Wastewater & Drinking Water Operator Certification Training

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

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Unit 1 – Overview of Basic Math

Learning Objectives

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

General Math Concepts

Addition, Subtraction, Multiplication, and Division

1. Addition can be stated in the following way:

   A + B = C   Example: 1 + 2 = 3

2. Subtraction can be stated in the following way:

   A – B = C   Example: 5 – 2 = 3

3. Multiplication can be stated in all of the following ways:

A x B = C	Example: 3 x 5 = 15
A*B = C	3*5 = 15
(A)(B) = C	(3)(5) = 15
A(B) = C	3(5) = 15
AB = C	NA

4. Division can be stated in all of the following ways:

A / B = C	Example: 6 / 2 = 3
A ÷ B = C	6 ÷ 2 = 3
'Per' implies division such as milligrams per liter.	mg / L

Fractions and Decimals

Fractions are a means of expressing a part of a group and are typically written in the form of "a/b", with "a" being the numerator and "b" being the denominator. For example, the fraction 4/6 represents the shaded portion of the circle below:

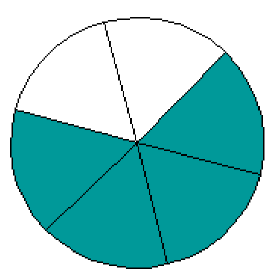


Figure 1.1 Example of a fraction

Addition and Subtraction of Fractions

If two fractions have the same denominator (bottom number), simply add or subtract the numerators (top numbers) and carry over the denominator:

$$\frac{A}{D} + \frac{B}{D} = \frac{C}{D} \qquad \text{Ex:} \quad \frac{2}{7} + \frac{3}{7} = \frac{5}{7}$$

If the denominators are not the same, the fractions cannot be added or subtracted until the denominators are made equal by finding a common multiple. To find a common multiple, first see if one denominator is a multiple of the other. If so, use the larger number as the common denominator:

Example 1: $\frac{4}{12} - \frac{1}{4} = \;\Rightarrow\; \frac{1}{4} \times \frac{3}{3} = \frac{3}{12} \;\Rightarrow\; \frac{4}{12} - \frac{3}{12} = \frac{1}{12}$

Note that [12 ÷ 4 = 3]. Since 12 is a multiple of 4, it can be used as the common denominator. Remember that in order to keep the value of the fraction the same you must multiply the entire fraction (1/4) by 3.

If the denominators are not the same and neither one is a multiple of the other, then multiply them together to find the common denominator.

Example 2: $\frac{1}{7} + \frac{1}{5} = \;\Rightarrow\; \frac{1}{7} \times \frac{5}{5} = \frac{5}{35}$, $\frac{1}{5} \times \frac{7}{7} = \frac{7}{35} \;\Rightarrow\; \frac{5}{35} + \frac{7}{35} = \frac{12}{35}$

7 x 5 = 35

Multiplication of Fractions

$$\frac{E}{C} \times \frac{F}{D} = \frac{EF}{CD}$$

To find the product of two fractions, multiply the numerators. Then multiply the denominators. Next, place the product of the numerators over the product of the denominators and simplify the fraction if possible.

Example 1:

$$\frac{4}{5} \times \frac{2}{3} = \frac{8}{15}$$

Division of Fractions

$$\frac{\frac{E}{F}}{\frac{C}{D}} = \frac{E}{F} \times \frac{D}{C} = \frac{ED}{FC}$$

To divide two simple fractions, invert (ie. flip over) the denominator; then multiply the fractions. Follow the rules for the multiplication of fractions.

Example 1:

$$\frac{\frac{5}{6}}{\frac{7}{8}} = \frac{5}{6} \times \frac{8}{7} = \frac{40}{42} = \frac{20}{21}$$

Converting Fractions to Decimals

When performing calculations using a fraction, it is typically more convenient to convert the fractions into decimals first. This is done by dividing the numerator by the denominator.

Example 1:

Convert 5/11 into a decimal.

Answer: 0.454545454545

Example 2:

Convert 73/15 into a decimal.

Answer: 4.866666666

Addition and Subtraction of Decimals

Adding and subtracting decimals is basically the same as adding and subtracting whole numbers. Just be sure to line up the terms so that all the decimal points are in a vertical line.

Example 1:

345.67 + 23.193 =

```
  345.67
+  23.193
  368.863
```

Multiplication of Decimals

Multiply the numbers just as if they were whole numbers. The number of decimal places to be used in the answer is equal to the sum of the decimal places in each number being multiplied.

Example 1:

4.52 x 1.3 =

```
   4.52   ( 2 decimal places)
 x  1.3   ( 1 decimal place)
   1356
 + 452
  5.876   ( 3 decimal places)
```

Division of Decimals

Division of decimals is similar to division of whole numbers. If necessary, make the divisor into a whole number by moving the decimal point to the right end of the divisor. Then move the decimal point of the dividend to the right the same number of places adding zeroes as needed. Now divide the numbers.

Example 1:

6 ÷ 0.24 =
(dividend) (divisor)

$0.24 \overline{)6.00} \longrightarrow 24\overline{)600} \longrightarrow$

```
      25
24 | 600
    - 48
     120
    -120
       0
```

Example 2:

0.24 ÷ 6 =
(dividend) (divisor)

$6\overline{)0.24} \longrightarrow$

```
    0.04
6 | 0.24
   -0.24
       0
```

Converting Decimals to Fractions

Sometimes it will be necessary to convert a decimal into a fraction. A decimal can be multiplied and divided by 1 without changing its value.

Example 1:

What is 0.8 expressed as a fraction?

$$\frac{0.8}{1} \times 1 = \left\{\frac{0.8}{1} \times \frac{10}{10}\right\} = \frac{8}{10} = \frac{(2 \times 4)}{(2 \times 5)} = \frac{2}{2}\left\{\frac{4}{5}\right\} = 1\left\{\frac{4}{5}\right\} = \frac{4}{5}$$

Answer: 4/5

Example 2:

What is 0.33 expressed as a fraction?

$$\frac{0.33}{1} \times 1 = \left\{ \frac{0.33}{1} \times \frac{100}{100} \right\} = \frac{33}{100} = \frac{(33 \times 1)}{(33 \times 3.03)} = \frac{33}{33} \left\{ \frac{1}{3.03} \right\} = 1 \left\{ \frac{1}{3.03} \right\} = \frac{1}{3}$$

Answer: 1/3

Calculations

1. 6/10 – 2/5 =

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

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

4. 5/9 ÷ 4/11 =

5. Convert 27/4 to a decimal.

6. Convert 0.45 to a fraction.

7. 4.27 x 1.6 =

8. 6.5 ÷ 0.8 =

9. 12 + 4.52 + 245.621 =

Basic Rules for Performing Calculations

There are four general rules to remember when performing calculations:

- Rule 1: Perform calculations from left to right.
- Rule 2: Perform all arithmetic within parentheses prior to arithmetic outside the parentheses
- Rule 3: Perform all multiplication and division prior to performing all addition and subtraction.
- Rule 4: For complex division problems, follow the previous rules starting with parenthesis. Next perform all multiplication and division above the line (in the numerator) and below the line (in the denominator); then proceed with the addition and subtraction. Finally divide the numerator by the denominator.

