Rules of Fractions

Rule 1-

A fraction is a numerical expression for division. The fraction ½ means the same as 1 ÷2. Think of a fraction as an unfinished division problem.

Fractions have a numerator and a denominator. For the fraction ½; 1 is the numerator and 2 is the denominator. The line drawn between them is call the fraction bar.

1	=	numerator
2	=	denominator

Rule 2

When the numerator and the denominator of a fraction are equal, the fraction reduces to one (1).

$$\frac{5}{5} = 1 \qquad \frac{2}{2} = 1 \qquad \text{or} \qquad \frac{meter}{meter} = 1 \qquad \frac{feet}{feet} = 1$$

Essentially, if the numbers or units are the same on the top and bottom a fraction, they cancel one another out and equal one.

Rule 3

Likewise, a whole number can be expressed as a fraction by putting 1 in the denominator or any number divided by one is itself.

$$\frac{7}{1} = 7 \qquad \frac{11}{1} = 11 \qquad \text{or} \qquad \frac{6\ feet}{1} = 6\ feet \qquad \frac{2.2\ miles}{1} = 2.2\ miles$$

Any whole number or even individual unit; if it appears to be alone and not a fraction it can always be put over one (1).

Problems

Complete the following few questions using the 3 rules of fractions.

$\frac{3}{11} =$ $\qquad$ $\frac{7}{7} =$ $\qquad$ $\frac{22\ inches}{?} = 22\ inches$

$\frac{7}{21} =$ $\qquad$ $\frac{3911}{3911} =$ $\qquad$ $\frac{17.1\ kilometers}{?} = 17.1\ kilometers$

$\frac{49}{121} =$ $\frac{mile}{mile} =$ $\frac{8.4\ gallons}{?} = 8.4\ gallons$

Percents & Decimals

Percentage represents a part of the whole. In a single water system alone there are multiple different amounts each water storage being different, different pipe sizes, different pump capacities, different chemical storage bins, strengths of chemical, and the list can go on and on. Using a simple reference of something commonly known such as 50% whatever item it is applied to, we automatically know the amount that is in the container.

Percentages	Decimal
11.00 %	0.11
60.00 %	0.60
0.50 %	0.005
0.07 %	0.0007
0.003 %	0.00003

By comparing the percentages column to the decimal column, we see the relationship between them. If we move the decimal point in a percentage two places to the left, we have a decimal; if we move the decimal point in a decimal two places to the right, we have a percentage. This is the same as dividing by or multiplying by 100.

To summarize to go from a:

Percent to a Decimal – **divide** the number by 100
or move the decimal point in the percentage two places to the **left**

Decimal to a Percent – **multiply** the number by 100
or move the decimal point in the decimal two places to the **right**

***It is always best to convert a percent to a decimal before doing any math computations with it.**

Often we are required to determine what percent one number is of another number. To do this, we convert the percentage to a decimal and multiply as appropriate.

Example: What is 25% of 90?

Solution: First, convert 25% to its decimal equivalent --- 0.25. Since we want "percent of" we multiply the decimal equivalent by the number we want to take the percentage of.

25% of 90 = ?
0.25 x 90 = 22.5

Think of **"percent of"** as meaning the same as **"multiply by."**

Example: What is 32% of 612?

Solution: Since 32% = 0.32, we get;

0.32 x 612 = 195.84

Sometimes we need to determine what percent some quantity is of another quantity.

Example: A 500-gallon tank contains 320 gallons. What percent of the tank is full?

Solution: Remember that a percent means parts per 100 parts. In this example, we need to express the problem as a fractional or decimal relationship and then convert the fraction or decimal to a percentage. First, think of the problem as a "parts per parts" problem. Relate the number of gallons in the tank to the total number of gallons available in the tank.

500 gallons represents the total the tank can hold or 100 %
320 gallons in a 500-gallon tank is the same as;
320 gallons/500 gallons or 320 gal ÷ 500 gal
320 gal ÷ 500 gal = 0.64
Converting the decimal 0.64 to a percent multiply by 100
0.64 x 100% gives us 64%.

SAMPLE PROBLEMS

(1) Write the decimal equivalent of the following percentages.

(a) 29% Answer __________

(b) 7% Answer __________

(c) 252% Answer __________

(d) 1/2 of 4% Answer __________

(2) Express the following decimals in percentages.

(a) 0.4 Answer __________

(d) 0.27 Answer __________

(c) 0.009 Answer __________

(b) 9.18 Answer __________

(3) A chemical solution tank with a 150-gal capacity is to be filled to the 70% mark. How many gallons are required to do this?

(4) A water treatment plant with a capacity of 350,000 gal/day is operating at 45% capacity. How much water is this plant processing?

Unit Conversions

In the water industry we often see many numbers as far as gallons (gal), milligrams per liter (mg/L), cubic feet (ft^3) area measurements in square feet (ft^2), and there are many more examples. These are either conversion factors or the final answers in some questions. However, we must learn how to use these factors in a 4-step process to make them useful to us. There are 2 valuable definitions that are crucial to understanding unit conversation calculations, and it will be described and taught in the first example of this section.

Example 1

Convert 15 feet to inches.

Step 1-Is to identify conversion factors needed in order create a clear path to your desired answer. Sometimes more than one conversion factors are required to complete the calculation.

1 foot = 12 inches

You can clearly see that 1 foot = 12 inches seems like the correct conversion factor. There is also some definitions we need to discuss first. Ratios is defined as two different numbers that are equal to each other. Look above 1 and 12 are not the same number but the units allow them to be equal. The other is proportions simply means ratios can be written as fractions as seen below.

$$\frac{1\,foot}{12\,inches} \quad or \quad \frac{12\,inches}{1\,foot}$$

Step 2-Is to write what you start with once and only once never more. Keeping in mind the rules of fractions.

$$\frac{15\,feet}{1}$$

15 feet alone is assumed to be over 1 according to Rule 3 of the fraction rules.

Step 3-Is to select the proper conversation factor form to get 15 feet to inches. You will need go back and look at Step 1 where proportions were defined. Rule 2 of fractions now comes into effect if feet are on the top of a fraction, they must be on the bottom to cancel. Select and write it out now like shown below.

$$\frac{15\,foot}{1} \;x\; \frac{12\,inches}{1\,foot} = ?$$

Step 4-Cancel the units on top and bottom and do the math! To do the math do everything across the top multiplied, and everything across the bottom. Divide at the end if you need too.

$$\frac{15\ \cancel{feet}}{1} \quad x \quad \frac{12\ inches}{1\ \cancel{foot}} = \frac{15\ x\ 12}{1\ x\ 1} = \frac{180\ inches}{1}$$

Answer is 180 inches.

These are the same rules you are going to use to solve for the next few problems before we move onto to Areas and Volumes review.

EXAMPLE: 8 MILES + 4 FEET + 50 YARDS = ?

SOLUTION; If all these are converted to feet, then:

8 miles= 8 miles x $\frac{5280\ feet}{1\ mile}$ = 42,240 feet

4 feet = (already in feet) = 4 feet

50 yards = 50 yards x $\frac{3\ feet}{1\ yard}$ = 150 feet

42,394 feet

EXAMPLE: 5 YARDS + 2 FEET + 10 INCHES = ?

SOLUTION: Convert these all to feet.

$$5 \text{ yards} = 5 \text{ yards} \times \frac{3 \text{ feet}}{1 \text{ yard}} = 15 \text{ feet}$$

$$2 \text{ feet} = \text{(already in feet)} = 2 \text{ feet}$$

$$10 \text{ in.} = 10 \text{ in.} \times \frac{1 \text{ feet}}{12 \text{ in.}} = \underline{0.83 \text{ feet}}$$

$$= 17.83 \text{ feet}$$

EXAMPLE: A storage tank holds 2000 cubic feet of water.

a. How many gallons of water will it hold?

b. How much does this amount of water weigh?

SOLUTION: To work this problem, you should refer to Table I.

a. Multiply 2000 cubic feet by 7.48 to obtain the number of gallons which this is equivalent to.

$2000 \text{ ft}^3 \times 7.48 = 14{,}960$ gallons

rounding off, we get 15,000 gallons

This works because 7.48 is the "conversion factor" used to convert form cubic feet to gallons. This conversion factor has units and it should be used with the units so mistakes are not made.

$$7.48 \text{ gallons per cubic foot} = 7.48 \text{ gal/ft}^3$$

When working with conversion factors and units, remember that units above the faction bar cancel out similar units below the fraction bar. For our example

$$2000 \cancel{\text{ft}^3} \times \frac{7.48\text{gal}}{1 \cancel{\text{ft}^3}} = 14{,}960 \text{ gal}$$

or approximately 15,000 gallons

Since ft^3 are in both the numerator and denominator (both above and below the fraction bar), they cancel each other out. Gallons appear only above the fraction bar, so our answer is in gallons.

b. Convert from gallons to pounds. The conversion factor used to convert water from gallons to pounds is 8.34 pounds per gallon or 8.34 lb/gal, therefore

15,000 gal x 8.34 lbs/gal = 125,100 lbs of water
125,100 lbs can be rounded to 125,000 lbs

In this case, gallons are in both the numerator and denominator and can therefore be cancelled.

Sample Problems

1. Convert 350 fpm to fps

2. Convert 750 gpm to gpd

3. Convert 9 cfs to gpm

4. Convert 560 gpm to cfs

CALCULATION OF AREAS

Area can be thought of as a measurement of the surface of a figure, having only two dimensions; length (L) and width (w). Units of length and width commonly used in the English system are the inch, foot, yard and mile; the common units in the metric system are the centimeter, meter and kilometer. Units of surface or area are expressed as square inches (in^2), square feet (sq.ft. or ft^2) and so forth depending on the unit of length used.

