Module 28:

Basic Math

Instructor Guide – Answer Key

Calculations

1. 6/10 – 2/5 =

Ans: 2/10, which can be reduced to 1/5.

2. If a tank is 5/8 filled with solution, how much of the tank is empty?

Ans: 3/8 of the tank is empty. Since the whole tank would equal 8/8, or 1, and 5/8 of it is filled, then that means 3/8 of it remains empty.

3. 1/2 x 3/5 x2/3 =

Ans: 6/30, which can be reduced to 1/5.

4. 5/9 ÷ 4/11 =

Ans: 55/36. You cannot reduce this fraction any further.

5. Convert 27/4 to a decimal.

Ans: 6.75. This answer is arrived at by dividing 4 into 27.

6. Convert 0.45 to a fraction.

Ans: 45/100, which can be reduced to 9/20.

7. 4.27 x 1.6 =

Ans: 6.832

8. 6.5 ÷ 0.8 =

Ans: 8.125

9. 12 + 4.52 + 245.621 =

Ans: 262.141

- -

Calculations

1. (85 x 17) + (22 x 12)

Ans: 1,445 + 264 = 1,709

2. $$\frac{(145 \times 9 \times 2) - (14 \times 9 \times 2) + 162}{(7 \times 5) - (10/2) + 150}$$

Ans: $$\frac{2{,}610 - 252 + 162}{35 - 5 + 150} = \frac{2{,}520}{180} = 14$$

Calculations

1. In Hampton City, the iron content of the raw water measures 5.0 mg/L. After treatment, the iron content is reduced to 0.2 mg/L. What is the percent removal of iron?

   Ans: Step 1: 5.0 mg/L – 0.2 mg/L = 4.8 mg/L (quantity of iron removed)

   Step 2: (4.8 mg/L ÷ 5.0 mg/L) x100% = 96% (percent removed)

2. Given a raw water turbidity of 18 NTU's and a finished water turbidity of 0.25 NTU's, calculate the percent removal.

   Ans: [(18 – 0.25) / 18] x 100% = 98.6%

Note that these problems can be done in multiple steps (problem 1) or in a single step (problem 2)

Calculations

1. Round 9.875 to two decimal points.

Ans: 9.88

2. Round 9,637 to the nearest thousand.

Ans: 10,000

3. Round 9,637 to the nearest hundred.

Ans: 9,600

4. Round 9,637 to the nearest tens.

Ans: 9,640

Calculations

1. 9 pounds x 3 pounds.

Ans: 9 pounds by 3 pounds = 27 square pounds.

2. 8 feet x 3 feet x 0.5 feet.

Ans: 8 feet x 3 feet x 0.5 feet = 12 cubic feet.

Unit 1 Review Exercise

1. Round 987.5321:

   a. To the nearest tens place.

   Ans: 990

   b. To the nearest hundredths place.

   Ans: 987.53

2. How many gallons of water would it take to fill a tank that has a volume of 6,000 cubic feet?

Ans: $\frac{6{,}000 \text{ cu ft}}{1} \times \frac{7.48 \text{ gal}}{1 \text{ cu ft}} = 44{,}880$ gal.

3. 3/4 - 1/8 =

Ans: $\frac{6}{8} - \frac{1}{8} = \frac{5}{8}$

4. 25 + 101.53 + 0.479 =

Ans: 127.009

5. We know that disinfection rates will increase as temperature increases. Assuming all else is equal, which tank would achieve disinfection first, Tank A at 40º F or Tank B at 15º C?

Ans: Tank B

In order to compare the temperatures to see which tank has the higher temperature, they must first be converted to the same units. You can either convert ºF to ºC or convert ºC to ºF. Let's look at both.

Step 1: Convert.

Tank A	Tank B
Celsius = (ºF – 32º) x 5/9	Fahrenheit = (ºC x 9/5) + 32º
= (40º F – 32º) x 5/9	= (15º C x 9/5) + 32º
= (8º F) x 5/9	= (27º C) + 32º
= 4.4º C	= 59º F

Step 2: Compare.