Example 1:

18 + 73 – 45 + 32 = 78

Example 2:

(312 x 4) + (27 x 9) = 1248 + 243 = 1,491

Example 3:

$$\frac{385 + (21/7) - (5 \times 13 \times 4)}{17 + 11 - (6 \times 4)} = \frac{385 + 3 - 260}{28 - 24} = \frac{128}{4} = 32$$

Calculations

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

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

Calculating Percentages

A percentage is equal to a part divided by the whole times 100. For example, there are 40 chlorine bottles at a treatment plant. If 24 of them are empty, what percentage is full?

Total – Empty = Full; 40 – 24 = 16 full bottles
(16 ÷ 40) x 100% = 40%

<u>Answer</u>: 40% (16 bottles)

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?

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

Rules for Rounding for Compliance Purposes

> *<u>Note</u>: Data reported to the State or EPA should be in a form containing the same number of significant digits as the NPDES permit limits or the NIPDWR MCL's.*

Rounding Decimals

Find the place value you want (the "rounding digit") and look at the digit just to the right of it.

- If that digit is less than 5, do not change the rounding digit but drop all digits to the right of it.
- If that digit is greater than or equal to 5, add one to the rounding digit and drop all digits to the right of it.

Example 1:

Round 3.234 to one decimal place= 3.2

Example 2:

Round 2.45 to one decimal place = 2.5

Round 2.449 to one decimal place = 2.4

Round 2.55 to one decimal place = 2.6

Rounding Whole Numbers

Find the place value you want (the "rounding digit") and look to the digit just to the right of it.

- If that digit is less than 5, do not change the rounding digit but change all digits to the right of the rounding digit to zero.
- If that digit is greater than or equal to 5, add one to the rounding digit and change all digits to the right of the rounding digit to zero.

Example 1:

Round 5,763 to the nearest hundred = 5,800

Example 2:

Round 25.501 to a whole number = 26

Example 3:

Round 16.499 to a whole number = 16

Calculations

1. Round 9.875 to two decimal places.

2. Round 9,637 to the nearest thousand.

3. Round 9,637 to the nearest hundred.

4. Round 9,637 to the nearest tens.

Multiplication of Units

Multiplication is used to express the relationship among area and volume.

Example 1:

The following is an example of how to multiply units to express area:

2 feet x 3 feet = 6 square feet

Example 2:

The following are examples of how to multiply units to express volume:

2 square feet x 5 feet = 10 cubic feet
3 feet x 2 feet x 4 feet = 24 cubic feet

Calculations

1. 9 feet x 3 feet

2. 8 feet x 3 feet x 0.5 feet

Metric System

The Metric System is the most commonly used system of weights and measures around the world and used almost exclusively in the scientific community. It utilizes both prefixes and symbols to describe values in magnitudes of ten.

Prefixes and Symbols

Prefix	Symbol	Meaning
Micro-	µ	0.000 001
Milli-	m	0.001
Centi-	C	0.01
Deci-	D	0.1
Unit		1
Deca-	Da	10
Hecto-	H	100
Kilo-	K	1,000
Mega-	M	1,000,000

Note: These prefixes are used in conjunction with the metric units of Gram (weight), Liter (volume) and Meter (length).

Converting within the Metric System

Sometimes it will be necessary to convert between different magnitudes of a unit. For instance, how many centimeters are in two meters?

$$2 \text{ m} \times \frac{100 \text{ cm}}{1 \text{ m}} = 200 \text{ cm}$$

Example 1:

A 300 milliliter BOD bottle contains how many liters of sample?

Answer:

$$\#\text{liters} = 300 \text{ mL} \times \frac{1 \text{ L}}{1{,}000 \text{ mL}} = 0.3 \text{ L}$$

Converting between the English and Metric systems.

Length

The metric unit of length is the Meter, which is equal to 3.28 feet.

Example 1:

A tank is 160 feet long. What is the equivalent length in meters?

Answer:

$$\text{Length in meters} = \frac{160 \text{ feet}}{3.28 \text{ feet/meter}}$$

Length in meters = 48.78 meters

Volume

The metric unit of volume is the Liter, which is equal to 0.264 gallons.

Example 1:

How many liters are contained in a 55-gallon drum?

Answer:

$$\text{\# of liters} = \frac{55 \text{ gallons}}{0.264 \text{ gal/liter}}$$

# of liters = 208 liters

Weight

The metric unit of weight is the Gram, which is equal to 0.0022 pounds.

Example 2:

How many kilograms does a 100 pound bag of polymer weigh?

Answer:

Step 1: First, calculate the weight of the polymer in grams:

$$\text{Weight of polymer in grams} = \frac{\text{100 lbs polymer}}{\text{0.0022 pounds/gram}}$$

Weight of polymer in grams = 45454.54 grams

Step 2: Next, convert the weight of the polymer from grams to kilograms, using the conversion factor of 1 kilogram equals 1,000 grams.

$$\text{Weight of polymer in kilograms} = \frac{\text{weight in grams}}{\text{1,000 grams/kilogram}}$$

$$\text{Weight of polymer in kilograms} = \frac{\text{45454.54 grams}}{\text{1000 grams/kilogram}}$$

Weight of polymer in kilograms = 45.45 kilograms

Temperature

The metric unit of temperature is Celsius. Temperature can also be measured in Fahrenheit. Water boils at 100 °C or 212°F. The conversion formulas are as follows:

- To convert from Celsius to Fahrenheit , use the following formula:
  $$\text{Fahrenheit} = \left(°C \times \frac{9}{5}\right) + 32°$$

- To convert from Fahrenheit to Celsius, use the following formula:
  $$\text{Celsius} = (°F - 32°) \times \frac{5}{9}$$

Example:

If the body temperature is 97°F, what is the equivalent Celsius temperature?

Answer:

$$\text{Celsius} = (°F - 32°) \times \frac{5}{9}$$

$$\text{Celsius} = (97°F - 32°) \times \frac{5}{9}$$

$$\text{Celsius} = (65) \times \frac{5}{9}$$

$$\text{Celsius} = 36.1°$$

Unit 1 Exercise

1. Round 987.5321:

   A.) To the nearest tens place.
   B.) To the nearest hundredths place.

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

3. 3/4 - 1/8 =

4. 25 + 101.53 + 0.479 =

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?

6. What is 0.22 expressed as a fraction?

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?

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

Unit 2 – Basic Formulas and Methods

Learning Objectives

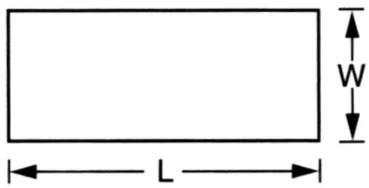
- Calculate the area of a rectangle, triangle, circle and cylinder.
- Calculate the volume of a rectangle, cone and cylinder.
- Understand how to perform Unit Cancellation.

Area

Area computations are of plain or two-dimensional surfaces without any depth. They are used routinely in the operation of a treatment plant. The following presents several computations for areas of different shapes. In each case, the final area is expressed in square feet.

Rectangle

The **area of a rectangle** is expressed as the length multiplied by the width, or as A = L x W.



A = L x W

Figure 2.1 The area of a rectangle[1]

- Area is expressed in units squared (i.e. square feet).
- Both length and width must be in the same units.
- The measurements, if not in the same units, must be converted to the appropriate units prior to performing the calculation.

Example 1:

How many square feet of grass will need to be mowed if a lawn is 275 feet long and 65 feet wide?

