1. There are eight beneficial uses of water categories. List four of them and give a brief description of the types of water uses in each.
   a. PUBLIC SUPPLY: water withdrawn by public and private water suppliers that is distributed to at least 25 people or water systems that have a minimum of 15 connections. Public supply water may also be furnished to commercial, domestic, industrial, and thermoelectric power suppliers.
   b. DOMESTIC: Water used both for indoor and outdoor household purposes is called domestic use. Within the home, water is used for bathing, cooking, drinking, flushing toilets, and washing clothes. Outdoor water use primarily involves watering gardens and lawns.
   c. IRRIGATION: water used for irrigation systems providing water for all agricultural and horticultural activities; irrigation of golf courses, cemeteries, turf farms; and irrigation for preirrigation, frost protection, and dust suppression.
   d. LIVESTOCK: water associated with dairy operations, feedlots, livestock watering operations, and other on farm usages.
   e. AQUACULTURE: water used for raising finfish and shellfish either for food, conservation, restoration, or sport is called aquaculture use.
   f. INDUSTRIAL: water use includes water used to cool, dilute, fabricate, transport, and wash. Some of the industries that consume large quantities of water include: chemical, food, paper, petroleum, and primary metal processing.
   g. MINING: water used to extract minerals such as coal, iron, sand, and gravel; crude petroleum; and natural gas
   h. THERMOELECTRIC POWER: water, primarily for coal-fired steam plants, that is used to generate electricity by steam turbines.

2. As water passes through the hydrologic cycle, it becomes contaminated with natural and anthropogenic contaminants. List the four major types of water pollution. Give a brief qualitative description of the water quality of each. Explain the difference between a point source and non-point source of pollution and give an example of each type of source.
   a. DOMESTIC WASTEWATER: wastewater discharged from a municipal wastewater treatment plant; contains suspended solids, organics, phosphorus, oil and grease, and pathogens.
   b. INDUSTRIAL WASTEWATER: wastewater discharged from an industrial wastewater treatment plant; contains suspended solids, organics, phosphorus, nitrogen, and metals.
   c. AGRICULTURAL RUNOFF: stormwater runoff from agricultural land; contains soil particles, phosphorus, nitrogen, animal wastes, and pesticides.
d. URBAN RUNOFF: stormwater runoff from urban or city area, normally from impervious roads, walks, etc.; contains oil, gasoline, nitrogen, phosphorus, leaves, and pesticides.

e. Point sources of pollution are sources that emanate from a single point. A domestic or industrial wastewater treatment plant is an example of a point source.

f. A nonpoint source is a diffuse source of pollution such as land areas, parking lots, roofs, and roads that generate large volumes of runoff containing various types of contaminants.

3. Water quality is classified by physical, chemical, biological or microbiological, and radiological parameters. Go to the United States Environmental Protection Agency’s website at www.epa.gov under the Office of Drinking Water. List three water quality parameters in each of the four categories (physical, chemical, microbiological, and radiological) along with the current maximum contaminant level (MCL) concentration or the required treatment technique (TT). Select from both primary and secondary standards.

   a. PHYSICAL: Turbidity, TT- disinfect and filter water; Color 15 c.u.; and Odor 3 TON.

   b. CHEMICAL: trihalomethanes (TTHMs) 0.10 mg/L; Arsenic 0.01 mg/L; and Cadmium 0.005 mg/L.

   c. MICROBIOLOGICAL: Cryptosporidium TT-disinfect and filter water; Giardia lamblia TT-disinfect and filter water; and Legionella TT-disinfect and filter water.

   d. RADIOLOGICAL: Alpha particles 15 pC/L; Beta particles 4 milliRems/yr; and Uranium 30 µg/L.

