1. Units

To measure any quantity or compare two physical quantities we need a universally accepted standard called Unit. The most common measurements involve measuring - length, weight and time. International System of Units (SI), the modern form of the metric system is the globally accepted standard. In the United States, it is customary to measure the physical quantities in English Engineering Units.

Fundamental Units		
Dimension	**English Engineering Units**	**SI**
time	second (s)	second (s)
length	foot (ft)	meter (m)
mass	pound mass (lb)	kilogram

The measurement of any physical quantity is expressed in terms of a number - which is the quantity and a specific unit. Thus, a measurement of 5000 ft is basically 5000 of the of length as measured in ft.

Using the fundamental physical measurements, mathematical calculations can be made to measure other physical quantities such as area (ft2), volume (ft3), velocity (ft/s), flow (ft3/s), density (lbs/ft3).

Depending on the what is being measured or quantified, there are appropriate and customary units of measure - for example - miles and inches for length, gallons and acre-ft for volume and milligrams and tons for mass.

Unit Conversion

Unit conversion is a process for changing the units of a measured quantity without changing its value. It involves utilizing a conversion factor which expresses the relationship between units that is used to change the units of a measured quantity without changing the value. Examples of conversion factors include:

Fundamental Units	
Dimension	**Conversion Factor**
time	$\frac{60\ sec}{min}, \frac{1,440\ sec}{day}$
length	$\frac{12\ in}{ft}, \frac{5,280\ ft}{mile}$
mass	$\frac{2,000\ lbs}{ton}, \frac{1000\ gm}{mg}$

Derived Units	
Dimension	**Conversion Factor**
area	$\frac{43,560\ ft^2}{acre}, \frac{60\ sec}{min}$
volume	$\frac{27\ ft^3}{yd}, \frac{7.48\ gal}{ft^3}$

The numerator and the denominator of any conversion factor always equals one, they have the same value expressed in different units.

For converting one measurement unit to another.

Step 1: Make sure the original unit is for the same measurement as the conversion unit. So if the original unit is for area, say ft^2 the conversion unit can be another area unit such as in^2 or acre but it cannot be gallons as gallon is a unit of volume.

Step 2: Write down the conversion formula as:

$$Quantity\ in\ converted\ unit = Quantity\ (\cancel{Original\ Unit}) * Conversion\ Factor\ \frac{Conversion\ unit}{\cancel{Original\ unit}}$$

Unit conversions may involve single factor where the original unit value is multiplied by the conversion factor to obtain the measured parameter in the converted (desired) unit.

For example:

Converting 1000 ft^3 to cu. yards:

$$1000\cancel{ft^3} * \frac{cu.yards}{27\cancel{ft^3}} = 37cu.yards$$

Other unit conversions may require multiplying by known constants along with conversion factors.

For example:

(a) Converting 3.5 ft^3/sec to MGD:

$$\frac{3.5\ \cancel{ft^3}}{\cancel{sec}} * \frac{7.48\ \cancel{gal}}{\cancel{ft^3}} * \frac{MG}{10^6\cancel{gal}} * \frac{1440 * 60\ \cancel{sec}}{day} = 2.3\ MGD$$

(b) Converting 1,000 L water to lbs:

$$1000\ \cancel{L} * \frac{\cancel{gal}}{3.785\ \cancel{L}} * \frac{8.34\ lbs}{\cancel{gal}} = 2,203\ lbs$$

$(Note: 8.34\ lbs/gal\ is\ density\ of\ water - a\ constant)$

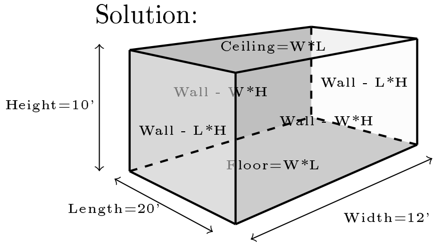
2. Area & Volume Calculations

Perimeter (P)/Circumference (C)
Rectangle: P [ft] = 2L [ft] + 2W [ft] where L = length and W = width
Circle: C [ft] = π × D [ft] where π = constant = 3.1415; and D = diameter
Area (A)
Rectangle: A [ft²] = L [ft] × W [ft] where L = Length and W = Width
Circle: where π = constant = 3.1415; D = diameter $A\left[ft^2\right] = \frac{1}{4} \times \pi \times D^2 \left[ft^2\right]$
Volume (V)
Regular Prism: V [ft³] = A $_{base}$ [ft²] × H [ft] where A_{base} is the area of the base; and H is the height or depth of the tank
Cone: $V\left[ft^3\right] = \frac{1}{3} A_{base}\left[ft^2\right] \times H\left[ft\right]$