Answer: A = L x W
A = 275 feet x 65 feet
A = 17,875 square feet

Example 2:

How much area is consumed by a control building that is 250 feet long, 110 feet wide and two stories tall?

Answer: A = L x W
A = 250 feet x 110 feet
A = 27, 500 square feet

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.

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

Triangle

The **area of a triangle** is expressed as the length of the base of the triangle multiplied by the height of the triangle divided in half, or as A = ½ B x H.

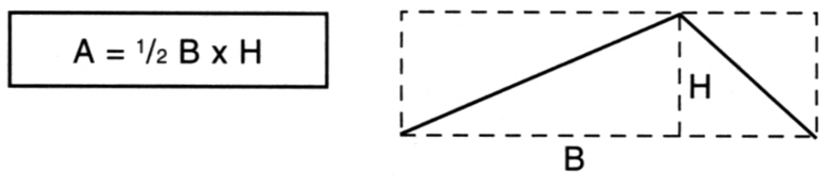


Figure 2.2 The area of a triangle[2]

> Example 1:
>
> Find the area of a triangle if the base is 5 feet and the height is 4 feet.
>
> Answer: A = ½ B x H
> A = ½ (5 feet x 4 feet)
> A = ½ (20 square feet)
> A = 10 square feet

Calculations

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

Circle

The **area of a circle** is expressed as $A = \pi R^2$ or $A = 0.785D^2$, where π is the Greek letter pi (pronounced pie), R = the radius and D = the diameter.

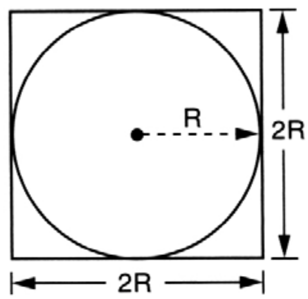


Figure 2.3 The area of a circle[3]

Pi is a constant that is used in many calculations involving circles and spheres. It is commonly approximated as 3.14. If accuracy becomes more critical, a closer approximation is 3.142857.

The **diameter** of a circle is the distance across the circle at its widest point. If the diameter of a circle is doubled, the area increases by a factor of four. The **radius** is equal to one-half of the diameter.

Example 1:

If a hose is 8 inches in diameter, what is the area?

Answer: $A = \pi R^2$
$A = (3.14)(4 \text{ inches})^2$
$A = (3.14)(16 \text{ square inches})$
$A = 50.2$ square inches

Example 2:

If the hose is doubled in size, what is the resultant area?

Answer: $A = \pi R^2$

$A = (3.14)\ (8 \text{ inches})^2$

$A = (3.14)\ (64 \text{ square inches})$

$A = 201 \text{ square inches}$

If expressed in square feet, the area is:

$A = \pi R^2$

$A = (3.14)\ (0.66 \text{ feet})^2$

$A = (3.14)\ (.4356 \text{ square feet})$

$A = 1.4 \text{ square feet}$

Cylinder

The **area of a cylinder** is expressed by combining two formulas: the area of a circle (πR^2) and the length of a circle ($\pi \times D$).

The area of a cylinder is calculated in several steps.

- The area of the top and/or bottom of the cylinder is calculated as the area of a circle, which is (πR^2).
- Next, the length of the circle is calculated so it can be multiplied by its height (H) to establish its area. This is done using the formula ($\pi \times D$).

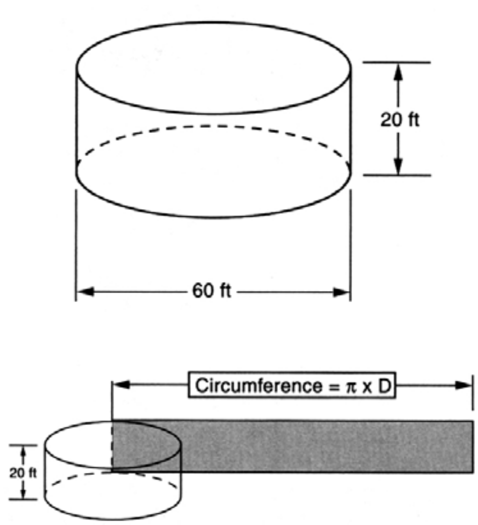


Figure 2.4 The area of a cylinder[4]

Example 1:

What is the surface area of a tank top with a 30 foot radius?

Answer: $A = \pi R^2$
$A = (3.14)\ (30\ \text{feet})^2$
$A = (3.14)\ (900\ \text{feet})$
A = 2,826 square feet

[*Note: If this is calculated using a calculator with* π *, the answer will be 2,827 square feet*.]

Example 2:

A steel tank with a roof is located on concrete pads and needs to be repainted. The tank is 50 feet in diameter and 12 feet high. How many square feet of surface area is exposed that would need to be repainted?

Answer: First, calculate the area of the top of the tank surface:
$A = \pi R^2$
$A = (3.14)\ (25\ \text{feet})^2$
A = (3.14) (625 square feet)
A = 1,962 square feet

Next, the area of the sides of the tank needs to be calculated:
$A = \pi \times D \times H$
A = (3.14) (50 feet) (12 feet)
A = 1,884 square feet

Next, both values are added together:
1,962 square feet + 1, 884 square feet = 3,846 square feet

[*Note: If this is calculated using a calculator with* π*, the answer will be 3,848 square feet.*]

Calculations

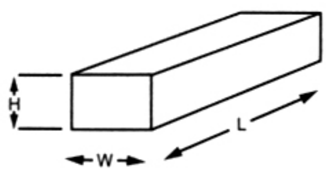
1. Treatment Plant X is planning to build a new aerobic digester with a diameter of 80 feet and a height of 30 feet. Calculate the total surface area of the new tank.

Volume

Volume is a measurement of the holding capacity of an object. These computations introduce a third dimension and are expressed in cubic units.

Rectangular

The **volume of a rectangular area**, such as a tank, is calculated by multiplying the length by the width by the height, or, V = L x W x H.



V = L x W x H

Figure 2.5 The volume of a rectangle[5]

- The volume can also be expressed as the area of the base multiplied by the height.
- The clarifier surface loading rate or a clarifier weir loading rate can be determined if the flow and the tank dimensions are known.
- The area is expressed in units cubed (i.e. cubic feet). All three measurements (length, width and height) must be in the same units and should be converted to the appropriate unit prior to performing the volume calculation.

Example 1:

Find the volume, in cubic feet, of an aeration tank which is 265 feet long, 25 feet wide and 14 feet deep.

Answer: V = L x W x H
V = (265 feet) (25 feet) (14 feet)
V = 92,750 cubic feet

Now calculate the volume of the tank in gallons. Note: 1 ft^3 = 7.48 gallons.

Answer: V in gallons = (92,750 cubic feet) x $\frac{7.48 \text{ gallons}}{\text{Cubic foot}}$
V = 693,770 gallons

If the tank is being drained at a constant rate of 450 gallons per minute (gpm), how long will it take, in both minutes and in hours, to drain the tank?

Answer: drain time = $\frac{693{,}770 \text{ gallons}}{450 \text{ gpm}}$
drain time = 1,542 minutes
drain time = 1,542 minutes x $\frac{1 \text{ hour}}{60 \text{ minutes}}$
drain time = 25.7 hours

Example 2:

A 500,000 gallon rectangular tank is 45 feet wide by 110 feet in length. If the flow into the tank is 10,000 gpm and an effluent weir is located along the 45 foot wide side, how many gallons per minute are flowing over one foot of weir?