4. Solids analysis is one of the most widely used parameters for assessing water quality. Use the following data for calculating total solids (TS), volatile solids (VS), dissolved solids (DS), total suspended solids (TSS), and total volatile suspended solids (TVSS). A sample volume of 150 ml was used in performing all solids analyses.

\[
\begin{align*}
\text{Tare mass of evaporating dish} & = 24.3520 \text{ g} \\
\text{Mass of evaporating dish plus residue after evaporation @ 105°C} & = 24.3970 \text{ g} \\
\text{Mass of evaporating dish plus residue after ignition @ 550°C} & = 24.3850 \text{ g} \\
\text{Mass of Whatman filter and tare} & = 1.5103 \text{ g} \\
\text{Mass of Whatman filter and tare after drying @ 105°C} & = 1.5439 \text{ g} \\
\text{Residue on Whatman filter and tare after ignition @ 550°C} & = 1.5199 \text{ g}
\end{align*}
\]

   a. TOTAL SOLIDS

\[
\begin{align*}
24.3970 \text{ g} & \\
-24.3520 \text{ g} & \\
0.0450 \text{ g}
\end{align*}
\]
\[
0.045 \text{g} \left( \frac{1}{150 \text{ ml}} \right) \left( \frac{1000 \text{ ml}}{1 \text{ L}} \right) \left( \frac{1000 \text{ mg}}{1 \text{ g}} \right) = 300 \text{ mg/L}
\]

b. VOLATILE SOLIDS
\[
\frac{24.3970 \text{ g}}{} - \frac{24.3850 \text{ g}}{} = \frac{0.0120 \text{ g}}{}
\]
\[
0.012 \text{g} \left( \frac{1}{150 \text{ ml}} \right) \left( \frac{1000 \text{ ml}}{1 \text{ L}} \right) \left( \frac{1000 \text{ mg}}{1 \text{ g}} \right) = 80 \text{ mg/L}
\]

c. TOTAL SUSPENDED SOLIDS
\[
\frac{1.5439 \text{ g}}{} - \frac{1.5103 \text{ g}}{} = \frac{0.0336 \text{ g}}{}
\]
\[
0.0336 \text{g} \left( \frac{1}{150 \text{ ml}} \right) \left( \frac{1000 \text{ ml}}{1 \text{ L}} \right) \left( \frac{1000 \text{ mg}}{1 \text{ g}} \right) = 224 \text{ mg/L}
\]

d. DISSOLVED SOLIDS = TOTAL SOLIDS - TSS
\[
\frac{300 \text{ mg/L}}{} - \frac{224 \text{ mg/L}}{} = \frac{76 \text{ mg/L}}{}
\]

e. TOTAL VOLATILE SUSPENDED SOLIDS
\[
\frac{1.5439 \text{ g}}{} - \frac{1.5199 \text{ g}}{} = \frac{0.0240 \text{ g}}{}
\]
\[
0.0240 \text{g} \left( \frac{1}{150 \text{ ml}} \right) \left( \frac{1000 \text{ ml}}{1 \text{ L}} \right) \left( \frac{1000 \text{ mg}}{1 \text{ g}} \right) = 160 \text{ mg/L}
\]

5. An ammonia nitrogen analysis performed on a wastewater sample yielded 30 mg/L as nitrogen. If the pH of the sample was 8.5, determine the ammonium nitrogen concentration (mg/L) in the sample assuming a temperature of 25°C.

\[
\text{NH}_4^+ \leftrightarrow \text{H}^+ + \text{NH}_3
\]
\[
\text{pH} = 8.5 \quad [\text{H}^+] = 10^{-8.5}
\]
\[
\frac{[\text{H}^+][\text{NH}_3]}{[\text{NH}_4^+]} = K_a 
\]
\[
\frac{[\text{NH}_3]}{[\text{NH}_4^+]} = \frac{K_a}{[\text{H}^+]} 
\]
\[
K_a = 5.6 \times 10^{-10}
\]
\[
\text{Total ammonia concentration} = [\text{NH}_3] + [\text{NH}_4^+] = 30 \text{ mg/L as N}
\]
\[ \% \text{NH}_4^+ = \frac{[\text{NH}_4^+] \times 100}{[\text{NH}_4^+] + [\text{NH}_3]} = \frac{100}{1 + \frac{[\text{NH}_3]}{[\text{NH}_4^+]}} = \frac{100}{1 + 5.6 \times 10^{-10}/10^{-8.5}} = 84.96\% \]

\[ \text{NH}_4^+ = 0.8496 \times (30 \text{ mg/g}) = 25.5 \text{ mg/L} \]

6. Calculate the theoretical oxygen demand (mg/L) of a solution containing 450 mg of glucose (C\textsubscript{6}H\textsubscript{12}O\textsubscript{6}) in 2 liters of distilled water.

\[ \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} \]