Tank A	vs.	Tank B
4.4º C	⟷	15º C
40º F	⟷	59º F

6. What is 0.22 expressed as a fraction?

Ans: $\frac{0.22}{1} \times 1 = \left\{\frac{0.22}{1} \times \frac{100}{100}\right\} = \frac{22}{100} = \frac{(11 \times 2)}{(11 \times 9.09)} = \frac{11}{11}\left\{\frac{2}{9.09}\right\} = 1\left\{\frac{2}{9.09}\right\} = \frac{2}{9}$

Note: Once again, it is ok to drop the decimal point and decimal places from the 9.09 since 0.22 was only an approximation of 2/9 (2/9 = 0.2222…)

7. If you disinfect a storage tank with 150 mg/L of 100% strength chlorine knowing there is a chlorine demand of 5 mg/L, what percentage of the applied dose is being consumed by the chlorine demand?

Ans: (5 mg/L ÷ 150 mg/L) x 100% = 3.3%

8. How much would the water in a 6,000 cu ft tank weigh in pounds? In kilograms?

Ans: $\frac{6{,}000 \text{ cu ft}}{1} \times \frac{62.37 \text{ lbs}}{1 \text{ cu ft}} = 374{,}220 \text{ lbs}$ and $\frac{374{,}220 \text{ lbs}}{1} \times \frac{1 \text{ kg}}{2.2 \text{ lbs}} = 170{,}100 \text{ kg}$

Calculations

1. What is the surface area of an uncovered tank that is 100 feet long, 25 feet wide and 15 feet high and how many gallons of paint would be needed to paint the outside of the tank? One gallon of paint will cover 200 square feet.

Ans: To determine how much paint is required to paint the outside of a tank, the total area must first be calculated. Keep in mind that there are four sides to the tank. Two sides are 100 feet long by 15 feet tall. The area for these sides is calculated as follows:

A = L x W
A = 100 feet x 15 feet = 1500 square feet
Because there are two sides with these dimensions, we add 1500 + 1500 and get a total area of 3,000 square feet for the two largest sides.

There are also two other sides which are smaller. These two sides are 25 feet wide and 15 feet high. The area for these sides is calculated as follows:

A = L x W
A = 25 feet x 15 feet = 375 square feet
Because there are two sides with these dimensions, we add 375 + 375 and get a total area of 750 square feet for the two smaller sides.

To get the total surface area, we add the area of the two larger sides and the area of the two smaller sides:
Surface area = 3,000 square feet + 750 square feet = 3,750 square feet

To determine how many gallons of paint are required:
We know that one gallon will cover 200 square feet, so we divide the total surface area of the tank by 200 square feet:

$$\text{Gallons of paint} = \frac{3{,}750 \text{ sq ft.}}{200 \text{ sq. ft. per gallon}}$$

Gallons of paint = 18.75 gallons of paint, or, 19 gallons.

2. If the tank had a cover, what would its area be?

Ans: If the tank has a cover, it would be 100 feet long by 25 feet wide. Its area would be:
A = L x W
A = 100 feet x 25 feet
A = 2,500 square feet.

Calculations

1. Find the area of a triangle with a base of 20 feet and a height of 16 feet.

Ans: The formula for calculating the area of a triangle is: A = ½ B x H.
A = ½ (20 feet) x (16 feet)
A = $\frac{320}{2}$ square feet
A = 160 square feet

- -

Calculations

1. Treatment Plant X is planning to build a new aerobic digester with a diameter of 80 feet and a height of 30 feet. Calculate the total surface area of the new tank.

Ans: Step 1: Calculate the area of the circle. Remember that the radius is equal to one half of the diameter, so in this problem, the radius is 40 feet.

$A = \pi R^2$
$A = (3.14)\ (40 \text{ feet})^2$
$A = (3.14)\ (1600 \text{ ft}^2)$
A = 5,024 square feet

Step 2: Calculate the area of the sides of the tank.