Some of the simpler shapes commonly encountered and their area formulas are given as follows:

The **RECTANGLE**, a four-sided figure having four right (90^o) angles.
Area = length (L) times width (w).

A = L x w

Example: Calculate the area of a room given dimensions of:
length = 34 feet
width = 22 feet

Solution: Write down the formula for determining the area of a rectangle. Substitute in the values given for length and width. Perform calculations.

Area = A = L x w

A = 34 ft x 22 ft = 748 square feet

The units are square feet because we have

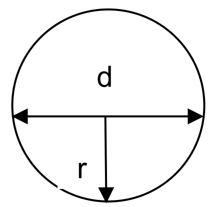
$ft \times ft = ft^2$

A **<u>CIRCLE</u>** is a closed curve in which all points on the curve are equally distant from a fixed point called the center. The length of measurement from the circle's center to the circle itself is called the radius (r). The diameter (d) is the length from one side of the circle to the other side, passing through the center point. The diameter is equal to 2 times the radius (d = 2r).

The area of a circle is given as pi (π) times the radius squared.
(π) is a constant value equal to approximately 3.14.

Area = 0.785 x diameter^2.

A = 0.785x d^2



Example: What is the area of a circle that has a diameter of 20 inches?

Solution: Because we are given a "radius", we know the shape of the area we are asked to determine is a circle. Therefore, we use the area of a circle formula, substitute in the given value and perform the calculation.

Area = A = 0.785 x d^2 = 0.785 x (20 in)^2 = 314 square inches(in^2)

<u>CALCULATION OF VOLUMES</u>

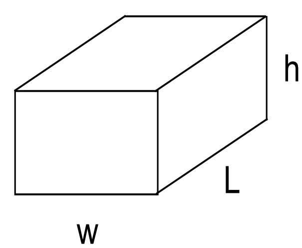
A figure in three dimensions is termed a solid figure and its size or occupied space is expressed in terms of its volume. The volumes of several common shapes are shown below. <u>Units</u> of volume for the most common shapes, rectangular prisms and cylinders, are expressed as the cube of the linear dimensions. For example, if we are measuring the contents of a box with dimensions given in feet, the unit of volume of the box will be cubic feet (ft^3). If the dimensions are given in inches, the unit of volume will be cubic inches (in^3). Another important unit of volume is the gallon. From the "units" discussion before, we know that the various units of volume can be converted from one to another, provided we know the proper relationships between the units (conversion factors).

The volumes (V) for some of the more common shapes are given below. Combining the information discussed here with the "converting units" information allows us to calculate the volumes of tanks, basins, cylinders, pipelines, etc. and convert from "cubic" units of volume to gallons. On the other hand, if we are given a volume in gallons, we can determine how many "cubic" units we need to hold this amount of water.

The **<u>RECTANGULAR PRISM</u>**

VOLUME = area of base (L x w) times height (h)

V = L x w x h



<u>Example</u>: Calculate the volume of a tank that has the following dimensions:

length = 34 feet

width = 14 feet

height = 11 feet

<u>Solution</u>: Since we are given length, width and height, we know the shape of the basin must be a rectangular prism.

We first write down the formula for the volume of a prism and then substitute in the appropriate dimensions.

$$V = L \times w \times h$$
$$V = 34 \text{ ft} \times 14 \text{ ft} \times 11 \text{ ft}$$
$$V = 5236 \text{ ft}^3$$

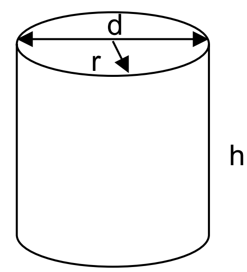
Our units are "cubic feet" because we are multiplying.

$$\text{ft} \times \text{ft} \times \text{ft} = \text{ft}^3$$

The **<u>CYLINDER</u>**

2 x radius = diameter

$V = 0.785\ d^2h$



<u>Example</u>: A chemical solution barrel 4 feet high has a diameter of 3 feet. How many gallons of solution can this barrel hold?

<u>Solution</u>: Write down the formula for determining the volume of a cylinder (barrel). Substitute the appropriate dimensions, being consistent with the units, and calculate. Convert from cubic feet to gallons.

$V = 0.785 \times d^2 \times 4 = 0.785\ (3 \text{ ft})^2 \times 4' = 28.26 \text{ ft}^3$

or rounded off, $V = 28 \text{ ft}^3$

Using the conversion factor for changing cubic feet to gallons

$$28 \text{ ft}^3 \times \frac{7.48 \text{ gal}}{1 \text{ ft}^3} = 209 \text{ gallons}$$

Special note: When determining the volume of a cylinder, you need the diameter (or radius) and another dimension. The other dimension is either the height or the length. We can think of cylinders in terms of their vertical height (like the height of a barrel or standpipe) or horizontally (like a length of water or sewer main). The volume formula is the same except we use "height" (h) in one case and "length" (L) in the other. For example, the volume of a barrel is

$$V = 0.785 \times d^2 \times h$$

Whereas the volume of a length of main is

$$V = 0.785 \times d^2 \times L$$

Whenever you are asked to determine the volume of a shape and you are given a diameter, then you know immediately that the shape is that of a cylinder. You then determine the volume by multiplying the cross-sectional area of the circle by the height or length. If you are to determine the volume of a shape that has dimensions of length, width and height, then the shape is a rectangular prism.

Sample Problems

(1) What is the area of a rectangular room measuring 32 ft in length and 42 ft wide?

(2) The standard isolation area of a municipal well is 200 feet in all directions from the well. How many square feet is this?

(5) What is the volume of a cylinder 15 feet high having a diameter of 9 feet? Express your answer in cubic feet and gallons.

(6) How many gallons of water will a water main hold that is 18 inches in diameter and 1500 feet long?

Concentration Expressions-Adding Chlorine to Water

Concentrations for chlorine and other chemicals and compounds in water are commonly expressed in terms of parts per million (ppm) or milligrams per liter (mg/L). These terms are the same as each other and used interchangeably. Part per million is defined as one pound of any substance in a million (M) pounds of another. For generality purposes, the million pounds (M lbs) will always be for water. We will be working exclusively the term as ppm not mg/L, but it vitally important to remember they are the same thing.

1 ppm = 1 mg/L

When calculating the concentration of a chemical in water, the weight of chemicals is place on the top of the part per million equation and the weight of water expressed in "M lbs" units, is placed on the bottom.

$$Part\ per\ Million\ (ppm) = \frac{pounds\ of\ chemical}{million\ pounds\ of\ water\ (M\ lbs)}$$

The part per million equation can be used with any chemical at any concentration. Listed below is the formula you need to familiarize yourself with:

$$ppm = \frac{pounds\ of\ pure\ chemical}{M\ lbs\ of\ Water}$$

Example: One pound of chlorine in 5,000 pounds of water is equal to what concentration expressed as ppm? as mg/L?

1st thing to do is always find the million pounds of water (M lbs).
Once you find the amount of water in pounds to get it to the big "M" units is to divide by a million.

$$\frac{5{,}000}{1{,}000{,}000} = 0.005 \text{ M lbs}$$

$$ppm = \frac{lbs\ of\ pure\ chemical}{M\ lbs\ of\ Water} = \frac{1\ lb}{0.005\ M\ lbs} = 200 \text{ ppm} = 200 \text{ mg/L}$$

Another thing, about the ppm equation is it can be used to find the amount of pure chemical that must be added to achieve a desired dose. Refer to the example below to simplify the algebraic process.

Example: Solve for the X in the following equation using the concept of cross multiple and divide.

$$\frac{7}{x} = \frac{5}{8}$$

Sample Problems

$$\frac{11}{31} = \frac{x}{12}$$ x=_______

$$26 = \frac{x}{8}$$ x=_______

Now, let's take that concept and look at the ppm equation.

$$ppm = \frac{pounds\ of\ pure\ chemical}{M\ lbs\ of\ Water}$$

The ppm is all alone on the left side and just like the sample problem rule 3 of fractions. At the beginning of this training, we learned any whole number can be assumed to be over 1. Putting ppm over 1 makes this a double fraction just like above and allows you to solve for pounds of pure chemical by using cross multiple technique.

Example: If water system sample from the distribution system has a concentration of 0.7ppm of chlorine and has total pumpage of 1 M gal. How many pounds of chlorine were added to the water system?

$$\frac{1\ M\ \cancel{Gal}}{1} x\ \frac{8.34\ lbs}{1\ \cancel{Gal}} = 8.34\ M\ lbs$$

$$0.7ppm = \frac{x}{8.34\ M\ lbs} \longrightarrow \frac{0.7ppm}{1} = \frac{x}{8.34\ M\ lbs}$$

You only need to multiple 0.7 ppm by 8.34 M lbs. In the process of doing units cancel leaving just pounds of pure chemical left. The 1 does not need to be multiplied because anything times 1 is itself.

0.7 ppm x 8.34 M lbs = 5.84 pure pounds of chlorine

These steps for this equation may help you solve other types of problems later on in the session.

<u>**Sample Problems**</u>

1) 5 pounds of chlorine in 7 million pounds of water equals what concentration in ppm?

2) 5 pounds of chlorine in 200,000 pounds of water equals what concentration in ppm?

3) 6 pounds of chlorine in 15,000 gallons equals what concentration in ppm?

4) Theoretically, how many pounds of pure chlorine must be added to 900,000 gallons of water to produce a residual of 2.0 ppm?

