Open-Ended Problems: A Future Chemical Engineering Education Approach. J. Patrick Abulencia and Louis Theodore.

14

Environmental Management

This chapter is concerned with process environmental management. As with all the chapters in Part II, there are several sections: overview, several technical topics, illustrative open-ended problems, and open-ended problems. The purpose of the first section is to introduce the reader to the subject of environmental management. As one might suppose, a comprehensive treatment is not provided although several technical topics are also included. The next section contains three open-ended problems; the authors' solution (there may be other solutions) are also provided. The final section contains 32 problems; *no* solutions are provided here.

14.1 Overview

This overview section is concerned with —as can be noted from its title— environmental management. As one might suppose, it was not possible to address all topics directly or indirectly related to environmental management. However, additional details may be obtained from either the references provided at the end of this Overview and/or at the end of the chapter.

Note: Those readers already familiar with the details associated with this subject may choose to bypass this Overview.

For better than four decades there had been an increased awareness of a wide range of environmental issues covering all sources: air, land, and water. More and more people are becoming aware of these environmental concerns, and it is important that chemical engineers, many of whom do not possess an understanding of environmental problems or have the proper information available when involved with environmental issues, develop capabilities in this area. All professionals, not only chemical engineers, should have a basic understanding of the technical and scientific terms related to these issues as well as the regulations involved. Hopefully this chapter will serve the needs of the chemical engineer—increasing his or her awareness of (and help solve) the environmental problems facing society.

The current human population on Earth is approximately 7 billion, and it almost certainly will increase in the future. The influence and effects of human activities on the environment have become increasingly evident at the local, state, national, and international levels, while issues of environmental degradation, health, safety, green chemistry and engineering, sustainability, etc., have become more pervasive and pressing. The net result is that there has been a more significant increase in both awareness and interest about the environment since the turn of this century.

Section titles and contents of this chapter are:

1. Environmental Regulations
2. Classification, Sources, and Effects of Pollutants
3. Multimedia Concerns
4. ISO 14000
5. The Pollution Prevention Concept
6. Green Chemistry and Green Engineering
7. Sustainability

Note that parts of the material in this Chapter have been adapted from:

1. M.K. Theodore and L. Theodore, *Introduction to Environmental Management* CRC Press/Taylor & Francis Group, Boca Raton, FL, 2010 [1].

2. G. Burke, B. Singh, and L. Theodore, *Handbook of Environmental Management and Technology*, John Wiley & Sons, Hoboken, NJ, 1992 [2].

The reader should also note that the subject of communicating risk was not addressed, although it does receive treatment in both of the above references. As with most environmental issues of a volatile and personal nature, public perception of risk is unfortunately often based on fear rather than facts. The strategy to employ in communicating risk is therefore an important area of concern in environmental management.

14.2 Environmental Regulations [3]

Environmental regulations are not simply a collection of laws on environmental topics. They are an organized system of statutes, regulations, and guidelines that minimize, prevent, and punish the consequences of damage to the environment. This system requires each individual – whether an engineer, physicist, chemist, attorney, or consumer – to be familiar with its concepts and case-specific interpretations. Environmental regulations deal with the problems of human activities and the environment, and the uncertainties of laws associated with them.

The National Environmental Policy Act (NEPA), enacted on January 1, 1970 was considered a "political anomaly" by some. NEPA was not based on specific legislation; instead, it referred in a general manner to environment issues and quality of life concerns. The Nixon Administration at that time became preoccupied with not only trying to pass more extensive environmental legislation, but also in implementing the laws. Nixon's White House Commission on Executive Reorganization proposed in the Reorganizational Plan #3 of 1970 that a single independent agency be established separate from the Council for Environmental Quality (CEQ). The plan was sent to Congress by President Nixon on July 9, 1970, and this new U.S. Environmental Protection Agency (EPA) began operation on December 2, 1970. The EPA was officially born.

In many ways, the EPA is the most far-reaching regulatory agency in the federal government because its authority is very broad. The EPA is charged to protect the nation's land, air, and water systems. Under a mandate of national environmental laws, the EPA continues to strive to formulate and implement actions that lead to a compatible balance between human activities and the ability of natural systems to support and nurture life [1].

The EPA works with both the states and local governments to develop and implement a comprehensive environmental program. Federal laws such as the Clean Air Act (CAA), the Safe Drinking Water Act (SWDA), the Resource Conservation and Recovery Act (RCRA), and the Comprehensive Environmental Response Compensation, and Liability Act (CERCLA), etc., [3] all mandate involvement by state and local government in the details of implementation.