$A = \pi \times D \times H$
A = (3.14) (80 feet) (30 feet)
A = 7,536 square feet

Now, add the values from Steps 1 and 2 to give the total surface area.

$7{,}536 \text{ ft}^2 + 5{,}024 \text{ ft}^2 = 12{,}560 \text{ ft}^2$

Instructor note: if students use a calculator with π, the resultant numbers will be 5,026 square feet, 7,539 square feet, and 12,565 square feet.

- -

Calculations

1. How many gallons of water could a 5 feet by 2 feet by 2 feet aquarium hold?

Ans: First, determine the volume of the aquarium using the formula V = L x W x H.
V = (5 feet) (2 feet) (2 feet)
V = 20 cubic feet
To convert the volume into gallons, multiply the above answer by 7.48 since there are 7.48 gallons of water in one cubic foot. This will give us an answer of 150 gallons of water.

As a bonus question, can anyone tell me how much the 150 gallons of water would weigh?

Ans: One gallon of water weighs 8.34 pounds, so to determine how much the 150 gallons weighs, multiply 150 by 8.34 and you get 1,251 pounds as the weight of the water.

2. What is the volume, in cubic feet, of the bed of a dump truck measuring 15 feet long, 7 feet wide, and 6 feet deep?

Ans: The volume of the bed of the dump truck can be determined using the formula V = L x W x H.
V = (15 feet) (7 feet) (6 feet)
V = 630 cubic feet

3. If a pump is filling a 10,000 gallon tank at the rate of 250 gpm, how long will it take to fill the tank?

Ans: Divide the volume of the tank (10,000 gallons) by the filling rate of 250 gallons/minute and you will get a fill time of 40 minutes.

4. If a flow of 10,000 gpm is going into a 500,000 gallon tank, what is the average detention time within the tank?

Ans: Detention time is sometimes compared to a fill time for a tank. Divide the volume of the tank (500,000 gallons) by the flow rate of 10,000 gpm, and you get a detention time of 50 minutes.

Calculations

1. A circular clarifier is 80 feet in diameter, a side water depth of 15 feet, and sloped towards a center depth of 19 feet. How much sludge would be in the 4 foot deep section of the tank bottom?

Ans: This requires using the formula for the area of a cone, which is: $V = \frac{\pi}{3} R^2 \times H$.

Since the diameter is 80 feet, we know the radius is 40 feet.

$$V = \frac{\pi}{3} R^2 \times H$$

$$V = (3.14)\ \frac{(40\text{ feet})^2}{3} \times 4\text{ feet}$$

$$V = (3.14)\ \frac{(1{,}600\text{ square feet})}{3}\ (4\text{ feet})$$

$$V = \frac{20{,}096}{3}\text{ cubic feet}$$

$$V = 6{,}699\text{ cubic feet}$$

To express this in gallons, multiply the volume in cubic feet by 7.48 gallons per cubic foot, and the answer in gallons is 50,108.

Instructor note: if students use a calculator with π, the resultant numbers will be 6,702 cubic feet and 50,131 gallons.

Calculations

1. A tank has a diameter of 100 feet and a depth of 12 feet. What is the volume in cubic feet and in gallons?

Ans: The diameter is 100 feet, so the radius is half of 100, or, 50 feet. The volume is determined by using the formula $V = \pi R^2 \times H$.
$V = (3.14)\ (50\text{ feet})^2\ (12\text{ feet})$
$V = (3.14)\ (2{,}500\text{ square feet})\ (12\text{ feet})$
$V = 94{,}200\text{ cubic feet}$

To convert this to gallons, we multiply the 94,200 cubic feet by 7.48 gallons per cubic foot, and get a total of 704,616 gallons.

