Wastewater & Drinking Water Operator Certification Training Instructor Guide

Module 28: Basic Math

This course includes content developed by the Pennsylvania Department of Environmental Protection (Pa. DEP) in cooperation with the following contractors, subcontractors, or grantees:

The Pennsylvania State Association of Township Supervisors (PSATS)
Gannett Fleming, Inc.
Dering Consulting Group
Penn State Harrisburg Environmental Training Center

A Note to the Instructor

Dear Instructor:

The primary purpose of this course, *Basic Math* is to provide an overview of the basic mathematical knowledge required to operate a water treatment plant or a wastewater treatment plant. This module has been designed to be completed in 5.5 hours, but the actual course length will depend upon content and/or delivery modifications and results of course dry runs performed by the Pa. DEP-approved sponsor. The number of contact hours of credit assigned to this course is based upon the contact hours approved under the Pa. DEP course approval process. To help you prepare a personal lesson plan, timeframes have been included in the instructor guide at the Unit level and at the Roman numeral level of the topical outline. You may need to adjust these timeframes as necessary to match course content and delivery modifications made by the sponsor. Please make sure that all teaching points are covered and that the course is delivered as approved by Pa. DEP.

Web site URL's and other references are subject to change, and it is the training sponsor's responsibility to keep such references up to date.

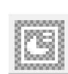
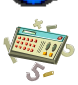
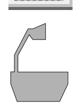
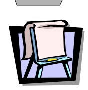
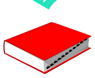
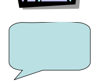
Delivery methods to be used for this course include:

- Lecture
- Exercises/Activities
- Calculations

To present this module, you will need the following materials:

- One workbook per participant
- Extra pencils
- Flip Chart
- Markers
- Laptop (loaded with PowerPoint) and an LCD projector **or** overheads of presentation and an overhead projector
- Screen
- Scientific Calculator(s)

Icons to become familiar with include:

Participant Workbook		Instructor Guide	
	Exercise/Activity	Same icons for Participant Workbook apply to the Instructor Guide.	
	Case Study	Ans:	Answer to exercise, case study, discussion, question, etc.
	Discussion Question		PowerPoint Slide
	Calculation(s)		Overhead
	Exercise		Flip Chart
	Key Definition(s)		Suggested "Script"
	Key Point(s)		

Instructor text that is meant to be general instructions for the instructor are designated by being written in script font and enclosed in brackets. For example:

[*Ask participants if they have any questions on how to read the table. Answer any questions participants may have about how to read the table.]*

If your module includes the use of a PowerPoint presentation, below are some helpful controls that you may use within the Slide Show.

PowerPoint Slide Show Controls

You can use the following shortcuts while running your slide show in full-screen mode.

To	**Press**
Advance to the next slide	N, ENTER, or the SPACEBAR (or click the mouse)
Return to the previous slide	P or BACKSPACE
Go to slide <number>	<number>+ENTER
Display a black screen, or return to the slide show from a black screen	B
Display a white screen, or return to the slide show from a white screen	W
Stop or restart an automatic slide show	S
End a slide show	ESC
Return to the first slide	Both mouse buttons for 2 seconds
Change the pointer to a pen	CTRL+P
Change the pen to a pointer	CTRL+A
Hide the pointer and button temporarily	CTRL+H
Hide the pointer and button always	CTRL+L
Display the shortcut menu	SHIFT+F10 (or right-click)
Erase on-screen annotations	E
Go to next hidden slide	H
Set new timings while rehearsing	T
Use original timings while rehearsing	O
Use mouse-click to advance while rehearsing	M

INTRODUCTION OF MODULE: 5 minutes

Display Slide 1—Module 28: Basic Math.

[*Welcome participants to "Module 28 – Basic Math." Indicate the primary purpose of this course is to provide an overview of the basic mathematical knowledge required to operate a water treatment plant or a wastewater treatment plant. State that this knowledge is required by plant personnel to effectively operate and prepare reports for their facility, establish chemical feed rates and assist with maintenance requirements*.]

[*Introduce yourself*.]

[*Provide a brief overview of the module*.]

This module contains 3 units. On page i, you will see the topical outline for Unit 1 – Overview of Basic Math, Unit 2 – Basic Formulas and Methods, Unit 3 – Advanced Formulas and the Appendices.

[*Briefly review outline*.]