Pollution Prevention covers domestic and primarily industrial means of reducing pollution. This can be accomplished through (a) proper residential and commercial building design; (b) proper heating, cooling, and ventilation systems; (c) energy conservation; (d) reduction of water consumption; and, (e) attempts to reuse or reduce material before they becomes wastes. Domestic and industrial solutions to environmental problems can be addressed by considering ways to make homes and workplaces more energy efficient as well as ways to reduce the amount of wastes generated within them. This topic receives attention from a regulatory perspective under a separate section heading in this chapter.

14.3 Classification, Sources, and Effects Of Pollutants [1,2]

Not long ago, the nation's resources were exploited indiscriminately. Waterways served as industrial pollution sinks; skies dispersed smoke from factories and power plants; and, the land proved to be a cheap and convenient place to dump industrial and urban wastes. However, society is now more aware of the environment and the need to protect it. The American people have been involved in a great social movement known broadly as *environmentalism*. Society has thus been concerned with the quality of the air one breathes, the water one drinks, and the land on which one lives and works. While economic growth and prosperity are still important goals, opinion polls indicate overwhelming public support for pollution control and a pronounced willingness to pay for them. The next three paragraphs present the reader with information on pollutants and categorizes their effects.

Pollutants are various noxious chemicals and refuse materials that impair the purity of the atmosphere, water, and soil. In the authors' judgment, the area most affected by pollutants is the atmosphere or air. Air pollution occurs when wastes pollute the air. Artificially or synthetically created wastes are the main sources of air pollution. They can be in the form of gases or particulates which result from the burning of fuel to power motor vehicles and to heat buildings. More air pollution can be found in densely populated areas, e.g., urban areas. The air over largely populated cities often becomes so filled with pollutants that it not only harms the health of humans but also affects plants, animals, and materials of construction.

Water pollution occurs when wastes are dumped into the water. Which can cause disease. In the U.S., water supplies are disinfected to kill disease causing germs. The disinfection, in some instances, does not and often cannot remove all the chemicals and metals that may cause health problems in the distant future.

Wastes that are dumped into the soil are a form of land pollution that damages the thin layer of fertile soil, which is essential for agriculture. In nature, cycles work to keep soil fertile. Wastes, including dead plants and wastes from animals, form a substance in the soil called *humus*. Bacteria then decay the humus and convert it into nitrates, phosphates, and other nutrients that feed growing plants.

14.4 Multimedia Concerns [1,2]

The current approach to the environmental waste management requires some rethinking. A multimedia approach helps in the integration of air, water, and land pollution controls and seeks solutions that do not violate the laws of nature. Thus, it integrates air, water, and land into a single concern while seeking a solution to pollution that does not endanger society or the environment. The obvious advantage of a multimedia pollution control approach is its ability to manage the transfer of pollutants so they will not continue to cause pollution problems. Among the possible steps in the multimedia approach are understanding the cross-media nature of pollutants, modifying pollution control methods so as not to shift pollutants from one medium to another, applying available waste reduction technologies, and training environmental professionals in a total environmental concept. The challenge for the future environmental professional include:

1. Conservation of natural resources
2. Control of air-water land pollution
3. Regulation of toxics and disposal of hazardous wastes
4. Improvement of quality of life

It is now increasingly clear that some treatment technologies, while solving one pollution problem, have created others. Most contaminants, particularly toxics, present problems in more than one medium. Since nature does not recognize neat jurisdictional compartments, these same contaminants are often transferred across media. Air pollution control devices and industrial wastewater treatment plants prevent waste from going into the air and water, respectively, but the toxic ash and sludge that these systems produce can also become hazardous waste problems themselves. For example, removing trace metals from a flue gas during the pollution control phase usually transfers the products to a liquid or solid phase. Does this exchange an air quality problem for a liquid or solid waste management problem? The reader should ponder this question. Waste disposed of on land or in deep wells can contaminate ground water, and evaporation from ponds and lagoons can covert solid or liquid waste into air pollution [3]. Other examples include acid deposition, residue management, water reuse, and hazardous waste treatment and/or disposal.

Control of cross media pollutants cycling in the environment is therefore an important step in the overall management of environmental quality. Pollutants that do not remain where they are released or where they are deposited move from source to receptor by many routes, including air, water, and land. Unless information is available on how pollutants are transported, transformed, and accumulated after they enter the environment, they cannot realistically and effectively be controlled. A better understanding of the cross-media nature of pollutants and their major environmental processes – physical, chemical, and biological – is required.