2. If the diameter is doubled, what is the tank capacity in cubic feet and gallons?

Ans: If the diameter is doubled, it becomes 200 feet and the radius becomes 100 feet. We still use the same formula used in the first calculation: $V = \pi R^2 \times H$.
$V = (3.14)\ (100\text{ feet})^2\ (12\text{ feet})$
$V = (3.14)\ (10{,}000\text{ square feet})\ (12\text{ feet})$
$V = 376{,}800\text{ cubic feet}$

To convert this to gallons, we multiply the 376,800 cubic feet by 7.48 gallons per cubic foot, and get a total of 2,818,464 gallons.

3. How many gallons of chemical would be contained in a full drum that is 3 feet tall and 1.5 feet in diameter?

Ans: First you must compute the volume of the drum. Since the radius is equal to one half of the diameter, we know that the radius of the drum is 0.75 feet. Again, we calculate the volume using the equation $V = \pi R^2 \times H$.
$V = (3.14)\ (0.75\ \text{feet})^2\ (3\ \text{feet})$
$V = (3.14)\ (0.5625\ \text{square feet})\ (3\ \text{feet})$
$V = 5.3$ cubic feet

To convert this to gallons, we multiply the 5.3 cubic feet by 7.48 gallons per cubic foot, and get a total of 40 gallons.

Calculations

1. How many mg/min are there in 1 lb/day?

Ans: Unknown Data: $\frac{?\ mg}{min}$ Known Data: $\frac{1\ lb}{day}$

Steps: List unknown data including units. Place data with same numerator unit to the right of the equal sign followed by a multiplication sign. Continue to place data into equation to systemically cancel all unwanted units until only the unknown units remain.

$$\frac{?\ mg}{min} = \frac{1{,}000\ mg}{1\ \cancel{g}} \times \frac{454\ \cancel{g}}{1\ \cancel{lb}} \times \frac{\cancel{1\ lb}}{\cancel{day}} \times \frac{\cancel{1\ day}}{1{,}440\ min} =$$

Now do the math (multiply all numerator values, multiply all denominator values, then divide numerator by the denominator.)

$$\frac{?\ mg}{min} = \frac{454{,}000\ mg}{1440\ min} = 315.3\ \frac{mg}{min}$$

2. How many hours will it take to empty a 55 gallon drum of a liquid chemical using a chemical feed pump that will pump at a rate of 30 ml/min?

Ans: Known Data: 55 gal and $\frac{30\ ml}{min}$ Unknown Data: ? Hours

$$\frac{?\ \text{Hours}}{1} = \frac{\text{hr}}{60\ \cancel{\text{mins}}} \times \frac{\cancel{\text{min}}}{30\ \cancel{\text{ml}}} \times \frac{3785\ \cancel{\text{ml}}}{\cancel{\text{gal}}} \times \frac{55\ \cancel{\text{gal}}}{1} = \frac{208175}{1800} = 115.6\ \text{hrs.}$$

Note: The pump rate is rearranged to place the time unit in the numerator.

Calculations

1. How many pounds per day of total phosphorus (TP) are discharged from a plant with a flow of 350,000 gallons per day (gpd) and an effluent TP concentration of 1.2 mg/L?

Ans: The formula is: Loading, lbs/day = (Flow, MGD) (Concentration, mg/L) (8.34 lbs/gal)
First we need to convert the 350,000 gallons into MGD. 350,000 gallons is equal to 0.35 MGD.
Next, we simply plug the numbers into our formula:
Loading, lbs/day = (0.35 MGD) (1.2 mg/L) (8.34 lbs/gal)
Loading, lbs/day = 3.5

Calculations

1. If a well pump delivers 400 gpm, and the chlorine dose is 2.5 mg/L, determine the appropriate chlorinator setting in lbs/day.

