1 Unit Conversions

1.1 Example Problems

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

2. Convert 3.5 ft^3/sec to MGD:
   $\frac{3.5 \ \cancel{ft^3}}{\cancel{sec}} * \frac{7.48 \ \cancel{gal}}{\cancel{ft^3}} * \frac{MG}{10^6 \cancel{gal}} * \frac{1440 * 60 \ \cancel{sec}}{day} = 2.3 \ MGD$

3. Convert 1,000 L water to lbs:
   $1000 \ \cancel{L} * \frac{\cancel{gal}}{3.785 \ \cancel{L}} * \frac{8.34 \ lbs}{\cancel{gal}} = 2,203 \ lbs$
   $(Note: 8.34 \ lbs/gal \ is \ density \ of \ water - a \ constant)$

1.2 Practice Problems

1. Given 1 ft = 30.48 cm and 5,280 ft = mile, convert 3 miles to cm
   Solution:
   $3 \ \cancel{miles} * \frac{5,280 \ \cancel{ft}}{\cancel{mile}} * \frac{30.48 \ cm}{\cancel{ft}} = \boxed{482,803 \ cm}$

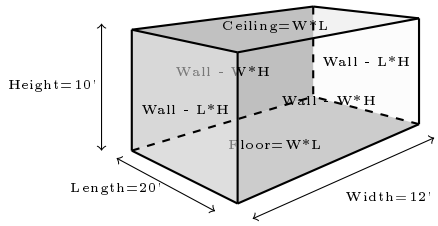
2. The wastewater flow to a treatment plant has a velocity of 61 cm/s. What is this velocity expressed in ft/min. Given: 1 ft = 30.48 cm
   Solution:
   $61 \ \frac{\cancel{cm}}{\cancel{s}} * \frac{ft}{30.48 \ \cancel{cm}} * \frac{60 \ \cancel{s}}{min} = \boxed{120 \ ft/min}$

3. As an operator of a wastewater plant you are treating a flow of 21 MGD, what is the flow in gallons per minute?
   Solution:
   $\frac{21 \cancel{MG}}{\cancel{day}} * \frac{1,000,000 \ gal}{\cancel{MG}} * \frac{\cancel{day}}{24 * 60 \ min} = \boxed{\frac{14,583 \ gal}{min}}$

2 Area & Volume

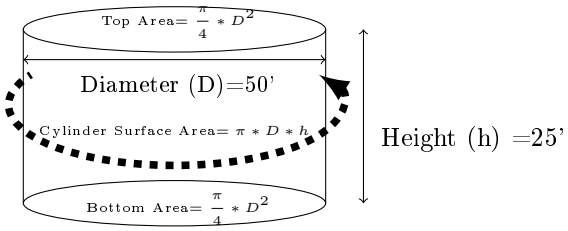
2.1 Example Problems

1. 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= $2 * 12 * 10ft^2 + 2 * 20 * 10ft^2 + 2 * 12 * 20ft^2$
   $= 240 + 400 + 480 = \boxed{1,120ft^2}$

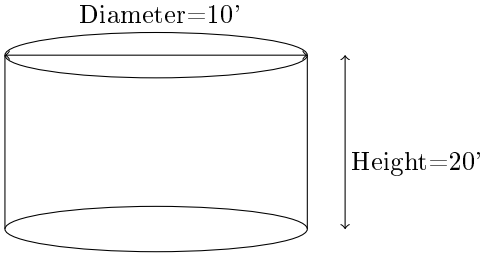
2. What is the surface area of a cylinder 50 ft diameter and 25 ft height?
   Solution:



   Surface area of cylinder = surface area of the top and bottom faces+surface area of the cylinder
   $\implies (2 * \frac{\pi}{4} * D^2) + (\pi * D * h) = 2 * 0.785 * 50^2 + 3.14 * 50 * 25 = \boxed{7,850ft^2}$

2.2 Practice Problems

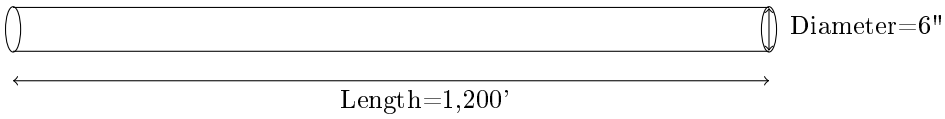
1. A cylindrical tank is 10 feet in diameter and 20 feet in height. 'What is the approximate capacity in liters?
   Solution:



