SOLUTIONS CHAPTER 1 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. How are the principles from microbiology used in the design of wastewater treatment processes and the remediation of contaminated soil?

Microorganisms, primarily, bacteria, are grown in aeration basins or reactors to treat wastewater biologically. Bacteria that are present in the soil and geologic formations are fed nutrients and oxygen to promote oxidation of hazardous wastes and organic compounds found in groundwater. In each of these examples, the bacteria oxidize the organic matter to carbon dioxide and water. They need organic carbon which is found in wastewater and different types of hazardous wastes in addition to the nutrients, nitrogen and phosphorus. Most bacteria are aerobic organisms requiring oxygen. Others are facultative which can live under aerobic or anaerobic conditions, however, they prefer aerobic.

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.]

The continuity equation is used extensively in fluids and hydraulics for designing pipelines. The continuity equation is presented below:

$$Q = AV$$

Where Q = volumetric flow rate, cfs (m^3/s),
A = cross-sectional area of pipe, ft^2 (m^2); and
V = velocity of flow in pipe, fps (mps).

Normally, the equation is solved for area, knowing the flow rate and selecting a pipe velocity of 4 to 6 fps.

The Bernoulli Equation is a special case of the energy equation where no head loss occurs. It is used for calculating the pressure and velocity between two points. Bernoulli's Equation is presented below.

$$\frac{P_1}{\gamma} + Z_1 + \frac{V_1^2}{2g} = \frac{P_2}{\gamma} + Z_2 + \frac{V_2^2}{2g}$$

Where P_1 and P_2 are the pressures at points 1 and 2,
V_1 and V_2 are the average flow velocities at points 1 and 2, and,
Z_1 and Z_2 are the elevations or distance from some datum to points 1 and 2.

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.

The major air pollutants purported to be causing the global warming phenomenon are called greenhouse gases. Scientists and engineers that support the global warming theory suggest that carbon dioxide and water vapor that is released during the combustion of fossil fuels is primarily responsible for the increase concentration of carbon dioxide and water vapor in the atmosphere. Major sources of fossil fuel combustion include automobiles, trucks, air planes, home heating with coal or natural gas, and electrical power plants that use coal or natural gas.

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 that are used for treating water. [*Hint*: Oxidation/reduction, gas transfer, precipitation.]

Chlorine is used at water treatment plants for a number of reasons: removal of hydrogen sulfide and killing of pathogens are two important examples. Chlorine in the form of sodium hypochlorite, (NaOCl), reacts with hydrogen sulfide according to the following stoichiometric equation which is an example of an oxidation/reduction reaction.

$$H_2S + NaOCl \rightarrow NaCl + H_2O + S\downarrow$$

Sulfide goes from an oxidation state of -2 to zero, therefore, it is oxidized. Chlorine though goes from an oxidation state of +1 to -1, meaning that it is reduced.

Gas transfer, wherein, a gas such as oxygen is transferred into water is used to raise the dissolved oxygen concentration and increase the palatability of the water. The diffusion of a gas into a liquid can be modeled with the following equation, which will be discussed in more detail in Chapter 9.

$$\frac{dC}{dt} = K_L a\left(C_S - C\right)$$

Where $\frac{dC}{dt} =$ transfer rate of gas, mg/L·time,
$K_L a =$ overall gas transfer coefficient, time^{-1},
C_S = dissolved gas saturation concentration in water, mg/L, and
C = desired concentration of dissolved gas in water, mg/L.

The oxygen also will react with soluble ions such as ferrous ion (Fe^{2+}) and manganous ion(Mn^{2+}) oxidizing them to higher valance states and producing insoluble compounds that will settle out of the water. These are examples of oxidation reduction reactions and are presented below.

$$4Fe^{2+} + O_2 + 10H_2O \rightarrow 4Fe(OH)_3 + 8H^+$$

$$2Mn^{2+} + O_2 + 2H_2O \rightarrow 2MnO_2 + 4H^+$$

The ferrous ion is oxidized from a valence of +2 to the +3 state, whereas, the manganous ion goes from +2 to +4. Oxygen is reduced in both reactions, going from a valence of 0 to -2.

Water softening using lime and soda ash are widely used methods for precipitating hardness causing ions (primarily Ca^{2+} and Mg^{2+}). The equations are presented in Chapter 8 of this text. Lime in the form of CaO is often added to raise the pH of the water to around 9 to 9.5. CaO reacts with water to form calcium hydroxide, $Ca(OH)_2$. The following stoichiometric equation shows the precipitation of calcium hardness, calcium bicarbonate, $Ca(HCO_3)_2$, as calcium carbonate,$CaCO_3$.

$$Ca(HCO_3)_2 + Ca(OH)_2 \leftrightarrow 2CaCO_3 + 2H_2O$$

5. Many environmentalists promote the idea of recycling solids 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?

For recycling systems to be effective; proper separation of metals, glass, and paper must be accomplished at the source. These items should be collected at least on a weekly basis and preferably, bi-weekly.