Ans:

$$\text{Flow} = \frac{400\ \text{gal}}{\text{min}} \times \frac{1440\ \text{min}}{\text{day}} \times \frac{1}{1{,}000{,}000}.$$

$$= 0.576\ \text{MGD}$$

Chemical Feed = (Flow, MGD)(Dose, mg/L)(8.34 lbs/gal)

= (0.576 MGD)(2.5 mg/L)(8.34 lbs/gal)

= 12 lbs/day

Calculations

1. What is the geometric monthly fecal coliform mean of a distribution system with the following FC counts: 24, 15, 7, 16, 31 and 23? The result will be inputted into a NPDES DMR, therefore, round to the nearest whole number.

Ans: Remember that the formula for geometric mean, as defined in the definition in the workbook is: $(X_1 \times X_2 \times X_3 \times \ldots X_n)^{1/n}$ where X is the sample value and n is the number of samples. Using the n^{th} root method, the answer is calculated as follows:

Step 1: Multiply all the values together.
(24 x 15 x 7 x 16 x 31 x 23) = 28748160

Step 2: Determine the number of tests done. In this example, the number of tests was 6, which becomes the n^{th} root, or, 1/6, which equals 0.166666666.

Step 3: Take the n^{th} root of the final multiplied number.
$(28748160)^{0.166666} = 17.5025$ or $\sqrt[6]{29748160}$

Remember that the geometric mean is representing a "life form" so round to the proper integer value, which in this case is 18.

Instructor note: If participants get 19.3 as their answer, they most likely computed the average, not the geometric mean.

2. What is the fecal coliform geometric mean of digested sludge with the following FC counts: 1502, 99, 460, 45, 590, 111 and 385?

Ans: Again, using the n^{th} root method, the answer is calculated as follows:

Step 1: (1502 x 99 x 460 x 45 x 590 x 111 x 385) = 7.760884×10^{16}
Note: Due to the length of the answer in step one, it is best expressed as an exponent.

Step 2: In this example, the number of tests was 7, which becomes the n^{th} root, or, 1/7, which equals 0.14285714.

Step 3: Take the n^{th} root of the final multiplied number.
$(7.760884 \times 10^{16})^{0.14285714} = 258.729.$ or $\sqrt[7]{7.760884 \times 10^{16}}$

Remember that the geometric mean is representing a "life form" so round to the proper integer value, which in this case is 259.

- -

☑ **Exercise**

1. What is the reading on the following meter? ___________

Ans: 8642

- -

☑ **Exercise 1**

An operator wants to disinfect a round storage tank with a flat bottom. The tank is 120 feet in diameter and 15 feet deep. The intended task is to achieve a chlorine residual of 100 mg/l after a 24 hour detention period during which time no flow will be entering or exiting the tank.

1. How many cubic feet are in the tank?

Ans: The volume is determined by using the formula $V = \pi R^2 \times H$.
$V = (3.14)(60 \text{ feet})^2 (15 \text{ feet})$

V = (3.14) (3600 square feet) (15 feet)
V = 169,560 cubic feet

2. How many gallons are in the tank?

Ans: Multiply 169,560 cubic feet by 7.48 gallons per cubic foot, and the answer is 1,268,309 gallons.

3. Assume there is a possible chlorine demand of 10 mg/l in addition to the 100 mg/l desired chlorine residual. What is the amount of 100% strength chlorine that should be fed into the tank?

Ans: If the chlorine demand is 10 mg/L and the desired concentration is 100 mg/l, we get a total dosage of 110 mg/L by adding these two numbers together.

In question 2, we calculated how many gallons are in the tank. Convert this to million gallons and it becomes 1.268 million gallons.

Chemical Feed, lbs/day = (Flow, MGD) (Dose, mg/L) (8.34 lbs/gal)
Chemical Feed, lbs/day = (1.268 MGD) (110 mg/L) (8.34 lbs/gal)
Chemical Feed, lbs/day = 1,163 pounds of 100% strength chlorine.

4. How much chlorine is consumed by the chorine demand?

Ans: From question 3, we know that the chlorine demand is 10 mg/L.