   $Volume = \frac{\pi}{4} D^2 * H = 0.785 * 10^2 * 20 \cancel{ft^3} * 7.48 \frac{\cancel{gallons}}{\cancel{ft^3}} * 3.78 \frac{liters}{\cancel{gallons}} = \boxed{44,462\ liters}$

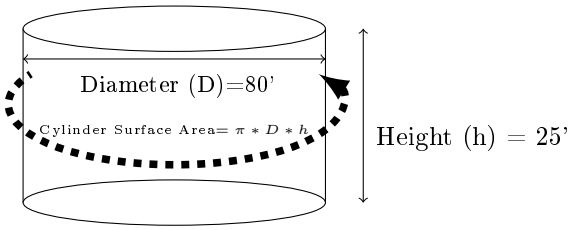
2. What is the volume of water in a sedimentation basin 80 feet long, 28 feet wide and a 9.5 feet water depth? Give your answer in gallons.
   Solution:
   $Volume = 80 * 28 * 9.5 \cancel{ft^3} * 7.48 \frac{gallons}{\cancel{ft^3}} = \boxed{159,174\ gallons}$

3. How many gallons will 1,200 feet of 6-inch pipe hold?
   Solution:



   $Volume = \frac{\pi}{4} D^2 * L = 0.785 * \left(\frac{6}{12}\right)^2 * 1200 \cancel{ft^3} * 7.48 \frac{gallons}{\cancel{ft^3}} = \boxed{1,762\ gallons}$

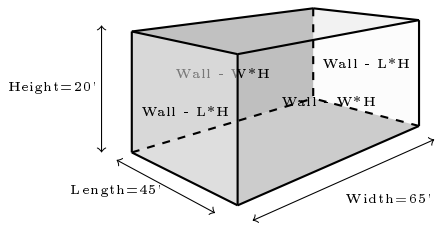
4. What is the surface area of a cylinder 80 ft diameter and 25 ft height? Cylindrical part surface area only. Disregard the floor and roof areas.
   Solution:



   $Surface\ area\ of\ cylinder = \pi * D * h = 3.14 * 80 * 25 = \boxed{6,280 ft^2}$

5. If the surface area of a clarifier is $5{,}025 ft^2$, what is its circumference?
   Solution:
   $Surface\ area = \frac{\pi}{4} * D^2 \implies 5025 ft^2 = 0.785 * D^2 ft^2 \implies D^2 = \frac{5025}{0.785} \implies D = \sqrt{6401.3} = 80 ft \implies Circumference = \pi * D = 3.14 * 80 ft = \boxed{251 ft}$

6. How many gallons of paint will be required to paint the inside walls of a 40 ft long x 65 ft wide x 20 ft high tank if the paint coverage is 150 sq. ft per gallon. Note: We are painting walls only. Disregard the floor and roof areas.
   Solution:



2 Walls W*H + 2 Walls L*H $= 2*65*20ft^2 + 2*40*20ft^2 = 2,600 + 1,600 = 4,200ft^2$

$\implies @150\frac{ft^2}{gal}\ paint\ coverage\ \rightarrow\ \frac{4,200\cancel{ft^2}}{150\frac{\cancel{ft^2}}{gal}} = \boxed{28\ gallons}$

7. What is the circumference of a 100 ft diameter circular clarifier?
   Solution:
   $Circumference = \pi * D = 3.14 * 100ft = \boxed{314ft}$

8. If the surface area of a clarifier is $5{,}025ft^2$, what is its diameter?
   Solution:
   $Surface\ area = \frac{\pi}{4} * D^2 \implies 5025ft^2 = 0.785 * D^2 ft^2 \implies D^2 = \frac{5025}{0.785} \implies D = \sqrt{6401.3} = \boxed{80ft}$

3 Concentration

3.1 Example Problems

1. What is the salt content in mg/l of a 2.5% salt solution?
   Solution: 25,000mg/l

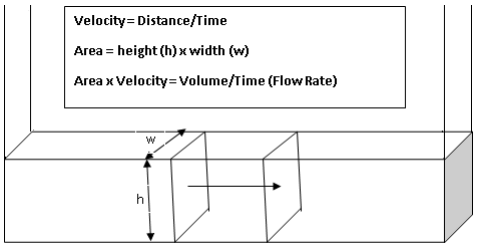
2. What is the % concentration of a solids content in a sludge with 5000 mg/l solids concentration?
   Solution:
   0.5%

