Wastewater Treatment Facility Operator's Math

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Math Workbook for Wastewater Operators

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For the majority of you, doing math problems is "not fun." It is something you do because you have to, maybe do "just once in a while," or possibly do once or twice to help you pass the exam. While this is understandable, it does present a problem. The only way you can develop complete confidence in coming up with the right answer is to follow a procedure for solving a math problem and then continue to practice using it! As someone once said, "Practice makes perfect."

The intent of this workbook is to give you a chance to practice some wastewater-related problems and to build your confidence. Based on our experience in both doing and teaching wastewater math, mistakes are often made when you:

- go too fast,
- do not stop and think about what the problem is asking for,
- do not write down the formula,
- do not write down the units with the appropriate number, or
- come up with an answer in the incorrect units.

If you practice, follow the correct procedures as discussed in this workbook and understand what you did, you will be much more confident of your own ability to solve those math problems.

Gene Erickson

Notes

Introduction to Math Concepts Review

As you use this workbook, some of you may come up with a slightly different answer than what is shown. This may be due to how you "rounded off" as you worked through the problem. Your answer is correct if you come within plus or minus 10% of what is given. If you are outside of that range, recheck your work. As you work problems within each topic, the problems become more difficult.

Answers are given in the back of the book. The first problem from each section and other selected problems are worked out completely.

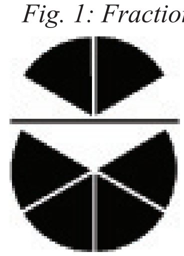
Fractions, Decimals, Ratios and Exponents

Fractions

Fractions are used when we want to express a portion of a whole object.

For example: If a pie is cut into six pieces and you eat two pieces, you have eaten 2/6 or 1/3 of the pie.

Fig. 1: Fractions, numerator and denominator



$$= \frac{2}{6} \text{ or } \frac{1}{3}$$

numerator

denominator

The top number, or *numerator*, represents how many parts we ate; the bottom number, or *denominator*, represents how many parts the whole pie has.

The bar in between divides the two numbers. This means the top number, *numerator*, is divided by the bottom number, *denominator*. The bar can also read *divided by* – for example, 1/2 is one *divided by* two.

Fractions can also be used in units of measurement such as, miles per hour (miles/hour) or miles per gallon (miles/gallon), where the word *per* means *divided by*.

Decimals

Decimal numbers, such as 3.25, are used when one needs more precision than whole numbers provide. Decimals are based on units of ten (tenths) and multiples of tenths. The value of a digit in a decimal number depends upon the place of the digit (see Table 1).

Table 1: Values of digits in decimal numbers

Place (underlined)	Name of Position
1.234567	Ones (units)
1.234567	Tenths
1.234567	Hundredths
1.234567	Thousandths
1.234567	Ten thousandths
1.234567	Hundred thousandths
1.234567	Millionths

A fraction having a 10 or multiple of 10 in the denominator can be written as a decimal. For example, the fraction 2/10 could be written as the decimal number 0.2. The period or *decimal point* before the two indicates that this is a decimal. The decimal 0.2 could be pronounced as *two tenths* or *zero point two*. Decimals are similar to money. A dime is 1/10 of a dollar. Two dimes are 2/10 or 1/5 of a dollar. To visualize this, see Figure 2.

Fig. 2: Two-tenths

1/10	1/10	1/10	1/10	1/10	1/10	1/10	1/10	1/10	1/10

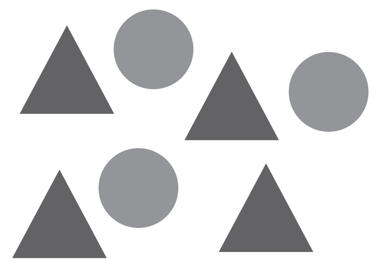
When adding or subtracting decimal numbers, remember to place the decimal points directly over and under each other.

Ratios

A ratio is a comparison of two numbers. Ratios can be written as:

- a fraction
- using the word "to"
- using a colon.

Fig.3: Ratios



For example, comparing the number of circles to the number of triangles in Fig.3, we can use a fraction and say "3/4", or say "three to four," or use a colon, 3:4.

Ratios tell how one number is related to another number. A ratio of 1:5 says that the second number is five times as large as the first.

Comparing Ratios

To compare ratios, write them as fractions. If ratios are equal when they are written as fractions, they are equal.

Multiplying or dividing each term by the same nonzero number will give an equal ratio. For example, the ratio 3:6 is equal to the ratio 1:2 because you can divide both 3 and 6 by 3 and produce 1:2. and To tell if two ratios are equal, use a calculator and divide. If the division gives the same answer for both ratios, then they are equal.

Proportion

A proportion is an equation with a ratio on each side. It is a statement that two ratios are equal. An example of an equal proportion: 1/2 = 3/6

Percent

A *percent* is a ratio whose second term is 100. Percent means "out of 100" or "parts per hundred. We can use the percent symbol (%) as a handy way to write a fraction whose denominator is 100. For example, instead of saying "27 out of every 100 professional volleyball players are female," we can say "27% of professional volleyball players are female."

A percent can also be written as a decimal by moving the decimal point two places to the left like this (or dividing by 100): 27% = 0.27 (Note: if there is no whole number, always use a zero before a decimal place.)

And a decimal can be written as a percent, by moving the decimal point two places to the right like this (or multiplying by 100): 0.65 = 65%

Relationship Between Ratios, Fractions, Decimals and Percents

At some time, you may need to interchange ratios, fractions, decimals and percents. Table 2 shows the relationship between them.

Table 2: Comparing Ratio, Fraction, Decimal & Percent

Ratio	Fraction	Decimal	Percent
7 to 100	7/100	0.07	7%
29 to 100	29/100	0.29	29%
64 to 100	64/100	0.64	64%

Exponents

Exponents are a shorthand way to show how many times a number (called the *base*) is multiplied times itself. A number with an exponent is said to be "raised to the power" of that exponent; the exponent is the "power".

Example 1: 6^2 means "six to the second power" or "six squared." To calculate, you would multiply 6 times itself two times: 6 x 6 = 36

Example 2: 4^3 means "four to the third power" or "four cubed." To calculate, multiply 4 times itself 3 times: 4 x 4 x 4 = 64

Exponents apply to units as well as numbers. For example:

1 ft x 1 ft x 1 ft = 1 ft^3 or 1 cubic foot (abbreviated cu ft)

Converting Units

When you are working math problems, numbers usually have units attached. Sometimes the units you are given are not the units in which you want to express your answer. So you need to *convert* units.

Converting units is easy when you use the *goalpost* method to set up your problems. *Conversion factors* (numbers **and units**) are placed within *goalposts* (|——|). You can keep adding goalposts with conversion factors until you end up with the units you are seeking. If you want a unit in the *numerator* (above the line) to cancel, add a conversion factor with that unit in the *denominator* (below the line). Since, in a conversion factor, both sides are equal, you can place it within the goalpost either way.

When you solve a problem, numbers above the line are multiplied together, then divided by numbers below the line. (If you need to add or subtract, do that before you multiply and/or divide.)

Units (feet, gallons, seconds, etc.) above and below the line will cancel each other out. If a problem is set up properly, the only units to the left of the '=' sign that do not cancel are the units in which you want to express your final answer.

For example: Change 2 years to seconds. (Conversion factors are placed so the denominator of the following factor cancels the numerator of the existing factor.)

$$\frac{2\text{ yrs}}{}\;\Bigg|\;\frac{365\text{ days}}{1\text{ yr}}\;\Bigg|\;\frac{24\text{ hrs}}{1\text{ day}}\;\Bigg|\;\frac{60\text{ min}}{1\text{ hr}}\;\Bigg|\;\frac{60\text{ sec}}{1\text{ min}} = 63{,}072{,}000\text{ seconds}$$

You could also do the opposite: Change 93,000,000 seconds to years. (Note: we use the same factors, but place them so the denominator of the next factor cancels the numerator.)

$$\frac{93{,}000{,}000\text{ sec}}{}\;\Bigg|\;\frac{1\text{ min}}{60\text{ sec}}\;\Bigg|\;\frac{1\text{ hr}}{60\text{ min}}\;\Bigg|\;\frac{1\text{ day}}{24\text{ hrs}}\;\Bigg|\;\frac{1\text{ yr}}{365\text{ days}} = 2.95\text{ yrs}$$

There is no limit to the number of conversion factors you can use. Use as many as you need to get from the units you have to where you want to be.

Should you need to *convert* your answer from one unit to another, such as from cubic feet/second to gallons/minute, you can easily do that by adding *goalposts* with appropriate conversion factors to convert from seconds to minutes (60 seconds = 1 minute) and cubic feet to gallons (1 cubic foot = 7.48 gallons). Place conversion factors within the goalposts in such a way that the units you want to get rid of will cancel and the units you want to convert to will remain. You can find conversion factors on the inside back cover of this manual and in the booklet *Wastewater Formulas and Conversion Factors*.

The first and last goalpost "upright" is omitted to eliminate extra lines. When doing problems, be sure to write down the formula you will use! Circle your answer(s).

To see how problems are set up, see the examples on the pages 13 and 17.

Significant Figures

Every measurement has a degree of uncertainty. The uncertainty comes from the accuracy of the measuring device and from the skill of the person doing the measuring. Because measured quantities are often used in calculations, the precision of the calculation is limited by the precision of the measurements on which it is based. For example, if you calculate area based on measurements to the nearest foot, it is ridiculous to try to give an answer to the nearest tenth or hundredth of a square foot. For this reason, we use significant figures to help us determine how to express calculated answers. A calculated number cannot be more accurate than the measurements upon which it is based.

We use the following significant figure rules to determine how many significant figures in a number:

- All non-zero numbers are significant. (1, 2, 3, 4, 5, 6, 7, 8, 9)
- Zeros within a number are significant. (Example: Both '3076' and '60.02' contain four significant figures.)
- Zeros that do nothing but set the decimal point are not significant. (So, the number '630,000' has two significant figures.)
- Trailing zeros that aren't needed to hold the decimal point are significant. (For example, '2.00' has three significant figures.)
- If you are not sure whether a digit is significant, assume that it isn't. (For example, if a problem reads: "The height is 200 inches," assume the height is known to one significant figure.)

There are also rules when adding, subtracting, multiplying and dividing numbers:

- When measurements are added or subtracted, the answer can contain no more decimal places than the least accurate measurement.
  Example: 22.25 ft + 7.125 ft + 11 ft

  When added together, you get 40.375 ft, but you should give the sum as '40' feet. (See *Rounding Off* below.)

- When measurements are multiplied or divided, the answer can contain no more significant figures than the least accurate measurement.
  Example: $\frac{29.5}{7}$ should be given as '4,' not '4.214'
- When the answer to a calculation contains too many significant figures, it must be rounded off. (See *Rounding Off* below.)

Losing Significant Figures

You may sometimes 'lose' significant figures when performing calculations. For example, if you subtract 21.75 – 21.50, the answer, '0.25' has two significant figures even though the original values contained four significant figures. When that happens, don't worry about it – just give the answer in the number of significant figures it has.

Rounding Off

When rounding off, the usual method is to round down numbers with digits less than '5' and round up numbers with digits '5' or greater.