14.5 ISO 14000 [1–8]

The International Organization for Standardization (ISO) is a private, nongovernmental, international standards body based in Geneva, Switzerland. Founded in 1947, ISO promotes international harmonization, and the development of manufacturing product and communications standards. It is a nongovernmental organization; however, governments are allowed to participate in the development of standards and many governments have chosen to adopt the ISO standards as their regulations. The ISO also closely interacts with the United Nations [4–5]. ISO has promulgated over 16,000 internationally accepted standards for everything from paper sizes to film speeds. Over 130 countries participate in the ISO as "Participating" members or as "Observer" members. The United States is a full-voting participating member and is officially represented in the ISO by the American National Standards Institute (ANSI).

Over the years the ISO has expanded the scope of their standards to incorporate areas such as the environment, energy conservation, service sectors, security, and managerial and organizational practice. The ISO's environmental mission is to promote the manufacturing of products in a manner that is effective, safe, and clean [6]. The ISO hopes to achieve this goal through the dedication and participation of more countries.

The ISO 14000 may be viewed as a generic environmental management standard. It can be applied to any organization and focuses on the processes and activities conducted by the company. It consists of standards and guidelines regarding environmental managed systems (EMSs). The idea for it first evolved from the United Nations conference on Environment and Development (UNCED), which took place in Rio de Janeiro in 1992. The topic of sustainable development (see last section in this chapter) was discussed there and the ISO made a commitment to support this subject [7].

The ISO 14000 standards were first written in 1996 and have subsequently been amended and updated. Their intended purpose is to assist companies and organizations to minimize their negative affect on the environment and comply with any laws, regulations, or environmental requirements that have been imposed on them. The ISO can also help to establish an organized approach to reducing any environmental impacts the company can control. Businesses that comply with these standards are eligible for certification. This certification is awarded by third-party organizations instead of the ISO [8].

14.6 The Pollution Prevention Concept [1–3,9]

The amount of waste generated in the U.S. has reached staggering proportions; according to the EPA nearly 3000 million metric tons of solid waste are generated annually. Although both the Resource Conservation and Recover Act (RCRA) and the Hazardous and Solid Waste Act (HSWA) encourage businesses to minimize the wastes they generate, the majority of current environmental protection efforts are centered around treatment and pollution cleanup.

The passage of the Pollution Prevention Act of 1990 has redirected industry's approach to environmental management: *pollution prevention* has now become the environmental option of the last decade of the 20th century and of the 21st century. Whereas typical waste management strategies concentrate on "end-of-pipe" pollution control, pollution prevention attempts to handle waste at the source (i.e., source reduction). As waste handling and disposal costs increase, the application of pollution prevention measures is becoming more attractive than ever before. Industry continues to explore the advantages of multimedia waste reduction and developing agendas to "strengthen" environmental design while "lessening" production costs.

There are significant opportunities for both the individual and industry to prevent the generation of waste; indeed, pollution prevention is today primarily stimulated by economics, legislation, liability concerns, and the enhanced environmental benefit of managing waste at the source. The EPA's Pollution Prevention Act of 1990 established pollution prevention as a national policy declaring "waste should be prevented or reduced at the source wherever feasible, while pollution that cannot be prevented should be recycled in an environmentally safe manner." [9] The EPA's policy establishes the following hierarchy of waste management:

1. Source reduction
2. Recycling/reuse
3. Treatment
4. Ultimate disposal

14.7 Green Chemistry and Green Engineering

Activities in the field of green engineering and green chemistry are increasing at a near exponential rate. This section aims to familiarize the reader with both green chemistry and green engineering by defining and setting principles to each; future trends are also discussed. Before beginning this section it is important that the term "green" should not be considered a new method or type of chemistry or engineering. Rather, it should be incorporated into the way scientists and engineers design for categories that include the environment, manufacturability, disassembly, recycle, serviceability and compliance. Today, the major element of "green" is to search for technology to reduce and/or eliminate waste from operation/processes, with an important priority being to not make it in the first place.

Green chemistry, also called *clean chemistry*, refers to that field of chemistry dealing with the synthesis, processing, and use of chemicals that reduce risks to humans and the environment [10]. It is defined as the invention, design, and application of chemical products and processes to reduce or to eliminate the use and generation of hazardous substances [11]. *Green* *engineering* is similar to green chemistry in many respects, as witnessed by the underlying urgency of attention to the environment seen in both sets of the principles [12].

14.8 Sustainability

Last, but not least, is the general subject of sustainability. The term *sustainability* has many different meanings to different people. To sustain is defined by some as to "support without collapse". Discussion of how sustainability should be defined was initiated by the Bruntland Commission. This group was assigned a mission to create a "global agenda for change" by the General Assembly of the United Nations in 1984. They defined sustainable very broadly: "Humanity has the ability to make development sustainable – to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs" [13].