To calculate the amount of chlorine consumed, use this formula:
Chemical Feed, lbs/day = (Flow, MGD) (Dose, mg/L) (8.34 lbs/gal)
Chemical Feed, lbs/day = (1.268 MGD) (10 mg/L) (8.34 lbs/gal)
Chemical Feed, lbs/day = 105.7 pounds.

5. If the operator wants to use sodium hypochlorite of 12% strength, how many gallons will be needed? Use a specific gravity of 1.168 for the sodium hypochlorite solution.

Ans: Most chlorine solutions do not weigh 8.34 pounds per gallon. As an example, sodium hypochlorite of 12% strength weighs approximately 10 pounds per gallon. This can be determined by multiplying the specific gravity of 1.168 times the normal weight of water (8.34 pounds), which yields a result of 9.74 pounds per gallon. This means that 9.74 pounds of the solution contains 1.168 pounds of chlorine per gallon.

In question 3, we determined the weight of 100% chlorine needed was 1,163 pounds. Since we are using a 12% solution in this problem, we must divide the 1,163 pounds by 12%, which yields 9,692 pounds of 12% solution. Next, we divide the 9,692 pounds of solution by its weight of 9.74 pounds and get 995 gallons.

6. In order to comply with maximum chlorine residual limits prior to discharge through the system, the tank effluent must be dechlorinated. The operator performs a chlorine residual test and determined it is 95 mg/L. Assume it requires 1 pound of dechlorination agent per 1 pound of chlorine, how much dechlorination agent will be required?

Ans: Dechlorination agent needed = (Flow, MGD) (Dose, mg/L) (8.34 lbs/gal)
Dechlorination agent needed = (1.268 MGD) (95 mg/L) (8.34 lbs/gal)
Dechlorination agent needed = 1,004.6 pounds

7. The tank is going to be emptied at a rate of 1,000 gpm (gallons per minute), how long will it take?

Ans: $\text{Rate} = \dfrac{1{,}268{,}309 \text{ gal}}{1{,}000 \text{ gpm}} = 1{,}268 \text{ min}$

8. The dechlorination process is going to be conducted at the same time the tank is being emptied. The dechlorination solution has an effective strength of 80% strength and a specific gravity of 1.0. What feed rate in gals/minute should the pump be set at to dose the 1,000 gpm flow out of the tank? How many gallons of the dechlorination agent will be used?

Ans: If the dechlorination agent is only 80% strength and we previously determined we would need 1005 pounds of dechlorination agent, then we need 1,256 pounds of solution. We know the solution weighs 8.34 pounds per gallon, so we can determine the total volume of solution by dividing 1,256 by 8.34. This gives a result of 151 gallons. From the information in question 7, we know the tank will empty in 1,268 minutes, so we divide the flow of 151 gallons by the time (1,268 minutes) and we get 0.119 gpm.

Liquid Feed = (1005 lbs) ÷ (8.34 lbs/gal x 80% / 100%)
= (1005 lbs) ÷ (6.67 lbs/gal)
= 151 gal

$\text{Rate} = \dfrac{151 \text{ gal}}{1{,}268 \text{ min}} = 0.119 \text{ gpm}$

☑ **Exercise 2**

A treatment plant daily flow is 250,000 gpd. And the flow is split equally between two aeration tanks. Each aeration tank is 75 feet long, 15 feet deep and 15 feet wide. The laboratory testing indicates the following: influent BOD_5 = 150 mg/L, influent $CBOD_5$ = 120 mg/L, effluent $CBOD_5$ = 6 mg/L and the MLVSS in each aeration tank is 3,500 mg/L.

1. What is the volume in cubic feet and in gallons, of each aeration tank?

Ans: V = L x W x H
V = (75 feet) (15 feet) (15 feet)
V = 16,875 cubic feet

To convert volume into gallons, multiply 16,875 cubic feet by 7.48 gallons per cubic foot, and you get 126,225 gallons.