Example: 7.3 would be rounded off (down) to '7'; but 7.7 would be rounded off (up) to '8.'

You can *round off* the number to fewer digits following these **rules for rounding off**:

- Determine how many digits (numbers) you want in your answer.
- Then, look at the next number (the number after those digits). If it is less than 5, just drop that number and all remaining numbers.
- If the number is 5 or more, make the preceeding number one unit greater, then drop all remaining numbers.

Example: If we want to round off 1.5263792 inches to *two* digits, we look at the *third* number. Since the third number, 2, is less than 5, we drop it and all remaining numbers and end up with 1.5 inches.

If we round off 1.5263792 inches to *three* digits, we look at the *fourth* number. Since the fourth number, 6, is more than 5, we make the preceeding number one unit larger, then drop the remaining numbers. So our answer becomes 1.53 inches.

When working problems, always wait until you get the final answer before rounding off.

Examples

Conversions

1. How many feet in 30 inches?

Given information / Conversion factor

$$\frac{30\ \cancel{\text{inches}}}{} \times \frac{1\ \text{foot}}{12\ \cancel{\text{inches}}} = 2.5\ \text{feet}$$

2. How many cubic feet (ft^3) in one cubic yard (yd^3)?
   (Note how units can also have exponents!)

$$\frac{1\ \cancel{yd^3}}{} \times \frac{3\ ft}{1\ \cancel{yd}} \times \frac{3\ ft}{1\ \cancel{yd}} \times \frac{3\ ft}{1\ \cancel{yd}} = 27\ ft^3 \text{ or } 27 \text{ cubic feet}$$

3. Express a flow rate of 1 cubic feet/second in gallons/minute.

$$\frac{1\ \cancel{\text{cubic foot}}}{1\ \cancel{\text{second}}} \times \frac{7.48\ \text{gallons}}{1\ \cancel{\text{cubic foot}}} \times \frac{60\ \cancel{\text{seconds}}}{1\ \text{minute}} = 449\ \text{gallons/minute*}$$

*Rounded to nearest gallon

4. Express a flow rate of 1 gallon/minute in gallons/day.

$$\frac{1\ \text{gallon}}{\cancel{\text{minute}}} \times \frac{60\ \cancel{\text{minutes}}}{1\ \cancel{\text{hour}}} \times \frac{24\ \cancel{\text{hours}}}{1\ \text{day}} = 1440\ \text{gallons/day}$$

5. If you know 1 gallon of water weights 8.34 pounds and that 1 cubic foot of water weighs 62.4 pounds, how many gallons are in 1 cubic foot of water?

   Think it through: You want to know how many gallons per cubic foot, so set up the conversion factors so those are the units that are left after canceling.

$$\frac{1\ \text{gallon}}{8.34\ \cancel{\text{pounds}}} \times \frac{62.4\ \cancel{\text{pounds}}}{1\ \text{cubic foot}} = 7.48\ \text{gallons/cubic foot}$$

Rearranging a Formula

Sometimes the way a formula is written, the item you are trying to find does not stand alone. You must rearrange or transpose the formula to solve for the unknown quantity.

When rearranging formulas, think of a formula as a balanced scale – the quantity on the left is equal to the quantity on the right. If we add an amount to one side of the scale, to keep balance we must also add the same amount to the other side. Similarly if we take away an amount from one side, we must also take the same amount away from the other side. The same applies to formulas. If we add an amount to one side, we must also add the same amount to the other to keep the formula equal. If we subtract an amount from one side we must also subtract the same amount from the other side.

Figure 4: Formulas are like a balanced scale.

This also applies to multiplication and division: if we multiply one side of a formula by any amount, we must also multiply the other side by the same amount. Similarly, if we divide one side of the formula by any amount we must also divide the other side by the same amount.

When you are trying to rearrange a formula, remember you may:

- **add or subtract the same quantity to or from both sides**
- **multiply or divide both sides by the same quantity**

Other operations are also allowed, such as squaring and taking the square root – as long as whatever you do to one side of the formula, you also do to the other.

How do you decide whether to add, subtract, multiply or divide? First, look at what you are trying to find and ask yourself: 'What has been done to it?' For example, suppose you are given the formula:

Formula

$$\textbf{Detention time} = \frac{\textbf{Volume}}{\textbf{Flow rate}}$$

and you want to find the volume. You see that, the way the formula is written, *volume* is divided by *flow rate*. To get *volume* to stand alone, you must "undo" the division by doing the opposite: multiplication. But remember, when working with a formula, whatever you do to one side, you **must** do to the other. In this case, you would multiply both sides by *flow rate* as shown below:

$$\textbf{Flow rate} \times \text{Detention time} = \frac{\text{Volume}}{\cancel{\text{Flow rate}}} \times \cancel{\textbf{Flow rate}}$$

Flow rate cancels out on the right side leaving *Volume* standing alone. We can flip sides and write:

Volume = Flow rate x Detention time

Suppose you start with the same formula, but you want to solve for the flow rate.

Formula $$\textbf{Detention time} = \frac{\textbf{Volume}}{\textbf{Flow rate}}$$

Since *Flow rate* is on the bottom (in the denominator), multiple both sides by *Flow rate* so it is on the top (in the numerator):

$$\textbf{Flow rate} \times \text{Detention time} = \frac{\text{Volume}}{\cancel{\text{Flow rate}}} \times \cancel{\textbf{Flow rate}}$$

Flow rate still does not stand alone – it has been multiplied by *Detention time*. To undo multiplication, we must divide both sides by *Detention time*, then cancel as shown below:

$$\text{Flow rate} \times \frac{\cancel{\text{Detention time}}}{\cancel{\textbf{Detention time}}} = \frac{\text{Volume}}{\textbf{Detention time}}$$

So finally, $$\text{Flow rate} = \frac{\text{Volume}}{\text{Detention time}}$$

In another example you know Flow rate and Area, and want to find Velocity. You choose the formula:

Formula **Flow rate = Velocity x Area**

Since the velocity has been multiplied by the area, you "undo" that by dividing **both sides of the equation** by area, then canceling, as shown below:

$$\frac{\text{Flow rate}}{\textbf{Area}} = \text{Velocity} \times \frac{\cancel{\text{Area}}}{\cancel{\textbf{Area}}}$$

Then, flip sides to get: $$\textbf{Velocity} = \frac{\textbf{Flow rate}}{\textbf{Area}}$$

Sometimes you may need to substitute terms in a formula. The formula below is the common formula used to find the area of a circle.

Formula $\mathbf{A} = \quad x\ \mathbf{r^2}$, where r is the radius

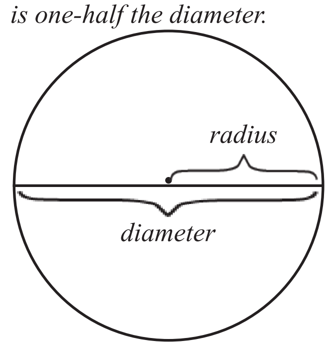
Often, however, you may know the diameter rather than the radius. Given the diameter, you could divide it by 2, since the radius is half the diameter. Or, you could replace *r* with *d/2* as shown below:

$$A = \quad x \left(\frac{d}{2}\right)^2$$

$$= 3.14 \ x \ \frac{d^2}{4} \quad \text{or} \quad \frac{3.14 \ x \ d^2}{4}$$

$$A = 0.785 \ x \ d^2$$

Figure 5: The radius of a circle is one-half the diameter.



Another formula that is used often in collection system calculations is:

Formula $\textbf{Slope} = \dfrac{\textbf{Rise}}{\textbf{Run}}$

Slope is defined as Rise/Run (the upward rise divided by the length of the run). Because the rise is less than the run, slope is a decimal number – always less than one. Often, one wants to know the *percent* slope. Remember, to change a decimal number to a percent, you must multiply by 100. And, whatever you do to one side of a formula, you *must* do to the other. So the formula becomes:

$$\text{Slope x } 100 = \frac{\text{Rise}}{\text{Run}} \text{ x } 100$$

$$\textbf{Slope (\%)} = \frac{\textbf{Rise}}{\textbf{Run}} \textbf{ x 100}$$

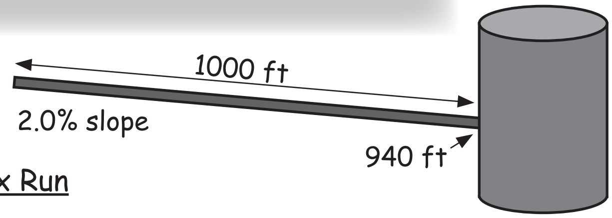
When using formulas to solve problems, take care to rearrange the formula correctly. If you must use several steps to do it, show those steps in your work so you can go back and see what you did. If you can't rearrange a formula correctly, you can't get a correct answer.

Don't forget that to get your final answer in the correct units, you may need to use one or more conversion factors!

Formula Examples

1. A 1000-foot pipe with a 2.0% slope enters a lift station at an invert elevation of 940.0 feet. What is the elevation at the other end of the pipe?

Formula $\text{Slope(\%)} = \frac{\text{Rise}}{\text{Run}} \times 100$



Rearrange formula: $\text{Rise} = \frac{\text{Slope (\%)} \times \text{Run}}{100}$

$\text{Rise} = \frac{2.0\% \times 1000\ \text{ft}}{100} = 20\ \text{feet}$

Reminder: dividing % by 100 changes the number to a decimal.

$\text{Elevation}_{\text{FINAL}} = \text{Elevation}_{\text{INITIAL}} + \text{Rise}$

$= 940\ \text{feet} + 20\ \text{feet} = 960\ \text{feet}$

2. What is the loading, in pounds/day, of wastewater with a strength of 500 mg/l and a flow rate of 0.89 million gallons/day?

Formula
Loading = concentration(mg/l) x flow (MGD) x 8.34 lb/gallon

When doing this problem, it is important to note that 1 mg/l is equivalent (equal) to 1 part per million (1 part/1 million parts). In this example, to show in a non-rigourous mathematical explanation that units cancel, we will use as a conversion factor a compound fraction – which is resolved by inverting the denominator and multiplying as shown in the second step.

$\text{Loading} = \frac{500\ \text{mg}}{\text{L}} \Big| \frac{0.89\ \text{million gal}}{\text{day}} \Big| \frac{8.34\ \text{lb}}{\text{gallon}} \Big| \frac{1\ \text{part/million parts}}{1\ \text{mg/L}}$

$= \frac{500\ \text{mg}}{\text{L}} \Big| \frac{0.89\ \text{million gal}}{\text{day}} \Big| \frac{8.34\ \text{lb}}{\text{gal}} \Big| \frac{1\ \text{L}}{1\ \text{mg}} \Big| \frac{1\ \text{part}}{1\ \text{million parts}}$

Loading = 3,711.3 lb/day

Complex Fractions

If someone asks you how many half dollars there are in one dollar, you probably wouldn't think twice before you said, "Two." Or, if they asked you how many quarters in a dollar, you could easily come up with the correct answer: "Four." When you are figuring this out, you are actually using complex fractions. If we write it mathematically, it would look like this:

$$\frac{1}{\frac{1}{2}} \quad \text{and} \quad \frac{1}{\frac{1}{4}}$$

When you solve complex fractions, you simply *invert and multiply* – that is, turn the denominator (bottom number) upside-down, then multiply the two numbers.