0.1 Example Problems

(a) The floor of a rectangular building is 20 feet long by 12 feet wide and the inside walls are 10 feet high. Find the total surface area of the inside walls of this building

Solution:



2 Walls W*H + 2 Walls L*H= $2 * 12 * 10ft^2 + 2 * 20 * 10ft^2$

$= 240 + 400 = \boxed{640ft^2}$

2 Walls W*H + 2 Walls L*H + Floor + Ceiling= $2 * 12 * 10ft^2 + 2 * 20 * 10ft^2 + 2 * 12 * 20ft^2$

$= 240 + 400 + 480 = \boxed{1,120ft^2}$

3. Concentration

Concentration is typically expressed as mg/l which is the weight of the constituent (mg) in 1 l (liter) of solution (wastewater). As 1 l of water weighs 1 million mg, a concentration of 1 mg/l implies 1 mg of constituent per 1 million mg of water or one part per million (ppm). **Thus, mg/l and ppm are synonymous.**

Sometimes the constituent concentration is expressed in terms of percentage.

For example: sludge containing 5% solids or a 12.5% chlorine concentration solution.

As one liter of water weighs 1,000,000 mg, one percent of that weight is 10,000 mg. So 1% solids implies 10,000 mg of solids per liter or 10,000 mg/l or 10,000 ppm.

$1\% concentration = 10,000\ \ ppm\ \ or\ \ \frac{mg}{l}$

$0.1\% concentration = 1,000\ \ ppm\ \ or\ \ \frac{mg}{l}$

$0.01\% concentration = 100\ \ ppm\ \ or\ \ \frac{mg}{l}$

$10\% concentration = 100,000\ \ ppm\ \ or\ \ \frac{mg}{l}$

$5\% concentration = 50,000\ \ ppm\ \ or\ \ \frac{mg}{l}$

$A\ \ 12.5\%\ \ bleach\ \ solution\ \ contains\ \ 12.5\%\ \ or\ \ 125,000\ \ \frac{mg}{l}\ \ of\ \ \ active\ \ chlorine$

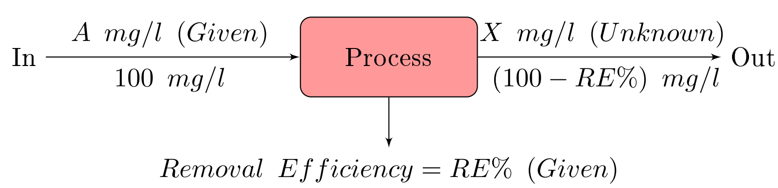
4. Process Removal Efficiency

- Process removal rate or removal efficiency is the percentage of the inlet concentration removed.
- It is used for quantifying the pollutant removal during wastewater treatment and is established based upon the amount of a particular wastewater constituent entering and leaving a treatment process.
- $Process\ \ Removal\ \ Rate\ \ (\%) = \frac{Pollutant\ \ In - Pollutant\ \ Out}{Pollutant\ \ In} * 100$
- If 10 units of a pollutant are entering a process and 8 units of pollutant are leaving (process removes 2 units), then the process removal rate for that pollutant is (10-8)/10*100=20%. In this example the process is 20% efficient in removing that particular pollutant.
- The amount of pollutant can be measured in terms of concentration (mg/l) or in terms of mass loading (lbs). The pounds formula is used for calculating the mass loadings.

The above example is for calculating the removal efficiency using the inlet and outlet concentrations or mass loading.

The methods below can be used for calculating either the inlet or outlet pollutant concentrations, if the removal efficiency and the corresponding inlet or outlet concentrations are given.

Case 1: Calculating outlet conc. (X) given the inlet conc. and removal efficiency (RE%):



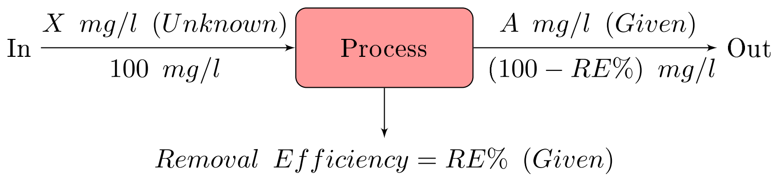
Using the fact that if the inlet concentration was 100 mg/l, the outlet concentration would be 100 minus the removal efficiency.

Setup the equation as: $\frac{Out}{In} : \ \frac{X\ \ mg/l}{A\ \ mg/l} = \frac{100 - RE\%}{100}$

Calculate X using cross multiplication - if $\frac{A}{B} = \frac{C}{D} \implies A = B * \frac{C}{D}$:

$X\ \ mg/l = A\ \ mg/l * \dfrac{100 - RE\%}{100}$

Case 2: Calculating inlet conc. (X) given the outlet conc. and removal efficiency (RE%):



Using the fact that if the inlet concentration was 100 mg/l, the outlet concentration would be 100 minus the removal efficiency.

