed, installed, and maintained, onsite wastewater treatment and disposal systems can offer a reliable long-term alternative to centralized publicly owned treatment works. Also, the current emphasis in many states on the examination of soil texture, structure, and color rather than on the traditional "perc test" to evaluate subsurface permeability at the disposal site and to design the system is reflected in the revised section. A discussion of the alternatives to the conventional septic tank and leaching field configuration has also been extended. In Chapter 10, a section introducing the topic of treatment plant operation and maintenance has been added.

Several miscellaneous, brief subjects have also been added to this fifth edition, including the discussion of sustainability of groundwater resources, net positive suction head, radiation, radioactive waste disposal, SCADA systems, and the EPA biosolids rule. A few more case studies and examples of GIS applications have been added, and a synopsis or summary has now been provided for each chapter of the book, to give students an opportunity for a quick review (or preview) of the major topics covered and to provide a balance, so to speak, in presentation of the material. The glossary and list of abbreviations in Appendix D has been expanded by about 10%, reflecting the new topics and technical terms added to the book. (The abbreviations, as well as a table of conversions, are included on the inside front cover.)

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 D 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 five 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 I have necessarily resisted the temptation (and requests by some instructors) to add even more topics and details. From my 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. I 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. Finally, I want to echo the words of the 13th-century mathematician Leonardo Fibonacci, who wrote at the beginning of his first book, "If by chance I have omitted anything more or less proper or necessary, I beg forgiveness, since there is no one who is without fault and circumspect in all matters."

Supplements

To access supplementary materials online, instructors need to request an instructor access code. Go to **www.prenhall.com,** click the **Instructor Resource Center** link, and then click **Register Today** for an instructor access code. Within 48 hours after registering you will receive a confirming e-mail including an instructor access code. Once you have received your code, go to the site and log on for full instructions on downloading the materials you wish to use.

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

Jerry A. Nathanson, MS, PE
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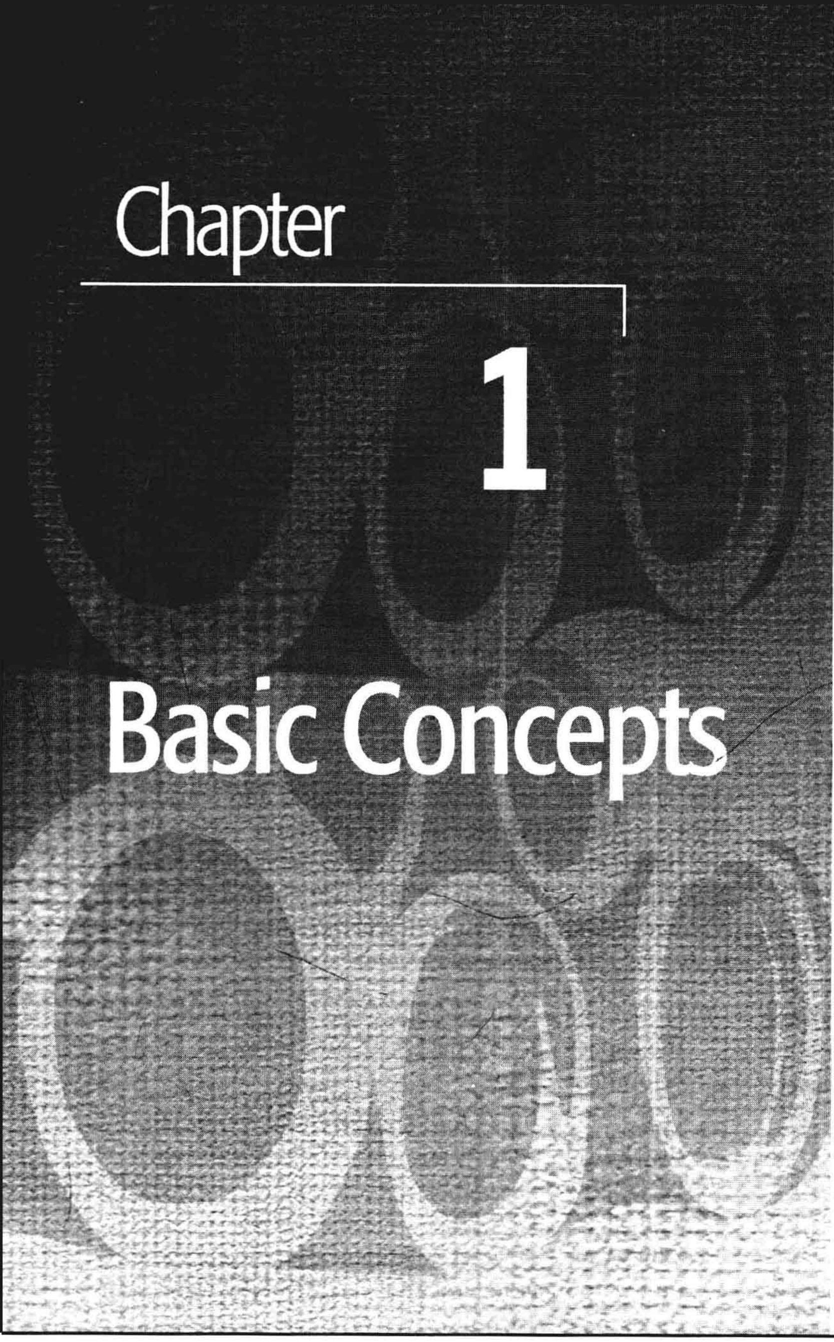

Chapter 1

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 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 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 (see Appendix B).

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.

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

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 issues will have to be considered before construction of the new community can begin. Usually, the project owner retains the services of an independent environmental consulting firm to address these issues. (See Case Study later in the chapter.)

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 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 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 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 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 refuse 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 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 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.