When you figured out how many half dollars in a dollar and how many quarters in a dollar, you did this in your head:

$$\frac{1}{\frac{1}{2}} = \frac{1}{} \times \frac{2}{1} = 2 \quad \text{and} \quad \frac{1}{\frac{1}{4}} = \frac{1}{} \times \frac{4}{1} = 4$$

Sometimes you may have a fraction on top of a fraction. Don't let that throw you. Just do the same thing: *invert and multiply*! For example: How many quarters (quarter dollars) are there in a half dollar? The math would look like this:

$$\frac{\frac{1}{2}}{\frac{1}{4}} = \frac{1}{2} \times \frac{4}{1} = \frac{4}{2} \text{ or } 2$$

If you have numbers with units, keep the units and cancel them when appropriate:

$$\frac{\frac{1}{2}\,\cancel{\text{dollar}}}{\frac{1}{4}\,\cancel{\text{dollar}}} = \frac{1}{2} \times \frac{4}{1} = \frac{4}{2} \text{ or } 2$$

Example: Find the detention time when the volume is 10,000 gal and the flow rate is 250 gal/min.

Formula **Detention Time =** $\frac{\textbf{Volume}}{\textbf{Flow Rate}}$

$$\text{Detention time} = \frac{10{,}000 \text{ gal}}{\frac{250 \text{ gal}}{1 \text{ min}}} = 10{,}000\,\cancel{\text{gal}} \times \frac{1 \text{ min}}{250\,\cancel{\text{gal}}} = \boxed{40 \text{ minutes}}$$

Solving Math Problems Checklist

Do not be tempted to look at a problem and start punching numbers into a calculator. Using a calculator this way only ensures you will get the wrong answer *quickly*. Instead, follow this checklist to help ensure success!

- ☐ Read the problem carefully. (You may need to read it twice!)
- ☐ Draw and label a picture of the problem.
- ☐ Think about the information you are given and what you want to know.
- ☐ Choose a formula (some problems may require more than one formula).
- ☐ Write down the formula as it is given. Rearrange it if it is not in the form you need.
- ☐ Replace the words in the formula with the numbers **and units** of the information you have been given (sometimes you may be given information you don't need – don't let that fool you!).
- ☐ If needed, add conversion factors to end up with the requested units. Cancel (cross off) units to make sure the only units left are the ones you want in your answer.
- ☐ Now, get out your calculator and multiply all the numbers on the top and divide by all the numbers on the bottom.
- ☐ Ask yourself if the final answer is reasonable for the question being asked.
- ☐ Double check to make sure your answer is in the units being asked for. (Many times answers are incorrect because of failure to make sure the final answer is in the correct units!)
- ☐ Smile at your correct answer ☺

Notes

Answers page 107.

Essential Math Refresher

1. Convert to decimals:
   a. 1/2
   b. 2/3
   c. 5/7
   d. 1/8

2. Find the values of the following:
   a. 23^2
   b. 13^3
   c. $31^2 + 12^3$
   d. $(6 + 21)^4$
   e. $(3 \times 2)^2$
   f. 0.5^3
   g. 15.75^2
   h. $\frac{3^2}{15}$

3. Find the square root of the following:
   a. 16
   b. 625
   c. 1, 296

4. Convert to percent:
   a. 0.35
   b. 1.27
   c. 0.02
   d. 3/5
   e. 0.045
   f. 2 1/5

5. Convert to decimal numbers:
   a. 46%
   b. 178%
   c. 0.65%

Conversions

To do these problems you will need to use one or more conversion factors found on the inside of the back cover of this manual or in the *Wastewater Formulas and Conversion Factors* booklet.

6. Convert the following:

a. 14,000 cubic feet to gallons

14,000 cubic feet		=	_______ gallons

b. 16,348 cubic feet to gallons

c. 14,000 gallons to cubic feet

d. 1,050 gallons to cubic feet

e. 103,842 square feet to acres

f. 4.5 acres to square feet

g. 5 cubic feet per second to gallons per minute

5 cu ft			=	gal
sec				min

Answers page 107.

h. 0.5 cubic feet per second to gallons per minute

i. 5 gallons per minute to cubic feet per second

j. 50 gallons per minute to cubic feet per second

k. 0.005 cubic feet per second to gallons per minute

l. 185 gallons per minute to cubic feet per second

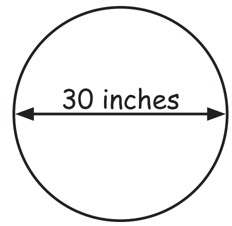
m. 0.035 cubic feet per second to gallons per minute

Circumference and Perimeter

7. Find the circumference, in feet of a circle with a diameter of 30 inches.

Formula **C = x D** *(where C = circumference and D = diameter)*

	diameter	conversion factor		
C = 3.14	~~inches~~	foot	=	________feet
		~~inches~~		



8. Find the circumference, in inches, of a circle with a diameter of 30 feet.

Formula

9. Find the circumference, in feet, of a circle with a diameter of 22.3 inches.

Formula

Answers page 107.

10. Find the perimeter, in feet, of a rectangle that is 35 feet long and 15 feet wide.

Formula $P = S_1 + S_2 + S_3 + S_4$

P = ___ ft + ___ ft + ___ ft + ___ ft = ___________feet

11. Find the perimeter, in feet, of a rectangle that is 100 inches long and 8 inches wide. (Reminder: Use a conversion factor to change inches to feet!)

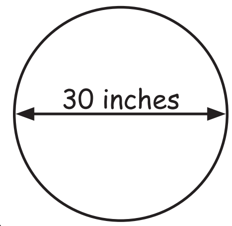
Formula

12. Find the perimeter, in feet, of a rectangle that is 85 feet long and 3 yards wide.

Formula

Area

13. Find the area, in square feet, of a circle with a diameter of 30 inches.



Formula $A = 0.785 \times D^2$

Diameter (inches | inches) — Conversion factor (square feet / square inches)

A = 0.785 | ~~inches~~ | ~~inches~~ | square feet / ~~square inches~~ = ____________sq ft

Reminder: Square inches = inches^2 or inches x inches)

14. Find the area, in square feet, of a circle with a diameter of 30 feet.

Formula

15. Find the area, in square feet, of a circle with a diameter of 36 inches.

Formula

Answers page 107.

16. Find the area, in square feet, of a rectangle with dimensions of 35 feet long and 15 feet wide.

Formula $A = L \times W$

A = ___ ft x ___ ft = _________ sq ft

17. Find the area, in square feet, of a rectangle with dimensions of 100 inches long and 8 inches wide. (Hint: Remember to use a conversion factor!)

Formula

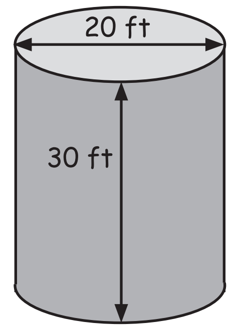
18. Find the area, in acres, of a lot that is 200 feet long and 60 feet wide.

Formula

Volume

19. Find the volume, in gallons, of a tank with a diameter of 20 feet and a depth of 30 feet.

Formula $V = 0.785 \times D^2 \times H$



Volume of a cylinder — Conversion factor

V = 0.785	~~ft~~	~~ft~~	~~ft~~	gallons
				~~cu ft~~

= ____________ gallons

20. Find the volume, in gallons, of a tank with a diameter of 27.4 feet and a depth of 11 feet.

Formula

21. Find the volume, in gallons, of a tank with a diameter of 120 inches and a depth of 180 inches.

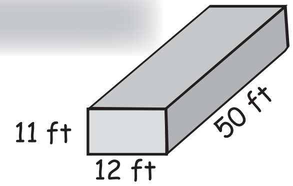
Formula

Answers page 107.

22. Find the volume, in gallons, of a tank that is 50 feet long, 12 feet wide and 11 feet deep.

Formula

V = L × W × H



Volume | **Conversion factor**

V = ___ ~~ft~~ | ___ ~~ft~~ | ___ ~~ft~~ | ___ gallons / ~~ft~~³ = ____________ gallons

23. Find the volume, in gallons, of a tank that is 80 feet long, 20 feet wide and 10 feet deep.

Formula

24. Find the volume, in gallons, of a tank that is 97.2 feet long, 10.5 feet wide and 10.5 feet deep.

Formula

Rearranging Formulas

25. Calculate the length of one side of a rectangle, in feet, that has a perimeter of 280 feet and is 20 feet wide.

Formula

26. Calculate the diameter of a circle, in feet, that is 94.2 feet in circumference.

Formula

27. Calculate the diameter of a circle, in feet, with an area of 19.625 square feet.

Formula

Answers page 107.

28. Find the length of one side of a rectangle, in feet, that has an area of 2400 square feet and is 20 feet wide.

Formula

29. You have one gallon of paint to paint both sides of an 8-foot tall fence that is 45 feet long. If one gallon covers 400 square feet, do you have enough paint?

Formula

30. A 180,000-gallon equalization basin is 120 feet long and 20 feet wide. When the basin is full, how deep, in feet, will the water be?

Formula

31. Your living room measures 25 feet by 15 feet. How many square yards of carpet do you need to cover the floor? If carpet (including installation) is $35 per square yard, how much will it cost to recarpet?

Formula

32. How many feet of snow fence does it take to enclose an excavation 20 feet in diameter if the fence is located 4 feet from the hole? (Hint: Draw a picture!)

Formula

Answers page 108.

33. Find the volume, in gallons, of an 18-inch force main that is 2 miles long.

Formula

34. An 8-foot deep tank has a diameter of 10 feet. Will its contents fit into a 5,000-gallon tanker? (Show your work!)

Formula

Notes

Answers page 108.

Detention Time

1. A rectangular primary clarifier is 75 feet long, 22 feet wide and 10 feet deep. If it receives a flow of 1,250,000 gallons per day, what is the detention time in hours?

   Formula

2. A rectangular secondary clarifier is 60 feet long, 30 feet wide and 8 feet deep. If the flow into the clarifier is 1,400,000 gallons per day, what is the detention time in hours?

   Formula

3. A clarifier is 70 feet long, 25 feet wide and 10 feet deep. If the flow is 2.78 MGD, what is the detention time in hours?

Formula

4. If a final clarifier is 95 feet in diameter, 11 feet deep and receives a flow of 7,000,000 gallons per day, what is the detention time in hours?

Formula

Answers page 108.

5. A clarifier receives a flow of 4, 320, 000 gallons per day. If the clarifier is 65 feet in diameter and 12 feet deep, what is the detention time in hours?

Formula

6. What is the detention time, in hours, of a clarifier that is 40 feet in diameter, 12 feet deep and receives a flow of 1.11 MGD?

Formula

7. A 30-acre stabilization pond system receives an average flow of 217,000 gallons per day. How many days will it take to raise the pond system from one foot to four feet?

Formula

8. A 10-acre stabilization pond system will receive an average flow of 90,000 gpd for the next 180 days. If this system has a storage depth of four feet, will it have adequate storage volume, in million gallons, to hold this amount of flow?