Setup the equation as: $\dfrac{In}{Out} : \dfrac{X\ \ mg/l}{A\ \ mg/l} = \dfrac{100}{100 - RE\%}$

Calculate X using cross multiplication - if $\dfrac{A}{B} = \dfrac{C}{D} \implies A = B * \dfrac{C}{D}$:

$X\ \ mg/l = A\ \ mg/l * \dfrac{100}{100 - RE\%}$

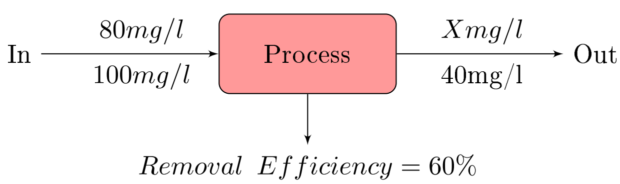
0.2 Example Problems

(a) What is the % removal efficiency if the influent concentration is 10 mg/L and the effluent concentration is 2.5 mg/L?

$Removal\ \ Rate(\%) = \dfrac{In - Out}{In} * 100 \implies \dfrac{10 - 2.5}{10} * 100 = \boxed{75\%}$

(b) Calculate the outlet concentration if the inlet concentration is 80 mg/l and the process removal efficiency is 60%

Solution:

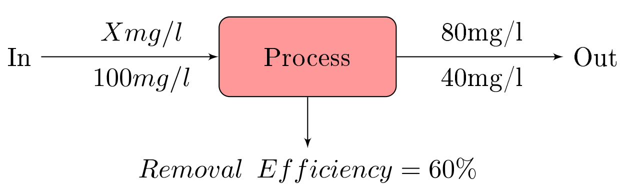


$\dfrac{Out}{In} : \dfrac{Actual\ \ Outlet(X)}{80} = \dfrac{100 - 60}{100}$

$\implies \dfrac{Actual\ \ Outlet(X)}{80} = 0.4$

$\implies Actual\ \ Outlet(X) = 0.4 * 80 = \boxed{32mg/l}$

(c) Calculate the inlet concentration if the outlet concentration is 80 mg/l and the process removal efficiency is 60%

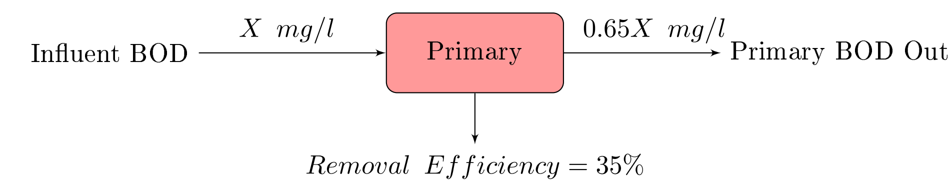


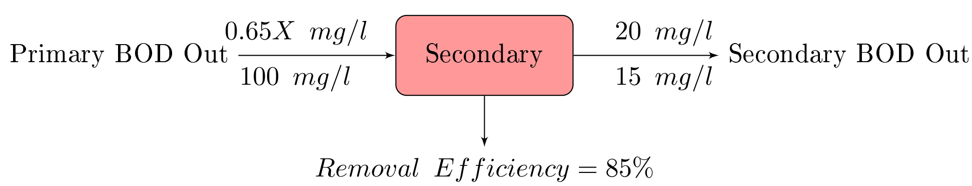
$$\frac{In}{Out} : \frac{Actual\ \ inlet\ \ (X)}{80} = \frac{100}{100-60} \implies \frac{Actual\ \ inlet\ \ (X)}{80} = 2.5$$

Rearranging the equation: $Actual\ \ inlet(X) = 2.5 * 80 = \boxed{200mg/l}$

(d) If a plant removes 35% of the influent BOD in the primary treatment and 85% of the remaining BOD in the secondary system, what is the BOD of the raw wastewater if the BOD of the final effluent is 20mg/l

Solution:





For the Secondary process:

$$\frac{In}{Out} : \frac{0.65X}{20} = \frac{100}{15} \implies X\ \ mg/l = \frac{100*20}{15*0.65} = \boxed{205\ \ mg/l}$$

Alternate Solution #1

$$\xrightarrow[\text{X}\frac{mg}{l}]{\text{Influent BOD}} \boxed{Primary} \xrightarrow[\text{X-0.35X=X*(1-0.35)=0.65X}\frac{mg}{l}]{\text{Primary Effluent BOD}} \boxed{Secondary} \xrightarrow[\text{0.65X-0.5525X=(0.65-0.5525)X=0.0975X}]{\text{Secondary Effluent BOD}}$$

