CHAPTER 1

Environmental Engineering as a Profession

Objectives

In this chapter, you will learn about:

- The demand for environmental engineers, and the ways environmental engineering enhances the health and well-being of society
- Duties and important characteristics of environmental engineers
- Three major environmental calamities that have occurred since 1947
- Professional licensure and lifelong learning as an environmental engineer
- A five-step, structured approach for solving engineering problems

1.1 WELCOME

As you begin your exploration of the environmental engineering profession, you may be curious, excited—perhaps even a little fearful of what will be expected of you. You are encountering the first challenge of your professional journey. This book will give you tools to develop the skills you need for solving environmental engineering problems as a college student and later as a practicing engineer. This chapter will show you some of the exciting things you can do in environmental engineering.

Your adventure with learning will not stop when you graduate. During your career, you will continue to learn, as technology and regulations change and new environmental dilemmas evolve. Environmental engineering is a dynamically growing field, and you will be a part of its future.

This book is an excellent source for students in the field of Civil Engineering, and for students in biology, chemistry, and geology. It provides a good background to the practical and valuable field of Environmental Engineering.

Welcome!

1.2 WHAT'S YOUR DEFINITION OF ENVIRONMENTAL ENGINEERING?

When we asked three people "on the street" what they thought an environmental engineer would do, they replied:

> "Take care of garbage and stuff like that."
> "Keep the air and water clean so we can use it."
> "Take care of pollution."

While these descriptions may be accurate to some degree, they only scratch the surface of the responsibilities of an environmental engineer today.

1.3 ENVIRONMENTAL ENGINEERS MAKE A DIFFERENCE

Environmental engineering has traditionally been a subspecialty of Civil Engineering, and at some colleges and universities it is housed in the Chemical Engineering department. Environmental engineers protect the health and well-being of the public by minimizing the release and impact of pollutants into the air, land, and water. Professionals in the field have studied chemistry, biology, mathematics, and engineering sciences. They work each day to design control and treatment systems that reduce or limit the negative effects that humans have on the many ecosystems of the world.

1.3.1 Jobs in Demand

The demand for environmental engineers continues to grow. The Bureau of Labor (http://www.bls.gov/oco/ocos027.htm) indicates that environmental engineers should have employment growth of 25% during the projected decade (2006–2016); this growth is much faster than the average for all occupations. The same data suggest that Computer Hardware, Electrical, and Mechanical engineering jobs are expected to have slower-than-average rates of employment growth through 2016. Civil and industrial engineers are expected to experience employment growth of 18% and 20%, respectively, over the projections decade.

An article in *Fortune Magazine* (Fisher, 2005) quoted David Levy (Chairman, Jerome Levy Forecasting Center) as declaring: "The greatest increase in demand by far will be folks who know how to clean up spaceship earth. That's because an increasingly health-conscious public is eager to find environmental engineers who can prevent problems rather than simply control those that already exist." Indeed, future professionals in this field will be in demand because they have skills and knowledge that governments, businesses, and industries will need to solve and prevent environmental problems.

1.3.2 A Lousy Report Card

Since 1998, the American Society of Civil Engineers (ASCE) has been rating the state of America's infrastructure. Table 1.1 shows scores from several recent report cards. The grades assigned to our systems that treat drinking water, wastewater, solid waste, and hazardous waste are alarming, as it appears that our country is barely passing! For nearly a decade, little to no progress has been made to improve our nation's deteriorating infrastructure.

This report is unacceptable, and improving these grades will require the expertise of environmental engineers. ASCE (2005) estimates that about $1.6 trillion must be invested to upgrade and renovate the environmental infrastructure. Additionally,

Table 1.1 ASCE Report Card on America's Infrastructure

	1998 grade	2001 grade	2005 grade
Drinking water	D	D	D–
Wastewater	D+	D	D–
Solid waste	C–	C+	C+
Hazardous waste	D–	D+	D

Source: ASCE (2005), ASCE (2001), ASCE (1998).

America's airports, bridges, dams, national power grid, public parks and recreation areas, railroads, security, schools, transit systems, and waterways will encounter problems to be solved by a team of professionals including environmental engineers.