Formula

Pond Discharge

1. You have a three-cell stabilization pond system; each pond is 12 acres. The maximum depth in each pond is 6 feet; the actual depth in each is 5 feet. If you expect a flow is 180,000 gallons per day, how many feet do you need to discharge if you would like to provide storate for the next 195 days? (Assume rainfall, evaporation and seepage balance each other.)

   Formula

2. You have a 10-acre primary and a 5-secondary pond system. The maximum depth in each is 6 feet; the actual depths are 5.5 feet and 6.0 feet, respectively. If you expect to receive 70,000 gallons per day, what will be the total amount of discharge, in feet, for which you will need to provide storage for 210 days? (Assume rainfall, evaporation and seepage balance each other.)

Formula

Answers page 109.

Percent Removal

1. Given the following laboratory data, find the asked for removal efficiencies.

Influent BOD	225 mg/L		Primary effluent BOD	153 mg/L		Plant effluent BOD	18 mg/L
Influent TSS	238 mg/L		Primary effluent TSS	114 mg/L		Plant effluent TSS	23 mg/L

Formula

A. What is the primary unit's BOD removal efficiency?

B. What is the primary unit's TSS removal efficiency?

C. What is the total plant's BOD removal efficiency?

D. What is the toal plant's TSS removal efficiency?

2. Given the following information from an activated sludge plant, calculate the asked for removal efficiencies.

Influent BOD	250 mg/L	Primary clarifier effluent BOD	160 mg/L	Final clarifier effluent BOD	10 mg/L
Influent TSS	264 mg/L	Primary clarifier effluent TSS	112 mg/L	Final clarifier effluent TSS	25 mg/L

Formula

A. Primary clarifier BOD removal efficiency
B. Primary clarifier TSS removal efficiency
C. Activated sludge/final clarifier BOD removal efficiency
D. Activated sludge/final clarifier TSS removal efficiency
E. Total plant BOD removal efficiency
F. Total plant TSS removal efficiency

Answers page 109.

3. Given the following information from a tricklling filter plant, calculate the asked for removal efficiencies.

Influent BOD	183 mg/L	Trickling filter effluent BOD	30 mg/L	Final clarifier effluent BOD	24 mg/L
Influent TSS	198 mg/L	Trickling filter effluent TSS	50 mg/L	Final clarifier effluent TSS	23 mg/L

Formula

A. Primary and trickling filter BOD removal efficiency
B. Primary and trickling filter TSS removal efficiency
C. Final clarifier BOD removal efficiency
D. Final clarifier TSS removal efficiency
E. Total plant BOD removal efficiency
F. Total plant TSS removal efficiency

4. Your trickling filter facility removes 87% of the BOD applied and 92% of the TSS applied. What is the influent BOD concentration and the influent TSS concentration if the effluent BOD is 24 mg/L and effluent TSS is 26 mg/L?

Formula

Answers page 110.

Pounds/Loading

1. If an activated sludge plant discharges 1,500,000 gallons per day of wastewater with a BOD concentration of 15 mg/L, how many pounds of BOD are discharged each day?

   Formula

2. If a trickling filter plant receives an influent total suspended solids (TSS) of 250 mg/L with a flow of 880,000 gallons per day, what would the TSS loading be on this plant?

   Formula

3. Using the figures below, calculate the information asked for:

Influent flow rate	6.34 MGD		Influent BOD	275 mg/L		Effluent BOD	20 mg/L
			Influent TSS	350 mg/L		Effluent TSS	25 mg/L

Formula

A. What is the average influent BOD loading in pounds per day?

B. What is the average influent TSS loading in pounds per day?

C. How many pounds per day of BOD are discharged each day?

D. How many pounds per day of TSS are discharged each day?

Answers page 110.

4. How many pounds per day of BOD would a city of 1,500,000 people contribute to a treatment facility?

   Formula

5. If an industry discharges 50,000 pounds per day of BOD to a treatment plant, how many people is this equivalent to?

   Formula

6. Which would discharge more pounds per day of BOD to a treatment facility: a city with a population of 50,000 or an industry with a BOD concentration of 500 mg/L and a flow of 250,000 GPD?

Formula

7. What is the chlorinator setting, in pounds per day, to treat a flow of 5,500,000 GPD if the chlorine dosage is 5 mg/L?

Formula

8. If the flow rate in problem #7 was increased to 6,300,000 GPD, how ***many more*** pounds per day would be needed? (Assume the same dosage rate.)

Formula

Answers page 110.

9. If a treatment plant discharges 750,000 GPD with a chlorine residual of 0.1 mg/L, how many pounds per day of chlorine would the receiving waters recieve?

   Formula

10. What would be the chemical feed rate, in milligrams per liter, if the chemical feed rate was 65 pounds per day and the flow was 650,000 GPD?

    Formula

11. A 150 gpm pump is discharging a chemical at the rate of 9 pounds per day to the wastewater. What is the dosage in mg/L?

    Formula

12. Given the following information about an activated sludge plant, how many pounds of solids are contained within the aeration tank?

    Mixed liquor suspended solids: 3,000 mg/L

    Aeration tank measures 70 feet long, 42 feet wide and 10 feet deep

Formula

13. If the activated sludge in problem #12 now has 5,000 mg/L of mixed liquor suspended solids concentration in the aeration tank, how many pounds of solids are now within the aeration tank?

Formula

Answers page 110.

14. If an activated sludge plant has a wasting rate of 500,000 GPD with a concentration of 2,500 mg/L, how many pounds per day of sludge are wasted?

Formula

15. If the wasting rate from problem #14 was reduced to 400,000 GPD, how many pounds per day of sludge would be wasted?

Formula

Notes

Pump Calibration – Lift Station

1. Using the information given, find the pumping rate, in gallons per minute, of a lift station pump.

Wet well diameter	8 feet		Drawdown time	225 seconds		Refill time	410 seconds
			Drawdown distance	1.26 feet		Refill distance	1.19 feet

Formula

2. Find the pumping rate, in gallons per minute, of a lift station pump given this information:

Wet well diameter	8 feet		Drawdown time	315 seconds		Refill time	523 seconds
			Drawdown distance	2.26 feet		Refill distance	2.35 feet

Formula

Answers page 111.

3. What is the pumping rate, in gallons per minute, of a lift station pump given the following information:

Wet well diameter	10 feet		Drawdown time	5 min 7 seconds		Refill time	7 min 23 seconds
			Drawdown distance	2 feet 4 inches		Refill distance	2 feet 5 inches

Formula

4. What is the pumping rate, in gallons per minute, of a lift station pump given the information below?
   Wet well diameter: 6 feet
   Drawdown:
   - Time at start : 9:10:20 (Hours:Minutes:Seconds)
   - Time at end: 9:13:09
   - Distance down to water surface at start: 8 feet 4 inches
   - Distance down to water surface at end: 9 feet 6 inches

   Refill:
   - Time at start : 9:13:09 (Hours:Minutes:Seconds)
   - Time at end: 9:18:17
   - Distance down to water surface at start: 9 feet 6 inches
   - Distance down to water surface at end: 8 feet 1-1/2 inches

Formula

Pumping Rate

1. In a lift station with a diameter of 10 feet, you are able to lower the water level 6 inches in 2 minutes. What is the pumping rate in gallons per minute?

Formula

2. What is the pumping rate, in gallons per minute, if you are wasting sludge to a 20-foot diameter tank and the depth increases 3 inches in 20 minutes?

Formula

3. A pump lowers the water level 3 feet in 30 minutes in a wet well that is 15 feet by 12 feet. If no influent flow is coming into the wet well, what is the pumping rate in gallons per minute?

Formula

4. A pump test is done for 15 minutes in a wet well that is 10 feet in diameter. During the test, flow is entering the tank at the same time at a rate of 200 gallons per minute. While pumping, the water rises 2 feet in 15 minutes. How much water is being pumped in gallons per minute?

   Formula

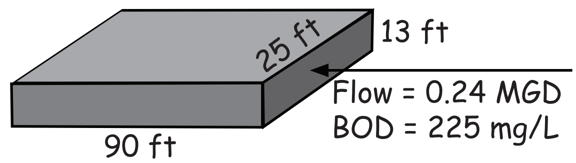
Notes

Answers page 111.

Activated Sludge Aeration Basin Organic Loading

1. An aeration basin is 90 feet long, 25 feet wide and 13 feet deep. If it receives a flow of 0.24 MGD at a BOD concentration of 225 mg/L, what is the basin's organic loading in pounds of BOD per day per 1,000 cubic feet?

Formula



Activated Sludge Aeration Basin Organic Loading

2. If an activated sludge aeration basin receives a flow of 0.69 MGD at a BOD concentration of 175 mg/L, how many pounds of BOD enter the aeration basin each day?

Formula

3. If the aeration basin from question #2 is 130 feet long, 35 feet wide and 15 feet deep, what is its organic loading in pounds of BOD/day/1,000 cubic feet?

Formula

Answers page 112.

4. The influent to an aeration basin averages 1,150 gpm at a BOD concentration of 125 mg/L. If the aeration basin is 125 feet long, 40 feet wide and 15 feet deep, what is its organic loading in pounds of BOD/day/1,000 cubic feet?

Formula

Activated Sludge Aeration Basin Organic Loading

5. Given the following information about an activated sludge plant, calculate the aeration basin loading in pounds of BOD/day/1,000 cubic feet.

Influent flow	1.46 MGD		Primary clarifier BOD removal efficiency	30%
Influent BOD	235 mg/L		Two aeration basins, each	140 feet x 40 feet x 15 feet

Formula

Answers page 112.

Activated Sludge F/M Ratio

1. An activated sludge aeration basin is 80 feet long, 20 feet wide and 12 feet deep. If the flow rate to it is 0.43 MGD at a CBOD concentration of 150 mg/L and the MLVSS concentration is 1,350 mg/L, what is the F/M ratio?

   Formula

2. An activated sludge aeration basin is 90 feet long, 25 feet wide and 15 feet deep. The flow rate to it is 0.75 MGD at a CBOD concentration of 210 mg/L. If the MLVSS concentration is 2,500 mg/L, what is the F/M ratio?

Formula

Answers page 112.

3. An activated sludge aeration basin is 75 feet long, 25 feet wide and 13 feet deep. The flow rate to it is 0.68 MGD at a CBOD concentration of 194 mg/L. If the MLVSS concentration is 2,114 mg/L, what is the F/M ratio?

Formula

Activated Sludge F/M Ratio

Use the following activated sludge plant data to calculate the information asked for in questions 4 and 5.

Average influent flow rate: 1,100 GPM
Influent CBOD concentration: 192 mg/L
Primary clarifier CBOD removal efficiency: 35%
Aeration basin dimentions: 125 feet x 40 feet x 15 feet
MLVSS concentration: 1,550 mg/L

4. What is the present F/M ratio?

   Formula

5. If you would like to increase the F/M ratio to 0.3/day, what would you need to change the MLVSS concentration to?

   Formula

Answers page 113.