Answer: $\frac{10{,}000 \text{ gpm}}{45 \text{ feet}}$ = 222 gpm/ft

Calculations

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

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?

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?

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?

Conical

The **volume of a cone** is expressed as 1/3 the volume of a circular cylinder of the same height and diameter or as $V = \frac{\pi}{3} R^2 \times H$

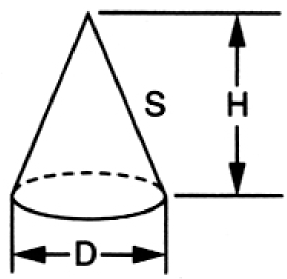


Figure 2.6 The volume of a cone[6]

Example 1:

Calculate the volume of a cone if the height at the center is 4 feet and the diameter is 100 feet.

Answer:

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

$\text{Volume} = \frac{(3.14)}{3} (50\text{ feet})^2 (4\text{ feet})$

Volume = (1.05) (2,500 square feet) (4 feet)

Volume = 10,500 cubic feet

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?

Cylindrical

The **volume of a cylinder** is expressed as the area of the base multiplied by the height or as $V = \pi R^2 \times H = 0.785 D^2 \times H$.

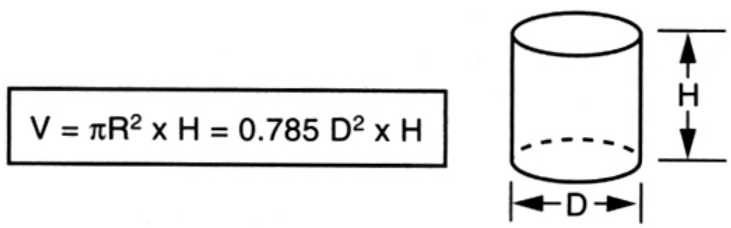


Figure 2.7 The volume of a cylinder[7]

Example 1:

What is the capacity, in gallons, of an aerobic digester that is 40 feet in diameter and 20 feet tall?

Answer: $V = \pi R^2 \times H$

$V = (3.14)\ (20\ \text{feet})^2 \times 20\ \text{feet}$

$V = (3.14)\ (400\ \text{square feet})\ (20\ \text{feet})$

$V = (3.14)\ (8000\ \text{square feet})$

$V = 25{,}120\ \text{cubic feet}$

$V = 25,\ 210\ \text{cubic feet} \times \dfrac{7.48\ \text{gallons}}{\text{r cubic foot}}$

$V = 187{,}898\ \text{gallons}$

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?

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

Unit Cancellation Method

The **Unit Cancellation Method** is a means of converting units by multiplying values by appropriate ratios. The numerator and denominator of the ratio should always contain equivalent values, expressed in different units.

Basic Rules and Hints:

1. Unit fractions should be written in a vertical format. A unit fraction has **one** unit in the numerator (above the line) and **one** unit in the denominator (below the line).

   A fraction is structured like this: $\frac{\text{numerator}}{\text{denominator}}$

   For example, GPM should be written as $\frac{\text{gal}}{\text{Min}}$ Note that "per" means divided by.

2. Any unit which appears in the **numerator** of one unit fraction and the **denominator** of another unit fraction should be canceled.

   The following is an example of how units are canceled:

   $$20\ \frac{\text{gal}}{\cancel{\text{min}}} \quad \times \quad 60\ \frac{\cancel{\text{min}}}{\text{hr}} = 1200\ \frac{\text{gal}}{\text{hr}}$$

3. It may be necessary to invert data and the corresponding units.

   $$10\ \frac{\text{gal}}{\text{min}} = \frac{1\ \text{min}}{10\ \text{gal}}$$

Caution: When you invert, make sure to keep numerical values with their original units. In the above example, the 10 stays with the gallons and is moved to the denominator.

Steps to solving problems using unit cancellation

Example 1: How many mL/min are in a flow of 5gal/day?

Step 1: List all unknown data including units in vertical format followed by an equal sign.

Example 1: Unknown data: $? \frac{\text{mL}}{\text{min}} =$

NOTE: You may need to invert data throughout the following steps.

Step 2: Place data (known or a conversion) that has the same numerator unit as the unknown numerator to the right of the equal sign. Add a multiplication sign. This positions your numerator.

Example 1: $? \ \frac{\text{mL}}{\text{min}} = 3785 \ \frac{\text{mL}}{\text{gal}}$

Step 3: To cancel unwanted denominator unit, place data (known or a conversion) that has the same numerator unit. Place a multiplication sign between each piece of data.

Example 1: $? \ \frac{\text{mL}}{\text{min}} = 3785 \ \frac{\text{mL}}{\cancel{\text{gal}}} \times \frac{5 \ \cancel{\text{gal}}}{1 \text{ day}}$

Step 4: Continue to place data (known or a conversion) into the equation to systematically cancel all unwanted units until only the unknown units remain.

Example 1: $? \ \frac{\text{mL}}{\text{min}} = 3785 \ \frac{\text{mL}}{\cancel{\text{gal}}} \times \frac{5 \ \cancel{\text{gal}}}{\cancel{\text{day}}} \times \frac{1 \ \cancel{\text{day}}}{1440 \text{ min}}$

Note 1: All units must cancel, leaving only the units you are solving for in the unknown data. If all units except the unknown units are <u>not</u> crossed out, check the list of known data to see if all relevant known data was used to solve the problem and all necessary conversions were made.

Note 2: If you need to invert the known data or conversion values and units to cancel, remember to carry the value with the appropriate unit.

Step 5: Multiply the values of all numerators and place this value in the numerator of the answer. Multiply the values of all denominators and place this value in the denominator of the answer. Divide to calculate the final answer.

Important: Check the answer to verify that the value is reasonable.

Example 1: $? \ \frac{\text{mL}}{\text{min}} = \frac{18{,}925 \ \text{mL}}{1440 \ \text{min}} = 13.1 \ \frac{\text{mL}}{\text{min}}$

Example 2:

How many meters long is a football field?

Answer:

$$\frac{100\ \cancel{\text{yards}}}{1} \times \frac{3\ \cancel{\text{feet}}}{1\ \cancel{\text{yard}}} \times \frac{1\ \text{meter}}{3.28\ \cancel{\text{feet}}} = 91.4\ \text{meters}$$

Calculations

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

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

[1] Kenneth D. Kerri, "Applications of Arithmetic to Collection Systems," in *Operation and Maintenance of Wastewater Collection Systems, A Field Study Training Program Volume I*, (Sacramento, CA: California State University, Sacramento Foundation, 1999), p. 560.

[2] Kerri, p.560.

[3] Kerri, p.560.

[4] Kerri, p. 561.

[5] Kerri, p. 562.

[6] Kerri, p. 562.

[7] Kerri, p. 562.

Unit 3 – Advanced Formulas

Learning Objectives

- Explain the following formulas and perform calculations using them: loading formula, chemical feed formulas, arithmetic mean (or average) and the geometric mean formula.
- Correctly perform various process control, reporting and administrative calculations.

The Application of Formulas in a Treatment Plant

In addition to solving area and volume calculations, operation of a water or wastewater facility involves using mathematical computations to ensure the proper operation of various processes, such as:

- Detention times.
- Rates - chemical feed, loading, and flow.
- Preparation of reports.