CHLORINE FORMS

Chlorine Gas (Cl_2) - As a gas, the available chlorine is 100%. This is a liquid chlorine, or gas liquefied under pressure, and is available in 150 pound cylinders and one ton containers. As noted previously, it reacts with water as follows:

$Cl_2 + H_2O \leftrightarrows HOCl + HCl$ ..and.. $HOCl \leftrightarrows H^+ + OCl^-$

Calcium Hypochlorite ($Ca[OCl]_2$) - This is a solid which contains 65% available chlorine. It is produced in powder, granular, and tablet form and is easily shipped and stored. It is sold under various trade names such as "HTH", "Perchloron" and "Pittchlor". This form must either be mixed with water to form a solution and pumped into the system, or added as is to a nonpressurized system. Its reaction with water is as follows:

$Ca(OCl)_2 + 2H_2O \leftrightarrows 2HOCl + Ca(OH)_2$ ...calcium hydroxide

$2HOCl \leftrightarrows 2H^+ + 2OCl^-$

Sodium Hypochlorite ($NaOCl$) - This is a liquid containing between 3% and 19% available chlorine. It is sold under numerous trade names such as, “Roman Cleanser", “Clorox Bleach", etc. It can be readily purchased at a variety of locations and is easy to use and handle. Because of this, it is the most common form of chlorine used in small water systems. Its reaction with water is as follows:

$NaOCl + H_2O \leftrightarrows HOCl + NaOH$ ...sodium hydroxide

$HOCl \leftrightarrows H^+ + OCl^-$

Example On a particular day, a treatment plant applies 150 lbs of chlorine, and the flow meter shows that 2,000,000 gallons of water were treated. How many ppm of chlorine were applied?

Solution Write down the parts per million formula and substitute the values for lbs of chemical and million lbs of water. Be sure million lbs of water are expressed in the unit "million lbs of water" and not in million "lbs of water".

$$\text{ppm} = \frac{\text{lbs of pure chemical}}{\text{million lbs of water}}$$

$$= \frac{150 \text{ lbs chlorine}}{2 \text{ M gal x } 8.34 \text{ lbs/gal}}$$

$$= \frac{150 \text{ lbs}}{16.7 \text{ M lbs}} = 9 \text{ ppm}$$

Therefore, 9 ppm of chlorine was applied.

When working problems to determine concentrations, be sure the units in the numerator and denominator are the same. For the above example, we were given gallons of water and needed to convert to "million pounds" (M lbs). For this, use of the conversion factor (8.34 lb/gal) was necessary. Water really weighs 8.34 lbs/gal only under standard conditions 20°C and no impurities dissolved or suspended in the water. Although standard conditions are rarely encountered in practice, this does not make significant differences in our answers. Occasionally, some compensation for conditions other than standard are made and the weight conversion factor is stated as 8.34 lbs/gal.

How we use the parts per million equation to solve a problem depends on how the problem is presented. In some cases, we are told how much chlorine (chemical) is to be dissolved in a certain amount of water. In this case, we simply use the standard equation

$$\text{ppm} = \frac{\text{lbs of pure chemical}}{\text{million lbs of water}}$$

substitute in the known values and perform the calculation.

Example: A chlorinator is set to feed 10 lbs of chlorine per day to a flow of 250 gpm. What is the chlorine dose in ppm?

Solution:

$$\text{ppm} = \frac{\text{lbs of pure chemical}}{\text{million lbs of water}}$$

lbs of chemical is given as 10, we need to determine how much water, in M lbs, we are chlorinating.

$$\frac{250 \text{ gal}}{\text{min}} \times \frac{60 \text{ min}}{\text{hr}} \times \frac{24 \text{ hrs}}{\text{day}} \times \frac{8.34 \text{ lbs}}{\text{gal}} = 3{,}002{,}400 \text{ lbs/day}$$

each day, we have 3,002,400 lbs = 3 M lbs

$$\text{ppm} = \frac{10 \text{ lbs}}{3 \text{ M lbs}} = 3.3 \text{ ppm}$$

In other problems, we are given (or are given information that allows us to determine) the ppm and million lbs of water, and we are asked to find the amount of chemical needed. For this type of problem, we use an adaptation of the standard ppm equation;

ppm x million lbs of water = lbs of pure chemical

The above equation was derived by solving for the unknown "lbs of pure chemical" using the principles we discussed. Let us look closer at the units for this equation.

ppm x million lbs of water = lbs of pure chemical

$$\frac{\text{lbs}}{\text{M lbs}} \times \frac{\text{M lbs of water}}{1} = \text{lbs pure (100\%) chemical}$$

With these concepts in mind, we can now calculate the amount of chemical needed to provide for a specific rate of application.

Example: A community chlorinates its drinking water. If 1.7 million gallons are pumped each day, how many pounds of 100% available chlorine are needed to produce 1.0 ppm?

Solution: Set up the parts per million equation, make appropriate substitutions, calculate:

$$\text{ppm} = \frac{\text{lbs of chlorine}}{\text{M lbs of water}}$$

$$1.0 \text{ ppm} = \frac{\text{lbs of chlorine}}{1.7 \text{ M gal} \times 8.34 \text{ lbs/gal}}$$

$$1.0 \text{ ppm} = \frac{\text{lbs of chlorine}}{14.2 \text{ M lbs of water}}$$

Now solve for the unknown pounds of chlorine by clearing the right side of the equation to get the "lbs of chlorine" by itself. We do this by multiplying both sides of the equation by 14.2 M lbs of water. Because "ppm" is lbs per M lbs, the M lbs cancel and we are left with lbs of chlorine.

$$\frac{1.0 \text{ lb}}{\text{M lbs}} \times \frac{14.2 \text{ M lbs}}{1} = 14.2 \text{ lbs of 100\% chlorine}$$

In most operations, 100% available chemical is not used (gas chlorine is the exception). Frequently, some other concentration of available chlorine is used. These concentrations are expressed in terms of "percent available chlorine." Typical percents include 5.25%, 10%, and 65% available chlorine.

One way to think of the "percent available" of the compound we are dealing with is as follows. Because percent is "parts per 100 parts" (see the fraction section for a review of this topic), "percent available" represents the amount of pure substance, in pounds, per 100 pounds of compound. Given that we have 65% available chlorine, we can easily calculate how many pounds of pure chemical are available provided we know how many pounds of compound we have.

Example — How many pounds of chlorine are in 4 lbs of a compound that has 65% available chlorine?

Solution — We calculate this by multiplying the weight of pure chlorine in the 65% pure compound, by the number of pounds of compound we have.

$$\frac{\text{65 lbs pure chlorine}}{\text{100 lbs of cmpd}} \times \frac{\text{4 lbs of compound (cmpd)}}{1} = \text{2.6 lbs pure } Cl_2$$

Therefore, 2.6 lbs of pure chlorine are contained in 4 lbs of a compound that has 65% available chlorine. The following sample problems will give you more practice.

SAMPLE PROBLEM

1. How many pounds of chlorine are in 10 lbs of a compound that has 65% available chlorine??

Suppose we are given a situation where a known volume of water is pumped on a daily basis and we desire to maintain a particular chlorine concentration in a drinking water. If we calculate, we need 9 lbs of 100% available chlorine to provide this concentration, how do we calculate how many pounds of 65% available chlorine we need for this?

If we think of "X" as the amount of 65% available chlorine needed to equal 9 lbs of 100% available chlorine, then

$$\frac{\text{65 lbs of pure chlorine}}{\text{100 lbs compound}} \times \text{"X"} = \text{9 lbs pure chlorine}$$

Solve for "X" by multiplying both sides by $\frac{\text{100 lbs cmpd}}{\text{65 lbs pure}}$

$$X = \frac{\text{9 lbs pure}}{1} \times \frac{\text{100 lbs cmpd}}{\text{65 lbs pure}}$$

$$X = \text{14 lbs cmpd}$$

Therefore, we need 14 lbs of 65% available chlorine. We need <u>more</u> chemical compound when the percent availability is less than 100% than we do with a chemical compound of 100% availability.

Sometimes the compound that contains the desired chemical is liquid. Before the amount of available chemical is determined, the weight of the compound must be calculated.

<u>Example</u> How many pounds of chlorine are in 5 gallons of compound that weighs 10 pounds per gallon and has 10% available chlorine??

<u>Solution</u> 5 gallon compound x $\frac{10\text{ lbs}}{1\text{ gal}}$ = 50 lbs of compound

Since the compound has a 10% chlorine availability

10% of 50 lbs = 0.10 x 50 lbs = 5 lbs of pure chlorine

By combining the various techniques discussed above with volume calculations, we can work computations involving disinfection of water mains.

<u>Example</u> How many gallons of liquid chlorine (5.25 % available chlorine) would be required to apply 50 ppm chlorine to 500 feet of new 6 inch watermain?? Assume liquid chlorine weighs 10 lbs/gallon.

<u>Solution</u> Diameter is 6 inches = 0.5 feet

Volume = area x length = (0.785 x d^2) x L

V = 0.785 x $(0.5\text{ft})^2$ x 500 ft = 98 ft^3 of water to apply chlorine to

98 ft^3 x 62.4 lbs/ft^3 = 6,100 lbs

6,100 lbs x $\frac{\text{M lbs water}}{1{,}000{,}000\text{ lbs}}$ = 0.0061 M lbs water

We know ppm = $\frac{\text{lbs chemical (chlorine)}}{\text{million lbs water}}$ => 50ppm = $\frac{\text{lbs of pure chlorine}}{0.0061}$

so, lbs of chlorine = ppm x million lbs water

50 x 0.0061 = 0.31 lbs of 100% chlorine

== 0.31 lbs pure

We know how many lbs of pure chlorine we need, how many lbs of 5.25% available chlorine do we need?