UNIT 1: 90 minutes

Display Slide 2 —Unit 1: Overview of Basic Math.

At the end of this unit, you should be able to:

- Review basic math functions
- Perform basic calculations and conversions containing fractions and decimals.
- State the basic rules for performing mathematical computations.
- Calculate percentages.

Display Slide 3—Unit 1: Overview of Basic Math.

The remaining objectives for Unit 1 are:

- Explain the rules for rounding decimals and whole numbers and correctly round each type of number.
- Understand how to multiply units.
- Understand the Metric system and how to convert between English and metric units.

OVERVIEW OF BASIC MATH: 60 minutes

General Math Concepts

In this section, we will discuss a few general math concepts. These concepts are important because they will enable you to correctly perform the calculations that we will review in later sections of this module. We will begin with an overview of the four basic math functions followed by a section on fractions and decimals.

Addition, Subtraction, Multiplication, and Division

[*Review the information in the workbook*.]

Fractions and Decimals

Now it's time to take a closer look at these functions involving fractions and decimals. Fractions and decimals can often be intimidating. Since it will be necessary for you to work with them at times, we're going to spend some time reviewing basic rules and tips.

Display Slide 4—Example of a Fraction.

This slide illustrates the concept of what a fraction is. Figure 1.1 shows 6 pieces of the circle, with 4 of them being shaded. In this example, 4 is the numerator and 6 is the denominator, thereby giving us our fraction of 4/6. Also, note that 4/6 is numerically equivalent to 2/3 because both the numerator and denominator in the 4/6 fraction can be divided by the same number, which in this case is the number 2. This is known as reducing or simplifying the fraction.

[*Review the information in the workbook*.]

Addition and Subtraction of Fractions

[*Review information in the workbook*.]

[*Use flipchart to work through the examples in the workbook*.]

[*Ask if there are any questions*.]

Multiplication of Fractions

Let's move onto the multiplication of fractions. Multiplying fractions is fairly simple.

[*Review the information in the workbook*.]

[*Review Example 1.*]

Division of Fractions

Dividing fractions is slightly more difficult. To divide fractions, you will use the same rules used in multiplying fractions, but with one extra step.

[*Review the information in the workbook*.]

[*Use flipchart to work through the example in the workbook*.]

[*Ask if there are any questions.*]

Converting Fractions to Decimals

Sometimes when working with formulas and equations, you will need to convert a fraction into a decimal. Let's take a look at how that is done.

[*Review the information in the workbook*.]

[*Review Examples 1 and 2 in the workbook. Be sure to explain that in both examples, the answer is arrived at by dividing the numerator by the denominator*.]

Now that you have successfully converted fractions into decimals, let's take a few moments to review a few basic rules to remember when calculating equations using these numbers. We'll start with addition and subtraction involving decimals.

Addition and Subtraction of Decimals

[*Review the information in the workbook*.]

Multiplication of Decimals

[*Review the information in the workbook*.]

[*Use flipchart to work through the example in the workbook*.]

Division of Decimals

Now let's take a look at how to divide numbers with decimals.

[*Review the information in the workbook*.]

Note that when the dividend is a whole number, 6 in this example, the decimal point is assumed to be to the right of the number. When setting up the problem, it is often helpful to place this decimal next to the number. Once you've done this, you can add zeroes to the whole number without changing the value. The number of zeroes that will need to be added is equivalent to the number of decimal places in the divisor, which in our example would be two.

[*Review Example 1.*]

What do you do if the dividend contains a decimal, but the divisor does not? Nothing; you simply divide the numbers. Let's take a look at example 2. It's the same numbers from the first example except they've been reversed.

[*Review Example 2.*]

[*Ask if there are any questions*.]

Converting Decimals to Fractions

Just as you may need to convert fractions to decimals, there may be occasions when you need to do the reverse.

[*Review the information in the workbook*.]

[*Review Example 1*.]

In this example, the decimal is carried out to the tenths place. Since any number divided by itself is equal to 1, we can multiply by 10/10 to get rid of the decimal. Note that we are not changing the <u>value</u> of 0.8 only the way it is written. To reduce the resulting fraction, we factor out the greatest common multiple (2) from both the numerator and the denominator, which yields 4/5.

[Review Example 2.]