The Water Infrastructure Network (WIN, a broad-based coalition of elected officials, water and wastewater providers, regulators, administrators, engineers, and environmentalists dedicated to preserving and protecting America's water and wastewater infrastructure) also cited the enormity of the work ahead. They forecasted unprecedented financial problems over the next 20 years for America's water and wastewater infrastructure. WIN (2004) projects that an annual investment of $23 billion over current allocations will be needed to meet the priorities as stated in the Clear Water Act (passed by Congress in 1977). The purpose of the act was to establish the "best available technology economically achievable" for wastewater discharges containing toxic substances and to provide the "best conventional pollutant control technology" for discharges containing conventional pollutants such as biochemical oxygen demand (BOD) and suspended solids (SS).

1.3.3 Basic Necessities—New Challenges

There will always be a high demand for qualified professional environmental engineers, since there is a continuous need for high-quality drinking water, clean air, and uncontaminated ground and surface water and land. Moreover, changes in population growth, habits, and lifestyles of people around the world create new challenges for environmental engineers. As the world's population approaches 7 billion, the auxiliary problems associated with providing sanitary living conditions are enormous and ever changing.

Here's a brief look at some changes that will impact future work in the field:

- Population increases create greater amounts of waste in terms of human excrement, discarded products, and food waste.
- Citizens tend to become more wasteful as their economic well-being increases.
- Modern lifestyles require considerable amounts of energy and resources from the earth. The liquids, solids, and gaseous wastes that are produced must be properly treated before being reintroduced into the environment.
- Endocrine disruptors such as human and veterinarian antibiotics, anti-inflammatory medicines, blood lipid regulators, and sex and steroidal hormones are being found in water and wastewater.

Environmental engineers must be proactive to develop alternative technologies and processes that minimize the production of pollutants and the needless wasting of the earth's resources. Sustainable processes are also required to enable us to meet not just our present needs but also those of future generations.

Challenges. Dilemmas. Ethical problems. Legal concerns. Political battles. Demands for cost-effective solutions. Balance between needs of the earth and needs of people. Remediation. Innovation. New technology. New problems. Each of these will require a team of *new professionals* ready to meet a future of environmental engineering!

1.4 DUTIES AND IMPORTANT CHARACTERISTICS OF ENVIRONMENTAL ENGINEERS

Being an environmental engineer is tremendously rewarding, because your skills can improve the quality of life and help sustain the ecological balance for future generations. The profession is a challenging one, requiring a strong foundation in science, math, and engineering. Professionals integrate knowledge in these areas to create engineered systems that treat pollutants in the atmospheric, aquatic, and terrestrial environments.

Most environmental problems are complex, because the treatment and transport of pollutants involve multiple mediums. For example, using a scrubber for removing particulate matter and gases from the discharge of a fossil-fuel power plant involves working with pollutants in three different phases. It requires knowledge of the chemical reactions involved in the combustion process and in the production of the air contaminants. The pollutants in the exhaust gas are transferred to the liquid phase during scrubbing, wherein the gases are neutralized and particles separated by gravity. Ultimately, the particulate matter removed will be disposed of in a landfill. There are other complex systems such as groundwater contamination from leaking underground storage tanks (LUSTs) in which physical, chemical, and biological processes must be understood and manipulated to engineer appropriate solutions. Environmental engineers work in a variety of settings, managing an array of tasks.

1.4.1 Multidisciplinary Teams

Environmental engineering jobs are stimulating, since you get to work on a wide range of projects and on multidisciplinary teams consisting of structural, mechanical, electrical, and geotechnical engineers and biologists, chemists, planners, economists, lawyers, and politicians. As a team player, you must have good communication skills and be able to convey your thoughts and designs to nontechnical and technical audiences in both written and oral forms. You will need to be able to deliver good oral presentations as well as make sketches and use appropriate software to prepare schematic diagrams and other types of engineering drawings.