$\frac{\text{5.25 lbs pure}}{\text{100 lbs cmpd}}$ x "X" = 0.31 lbs 100% available Cl_2

Solving for "X", we get

$$X = 0.31 \text{ lbs pure} \times \frac{100 \text{ lbs cmpd}}{5.25 \text{ lbs pure}}$$

X = 5.9 lbs of cmpd

Now determine the gallons of liquid chlorine needed. Since our compound weighs 10 lbs/gal,

$$5.9 \text{ lbs} \times \frac{1 \text{ gal}}{10 \text{ lbs}} = 0.59 \text{ gal } 5.25\% \text{ liquid } Cl_2$$

SAMPLE PROBLEMS

2. How many pounds of chlorine are in 9 gallons of a solution that weighs 10 pounds per gallon and has 5% available chlorine??

3. How many pounds of calcium hypochlorite (65% available chlorine) would be required to disinfect 800 feet of 8-inch water main with 50 ppm of chlorine??

As in math there is multiple ways to do the same question. In the above examples we explored the concept of converting from pure chlorine to a compound containing 5.25% available chlorine.

Recall, this question earlier:

$$X = 0.31 \text{ lbs } \cancel{\text{pure}} \times \frac{100 \text{ lbs compound}}{5.25 \text{ lbs } \cancel{\text{pure}}} = \qquad X = 5.9 \text{ lbs of compound}$$

In order, to do what is being done above one must pull this unit conversion factor from the stated question. Trying to imagine an artificial amount of 100 pounds of something without physically seeing it can be hard. Let's try something else that some people will find easier to visualize. In a given question, there will be a percentage that represents the actual available percentage of a pure element in a compound. Earlier, in this course you learned **how to convert percentage to decimals by simply moving the decimal point within the percentage two places to the left**.

<u>RECALL:</u> 72.00% → 72.00% = 0.72

Percentages are given in the questions now let's discuss any easy approach to using them other than trying to imagine 100 lbs of compound and the amount of pure based on the percent.

.

To summarize this "Rule of Thumb":

Going from compound to pure, you multiple by the percent.
Going from pure to compound, you divide by the percent.

<u>Example</u>: How many gallons of liquid chlorine (5.25% available chlorine) would be required to apply 50 ppm chlorine to 500 feet of new 6-inch watermain? Assume liquid chlorine weighs 10 lbs/gallon.

<u>Solution:</u> Diameter is 6 inches. Convert to feet by dividing by 12 = 0.5 feet
Volume = area x length = $(0.785 \times d^2) \times L$
$V = 0.785 \times 0.5 \times 0.5 \times 500 = 98ft^3$ of water supply to apply chlorine to
$98\ ft^3 \times 7.48\ gal/ft^3 \times 8.34\ lbs/gal = 6100$ lbs of water

$$\frac{6100 \text{ lbs of water}}{1{,}000{,}000 \text{ lbs of water}} = 0.0061 \text{ M lbs of water}$$

We know $\text{ppm} = \dfrac{\text{lbs of pure chemical}}{\text{M lbs of Water}}$

So lbs of pure chemical = ppm x M lbs of Water
50 ppm x 0.0061 M lbs of Water = 0.31 lbs of pure chlorine

We now know how many pounds of pure chlorine we need, but the problem asks for gallons of a liquid chlorine compound, how do we convert to this?

Now instead of trying to imagine 100 pounds of something like the previous example to this, let's make it easier. Look for the percent within the initial question and convert to decimal.

5.25% = 0.0525

Using the rule of thumb, we have a pure chemical and need to convert to compound, we need to divide.

$$\frac{\text{0.31 lbs of chlorine}}{0.0525} = \text{5.9 lbs of compound}$$

Now determine the gallons of liquid chlorine needed. Since our compound weighs 10 lbs/gal. You can simple divide by the 10 lbs/gal to get your answer.

$$\frac{\text{5.9 lbs of compound}}{\text{10 lbs/gal}} = \text{0.59 gallons of 5.25\% liquid chlorine.}$$

Chlorine Review Problems

How many pounds of chlorine are in 6 gallons of a solution that weighs 10 pounds per gallon and has 10% available chlorine?

How many pounds of chlorine are in 9 gallons of a solution that weighs 10 pounds per gallons and has 5% available chlorine?

Eight pounds of chlorine in 650,000 lbs of water equals what concentration in ppm?

Five pounds of chlorine in 300,000 lbs of water equals what concentration in ppm?

If 65 pounds of chlorine are added to 6 million gallons of water, what is the concentration of chlorine?

What is the concentration of chlorine if 22 pounds of chlorine are added to 275,000 gallons of water?

What is the concentration of chlorine if 17 pounds of chlorine are added to 120,000 gallons of water?

How many pounds of chlorine are in a 20 gallon solution that weighs 10.4 pounds per gallon and has 5.25% available chlorine?

Calculate how much HTH powder in pounds (65% available chlorine) would be required to obtain a chlorine dose of 75 ppm in an elevated water tank 45 feet in diameter and 70 feet deep.

How many gallons of bleach (5.25% available chlorine) would be required to apply 50 ppm chlorine to 500 feet of new 6-inch watermain? Assume bleach weighs 10 lbs/gallon.

How many pounds of calcium hypochlorite (65% available chlorine) would be required to disinfect 1,000 feet of 12-inch water main with 50 ppm of chlorine?

It is desired to apply 3 mg/l of chlorine to a well which pumps 500 gallons/minute (gpm). How many pounds of chlorine gas are used in one day?

A water supply has a chlorine demand of 3 mg/l. It is desired to maintain a residual throughout the distribution system of 0.4 parts per million. How many gallons of sodium hypochlorite (12% available) are needed to maintain this residual knowing that the water supply pumps 300,000 gallons each day? Assume one gallon of sodium hypochlorite weighs 10.4 pounds.

A water treatment plant treating 10 MGD is prechlorinating with 150 pounds of chlorine gas per day and postchlorinating with 100 pounds of chlorine gas per day. What are the respective prechlornation and postchlorination application rates in mg/l?

Estimate the chlorine dose in mg/l if a chlorinator feeds at a rate of 21 lbs per 24 hours and the flow is 0.60 MGD.

A new 18-inch well must be disinfected. You want a chlorine residual of 125 ppm. The depth of the well is 1000 feet and the static water level is 200 feet below the top of the casing. How many pounds of chlorine will you need?

You are required to add chlorine to your water supply for disinfection. You have determined that your system has a chlorine demand of 0.9 ppm and you wish to maintain a chlorine residual of 0.5ppm. The flow through your treatment plant is 11 MGD (million gallons per day). Assume you are using 15% Sodium Hypochlorite and it weighs 10.4 lbs/gallon. Your chemical feed pump should be set at

Chlorination Questions

1. How many gallons of sodium hypochlorite (12.5%) are required to disinfect a 6-inch diameter water line that is 1,000 feet long using 50 mg/L chlorine solution? Assuming liquid sodium hypochlorite weighs 10 lbs/gal.

2. How much chlorine gas is required to treat 5 million gallons of water to provide a 0.7 residual?

3. How many pounds of available chlorine are there in 50 pounds of 65% calcium hypochlorite?

4. A chlorinator is set to feed 20 pounds of chlorine in 24 hours to a flow of 0.85 MGD. Find the chlorine dose in mg/L.

5. What should be the setting on a chlorinator (lbs chlorine per 24 hours) if the service pump usually delivers 600 gpm and the desired chlorine dosage is 4.0 mg/L?

6. How many pounds of 65% HTH chlorine will be required to disinfect 400 feet of 8-inch water main at 50 ppm?

7. What should the chlorinator setting be (lbs/day) to treat a flow of 2 MGD if the chlorine demand is 5 mg/l and a chlorine residual of 0.8 mg/l is desired?

8. How many pounds per day of HTH (65% available chlorine) are required to disinfect 10,000 feet of 8-inch water line if an initial dose of 20 mg/l is required?

9. Your water has a chlorine demand of 1.4 ppm and you desire a residual of 0.7 ppm. What should your chlorine dose be?

10. A new 12-inch well must be disinfected. You want a chlorine residual of 100 ppm. The depth of the well is 1000 feet and the static water level is 300 feet below the top of the casing. How many pounds of chlorine will you need?

11. The pump in your main well has been replaced. The well driller dumps 6 pounds of HTH down the well for disinfection. What is the concentration of Cl in the well?
    Assume: HTH contains 65% available chlorine; Well diameter = 18 inches for the entire well depth
    Well depth = 600 feet; Static water level = 150 feet below top of casing

12. You are required to add chlorine to your water supply for disinfection. You have determined that your system has a chlorine demand of 0.8 ppm and you wish to maintain a chlorine residual of 0.5 ppm. The flow through your treatment plant is 5 MGD. Assume 100% available chlorine. Your chlorinator should be set at

13. What is the chlorine dose if you apply 120 pounds of 12.5% sodium hypochlorite in 2 days with a flow of 2.5 MGD?

14. As water superintendent, you must determine the chemical costs of chlorinating your water supply. Assume the following data applies to your system:

Average daily pumpage = 1.5 MGD	Average chlorine demand = 1.0 ppm
Desired chlorine residual = 0.3 ppm	Gas chlorine at 19 cents per pound

What would be the yearly chlorine costs?

15. A barrel 3 feet tall and 2.5 feet in diameter is filled with sodium hypochlorite. This chlorine solution is fed to a well which pumps for 16 hours at a rate of 400 gpm. After this period of time, the level in the barrel has dropped 9 inches. How many pounds of sodium hypochlorite is used? Assume NaOCl contains 12.5% available chlorine and weighs 10 lbs/gal.