Activated Sludge Solids Retention Time (SRT)

1. Given the following data about an activated sludge plant, calculate the SRT at which it is operating:
   Aeration basin dimensions: 110 feet x 40 feet x 13 feet
   Influent flow rate: 1.47 MGD
   Final clarifier dimensions: 50 feet x 25 feet x 13 feet
   MLVSS concentration: 1,500 mg/L
   Waste sludge concentraion: 7,750 mg/L
   Waste sludge flow rate: 20,000 GPD
   Effluent TSS: 17 mg/L

Formula

2. Given the following data about an activated sludge plant, calculate the SRT at which it is operating:
   Influent flow = 9,020,000 GPD
   Aeration basin dimensions: 160 ft x 50 ft x 18 ft
   Final clarifier dimensions: 94-ft diameter; 12 ft deep
   MLVSS concentration: 2,800 mg/L
   Waste sludge concentration: 5440 mg/L
   Waste sludge flow rate: 91,000 GPD
   Effluent TSS concentration: 10 mg/L

Formula

Answers page 113.

3. Calculate the SRT for the following activated sludge plant.
   Influent flow rate: 1097 GPM
   Aeration basin dimensions: 120 feet x 35 feet x 14 feet
   Final clarifier dimensions: 55 feet in diameter and 12 feet deep
   MLVSS concentration: 1,550 mg/L
   Waste sludge concentration: 7,500 mg/L
   Effluent TSS concentration: 24 mg/L
   Waste sludge flow rate: 15 GPM

Formula

4. Calculate the SRT for the following activated sludge plant.
   Influent flow rate: 875 gpm
   - Aeration basin dimensions: 110 feet x 35 feet x 15 feet
   - Final clarifier dimensions: 40 feet diameter and 12 feet deep
   - MLVSS concentration: 2,870 mg/L
   - Waste sludge concentration: 8,000 mg/L
   - Effluent TSS concentration: 28 mg/L
   - Waste sludge flow rate: 16 gpm

Formula

Answers page 113.

5. Calculate the wasting rate, in gallons per minute, for the following activated sludge plant.
   SRT = 25/day
   Influent flow rate: 4.36 MGD
   Aeration tanks: 4 tanks, each 160 feet x 40 feet x 18 feet
   Final clarifiers 2 clarifiers, each 60 feet diameter and 15 feet deep
   MVLSS concentration: 3,870 mg/L
   Waste sludge concentration: 9,000 mg/L
   Effluent TSS concentration: 12 mg/L

Formula

Notes

Answers page 114.

Trickling Filter – Organic/Hydraulic Loading

1. What is the organic loading rate, in pounds per day per 1,000 cubic feet, on a trickling filter that is 80 feet in diameter and 6 feet deep if it receives a flow of 0.5 MGD with a BOD concentration of 100 mg/L?

   Formula

2. What is the hydraulic loading rate in MGD per acre on a trickling filter that is 80 feet in diameter and 6 feet deep if it receives a flow of 0.5 MGD (with a 2:1 recirculation ratio) and has a BOD concentration of 100 mg/L?

Formula

Answers page 115.

3. Given the following data from a trickling filter plant, calculate the information asked for in A and B:
   - Influent flow: 1.3 MGD
   - No recirculation
   - BOD to trickling filter: 125 mg/L
   - Trickling filter diameter: 100 feet
   - Trickling filter depth: 7.5 feet

A. Calculate the organic loading in pounds/day/1,000 cubic feet.

Formula

B. Calculate the hydraulic loading in MGD/acre.

Formula

4. Given the following data from a trickling filter plant, calculate the information asked for in A and B:
   Influent flow: 2.4 MGD
   Recirculation rate is 1:1
   BOD to trickling filter: 135 mg/L
   Trickling filter diameter: 85 feet
   Trickling filter depth: 8 feet

A. Calculate the organic loading in pounds/day/1,000 cubic feet.

Formula

B. Calculate the hydraulic loading in MGD/acre.

Formula

Answers page 115.

5. Given the following data from a trickling filter plant, calculate the information in A and B:
   - Influent flow rate average: 1,350 GPM
   - Recirculation rate is 2.35:1
   - Plant influent wastewater BOD: 225 mg/L
   - Primary clarifier BOD removal: 32%
   - Trickling filter diameter: 95 feet
   - Trickling filter depth: 6 feet

A. Calculate the organic loading in pounds/day/1,000 cubic feet.

Formula

B. Calculate the hydraulic loading in MGD/acre.

Formula

Trickling Filter – Organic/Hydraulic Loading

6. Given the following data from a trickling filter plant, calculate the information asked for in A and B:
   Influent flow: 1.37 MGD
   No recirculation
   BOD to trickling filter: 135 mg/L
   Trickling filter diameter: 80 feet
   Trickling filter depth: 8.5 feet

A. Calculate the organic loading in pounds/day/1,000 cubic feet.

Formula

B. Calculate the hydraulic loading in MGD/acre.

Formula

Answers page 115.

7. Given the following data from a trickling filter plant, calculate the information in A and B:
   Influent flow: 2.48 MGD
   Recirculation rate is 1:1.2
   BOD to trickling filter: 125 mg/L
   Trickling filter diameter: 90 feet
   Trickling filter depth: 7.5 feet

A. Calculate the organic loading in pounds/day/1,000 cubic feet.

Formula

B. Calculate the hydraulic loading in MGD/acre.

Formula

Trickling Filter – Organic/Hydraulic Loading

8. Given the following data from a trickling filter plant, calculate the information asked for in A and B:

   Influent flow rate averages: 1,300 GPM
   Recirculation rate is 2.25:1
   Plant influent wastewater BOD: 205 mg/L
   Primary clarifier BOD removal: 25%
   Trickling filter diameter: 98 feet
   Trickling filter depth: 6 feet

A. Calculate the organic loading in pounds/day/1,000 cubic feet.

Formula

B. Calculate the hydraulic loading in MGD/acre.

Formula

Answers page 115.

Rotating Biological Contactor Organic/ Hydraulic Loading

1. A rotating biological contactor (RBC) system receives a flow of 2,000,000 gallons per day and a BOD of 225 mg/L. The total surface area of media is 1,200,000 square feet.

A. Calculate the organic loading rate in pounds/day/1,000 square feet?

Formula

B. Calculate the hydraulic loading rate in gallons/day/square feet?

Formula

2. A rotating biological contactor (RBC) system receives a flow of 1.25 MGD with a BOD of 300 mg/L. The total surface area of media is 900,000 square feet.

A. What is the organic loading rate in pounds/day/1,000 square feet?

Formula

B. What is the hydraulic loading rate in gallons/day/square feet?

Formula

Answers page 116.

3. Your rotating biological contactor (RBC) plant is designed for nitrogen removal at a hydraulic loading of 1.0 - 2.5 GPD/square foot. However, your effluent data indicates that nitrogen removal is below expected values. Using the following information, find out whether you are experiencing a hydraulic overload.
   Influent flow: 4.5 MGD
   Influent BOD: 250 mg/L
   Three trains, each with four shafts; each shaft contains 125,000 square feet of media

   Formula

4. As an operator, you would like to determine whether your two-train (each train has four shafts) rotating biological contactor (RBC) is organically overloaded. Your plant is designed to receive 2 pounds per day per 1,000 square feet. If the present flow is 550,000 GPD and your average influent BOD is 250 mg/L, are you organically overloaded if each shaft has 100,000 square feet of media?

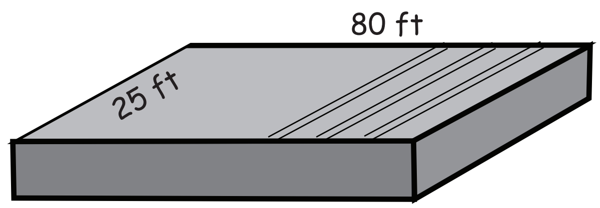
Formula

Answers page 116.

Clarifiers – Weir Overflow Rate

1. A final clarifier is 75 feet in diameter and receives a flow of 1.75 MGD. If the effluent weir is located 18 inches from the clarifier wall, what is the weir overflow rate in gallons per day per foot?

Formula



2. A primary clarifier is 80 feet long and 25 feet wide and has three launders (a total of six weirs) across its width. If it receives a flow of 1.5 MGD, what is the weir overflow rate in gal/day/foot?

Formula

3. A final clarifier is 95 feet in diameter, 13 feet deep and receives a flow of 3.75 MGD. If it has a single effluent weir located 18 inches inside the outside wall, what is the weir's overflow rate in gal/day/foot?

   Formula

4. A primary clarifier is 75 feet long, 25 feet wide and has four launders (a total of eight weirs) across its width. If it receives a flow of 1,050 GPM, what is the weir overflow rate in gal/day/foot?

   Formula

Answers page 116.

5. A final clarifier is 40 feet in diameter and has two effluent weirs. One weir is located 18 inches from the outside wall; the other is located 30 inches from the outside wall. If the clarifier receives a flow of 730 GPM, what is the weir overflow rate in gal/day/foot?

   Formula

6. A rim-feed final clarifier is 60 feet in diameter and has two effluent weirs. The first weir is located 18 feet from the outside wall and the second is located 24 inches inside the first one. If the clarifier receives a flow of 680 GPM, what is the weir overflow rate in gal/day/foot?

   Formula

Notes

Answers page 117.

Clarifiers – Surface Settling Rate

1. What is the surface settling rate in gallons per day per square foot of a clarifier that is 90 feet in diameter if the flow rate to it is 3.0 MGD?

   Formula

2. A primary clarifier is 80 feet long and 25 feet wide. If it receives a flow of 1.5 MGD, what is the surface settling rate in gal/day/square foot?

   Formula

3. If a final clarifier is 95 feet in diameter, 13 feet deep and receives a flow of 3.75 MGD, what is its surface settling rate in gal/day/square foot?

   Formula

4. A primary clarifier is 75 feet long and 25 feet wide. If it receives a flow of 1,050 GPM, what is the surface settling rate in gal/day/square foot?

   Formula

5. If a final clarifier is 40 feet in diameter, 13 feet deep and receives a flow of 570 GPM, what is its surface settling rate in gal/day/square foot?

   Formula

Answers page 117.

6. A treatment plant has four rectangular primary clarifiers, each 60 feet long and 20 feet wide. If the total flow to the plant is 1,800 GPM and the flow is split equally among the four clarifiers, what is the surface settling rate of each?

Formula

7. A treatment plant has two final clarifiers: one is 60 feet in diameter; the other is 40 feet in diameter. The flow is split so that the larger clarifier receives twice the flow of the smaller one. If the plant's influent flow rate averages 2,100 GPM, what is the surface settling rate of each clarifier?

Formula

Notes

Answers page 117.

Laboratory – Total/Volatile Solids

1. Using the laboratory information shown below, calculate the percent total solids
   Weight of dish (tare): 37.25 gm
   Weight of dish and wet solids: 97.25 gm
   Weight of dish and dried solids: 40.50 gm

   Formula

2. After burning the dried sludge in the crucible (question #1) in a muffle furnace and using the following information, find the percent volatile solids.
   Weight of dish (tare): 37.25 gm
   Weight of dish and dried solids (before ignition): 40.50 gm
   Weight of dish and solids after burning (after ignition): 37.76 gm

   Formula

3. Using the laboratory information shown below, calculate the percent total solids.
   Weight of dish (tare): 38.41 gm
   Weight of dish and wet solids: 112.69 gm
   Weight of dish and dried solids: 40.85 gm

   Formula

4. After burning the dried sludge in the crucible (question #3) in a muffle furnace and using the following information, find the percent volatile solids.
   Weight of dish (tare): 38.41 gm
   Weight of dish and dried solids (before ignition): 40.85 gm
   Weight of dish and solids after burning (after ignition): 39.16 gm

   Formula

Answers page 117.