↓ (0.35X)BOD Removed ↓ (0.65*0.85)X = 0.5525X BOD Removed

$$\implies 0.0975X = 20 \implies X = \frac{20}{0.0975} = \boxed{205\frac{mg}{l}}$$

Alternate Solution #2:

$$\xrightarrow[\text{X}\frac{mg}{l}]{\text{Influent BOD}} \boxed{Primary} \xrightarrow[\text{0.65X}]{\text{Primary Effluent BOD}} \boxed{Secondary} \xrightarrow[\text{(0.65*0.15)X}]{\text{Secondary Effluent BOD}}$$

↓ (0.35X)BOD Removed ↓ (0.65X*0.85)BOD Removed

Primary Effluent BOD = Influent BOD * (1-Primary BOD Removal), and

Secondary Effluent BOD=[Primary Effluent BOD]*(1-Secondary BOD Removal)

Secondary Eff. BOD=[Influent BOD * (1-Primary BOD Removal)]*(1-Secondary BOD Removal)

Therefore, 20 = [X*(1-0.35)] * (1-0.85)= X*0.65*0.15

$$\implies 20\ \frac{mg}{l} = 0.0975X \implies X = \frac{20}{0.0975} = \boxed{205\ \frac{mg}{l}}$$

5. Pumping For Grades I & II, pumping rate problems include the following:

Method:

Step 1. Multiply the pump flow rate by the time interval

Make sure:

- The time units - in the given time interval and in the pump flow rate match

0.3 Calculating time to pump a certain volume

Method: Step 1. Calculate the total volume pumped

Step 2. Divide the total volume by the pump flow rate

Make sure:

- The volume units - in the volume that needs to be pumped and in the pump flow rate match
- The time unit in the pump flow rate needs to be converted to the time unit that you need the answer in

(a) A sludge pump is set to pump 5 minutes each hour. It pumps at the rate of 35 gpm. How many gallons of sludge are pumped each day?

Solution:

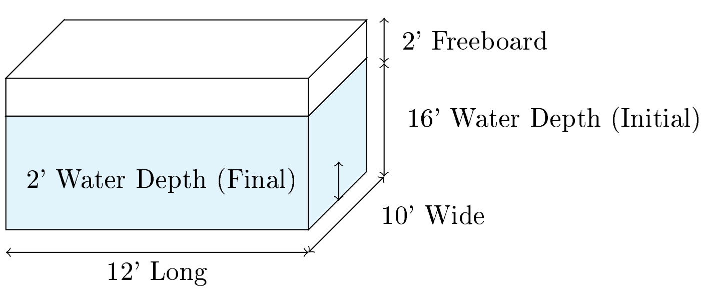
$$\frac{35\ gal\ sludge}{\cancel{min}} * \frac{5\ \cancel{min}}{\cancel{hr}} * \frac{24\ \cancel{hr}}{day} = \boxed{\frac{4,200\ gallons}{day}}$$

(b) A sludge pump operates 5 minutes each 15 minute interval. If the pump capacity is 60 gpm, how many gallons of sludge are pumped daily?

$$\frac{60\ gal\ sludge}{\cancel{min}} * \frac{5\ \cancel{min}}{15\ \cancel{min}} * 1440\frac{\cancel{min}}{day} = \boxed{\frac{28,800\ gal\ sludge}{day}}$$

(c) Given the tank is 10ft wide, 12 ft long and 18 ft deep tank including 2 ft of freeboard when filled to capacity. How much time (minutes) will be required to pump down this tank to a depth of 2 ft when the tank is at maximum capacity using a 600 GPM pump

Solution:



Volume to be pumped$=12\ ft * 10\ ft * (16-2)\ ft = 1,680 ft^3$

$$\implies \frac{1,680\cancel{ft^3} * 7.48\frac{\cancel{gal}}{\cancel{ft^3}}}{600\frac{\cancel{gal}}{min}} = \boxed{21 min}$$

hydraulic grade line (HGL)

The surface or profile of water flowing in an open channel or a pipe flowing partially full. If a pipe is under pressure, the hydraulic grade line is that level water would rise to in a small, vertical tube connected to the pipe.

PRESSURE

Water pressure is measured in terms of pounds per square inch (psi) and feet of head (height of a water column in feet). A column of water 2.31 feet high creates a pressure of 1 psi. The water pressure at the bottom of a storagetank can be used to determine the water level in the tank. Centrifugal pumps are rated in feet of Total Dynamic Head (TDH) but system pressures are measured in psi. All watersystem operators must be able to convert from one pressure unit to the other. .If the pressure (psi) is known, the height of the water column can be determined by multiplying the psi by 2.31.