3.2 Practice Problems

1. A 6.35% solution is is equivalent to _____ mg/l
   Answer:
   63,500 mg/l

4 Flow and Velocity

1. Calculate the velocity of a 14 MGD flow in a 6 ft wide channel with a water depth of two feet.



$Flow(Q) = Velocity(V) * Area(A)$

$\implies Flow\Big[14\frac{MG}{day} * \frac{10^6 gal}{MG} * \frac{ft^3}{7.48gal} * \frac{day}{24*60*60sec}\Big]\frac{ft^3}{sec} = Velocity(V)\frac{ft}{sec} * Area(6*2)ft^2$

$$\implies 21.7\frac{ft^3}{sec} = V\frac{ft}{sec} * 12ft^2$$

$$\implies V\frac{ft}{sec} = \frac{21.7\frac{\cancel{ft^3}}{sec}}{12\cancel{ft^2}^{\,ft}} = \boxed{1.8\frac{ft}{sec}}$$

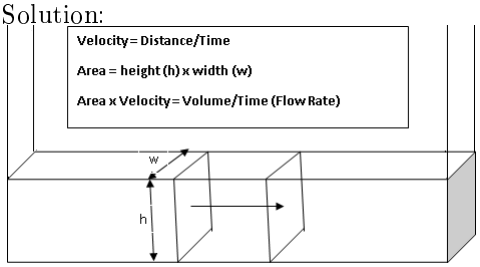
2. If a chemical is added in a sewer where wastewater is flowing at a velocity of 3.1 feet per second, how many minutes would it take for the chemical to reach the plant 7 miles away?
   Solution:
   $\text{Min} = \frac{1}{3.1}\frac{sec}{ft} * \frac{5280ft}{mile} * 7miles * \frac{min}{60sec} = \boxed{199min}$

3. A plastic float takes 9.8 seconds to travel a distance of 25 feet in a wastewater channel. The channel is 3 ft 8 in. wide and the water level in this channel is 28 inches. What is the wastewater flow in GPM
   Solution:

   $Q = V * A$

   $$\implies Q = \frac{25ft}{9.8s} * \left((3 + \frac{8}{12}) * \frac{28}{12}\right)ft^2 * 7.48\frac{gal}{ft^3} * 60\frac{s}{min} = \boxed{9,795\frac{gal}{min}}$$

4. Calculate the flow, in gpd, that would pass through a grit chamber 2 feet wide, at a depth of 6 inches, with a velocity of 1 ft /sec
   a. 646,272gpd
   b. 610,000gpd
   c. 300,272gpd
   d. 576,534gpd
   Solution:



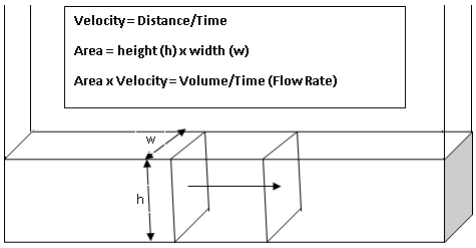
   $Q = V * A$

   $Q = 1\frac{ft}{s} * (2 * 0.5)ft^2 = 1\frac{ft^3}{s}$

   $$Q = 1\frac{\cancel{ft^3}}{\cancel{s}} * \frac{(1440 * 60)\cancel{s}}{day} * 7.48\frac{gal}{\cancel{ft^3}} = \boxed{646,272\frac{gal}{day}}$$

4.1 Practice Problems

1. A wastewater channel is 3.25 feet wide and is conveying a wastewater flow of 3.5 MGD. The wastewater flow is 8 inches deep. Calculate the velocity of this flow.
   Solution:



$$Q = V * A \implies V = \frac{Q}{A}$$

$$\implies V\frac{ft}{s} = \frac{3.5\frac{\cancel{MG}}{\cancel{day}} * \frac{1000000\cancel{gal}}{\cancel{MG}} * \frac{ft^3}{7.48\cancel{gal}} * \frac{\cancel{day}}{(1440*60)s}}{(3.25*0.75)\cancel{ft^2}} = \boxed{2.2\frac{ft}{s}}$$

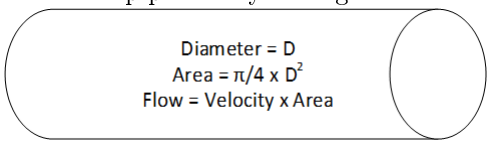
2. A plastic float is dropped into a wastewater channel and is found to travel 10 feet in 4.2 seconds. The channel is 2.4 feet wide and is flowing 1.8 feet deep. Calculate the flow rate of this wastewater in cubic feet per second.