1.4.2 Work Outdoors

Environmental engineering is especially appealing to those who enjoy outdoor activities and wish to sustain a healthy environment. It is not unusual for environmental engineers to develop and implement protocols for collecting air, water, and soil samples. On occasion, they will actually supervise the collection of the samples. Where construction projects involve building new water or wastewater treatment facilities or managing and supervising the cleanup of a contaminated hazardous waste site, environmental engineers may serve as resident observers. Performing soil surveys, environmental assessments, water-quality surveys, and hydraulic and hydrologic surveys all involve activities outdoors.

1.4.3 Consulting Firms

Many environmental engineers work for engineering consulting firms to solve a variety of environmental problems. Newly graduated environmental engineers tend to focus on technical issues related to the selection and design of appropriate technologies to treat water, wastewater, air pollution, groundwater, and contaminated soil. After several years of perfecting their technical expertise, they may progress to project management or to formation of their own firms as entrepreneurs.

1.4.4 Government

Some environmental engineers work for city or county governments and municipalities. They oversee the operation of public works departments, engineering departments, water treatment plants, and wastewater reclamation facilities. Planning and budgeting of major projects is their prime responsibility.

1.4.5 Regulatory Agencies

Environmental engineers also work at federal and state regulatory agencies. They are responsible for reviewing and permitting of new water and wastewater treatment plants, air-pollution control technologies, cleanup of contaminated land sites, and the siting and operation of sanitary landfills.

1.4.6 Industry

Industries such as pulp and paper manufacturing, textile processing, petroleum and petrochemical, pharmaceutical, and meat processing employ environmental engineers to ensure compliance with environmental regulations. Some environmental engineers develop ways to reduce and minimize the quantity of water used and the amount of pollutants produced at such facilities; while others are responsible for operating on-site industrial wastewater treatment plants or pretreatment systems, baghouses and electrostatic precipitators for air emissions, and disposal of residuals and sludges in landfills.

1.4.7 Academia

Environmental engineers employed in academia teach and serve as mentors to the next generation of engineers. They are rewarded and motivated by seeing their students learn and become productive citizens in society. Professors also engage in scholarly activities, such as research to explore innovative and cost-effective ways to reduce the effects of pollution on the environment. They also develop new teaching strategies and paradigms to enhance learning in the classroom. An important aspect of being a professor is presenting ideas and research results on technical and education-related activities at conferences and in peer-reviewed journals.

1.4.8. Does Environmental Engineering Match My Interests?

The foregoing information should help you understand whether environmental engineering suits your personality. At this point in your career, you are just beginning to develop the skills needed by a professional environmental engineer. The environmental engineering curriculum has been designed to provide both the soft and hard skills you will require. Your faculty advisor and instructors will mentor and assist you in your development along the way. Your commitment and perseverance will lead you to your goals.

1.5 ENVIRONMENTAL CALAMITIES

A number of environmental calamities have occurred in recent decades. Table 1.2 provides references for these tragedies, three of which are described below. In some instances, defining the effects associated with the release of certain pollutants (such as synthetic organic compounds, SOCs) into the environment took several years, since new technology was needed to detect and monitor the compounds at low levels, and the links between SOCs and their metabolites to related health effects were difficult to identify.

1.5.1 Love Canal

One stark example of chemical contamination of the environment occurred at Love Canal near Niagara Falls, New York. During the 1890s, William T. Love envisioned building a canal to connect the upper and lower Niagara Rivers to facilitate the production of hydroelectricity. Because of economic fluctuations, Love's project was doomed. In 1920, Love's land was sold to the City of Niagara Falls in a public auction

Table 1.2 Environmental Calamities in Recent History

Name	Pollutant Released	Date	Reference
Milwaukee	*Cryptosporidium* in drinking water	March 23, 1993–April 8, 1993	http://en.wikipedia.org/wiki/Milwaukee_Cryptosporidium_outbreak
Chernobyl	Radiation	April 26, 1986	www.chernobyl.com/info.htm
Love Canal	Toxic wastes	1920 to 1950s	www.epa.gov/history/topics/lovecanal/01.htm
Bhopal, India	Methyl isocyanate	December 2–3, 1984	www.bhopal.org/whathappened.html
Exxon Valdez	Crude oil	March 23, 1989	www.bytesurgery.com/missionpossible/mp/text/exxon.html
Smog in Great Smoky Mountains	Ozone and acid rain	1991 to 2001	www.aldha.org/smoky2.htm
Hurricane Katrina (*Natural Calamity*)	Pathogens, pesticides, dioxins, and debris	August 29, 2005	*Environmental Health Perspectives*, Vol 114, No 1, January 2006.

