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

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Water Management

This chapter is concerned with process water management. As with all the chapters in Part II, there are several sections: Overview, several technical topics, illustrative open-ended problems open-ended problems. The purpose of the first section is to introduce the reader to the subject of water management. As one might suppose, a comprehensive treatment is not provided although several technical topics are also included. The second section contains three open-ended problems; the authors' solutions (there may be other solutions) are also provided. The third (and final) section contains 46 problems; *no* solutions are provided here.

17.1 Overview

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

Traditionally, water management emphasized the importance of this natural resource for navigation, commerce, farming and agriculture, consumption, and recreation. More recently, water policy discussions have expanded to encompass the sustainable use of water for both current and future generations. From a broad perspective, water management incorporates aspects of addressing water as both a natural resource *and* a commodity. More scrutiny is being placed on water management priorities competition for readily available water increases.

The authors believe that the number one global *environmental* problem is the lack of potable water. Perhaps it is or will soon become the number one global problem. At a minimum, it will achieve greater significance in the years ahead [1]. Nations go to war over oil (or other natural resources) but there are resources that can replace oil. Water? There really is no substitute. And therein lies the problem, particularly with many of the undeveloped nations.

The EPA, in partnership with state and local governments is responsible for improving and maintaining water quality. These efforts are centered around one theme: maintaining the quality of drinking water. This is addressed by monitoring and treating drinking water prior to consumption and by minimizing the contamination of surface waters and protecting against contamination of ground water needed for human consumption.

The most severe and acute public health effects from contaminated drinking water, such as cholera and typhoid, have been essentially eliminated in the U.S. However, some less acute and immediate hazards remain in the nations tap water. These hazards are associated with a number of specific contaminants in drinking water. Contaminants of special concern to the EPA are lead, radionuclides, microbiological contaminants, and disinfection byproducts. These are detailed below.

The primary source of lead in drinking water is corrosion of plumbing materials such as lead service lines and lead solders in water distribution systems, as well as in houses and larger buildings. Virtually all public water systems serve households with lead solders of varying ages, and most faucets are made of materials that can contribute some lead to drinking water.

Radionuclides are radioactive isotopes that emit radiation as they decay. The most significant radionuclides in drinking water are radium, uranium, and radon, all of which occur naturally in nature. While radium and uranium enter the body by ingestion, radon is usually inhaled after being released in the air during showers, baths, and other activities such as washing clothes or dishes. Radionuclides in drinking water occur primarily in those systems that use ground water. Naturally occurring radionuclides are seldom found in surface waters (such as rivers, lakes, and streams) [1].

Water contains many microbes – bacteria, viruses, and protozoa. Although some organisms are harmless, others can cause disease. Contamination continues to be a national concern because contaminated drinking water systems can rapidly spread disease.

Disinfection byproducts are produced during water treatment by the chemical reactions of disinfectants with naturally occurring or synthetic organic materials present in untreated water. Since these disinfectants are essential to ensure safe drinking water, the EPA is presently looking at ways to minimize the risks from byproducts.

Drinking-water safety cannot be taken for granted. There are many chemical and physical threats to drinking certain water supplies. Chemical threats include contamination from improper chemical handling and disposal, animal wastes, pesticides, human waste, and naturally occurring substances. Drinking water that is not properly treated or disinfected, or that travels through an improperly maintained distribution system, can also become contaminated and subsequently pose a health risk. Physical threats include failing water supply infrastructure and threats posed by tampering or terrorist activity [2]. These topics receive treatment in this chapter. The remainder of the chapter addresses the following areas:

1. Water as a Commodity and Human Right
2. The Hydrologic Cycle
3. Water Usage
4. Regulatory Status
5. Acid Rain
6. Treatment Processes
7. Future Concerns

It should be noted that much of the material has been adapted from the work of Carbonaro [2].

17.2 Water as a Commodity and as a Human Right

From a commodity perspective, arguments are made that assessing a price for water promotes investment in developing reliable water sources and encourages conservation. Placing a value on water will have the positive affect of encouraging better water management policies. Conversely, the lack of an economic driver to penalize water use will invariably work against conservation and reuse.

The term “full-cost pricing of water” recently has worked its way into the debate on water management. The recognition of the full cost of accessing and supplying water highlights the value and economic impact of providing water in sufficient quantity and quality to meet the desired needs of society.