Chlorine Review Problems

How many pounds of chlorine are in 6 gallons of a solution that weighs 10 pounds per gallon and has 10% available chlorine?

$6\,gal \times \frac{10\,lbs}{1\,gal} = \underset{comp}{60\,lbs} \times .10 = 6$ lbs of pure

How many pounds of chlorine are in 9 gallons of a solution that weighs 10 pounds per gallons and has 5% available chlorine?

$9\,gal \times \frac{10\,lbs}{1\,gal} = 90$ lbs of comp $\times .05 = 4.5$ lbs of Cl_2

Eight pounds of chlorine in $\frac{650{,}000}{1{,}000{,}000}$ lbs of water equals what concentration in ppm?

$\frac{8}{.65\,M\,lbs\,H_2O} = 12.3\,ppm$

Five pounds of chlorine in $\frac{300{,}000}{1{,}000{,}000}$ lbs of water equals what concentration in ppm?

$5/.3\,M\,lbs = 16.67\,ppm$

If 65 pounds of chlorine are added to 6 million gallons of water, what is the concentration of chlorine? $6 \times 8.34 = 50.04\,M\,lbs\,H_2O$

$\frac{65}{50.04\,M\,lbs} = 1.3\,ppm$

What is the concentration of chlorine if 22 pounds of chlorine are added to 275,000 gallons of water? $275{,}000\,gal \times 8.34 = \frac{2293500}{1{,}000{,}000} = 2.29\,M\,lbs\,H_2O$

$\frac{22}{2.29} = 9.61\,ppm$

What is the concentration of chlorine if 17 pounds of chlorine are added to 120,000 gallons of water?

$120{,}000\,gal \times 8.34 = \frac{1{,}000{,}800\,lbs}{1{,}000{,}000} = 1\,M\,lbs$

$\frac{17}{1} = 17\,ppm$

How many pounds of chlorine are in a 20 gallon solution that weighs 10.4 pounds per gallon and has 5.25% available chlorine?

$20\,gal \times \frac{10.4\,lbs}{1\,gal} = 208\,lbs$ of comp $\times .0525 = 10.92\,lbs$ of pure

Calculate how much HTH powder in pounds (65% available chlorine) would be required to obtain a chlorine dose of 75 ppm in an elevated water tank 45 feet in diameter and 70 feet deep.

$V = .785d^2 \times h$

$.785 \times 45ft \times 45ft \times 70ft \times 8.34 \times 7.48 = \frac{6{,}941{,}613\,lbs \text{ of } H_2O}{1{,}000{,}000} = 6.94\,M\,lbs\,H_2O$

$75 \times 6.94 = \frac{520.5\,lbs \text{ of } \cancel{comp}\text{ pure}}{.65} = 800.77\,lbs$ of ~~pure~~ comp

How many gallons of bleach (5.25% available chlorine) would be required to apply 50 ppm chlorine to 500 feet of new 6-inch watermain? Assume bleach weighs 10 lbs/gallon.

$.785 \times .5 \times .5 \times 500 \times 7.48 \times 8.34 = \frac{6121.3\,lbs}{1{,}000{,}000} = .006\,M\,lbs\,H_2O$ 12

$50\,ppm \times .006\,M\,H_2O = \frac{.3\,lbs \text{ of } \cancel{comp}\text{ pure}}{.0525} = \frac{5.71\,lbs \text{ of } \cancel{pure}\text{ comp}}{10} = .57\,gal$

How many pounds of calcium hypochlorite (65% available chlorine) would be required to disinfect 1,000 feet of 12-inch water main with 50 ppm of chlorine?

$.785 \times 1 \times 1 \times 1000 \times 7.48 \times 8.34 = \frac{48971}{1{,}000{,}000} = .0489\,M\,lbs$ 12

$50\,ppm \times .0489\,M\,lbs\,H_2O = \cancel{2445}\,lbs$ of ~~comp~~ pure

$\frac{2.445}{.65} = 3.76\,lbs$ of ~~pure~~ comp

A new 18-inch well must be disinfected. You want a chlorine residual of 125 ppm. The depth of the well is 1000 feet and the static water level is 200 feet below the top of the casing. How many pounds of chlorine will you need?

18/12 = 1.5 ft   1000 - 200 = 800ft for height

$.785 \times 1.5 \times 1.5 \times 800 \times 7.48 \times 8.34 = \frac{88147 \text{ lbs of } H_2O}{1{,}000{,}000} = .088$ M lbs H_2O

$.088 \times 125$ppm = ~~lbs~~ 11 lbs. of ~~[illegible]~~ Cl_2

You are required to add chlorine to your water supply for disinfection. You have determined that your system has a chlorine demand of 0.9 ppm and you wish to maintain a chlorine residual of 0.5ppm. The flow through your treatment plant is 11 MGD (million gallons per day). Assume you are using 15% Sodium Hypochlorite and it weighs 10.4 lbs/gallon. Your chemical feed pump should be set at

.9 + .5 = 1.4 ppm total dose   11 MGD x 8.34 = 91.74 M lbs H_2O

$1.4 \times 91.74 = \frac{128.44 \text{ lbs of pure}}{.15} = \frac{856.27 \text{ lbs of pure}}{10.4} = 82.33$ gal of chlorine solution

It is desired to apply 3 mg/l of chlorine to a well which pumps 500 gallons/minute (gpm). How many pounds of chlorine gas are used in one day?

$\frac{500 gal}{1 min} \times \frac{8.34 lbs}{1 gal} \times \frac{60 min}{1 hr} \times \frac{24 hr}{1 day} = \frac{6,004,800 lbs}{1,000,000} = 6\ M lbs\ H_2O$

$3 ppm \times 6\ M\ lbs\ H_2O = 18 lbs$ of gas

A water supply has a chlorine demand of 3 mg/l. It is desired to maintain a residual throughout the distribution system of 0.4 parts per million. How many gallons of sodium hypochlorite (12% available) are needed to maintain this residual knowing that the water supply pumps 300,000 gallons each day? Assume one gallon of sodium hypochlorite weighs 10.4 pounds.

total dose = demand + residual = 3 + .4 = 3.4 ppm

$300,000 gal \times 8.34 = \frac{2,502,000 lbs}{1,000,000} = 2.5\ M\ lbs\ H_2O$

$3.4 ppm \times 2.5\ M\ lbs = \frac{8.5 lbs\ of\ pure}{.12} = \frac{70.83 lbs\ of\ comp}{10.4} = 6.81$ gal of chlorine solution

A water treatment plant treating 10 MGD is prechlorinating with 150 pounds of chlorine gas per day and postchlorinating with 100 pounds of chlorine gas per day. What are the respective prechlornation and postchlorination application rates in mg/l?

$8.34 \times 10\ MGD = 83.4\ M\ lbs$

$\frac{150}{83.4} = 1.8 ppm$

$\frac{100}{83.4} = 1.2 ppm$

Estimate the chlórine dose in mg/l if a chlorinator feeds at a rate of 21 lbs per 24 hours and the flow is 0.60 MGD.

$.6 \times 8.34 = 5.004\ M\ lbs\ H_2O$

$\frac{21}{5} = 4.2 ppm$

Chlorination Questions

1. How many gallons of sodium hypochlorite (12.5%) are required to disinfect a 6-inch diameter water line that is 1,000 feet long using 50 mg/L chlorine solution? Assume sodium hypochlorite weighs 10 lbs/ gal?

$6/12 = .5\ ft = D$

$.785 \times .5 \times .5 \times 1000 \times 7.48 \times 8.34 = \frac{12,243\ lbs}{1,000,000\ lbs} = .012$ M lbs H_2O

$.012 \times 50\ ppm = \frac{.6\ lbs\ of\ pure}{.125} = \frac{4.8\ lbs\ of\ pure}{10\ lbs/gal} = .48$ gal of sodium hypochlorite

2. How much chlorine gas is required to treat 5 million gallons of water to provide a 0.7 residual?

$5 \times 8.34 = 41.7$ M lbs H_2O

$41.7 \times .7 = 29.19$ lbs of pure (gas)

3. How many pounds of available chlorine are there in 50 pounds of 65% calcium hypochlorite?

$50\ comp \times .65 = 32.5$ lbs of pure

4. A chlorinator is set to feed 20 pounds of chlorine in 24 hours to a flow of 0.85 MGD. Find the chlorine dose in mg/L.

$.85\ MGD \times 8.34 = 7.09$ M lbs of H_2O

$\frac{20}{7.09} = 2.82$ ppm

5. What should be the setting on a chlorinator (lbs chlorine per 24 hours) if the service pump usually delivers 600 gpm and the desired chlorine dosage is 4.0 mg/L?

$\frac{600\ gal}{1\ min} \times \frac{60\ min}{1\ hr} \times \frac{24\ hr}{1\ day} + \frac{8.34\ lbs}{1\ gal} - \frac{7,205,760\ lbs}{1,000,000} = 7.21$ M lbs H_2O

$7.21 \times 4 = 28.84$ lbs of pure

6. How many pounds of 65% HTH chlorine will be required to disinfect 400 feet of 8-inch water main at 50 ppm?

$\frac{8}{12}$

$.785 \times .67 \times .67 \times 400 \times 7.48 \times 8.34 = \frac{8793.2\ lbs}{1,000,000} = .0088$ M lbs H_2O

$50 \times .0088 = \frac{.44\ lbs\ of\ pure}{.65} = .677$ lbs of HTH

7. What should the chlorinator setting be (lbs/day) to treat a flow of 2 MGD if the chlorine demand is 5 mg/l and a chlorine residual of 0.8 mg/l is desired?