5. Using the laboratory data below, calculate the percent total solids and the percent volatile solids.
   Weight of dish (tare): 34.20 gm
   Weight of dish and wet sludge: 114.38 gm
   Weight of dish and dried solids (before ignition): 35.63 gm
   Weight of dish and solids after burning (after ignition): 34.62 gm

A. Percent total solids:
Formula

B. Percent volatile solids:
Formula

Notes

Answers page 118.

Laboratory – Total Suspended Solids/Volatile Suspended Solids

1. Using the data below, calculate the total suspended solids in mg/L.
   Weight of dry filter (tare): 1.1798 gm
   Weight of filter and dried solids: 1.1944 gm
   Volume of sample: 500 ml

   Formula

2. After burning the dried solids on the filter (question #1) in a muffle furnace and using the following information, find the volatile suspended solids in mg/L.
   Weight of dry filter (tare) 1.1798 gm
   Weight of filter and dried solids: 1.1944 gm
   Volume of sample: 500 ml
   Weight of filter and solids after ignition: 1.1818 gm

   Formula

3. Using the data below, calculate the total suspended solids in mg/L.
   Weight of dry filter (tare): 1.1789 gm
   Weight of filter and dried solids: 1.2148 gm
   Volume of sample: 150 ml

   Formula

4. After burning the dried solids on the filter (question #1) in a muffle furnace and using the following information, find the volatile suspended solids in mg/L.
   Weight of dry filter (tare): 1.1789 gm
   Weight of filter and dried solids: 1.2148 gm
   Volume of sample: 150 ml
   Weight of filter and solids after ignition: 1.1879 gm

   Formula

Answers page 118.

5. Using this data, calculate the TSS in mg/L, the percent VSS and the VSS in mg/L:
   Weight of dry filter (tare): 1.1774 gm
   Weight of filter and dried solids: 1.2369 gm
   Volume of sample: 50 ml
   Weight of filter and solids after ignition: 1.1947 gm

A. Total suspended solids (TSS) in mg/L:

Formula

B. Percent volatile suspended solids:

Formula

C. Volatile suspended solids (VSS) in mg/L:

Formula

Notes

Answers page 118.

Laboratory – Volatile Acid/Alkalinity Ratio

1. Volatile acids: 100 mg/L; alkalinity: 250 mg/L
   What is the volatile acid-alkalinity ratio?

2. Volatile acids: 125 mg/L; alkalinity: 250 mg/L
   What is the volatile acid-alkalinity ratio?

3. Volatile acids/alkalinity: 0.5; Volatile acids: 100 mg/L
   What should be the alkalinity concentration (in mg/L) to maintain a volatile acid/alkalinity ratio of 0.5?

4. Volatile acids/alkalinity: 0.45; Alkalinity: 300 mg/L
   What should be the volatile acid concentration (in mg/L) to maintain a volatile acid/alkalinity ratio of 0.45?

Notes

Answers page 119.

Geometric Mean

1. What is the geometric mean of these fecal coliform results: 10, 50, <10, 150?
   (See procedure in formula book.)

2. What is the geometric mean of these fecal coliform results: 0, 20, <10, 100?

3. What is the geometric mean of these fecal coliform results: 10, 50?

4. What is the geometric mean of these fecal coliform results: 20, 40, 60?

5. What is the geometric mean of the following fecal coliform results?
   30, 45, 70, 80, 1000, 10

Notes

Answers & Selected Problems

Essential Math Refresher

1. a. 0.50; b. 0.67; c. 0.71; d. 0.13

2. a. 529; b. 2197; c. 2689; d. 531,441; e. 36; f. 0.13; g. 248.07; h. 0.60

3. a. 4; b. 25; c. 36

4. a. 35%; b. 127%; c. 2%; d. 60%; e. 4.5%; f. 220%

5. a. 0.46; b. 1.78; c. 0.0065

6. a. 104,720 gallons;

14,000 ~~cu ft~~	7.48 gallons	= 104,720 gal
	1 ~~cu ft~~	

   b. 122,283.04 gallons; c. 1,871.66 cu ft; d. 140.37 cu ft; e. 2.38 acres; f. 196,020 sq ft; g. 2245 gpm; h. 224.5 gpm; i. 0.01 cfs; j. 0.11 cfs; k. 2.24 gpm; l. 0.41 cfs; m. 15.7 gpm

7. C = D =

3.14	30 ~~in~~	1 ft	= 7.85 ft
		12 ~~in~~	

8. 1130.4 inches

9. 5.84 feet

10. $P = S_1 + S_2 + S_3 + S_4$
    = 35 ft + 15 ft + 35 ft + 15 ft = 100 feet

11. 18 feet

12. 189 feet

13. $A = 0.785 \times D^2$

= 0.785	30 ~~in~~	30 ~~in~~	1 sq ft	= 4.91 sq ft
			144 ~~sq in~~	

14. 706.50 sq ft

15. 7.065 sq ft

16. A = L x W = 35 ft x 15 ft = 525 sq ft

17. 5.56 sq ft

18. 0.28 acres

19. $V = 0.785 \times D^2 \times H$

= 0.785	20 ~~ft~~	20 ~~ft~~	30 ~~ft~~	7.48 gallons
				1 cu ~~ft~~

    = 70461.60 gal

20. 48,491.44 gal

21. 8807.7 gal

22. V = L x W x H

= 50 ~~ft~~	12 ~~ft~~	11 ~~ft~~	7.48 gallons
			1 ~~cu ft~~

    = 49,368 gal

23. 119,680 gal

24. 80,157.92 gal

25. 120 ft

26. 30 ft

27. 5 ft

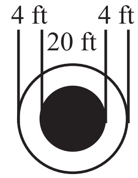
28. 120 ft

29. No – you need to buy one more gallon.

30. 10 feet

31. 41.67 sq yds; cost $1,458.33

32. C = d
= 3.14 x 28 = 87.92 feet

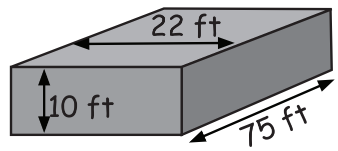


33. 139,513.96 gal

34. Yes. You need room for 4,697.44 gallons.

Detention Time

1. Detention Time = $\frac{\text{Volume}}{\text{Flow Rate}}$

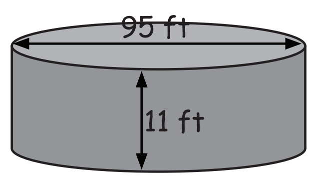


$$\text{Detention Time} = \overbrace{\frac{75\,\text{ft} \times 22\,\text{ft} \times 10\,\text{ft}}{}}^{\text{Volume}} \times \overbrace{\frac{7.48\,\text{gal}}{1\,\text{cu. ft.}}}^{\text{Conversion factor}} \times \underbrace{\frac{1\,\text{day}}{1{,}250{,}000\,\text{gal}}}_{\text{Flow rate}} \times \overbrace{\frac{24\,\text{hours}}{1\,\text{day}}}^{\text{Conversion factor}}$$

= 2.37 hrs

2. 1.85 hrs

3. 1.13 hrs



4. Detention Time = $\frac{\text{Volume}}{\text{Flow Rate}}$

$$\text{Detention Time} = \frac{0.785 \times 95\,\text{ft} \times 95\,\text{ft} \times 11\,\text{ft}}{} \times \frac{7.48\,\text{gal}}{1\,\text{cu ft}} \times \frac{1\,\text{day}}{7{,}000{,}000\,\text{gal}} \times \frac{24\,\text{hours}}{1\,\text{day}}$$

= 2 hrs

5. 1.65 hours

6. 2.44 hours

7. 135.21 days

8. No. You have storage for 13.04 MG; you will need storage for 16.20 MG.

Pond Discharge

1. Storage needed (acre-feet) = $\frac{180{,}000\ \text{gal}}{\text{day}} \times \frac{195\ \text{days}}{} \times \frac{1\ \text{acre-ft}}{326{,}000\ \text{gal}}$ = 107.67 acre-ft

   Storage available (acre-ft) = $\frac{3\ \text{cells}}{} \times \frac{12\ \text{acres} \times 1\ \text{ft}}{\text{cell}}$ = 36 acre-ft

   Difference between storage needed and storage available: 107.67 – 36 = 71.67 acre-ft

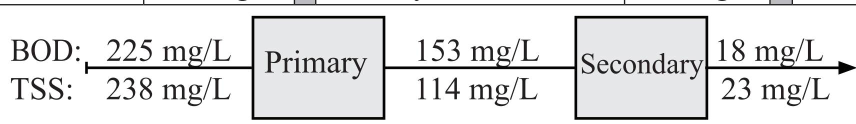
   Total feet needed = $\frac{71.67\ \text{acre-ft}}{12\ \text{acres}}$ = **5.97 feet**

2. 8.02 feet

Percent Removal

1.

Influent BOD	225 mg/L	Primary effluent BOD	153 mg/L	Plant effluent BOD	18 mg/L
Influent TSS	238 mg/L	Primary effluent TSS	114 mg/L	Plant effluent TSS	23 mg/L



   A. Percent removal = $\frac{\text{In - Out}}{\text{In}} \times 100\%$ = $\frac{225\ \text{mg/L} - 153\ \text{mg/L}}{225\ \text{mg/L}} \times 100\%$ = **32%**

   B. 52%
   C. 92%
   D. 90%

2. A. 36%
   B. 58%
   C. 94%
   D. 78%
   E. 96%
   F. 91%

3. A. 84%
   B. 75%
   C. 20%
   D. 54%
   E. 87%
   F. 88%

4. BOD = 185 mg/L; TSS = 325 mg/L *(Note: Divide effluent by the decimal equivalent of percent not removed.)*

Answers & Selected Problems

Pounds/Loading

1. Loading = Concentration x Flow (in MGD) x 8.34 lbs/gal

$$= 15\ \cancel{mg/L} \times \frac{1{,}500{,}000\ \cancel{gal}}{day} \times \frac{1\ \cancel{MG}}{1{,}000{,}000\ \cancel{gal}} \times 8.34\ lbs/\cancel{gal} = \boxed{187.65\ lbs/day}$$

NOTE: For an explanation of how these units cancel, see page 16!