In this example it is permissible to drop the decimal and place values in 3.03 since 0.33 was only an approximate value of 1/3. [1/3= 0.33333…]

Now it's time for you to try a few conversions on your own. Take ten minutes to answer the questions in your workbook and then we will review the answers.

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

Basic Rules

Before we continue any further, we need to discuss some basic mathematical rules. Computations must be performed in the proper sequence to assure that the answer properly addresses the problem requirements. It is also important that the final answer be presented in terms that reflect the accuracy of the data used in preparing the computation. In each case, this requires strict adherence to rules. Let's take a look at these rules.

[*Review the four rules listed in the workbook*.]

Let's take a look at some examples that will show how these rules are used. In example 1, the only rule we need to follow is rule #1.

[*Review Example 1 in the workbook*.]

In example 2, we need to follow rules #1 and #3.

[*Review Example 2 in the workbook*.]

In example 3, we need to use rule #4.

[*Review Example 3 in the workbook*.]

Now that you are familiar with the rules for performing calculations and the concept of fractions, it is time for you to do a few calculations. Take five minutes to do the calculations on page 1-9 of your workbook and then we will review the answers.

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

Calculating Percentages

In water and wastewater treatment, it is important to be familiar with percents. For example, you often will want to know the percent removal for a particular treatment process. Let's take a moment to review how to calculate percentages.

[*Review the information and example in the workbook.*]

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

   <u>Step 2</u>: (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)*.]

Rules for Rounding

Another math concept you will need to be familiar with is the concept of rounding numbers. You may find yourself rounding both decimals and whole numbers. In either case, there are rules that apply, so let's discuss them now, beginning with the rules for rounding decimals.

Rounding Decimals

[*Review information in the workbook*.]

Let's take a look at some examples. In Example 1, the rounding digit is 2. Since the digit to the right of the rounding digit is 3, which is less than 5, we keep the rounding digit and drop the remaining digits, thus giving us the answer of 3.2. In Example 2, we see several examples of how to round numbers when the digit to the right of the rounding digit is 5.

[*Review Examples 1 and 2*.]

Rounding Whole Numbers

The rules that apply to rounding whole numbers are slightly different than those that apply to rounding decimals.

[*Review information in the workbook*.]

Let's look at some examples of the rules of rounding whole numbers. In our first example, we see that the digit to the right of the rounding digit is greater than 5, so we add one to the rounding digit and change the remaining digits to zero, which gives us our answer of 5,800. In Example 2, the digit to the right of the rounding digit is 5, so we round to the even number, which is 26. In the third example, the digit to the right of the rounding digit is less than 5, so we keep the rounding digit as is and then change all the digits to the right of it to zero, thus giving us our answer of 16. Now take three minutes to complete the four rounding exercises in your workbook.

[*Review Examples 1, 2, and 3*.]

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

Multiplication of Units

The final math concept we will review before moving on to the Metric system is the multiplication of units.

[*Review the information in the workbook, including Examples 1 and 2*.]

In your workbook you will find two calculations. You have three minutes to do these calculations and then we will review the answers.

[*Review answers to calculations with participants*.]

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.

The Metric System: <u>30 minutes</u>

Metric System

We cannot end this unit without a brief discussion of the Metric system. As an operator you will often work with the Metric and English systems of measurement, so it is important to understand them both individually as well as how they relate to each other.

[Review the information in the workbook.]

Prefixes and Symbols

[*Review the chart in the workbook*.]

Converting within the Metric system

[*Review the information in the workbook. Review Example 1*.]

Converting between the English and Metric systems

Converting between English and Metric units is a common task for operators. Let's take a look at some examples.

Length

[*Review information in the workbook and the example*.]

Volume

[*Review information in the workbook and the example*.]

Converting between the English and Metric systems, Con't.

Weight

[*Review information in the workbook and the example*.]

Temperature

[*Review information in the workbook*.]

Converting between the English and Metric systems, Con't.

Temperature, Con't.

[*Review example*.]

This brings us to the end of Unit 1. Please take 10 minutes and work on the Unit 1 Review Exercise beginning on page 1-16.

[*Review answers to calculations with participants*.]

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	$\longleftrightarrow$	15º C
40º F	$\longleftrightarrow$	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 $\frac{374{,}220 \text{ lbs}}{1} \times \frac{1 \text{ kg}}{2.2 \text{ lbs}} = 170{,}100 \text{ kg}$

Are there any questions on Unit 1? We will now move on to Unit 2 – Basic Formulas and Methods.