$2 \times 8.34 = 16.68$ M lbs H_2O

$5 + .8 = 5.8$ ppm total dose

$5.8 \times 16.68 = 96.77$ lbs of Cl_2

8. How many pounds per day of HTH (65% available chlorine) are required to disinfect 10,000 feet of 8-inch water line if an initial dose of 20 mg/l is required?

$\frac{8}{12}$ $.785 \times .67 \times .67 \times 10{,}000 \times 7.48 \times 8.34 = \frac{219{,}830 \text{ lbs}}{1{,}000{,}000} = .22$ M lbs H_2O

$.22 \times 20 = \frac{4.4}{.65}$ lbs of pure $= 6.77$ lbs of HTH

9. Your water has a chlorine demand of 1.4 ppm and you desire a residual of 0.7 ppm. What should your chlorine dose be?

$1.4 + .7 = 2.1$ total dose

10. A new 12-inch well must be disinfected. You want a chlorine residual of 100 ppm. The depth of the well is 1000 feet and the static water level is 300 feet below the top of the casing. How many pounds of chlorine will you need?

$1000 - 300 = 700$ ft

$.785 \times 1 \times 1 \times 700 \times 7.48 \times 8.34 = \frac{34280 \text{ lbs}}{1{,}000{,}000} = .0342$ Mlbs of H_2O

$.0342 \times 100 = 3.42$ lbs of pure Cl_2

11. The pump in your main well has been replaced. The well driller dumps 6 pounds of HTH down the well for disinfection. What is the concentration of Cl in the well?
Assume: HTH contains 65% available chlorine; Well diameter = 18 inches for the entire well depth
Well depth = 600 feet; Static water level = 150 feet below top of casing

$18/12 = 1.5$ ft

$6 \times .65 = 3.9$ lbs of pure

$600 - 150 = 450$ ft

$.785 \times 1.5 \times 1.5 \times 450 \times 7.48 \times 8.34 =$

$\frac{3.9}{.0496} =$ 78.63 ppm

$\frac{49583 \text{ lbs}}{1{,}000{,}000} = .0496$ M lbs H_2O

12. You are required to add chlorine to your water supply for disinfection. You have determined that your system has a chlorine demand of 0.8 ppm and you wish to maintain a chlorine residual of 0.5 ppm. The flow through your treatment plant is 5 MGD. Assume 100% available chlorine. Your chlorinator should be set at

$.8 + .5 = 1.3$ ppm total dose

$5 \times 8.34 = 41.7$ M lbs H_2O

$1.3 \times 41.7 = 54.21$ lbs of pure

13. What is the chlorine dose if you apply 120 pounds of 12.5% sodium hypochlorite in 2 days with a flow of 2.5 MGD? $\times 2 = 5$ MGD $\times 8.34 = 41.7$ M lbs H_2O

$120 \times .125 = 15$ lbs of pure

$\frac{15}{41.7} = .36$ ppm

14. As water superintendent, you must determine the chemical costs of chlorinating your water supply. Assume the following data applies to your system:

Average daily pumpage = 1.5 MGD
Desired chlorine residual = 0.3 ppm
Average chlorine demand = 1.0 ppm
Gas chlorine at 19 cents per pound

What would be the yearly chlorine costs?

1.3 ppm total dose

1.5 × 8.34 = 12.51 M lbs of H_2O
1.3 × 12.51 = 16.26 lbs of Cl_2 × .19 = \$3.0899 7 × 365 = \$1127.84 yearly

15. A barrel 3 feet tall and $\boxed{2.5}$ feet in diameter is filled with sodium hypochlorite. This chlorine solution is fed to a well which pumps for 16 hours at a rate of 400 gpm. After this period of time, the level in the barrel has dropped 9 inches. How many pounds of sodium hypochlorite is used? Assume NaOCl contains 12.5% available chlorine and weighs 10 lbs/gal.

$9/12 = .75 \text{ ft}$ $.785 \times 2.5 \times 2.5 \times .75 = 3.68 \text{ ft}^3 \times \frac{7.48 \text{ gal}}{1 \text{ ft}^3} = 27.53 \text{ gal} \times \frac{10 \text{ lbs}}{1 \text{ gal}} =$

275.3 lbs of ~~NaOH~~ used
Bleach

* a bunch of useless #'s in this problem

In Michigan, the optimum fluoride concentration is 0.7 mg/l, and is based on new findings and recommendations from the Center for Disease Control, released in 2014.

The maximum contaminant level for fluoride was established by the EPA revised the maximum contaminant level to 4.0 mg/l.

Long term exposure to fluoride concentrations above 4 mg/l can cause osteosclerosis, calcification of the ligaments and tendons, and consolidations of the vertebrae. Accidental ingestion of toxic overdoses generally causes vomiting, stomach cramps, and diarrhea.

BENEFITS

Fluoridation is one of the most cost-effective health measures available. For every dollar spent on water fluoridation, up to 50 dollars in dental bills may be saved. The cost of fluoridation is about 50 cents per person per year.

Results indicated a 60 percent reduction in dental cavities in children who drank fluoridated water compared to children in the nonfluoridated control communities. These results led to the promotion and widespread use of water fluoridation as an important public health measure.

When fluoridated water is ingested, the fluoride ion seeks out and is deposited in the bone structure of the body. About 20% of the fluoride is incorporated onto the tooth surface while drinking the water. Most of the remaining fluoride passes through the stomach and is distributed throughout the skeletal structure, including the teeth. Incorporation of fluoride is most rapid during the time of the child's formation and growth. This time period is roughly from the 4^{th} month of pregnancy to the 10^{th} year. The presence of fluoride makes the tooth more resistant to the bacterial acids which cause tooth decay. There is also some evidence to show that higher levels of fluoride strengthen the bones of older people, thus reducing the incidence of bone fractures.

FLUORIDE CHEMICALS

Fluoride, a gaseous halogen, is the thirteenth most abundant element found in the earth's crust. It is never found in its free state in nature, but is always in combination with other elements as fluoride compounds. These compounds include fluorspar, apatite and cryolite. Due to its abundance in nature, fluoride is found naturally in all waters. Concentrations will of course vary depending on the quantity of fluoride containing minerals in the area. The deeper the ground water, the greater the concentration of fluoride in the water.

The most used compounds to fluoridate water are sodium fluoride, sodium fluorosilicate and hydrofluorosilicic acid. A comparison of fluoridation chemicals is described below. All these chemicals are refined from minerals found in nature and they yield fluoride ions identical to those found in natural waters.

Sodium Fluorosilicate (Na_2Sif_6):
A white, odorless crystalline powder. A compound of pure (100%) sodium silicofluoride contains 60.6% actual fluoride. Commercially, the compound is typically 98% pure and contains 59.4% actual fluoride.

Sodium Fluoride (NaF):
A white, odorless compound available as a powder or in the form of crystals. A compound of pure (100%) sodium fluoride. Contains 45.2% actual fluoride. Commercially, the compound is typically 98% pure and contains 44.2% actual fluoride. It has a relatively constant solubility of 4% in water, which makes it especially suitable for use with a saturator feed system.

Hydrofluorosilicic Acid (H_2SiF_6):
A straw-colored, transparent, corrosive liquid having a pungent odor. A 100% solution of hydrofluorosilicic acid will contain 79.1% actual fluoride.
However, the acid is usually sold at 25-30% strength. Therefore, a 25% acid would contain 19.8% actual fluoride.

In all operations, 100% available fluoride is not available. However, other concentrations of available fluoride are used. These concentrations are expressed in terms of "percent available fluoride." Typical percent's include 19.8%, 44.2%, and 59.4% available fluoride.

One way to think of the "percent available" of the compound we are dealing with is as follows. Because percent is "part of the whole" (see the fraction section for a review of this topic), "percent available" represents the amount of pure substance, in pounds, per 100 pounds of compound. Given that we have 59.4% available fluoride, we can easily calculate how many pounds of pure chemical are available provided we know how many pounds of compound we have.

<u>Example</u>: How many pounds of fluoride are in 4 lbs of a compound that has 59.4% available fluoride?

<u>Solution</u>: We calculate this by multiplying the weight of pure fluoride in the 59.4% (convert to a decimal) available compound, by the number of pounds of compound we have.

0.594 x 4 lbs of compound (cmpd) = 2.38 lbs pure F_2

Therefore, 2.38 lbs of pure fluoride are contained in 4 lbs of a compound that has 59.4% available fluoride. The following sample problems will give you more practice.

SAMPLE PROBLEM

1. How many pounds of fluoride are in 10 lbs of a compound that has 44.2% available fluoride?

Suppose we are given a situation where a known volume of water is pumped on a daily basis and we desire to maintain a particular fluoride concentration in a drinking water.

Example

If we calculate, we need 9 lbs of 100% available fluoride to provide this concentration, how do we calculate how many pounds of 19.8% available fluoride we need for this?

If we think of "X" as the amount of 19.8% available fluoride needed to equal 9 lbs of 100% available fluoride, then

$$\text{X Lbs of compound} = \frac{\text{9 lbs pure fluoride}}{0.198}$$

Simply divide weight of pure fluoride by the percentage that has been converted to a decimal form.

$$\text{X} = \text{45.45 lbs cmpd}$$

Therefore, we need 45.45 lbs of 19.8% available fluoride. We need <u>more</u> chemical compound when the percent availability is less than 100% than we do with a chemical compound of 100% availability.

Sometimes the compound that contains the desired chemical is liquid. Before the amount of available chemical is determined, the weight of the compound must be calculated.

Example: How many pounds of fluoride are in 5 gallons of compound that weighs 10 pounds per gallon and has 19.8% available fluoride?