2. 1,834.80 pounds per day

3. A. 14,540.79 lbs/day
   B. 18,506.46 lbs/day
   C. 1,057.51 lbs/day
   D. 1,321.89 lbs/day

4. 255,000 lbs/day

5. 294,117.65 people

6. City: 8,500 lbs/day; Industry: 1,042.5 lbs/day

7. 229.35 lbs/day

8. 33.36 lbs/day

9. 0.63 lbs/day

10. 11.99 mg/L

11. 5 mg/L

12. 5,502 pounds

13. 9,170 pounds

14. 10,425 pounds per day

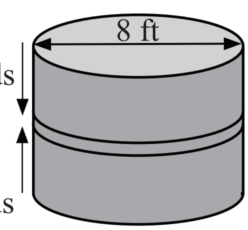
15. 8,340 pounds per day

Pump Calibration – Lift Station

1. Pumping Rate = $\frac{\text{Drawdown Volume}}{\text{Drawdown Time}} + \frac{\text{Refill Volume}}{\text{Refill Time}}$

Drawdown:
Time: 225 seconds
Distance: 1.26 ft

Refill:
Time: 410 seconds
Distance: 1.19 ft



Drawdown Volume = $0.785 \times D^2 \times H$

$$= \frac{0.785 \times 8\ \cancel{ft} \times 8\ \cancel{ft} \times 1.26\ \cancel{ft} \times 7.48\ gal}{1\ \cancel{cu\ ft}} = 473.50\ gal$$

Refill Volume = $0.785 \times D^2 \times H$

$$= \frac{0.785 \times 8\ \cancel{ft} \times 8\ \cancel{ft} \times 1.19\ \cancel{ft} \times 7.48\ gal}{1\ \cancel{cu\ ft}} = 447.20\ gal$$

Drawdown time = $225\ \cancel{sec} \times \frac{1\ min}{60\ \cancel{sec}} = 3.75\ min$ Refill time = $410\ \cancel{sec} \times \frac{1\ min}{60\ \cancel{sec}} = 6.83\ min$

Pumping Rate = $\frac{\text{Drawdown Volume}}{\text{Drawdown Time}} + \frac{\text{Refill Volume}}{\text{Refill Time}} = \frac{473.50\ gal}{3.75\ min} + \frac{447.20\ gal}{6.83\ min}$

$$= 126.26\ gal/min + 65.48\ gal/min = \boxed{191.74\ gal/min}$$

Pump Calibration – Lift Station continued

2. 263.05 gal/min

3. 460 gal/min (Reminder: Did you change seconds to minutes by dividing by 60 and inches to feet by dividing by 12? Drawdown time should be 5.12 min; refill time should be 7.38 min!)

4. 144.2 gal/min

Pumping Rate

1. Pumping rate = $\frac{\text{Volume pumped}}{\text{Time pumped}}$

Volume of cylinder — Conversion factors

Volume	= 0.785	10 ft	10 ft	6 in	1 ft	7.48 gal
					12 in	1 cu ft

Pumping rate = $\frac{\text{293.59 gal}}{\text{2 min}}$ = 146.79 gal/min

2. 29.35 gal/min

3. Pumping rate = $\frac{\text{volume}}{\text{time}}$ (Volume of tank = L x W x H)

= 15 ft	12 ft	3 ft	7.48 gal		= 134.64 gal/min
			1 cu ft	30 minutes	

4. 121.71 gal/min (Actual pumping rate = influent flow minus pumping rate)

Activated Sludge Aeration Basin Organic Loading

1. Organic Loading = $\frac{\text{Lbs per day of BOD to Aeration Tank}}{\text{Volume of Aeration Tank}}$

Lbs per day of BOD to Aeration Tank = Concentration x Flow (in MGD) x 8.34 lb/gal
= 225 mg/L x 0.24 MGD x 8.34 lb/gal = 450.36 lb/day
Note: For an explanation of how these units cancel, see page 16.

Vol of Tank = L x W x H = 90 ft x 25 ft x 13 ft = 29,250 cubic feet
(Note: problem asks for units per 1000 cubic feet. Divide by 1000 to get 29.25/1000 cubic feet.)

Organic Loading = $\frac{\text{450.36 lbs/day}}{\text{29.25 1000 cu ft}}$ = 15.40 lbs/day/1000 cu ft

Activated Sludge Aeration Basin Organic Loading continued

2. 1,007.06 pounds/day

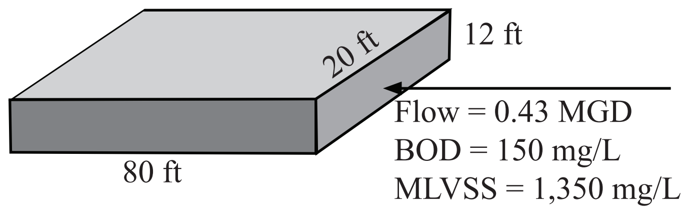
3. 14.76 lb BOD/day/1,000 cu ft

4. 23.07 lb BOD/day/1,000 cu ft

5. 11.92 lb BOD/day/1,000 cu ft

Activated Sludge F/M Ratio

1.



$$F/M = \frac{\text{Lbs of Food to Aeration Tank}}{\text{Lbs of Solids under Aeration}}$$

Lbs of Food to Aeration Tank = Concentration (mg/L) x Flow (in MGD) x 8.34 lbs/gal
= 150 mg/L x 0.43 MGD x 8.34 lb/gal = 537.93 lb/day

Lbs of Solids under Aeration = MLVSS (mg/L) x Tank Volume (MG) x 8.34 lb/gal

$$= \underbrace{1350\ \text{mg/L}}_{\text{MLVSS}} \times \underbrace{80\ \cancel{\text{ft}} \times 20\ \cancel{\text{ft}} \times 12\ \cancel{\text{ft}}}_{\text{Tank volume}} \times \underbrace{\frac{7.48\ \cancel{\text{gal}}}{1\ \cancel{\text{cu ft}}} \times \frac{1\ \text{MG}}{1{,}000{,}000\ \cancel{\text{gal}}}}_{\text{Conversion factors}} \times 8.34\ \text{lbs/gal} = 1616.97\ \text{lbs}$$

$$F/M = \frac{537.93\ \cancel{\text{lbs}}/\text{day}}{1616.97\ \cancel{\text{lbs}}} = \boxed{0.33/\text{day}}$$

2. 0.25/day

3. 0.34/day

4. 0.23/day

5. 1,170 mg/L

Activated Sludge Solids Retention Time (SRT) and Wasting Rate

1. $$\text{SRT} = \frac{{}^{A.}\text{Total Lbs MLSS in Secondary System}}{{}^{B.}\text{Lbs Activated sludge wasted per day} + {}^{C.}\text{Lbs TSS lost in effluent per day}}$$

A. Total Lbs MLSS (Aeration & Clarifier) = conc. (mg/L) x **total volume (MG)** x 8.34lbs/gal

Total volume $= \text{Vol}_{\text{Aeration tank}} + \text{Vol}_{\text{Clarifier}}$ *(Note: includes conversion factors)*

$$= \underbrace{110\text{ ft} \times 40\text{ ft} \times 13\text{ ft}}_{\text{Aeration tank volume}} \times \underbrace{\frac{7.48\text{ gal}}{1\text{ cu ft}} \times \frac{1\text{ MG}}{1{,}000{,}000\text{ gal}}}_{\text{Conversion factors}} + 50\text{ ft} \times 25\text{ ft} \times 13\text{ ft} \times \frac{7.48\text{ gal}}{1\text{ cu ft}} \times \frac{1\text{ MG}}{1{,}000{,}000\text{ gal}}$$

= 0.549 MG

Total lbs MLSS (aeration & clarifier) = 1,500 mg/L x 0.549 MG x 8.34 lb/gal
= 6,867.99 lbs

B. Lbs activated sludge wasted per day = conc (mg/L) x Flow (MGD) x 8.34 lbs/gal
= 7,750 mg/L x 0.020 MGD x 8.34 lbs/gal
= 1,292.70 lbs/day

C. Lbs TSS lost in effluent per day = conc (mg/L) x Flow (MGD) x 8.34 lbs/gal
= 17 mg/L x 1.47 MGD x 8.34 lbs/gal
= 208.42 lbs/day

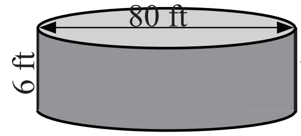
$$\text{SRT} = \frac{6867.99\text{ lbs}}{1292.70\text{ lbs/day} + 208.42\text{ lbs/day}}$$

Reminder: Add first; then divide!

SRT = 4.58 days

2. 8.13 days
3. 5.06 days
4. 7.12 days
5. 44.71 gpm

Trickling Filter Organic/Hydraulic Loading



Flow = 0.5 MGD
BOD = 100 mg/L

1. Organic Loading = $\dfrac{\text{Lbs per day applied to filter}}{\text{Volume of filter media}}$

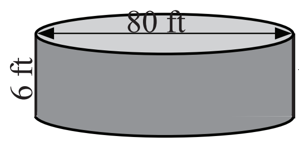
A. Lbs per day applied to filter = concentration (mg/L) x Flow (MGD) x 8.34 Lbs/gal
= 100 mg/L x 0.5 MGD x 8.34 Lbs/gal
= 417 Lbs/day

B. Volume of filter media = 0.785 x D^2 x H
= 0.785 x 80 ft x 80 ft x 6 ft
= 30,144 cu ft or 30.144 1000 cu ft

> *Note:*
> *To change cubic feet to 1000 cubic feet, divide by 1000.*

Organic Loading = $\dfrac{\text{Lbs per day applied to filter}}{\text{Volume of filter media}}$

= $\dfrac{\text{417 Lbs/day}}{\text{30.144 1000 cu ft}}$ = **13.83 Lbs/day/1000 cubic feet**



Flow = 0.5 MGD
BOD = 100 mg/L
2:1 Recirculation ratio

2. Hydraulic Loading Rate = $\dfrac{\text{Total flow to filter*}}{\text{Surface area of filter}}$

*Total flow = influent flow + recirculation flow

Think it through: The total flow is the sum of the influent flow and the recirculation flow. Since the recirculation ratio is 2:1, the recirculation flow is 2 times the influent flow or 1.0 MGD. So the total flow is 0.5 MGD (the influent flow) + 1.0 MGD (the recirculation flow) or 1.5 MGD

Hydraulic Loading Rate = $\dfrac{\text{Total flow to filter}}{\text{Surface area of filter}}$

Total flow: 1.5 MGD; Surface area: 0.785 x 80 ft x 80 ft; Conversion factor: 43,560 sq ft / 1 acre

$$= \frac{1.5\ \text{MGD}}{0.785 \times 80\ \cancel{\text{ft}} \times 80\ \cancel{\text{ft}}} \times \frac{43{,}560\ \cancel{\text{sq ft}}}{1\ \text{acre}}$$

= **13 MGD/acre**

Trickling Filter Organic/Hydraulic Loading, continued

3. A. 23.02 pounds/day/1,000 cubic feet
   B. 7.22 MGD/acre

4. A. 59.55 pounds/day/1,000 cubic feet
   B. 36.86 MGD/acre

5. A. 58.36 pounds/day/1,000 cubic feet
   B. 40.04 MGD/acre

6. A. 36.12 pounds/day/1,000 cubic feet
   B. 11.88 MGD/acre

7. A. 54.22 pounds/day/1000 cubic feet
   B. 31.08 MGD/acre

8. A. 50.95 pounds/day/1,000 cubic feet
   B. 35.17 MGD/acre

Rotating Biological Contractor Organic/Hydraulic Loading

1. A. Organic Loading = $\dfrac{\text{pounds per day applied to RBC}}{\text{total surface area (in 1,000 sq feet)}}$

   Think it through: The pounds per day applied to the RBC is
   the concentration (in mg/L) X flow (in MGD) X 8.34 lbs/gal (conversion factor)

$$\text{Organic Loading} = \overbrace{225 \text{ mg/L}}^{\text{Concentration}} \times \overbrace{2.0 \text{ MGD}}^{\text{Flow}} \times \overbrace{\frac{8.34 \text{ lbs}}{\text{gal}}}^{\text{Conversion factor}} \times \underbrace{\frac{1{,}000}{1{,}200{,}000 \text{ sq ft}}}_{\text{Surface area / 1000 sq ft}}$$