UNIT 2: 120 minutes

Display Slide 5—Unit 2: Basic Formulas and Methods.

At the end of this unit, you should be able to:

- Calculate the area of a rectangle, triangle, circle and cylinder.
- Calculate the volume of a rectangle, cone and cylinder.
- Understand how to perform Unit Cancellation.

CALCULATING AREA AND VOLUME: 75 minutes

We have just completed an overview of some basic mathematical concepts. Now we are going to move on to concepts, which are somewhat more complex – calculating the area and the volume of various objects such as rectangles, triangles, circles and spheres.

Area computations can be used to estimate how much paint may be required to coat a tank, repave a road or compute the surface area of a process unit. The former is an example of computations required to maintain the physical facility. The latter is a requirement when computing compliance with operating parameters.

Volume computations, however, deal with the quantity of substance an object can hold. Volume computations may be involved in ordering chemicals. If a storage tank is partially filled, the operator would compute how much chemical to order by knowing the diameter of the tank and the depth available for refill. Volumes are also used to establish detention times for basins.

Area

Let's return our attention to the concept of calculating area, beginning with how to calculate the area of a rectangle.

[*Review the information in the workbook*.]

Rectangle

[*Review the definition of the area of a rectangle*.]

Display Slide 6—The Area of a Rectangle.

[*This slide represents the definition in the workbook*.]

[*Review the information in the workbook*.]

[*Use flipchart to work through Example 1 in the workbook*.]

[*Use flipchart to work through Example 2 in the workbook*.]

Now it is time for you to try some calculations on your own. You have five minutes to do the calculations in your workbook.

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:

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

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.

Triangle

Next we will learn how to calculate the area of a triangle.

Display Slide 7—The Area of a Triangle.

[*This slide represents the definition in the workbook.*]

[*Review definition of the area of a triangle.*]

[*Use flipchart to work through Example 1 in the workbook*.]

Now that we have reviewed how to calculate the area of a triangle, try a calculation on your own.

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

Circle

So far, we have learned how to calculate the area of both a rectangle and a triangle. Now we will review how to compute the area of a circle.

Display Slide 8—The Area of a Circle.

[*This slide represents the definition in the workbook.*]

[*Review definition of the area of a circle*.]

As you can see from our definition of how to calculate the area of a circle, there are a number of terms you need to be familiar with. Let's review those now.

[*Review the three definitions in the workbook*.]

Now that we are familiar with the terms used when calculating the area of circles, let's look at some examples.

[*Use flipchart to work through Example 1 in the workbook*.]

[*Use flipchart to work through Example 2 in the workbook*.]

Cylinder

Another type of area calculation you will need to be familiar with as a treatment plant operator is the calculation for the area of a cylinder.

Display Slide 9—The Area of a Cylinder.

[*This slide represents the definition in the workbook*.]

[*Review definition of the area of a cylinder*.]

[*Review information in the workbook*.]

[*Use flipchart to work through Example 1 in the workbook*.]

[*Use flipchart to work through Example 2 in the workbook*.]

Now try a calculation on your own. Work on the calculation on page 2- 8 of your workbook. You have three minutes and then we will review the answer.

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

[*Instructor note: depending upon class understanding, participants may not be sure how you can have 'square feet' when you refer to a circular tank. Explain it to them as follows*:]

Try to visualize that the layer of window screen is placed over the top of the tank and you know how many squares cover one inch; by counting the number of squares you determine the surface area in square units. As you need to become more precise the size of the squares decreases.

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

$A = \pi \times D \times H$
$A = (3.14)\ (80 \text{ feet})\ (30 \text{ feet})$
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.*]

Volume

All of the computations we just reviewed were two-dimensional computations, or computations in which we calculated the area of an object. Three-dimensional objects are different than two dimensional objects because they involve a third dimension, which has to be incorporated into our calculations. When a third dimension is involved, we need to calculate the volume of an object instead of area.

For example, at times, operators are involved in installing new utility lines on site and have to excavate trenches. In this instance, you may need to compute the dimension of the excavation so you could order the correct quantity of stone in terms of cubic yards or tons. We will now review how to perform various three dimensional computations.

Rectangular

We will start with learning how to calculate the volume of a rectangle.