Loading Formula

The **loading formula** is used to evaluate how much of a particular substance is being applied to a treatment unit during a specific time period. It is a general formula that can be modified to address a variety of processes including but not limited to aerator loading and applied solids. The formula is:

Loading, lbs/day = (Flow, MGD) x (Concentration, mg/L) x (8.34 lbs/gal)

- One gallon of water weighs 8.34 lbs.
- Flow must always be in million gallons per day (MGD) for the above formula.

Example 1: (Note: This example of the Loading Formula will address Total Suspended Solids)

How many pounds per day of total suspended solids (TSS) are in the 0.122 million gallons per day (MGD) influent waste stream which has a TSS concentration of 234 mg/L?

Answer:

Loading (TSS), lbs/day = (Flow, MGD) (Concentration, mg/L) (8.34 lbs/gal)
TSS, lbs/day = (0.122 MGD) (234 mg/L) (8.34 lbs/gal)
TSS, lbs/day = 238 lbs/day

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?

Chemical Feed Formulas

The **chemical feed formulas** indicate how many gallons or pounds of chemical are added to a treatment system.

Dry chemical feed means you are adding a dry chemical product directly into the plant flow. The dry feed formula is a variation of the loading formula:

Dry Feed Rate, lbs/day = (Flow, MGD) x (Dose, mg/L) x (8.34 lbs/gal)

Liquid chemical feed calculations require additional steps and information. The liquid feed formula is a two-step variation of the dry feed formula:

Step 1: Dry Feed Rate, gal/day = (Flow, MGD) x (Dose, mg/L) x (8.34 lbs/gal)

Step 2: Liquid Feed Rate, gal/day = (Dry Feed Rate, lbs/day) ÷ (Active Strength, lbs/gal)

- *Special Considerations* – Often times, you will not be using chemicals that are full strength and/or the specific gravity of a chemical will be given instead of the active strength, in which case the following formula can be used to calculate the active strength:

  Active Strength, lbs/gal = (specific gravity of the chemical) x (8.34 lbs/gal-density of water) x (% Strength of the solution ÷ 100)

Example 1:

An operator wants to disinfect a 500,000 gallon storage tank and maintain a residual of 100 mg/L for a period of 24 hours. Assume there is a possible chlorine demand of 15 mg/L. If the operator uses 12.5% sodium hypochlorite, how many gallons will be needed? Use a specific gravity of 1.17 for the sodium hypochlorite solution.

Answer:

Step 1: Calculate the chlorine dose.

Chlorine dose, mg/L = (Chlorine Residual, mg/L) + (Chlorine Demand, mg/L)
= 100 mg/L + 15 mg/L
= 115 mg/L

Step 2: Calculate the Dry Feed rate as if using a 100% strength solution:

Sodium Hypochlorite, lbs/day = (Flow, MGD) (Dose, mg/L) (8.34 lbs/gal)
= (0.5 MGD) (115 mg/L) (8.34 lbs/gal)
= 479.6 lbs/day

Step3: Using the specific gravity, calculate the active strength of the solution:

Active Strength, lbs/gal = (Specific Gravity) x (density of water, 8.34 lbs/gal) x (% strength solution ÷ 100)
= (1.17) x (8.34 lbs/gal) x (12.5 ÷ 100)
= 1.22 lbs/gal

Step 4: Calculate the Liquid Feed rate:

Sodium Hypochlorite, gal/day = (Dry Feed Rate, lbs/day) ÷ (Active Strength, lbs/gal)
= (479.6 lbs/day) ÷ (1.22 lbs/gal)
= 393.2 gal

Note: Reliance on formulas has been the reason for much of the confusion and difficulty people have had with chemical feed calculations, especially when they try to do liquid feed problems. To overcome some of the common difficulties associated with these calculations, Pa. DEP has developed diagrams to help you work through feed calculations. For an example of the liquid feed diagram, please see Appendix 4. Your instructor may review the diagram at the end of the course if time permits.

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.

Arithmetic Mean Formula (or Average)

The **Arithmetic Mean** = $X_1 + X_2 + X_{3\ldots}X_n)/n$ where X is the sample value and n is the number of samples. This formula is more commonly known as the average.

Example 1:

What is the average concentration of the following TSS samples (the average monthly permit limit for TSS is 30 mg/L): 29, 24 and 28?

Answer:

Using the arithmetic mean method, the answer is derived as follows:

Step 1: Add all the values (X_1, $X_2 \ldots X_n$) together.

29 + 24 + 28 = 81

Step 2: Determine the number of tests done. In this example, the number of tests was 3, so n = 3.

Step 3: Take the sum of the sample values and divide by the number of samples.

81/3 = 27 mg/L TSS

Geometric Mean Formula

The **Geometric Mean** = $\sqrt[n]{(X_1 \times X_2 \times X_3 \times \ldots X_n)}$ <u>or</u> $(X_1 \times X_2 \times X_{3\ldots}X_n)^{1/n}$ where X is the sample value and n is the number of samples. This formula is also known as the n^{th} root method.

- The Geometric Mean is only for fecal coliform counts. It can be used for the plant effluent or when performing coliform testing on digested treated plant sludge.

The n^{th} Root Method

Example 1:

What is the geometric mean of 10, 100 and 1,000?

Answer:

Using the n^{th} root method, the answer is derived as follows:

Step 1: Multiply all the values (X_1, X_2…X_n) together.

(10) (100) (1000) = 1,000,000

Step 2: Determine the number of tests done. In this example, the number of tests was 3, so n = 3.

Step 3: Take the 3^{rd} root of the final multiplied number.

$\sqrt[3]{1{,}000{,}000} = 100$ Or $(100{,}000)^{1/3} = 100$

Example 2:

What is the geometric monthly fecal coliform mean of a treatment plant with the following FC counts: 321 colonies/100 ml, 627, 113, 4876 and 251? What is the value rounded to an integer or whole number?

Answer:

Using the n^{th} root method, the answer is derived as follows:

Step 1: Multiply all the values together.

(321) (627) (113) (4876) (251) = $2.783482115 \times 10^{13}$

Step 2: Determine the number of tests done. In this example, the number of tests was 5, so n = 5.
Step 3: Take the 5^{th} root of the multiplied number.

$\sqrt[5]{(2.783482115 \times 10^{13})} = 488.5597$ Or $(2.783482115 \times 10^{13})^{1/5} = 488.5597$

Using only the integer value of this number, the final answer then becomes 488.

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.

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

Process Control, Reporting and Administration

The loading through a treatment plant should be equally divided among the units if all units are the same capacity.

To determine the efficiency of a specific treatment unit, the influent and effluent concentrations for the same parameter must be known.

Example 1:
An operator wants to dose a treatment unit with a flow of 0.25 MGD to a level of 4.5 mg/L with a specific chemical. If the chemical is 100% pure, how many pounds should be added?
Active Strength, lbs/gal = (specific gravity of the chemical) x (the density of water, 8.34 lbs/gal) x (% Strength of the solution ÷ 100)
Answer:

Chemical Feed, lbs/day = (Flow, MGD) (Dose, mg/L) (8.34 lbs/gal)
= (0.25 MGD) (4.5 mg/L) (8.34 lbs/gal)
= 9.38

If the concentration strength of the chemical is 12%, which weighs approximately 9.7 pounds per gallon, how many gallons will be necessary?