$= \boxed{3.13 \text{ lbs/day/1000 sq ft}}$

   B. Hydraulic Loading = $\dfrac{\text{Flow rate}}{\text{Total surface area of media}}$

$= \dfrac{2{,}000{,}000 \text{ gal/day}}{1{,}200{,}000 \text{ sq ft}}$

$= \boxed{1.67 \text{ gal/day/sq ft}}$

NOTE: To change 1,200,000 sq ft to per 1,000 sq ft, you divide by 1,000 BUT, since that results in a complex fraction, invert and multiply so the 1,000 actually ends up on top. *For more information, see page 18.*

Rotating Biological Contractor Organic/Hydraulic Loading, continued

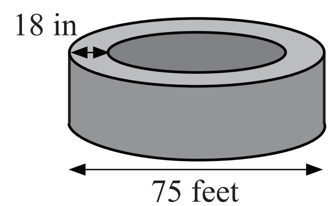
2. A. 3.48 pounds/day/1000 sq ft
   B. 1.39 gal/day/sq ft

3. Yes – present hydraulic loading of 3.0 GPD/sq ft

4. No – present BOD loading is 1.43 pounds per day for 1,000 sq ft or 72 percent of design

Clarifiers Weir Overflow Rate

1. Weir overflow rate = $\dfrac{\text{Flow rate}}{\text{Weir length}}$



NOTE #1: Since the weir is 18 inches in from the wall on both sides, you need to subtract 18 inches from each side or 3 feet total from the overall diameter to get the diameter of the weir.

NOTE #2: Since the weir is a circle, the length is the circumference of the circle.

$$\text{Weir overflow rate} = \overbrace{\frac{1.75\ \cancel{\text{million gal}}}{\text{day}}}^{\text{Flow rate}} \underbrace{\frac{1{,}000{,}000\ \text{gal}}{1\ \cancel{\text{million gal}}}}_{\substack{\text{Conversion}\\ \text{factor}}} \underbrace{\frac{1}{3.14 \mid 72\ \text{ft}}}_{\substack{\text{Circumference}\\ \text{(length)}}}$$

$$= \boxed{7{,}740.6\ \text{gal/day/ft}}$$

2. 10,000 gal/day/ft

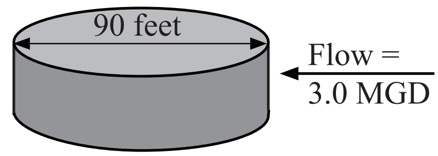
3. 12,981.17 gal/day/ft

4. 7,560 gal/day/ft

5. 4,649.68 gal/day/ft

6. 7,087.43 gal/day/ft

Clarifiers Surface Settling Rate



1. Surface settling rate = $\dfrac{\text{Flow rate}}{\text{Surface area}}$

Flow; Conversion factor; Surface area $(0.785 \times D^2)$

$$= \frac{3.0\ \text{million gal}}{\text{day}} \times \frac{1{,}000{,}000\ \text{gal}}{1\ \text{million gal}} \times \frac{1}{0.785 \times 90\ \text{ft} \times 90\ \text{ft}}$$

$$= 471.81\ \text{gal/day/sq ft}$$

2. 750 gal/day/sq ft

3. 529.32 gal/day/sq ft

4. 806.40 gal/day/sq ft

5. 653.50 gal/day/sq ft

6. 540 gal/day/sq ft

7. 60 ft clarifier = 713.38 gal/day/sq ft; 40 ft clarifier = 802.55 gal/day/sq ft

Lab Total / Volatile Solids

1. Total solids (in %) = $\dfrac{\text{Weight of dry solids}}{\text{Weight of wet solids}} \times 100\%$

$$= \frac{3.25\ \text{gm}}{60\ \text{gm}} \times 100\% = 5.42\%$$

NOTE: Remember to subtract the weight of the dish to get the weight of the solids only.

2. 84.31%

3. 3.28%

4. 69.26%

5. A. 1.78%
   B. 70.63%

Answers & Selected Problems

Lab Total Suspended/ Volatile Suspended Solids

1. Total suspended solids $= \dfrac{\text{Weight of suspended solids}}{\text{Volume of sample}}$

$$= \frac{0.0146 \text{ gm}}{500 \text{ ml}} \left| \frac{1{,}000 \text{ mg}}{1 \text{ gm}} \right| \frac{1{,}000 \text{ ml}}{1 \text{ L}}$$

$$= 29.2 \text{ mg/L}$$

NOTE: Remember to subtract the weight of the filter to get the weight of the solids only.

2. Volatile suspended solids $= \dfrac{\text{Weight of material lost by burning}}{\text{Volume of sample}}$

$$= \frac{0.0126 \text{ gm}}{500 \text{ ml}} \left| \frac{1{,}000 \text{ mg}}{1 \text{ gm}} \right| \frac{1{,}000 \text{ ml}}{1 \text{ L}}$$

$$= 25.2 \text{ mg/L}$$

*NOTE: To get the material lost by burning, subtract the weight of the filter and solids after ignition **from** the weight of the filter and dried solids before ignition.*

3. 239.3 mg/L

4. 179.30 mg/L

5. A. 1190 mg/L
   B. 70.9%
   C. 844 mg/L

Lab Volatile Acid/ Alkalinity Ratio

1. Volatile Acid/Alkalinity Ratio $= \dfrac{\text{Volatile acid}}{\text{Alkalinity}} = \dfrac{100 \text{ mg/L}}{250 \text{ mg/L}} = 0.40$

2. 0.50

3. 200 mg/L

4. 135 mg/L

Geometric Mean

See the procedure for calculating geometric mean on page 7 in *Wastewater Formulas & Conversion Factors*.

1. • Drop the “<”.
   • Multiply all results: 10 x 50 x 10 x 150 = 750,000
   • Push the y^x or x^y key.
   • Enter the number of values used in step #1 (four) and push the 1/x key OR divide 1 by the number of values used in step #1 (1 ÷ 4 = 0.25) and enter that into the calculator
   • Push the “=” key.

   29.43

2. 11.89

3. 22.36

4. 36.34

5. 65.03

Notes

Common Formulas & Abbreviations

Perimeter

- Rectangle or square: $P = S_1 + S_2 + S_3 + S_4$
- Circle: C = x D (*where* *= 3.14*)

Area

- Rectangle or square: A = L x W
- Circle: $A = 0.785 \times D^2$
- Triangle: $A = \frac{B \times H}{2}$

Volume

- Rectangle: Volume = Area x Height
  Volume = L x W x H
- Cylinder: Volume = Area x Height
  Volume = $0.785 \times D^2 \times H$
- Cone: Volume = $\frac{\text{Area} \times \text{Height}}{3}$
  Volume = $\frac{0.785 \times D^2 \times H}{3}$

Velocity

- Velocity = $\frac{\text{distance traveled}}{\text{time}}$
- Velocity = $\frac{\text{flow rate}}{\text{area}}$

Percent Removal

$$\% \text{ removal} = \frac{\text{influent - effluent}}{\text{influent}} \times 100\%$$

Calibrated Pumping Rate

Calibrated pumping rate (gal/min)

$$= \frac{\text{drawdown volume (gal)}}{\text{time to drawdown wet well (min)}} + \frac{\text{refill volume (gal)}}{\text{time to refill wet well (min)}}$$

Detention Time

$$\text{Detention time} = \frac{\text{volume of tank}}{\text{flow rate to or from tank}}$$

Loading

Loading (lb/day) =
conc (mg/l) x flow (MGD) x 8.34 lbs/gal

Feed rate (lb/day) =
dosage (mg/l) x flow (MGD) x 8.34 lbs/gal

Food to Microorganism Ratio (F/M)

F/M =

$$\frac{\text{CBOD (mg/l)} \times \text{flow (MGD)} \times 8.34 \text{ lb/gal}}{\text{MLVSS (mg/l)} \times \text{Vol Aer Tank (MG)} \times 8.34 \text{ lb/gal}}$$

Common Abbreviations

- A = Area
- C = circumference
- Cu in = cubic inches or inches^3
- Cu ft = cubic feet or feet^3
- cfs = cubic feet per second
- D = diameter
- Ft = foot or feet
- Gal = gallons
- gpm = gallons per minute
- H = height
- In = inch
- L = length
- Lb = pound
- Mgal or MG = million gallons
- mg/L = milligrams per liter
- Min = minute
- P = perimeter
- Pi or = 3.14
- ppm = parts per million
- R = radius
- Rise = vertical distance or height
- Run = horizontal distance or length
- S = side of a rectangle
- Sq in = square inches or inches^2
- Sq ft = square feet or feet^2
- V or Vol = volume
- Vel = velocity
- W = width
- Yr = year

Conversion Factors

Length

1 inch	= 2.54 centimeters	= 25.4 millimeters
1 foot	= 12 inches	= 0.305 meters
1 yard	= 3 feet	= 0.914 meters
1 mile	= 5,280 feet	= 1,760 yards
1 meter	= 39.37 inches	= 3,281 feet
1 kilometer	= 0.621 miles	= 1,000 meters

Volume

1 cubic foot	= 1,728 cubic inches
1 cubic foot	= 7.48 gallons
1 cubic yard	= 27 cubic feet
1 acre-inch	= 27,152 gallons
1 acre-foot	= 43,560 cubic feet
1 acre-foot	= 326,000 gallons
1 gallon	= 3.785 liters
1 gallon	= 231 cubic inches
1 gallon	= 4 quarts
1 cubic meter	= 35.3 cubic feet
1 cubic meter	= 1.3 cubic yards
1 liter	= 0.2642 gallons
1 liter	= 1,000 milliliters

Area

1 square foot	= 144 square inches
1 square yard	= 9 square feet
1 square mile	= 640 acres or 1 section
1 square meter	= 10.764 square feet
1 square meter	= 10,000 square centimeters
1 acre	= 43,560 square feet
1 hectare	= 2.471 acres

Flow

1 cubic foot/second	= 449 gallons/minute
1 gallon/second	= 0.133 cubic feet/second
1 gallon/second	= 8.028 cubic feet/minute
1 gallon/minute	= 0.00223 cubic feet/second
1 gallon/minute	= 1440 gallons/day

Weight

1 gallon	= 8.34 pounds of water
1 cubic foot	= 62.4 pounds of water
1 foot of water	= 0.433 pounds per square inch
1 pound	= 0.454 kilograms
1 kilogram	= 1,000 grams
1 pound per square inch	= 2.31 feet of water
1 liter	= 1,000 grams
1 mg/kg or 1 ppm or 1 mg/l	= 0.0022 pounds/ton or 0.0001%
1 mg/l	= 1000 g/l

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