UNIT CONVERSIONS

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:

$$Quantity\ \ in\ \ converted\ \ unit = Quantity\ \ in\ \ \cancel{original unit} * \frac{conversion\ \ unit}{\cancel{original\ \ unit}}$$

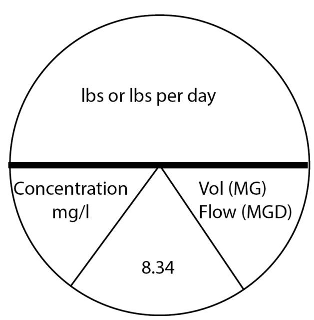
POUNDS FORMULA

Pounds formula is used for:

- Calculating the quantity in pounds of a particular wastewater constituent entering or leaving a wastewater treatment process
- Calculating the pounds of chemicals to be added

So if the concentration of a particular constituent (in mg/liter) and the volume or flow of wastewater is given, one can calculate the amount of that constituent in pounds using the following – Pounds Formula:

$$lbs\ \ \textbf{or}\ \ \frac{lbs}{day} = concentration(\frac{mg}{l}) * 8.34 * volume(MG)\ \ \textbf{or}\ \ flow(\frac{MG}{day})(MGD)$$



There are three variables – (lbs, concentration and volume) and one constant (8.34) in the pounds formula. Knowing any of the two variables in the formula, one can calculate the third (unknown) variable by rearranging the equation.

NOTE: Concentration is typically expressed as mg/l which is the weight of the constituent (mg) in 1 liter (L) of solution (wastewater). As 1L 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.

$1\% concentration = 10,000 ppm \ or \ \frac{mg}{l}$	$0.1\% concentration = 1,000 ppm \ or \ \frac{mg}{l}$
$0.01\% concentration = 100 ppm \ or \ \frac{mg}{l}$	$12.5\% concentration = 125,000 ppm \ or \ \frac{mg}{l}$

PROCESS REMOVAL RATES OR 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.

$$Process \ Removal \ Rate \ (\%) = \frac{Pollutant \ In - Pollutant \ Out}{Pollutant \ In} * 100$$

So if 10 units of a pollutant are entering a process and 8 units of pollutant are leaving, then the process removal rate for that pollutant is (10-8)/10*100=20% In the example above 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 method 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 concentration (X) given inlet concentration and removal efficiency:

Setup the equation as: $\frac{Actual \ Outlet \ (X)}{Actual \ Inlet} = \frac{100 - Removal \ Efficiency}{Inlet \ of \ 100}$

Note: The above equation uses the fact that if the inlet concentration was 100 mg/l, the outlet concentration would be 100 minus the removal efficiency.

Case 2: Calculating inlet concentration (X) given the outlet concentration and removal efficiency: Setup the equation as: $\frac{Actual\ \ inlet\ \ (X)}{Actual\ \ outlet} = \frac{100}{100 - Removal\ \ efficiency}$

Note: The above equation uses the fact that if the inlet concentration was 100 mg/l, the outlet concentration would be 100 minus the removal efficiency.

PRELIMNARY TREATMENT

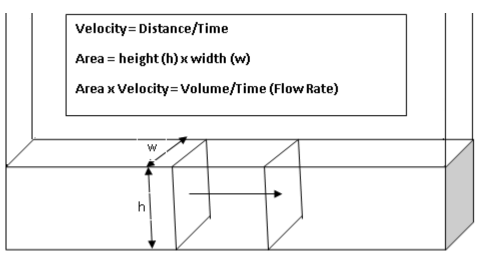
Flow Rate - Q (volume/time) = velocity (distance or length traveled /time) * surface area

Velocity is the speed at which the water is flowing. It is measured in units of length/time – ft./sec.

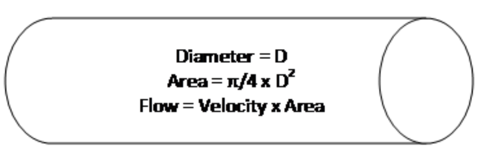
Velocity of water flowing through can be calculated by dividing the flow rate by area of the flow stream.

$$Velocity\ \ \frac{length}{time} = \frac{flow\ \ rate(\frac{volume\ \ or\ \ cubic\ \ length}{time})}{surface\ \ area\ \ in\ \ the\ \ direction\ \ of\ \ flow - square\ \ length}$$

For a flow in a channel:



For a flow in a pipe:



PRIMARY TREATMENT

Types of Math Problems Related to Primary Sedimentation

1. Finding the clarifier hydraulic or surface loading rate

The hydraulic or surface loading rate measures how rapidly wastewater moves through the primary clarifier. It is measured in terms of the number of gallons flowing each day through one square foot surface area of the clarifier.

$$Clarifier\ \ hydraulic\ \ loading\ \ \left(\frac{gpd}{ft^2}\right) = \frac{Clarifier\ \ influent\ \ flow(gpd)}{Clarifier\ \ surface\ \ area(ft^2)}$$

Rectangular clarifier surface area = width * length

Circular clarifier surface area = 0.785 * Diameter^2

2. Finding the clarifier detention time

Detention time is the length of time that wastewater stays in the settling tank is called the detention time.