Answer:
First calculate the active strength (Note: 9.7 lbs/gal = the specific gravity x 8.34 lbs/gal-density of water):

Active Strength, lbs/gal = (specific gravity of the chemical) x (8.34 lbs/gal-density of water) x (% Strength of the solution ÷ 100

Active Strength, lbs/gal = 9.7 lbs/gal x (12% ÷ 100)
= 1.164 lbs/gal

Gallons of sodium hypochlorite = 9.38 lbs/day ÷ 1.164 lbs/gal
= 8.06 gal/day

Example 2:

The flow through a treatment unit is 1.25 MGD and the amount of chemical feed is 30 pounds per day. What is the dosage?
Answer:

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

$$\text{Dose, mg/L} = \frac{\text{Chemical Feed, lbs/day}}{\text{(Flow, MGD) (8.34 lbs/gal)}}$$

$$\text{Dose, mg/L} = \frac{\text{30 lbs/day}}{\text{(1.25 MGD)(8.34 lbs/gal)}}$$

$$\text{Dose, mg/L} = \frac{30}{10.425}$$

Dose, mg/L = 2.88

Example 3:

An operator weighs the amount of chemicals dispensed by a metering system for 10 minutes. The amount is 1.2 pounds and the control is set at 35%. Assume a linear output by the feed system. What is the calculated set point for a feed rate of 200 pounds per day?

Answer:
If 1.2 pounds of chemical are dispensed per 10 minutes, then 0.12 pounds are dispensed per minute.

If there are 24 hours per day, and 60 minutes per hour, then there are a total of 1440 minutes per day.

Chemicals dispensed per day = (0.12 pounds/minute) (1440 minutes/day)

Chemicals dispensed per day = 172.8 pounds/day

$$\text{Setting} = \frac{\text{Desired feed rate}}{\text{Current feed rate}} \times \text{setting \%}$$

$$= \frac{\text{200 lbs/day}}{\text{172.8 lbs/day}} \times \text{setting \%}$$

= (1.1574) (35%)

= 40%

Example 4:

A tank has the dimensions of 40 feet by 150 feet in length and an effective depth of 15 feet. If the suspended solids concentration in the tank is 3,000 mg/L, how many pounds of solids are in the tank?

Answer:

Step 1: Calculate the volume of the tank.
V = L x W x H
V = (150 feet) (40 feet) (15 feet)
V = 90,000 cubic feet

Step 2: Convert cubic feet into gallons.
gallons = 90,000 cubic feet x 7.48 gallons/cubic foot
gallons = 673,200 gallons, or 0.6372 MG

Step 3: Calculate the pounds of solids in the tank.
Loading, lbs/day = (Flow, MGD) (Concentration, mg/L) (8.34 lbs/gal)
= (0.6732 MGD) (3,000 mg/l) (8.34 lbs/gal)
= 16,843 pounds

If the tank is one of four aeration tanks in an activated sludge Wastewater Treatment Plant (WWTP), and the incoming BOD_5 is 175 mg/l at a total WWTP flow rate of 0.75 MGD what is the food to microorganism ratio?

Answer:

Step 1: Calculate the pounds of feed
Feed, lbs/day = (Flow, MGD) (Dose, mg/L) (8.34 lbs/gal)
Feed, lbs/day = (0.75 MGD) (175 mg/L) (8.34 lbs/gal)
Feed, lbs/day = 1,095 pounds

Step 2: Since the 1,095 pounds are distributed across four tanks, only 274 pounds of feed are used for one tank.

Step 3: Calculate the food to microorganism ratio.

$$\text{F/M ratio} = \frac{\text{Food, lbs}}{\text{Microorganism, lbs}}$$

$$\text{F/M ratio} = \frac{\text{274 lbs}}{\text{16,843 lbs}}$$

F/M ratio = 0.016

Example 4 – continued

If two of the aeration tanks are out of service, how much does the loading increase to the remaining two tanks?

Answer:

If there are only two tanks in service, then the 1,095 pounds of feed are distributed across 2 tanks, meaning each tank is fed 547.5 pounds.

$$\text{F/M ratio} = \frac{\text{Food, lbs}}{\text{Microorganism, lbs}}$$

$$\text{F/M ratio} = \frac{\text{547.5, lbs}}{\text{16,843 lbs}}$$

F/M ratio = 0.0325

Reading an Electric Meter

- ➢ Read from left to right.
- ➢ Record the smallest digit that the needle went past.
- ➢ Remember that the meter reads in kilowatt hours (kwh).

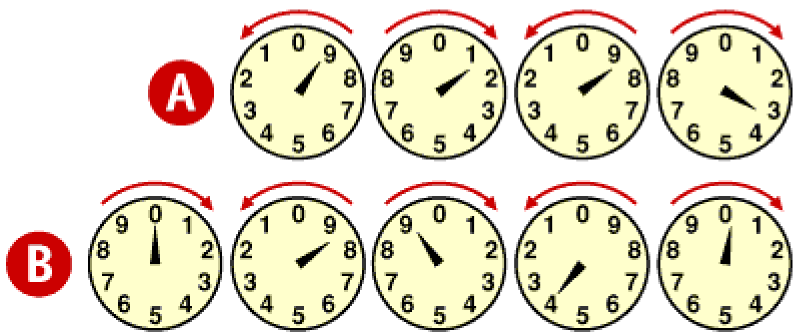


Figure 3.1 An Electric Meter [1]

Example 1:

What is the reading of Meter A in Figure 3.1?

Answer:

9183

What is the reading of Meter B in Figure 3.1?

Answer: 98940

☑ Exercise

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

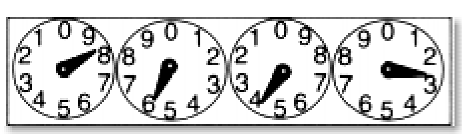


Figure 3.2 Electric Meter[2]

Final Exercises

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.

Exercise 1

1. How many cubic feet are in the tank?

2. How many gallons are in the tank?

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?

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

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.

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?

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

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?

☑ 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?

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

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

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

5. Calculate the removal efficiency for CBOD of the facility using the following formula:

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

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

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

☑ 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.

2. Discuss the advantages/disadvantages of both options.

Appendix 1
Abbreviations/Conversions

ac	acre	km	kilometer
ac-ft	acre-feet	kN	kilonewton
af	acre feet	kW	kilowatt
amp	ampere	kWh	kilowatt hour
^oC	degrees Celsius	L	liter
CFM	cubic feet per minute	lb	pound
CFS	cubic feet per second	lbs/sq in	pounds per square inch
cm	centimeter	m	meter
cu ft	cubic feet	M	mega
cu in	cubic inch	M	million
cu m	cubic meter	mg	milligram
cu yd	cubic yard	MGD	million gallons per day
^OF	degrees Fahrenheit	mg/L	milligrams per liter
ft	feet or foot	min	minute
ft-lb/min	foot pounds per minute	mL	milliliter
g	gravity	mm	millimeter
gal	gallon	N	Newton
gal/day	gallons per day	ohm	ohm
gm	gram	Pa	Pascal
GPD	gallons per day	ppb	parts per billion
gpg	grains per gallon	ppm	parts per million
GPM	gallons per minute	psf	pounds per square foot
gr	grain	psi	pounds per square inch
ha	hectare	psig	pounds per square inch gage
hP	horsepower	RPM	revolutions per minute
hr	hour	sec	second
in	inch	sq ft	square foot
k	kilo	sq in	square inches
kg	kilogram	W	watt