Sustainability involves simultaneous progress in four major areas:

1. Human
2. Economic
3. Technological, and
4. Environmental

Sustainability requires conservation of resources while minimizing depletion on nonrenewable resources, and using sustainable practices for managing renewable resources [14]. However, there can be no product development or economic activity of any kind without available resources. Other than solar and nuclear energy, the supply of resources is *finite*. Efficient designs conserve resources while also reducing impact caused by material extraction and related activities. Depletion of nonrenewable resources and overuse of otherwise renewable resources limits their availability to future generations.

Another important element of sustainability is the maintenance of the structure and function of the ecosystem. Because the health of human populations is connected to the health of the natural world, the issue of ecosystem health is a fundamental issue of concern to sustainable development. Thus, sustainability requires that the health of all diverse species as well as their interrelated ecological functions be maintained. As only one species in a complex web of ecological interactions, humans cannot separate their survivability from that of the total ecosystem.

Summarizing, sustainability is a term that is used with greater frequency in the environmental community and with sometimes varied meanings. In short, sustainability means the capacity to endure. A more specific definition of sustainability refers to the long-term maintenance of well-being, which has environmental, economic, and social dimensions, and includes the responsible management of resource use. Interest and concern in this area is increasing at a near exponential rate.

A detailed and expanded treatment of environmental management is available in the following three references.

1. M.K. Theodore and L. Theodore, *Introduction to Environmental Management*, CRC Press/ Taylor & Francis Group, Boca Raton, FL, 2010 [1].
2. G. Burke, B. Singh, and L. Theodore, *Handbook of Environmental Management and Technology*, 2nd edition, John Wiley & Sons, Hoboken, NJ, 2000 [2].
3. L. Theodore, *Chemical Engineering: The Essential Reference*, McGraw-Hill, New York City, NY, 2014 [15].

14.9 Illustrative Open-Ended Problems

This and the last section provide open-ended problems. However, solutions *are* provided for the three problems in this section in order for the reader to hopefully obtain a better understanding of these problems which differ from the traditional problems/illustrative examples. The first problem is relatively straight forward while the third (and last problem) is somewhat more difficult and/or complex. Note that solutions are not provided for the 32 open-ended problems in the next section.

Problem 1: Briefly describe the major thrust or goals or provisions of the following laws:

1. The National Environmental Policy Act of 1970 (as amended in 1989) (NEPA); (Public Law 91-190, 42 United States Code section 4321 et seq.)
2. The Resource Conservation and Recovery Act of 1976 (as amended in 1988) (RCRA); (Pubic Law 94-580, 42 United States Code section 6901 et seq.)
3. The Comprehensive Environmental Response, Compensation and Liabilities Act of 1980 (CERCLA or Superfund); Public Law 96-510, 42 United States Code section 9601 et seq.)

4. The Superfund Amendments and Reauthorization Act of 1986 (SARA) Title III – also known as The Emergency Planning and Community Right-to-Know Act; (Public Law 99-499, 42 United States Code section 11001 et seq.)
5. The Pollution Prevention Ace of 1990 (Public Law 101-508).

Comment: The texts of the laws may be found in the United States Code which many libraries possess. Discussions of these laws may also be found in many texts on the environment [1–3].

Solution: The description of the major thrust and the choice of goals and provisions given for each law is subjective and therefore one's answers may not exactly match those given here.

1. The National Environmental Policy Act (NEPA) requires any federal agency proposing a project that might affect the environment to prepare an *environmental impact statement*. The statement describes the project's adverse effect on the environment as well as its benefits. The statement also includes a discussion of alternatives.
2. The Resource Conservation and Recovery Act (RCRA) aims primarily to protect the environment from the mishandling of land disposal of municipal, industrial, commercial and hazardous wastes. A major part of the law relevant to pollution prevention is Subtitle C, regulations pertaining specifically to hazardous waste management. A waste is hazardous if it appears on a designated list or possesses certain defined characteristics (ignitability, corrosivity, reactivity, and/or extraction procedure toxicity) as determined by prescribed tests. Hazardous waste generators, transporters, and hazardous waste treatment/storage/disposal facilities are required to keep records, submit reports, meet standards set forth in regulations, and to obtain permits. RCRA attempts to create a *cradle-to-grave* hazardous waste management system.
3. The Comprehensive Environmental Response, Compensation and Liabilities Act of 1980 (CERCLA or "Superfund") attempts to provide the means by which abandoned hazardous waste sites may be remediated. A special tax is placed on certain chemicals to raise the needed funds. A list of hazardous waste sites needing clean-up (The National Priorities List) is generated through an evaluation of the relative risk to

public health and the environment posed by each site. The U.S. Environmental Protection Agency (EPA) is given the authority to seek reimbursement for the clean-up expenses from the owners/operators of the site and from the generators of the waste.