MW of glucose: 180 \quad MW of oxygen: 192

\[ \frac{450 \text{ mg Glucose}}{2 \text{ L}} \times \left( \frac{192 \text{ kg}}{180 \text{ kg}} \right) = 240 \frac{\text{mg O}_2}{\text{L}} \]

7. A result of a 7-day BOD test performed on a sample from an oligotrophic lake was 10 mg/L. The base “e” BOD rate constant determined from previous studies was estimated to be 0.10 days\(^{-1}\). Determine the ultimate BOD and 5-day BOD of the sample taken from the lake.

\[ \text{BOD}_t = \text{BOD}_u \left( 1 - e^{-kt} \right) \]

\[ 10 \frac{\text{mg}}{\text{L}} = \text{BOD}_u \left( 1 - e^{-0.10\text{d}^{-1} \times 7\text{d}} \right) \quad \text{BOD}_u = 19.86 \text{ mg/L} \]

\[ \text{BOD}_t = \text{BOD}_u \left( 1 - e^{-kt} \right) = 19.86 \frac{\text{mg}}{\text{L}} \left( 1 - e^{-0.10\text{d}^{-1} \times 5\text{d}} \right) = 7.81 \text{ mg/L} \]

8. A 5-day BOD test is performed on an industrial wastewater sample that contains no bacteria; therefore, a “seeded” BOD test is run. Ten ml of “seed” are added to 20 liters of dilution water. Thirty milliliters of industrial wastewater are added to a 300 ml BOD bottle and the remaining volume consists of “seeded” dilution water. The average dissolved oxygen concentration of the diluted wastewater samples and blanks (seeded dilution water) on the first day of the test were 7.5 mg/L and 9.0 mg/L, respectively. After incubating separate BOD bottles at 20°C for 5 days, the average DO concentration of the diluted wastewater BOD bottles and seeded dilution water BOD bottles were 3.1 and 8.5 mg/L, respectively. Calculate the 5 day BOD of the industrial wastewater.

\[ \text{BOD}_t \left( \text{mg/L} \right) = \frac{(D_1 - D_2) - (B_1 - B_2) f}{P} \]
0.10 ml of sample / 30 ml of BOD bottle = 0.10

\[ P = \frac{\text{ml of sample}}{\text{volume of BOD bottle}} \]

% Seed in \( B_1 \) = \( \frac{10 \text{ ml}}{20 \text{ L} \times (1000 \text{ ml/L})} = 0.0005 \)

Volume of seed in dilution water added to wastewater sample = 0.0005 \times 270 ml = 0.135 ml

% Seed in \( D_1 \) = \( \frac{0.135 \text{ ml}}{300 \text{ ml}} = 0.00045 \)

\[ f = \frac{\text{% seed in } D_1}{\text{% seed in } B_1} = \frac{0.00045}{0.0005} = 0.90 \]

\[ BOD_t (\text{mg/L}) = \frac{(D_1 - D_2) - (B_1 - B_2)f}{P} \]

\[ = \frac{(7.5 - 3.1) - (9 - 8.5) \times 0.9}{0.10} = 39.5 \text{ mg/L} \]

9. A multiple tube fermentation test was performed on a highly eutrophic reservoir water sample. A set of 15 test tubes with sample sizes of 10, 1.0, and 0.1 ml were used in the analysis resulting in the following number of positive tubes: 5-2-1. Estimate the most probable number (MPN) per 100 ml of sample and compare your answer to the value presented in Standard Methods (1998).

\[ \text{mL of sample in all tubes} = 5(10.0) + 5(1.0) + 5(0.1) = 55.5 \]

\[ \text{mL of sample in neg. tubes} = 0(10.0) + 3(1.0) + 4(0.1) = 3.4 \]

\[ \text{MPN} = \frac{(8 \times 100)}{[(3.4 \text{ ml}) \times (55.5 \text{ ml})]^{0.5}} = 58 \]

The MPN value from Standard Methods is \( 70 \text{ MPN/100 ml} \).

10. Discuss in your own words what is meant by an indicator organism. Which group of organisms is used as an indicator organism and why? List three groups of pathogenic organisms that may be found in water and wastewater.

An indicator organism is typically a bacterium that is used to signify the presence of pathogens. Indicator organisms should be numerous, non-pathogenic, and easy to enumerate. The coliform group of bacteria are used as indicator organisms.

Four groups of pathogenic organisms: viruses, protozoa, helminths, and bacteria.