Solution: 5 gallon compound x $\frac{10 \text{ lbs}}{1}$ = 50 lbs of compound

Since the compound has a 19.8% fluoride availability

19.8% of 50 lbs = 0.198 x 50 lbs = 9.9 lbs of pure fluoride

By combining the various techniques discussed above with volume calculations, we can work computations involving disinfection of water mains.

As in math there is multiple ways to do the same question. In the above examples we explored the concept of converting from pure fluoride to a compound containing 19.8% available fluoride.

Let's try something else that some people will find easier to visualize. In any question, there will be a percentage given to represent the actual available percentage of a pure element in a compound. Earlier, in this course you learned **how to convert percentage to decimals by simply moving the decimal point within the percentage two places to the left**.

RECALL: 72.00% ➡ 72.00% = 0.72

Percentages are given in the questions now let's discuss any easy approach to using them other than trying to imagine 100 lbs of compound and the amount of pure based on the percent.

.

To summarize when:

Going from compound to pure, you multiple by the percent.
Going from pure to compound, you divide by the percent.

Example: How many gallons of hydrofluorosilicic acid (19.8% available fluoride) would be required to apply 2 ppm fluoride to a water system's clear well that has a diameter of 100 feet and a depth of 25 feet? Assume the acid weighs 10 lbs/gallon.

Solution: Volume = area x length = (0.785 x d^2) x D

V = 0.785 x 100 x 100 x 25 = 196250 ft^3 of water supply to apply fluoride

196250 ft^3 x 7.48 gal/ft^3 x 8.34 lbs/gal = 12,242,703 lbs of water

$$\frac{\textbf{12,242,703 lbs of water}}{\textbf{1,000,000 lbs of water}} = \textbf{12.243 M lbs of water}$$

We know $\text{ppm} = \frac{\text{lbs of pure chemical}}{\text{M lbs of Water}}$

So lbs of pure chemical = ppm x M lbs of Water

2 ppm x 12.243 M lbs of Water = 24.49 lbs of pure fluoride

We now know how many pounds of pure fluoride we need, but the problem asks for gallons of acid needed, how do we convert to this?

Look for the percent within the initial question and convert to decimal.

19.8% = 0.198

Using the rule of thumb, we have a pure chemical and need to convert to compound, we need to divide.

$$\frac{\textbf{24.49 lbs of fluoride}}{\textbf{0.198}} = \textbf{123.69 lbs of compound}$$

Now determine the gallons of acid needed. Since our compound weighs 10 lbs/gal. You can simply divide by the 10 lbs/gal to get your answer.

$$\frac{\textbf{123.69 lbs of compound}}{\textbf{10 lbs/gal}} = \textbf{12.37 gallons of 19.8\% hydrofluorosilicic acid.}$$

We are going to do another sample problem before moving into the remaining review/homework questions. When we discussed the different forms of fluoride compounds earlier 2 of them are salts. These salts can be naturally occurring in different rock formations around the world. There are several areas with naturally occurring fluoride in the water. Michigan is one of these places especially where we have aquifers within rock formations.

Sample: How many gallons of 25% hydrofluorosilicic acid (19.8% available fluoride) need to be added to a water supply that pumps a total 450 gpm for 10 hours. The system has a naturally occurring fluoride level of 0.3 ppm and a desired residual of 0.7ppm. Assume that the acid weighs 10.8 pounds per gallon.

First, as always given chemical addition questions solve for M lbs of water.

$$\frac{\mathbf{450}\ \cancel{\boldsymbol{gallons}}}{\mathbf{1}\ \boldsymbol{minute}}\ \boldsymbol{x}\frac{\mathbf{8.34}\ \boldsymbol{lbs}}{\mathbf{1}\ \cancel{\boldsymbol{gallon}}}=\mathbf{3753}\ \boldsymbol{lbs/min}$$

Now determine the total time of pumping and then multiple it by lbs/min.

10 hours x 60 minutes = 600 minutes

$$\textbf{600 minutes x 3753 lbs/min} = \frac{\textbf{2,251,800 lbs}}{\textbf{1,000,000}} = \textbf{2.252 M lbs of water}$$

Now to determine the ppm applied. This is the tricky part of this question. If naturally occurring fluoride exists in the water similar to this example you need to determine how much you're going to add to reach the desired residual.

Desired – Natural = Dosage Added

0.7ppm - 0.3ppm = 0.4ppm added

Now do the remaining steps like the previous example:

$$\frac{\mathbf{0.4}\ \boldsymbol{ppm}}{\mathbf{1}}=\frac{\boldsymbol{x}}{\mathbf{2.252}\ \boldsymbol{M}\ \boldsymbol{lbs}}\quad\Rightarrow\quad \textbf{X = 0.90 lbs of pure fluoride}$$

19.8%=0.198

$$\frac{\textbf{0.9 lbs of fluorine}}{\mathbf{0.198}}=\mathbf{4.55}\ \boldsymbol{lbs\ of\ compound}$$

$$\frac{\mathbf{4.55}\ \boldsymbol{lbs\ of\ compound}}{\mathbf{10.8}\ \boldsymbol{lbs/gal}}=\mathbf{0.42}\ \boldsymbol{gallons\ of}\ \mathbf{25\%}\ \boldsymbol{acid}$$

Please continue to the review questions use these examples as references.

Additional Fluoride Questions

1. How many gallons of 25% (19.8% actual fluoride) hydrofluorosilicic acid will be required to apply 1.0 ppm of fluoride to 1 million gallons of water? Assume that 1 gallon of acid weighs 10.4 pounds.

2. How many gallons of 25% hydrofluorosilicic acid will be required to apply 1.0 ppm of fluoride in 1 million gallons of water if the natural fluoride concentration is 0.3 mg/l? Assume the acid weighs 10.4 pounds per gallon 25% acid has 79.1% available fluoride.

3. How many gallons of 25% hydrofluorosilicic acid (10.4 lb/gal) are required if the average pumping rate is 400 gpm for 4 hours, the natural fluoride concentration is 0.4 mg/l, and the final desired concentration is 1.0 mg/l? (Given: 100 % of solution of hydrofluorosilicic acid contains 79.1 % pure fluoride.)

4. Sodium fluoride is sometimes applied by means of a saturator. In this treatment, excess sodium fluoride is added to the solution container, and is applied as a 4% solution (maximum solubility). The amount of fluoride used can be determined by measuring the number of gallons of the 4% solution used in a given period of time. If a city pumps 480,000 gallons of water per day, and 26.4 gallons of 4% sodium fluoride solution was used, what was the fluoride dose? Assume the weight of the 4% solution is 8.4 pounds per gallon.

5. How many gallons of 25% hydrofluorosilicic acid (10.4 lbs/gal) will be required for a period of 30 days if the average daily pumping rate is 700 gpm, the natural fluoride concentration of 0.45 mg/l, and the fluoride concentration desired is 1.05 mg/l?

6. What is the resulting concentration of fluoride in the water distribution system if the natural fluoride content is 0.15 ppm and 16.2 pounds of 25% hydrofluorosilicic acid is added during the day when the pumpage of water is 350 gpm for 12 hours and 225 gpm for the remaining 12 hours?

7. A city is applying fluoride to their well water. The raw water contains 0.3 mg/l of fluoride. The treated water should contain 0.9 mg/l of fluoride. The city wells produce 1100 gpm for 8 hours, how many pounds of hydrofluorosilicic acid will be used? The strength of the acid is 25 %. 100 % hydrofluorosilicic acid contains 79.1 % fluoride.

8. A water supply uses 79 pounds of hydrofluorosilicic acid per day. How many pounds of fluoride ion are they adding? Assume hydrofluorosilicic acid concentration is 25% and contains 79.1% F ion.

9. A water treatment plant produces 700 gpm of finished water and uses hydrofluorosilicic acid to add fluoride to the water. The natural fluoride concentration is 0.4 mg/l and 0.5 mg/l is added. Assume 1 pound of hydrofluorosilicic acid contains 0.198 pounds of fluoride ion and weighs 10.8 lbs per gallons. What is the total fluoride concentration in the treated water? How many gallons of acid are added in one day?

10. A water supply produces 6 MGD of finished water and reports using 475 pounds of hydrofluorosilicic acid each day. Assume hydrofluorosilicic acid is 25% pure and contains 79.1 % Fluoride ion. What is the calculated dose of F ion? Is the dosage acceptable?

11. What is the testing method used for measuring fluoride?

12. In the past 10 hours, 3.2 M gallons of water have been treated at your filtration plant. During this time 75 pounds of sodium fluoride have been added to the water. Calculate the fluoride dose. Assume the sodium fluoride compound is 100% pure and has 45.2% fluoride ion.

13. A water treatment plant produces 1300 gpm of finished water and uses hydrofluorosilicic acid to add fluoride to the water. The natural fluoride concentration is 0.1 mg/l and 0.5 mg/l is added. Assume 1 pound of hydrofluorosilicic acid contains 0.198 pounds of fluoride ion. What is the total fluoride concentration in the treated water? How much acid was added in 24 hours?

14. A fluoride solution drum is 60 inches high and 30 inches in diameter. The compound is hydrofluosilicic acid and weighs 10.4 pounds per gallon. Assume fluorosilicic acid concentration is 25% and contains 79.1% F ion. Calculate the volume in gallons in each inch of drawdown.

Answer Key

Additional Fluoride Questions

1. How many gallons of 25% (19.8% actual fluoride) hydrofluorosilicic acid will be required to apply 1.0 ppm of fluoride to 1 million gallons of water? Assume that 1 gallon of acid weighs 10.4 pounds.