4. The Superfund Amendments and Reauthorization Act of 1986 (SARA) Title III- also known as The Emergency Planning and Community Right-to-Know Act, requires each state to establish local emergency planning districts and committees to develop, together with certain chemical facilities, contingency plans for handling and responding to the release of an "Extremely Hazardous Substance". The affected facilities are those that have on their premises any chemical found on a list of "Extremely Hazardous Substances" published by the EPA in an amount known as the "Threshold Planning Quantity" which is given on the same list. These facilities must submit an inventory of these chemicals and also report releases of reportable quantities of these chemicals to the emergency planning committee. Facilities must also account for the total quantity of substances brought in versus the amount shipped out (mass balance study). The difference could indicate a release of the chemical. The EPA is to maintain a database of release reports which is available to the public
5. The Pollution Prevention Act of 1990 seeks to make the reduction of the production of pollutants ("source reduction") the primary means for controlling pollution (as opposed to treatment, storage, and disposal). The EPA is to establish a source reduction program that: collects and disseminates information; provides financial assistance to states; establishes standard methods for measuring source reduction; provides a source reduction clearinghouse; creates an advisory panel of experts from government, industry and public groups; establishes training and award programs; promotes a multi-media approach to source reduction; and, establishes a special office to oversee the implementation of this law. (See also Overview).

Problem 2: Discuss the relative merits of transportation of goods by trucks and by railroad from the point of view of environmental management. Be as specific as possible in the comments regarding environmental pollution production and energy utilization requirements of each mode of transportation. Identify the type of data needed to provide a quantitative analysis of this problem.

Solution: Data needed for a quantitative analysis of this problem must be in the form of relative emission rates per unit mass transported. Emission data for loading and unloading activities should also be provided.

Merits of Truck Transportation:

1. Trucks can usually travel a more direct route for a delivery (fewer miles traveled) than trains. This is due to the fact that the infrastructure of roads and highways is much more extensive than that of the railroads. In many cases, a truck will carry an entire load to a single destination, taking the most direct route. Because the railroad is limited by its infrastructure, trains will most likely have to travel farther to reach the same destination.
2. Truck engines produce fewer emissions that railroad engines. Beginning in 1991, the EPA set emission standards for all classes of heavy-duty over-the-road trucks. The emission standards require heavy-duty diesel engine manufacturers to decrease engine emissions of particulates (carbon soot), hydrocarbons, NO_x, and CO. To meet these standards, engine manufacturers had to redesign many engine components and develop better combustion technologies. So far, the EPA has not set emission standards for railroad diesel engines. Railroad diesels are typically much larger than truck diesels and are built by different manufacturers. Because there are no emission standards for the railroad diesels, they continue to be built with less expensive, obsolete engine technology that produces higher emissions. To compare exhaust emissions on an equal basis, they need to be measured in grams per hour per horsepower produced, or tons of load delivered per kilogram of pollution per mile.

Merits of Railroad Transportation

1. Unlike trucks, trains can couple several hundred cars together and pull them with only a few large diesel engines. Because of this, trains accelerate very slowly but are able to reach and maintain crusing speeds (analogous to a large,

heavy car with an undersized engine). Because a train has a much lower power-to-weight ratio than a truck, it has a better fuel economy. To compare a train and truck on an equal basis, the fuel economy (mpg) should be calculated for both and divided by the total weight carried, resulting in mpg per ton values.

2. Trains travel at steadier speeds than trucks. Fuel economy and emissions are optimized during steady-state operating conditions with an internal combustion engine. Trucks are exposed to much more stop-and-go driving than trains during which the engine is repeatedly accelerated and decelerated. Engines get poor fuel economy during acceleration because more fuel must be used to prevent them from "bucking" or "stalling". Likewise, emissions are much higher during acceleration due to the overfueling that takes place. With a diesel engine, one can actually see the emissions (particulates) bellowing from the exhaust during acceleration.

Another section could be added discussing the proper balance of trucking and railroad use. Some would say that the policy has gone too far from the optimum in the direction of trucks or buses and make too little use of trains. The discussion could include an analysis of the optimal mix of trucking and trains to deliver goods in a fashion that maximizes pollution prevention.

Problem 3: Identify the following sources as pollutants, waste, or neither, and classify them as storage and handling or process, fugitive, or secondary emissions. Suggest ways to eliminate or reduce each source.

1. A truck delivers a load of coal to a plant. The coal is dumped into a storage bin at the site, generating coal dust.
2. A solvent bath has a lid that is closed during downtime when the bath is in use. The liquid is exposed to the air.
3. Spent solvent from a bath must be replaced periodically. The used solvent is stored in a drum until it is removed from the site.
4. Solvent is emitted from the stack of a chemical plant. In the atmosphere it undergoes chemical reactions and may contribute to aerosol (smog) formation. Classify both the solvent and the aerosol.