   Solution:

   $$Q = V * A$$

   $$\implies Q\left(\frac{ft^3}{s}\right) = \frac{10ft}{4.2s} * (2.4*1.8)ft^2 = \boxed{10.3\frac{ft^3}{s}}$$

3. A 12 inch pipe conveys sewage at 2.6 feet per second. What is the flow expressed in MGD? Solution:



   $$Q = V * A$$

   $$Q = 2.6\frac{\cancel{ft}}{\cancel{s}} * 0.785 * 1^2\cancel{ft^2} * 7.48\frac{\cancel{gal}}{ft^3} * \frac{MG}{1,000,000\cancel{gal}} * \frac{(1440*60)\cancel{s}}{day} = \boxed{1.3MGD}$$

4. A sewer line to a wastewater treatment plant is 12 miles long. If the wastewater is flowing at 2.2 fps, approximately. How long will it take for wastewater to reach the plant?

   Solution:

   $$time\ to\ reach\ plant\ (hrs) = \frac{\cancel{s}}{2.2\cancel{ft}} * \frac{5280\cancel{ft}}{\cancel{mile}} * 12\cancel{miles} * \frac{hrs}{(60*60)\cancel{s}} = \boxed{8hrs}$$

5 Primary Treatment

5.1 Example Problems

1. If a clarifier has a capacity of 0.25 MG, what is the detention time in hours if it receives a flow of 3 MGD

   Solution:

   $$Clarifier\ detention\ time\ (hr) = \frac{Clarifier\ volume(MG)}{Influent\ flow\ (MG/hr)}$$

   $$Clarifier\ detention\ time\ (hr) = \frac{0.25\cancel{MG}}{\frac{3\cancel{MG}}{\cancel{day}} * \frac{\cancel{day}}{24hrs}} = \boxed{2hrs}$$

2. If a 90 ft diameter primary clarifier operating at water depth of 20 ft is treating a 12MGD flow, calculate the surface loading rate (gal/(day-sq.ft).

   Solution:

   $$Clarifier\ hydraulic\ loading\ \left(\frac{gpd}{ft^2}\right) = \frac{\frac{12\cancel{MG}}{day} * \frac{10^6 gal}{\cancel{MG}}}{0.785 * 90^2 ft^2} = \boxed{1,887 gpd/ft^2}$$

3. What is the weir overflow rate (gpd/ft) when treating a 15 MGD flow in a 105 ft diameter primary sedimentation tank operating at water depth of 20 ft.

   Solution:

   $$Clarifier\ detention\ time\ (hr) = \frac{(0.785 * 105^2 * 20)\cancel{ft^3}}{\frac{15\cancel{MG}}{\cancel{day}} * \frac{10^6 \cancel{gal}}{\cancel{MG}} * \frac{\cancel{ft^3}}{7.48\cancel{gal}} * \frac{\cancel{day}}{24 hrs}} = \boxed{2.1 hrs}$$

5.2 Practice Problems

1. A circular clarifier receives a flow of 11 MGD. If the clarifier is 90 ft. in diameter and is 12 ft. deep, what is: a) the hydraulic/surface loading rate, b) weir overflow rate, and c) clarifier detention time in hours?

   Solution:

   a) Hydraulic/surface loading rate:

   $$Clarifier\ hydraulic\ loading\ \left(\frac{gpd}{ft^2}\right) == \frac{\frac{11\cancel{MG}}{day} * \frac{10^6 gal}{\cancel{MG}}}{0.785 * 90^2 ft^2} = \boxed{1,730 gpd/ft^2}$$

   b) Weir overflow rate:

   $$Weir\ overflow\ rate\left(\frac{gpd}{ft}\right) = \frac{\frac{11\cancel{MG}}{day} * \frac{10^6 gal}{\cancel{MG}}}{3.14 * 90 ft} = \boxed{38,924 gpd/ft}$$

   c) Clarifier detention time:

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

   $$Clarifier\ detention\ time\ (hr) = \frac{(0.785 * 90^2 * 15)\cancel{ft^3}}{\frac{11\cancel{MG}}{\cancel{day}} * \frac{10^6 \cancel{gal}}{\cancel{MG}} * \frac{\cancel{ft^3}}{7.48\cancel{gal}} * \frac{\cancel{day}}{24 hrs}} = \boxed{2 hrs}$$

2. At a 2.5 MGD wastewater treatment plant the primary clarifier has a detention time of 2 hours. How many gallons does this clarifier hold?