and was later used as a chemical waste disposal site. The Hooker Chemical Company (a subsidiary of Occidental Petroleum) acquired the site in 1947 and buried 21,800 tons of toxic waste in the area in a five-year period. In 1952, Hooker closed the site and covered the canal with earth. The company later sold the site to the Niagara Falls Board of Education, and a school and 100 homes were built on it.

During the intervening years, residents complained of strange odors and substances percolating to the surface in their yards. Numerous miscarriages and birth defects were reported by the New York State Health Department. In 1978, after Lois Gibbs and an associate held two Environmental Protection Agency (EPA) officials hostage in her home, President Carter declared a federal emergency at Love Canal. Finally on May 21, 1980, because of to the persistence of Lois Gibbs and other residents, President Carter and the Environmental Protection Agency agreed to relocate all families living at Love Canal. Occidental Petroleum eventually spent more than $200 million to clean up the site. This calamity led Congress to pass the Superfund Law, which holds companies responsible for the cleanup of hazardous waste sites. *Was it ethical for Hooker Chemical Company to sell the Love Canal to the Niagara Falls Board of Education?*

1.5.2 Milwaukee *Cryptosporidium* Outbreak

From March 23 through April 8, 1993, ineffective filtration at one of Milwaukee's water treatment plants caused an estimated 403,000 residents to become ill due to the inadequate removal of the protozoan parasite, *Cryptosporidium parvum* (Corso et al., 2003). Turbidity levels in the treated water exceeded normal levels. Over 100 deaths, mainly of the elderly and those with compromised immune systems, were attributed to this outbreak. *Could anything have been done to prevent this parasite from entering the water distribution system?*

1.5.3 Chernobyl Nuclear Disaster

On April 26, 1986, for a period of 10 days, radioactive material was released into the atmosphere from Number 4 nuclear reactor at the Chernobyl Power Plant (www.chernobyl.com/info.htm). Numerous safety precautions had not been followed, resulting in a meltdown of the reactor core. Estimates indicate that local residents were exposed to radioactivity 100 times greater than that of the Hiroshima bomb. Thirty people were killed immediately, and estimates suggest that over 15 million people were impacted by this disaster. Babies are still being born in this area with no arms, no eyes, and only stumps for limbs. *What actually caused the meltdown, and is there an antidote for radiation poisoning?*

1.6 BECOMING AN ENVIRONMENTAL ENGINEER: A LIFELONG PROCESS

Becoming an environmental engineer is a lifelong journey. First, one must receive four years of formal training and meet the requirements for professional licensure. Then, one must continue one's education in order to remain technically competent and current.

1.6.1 College Education

Traditionally, environmental engineers have been trained as civil engineers and pursued graduate degrees in "Sanitary" or "Environmental" Engineering. Formal training normally consisted of obtaining a four-year, Bachelor of Science (BS) degree in civil engineering from an ABET, Inc. accredited engineering program; and then specializing at the graduate level in a particular area such as water, wastewater, air pollution, solid wastes, or hazardous wastes.

Obtaining a Master of Engineering (ME) or Master of Science (MS) in Environmental Engineering normally takes one or two years past the baccalaureate. Two or three more years beyond the master's are normally required to obtain the Doctor of Philosophy (PhD) or Doctor of Science (DSc).

Several colleges and universities now offer four-year undergraduate degrees in environmental engineering. Table 1.3 shows a typical undergraduate environmental engineering curriculum by semester.