2. What is the average detention time in the aeration basins?

Ans: The flow of 250,000 gpd is split between two tanks, which means each tank has a flow of 125,000 gallons. In question 1, we calculated the capacity of the tank as 126,225 gallons. To determine the detention time, divide the tank capacity of 126,225 gallons by the flow of 125,000 gallons per day, for a result of 1.01 days.

3. What is the organic loading to the facility in pounds of BOD_5 and also in $CBOD_5$?

Ans: BOD_5 Loading, lbs/day = (Flow, MGD) (Concentration, mg/L) (8.34 lbs/gal)
Loading, lbs/day = (0.25 MGD) x (150 mg/L) x (8.34 lbs/gal)
Loading, lbs/day = 313 lbs/day

$CBOD_5$ Loading, lbs/day = (Flow, MGD) (Concentration, mg/L) (8.34 lbs/gal)
Loading, lbs/day = (0.25 MGD) x (120 mg/L) x (8.34 lbs/gal)
Loading, lbs/day = 250 lbs/day

4. How many pounds of $CBOD_5$ are discharged from the facility?

Ans: $CBOD_5$ discharged = (Flow, MGD) (Dose, mg/L) (8.34 lbs/gal)
$CBOD_5$ discharged = (0.25 MGD) (6 mg/L) (8.34 lbs/gal)
$CBOD_5$ discharged = 12.51 pounds per day. If rounded to the closest integer, the answer becomes 13 pounds per day.

5. What is the removal efficiency for the facility?

Ans: You can not, and must not, compare BOD_5 in the influent with $CBOD_5$ in the effluent; therefore, the only removal efficiency which can be calculated is for $CBOD_5$:

$$\text{Removal efficiency, } CBOD_5 = \frac{\text{influent } CBOD_5 - \text{effluent } CBOD_5}{\text{Influent } CBOD_5} \times 100\%$$

$$\text{Removal efficiency } CBOD_5 = \frac{120 \text{ mg/L} - 6 \text{ mg/L}}{120 \text{ mg/L}} \times 100\%$$

Removal efficiency $CBOD_5$ = 95%

6. How many pounds of biomass are in the two aeration tanks?

Ans: Previously the volume of 1 tank was determined to be 126,225 million gallons. First, multiply 126,225 by 2 to get a total volume of 252,450. Then convert that to MGD by dividing it by 1,000,000 and we get 0.252. Next we use the formula:
Loading, lbs/day = (Flow, MGD) (Concentration, mg/L) (8.34 lbs/gal)
Loading, lbs/day = (0.252 MGD) (3,500 mg/L) (8.34 lbs/gal)
Loading, lbs/day = 7,356 pound

7. Based upon the organic loading and MLVSS concentration, calculate the F/M.

Ans: The food, as measured by BOD_5, is 313 pounds (this was calculated in Question 3). The microorganism is 7356 pounds, as determined in Question 6. Based on this information:

$$F/M = \frac{313}{7356}$$

F/M = 0.043

The food, as measured by $CBOD_5$, is 250 pounds (this was calculated in Question 3). The microorganism is still 7356 pounds, as determined in Question 6. Based on this information:

$$F/M = \frac{250}{7356}$$

F/M = 0.034

It is important to recognize the difference between using BOD_5 and $CBOD_5$ when evaluating organic loading. A substantial amount of operational guidelines and design information about F/M was developed using BOD_5 information.

☑ **Exercise 3**

An operator runs 4 solids tests per week for every week of the year but available laboratory time is limited and at times he is behind schedule. The operator is evaluating the use of outside laboratory services.

- The operator is paid $15/hour but also has fringe benefits that account for another 45% of his total labor cost. Currently the testing is conducted at the facility and requires 45 minutes per test. The laboratory supplies cost $250 per year for the solids testing. The laboratory equipment cost $2,000 when originally purchased 4 years ago. With proper care and maintenance the equipment has an expected service life of 20 years.

- The operator obtained a price quote of $15 per solids test from an outside contract laboratory. The laboratory can return the analytical results within 3-4 weeks.