Advantages

A) Conserves our natural resources
B) Reduces the quantity of solid waste that is disposed in landfills.
C) Creates jobs.
D) Potential to make money or at least break even.

Disadvantages

A) Various components, metals, glass, paper, etc., must be separated at source.
B) Each component must be collected separately unless separation and sorting equipment is available to do this. This is expensive to do.
C) The public is not always willing to support recycling/reuse by separating their wastes at the source.

D) The public sometimes is hesitant to purchase materials that have been recycled.

We believe that recycling 50% of solid waste that is generated at homes and businesses is impossible to achieve. Most communities are lucky if 20 to 25% of the solid waste that is produced ends up being recycled and reused. Even if it were possible to recycle 50% of the components of solid waste; there comes a point in which most of the materials in appliances and other household items can no longer be recycled. It sounds like a good idea in theory, but impractical to implement and difficult to achieve.

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 and is 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.

Stormwater runoff from urban areas would likely contain some of the following contaminants: oil, gasoline, suspended solids, paper, plastic, and leaves.

Stormwater runoff from agricultural areas would likely contain some of the following contaminants: nitrogen, phosphorus, suspended solids, animal wastes, paper, and leaves.

One form of the equation used in performing the rational method of calculating stormwater runoff volumes is presented below.

$$Q = C\,I\,A$$

Where Q = peak runoff flow, ft^3/s,
C = dimensionless runoff coefficient dependent upon the imperviousness (permeability) of the land surface; ranges from approximately 0.2 to 1.0, low values relate to high imperviousness
I = rainfall intensity, in/h, and
A = drainage area, acres.

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

$$\text{Volume} = L \times W \times H$$

$L:W = 4:1 \qquad L = 4W$

$W:D = 1:1 \qquad W = D = 25\,\text{ft}$

The length of the basin is equal to 4 times the width = 4×(25 ft) = 100 feet.

Therefore, the volume is calculated as follows:

$$\text{Volume} = L \times W \times H = 100\text{ ft} \times 25\text{ ft} \times 25\text{ ft} = \boxed{62{,}500\text{ ft}^3}$$

8. A 25-meter-diameter circular tank that is 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.

The cross-sectional area of a circular tank is equal to the area of circle. The area of a circle can be determined from either of the following two equations.

$$A = \pi r^2 \qquad\qquad A = \frac{\pi D^2}{4}$$

Where r = radius of the circular tank, m, and
D = diameter of the circular tank, m.

The cross-sectional area of the circular tank is approximately 491 square meters.

$$A = \frac{\pi D^2}{4} = \frac{\pi (25\,\text{m})^2}{4} = \boxed{491\,\text{m}^2}$$

The circumference of the tank is calculated using the equation for the circumference of a circle which is presented below.

$$\text{Circumference} = 2\pi r = \pi D$$

The circumference of the circular tank is approximately 78.5 meters.

$$\text{Circumference} = \pi D = \pi (25\,\text{m}) = \boxed{78.5\text{ m}}$$

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.

From a periodic table the atomic weights of sulfur (S) and oxygen (O) are 32 and 16, respectively. The molecular weight of sulfur dioxide is calculated as follows:

$$\text{MW of } SO_2 = 32 + 2(16) = 64$$

From the stoichiometric equation, 32 kg of sulfur produce 64 kg of sulfur dioxide. The kilograms of SO_2 produced from combustion each day are

$$SO_2 \frac{\text{kg}}{\text{d}} = \frac{2.0\times10^4 \text{ g coal}}{\text{d}} \times (0.05 \text{ Sulfur}) \times \left(\frac{1 \text{ kg}}{1{,}000 \text{ g}}\right) \times \left(\frac{64 \text{ kg } SO_2}{32 \text{ kg S}}\right) = \boxed{2 \frac{\text{kg } SO_2}{\text{d}}}$$

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.]

$$Cl \frac{\text{kg}}{\text{d}} = \frac{1.0\times10^4 \text{ m}^3}{\text{d}} \times \left(\frac{10 \text{ mg}}{\text{L}}\right) \times \left(\frac{1 \text{ kg}}{10^6 \text{ mg}}\right) \times \left(\frac{1{,}000 \text{ L}}{1 \text{ m}^3}\right) = \boxed{\frac{100 \text{ kg Cl}}{\text{d}}}$$