1.6.2 Professional Licensure

During the senior year, most environmental engineering students take the Fundamentals of Engineering (FE) examination. This nationally normalized test, administered by the National Council of Examiners for Engineering and Surveying (NCEES), leads to becoming a licensed professional engineer (PE). The 8-hour FE examination tests environmental engineers on their understanding of the basic sciences, math, ethics, engineering economy, statics, dynamics, thermodynamics, electrical, and engineering sciences. Upon passing the FE, graduates work four years under the mentorship of a licensed PE before they become eligible to take the 8-hour Professional Engineering (PE) exam, which focuses on design and the application of environmental engineering principles. Passing the PE exam permits one to become a registered or licensed professional engineer, allowed to sign and seal engineering drawings, plans, and specifications and essentially to practice environmental engineering. It is anticipated by 2015 that students graduating from civil and environmental engineering programs will have an additional 30-credit-hour requirement for professional licensure imposed by the National Council of Examiners for Engineering and Surveying (NCEES).

Table 1.3 Undergraduate Environmental Engineering Curriculum

	Fall	Spring
Freshman	Chemistry I	Chemistry II
	Computer Programming	Introduction to Design
	Calculus I	Calculus II
	Humanities I	Humanities II
	Freshman Experience	Ethics
Sophomore	Physics I	Physics II
	Statics	Dynamics
	Electrical I	Electrical II
	Intro Environmental Engineering	Probability & Statistics
	Differential Equations	Thermodynamics
Junior	Engineering Economy	Engineering Systems Analysis
	Biology	Geology
	Technical Communication	Hydrology
	Hydraulics	Wastewater Treatment
	Humanities III	Solid Waste Management
Senior	Air Pollution Control	Air Chemistry
	Public Health	Remediation
	Water Treatment	Environmental Engineering Lab
	Senior Design I	Senior Design II
	Groundwater Hydrology	Technical Elective
	Humanities IV	Humanities V

1.6.3 Engineering Ethics

The engineering occupation consists of professionals who must make ethical decisions. Ethics is the study of morals, which guide our conformance to a standard of what is right and wrong. By definition, professionals possess sophisticated skills, formal education, and standards that have been established by societies or organizations for admission to the profession. Each person makes moral choices in his or her relationships. Engineering ethics involves rules and standards governing the conduct of engineers in their professional lives.

Many professional societies have prepared codes of ethics to provide guidance for the working engineer. The National Society of Professional Engineers (NSPE) has sought to promote professional licensure and a code of ethics across the engineering field. Listed below are the fundamental canons promulgated by NSPE. Note how each canon reflects a specific precedence with respect to the engineer's consideration for clients, employers, the profession, and the public.

Engineers, in the fulfillment of their professional duties, shall (http://www.nspe.org/index.html):

1. Hold paramount the safety, health, and welfare of the public.
2. Perform services only in areas of their competence.
3. Issue public statements only in an objective and truthful manner.
4. Act for each employer or client as faithful agents or trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

1.6.4 Continuing Education

Environmental engineers must remain knowledgeable of current technologies. Professional engineering societies and organizations play a vital role in helping environmental engineers maintain their technical competency and currency. They promote training seminars, workshops, and conferences to keep their constituents informed. To promote lifelong learning, each professional society publishes journals with peer-reviewed articles on technical issues, engineering ethics, regulatory updates, and innovative technologies.

The American Academy of Environmental Engineers is the primary society that promotes environmental engineering. A variety of organizations, however, focus on environmental issues. The American Society of Civil Engineers (ASCE) is probably the engineering society most familiar to many environmental engineers, as historically most have been trained as civil engineers. Municipal and industrial wastewater treatment and sludge treatment and disposal issues are promoted by the Water Environment Federation (WEF). Environmental engineers interested in water treatment and related water issues are normally members of the American Water Works Association (AWWA). For those interested in air pollution and solid and hazardous waste management, the Air and Waste Management Association (AWMA) is the society to contact. The Association of Environmental Engineering and Science Professors (AEESP) is an environmental organization for those affiliated with academia. Table 1.4 lists the websites for some of the most prominent societies associated with environmental issues.

Table 1.4 Website Addresses for Organizations with Environmental Engineers

Organization	Web Address
Air and Waste Management Association	www.awma.org
American Academy of Environmental Engineers	www.aaee.net
American Society of Civil Engineers	www.asce.org
American Society for Engineering Education	www.asee.org
American Water Works Association	www.awwa.org
Association of Environmental Engineering and Science Professors	www.aeesp.org
Solid Waste Association of North America	www.swana.org
Water Environment Federation	www.wef.org

1.7 PROBLEM SOLVING

Environmental engineers solve a variety of problems. One must first identify and understand the problem or system, then define the parameters used to model the system; and finally solve the problem. For many environmental problems, you will need to perform energy and material balances around the system to solve them.