5. In a plating operation, a part is dipped in a chemical bath, and the dipped piece is transferred to a rinse bath several feet away. During the transfer, the dipped piece drips chemicals onto the plant floor ("dragout"). Most of the resulting chemical spill evaporates and the rest is washed down the drain, which eventually finds its way into the city sewer system.
6. A pump through which an organic solvent is flowing has a small, undetected leak.
7. A sulfuric acid solution is used to regenerate an ion exchange column.
8. A sulfuric acid stream is neutralized by mixing with a caustic stream from another part of the process. Classify both the reagent streams and the neutralized stream from the process.

Comment: Refer to the literature for additional information [1,2,9].

Solution: One person's solution to the eight categories is presented below.

1. The coal dust is a storage and handling emission. An accurate estimate of the amount of dust generated may be very difficult to make, as are suggestions for reducing this source. However, proper enclosure of the transfer point and exhausting the dust to a control system may minimize the emission rate. This dust contributes to the ambient particulate loading and as such is considered a pollutant. (Emission factors exist for this source).
2. The evaporating solvent is classified as a fugitive emission. An estimate of the magnitude of this emission can be made by comparing volumes of fresh and spent solvent in the bath. One possibility is for the development of an automated system that raises the lid only for purposes of inserting or removing parts. It may also be possible to reduce evaporation by temperature control of the bath (providing the bath is effective at reduced temperatures) or of the air space above the solvent liquid surface, i.e., a vapor condenser. Another option might be to install an exhaust hood to remove fumes, which can then be treated (for example, absorbed before the air is vented to the atmosphere). The evaporated solvent is considered an air pollutant.
3. The spent solvent is a process emission and may be classified as a hazardous waste, depending upon its chemical

composition. The amount of solvent waste may be reduced by recovering the solvent and reusing it (via distillation or other appropriate methods). It may be possible to replace the solvent with one that is not environmentally hazardous.

4. The solvent emitted from the stack (as a gas) is a process emission, and is classified as a pollutant. The amount of solvent lost in this way may be reduced by condensation of the solvent and separation from the stack gas. The aerosol is classified as a secondary pollutant. This term refers to pollutants that result from further reaction of primary emissions; frequently, secondary pollution occurs at different locations (downwind, for example) away from the primary emission. The production of secondary pollutants depends upon a number of ambient conditions, primarily ambient volatile organic levels, No levels, temperature, and solar irradiation. In general, smog levels can be reduced by a concerted program of emissions abatement from automobiles and industry, leading to reduced ambient concentrations.
5. The "spill" occurs as a part of the processing of the piece and can be classified as a process emission. Depending upon the chemicals used in the bath, the water used to wash the spill down the drain may become a waste or hazardous waste stream. It may be possible to reduce the problem by changing the location of the rinse bath so that the path of the piece remains over collection tanks, and by suspending the piece for a longer amount of time over the bath to allow most of the bath solution to drip back into the tank.
6. The leaked solvent is a fugitive emission. An estimate of the amount of solvent lost as fugitive emissions can be made by performing a material balance for the solvent over the entire process. Checking the integrity of the pump may reveal a repairable leak, or it may be necessary to switch to a different type of pump that is less likely to leak. It may also be possible to reduce this type of loss in process piping (at gaskets, for example) by shrink-wrapping the joint or otherwise containing the vapor. If possible, another solvent might be considered that has a lower vapor pressure or that is less corrosive to the pump interior.
7. If the acidic stream has a $pH < 2$, it is classified as a hazardous waste and must undergo further treatment before disposal. Similarly, if a caustic effluent has a $pH > 12$, it is classified as

a hazardous waste. It may be possible to replace the acidic cleaner with one that is not classified as hazardous. It may also be possible to recover spent solution and recycle it for cleaning purposes, reducing the amount of waste generated.

8. If either the acidic or caustic stream is classified as hazardous (see 7), the neutralized stream may also be considered hazardous even if its pH is greater than 2 and less than 12. This is known as the "derived-from" rule, which assigns the hazardous classification to derivatives from hazardous wastes. It may be possible to reduce the amount of neutralized solution to be processed by concentrating it; the water thus recovered may be recycled for use in other parts of the process.

14.10 Open-Ended Problems

This last section of the chapter contains open-ended problems as they relate to environmental management. No detailed and/or specific solution is provided; that task is left to the reader, noting that each problem has either a unique solution or a number of solutions or (in some cases) no solution at all. These are characteristics of open-ended problems described earlier.

There are comments associated with some, but not all, of the problems. The comments are included to assist the reader while attempting to solve the problems. However, it is recommended that the solution to each problem should initially be attempted *without* the assistance of the comments.