1 cu ft H_2O	7.48 gal	1 MGD	694 gpm	1 liter	0.264 gal	1 kilowatt	1.34 hp
1 gal H_2O	8.34 lbs	1 MGD	1.547 cfs	1 cu meter	264 gal	0.746 KW	1 hp
1 cu ft H_2O	62.37 lbs	1 liter/sec	15.85 gpm	1 gal	3.785 liter	1 hp	550 ft-lb/sec
231 cu in	1 gal	1 cu meter/sec	22.83 MGD	1 meter	3.28 feet	1 psi	2.31 feet H_2O
27 cu ft	1 cu yd	1 kilogram	2.2 lbs	1 centimeter	0.394 inch	64.7 grains	1 mg
1 % solids	10,000 mg/l	454 gram	1 lb	1 acre	43,560 sq ft	1 grain/gal	17.1 mg/l

Appendix 2
Key Definitions

Area is the number of square units that covers a shape or figure.

A **Decimal point** is used to represent numbers that are not whole numbers. It is used to indicate the portion of something which does not make up a whole unit.

The **denominator** is the expression written below the line in a fraction. It indicates the number of parts into which one whole is divided.

Density is how much a certain volume of something weighs. Density of a liquid is calculated by dividing the weight of the liquid by its volume. In the metric system, the density of water is always 1.

The **diameter** is the longest distance from one end of a circle to the other.

A **fraction** is an expression that indicates the quotient of two quantities, such as 1/3.

An **integer** is the whole portion of a number. It does not include any part of the decimal, which could be part of the number. For example, if a number is 25.33, the integer is 25.

The **numerator** is the expression written above the line in a fraction. It indicates the number of parts of the whole.

The **radius** is the distance from the center of a circle to any point on the circle. It is equal to one-half of the diameter.

Rounding is a technique used in conjuction with significant figures to properly reflect the accuracy of a measurement. When rounding, you adjust a value to properly reflect its intended usage.

Specific gravity is a term used in chemical feed that refers to the density of a substance compared to the density of water. In the metric system, specific gravity is equal to density. In the English system it is calculated by dividing the density of a substance by the density of water.

Volume is a measurement of space or capacity.

Appendix 3
Additional Advanced Formulas

The following formulas are typical of those used in the day-to-day operation of a treatment plant. In each case it is important that the proper units of value are used throughout the computation to assure that the final outcome is presented in the proper format.

Flow

$$\text{Flow MGD} = \frac{(\text{Flow GPM})\ (60\ \text{minutes/hour})\ (24\ \text{hours/day})}{1{,}000{,}000/\text{M}}$$

$$\text{Flow gpm} = \frac{(\text{Flow MGD})\ (1{,}000{,}000/\text{M})}{(60\ \text{minutes/hour})\ (24\ \text{hours/day})}$$

$$\text{Flow CFS} = \frac{(\text{Flow MGD})\ (1{,}000{,}000/\text{M})}{(7.48\ \text{gal/cu ft})\ (24\ \text{hrs/day})\ (60\ \text{min/hr})\ (60\ \text{sec/min})}$$

Grit Channels

Velocity

$$\text{Velocity, ft/sec} = \frac{\text{Distance Traveled, ft}}{\text{Time, sec}}$$

$$\text{Velocity, ft/sec} = \frac{\text{Flow, CFS}}{\text{Area, sq ft}}$$

$$\text{Grit Removed, cu ft/MG} = \frac{\text{Volume of Grit, cu ft}}{\text{Volume of Flow, MG}}$$

Sedimentation Tanks and Clarifiers

$$\text{Detention Time, hr} = \frac{(\text{Tank Volume, cu ft})(7.48\ \text{gal/cu ft})(24\ \text{hrs/day})}{\text{Flow, gal/day}}$$

$$\text{Surface Loading, GPD/sq ft} = \frac{\text{Flow, GPD}}{\text{Surface Area, sq ft}}$$

$$\text{Weir Overflow, GPD/ft} = \frac{\text{Flow, GPD}}{\text{Length of Weir, ft}}$$

Solids Applied, lbs/day = (Flow, MGD) (Solids, mg/l) (8.34 lbs/gal)

$$\text{Solids Loading, lbs/day/sq ft} = \frac{\text{Solids Applied, lbs/day}}{\text{Surface Area, sq ft}}$$

Trickling Filters (TF) and Rotating Biological Contactors (RBC)

$$\text{Hydraulic Loading, GPD/sq ft} = \frac{\text{Flow, GPD}}{\text{Surface Area, sq ft}}$$

BOD_5 Applied (TF), lbs/day = (Flow, MGD) (BOD_5, mg/l) (8.34 lbs/gal)

$$\text{Organic Loading (TF), lbs } BOD_5\text{/day/1000 cu ft} = \frac{BOD_5\ \text{Applied, lbs/day}}{\text{Volume of Media, 1000 cu ft}}$$

Soluble BOD Applied (RBC), lbs/day = (Flow, MGD) (Soluble BOD_5, mg/l) (8.34 lbs/gal)

$$\text{Organics Loading (RBC) lbs } BOD_5\text{/day/1,000 sq ft} = \frac{\text{Soluble } BOD_5\ \text{Applied, lbs/day}}{\text{Surface Area of Media, 1,000 sq ft}}$$

Activated Sludge

$$\text{Sludge Volume Index, SVI} = \frac{(\text{Settleable Solids, \%})\ (10{,}000)}{\text{Mixed Liquor Suspended Solids (MLSS), mg/l}}$$

$$\text{Mean Cell Residence Time, MCRT} = \frac{\text{Mixed Liquor Volatile SS MLVSS in Aerators, lbs}}{\text{Waste MLVSS, lbs/day + Effluent VSS, lbs/day}}$$

$$\text{Waste MLVSS, lbs/day} = \frac{\text{MLVSS, lbs}}{\text{MCRT, days}} - \text{Effluent VSS, lbs/day}$$

Aerator Solids, lbs = (Tank Volume, MG) (MLSS, mg/l) (8.34 lbs/gal)

Aerator Loading, lbs BOD_5/day = (Flow, MGD) (Primary Effluent BOD_5, mg/l) (8.34 lbs/day)

$$\text{Sludge Age, days} = \frac{(\text{MLSS, mg/l})\ (\text{Tank Volume, MG})\ (8.34\ \text{lbs/gal})}{(\text{SS in Primary Effluent, mg/L})\ (\text{Flow, MGD})\ (8.34\ \text{lbs/gal})}$$

Organic Loading

BOD_5 Applied, lbs/day = (BOD_5, mg/L) (Flow, MGD) (8.34 lbs/gal)

Volume of Media, 1,000 cu ft = (Surface Area, sq ft) (Depth, ft)

$$\text{Organic Loading, lbs } BOD_5\text{/day/1,000 cu ft} = \frac{BOD_5\ \text{Applied, lbs/day}}{\text{Volume of Media, 1,000 cu ft}}$$

Chlorine Calculations

Chlorine Demand, mg/s = Chlorine Dose, mg/l – Chlorine Residual, mg/l

Chlorine Feed Rate, lbs/day = (Flow, MGD) (Dose, mg/l) (8.34 lbs/gal)