There is another water policy perspective that is gaining more widespread attention. Should water be managed as a human right? In effect, all people should have access to clean and adequate water resources for basic personal and domestic needs. One can argue that the human right aspect of water management is an integral part of sound water management practices. However, the human right perspective of water supply and management is an evolving principal with likely increasing impacts to sustainable water management in the coming years. Conflicts exist between all the various water management strategies. Yet, all play a role in providing a sustainable water supply. The importance of water management in protecting the environment and providing a sustainable and affordable water supply is evolving, and needs to be more fully addressed in the future.

17.3 The Hydrologic Cycle [2]

Water is the original renewable resource. Although the total amount of water on the surface of the Earth remains fairly constant over time, individual water molecules carry with them what the authors describe as a rich history. The water molecules contained in the water one drank yesterday may have fallen as rain last year from a distant place or could have been used decades, centuries, or even millennia ago by one’s ancestors.

Water may be assumed to be always in motion, and the hydrologic cycle describes this movement from place to place. The vast majority (96.5%) of water on the surface of the Earth is contained in the oceans. With respect to the cycle, solar energy heats the water at the ocean surface and some of it evaporates to form water vapor. Air currents take the water vapor up into the atmosphere along with water transpired from plants and evaporated from the soil. The cooler temperatures in the atmosphere cause the vapor to condense into clouds. Clouds transverse the world until the moisture capacity of the could is exceeded (supersaturated) and the water falls as precipitation. Most precipitation in warm climates is displaced into the oceans or onto land, where the water flows over the ground as surface *run-off*. Runoff can enter rivers and streams which in turn transport the water to the oceans, accumulate, and be stored as freshwater for long periods of time. In cold climates, precipitation often falls as snow and can accumulate as ice caps and glaciers which can store water for thousands of years [3,4]

Throughout this cycle, water picks up contaminants originating from both naturally occurring and anthropogenic sources. Depending upon the type and amount of contaminant present, water present in river, lakes and streams or beneath the ground may become unsafe for use.

17.4 Water Usage

The term *natural waters* consist of surface waters and ground waters. The term *surface water* refers to the freshwater in rivers, streams, creeks, lakes, and reservoirs, and the saline's water present in inland seas, estuaries and the oceans. The source of freshwater is vitally important to everyday life. The main uses of surface water include drinking water and other public uses, irrigation uses, and for use by the thermoelectric power industry to cool the electricity-generating equipment.

17.5 Regulatory Status [5]

The development to follow in this section will solely address the Safe Drink Water Act. A more comprehensive treatment is available in the literature [5].

17.5.1 The Safe Drinking Water Act (SDWA)

The first legislation enacted in the U.S. to protect the quality of drinking water was the Public Health Service Act (PHSA) of 1912. The PHSA brought together the various federal health authorities and programs at that time, such as the Public Health Service and the Marine Hospital Service, under one statute. The PHSA authorized scientific studies on the impact of water pollution and human health, and introduced the concept of water quality standards. True national drinking water standards were not established, however, until 60 years later with the Safe Drinking Water Act.

The SDWA, originally passed by Congress in 1974, was authorized by the EPA to set national health-based standards for drinking water to protect against both naturally occurring and man-made contaminants that may be found in drinking water. Since its enactment, there have been over 10 major revisions and additions, the most substantial changes occurring in earlier amendments in 1986 and 1996.

The SDWA applies to every public water supply systems (PWS) in the U.S., and approximately 87% of all water used in the U.S. is drawn from PWSs [6]. There are currently more than 160,000 PWS systems currently in the U.S. PWS include: municipal water companies, homeowner associations, schools, businesses, campgrounds, and shopping malls. The EPA works with these PWS systems, along with state and city agencies, to assure that these standards are met. Originally, the SDWA focused primarily on treatment as the means of providing safe drinking water. The 1996 amendments greatly expanded the existing law which now includes source water protection, protection of wells and collection systems making certain water is treated by qualified operators, funding for water system improvements, and making information available to the public on the quality of their local drinking water.

Drinking water standards are regulations that EPA has established to control the concentration of contaminants in the drinking water supply. In most cases, EPA delegates responsibility for implementing drinking water standards to states (and tribes). Drinking water standards apply to PWSs, which provide water for human consumption through at least 15 service connections, or regularly serve at least 25 individuals.