Display Slide 10—The Volume of a Rectangle.

[*This slide represents the definition in the workbook*.]

[*Review definition of the volume of a rectangle*.]

[*Review information in the workbook*.]

Let’s take a look at some examples that will require you to compute the volume of a rectangle.

[*Use flipchart to work through Example 1 in the workbook*.]

Now let’s look at another example.

[*Use flipchart to work through Example 2 in the workbook.*.]

[Optional: divide the class into small groups of 2-4 people and have them work the calculations as a group.]

You will have about ten minutes to perform the calculations in your workbook and then we will review the answers to the calculations.

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.

Conical

We will now turn our attention to calculating the volume of a cone.

Display Slide 11—The Volume of a Cone.

[*This slide represents the definition in the workbook*.]

[*Review definition of the volume of a cone*.]

[*Use flipchart to work through Example 1 in the workbook*.]

Now it’s your turn to compute the volume of a cone. Take five minutes to complete the calculation in your workbook.

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.*]

Cylindrical

Next we will discuss how to calculate the volume of a cylinder.

Display Slide 12—The Volume of a Cylinder.

[*This slide represents the definition in the workbook*.]

[*Review definition of the volume of a cylinder*.]

[*Use flipchart to work through Example 1 in the workbook*.]

[Optional: divide the class into small groups of 2-4 people and have them work the calculations as a group.]

We will wrap up this unit by having you perform the three calculations in your workbook. You have approximately ten minutes to do these calculations.

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 $V = \pi R^2 \times H$.
$V = (3.14)\ (50 \text{ feet})^2\ (12 \text{ feet})$
$V = (3.14)\ (2{,}500 \text{ square feet})\ (12 \text{ feet})$
$V = 94{,}200$ 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: $V = \pi R^2 \times H$.
$V = (3.14)\ (100 \text{ feet})^2\ (12 \text{ feet})$
$V = (3.14)\ (10{,}000 \text{ square feet})\ (12 \text{ feet})$
$V = 376{,}800$ 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.

Unit Cancellation Method: 45 minutes

[*Review the definition. Review the basic rules*.]

Let's look at two examples of the unit cancellation method. The purpose of these examples is to show you how the units cancel each other out: therefore, you do not need to concern yourself at this point with knowing or understanding the conversion factors.

[*Work through the steps and Example 1 in the workbook.*]

[*Finish example 1*.]

[*Review Example 2.*]

Now that we've reviewed some examples, take about 15 minutes to try the following two calculations; then we will work through the problem together.

Calculations

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

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

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.

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

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

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

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 $\frac{30\ \text{ml}}{\text{min}}$ 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.

This brings us to the end of unit 2. Before we move on, are there any questions? Let's begin the final Unit: Unit 3 – Advanced Formulas.

Point out that references for this unit are located on this page.

UNIT 3: <u>120 MINUTES</u>

Display Slide 13—Unit 3: Advanced Formulas.

At the end of this unit, you should be able to:

- Explain the following formulas and perform calculations using them: loading formula, chemical feed formulas, and the geometric mean formula.

- Correctly perform various process control, reporting and administrative calculations.

In Units 1 and 2, we discussed a few basic mathematical concepts and we learned how to perform area and volume calculations as well as unit cancellation. In this unit, we will discuss formulas that are used in the operation of a treatment plant.

The Application of Formulas in a Treatment Plant

In this next section, we are going to examine some of the basic functions and formulas you will encounter in your work at a treatment plant. Specifically, we will review the loading formula, chemical feed formulas and the geometric mean formula. Let's begin with the loading formula.

Loading Formula

[*Review the definition listed in the workbook.*]

[*Review the information in the workbook.*]

Let's take a look at an example of the loading formula.

[*Use flipchart to work through Example 1 in the workbook*.]

Now it's your turn to try a calculation using the loading formula.

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

Chemical Feed Formulas

The next formulas we will discuss are the dry and liquid chemical feed formulas. The formula for dry chemical feed is simply a modification of the loading formula. Like the loading formula, the dry chemical feed formula uses the flow and the 8.34 lbs/gal conversion factor. The difference between the loading and feed formulas is that the chemical feed formula uses the dose while the loading formula uses concentration. Calculating liquid chemical feed is slightly more complex and requires the use of multiple formulas.

[*Review the definition listed in the workbook*.]