Chemical Feeder Setting

Chemical Dose, lbs/day = (Flow, MGD) (Dose, mg/lL (8.34 lbs/gal)

Chemical Feeder Setting, ml/min = $\frac{\text{(Flow, MGD) (Chemical Dose, mg/l) (3.875 l/gal) (1,000,000/M)}}{\text{(Liquid Chemical, mg/l) (24 hr/day) (60 min/hr)}}$

Chemical Feeder Settling, gal/day = $\frac{\text{(Flow, MGD) (Chemical Dose, mg/l) (8.34 lbs/day)}}{\text{Liquid Chemical, lbs/gal}}$

Liquid Feed Pump Calibration

Chemical Feed, lbs/day = $\frac{\text{(Chemical Conc., mg/L) (Volume Pumped, mL) (60 min/hr) (24 hr/day)}}{\text{(Time Pumped, min) (1,000, mL/L) (1,000, mL/mg) (454 gm/lb)}}$

Chemical Feed, GPM = $\frac{\text{Chemical Used, gal}}{\text{(Time, hr) (60 min/hr)}}$

Chemical Feed, GPM = $\frac{\text{(Chemical Feed Rate, mL/sec) (60 sec/min)}}{\text{3.875 mL/gal}}$

Chemical Solution, gal = $\frac{\text{(Chemical Solution, \%) (8.34 lbs/gal)}}{\text{100 \%}}$

Feed Pump, GPD = $\frac{\text{Chemical Feed, lbs/day}}{\text{Chemical Solution, lbs/gal}}$

Feeder Setting, % = $\frac{\text{(Desired Feed Pump, GPD) (100 \%)}}{\text{Maximum Feed Pump, GPD}}$

Dry Sludge

Dry Sludge Hauled Off-Site, Tons =
(Liquid Sludge, gal) (% Dry Solids) (0.0000417, Conversion. Factor)

Dry Sludge Hauled Off-Site, Tons =
(Dewatered Sludge, Tons) (% Dry Solids) (0.01, Conversion. Factor)

Flow

$$\text{Average Daily Discharge} = \frac{(Q_1 + Q_2 + Q_3 + \dots Q_N)}{N}$$

Where Q is the flow measured at any given time during the day, and N is the number of times the flow is measured.

Example
Q_1 = 2.3 MGD
Q_2 = 2.7 MGD
Q_3 = 2.5 MGD
Q_4 = 2.1 MGD

$$\text{Daily Discharge} = \frac{(2.3 + 2.7 + 2.5 + 2.1)}{4} = 2.4 \text{ MGD}$$

$$\text{Average Weekly Discharge} = \frac{(Q_1 + Q_2 + Q_3 + \dots Q_7)}{N}$$

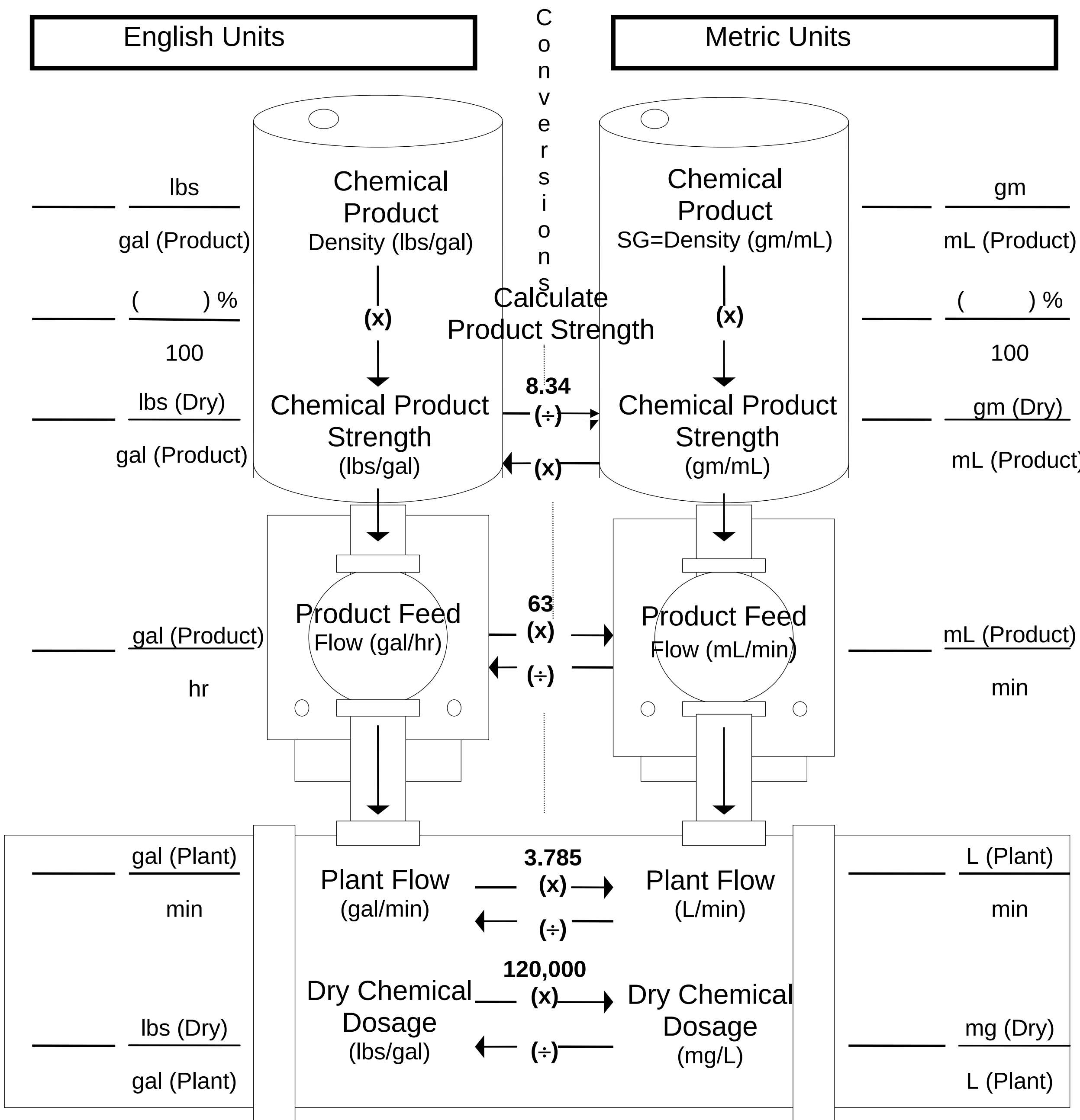
Where Q is the daily discharge for days that flow is measured, and N is the number of days in the week (7) that flow is measured.

$$\text{Average Monthly Discharge} = \frac{(Q_1 + Q_2 + Q_3 + \dots Q_{31})}{N}$$

Where Q is the daily discharge for the days that flow is measured, and N is the number of days in the month that flow is measured.

Appendix 4
DEP Chemical Feed Diagram

Liquid Chemical Feed



Procedure: Fill in known data; put a question mark (?) for the value of the unknown data; convert all data to the units on the side where the (?) was placed and fill in the values; use unit cancellation to solve for the unknown.

Unit cancellation:

[1] http://www.wyoenergy.com/meter_reading.asp

[2] http://www.greercpw.com/electric_meter.htm