There are 32 open-ended problems in this section. As stated above, if difficulty is encountered in solving any particular problem, the reader should next refer to the comment, if any is provided with the problem. The reader should also note that the more difficult problems are generally located at or near the end of the section.

1. Describe the early history associated with environmental management.
2. Discuss the recent advances in the general field of environmental management.
3. Select a refereed, published technical article on the environment from the literature and provide a review.

4. Provide some normal everyday domestic applications involving the general topic of the environment.
5. Develop several original problems related to environmental management that would be suitable as illustrative examples in a book.
6. Prepare a list of the various technical books that have been written on the environment. Select the three best (be sure to select at least one written by one of the authors) and justify your answer. Also select the three weakest books and, once again, justify your answer.
7. As a well educated person in environmental management attending a public hearing on a risk-assessment study where the outcome is "no potential health or hazard to the public", what are the main concerns you would have in order to be convinced that the results are reliable and acceptable?
8. Provide a short paragraph on each of the following environmental management topics:
   - Air pollution control equipment
   - Atmospheric dispersion modeling
   - Indoor air quality
   - Industrial wastewater management
   - Wastewater treatment technologies
   - Wastewater treatment processes
   - Solid waste management
   - Superfund
   - Municipal solid waste management
   - Hospital waste management
   - Nuclear waste management
9. What does the term "multimedia analysis" refer to?
10. Acid rain results from the dissolution of nitrogen and sulfur oxides into precipitation to form acids that reach the earth's surface. In recent years studies have shown that the pH level of rain has decreased, becoming acidic as the atmospheric level of these nitrogen and sulfur oxides has increased. Areas in Scotland and the northeastern US have shown the most dramatic effects of this acidic deposition. Acid rain potentially harms forests, lakes, and even drinking water in extreme cases. How did Title IV of the Clean Air Act of 1990 address the acid rain problem in the US?

11. Define the greenhouse effect and global warming. Also discuss the relationship between the two.
12. Do you believe global warming is a problem? Explain.
13. You are a consulting engineer hired by a company to evaluate waste minimization opportunities in the organization. Outline your approach for conducting a waste minimization assessment.
14. A key to identifying and applying pollution prevention (P^2) principles is to understand the total life-cycle of a product or material. Identify and discuss potential opportunities for P^2 for a "juice-pack" of orange juice.
    Comment: Both packaging and content are components of this popular product.
15. What are the most common methods used to estimate the quantity of waste generated in a community?
16. Identify the major contaminants affecting indoor air quality, and provide a potential source and the methods of control of each contaminant.
17. Indoor air quality is a relatively recent concern in environmental management.
    - Explain why indoor air quality is a concern.
    - Explain what has caused indoor air quality to be of greater concern now than in the past.
    - Describe some of the immediate and long-term health effects of indoor air quality exposure.
    - What are some of the costs of indoor air quality problems?
    - Compare indoor air pollution with ambient air pollution. Show why indoor air quality can be of greater concern than ambient air quality.
18. Why is noise considered an environmental problem?
19. Explain the mechanism of hearing and the effect of noise exposure on individuals.
20. Define ISO in layman terms.
21. Discuss the provisions of ISO 14000 in layman terms.
22. You have been hired as the environmental officer for a manufacturing company that intends to enter the global market. As part of the business plan for the company entering the global market, the company intends to become ISO 14000 certified. What are the major components of ISO

14001 EMS that must be implemented by the company in order to pass the audit requirement for certification?

23. Refer to the previous problem. List and discuss the benefits and pitfalls of the ISO 14000 series of standards to industry from an international point of view.
24. Composting is the biological decomposition of organic waste material by microorganisms. It is one of the major treatment alternatives for municipal solid waste, especially in developing countries where solid wastes contain mostly organic carbon sources and are rich in nutrients. During the process, certain physical, chemical and biological changes take place which alter the character of the waste material. Describe these physical, chemical, and biological changes as municipal solid waste is converted to humus in the composting process.
25. Choose a small political jurisdiction that operates its own solid-waste collection system. Find out the quantity of solid waste collected, any waste processing that takes place, and the ultimate disposal option used for this waste stream. Obtain cost information for waste collection and waste disposal.

    Find out what type of recycling, if any, is done in the jurisdiction. For a class of material not yet widely recycled, develop a plan to collect, process, and sell this recycled product. Make rough engineering estimates of the cost of operating the recycling process. Determine the savings incurred because of reduced waste collection and/or disposal costs. As recycling is almost always not economically attractive, look for other values to society that this recycling represents, and incorporate these ideas as quantitatively as possible into a persuasive report selling your project.
26. Describe technical issues that must be considered in the design of a waste landfill. Also describe the issues if the waste is hazardous.
27. Hospitals are places where sick or injured people go to get cured, but themselves present health and hazard problems to patients. In examining the many different activities of a hospital, list and group as many possible health problems as you can.