$psi * 2.31 = Feet\ of\ Head$

EXAMPLE:

A pressure gauge at the bottom of a storage tank reads 30 psi. What is the water level in the tank?

Convert psi to feet of head

$30psi * 2.31 = 69.3\ feet\ of\ water\ above\ the\ gauge$

If the height of a column of water is known, the pressure it exerts can be determined by dividing the feet of head by 2.31.

$\frac{Head\ ft}{2.31} = psi$

EXAMPLE:

The reservoir level is 115 feet above the pump discharge. What is the discharge pressure on the pump?

Convert feet of head to psi.

$\frac{115feet}{2.31} = 49.8psi$

FLOW

The amount of water moving through the system can be measured in one of three different units. They are gpm (gallons per minute), mgd (millions of gallons per day), and cfs (cubic feet per second). The conversions are listed below.

$mgdx700 = gpm$

$\frac{gpm}{700} = mgd$

$cfsx449 = gpm$

$\frac{gpm}{449} = cfs$

EXAMPLES:

A system uses 2 mgd. How many gallons per minute does it use?

Convert mgd to gpm

$2mgdx700 = 1400gpm$

A pipeline has a carrying capacity of 3 cfs. How many gpm can it handle?

Convert cfs to gpm

$3cfsx449 = 1347gpm$

A well pumps 350 gpm. How many mgd will it pump?

Convert gpm to mgd

$\frac{350gpm}{700} = 0.5mgd$

AREAS

In order to calculate volumes of circular tanks and velocities in pipes, the area of the circle must first be determined. There are two basic formulae used to calculate the area of a circle.

$Area = 3.1416xr2Area = d2x0.785$

r = radius d = diameter

EXAMPLES:

A sedimentation basin is 60 feet in diameter. What is the surface area of the tank?

Calculate the area

$3.1416x30'x30' = 2830squarefeet$

$60'x60'x0.785 = 2830squarefeet$

A pipeline has diameter of 12 inches. What is the area of the pipe?

Calculate the area

$3.1416x6"x6" = 113squareinches$

$12"x12"x0.785 = 113squareinches$

VOLUMES

The volume of a rectangular tank can be determined by
multiplying the length, height, and width together.

Volume of rectangular tank (ft3) = L' x H' x W'

EXAMPLE:

A sedimentation basin is 60' long by 40' wide and 10'
deep. What is the volume of the tank in cubic feet?

Calculate the volume

60' x 40' x10' = 24,000 cubic feet (ft3)

The volume of a circular tank can be determined by multiplying the area of the by the height (or depth) of the tank.

$Volumeofcirculartank(ft3) = 3.1416xr'2xH'$

or

$Volumeofcirculartank(ft3) = d'2x0.785xH'$

EXAMPLE:

A sedimentation basin is 60'in diameter and 12' deep. What is the volume of the tank?

Calculate the volume

$3.1416x30'x30'x12' = 33,900cubicfeet(ft3)$

or

$60'x60'x0.785x12' = 33,900cubicfeet(ft3)$

VOLUMES IN GALLONS

It is often necessary to calculate a volume of a tank or pipe in gallons rather than cubic feet. In most cases the volume must be calculated in cubic feet and then converted into gallons. This is determined by multiplying cubic feet by 7.48.

$Cubicfeetx7.48 = gallons$

EXAMPLE:

A sedimentation basin is 60' long by 40' wide and 10' deep. What is the volume of the tank in cubic feet?

Calculate the volume

$60'x40'x10' = 24,000ft3$

Convert cubic feet to gallons

$24,000ft3x7.48 = 179,500gallons$

A circular tank has a diameter of 40 feet and is 10 feet deep. How many gallons will it hold?

Calculate the volume

$1416x20'x20'x10' = 12,600ft3$

or

$40'x40'x0.785x10' = 12,600ft3$

Convert cubic feet to gallons

$12,600ft3x7.48 = 94,200gallons$

VOLUMES OF PIPES

The number of gallons contained in a one-foot section of pipe can be determined by squaring the diameter (in inches) and then multiplying by 0.0408. To determine the number of gallons in a particular length of pipe multiply the gallons per foot by the number of feet of pipe.

$Volume(gal) = D\text{J}2x0.0408xLength'$

EXAMPLES:

A 12" line is 1100 ft long. How many gallons does the pipe hold?

Find the volume of the pipe in gallons

$12\text{"}x12\text{"}x0.0408x1100 = 6460gallons$

A 6" line is 654 ft long. How many gallons does the pipe hold?