   Solution:

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

   $$\implies Clarifier\ volume(gal) = Clarifier\ detention\ time\ (hr) * Influent\ flow\ (gal/hr)$$

   $$\implies Clarifier\ volume(gal) = \left(2\ hrs\right) * \left(2.5 * 10^6\ \frac{gal}{day} * \frac{day}{24\ hrs}\right) = \boxed{208,333\ gals}$$

6 Sludge Pumping

6.1 Example Problems

1. How many lbs/day of solids are removed in a clarifier treating a 6 MGD flow if the average inlet concentration is 320 mg/l and its average outlet concentration is 80 mg/l

   Solution:

   Applying pounds formula:
   $$\frac{lbs\ \ solids\ \ removed}{day} = 6MGD * (320 - 80)\frac{mg}{l} * 8.34 = \boxed{120,096\frac{lbs\ \ solids}{day}}$$

2. A clarifier has a TSS removal efficiency of 50%. If the influent TSS concentration is 220 mg/L, how many lbs/day of TSS are removed if the flow is 10 MGD. Also, how many cu. ft of sludge is pumped if the sludge has a TS concentration of 5%.
   $lbs\ \ solids\ \ removed = (220 * 0.50)mg/l * 10MGD * 8.34 = 9,174lbs\ \ solids\ \ per\ \ day$
   $$\frac{ft^3\ \ sludge}{day} = \frac{9,174\ \cancel{lbs\ solids}}{day} * \frac{1\ \cancel{lb\ sludge}}{0.05\ \cancel{lbs\ solids}} * \frac{\cancel{gal\ sludge}}{8.34\cancel{lb\ sludge}} * \frac{ft^3\ \ sludge}{7.48\ \cancel{gal}} = \boxed{2,941\frac{ft^3\ \ sludge}{day}}$$

6.2 Practice Problems

1. A community has a total flow of 15 MGD which is passed through a primary treatment plant which removes 60% of the TSS and 35% of the BOD. The average strength of the influent is 400 mg/l TSS and 275 mg/l BOD. If the total solids of the raw sludge is 5%, how many cu. ft of sludge is pumped daily?
   Solution:
   $lbs\ \ solids\ \ removed = (400 * 0.60)mg/l * 15MGD * 8.34 = 30,024lbs\ \ solids\ \ per\ \ day$
   $$\frac{ft^3\ \ sludge}{day} = \frac{30,924\ \cancel{lbs\ solids}}{day} * \frac{1\ \cancel{lb\ sludge}}{0.05\ \cancel{lbs\ solids}} * \frac{\cancel{gal\ sludge}}{8.34\cancel{lb\ sludge}} * \frac{ft^3\ \ sludge}{7.48\ \cancel{gal}} = \boxed{9,626\frac{ft^3\ \ sludge}{day}}$$

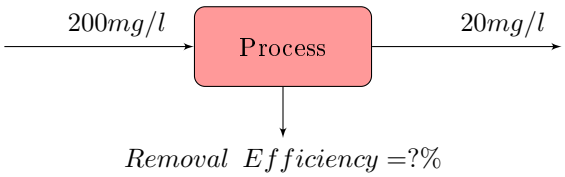
2. How many lbs of solids are removed daily by a primary clarifier treating a 6 MGD flow if the average influent TSS concentration is 300 mg/l and the clarifier TSS removal efficiency is 67%?
   Solution:
   As the removal efficiency is 67%, 0.67 * 300 mg/l = 201 mg/l solids are removed.
   The total lbs removed can be calculated using the lbs formula.
   $$\frac{lbs\ \ solids}{day} = 6MGD * 201\frac{mg\ \ SS}{l} * 8.34 = \boxed{10,058\frac{lbs\ \ solids}{day}}$$

7 Removal Efficiency

7.1 Example Problems

1. The influent to a trickling filter plant is 200 mg/L and the effluent BOD is 20 mg/L. What is the BOD removal efficiency (%)?