The SDWA 1996 Amendments also required the EPA to identify potential drinking water problems, establish a prioritized list of chemical of concern, and establish a set of standards where appropriate. Peer-reviewed science and data are required to support an intensive technological evaluation which includes many factors such as: the occurrence of the chemicals in the environment; human exposure and risks of adverse health effects in the general population and sensitive subpopulations; analytical methods of detection; technical feasibility; and, impacts of any regulations on water systems, the economy, and public health.

National Primary Drinking Water Regulations (NPDWRs or primary standards) are the legally enforceable Maximum Contaminant Levels (MCLs) and treatment techniques that apply to public water supply. The contaminants are divided up into the following groups, according to the type of contaminant: inorganic chemicals; organic chemicals; microorganisms; disinfectants; disinfection byproducts; and, radionuclides. A list of these contaminants and their respective standard is available in the literature [2,5].

National Secondary Drinking Water Regulations (NSDWRs or secondary standards) are nonenforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. The EPA recommends secondary standards for water systems but does not require systems to comply; state and local agencies may choose to adopt these as enforceable standards. The SDWA also includes a process where new contaminants are identified that may require regulation in the future with a primary standard. EPA is required to periodically release a Contaminant Candidate List (CCL) which is used to prioritize research and data collection efforts to help determine whether a specific contaminant should be regulated.

17.5.2 The Clean Water Act (CWA)

Along with the SDWA, the CWA has played an important role in assuring and maintaining the safety of both the sources and quality of drinking water. Growing public awareness and concern for controlling water pollution led to the enactment of the Federal Water Pollution Control Act Amendments of 1972. As amended in 1977, this law became commonly known as the CWA. The CWA established the basic structure for regulating discharges of pollutants into the waters of the U.S. It gave EPA the authority to implement pollution control programs such as setting wastewater standards. The CWA also extended earlier requirements to set water quality standards for all contaminants in surface waters. The CWA made it unlawful for any person or organization to discharge any pollutant from a source into navigable waters unless a permit was obtained that dictated the terms of the release. It also funded the construction of wastewater treatment plants under the construction grants program. Pollutants regulated under the CWA include biochemical oxygen demand (BOD), total suspended solids (TSS), fecal coliform, oil and grease, toxic chemicals (priority pollutants); and, various contaminants not identified as either conventional or priority (nonconventional pollutants).

The CWA introduced a *permit system* for regulating *point sources* of pollution. A point source is defined as a single identifiable and localized source of a contaminant. Point-source pollution can usually be traced back to a single origin or source. Examples of point source include industrial facilities (e.g., manufacturing, mining, oil and gas extraction, etc.), municipal and some agricultural facilities (e.g., animal feedlots), etc. Point-sources are not allowed to be discharged into surface waters without a permit from the National Pollutant Discharge Elimination System (NPDES). This system is managed by the EPA in partnership with the pertinent state environmental agencies. EPA has authorized 45 states to issue permits directly to the discharging facilities. The EPA regional office directly issues permits in the remaining water quality-based standards states and territories [7].

Water quality standards (WQS) are risk-based requirements which set site-specific allowable pollutant levels for individual water bodies such as rivers, lakes, streams, and wetlands. A water quality standard defines the water quality goals of a water body by designating the use(s) to be made of the water (e.g., recreation, water supply, aquatic life, and agriculture), by setting criteria necessary to protect the users, and by preventing degradation of water quality through anti-degradation provisions. The criteria are numeric pollutant concentrations similar to an MCL for drinking water. States adopt water quality standards to protect public health or welfare, enhance the quality of water, and serve the purposes of the CWA.

A *total maximum daily load* (TMDL) is defined as the maximum amount of a pollutant that a water body can receive and still meet WQS. It is the collective sum of the allowable loads of a single pollutant from all contributing point and non point sources. The calculation includes a *margin of safety* to ensure that the water body can be used for the purposes the state has designated [7].

17.6 Acid Rain

Acid rain with a pH below 5.6 is formed when certain anthropogenic air pollutants travel into the atmosphere and react with moisture and sunlight to produce acidic compounds. Sulfur and nitrogen compounds released into the atmosphere from different industrial sources are now believed to play the biggest role in the formation of acid rain. The natural processes which contribute to acid rain include lightning, ocean spray, decaying plants and bacterial activity in the soil and volcanic eruptions. Anthropogenic sources include those utilities, industries, businesses, and homes that burn fossil fuels, plus motor vehicle emissions. Sulfuric acid is the type of acid most commonly formed in areas that burn coal for electricity, while nitric acid is more common in areas that have a high density of automobiles and other internal combustion engines.