$1\ Mgal \times \frac{8.34\ lbs}{1\ gal} = 8.34\ M\ lbs\ H_2O$

$1.0\ ppm = \frac{lbs\ of\ F_2}{8.34\ M\ lbs\ H_2O}$ x

$\frac{8.34\ lbs\ of\ F_2}{.198} = \frac{42.12\ lbs\ of\ Acid}{10.4} = 4.05\ gallons\ of\ acid$

2. How many gallons of 25% hydrofluorosilicic acid will be required to apply 1.0 ppm of fluoride in 1 million gallons of water if the natural fluoride concentration is 0.3 mg/l?

$1.0 - 0.3 = 0.7\ ppm\ added$

$1\ M\ gal\ H_2O \times \frac{8.34\ lbs}{1\ gal} = 8.34\ M\ lbs\ H_2O$

$0.7\ ppm = \frac{x\ lbs\ of\ F_2}{8.34\ M\ lbs\ H_2O} = 5.84\ lbs\ of\ F_2$

$\frac{5.84}{.198} = \frac{29.49\ lbs\ of\ acid}{10.4} = 2.84\ gal\ of\ acid$

3. How many gallons of 25% hydrofluorosilicic acid (10.4 lb/gal) are required if the average pumping rate is 400 gpm for 4 hours, the natural fluoride concentration is 0.4 mg/l, and the final desired concentration is 1.0 mg/l? (Given: 100 % of solution of hydrofluorosilicic acid contains 79.1 % pure fluoride.)

$1.0\ ppm - 0.4\ ppm = 0.6\ ppm\ added$

$\frac{4\ hrs}{1} \times \frac{60\ min}{1\ hr} = 240\ min \times \frac{400\ gal}{1\ min} = 96{,}000\ gal \times \frac{8.34\ lbs}{1\ gal} = \frac{800{,}640}{1{,}000{,}000} = 0.801\ M\ lbs\ H_2O$

$0.6\ ppm = \frac{x\ lbs\ of\ F_2}{0.801\ M\ lbs\ H_2O} = \frac{.48\ lbs\ of\ F_2}{(.791 \times .25)} = \frac{.48}{.198} = \frac{2.42\ lbs\ of\ Acid}{10.4} = .23\ gal\ of\ Acid$

4. Sodium fluoride is sometimes applied by means of a saturator. In this treatment, excess sodium fluoride is added to the solution container, and is applied as a 4% solution (maximum solubility). The amount of fluoride used can be determined by measuring the number of gallons of the 4% solution used in a given period of time. If a city pumps 480,000 gallons of water per day, and 26.4 gallons of 4% sodium fluoride solution was used, what was the fluoride dose? Assume the weight of the 4% solution is 8.4 pounds per gallon.

$480{,}000\ gal \times \frac{8.34\ lbs}{1\ gal} = \frac{4{,}003{,}200\ lbs}{1{,}000{,}000} = 4.003\ M\ lbs\ H_2O$

% of F_2 in sodium fluoride

$26.4\ gal \times \frac{8.4\ lbs}{gal} = 221.76\ lbs \times (.04 \times .442) = 3.92\ lbs\ of\ F_2$

$ppm = \frac{3.92\ lbs\ of\ F_2}{4.003\ M\ lbs\ H_2O} = .98\ ppm$

(.198)

5. How many gallons of 25% hydrofluorosilicic acid (10.4 lbs/gal) will be required for a period of 30 days if the average daily pumping rate is 700 gpm, the natural fluoride concentration of 0.45 mg/l, and the fluoride concentration desired is 1.05 mg/l? 1.05 ppm − 0.45 ppm = 0.6 ppm

$\frac{700\,gal}{1\,min} \times \frac{8.34\,lbs}{1\,gal} \times \frac{1440\,min}{1\,day} = \frac{8{,}406{,}720\,lbs}{1{,}000{,}000} = 8.407\,M \times 30 = 252.21\,M$ lbs H_2O

$0.6\,ppm = \frac{x\ lbs\ of\ F_2}{252.21\,M\ lbs\ H_2O} = \frac{151.33\ lbs\ of\ F_2}{.198} = \frac{764.29\ lbs\ of\ Acid}{10.4} = 73.49$ gal of Acid

6. What is the resulting concentration of fluoride in the water distribution system if the natural fluoride content is 0.15 ppm and 16.2 pounds of 25% (.198) hydrofluorosilicic acid is added during the day when the pumpage of water is 350 gpm for 12 hours and 225 gpm for the remaining 12 hours?

$12\,hrs \times \frac{60\,min}{1\,hr} = 720\,min$

$\frac{350\,gal}{1\,min} \times \frac{8.34\,lbs}{1\,gal} \times \frac{720\,min}{1} = 2{,}101{,}680\,lbs$

$\frac{225\,gal}{1\,min}\ \frac{8.34\,lbs}{1\,gal} \times 720\,min = 1{,}351{,}080\,lbs$

$16.2 \times .198 = 3.21$ lbs of F_2

$+\ \frac{3452760}{1{,}000{,}000} = 3.453\,M$ lbs

$.93 + .15 = 1.08\,ppm = \frac{3.21\ lbs\ of\ F_2}{3.453\,M\ lbs\ H_2O}$

7. A city is applying fluoride to their well water. The raw water contains 0.3 mg/l of fluoride. The treated water should contain 0.9 mg/l of fluoride. The city wells produce 1100 gpm for 8 hours, how many pounds of hydrofluorosilicic acid will be used? The strength of the acid is 25 %. 100 % hydrofluorosilicic acid contains 79.1 % fluoride. 0.9 ppm − 0.3 ppm = 0.6 ppm applied

$0.6\,ppm = \frac{x\ lbs\ of\ F_2}{4.404\,M\ lbs\ H_2O} = \frac{2.64\ lbs\ of\ F_2}{(.25 \times .791)} = \frac{2.64}{.198} = 13.33$ lbs of Acid

8 hrs × 60 = 480 min

1100 × 480 = 528,000 gal × 8.34 = 4,403,520 lbs

$\frac{4{,}403{,}520\,lbs}{1{,}000{,}000} = 4.404\,M$ lbs

8. A water supply uses 79 pounds of hydrofluorosilicic acid per day. How many pounds of fluoride ion are they adding? Assume hydrofluorosilicic acid concentration is 25% and contains 79.1% F ion.

$79 \times .25 \times .791 = 15.62$ lbs of F

9. A water treatment plant produces 700 gpm of finished water and uses hydrofluorosilicic acid to add fluoride to the water. The natural fluoride concentration is 0.4 mg/l and 0.5 mg/l is added. Assume 1 pound of hydrofluorosilicic acid contains 0.198 pounds of fluoride ion and weighs 10.8 lbs per gallons. What is the total fluoride concentration in the treated water? How many gallons of acid are added in one day?

0.4ppm + 0.5ppm = 0.9ppm total

$\frac{700\text{gal}}{1\text{min}} \times \frac{8.34\text{lbs}}{1\text{gal}} \times \frac{1440\text{min}}{1\text{day}} = \frac{8,406,720 \text{ lbs}}{1,000,000} = 8.407$ M lbs

$0.5\text{ppm} = \frac{x \text{ lbs of } F_2}{8.407 \text{ M lbs} H_2O} = \frac{4.2 \text{ lbs of } F_2}{.198} = \frac{21.21 \text{ lbs of acid}}{10.8} = 1.96$ gal of Acid

10. A water supply produces 6 MGD of finished water and reports using 475 pounds of hydrofluorosilicic acid each day. Assume hydrofluorosilicic acid is 25% pure and contains 79.1 % Fluoride ion. What is the calculated dose of F ion? Is the dosage acceptable? $475 \times .25 \times .791 = 93.93$ lbs of pure F

6 mgal $\times 8.34 = 50.04$ M lbs

$\frac{93.93 \text{ lbs of } F_2}{50.04 \text{ M lbs} H_2O} = 1.88$ppm

No, recommended Fluoride is 0.7ppm

11. What is the testing method used for measuring fluoride?

SPADNS

12. In the past 10 hours, 3.2 M gallons of water have been treated at your filtration plant. During this time 75 pounds of sodium fluoride have been added to the water. Calculate the fluoride dose. Assume the sodium fluoride compound is 100% pure and has 45.2% fluoride ion. 3.2 Mgal x 8.34 = 26.688M lbs H_2O

75 lbs x .452 = 33.9 lbs of F_2 ?

$\frac{33.9}{26.688} = 1.27$ ppm

13. A water treatment plant produces 1300 gpm of finished water and uses hydrofluorosilicic acid to add fluoride to the water. The natural fluoride concentration is 0.1 mg/l and 0.5 mg/l is added. Assume 1 pound of hydrofluorosilicic acid contains 0.198 pounds of fluoride ion. What is the total fluoride concentration in the treated water? How much acid was added in 24 hours?

0.1+0.5=0.6 ppm total

$\frac{1300 gal}{1 min} \times \frac{1440 min}{1 day} \times \frac{8.34}{1 gal} = \frac{15,612,480 \text{ lbs}}{1,000,000} = 15.612M$ lbs H_2O

.5 ppm = $\frac{x \text{ lbs of } F_2}{15.612 M \text{ lbs } H_2O}$ = $\frac{7.806 \text{ lbs of } F_2}{.198}$ = 39.42 lbs of Acid

14. A fluoride solution drum is 60 inches high and 30 inches in diameter. The compound is hydrofluosilicic acid and weighs 10.4 pounds per gallon. Assume fluorosilicic acid concentration is 25% and contains 79.1% F ion. Calculate the volume in gallons in each inch of drawdown.

1/12 = .08' ft   V = .785 x 2.5 x 2.5 x .08 x 7.48 = 2.94 gal

30/12 = 2.5ft