Find the volume of the pipe in gallons

$6\text{"}x6\text{"}x0.0408x654 = 960gallons$

VELOCITY

The velocity of the water moving through a pipe can be determined if the flow in cubic feet per second (cfs) and the diameter of the pipe (inches) are known. The area of the pipe must be calculated in square feet (ft2) and the flow is then divided by the area.

$$\frac{Velocity(fps)}{Area(ft2)} = Flow(cfs)$$

EXAMPLE:

A 24" pipe carries a flow of 11 cfs. What is the velocity in the pipe? Change diameter in inches to feet

$24\text{"}/12\text{"}perft = 2ft.$

Find area of the pipe in sq.ft.

$1x1x3.1416 = 3.14sq.ft.$

Find the velocity in fps

$$\frac{11cfs}{3.14sq.ft.} = 3.5fps$$

The flow through a pipe (cfs) can be determined if the velocity and pipe diameter are known. The area of the pipe must be calculated in square feet and then multiplied by the velocity (fps.)

EXAMPLES:

A 12"' pipe carries water at a velocity of 5.0 fps. What
is the flow in cfs?

Change inches to ft.

$12"/12" per ft = 1 ft.$

Find area of the pipe in sq.ft.

$0.5x0.5x3.1416 = 0.785 sq.ft.$

Find the flow in cfs

$5.0 fps x 0.785 sq.ft. = 3.9 cfs$

A 12" pipe carries 1400 gpm at 4.0 fps velocity and reduces to a 6" pipe. What is the velocity in the 6" pipe?

Convert flow to cfs

$$\frac{1400 gpm}{449 gpm/cfs} = 3.12 cfs$$

Change inches to ft.

$$\frac{6"}{12" per ft} = 0.5 ft.$$

Find area of the pipe in sq.ft.

$0.25' x 0.25' x 3.1416 = 0.196 sq.ft.$

Find the velocity in fps

$3.12 cfs = 16 fps$

0.196 sq.ft.

DETENTION TIME

Detention time (D.T.) is the length of time in minutes or hours for one gallon of water to pass through a tank. To calculate detention time, the capacity of a tank in gallons is divided by the flow in gallons per minute (gpm) or gallons per day (gpd). If gpm is used, the answer will be in minutes and must be divided by 60 minutes to get hours. If gpd is used, the answer will be in days and must be multiplied by 24 hours. The detention time formula can also be used to calculate how long it will take to fill a tank.

EXAMPLES:

A 50,000 gallon tank receives 250,000 gpd flow. What is the detention time in hours? Find detention time in days

$$\frac{50,000 gal}{250,000 gal/day}. = 0.2 days$$

Change days to hours

$0.2 days x 24 hrs/day = 4.8 hours$

A tank is 60' x 80' x 10' and the flow is 2.0 mgd? What is the detention time in hours? Find Volume in cubic feet

$60' x 80' X 10' = 48,000 cu.ft.$

Change cubic feet to gallons

$48,000 cu.ft. X 7.48 gal/cu.ft. = 359,000 gal.$

Change mgd to gal/day

$2.0 mgd = 2,000,000 gal/day$

Find D.T. in days

$$\frac{359,000 gal}{2,000,000 gal/day} = 0.18 days$$

Change days to hours

$0.18 days x 24 hrs/day = 4.3 hours$

A tank is 100' in diameter and 22 feet deep. If the flow into the tank is 1500 gpm and the flow out of the tank is 300 gpm, how many hours will it take to fill the tank?

Calculate the volume in cubic feet

$3.1416x50'x50'x22' = 173,000ft3$

or

$100'x100'x0.785x22' = 173,000ft3$

Change cubic feet to gallons

172,800 ft3 x 7.48 = 1,290,000 gallons

Calculate the net inflow

$1500gpm\breve{}300gpm = 1200gpm$

Calculate how long until full (detention time)

$$\frac{1,290,000gal}{1200gpm} = 1075minutes$$

Change minutes to hours

$$\frac{1075min}{60min/hr} = 17.9hours$$

DOSAGE

Chemical dosages are measured in ppm (parts per million) or mg/l (milligrams per liter.) Parts per million (ppm) is always a comparison of weight (pounds per million pounds). One pound of chemical added to one million pounds of water would be a dosage of 1 ppm. Since each gallon of water

weighs 8.34 pounds, one million gallons of water weighs 8.34 million pounds and would require 8.34 pounds of chemical to obtain a dosage of l ppm. Milligrams per liter (mg/l) is the metric term for a dosage equal to ppm.