There are several ways that acid rain affects the environment [7].

1. Contact with plants can harm plants by damaging outer leaf surfaces and by changing the root environment.
2. Contact with soil and water resources can harm fish and leach away nutrients in the soil. Due to the acid in the rain, fish-kills in ponds, lakes and oceans, as well as effects on aquatic organisms, are common occurrences. Acid rain can cause

minerals in the soil to dissolve and be leached away. Many of these minerals are nutrients for both plants and animals.
3. Acid rain mobilizes trace metals, such as lead and mercury. When significant levels of these metals dissolve from surface soils they may accumulate elsewhere, leading to poisoning.
4. Acid rain had been known to damage structures and automobiles due to accelerated corrosion rates.

The environmental effects of acid rain are usually classified into four general categories.

1. Aquatic
2. Terrestrial
3. Materials
4. Human

Although there is evidence that acid rain can cause certain effects in each category, the extent of those effects is uncertain. The risks that these effects may pose to public health and welfare are also unclear and difficult to quantify.

17.7 Treatment Processes

Municipal wastewater is composed of a mixture of dissolved, colloidal, and particulate organic and inorganic materials. However, municipal wastewater contains 99.9% water. The total amount of the substances accumulated in a body of waste water is referred to as the *mass loading*. The concentration of any individual component is constantly changing as a result of sedimentation, hydrolysis, and microbial transformation and degradation of organic compounds.

Treatment technologies can essentially be divided into three broad categories [8]:

1. Physical
2. Chemical
3. Biological

Many treatment processes combine two or all three categories to provide the most economical treatment. There are a multitude of treatment technologies for each of these categories.

Finally, the biochemical oxygen demand (BOD) test was developed in an attempt to reflect the depletion of oxygen that would occur in a stream due to utilization by living organisms as they metabolize organic matter. BOD is often used as the sole basis for determining the efficiency of the treatment plant in stabilizing organic matter. Effluent ammonia-nitrogen poses an analytical problem in measuring BOD. At 20°C (68°F), the nitrifying bacteria in raw domestic wastewater usually are significant in number and normally will not grow sufficiently during the 5-day BOD test to exert a measurable oxygen demand. Thus, the BOD test may require correction for nitrification to obtain a true measure of the treatment plant performance in removing organic matter.

The *chemical oxygen demand (*COD*)* analysis is more reproducible and less time-consuming. The COD test and the BOD test can be correlated, but the correlation ultimately gives *qualitative* value. The COD test measures the non-biodegradable as well as the ultimate biodegradable organics. A change in the ratio of biodegradable to non-biodegradable organics affects the correlation between the COD and BOD. Such a correlation is specific for a particular waste, but may vary considerable between treatment plant influent and effluent. Additional information is available in the literature [2,7,8].

17.8 Future Concerns

Is water conservation the answer? Water conservation has become an important topic in today's environmentally conscious society. Numerous urban centers are experiencing water shortages and are building dams to help curb the ever-increasing demand for water. These dams often have an undeniable impact on the natural environment, killing numerous species of animals and plants. In any event, conservation of this resource is very much needed and can be accomplished through personal conservation efforts, as well as conscientious building design. (See previous Chapter).

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

1. R. Carbonaro, *Introduction to Environmental Management*, M.K. Theodore and L. Theodore, CRC Press/ Taylor & Francis Group, Boca Raton, FL, 2010 [2].
2. L. Theodore, *Chemical Engineering: The Essential Reference*, McGraw-Hill, New York City, NY, 2014 [9]

3. R. Thomann and J. Mueller, *Principles of Surface Water Quality – Modeling and Control*, Harper and Row, New York City, NY, 1987 [10].

17.9 Illustrative Open-Ended Problems

This and the last section provides 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 straightforward while the third (and last problem) is somewhat more difficult and/or complex. Note that solutions are not provided for the 46 open-ended problems in the next section.