It is also the time it takes for a unit volume of wastewater to pass entirely through a primary clarifier

$$Clarifier\ \ detention\ \ time\ \ (hr) = \frac{Clarifier\ \ volume(cu.ft\ \ or\ \ gal)}{Influent\ \ flow\ \ (cu.ft\ \ or\ \ gal)/hr)}$$

Rectangular clarifier volume = width * length * depth of water

Circular clarifier volume = 0.785 * Diameter^2 * depth of water

Typically volume is calculated in cu. ft and influent flow is given in gallons. Use 7.48 gal/ft^3 conversion factor to convert volume in cu. ft to gallons.

3. Weir overflow rate

The weirs at the end of the primary clarifier allow for the even distribution of the the outlet flow across the entire length of the weir. An adequate length of weir is needed to ensure smooth and even flow of wastewater over the weirs. Weir overflow rate measures the number of gallons of wastewater per day flowing over one foot of weir.

$$Weir\ over\ flow\ rate\Big(\frac{gpd}{ft}\Big) = (Clarifier\ influent\ flow\Big(\frac{gpd}{Total\ effluent\ weir\ length\ (ft)}\Big)$$

Circular clarifier weir length = 3.14 * Diameter

4. Clarifier removal efficiency

Primary sedimentation removes suspended wastewater solids which includes BOD. The efficiency of the primary is established as the percentage of the amount of parameter removed. The parameter may quantified as mass (lbs) or as concentration (mg/l).

$$Removal\ efficiency(\%) = \frac{Parameter\ In - Parameter\ Out}{Parameter\ In} * 100$$

For TSS removal:

$$TSS\ Removal\ efficiency(\%) = \frac{TSS_{In}\ (mg/l) - TSS_{Out}\ (mg/l)}{TSS_{In}\ (mg/l)} * 100$$

For BOD removal:

$$BOD\ Removal\ efficiency(\%) = \frac{BOD_{In}\ (mg/l) - BOD_{Out}\ (mg/l)}{BOD_{In}\ (mg/l)} * 100$$

5. Solids Removal

Type 1 Problems: These involve calculating lbs of solids removed given any two of the following TSS parameters - inlet concentration, outlet concentration and removal efficiency.

a. If the inlet and outlet concentrations are given, calculate the mg/l of TSS removed using:

$$TSS_{removed} = TSS_{in}(mg/l) - TSS_{out}(mg/l)$$

Then knowing the flow, use the lbs formula to calculate the lbs solids removed.

b. If either inlet or outlet concentration is given along with the clarifier removal efficiency, using the removal efficiency calculate the unknown outlet concentration (if only the inlet is given) or the inlet concentration (if only the outlet is given)

i) If inlet and removal efficiency is given, calculate the outlet by subtracting the product of inlet and removal efficiency from the inlet.

$$TSS_{out} = TSS_{in} - (TSS_{in} * \%Removal)$$

Example if the removal efficiency is 60% and the inlet concentration is 300mg/l:

$$TSS_{out} = 300 - 300 * 0.6 = 120mg/l$$

ii) If outlet and removal efficiency is given, calculate the inlet concentration by dividing the outlet by (1-removal efficiency).

$$TSS_{in} = \frac{TSS_{out}}{1 - \%Removal}$$

Example if the removal efficiency is 60% and the outlet concentration is 120mg/l:

$$TSS_{in} = \frac{120}{1 - 0.6} = 300mg/l$$

Note: You may derive the above formulas by algebraically manipulating: $\%Removal = \dfrac{TSS_{in} - TSS_{out}}{TSS_{in}}$

Example: How many lbs of solids are removed daily by a primary clarifier treating a 6 MGD flow if the average influent TSS concentration is 300 mg/l and the clarifier TSS removal efficiency is 67%.

$TSS_{out} = 300mg/l - 300 * 0.67) = 99mg/l$

$lbs\ \ solids\ \ removed = (300 - 99)mg/l * 8.34 * 6MGD = \boxed{10,058\ \ lbs\ \ solids\ \ removed\ \ per\ \ day}$

Type 2 Problems: These involve calculating the amount of sludge pumping given the solids removed. The solids removed from the primary clarifier is sludge with a typical solids concentration of about 3% to 5%.

Given the amount of total solids removed and given the sludge concentration, the volume of sludge pumping can be calculated as follows:

$$\frac{ft^3 \;\; sludge \;\; pumped}{day} = \frac{lbs \;\; solids \;\; (removed)}{day} * \frac{1 \;\; lb \;\; sludge}{(\%) \;\; lbs \;\; solids} * \frac{gal \;\; sludge}{8.34 lb \;\; sludge} * \frac{ft^3 \;\; sludge}{7.48 \;\; gal}$$

So for the solids removed in the above example, if the primary sludge has 5% solids, the required sludge pumping can be calculated as:

$$\frac{ft^3 \;\; sludge}{day} = \frac{10,058 \;\; \cancel{lbs \;\; solids}}{day} * \frac{1 \;\; \cancel{lb \;\; sludge}}{0.05 \;\; \cancel{lbs \;\; solids}} * \frac{\cancel{gal \;\; sludge}}{8.34 \cancel{lb \;\; sludge}} * \frac{ft^3 \;\; sludge}{7.48 \;\; \cancel{gal}} = \boxed{3,224 \frac{ft^3 \;\; sludge}{day}}$$