Most engineers use a structured approach to solve problems or to develop computer algorithms. The following five-step method is recommended for solving most engineering problems.

1. Identify and define the problem clearly and concisely. List all pertinent data, the knowns and unknowns, along with the appropriate units.
2. Make a sketch or diagram of the system and label all parts.
3. Select the appropriate theory or equations, estimate values where data are missing, and make assumptions to simplify the solution.
4. Solve the problem using mathematical equations, graphical procedures, or trial-and-error methods. In many cases, an energy and materials balance must be completed.
5. Check your answer to see if it makes sense, is reasonable/correct, and verify results by an alternative method if possible.

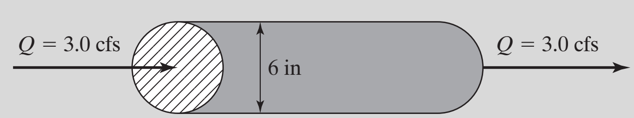
EXAMPLE 1.1

Computing velocity of flow in a pipe

Calculate the average velocity of water flowing in a 6-inch-diameter pipe if the flow rate is 3.0 cubic feet per second.

Solution

1. Find the average velocity of water in the pipe.
   Q = volumetric flow rate = 3.0 ft^3/s
   pipe diameter = D = 6 inches
2. Draw a figure.



3. Assume that the pipe is flowing full.
   area of a circle: $A = \pi D^2/4$
   A = cross-sectional area of pipe, ft^2 (cross-hatched area in figure)
   D = pipe diameter, ft
   continuity equation: $Q = A \times V$
   Q = volumetric flow rate, ft^3/s
   V = average flow velocity in pipe, ft/s
4. Solve for the cross-sectional area of the pipe.

$$A = \pi D^2/4$$

$$A = \frac{\pi(6\text{ in})^2}{4} = 28.27\text{ in}^2 \times \frac{1\text{ ft}^2}{144\text{ in}^2} = 0.196\text{ ft}^2$$

Solve for velocity by rearranging the continuity equation.

$$Q = AV$$

$$V = \frac{Q}{A}$$

$$V = \frac{3.0 \text{ ft}^3/\text{s}}{0.196 \text{ ft}^2} = 15.3 \frac{\text{ft}}{\text{s}}$$

5. Check by comparing the original Q ($3.0 \text{ ft}^3/\text{s}$) in the problem statement with the calculated Q ($2.99 \text{ ft}^3/\text{s}$) based on the area and the calculated velocity.

$$Q = AV$$

$$Q = 0.196 \text{ ft}^2 \times \left(15.3 \frac{\text{ft}}{\text{s}}\right) = 2.99 \cong 3.0 \frac{\text{ft}^3}{\text{s}} \quad \text{Checks}$$

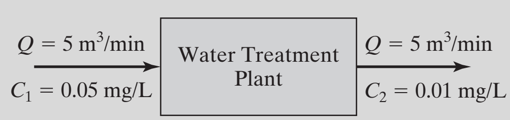
EXAMPLE 1.2

Calculating mass removal rates

Groundwater from a deep well is being pumped to a small water treatment plant at $5 \text{ m}^3/\text{min}$. The water contains 0.05 mg/L of arsenic (As), and the primary drinking-water standard is set at 0.01 mg/L of arsenic. Calculate the number of grams of arsenic that must be removed from the water each day to meet the standard.

Solution

1. Find the mass of arsenic that must be removed daily.
   Q = volumetric flow rate = $5 \text{ m}^3/\text{min}$
   C_1 = concentration of arsenic in raw water = 0.05 mg/L
   C_2 = concentration of arsenic in treated water = 0.01 mg/L
2. Draw a figure.