Problem 1: Microbial regrowth can be defined as an increase in viable microorganism concentrations in drinking water downstream of the point of disinfection after treatment. These microorganisms may be coliform bacteria, bacteria enumerated by the heterotrophic plate count (HPC bacteria), other bacteria, fungi, or yeasts. Regrowth of bacteria in drinking water can lead to numerous associated problems including multiplication of pathogenic bacteria such as *Legionella pneumophila*, deterioration of taste, odor, and color of treated water, and intensified degradation of the water mains, particularly cast iron, by creating anaerobic conditions and reducing pH in a limited area. In order to obtain stable drinking water (i.e., to control regrowth), one needs to understand the sources of biological instability. List 5 factors that affect regrowth in a water distribution system.

Solution:

Five factors that affect regrowth in a water distribution system are:

1. Water quality (e.g., concentration of organic carbon and nutrients, temperature, disinfectant residual, etc.)
2. Pipe materials and conditions.
3. Flow conditions in the distribution systems (e.g., detention time, flow velocity, wall shear stress, flow reversals, etc.)
4. Water treatment processes
5. Presence, type, concentration, and physiological state of the bacteria.

Problem 2: Land treatment of industrial wastewater is a process in which wastewater is applied directly to the land. This type of treatment is most common for food processing wastewater including meat, poultry, dairy, brewery, and winery wastes. The principal rationale of this practice is that the soil is a highly efficient biological treatment reactor, and food processing wastewater is highly degradable. This treatment practice is usually carried out by distributing the wastewater through spray nozzles onto the land or letting the water run through irrigation channels.

Suppose that the rate of the wastewater flowing to a land application site is 178 gal/acre·min and the irrigated land area is 5.63 acres. The entire irrigation process lasts 7.5 h/d. Calculate the mass of BOD_5 remaining in the soil after the land treatment process is complete (assume a BOD_5 removal efficiency by the land treatment process is 95%)? Perform the calculations for various wastewater BOD_5 concentrations, e.g., 50 mg/L. Comment on the results.

Solution: Perform the first calculation for a BOD_5 concentration of 50 mg/L. The amount of the wastewater flowing to the land is:

$$\begin{aligned}&(178 \text{ gal/acre}\cdot\text{min})(60 \text{ min/h})(7.5 \text{ h/d})(5.63 \text{ acre})\\&= 450{,}963 \text{ gal/d}\end{aligned}$$

The amount of BOD_5 remaining, BOD_5(R), is

$$\begin{aligned}BOD_5(R) &= (450{,}963 \text{ gal/d})(1.00 - 0.95)(50 \text{ mg/L})(3.785 \text{ L/gal})\\&= 4{,}267{,}688 \text{ mg/d}\end{aligned}$$

$$\begin{aligned}BOD_5(R) &= 4{,}267{,}688 \text{ mg/d } (1 \text{ g}/1{,}000 \text{ mg})(454 \text{ g/lb})\\&= 9.4 \text{ lb/d}\end{aligned}$$

The reader is left the exercise of repeating the calculation for other BOD_5 concentrations and commenting on the results.

Problem 3: In 1947, two ships docked in Texas City, Texas, with tons of ammonium nitrate fertilizer and other cargo aboard. These ships caught fire, burned and exploded over a period of more than 16 hours. The explosions were so powerful that almost 600 people were killed and more than 3,500 were injured. The port area and much of the city was destroyed. One of the ship's anchors was thrown approximately 2 miles inland where it still lies today as a memorial to the incident.

In 1986, Congress approved Title III of the Superfund Amendments and Reauthorization Act (SARA), also known as the Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986. Among other things, this law requires any facility that produces, uses or stores any chemical on a published list in excess of the "Threshold Planning Quantity" to notify local emergency response entities (such as the fire department, police department, hospitals, etc.) of the quantity, identity, and nature of these chemicals; to cooperate with a Local Emergency Planning Committee (LEPC); and, to develop an emergency plan to be used in the event of a release.

While the regulatory definition of a "facility" includes transportation vessels and port authorities for release reporting, these entities are exempted from notification and emergency planning requirements. As a result, emergency response planning against another Texas City disaster is not a requirement of the EPCRA legislation.

Prepare a list of areas of concerns that would have to be addressed if the Title III notification and emergency planning requirements were applied to port areas; particularly addressing the water management aspect of this problem.

Comment: Among other things, the reader may wish to address matters such as the short residence time of in-transit materials and the political (as opposed to legal) ramifications of applying regulation of this kind to foreign flag carriers. See also Chapter 15.