[*Review the information in the workbook.*]

[*Continue to review the information in the workbook*.]

Let's take a look at an example of how we would use the liquid feed formulas.

[*Use flipchart to work through Example 1 in the workbook*.]

[*Review the note following the example*.]

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

Geometric Mean Formula

Our next formula is the geometric mean formula.

[*Review the defintion in the workbook*.]

[*Review the information in the workbook*.]

Examples 1 and 2 show how to calculate the geometric mean by using the n^{th} root method.

[*Use flipchart to work through Example 1 in the workbook. When reviewing the examples be sure to point out that the n^{th} root is calculated using a scientific calculator*.]

[*Use flipchart to work through Example 2 in the workbook*.]

[*Optional: divide the class into small groups of 2-4 people and have them work the calculations as a group*.]

There are two geometric mean calculations in your workbook for you to do. You have ten minutes to complete these calculations.

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: $(1502 \times 99 \times 460 \times 45 \times 590 \times 111 \times 385) = 7.760884 \times 10^{16}$
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.

In this next section, we will review some of the calculations you may need to perform as part of your process control, reporting and administration duties.

Process Control, Reporting and Administration

[*Review the information in the workbook*.]

Examples

This first example involves calculating chemical feed; a task you may frequently encounter as part of your job responsibilities.

[*Use flipchart to work through Example 1 in the workbook*.]

In the second example, the chemical feed calculation is still used, however, this time you need to manipulate the formula to calculate dosage.

[*Use flipchart to work through Example 2 in the workbook*.]

Example 3 deals with feed rate settings. Let's review the example.

[*Use flipchart to work through Example 3 in the workbook*.]

Example 4 requires us to calculate volume and then use that information for the loading formula.

[*Use flipchart to work through Example 4 in the workbook*.]

[*Finish working through Example 4 on the flipchart*.]

In addition to performing calculations using the loading, chemical feed and geometric mean formulas, there may be times when you are required to read an electric meter. In this section, we will talk about how that is done.

Reading an Electric Meter

[*Review the information in the workbook*.]

Now let's take a look at an example.

[*Review the example in the workbook*.]

Now try to read a meter on your own by doing the exercise in your workbook.

Exercise

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

Ans: 8642

Final Exercises

[Optional: For the final 3 exercises, divide the class into small groups of 2-4 people and have them work the calculations as a group.]

Now it is time for you to complete some final exercises that will require you to synthesize much of the information we have covered in the three units of this module. Let's begin with Exercise 1. You will have ten minutes to complete this exercise and then we will review the answers.

☑ 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

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

Next you will do exercise two. Again, you will have ten minutes to complete this exercise and then we will review the answers.

☑ 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.

Now it's time for the last exercise. You will have ten minutes to complete it.

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.

Labor Cost

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.

Chemical and Equipment Cost
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

Total Cost
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.

Cost per test for in house

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.

We have now completed the Basic Math module. Before I review the appendices included in this module, are there any questions regarding any of the material we have covered?

Appendix 1
Abbreviations/Conversions

On this page, you will find Appendix 1, which lists common abbreviations and conversions you may need to use when performing mathematical calculations. This has been provided as a reference tool for you to consult as needed.

Appendix 2
Key Definitions

Beginning on page A-2, you will see Appendix 2, which provides Key Definitions.

Appendix 3
Additional Advanced Formulas

Beginning on page A-3, you will see Appendix 3. In this appendix, you will find multiple formulas that are more advanced than those covered in this module. Many of these formulas will be used during your day-to-day duties as a treatment plant operator. On this first page of the appendix, you will find formulas for flow and grit channels.

On this page are formulas used for sedimentation tanks and clarifiers and trickling filters and rotating biological contactors.

The third page of this appendix lists formulas used when dealing with activated sludge and organic loading as well as chlorine calculations.

The next page of the appendix lists formulas used for chemical feed settings, liquid feed pump calibrations, and dry sludge calculations.

The last page of Appendix 3 lists additional formulas used for flow.

Appendix 4

DEP Chemical Feed Diagram

Liquid Chemical Feed

On page A-8, you will see Appendix 4. This appendix contains an example of the DEP chemical feed diagram for liquid feed.

[*If time permits, you may choose to review this material. Listed below are the steps needed to use the diagram.*]

[*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.*]

[*Point out that references for this unit are located on this page*.]