28. Do you believe electromagnetic fields pose a health problem? Explain your answer.
29. The International Convention For The Prevention of Pollution From Ships, to which the U.S. is a Party, specifies the conditions under which an oil tanker may discharge oil into the sea. List and comment on these conditions.
30. The Pasquel-Gifford atmospheric dispersion coefficients (σ_x, σ_y) are provided in graphical chart form [16]. Convert these charts into any suitable equation form. Also convert the data available for instantaneous releases into equation form.
31. Sansaverino Waste Management has hired you to develop a plan to economically extract valuable resources in their landfill sites. Your plan should address both near term (this decade) and longer term action(s).
32. Whenever a difference in velocity exists between a particle and its surrounding fluid, the fluid will exert a resistive force upon the particle. Either the fluid (gas) may be at rest with the particle moving through it or the particle may be at rest with the gas flowing past it. It is generally immaterial which phase (solid or gas) is assumed to be at rest; it is the *relative* velocity between the two that is important. The resistive force exerted on the particle by the gas is called the *drag* and this effect plays a major role in the design of particulate air pollution control equipment.

    In treating fluid flow through pipes, a friction factor term is used in many engineering calculations (see Fluid Flow – Chapter 5). An analogous factor, called the drag coefficient, is employed in drag force calculations for flow past particles.

    Consider a fluid flowing past a stationary solid sphere. If F_D is the drag force and ρ is the density of the gas, the drag coefficient, C_D, is defined as

$$C_D = \frac{F_D}{A_p}\frac{2g_c}{\rho v^2} \tag{14.1}$$

    From dimensional analysis, one can then show that the drag coefficient is solely a function of the particle Reynolds number, Re, i.e.,

$$C_D = C_D(\mathrm{Re}) \tag{14.2}$$

where

$$\mathrm{Re} = \frac{d_p v \rho}{\mu} \tag{14.3}$$

The quantitative use of the equation of particle motion requires numerical values of the drag coefficient as a function of the Reynolds number. Graphical values are presented in Figure 14.1.

Numerous models (equations) have been developed to convert Figure 14.1 into equation form. One drag coefficient model is given by Equation (14.4) [17]:

$$\begin{aligned} \log C_D = {} & 1.35237 - 0.60810(\log\mathrm{Re}) - 0.22961(\log\mathrm{Re})^2 \\ & + 0.098938(\log\mathrm{Re})^3 + 0.041528(\log\mathrm{Re})^4 \\ & - 0.032717(\log\mathrm{Re})^5 + 0.007329(\log\mathrm{Re})^6 \\ & - 0.0005568(\log\mathrm{Re})^7 \end{aligned} \tag{14.4}$$

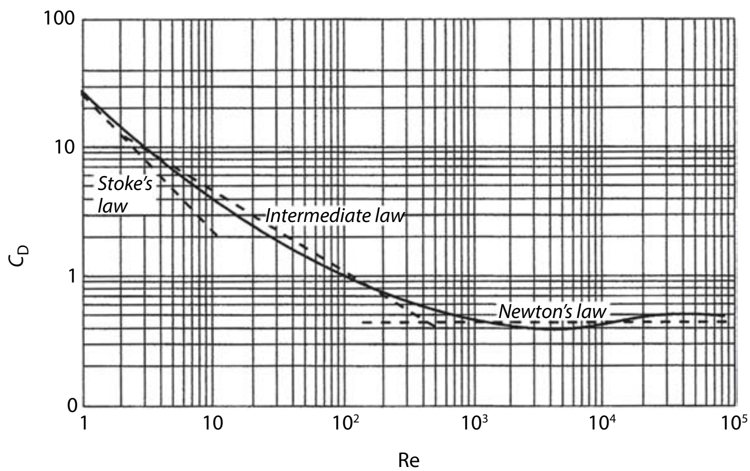

Figure 14.1 Drag coefficients for spheres.

This is an empirical equation that was obtained by the use of a statistical fitting technique. An advantage of using this correlation is that it is not partitioned for application only to a specific Reynolds number range. However, the lengthy calculation can limit its use. Still another empirical equation [18] is

$$C_D = \left[0.63 + (4.80/\sqrt{\mathrm{Re}})\right]^2 \tag{14.5}$$

This correlation is also valid over the entire spectrum of Reynolds numbers. Its agreement with literature values in the range of 30 < Re < 10,000 is fair. This correlation lends itself easily to manual calculations.

Develop a better model to represent Figure 14.1 in equation form.

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