$1gallon = 8.34lbs.$

$1ppm = 1mg/l$

The number of pounds of chemical needed to achieve a certain dosage can be determined by multiplying the ppm by the number of millions of gallons treated and then by 8.34 lbs/gal. The amount of water to be treated must always be in terms of millions of gallons (mgd). mg/l x mgd x 8.34 = pounds per day

EXAMPLE:

How many lbs/day of chlorine are needed to provide a dosage of 2.2 mg/l in 800,000 gal/day?

Change gal/day to mgd

$800,000gpd = 0.8mgd$

Calculate lbs/day

$2.2mg/lx0.8mgdx8.34 = 14.7lbs/day$

If HTH is used, instead of chlorine gas, only 65-70% of each pound will be chlorine. Therefore, the amount of HTH must be calculated by dividing the pounds of chlorine needed by 0.65 or 0.70.

EXAMPLES:

A tank is 44' in diameter and 22' high and is dosed with 50 ppm of chlorine. How many pound of 70% HTH is needed?

Find the volume of the tank in cubic feet

$22'x22'x3.1416x22' = 33,450cu.ft.$

Change cu.ft. to gallons

$33,450x7.48 = 250,000gallons$

Change gallons to mgd

$250,000gallons = 0.250mgd$

Find lbs of chlorine

$50ppmx0.25mgx8.34 = 104.25lbsofchlorine$

Change percent available to a decimal equivalent

$70\% = 0.70$

Find lbs of HTH

$\frac{104.25lbsCl}{0.70} = 149lbsofHTH$

A chlorine pump is feeding 10% bleach at a dosage of 5 mg/l. If 2,200,000 gallons are treated in 16 hours, how many gallons per hour is the pump feeding?

Change gallons to mg

$2,200,000gallons = 2.2mg$

Find lbs of chlorine

$5ppmx2.2mgx8.34 = 91.7lbsofChlorine$

Change percent available to a decimal equivalent

$10\% = 0.10$

Find lbs of Bleach

$\frac{91.7lbsCl}{0.10} = 917lbsofBleach$

Find gallons of Bleach

$\frac{917lbsBleach}{8.34lbs/gal} = 110gallonsofBleach$

Find gallons per hour

110 gal. = 6.9 gal/hr

16 hr

A 12" pipe is 1880' long and must be disinfected with 50 ppm of 65% HTH. How many pounds of HTH are needed? Find the volume of the pipe in gallons

$12\text{”}x12\text{”}x.0408x1880' = 11,045gallons$

Change gallons to mgd

$11,045gallons = 0.011mgd$

Find lbs of chlorine

$50ppmx0.011mgdx8.34 = 4.6lbsofChlorine$

Change percent available to a decimal equivalent

$65\% = 0.65$

Find lbs of HTH

$4.6lbsCl = 7.1lbsofHTH$

0.65

Liquid chemical dosages can be calculated to determine the gallons per day. Chemical feed pumps are calibrated using ml/min. If you take 3785 ml/gal and divide it by 1440 min/day, the conversion for gal/day to ml/min can be determined.

$\frac{3785ml/gal}{1440min/day} = 2.6ml/min/gal/day$

Gal/day x 2.6 = ml/min

EXAMPLES:

A 20% available Fluoride solution is used to dose 2,000,000 gpd at 450 ppb (parts per billion). How many ml/min is the pump feeding?

Change 450 ppb to ppm

$450ppb = 0.45ppm(mg/l)$

Change 2,000,000 gpd to mgd

$2,000,000gpd = 2.0mgd$

Find lbs of Fluoride

$0.45ppmx2.0mgdx8.34 = 7.5lbs/day$

Change percent available to a decimal equivalent

$20\% = 0.2$

Find lbs of Fluoride solution

$7.5lbsF = 37.5lbsofFsolution$

0.2

Find gallons of fluoride

$37.5lbssolution = 4.5gpd$

8.34 lbs/gal

Change gallon/day to ml/min

$4.5gpdx2.6 = 11.7ml/min$

An 18% available Alum solution is used to dose 600,000 gpd at 25 mg/l. How many ml/min is the pump feeding?

Change 600,000 gpd to mgd

$25mg/lx0.6mgdx8.34 = 125lbs/day$

Change percent available to a decimal equivalent 18%= 0.18

Find lbs of Alum solution

$$\frac{125lbsAlum}{0.18} = 695lbsofAlumsolution$$

Find gallons of Alum

$$\frac{695lbssolution}{8.34lbs/gal} = 83.3gpd$$

Change gallon/day to ml/min

$83.3gpdx2.6 = 217ml/min$

Sometimes there is too much information in the question.

The example below has too much information. The well flow and storage tank data are not needed to work the problem.

EXAMPLE:

A system has a well that produces 200 gpm and a 1500 gallon storage tank. There are 120 homes on the systems and the average daily consumption is 350 gallons/home. A chlorine dosage of 1.3 ppm is maintained using 65% HTH. How many pounds of HTH must be purchased each year?