Solution: The following baker's dozen areas should be addressed in the notification and emergency planning for port areas:

1. Who shall be responsible for notification and/or emergency planning – the shipper, transporter, or port operator?
2. How shall the inventory of the materials flowing in and out of the area to be maintained?
3. Should there be a minimum storage time that triggers notification and emergency planning?
4. Should an emergency plan be developed for the release of every chemical that ever flowed through the port, even though some of those chemicals may never be present in the area again?
5. What notification and emergency planning criteria should be adopted for large quantities of listed materials that frequently flow through the port but are present for only short periods of time?
6. Should limits be placed on the quantities of some materials being stored in the port area at a given time?
7. Should ports be classified as to what materials are allowed to enter them?
8. Should segregation of cargo by compatibility groups be required for materials waiting to be loaded or trans-shipped?

9. Should port areas be rezoned to reduce the surrounding population?
10. Are evacuation plans possible for port areas in large cities?
11. If there sufficient authority under current law to accomplish this task or is new legislation required?
12. What would be the political consequences of requiring foreign ships to adhere to these regulations?
13. What would be the cost of applying these regulations to port areas?

Any other suggestions?

17.10 Open-Ended Problems

This last section of the chapter contains open-ended problems as they relate to water 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 46 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 water management.
2. Discuss the recent advances in the water management.
3. Select a refereed, published article on water management from the literature and provide a review.
4. Provide some normal everyday domestic applications involving the general topic of water management.
5. Develop an original problem on water management that would be suitable as an illustrative example in a book.

6. Prepare a list of the various technical books that have been written on water management. Select the three best and justify your answer. Also select the three weakest books and, once again, justify your answer.
7. Prepare a list of the various physical properties of water.
8. Prepare a list of the various chemical properties of water.
9. Prepare a list of the average chemical composition of natural waters.
10. Describe some of the dissolved minerals in natural waters.
11. Describe some of the dissolved gases in natural waters.
12. Describe some of the heavy metals in natural waters.
13. Describe some of the organic constituents in natural waters.
14. Describe some of the nutrients in natural waters.
15. Provide your description of the hydrologic cycle.
16. Provide a one paragraph description of the Safe Drinking Water Act (SDWA) and the Clean Water Act (CWA).
17. Discuss both the national primary drinking water regulations and the national secondary standards for drinking water.
18. Describe the regulations associated with municipal wastewater treatment.
19. Describe the regulations associated with industrial wastewater treatment.
20. Explain why the water quality in the U.S. has improved in the last 40+ years.
21. What are the characteristics of municipal wastewater? What are the characteristics of industrial wastewater?
22. What are some of the sources of industrial wastewater pollution?
23. List and describe the various wastewater treatment processes.
24. Describe sludge characteristics.
25. Provide a layman's description of eutrophication.
26. Discuss the advantages of modeling water systems.
    Comment: Refer to the classic work of R. Thomann and J. Mueller, "Principles of Surface Water Quality – Modeling and Control," Harper and Row, New York City, NY, 1987 [10].
27. Define acid rain and offer your thoughts on controlling/reducing/eliminating acid rain.

28. List the possible sources of highly toxic hexavalent chromium (Cr^{6+}) and methods to remove it from a wastewater stream.
29. Provide your definition of advanced wastewater treatment.
30. Provide a layman definition of nonpoint source (NPS) water pollution.

    Comment: Consider the role agriculture urban runoff, abandoned mines, construction, land disposal, etc… can play in addressing this issue. Also refer to the literature for additional details [2,10]
31. Describe the complexity of factors that arise in determining water quality.
32. What are some of the water quality issues that affect the operating of water treatment plants for treating domestic water supplies?
33. What are the three major process components used to treat water sources to be used for potable water supplies. Explain why are they utilized.
34. One important aspect of water quality management is the assignment of allowable point source wastewater discharges to a receiving water body such that the water quality objectives for that water body can be maintained. This management process is called Waste Load Allocation (WLA).
    - What are some of the important steps that should be included in the WLA process?
    - What are the three major parameters regulated under the NPDES program for municipal wastewater discharges and what are the maximum concentrations allowed for each of these parameter in NPDES permits? Comment on these regulations.
35. Sludge generated in a water or waste treatment plant usually contains substantial amounts of water and therefore needs to be processed to reduce the water content (the process is called sludge dewatering) for ultimate disposal or landfilling. A municipal water treatment plant in Kansas produces 1.05 tons of sludge everyday. The wet sludge (before watering) has a density of 1.05 g/cm^3, which increases after being treated. How much additional space would be needed in a landfill site annually if the wet sludge (before dewatering) were treated. How much additional space would be needed in a landfill site annually if the wet

sludge were dumped directly into the landfill site without dewatering?