3. Assume that the volumetric flow rate is the same into and out of the water treatment plant.
   mass removed = mass in − mass out
   mass of arsenic = $Q \times C$
   Q = volumetric flow rate, m^3/min
   C_1 = concentration of arsenic in raw water = 0.05 mg/L
   C_2 = concentration of arsenic in treated water = 0.01 mg/L
4. Solve for the mass of arsenic entering and exiting the water treatment plant.

$$\text{mass in} = Q \times C_1 = 5 \frac{\text{m}^3}{\text{min}} \left(0.05 \frac{\text{mg}}{\text{L}}\right) \left(\frac{1000 \text{ L}}{1 \text{ m}^3}\right) \left(\frac{60 \text{ min}}{1 \text{ h}}\right) \left(\frac{24 \text{ h}}{1 \text{ d}}\right) \left(\frac{1 \text{ g}}{1000 \text{ mg}}\right)$$

$$\text{mass in} = Q \times C_1 = 360 \text{ g/d}$$

$$\text{mass out} = Q \times C_2 = 5 \frac{\text{m}^3}{\text{min}} \left(0.01 \frac{\text{mg}}{\text{L}}\right) \left(\frac{1000 \text{ L}}{1 \text{ m}^3}\right) \left(\frac{60 \text{ min}}{1 \text{ h}}\right) \left(\frac{24 \text{ h}}{1 \text{ d}}\right) \left(\frac{1 \text{ g}}{1000 \text{ mg}}\right)$$

$$\text{mass out} = Q \times C_2 = 72 \text{ g/d}$$
$$\text{mass of arsenic removed} = \text{mass in} - \text{mass out} = 360 - 72 = 288 \text{ g/d}$$

5. Check by subtracting C_2 from C_1 and multiplying this difference by the volumetric flow rate.

$$\text{mass of arsenic removed} = Q\,(C_1 - C_2)$$
$$Q\,(C_1 - C_2) = \left(5\,\frac{\text{m}^3}{\text{min}}\right)\left(0.05 - 0.01\,\frac{\text{mg}}{\text{L}}\right)\left(\frac{1000 \text{ L}}{1 \text{ m}^3}\right)\left(\frac{60 \text{ min}}{1 \text{ h}}\right)\left(\frac{24 \text{ h}}{1 \text{ d}}\right)\left(\frac{1 \text{ g}}{1000 \text{ mg}}\right)$$

$Q\,(C_1 - C_2) = 288$ g/d, which is equal to the mass of arsenic removed in Step 4.

1.8 ENVIRONMENTAL MANAGEMENT

Environmental issues related to our air, land, and water resources will continue as high-quality water sources diminish; global warming affects climate, causing drought in some areas and flooding in others; and with the loss of rain forests and fertile land for growing crops continues. Environmental engineers must work closely with the civil engineering profession to develop sustainable processes and designs to maintain worldwide infrastructure (transportation systems, wastewater collection and treatment systems, water distribution and treatment systems, sanitary landfills, etc.) while minimizing adverse affects on the ecosystem.

Environmental management involves managing human interaction and impact on the living (biotic) and nonliving (abiotic) environment. The International Organization for Standardization (ISO) has developed ISO 14000 environmental management standards to help companies minimize adverse affects from their operations on the environment. In the United States, all federal agencies must prepare a detailed statement known as an Environmental Impact Statement (EIS), as required by the National Environmental Policy Act (NEPA). The U.S. Environmental Protection Agency (EPA) reviews EISs prepared by all federal agencies and ensures that its own actions are in compliance with NEPA.

To sustain our ecosystem and our modern way of life, environmental engineers will be called upon to develop innovative and better solutions with regard to management of air resources, water supply and treatment systems, wastewater collection and treatment systems, and solid and hazardous waste collection, treatment, and disposal systems. Problems associated with pollution must be prevented and minimized by using alternative processes and fuels. Companies must produce products that have long life and the potential to be reused, and that require less energy and water to manufacture.

SUMMARY

Environmental engineering is an engineering specialty that involves identifying, designing, and implementing systems to protect human health and well-being and the environment. Environmental engineers have a prominent role in maintaining a high quality of life by providing potable water and clean air, remediating contaminated land, and minimizing the adverse effects of pollution on the environment.