Find system consumption

$120 homes x 350 gallons/day/home = 42,000 gpd$

Change gallons/day to mgd

$42,000 gallons/day = 0.042 mgd$

Find lbs/day of chlorine

$1.3 ppm x 0.042 mg x 8.34 = 0.45 lbs/day of Cl$

Change percent available to a decimal equivalent

$65\% = 0.65$

Find lbs/day of HTH

$$\frac{0.45 lbs Cl}{0.65} = 0.7 lbs/day of HTH$$

Find lbs/year of HTH

$0.7 lbs/day x 365 days/year = 255.5 lbs/year$

WIRE-TO-WATER CALCULATIONS

The term wire-to-water refers to the conversion of electrical horsepower to water horsepower. The motor takes electrical energy and converts it into mechanical energy. The pump turns mechanical energy into hydraulic energy. The electrical energy is measured as motor horsepower (MHp.) The mechanical energy is measured as brake horsepower (BHp.) And the hydraulic energy is measured as water horsepower (WHp.) Horsepower is measured by lifting a weight a given distance in a specific time period. One horsepower is the amount of energy required to produce 33,000 ft-lbs of work per minute. That means that lifting 33,000 pounds one foot in one minute or lifting one pound 33,000 feet in the air in one minute

would both require one horsepower worth of energy. When water is pumped, performance is measured in flow (gallons/minute) and pressure (feet of head). If you multiply gallons per minute and feet of head the resulting units would be gallon-feet per minute. Multiply gallon-feet per minute by 8.34 pounds/gallon and the units become foot pounds (of water) per minute. This can now be converted to water horsepower by dividing by 33,000 ft-lbs/min per horsepower.

$$\frac{Gpm}{33,000 ft - lbs/min/Hp} x 8.34 x Feet of Head = Water Horsepower (WHp)$$

This equation can be further simplified to:

$$\frac{Gpm}{3960} x Feet of Head = Water Horsepower (WHp)$$

Brake horsepower is the amount of energy that must go into the pump to produce the required WHp. Loses due to friction and heat in the pump reduce the pump's efficiency and require more energy in than goes out. If a pump is 80% efficient, it requires 10 BHp to generate 8 WHp.

$$\frac{Brake Hp}{Pump Efficiency} = Water Hp$$

Motor horsepower is the amount of electrical energy that must go into the motor to produce the required BHp. Loses due to friction and heat in the motor reduce the motor's efficiency and require more energy in than goes out. If a motor is 88% efficient, it requires 10 BHp to generate 8.8 BHp.

$$\frac{Motor Hp}{Motor Eff} = Brake Hp$$

or

$$\frac{Motor Hp}{Motor Eff x Pump Eff} = Water Hp$$

Motor horsepower can be converted into kilowatts by multiplying by 0.746 Kw/Hp. Kilowatt-hours can be determined by multiplying kilowatts by run time in hours. MotorHp x 0.746 Kw/Hp x Hours = Kw-Hours of electricity The following example has seven problems that relate to wire-to-water calculations. Each

problem will take the calculation one step further. It is intended to show how the steps are linked, not to represent an example of a set of exam questions. An actual exam question would possibly
require the calculation of Water horsepower (Problems 1-3) or calculation of cost of operation (Problems 1-7).

Pump Data:

6 Feet - Negative Suction Head

96 Feet - Discharge Head

17 Feet - Friction Loss

400 gpm - Flow

Motor Efficiency - 90%

Pump Efficiency - 80%

What is the static head on the pump?

$96ft + 6ft = 102ft$

What is the total dynamic head?

$96ft + 6ft + 17ft = 119ftTDH$

What is the Water Horsepower that the pump delivers?

$\frac{400gpm}{3960}x119ft = 12WHp$

What is the Brake Horsepower?

Change 80% to a decimal

Find Brake Horsepower

$\frac{12Whp * 0.80PumpEff}{=}15BHp$

What is the Motor Horsepower?

Change 90% to a decimal

$90\% = 0.90$

Find Motor Horsepower

15 BHp = 16.7 MHp

0.90 Motor Eff

How many Kilowatts of electricity does the motor require?

6.7 MHp x 0.746 Kw/Hp = 12.5 Kw

If the pump runs 13 hours a day and electric rates are \$0.09/Kw-Hour; How much does it cost to run the pump for a month (30 days)?

Find Kw-Hours per day

$12.5Kwx13hours/day = 162Kw - Hours/day$

Find cost per day

$162Kw - Hoursx\$0.09/KwHour = \$14.58/day$

Find cost for the month

$14.58/dayx30days/month = \$437.40/month$