Comment: This practice is no longer permitted by law because of leachate and gas production concerns in sanitary landfills.

36. Flocculation is a physical process used to encourage small particles to aggregate into larger particles, or floc. It is an essential component of most water treatment plants in which flocculation, sedimentation, and filtration processes are integrated to effectively remove suspended particles from water. Chemicals (such as alum, polyelectrolytes, etc.) are usually added to achieve agglomeration among small particles in water.

    Jar tests are used to estimate the optimum amount of chemicals needed to ensure proper flocculation. In a jar test conducted for a given water treatment plant, 4L samples were poured into a series of jars. After the test, the jar that has been dosed with 20 mL of alum solution containing 5 mg Al(III)/mL showed optimal results. Calculate the pounds per day of alum [$Al_2(SO_4)_3 \bullet 14H_2O$, MW = 594.4 g/gmol] that should be added to the raw water for various water treatment flow rates, e.g., 90 Mgal/d.

37. Cyanide-bearing waste is to be treated by a batch process using alkaline chlorination. In this process, cyanide is reacted with chlorine under alkaline conditions to produce carbon dioxide and nitrogen as end products. The cyanide holding tank contains a cyanide concentration of 18 mg/L. Assuming that the reaction proceeds according to its stoichiometry, answer the following questions.
    - How many pounds of chlorine are needed?
    - How long will the hypochlorinator have to operate if the hypochlorinator can deliver 900 L/d of chlorine?
    - How long should the caustic soda feed pump operate if the pump delivers 900 L/d of 10 wt% caustic soda solution?

    Perform the above calculations for various holding tank volumes, e.g., 28 m^3.

38. Natural water bodies possess a capacity to stabilize organic matter without seriously affecting their general quality and aesthetics. The process is called self-purification, which involves various microorganisms (e.g., bacteria, algae,

etc.). Draw a diagram incorporating a processes that could occur in a lake or pond when wastewater is discharged intermittently into it. Describe the carbon and nitrogen cycles related to these processes and locate where they should occur in the water body.

39. The state of Florida has contracted Theodore Partners (TP) to determine whether the present water requirements will be adequate in the future. You have been hired by TP to conduct the study. Submit a report detailing the results of your analysis.
40. Refer to Problem 2 in the previous Section. Perform the calculations for various BOD removal efficiencies at given wastewater BOD concentrations. Comment on the results.
41. Refer to the previous problem. Perform the calculations for various combnations of wastewater BOD_5 concentrations and BOD_5 removal efficiencies. Comment on the results. Also, attempt to correlate the results.
42. The following 5-day biochemical oxygen demand (BOD_5) and total suspended solids (TSS) data were collected at a local municipal wastewater treatment plant over a 7-day period. (See Table 17.1). The NPDES permit limitation for BOD_5 and TSS effluent concentrations from this wastewater treatment plant are 45 mg/L on a 7-day average. Based on this information, is the treatment plant within its NPDES

Table 17.1 Daily BOD_5 and TSS Effluent Concentration Data Collected Over a 7-Day Period at a Municipal Wastewater Treatment Plant

Day	BOD (mg/L)	TSS (mg/L)
1	45	20
2	79	100
3	64	50
4	50	42
5	30	33
6	25	25
7	21	15

permit limits? Based on your calculations, comment on how to bring the plant into compliance if it is out of compliance.

43. Estimate your daily water requirements. Then, actually calculate/record your daily water requirements for each day over a period of month. Also, calculate the mean and standard deviation of those data, and compare the calculated results with your output estimate. (See also Chapter 19).
44. Research the literature and develop present-day water availability and requirements for third-world nations.
45. Research the literature and develop water availability and requirements at the turn of the century for third-world nations.
46. One of the authors regularly visits Florida for sun-and-fun activities that include paramutual wagering. Many Floridians are concerned about a "water problem". Discuss this problem and outline what steps can be taken to alleviate future concerns in this area.

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