1. Compare the total cost for the solids testing for either in house or the contract laboratory.

Ans: First we must determine the costs of testing in house, which will involve the labor costs, chemical cost and equipment cost, so we must calculate each of these.

<u>Labor Cost</u>

Step 1: $15/hour + 45% for benefits
$15/hour multiplied by 0.45 (which is the decimal representation of 45%) yields $6.75 for benefits
$15.00 + $6.75 = $21.75/hour

Step 2: 45 minutes equals 0.75 hours 45 minutes divided by 60 minutes = 0.75 hour
(0.75 hour/test) (4 test/week) = 3 hours/week for testing

Step 3: Yearly labor cost = (time per week for testing) (52 weeks/year) (hourly labor rate)
Yearly labor cost = (3 hrs/week) (52 weeks/year) ($21.75/hour)
Yearly labor cost = $3,393 labor cost for the year.

<u>Chemical and Equipment Cost</u>
As stated in the information supplied in the question, chemical costs are $250/year. Next, we must calculate the annual cost of the equipment. We know that the equipment cost is $2,000 and it is expected to last 20 years. Based on this information, the annual cost of the equipment is:

$$\text{Annual cost} = \frac{\text{Total cost of equipment}}{\text{Life expectancy of equipment}}$$

$$\text{Annual cost} = \frac{\$2{,}000}{20 \text{ years}}$$

Annual cost = $100/year

<u>Total Cost</u>
The total cost is calculated by adding together the cost of labor, the cost of the chemicals and the cost of the equipment: $3,393 + $250 + $100 = $3,743 total annual cost.
<u>Cost per test for in house</u>
We know from the information supplied above that the operator performs 4 tests per week. To determine the total number of tests per year, we multiply 4 tests/week by 52 weeks/year and find that a total of 208 tests per year are done. Now we have to determine the cost per test, which is done as follows:

$$\text{Cost per test} = \frac{\text{Total annual cost}}{\text{Number of tests/year}}$$

$$\text{Cost per test} = \frac{\$3{,}743}{208}$$

Cost per test = about $18.00 per test

Cost of Using Contract Lab
We know that the contract lab provided a quote of $15 per test. We will use this piece of information to calculate the cost of using the contract lab.
Cost of contract lab = (number tests/week) (52 weeks/year) (cost per test)

Cost of contract lab = (4 tests/week) (52 weeks/year) ($15/test)

Cost of contract lab = $3,120 dollars

2. Discuss the advantages/disadvantages of both options.

Ans: Let's compare the two options:

In house – This is more expensive but the results from the testing are known within 1-2 days. The information may be needed to make process control decisions and delay of a proper process adjustment by 3-4 weeks may result in a NPDES Permit violation. There is still about 16 years left on service life for the equipment; therefore; replacement is not needed in the immediate future.

Contract lab - Contract lab costs are about $3.00 less per test ($18.00 - $15.00 = $3.00). This means we are looking at an annual savings of $623 per year ($3,743 - $3,120 = $623). However, it takes almost a month to receive results from the lab. Can a process decision be delayed for this length of time? In some situations, if the operator is already overworked, it may be necessary to use contract lab services so the operator can catch up.

Summary - Once the operator is caught up, he must review his workload to determine how, or if, he can improve. Delaying process adjustments may result in penalties or fines of several thousand dollars per day. In Question 1, part c, the labor cost shows 52 weeks per year testing. It is not expected that the operator works without any vacation or never has a sick day; however, the NPDES Permit may have a defined testing schedule which would require use of another person or lab. This may be a good choice for usage of the contract lab.

To complete the Feed diagram:

Step 1. **Fill in the known data.**

Step 2. Put a question mark (?) for the value of any unknown data that you need.

Step 3. If the unknown data is on the Metric system side, use the conversions provided to move each piece of known (English system) data across to the metric side. Likewise if the unknown data is on the English side, convert the known (Metric system) data to the English side.

Step 4. Use unit cancellation to solve for the product feed rate.