Graduating from an ABET-accredited engineering program provides students with the formal training necessary to become environmental engineers. Traditionally, environmental engineers were trained as civil engineers at the undergraduate level and pursued graduate work at the master's or doctoral level to become environmental engineers. Several colleges and universities now offer undergraduate and graduate environmental engineering programs.

Completing the requirements for the bachelor's degree in environmental engineering is just the first step in becoming an environmental engineer. Learning is a lifelong process, and environmental engineers must remain current with new technologies and ever-changing regulations. This may be accomplished by actively participating in professional societies and reading technical literature to keep abreast of state-of-the-art science and technology.

Most often, environmental engineers work on multidisciplinary teams along with lawyers, chemists, biologists, planners, regulators, and other engineers to solve environmental problems. Employment opportunities for environmental engineers are diverse, ranging from engineering consulting to environmental law, from academic to governmental, and from municipal to industrial. It is anticipated that the strong demand for environmental engineers will continue into the next decade.

KEY WORDS

environmental engineer
ecological balance
pollution
life long learning
professional engineer
problem solving
air, land, and water environments

EXERCISES

For Exercises 1 through 6, use the Internet to perform a Google search for help in answering the questions. If necessary, seek out a professor or environmental engineer to discuss the topics presented. Then prepare a written paragraph or two for each topic, including the ideas discussed with the professor or engineer. Discuss the role each topic plays in environmental engineering. Include comments on the types of problems that the engineer may confront and how to solve these problems for each topic.

1.1 How are the principles from microbiology used in the design of wastewater treatment processes and the remediation of contaminated soil?

1.2 List and discuss two equations from fluids and hydraulics that are used by environmental engineers in the design of water distribution and wastewater collection systems. [*Hint:* Continuity and Bernoulli's equation.]

1.3 Environmental engineers and scientists have reported that global warming may be a real problem. List and discuss the major causes and the air pollutants that are associated with this phenomenon.

1.4 Environmental engineers are responsible for designing water treatment plants that provide safe, potable drinking water to the public. What chemical principles are used for removing pollutants from water? Give some examples of unit processes used for treating water. [*Hint:* Oxidation/reduction, gas transfer, precipitation.]

1.5 Many environmentalists promote the idea of recycling solid wastes. Collection, separation, and recycling systems are often designed by environmental engineers. Discuss the advantages and disadvantages of recycling metals, glass, and paper discarded in solid wastes. Some politicians advocate recycling and reusing 50% of the materials discarded. Is this realistic or even possible? Why or why not?

1.6 Hydrology is another area in which environmental engineers are highly involved. During storm events, rain that falls to the surface either percolates into the soil to replenish ground water supplies or becomes surface runoff. Stormwater runoff from impervious areas in cities or from agricultural areas contributes large volumes of water of poor quality, due to pollutant entrapment and dissolution. List and discuss some of the contaminants that might be found in urban stormwater runoff versus agricultural runoff. Typically, the rational method or equation is used for estimating the volume of runoff. Write down the equation and list the variables along with the appropriate units for each parameter in the equation.

1.7 A long, rectangular settling basin is used for removing suspended solids during water treatment. The basin's length-to-width ratio is 4:1 and its width-to-depth ratio is 1:1. Determine the basin's volume in cubic feet if its depth is 25 feet.

1.8 A 25-meter-diameter circular tank 10 meters deep is used for storing liquid sodium hydroxide solution at a wastewater treatment plant. Determine the tank's cross-sectional area in square meters and its circumference in meters.

1.9 Bituminous coal containing 5% (weight basis) sulfur is burned at a power plant to provide energy for generating electricity. Assume the combustion of coal is complete and the following equation can be used for modeling the oxidation of sulfur into sulfur dioxide.

$$S + O_2 \rightarrow SO_2$$

Determine the kilograms of sulfur dioxide produced daily if 20,000 kilograms of coal are combusted each day.

1.10 Chlorine is the most widely used disinfectant for killing pathogens during water treatment. Determine the kilograms of chlorine used daily at a water treatment plant handling 10,000 cubic meters per day of flow at a chlorine dosage of 10 mg/L. [*Hint:* Multiply the flow rate by chlorine dosage and make appropriate conversions.]

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