Solution:



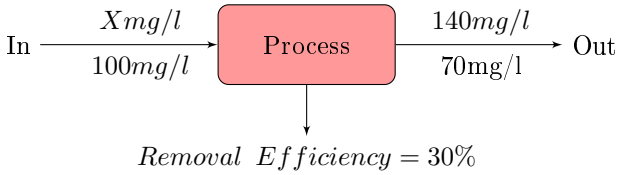
$$Removal\ \ Efficiency\ \ (\%) = \frac{In - Out}{In} * 100 \implies \frac{200 - 20}{200} * 100 = \boxed{90\%}$$

2. Calculate the primary clarifier influent solids concentration if its outlet concentration is 60 mg/l and the known clarifier removal efficiency is 75%?

$$\frac{Actual\ \ inlet\ \ (X)}{Actual\ \ outlet} = \frac{100}{100 - Removal\ \ efficiency}$$
$$\frac{Actual\ \ inlet\ \ (X)}{60} = \frac{100}{100 - 75} = 4$$
$$\implies Actual\ \ inlet\ \ (X) = 4 * 60 = \boxed{240mg/l}$$

3. If a primary clarifier consistently operates at 30% efficiency and produces an effluent which averages 140 mg/l BOD, what is the influent BOD?

Solution:



$$\frac{Actual\ \ inlet\ \ (X)}{Actual\ \ outlet} = \frac{100}{100 - Removal\ \ efficiency}$$
$$\frac{Actual\ \ inlet\ \ (X)}{140} = \frac{100}{100 - 30} = 1.43$$
$$\implies Actual\ \ inlet\ \ (X) = 1.43 * 140 = \boxed{200mg/l}$$

7.2 Practice Problems

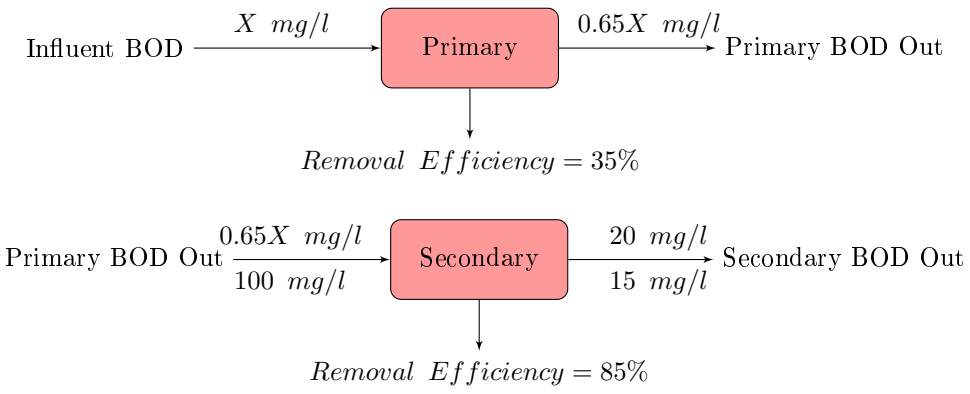
1. What is the % removal efficiency if the influent concentration is 10 mg/L and the effluent concentration is 2.5 mg/L?

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

2. 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:



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

Alternate Solution #1

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

$$\downarrow \text{(0.35X)BOD Removed} \qquad \downarrow \text{(0.65*0.85)X = 0.5525X BOD Removed}$$

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

Alternate Solution #2:

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

$$\downarrow \text{(0.35X)BOD Removed} \qquad \downarrow \text{(0.65X*0.85)BOD Removed}$$

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

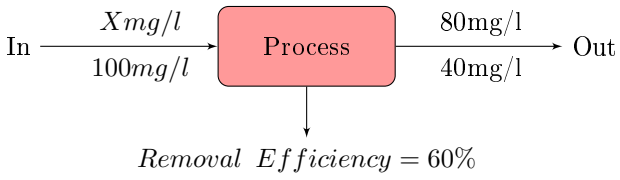
Secondary Effluent BOD=[Primary Effluent BOD]*(1-Secondary BOD Removal)

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

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

3. Calculate the inlet concentration if the outlet concentration is 80 mg/l and the process removal efficiency is 60%



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

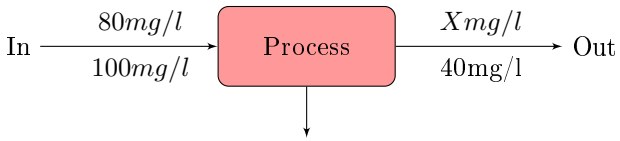
$$\implies \frac{Actual\ inlet\ (X)}{80} = 2.5$$

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

4. Calculate the outlet concentration if the inlet concentration is 80 mg/l and the process removal effi-

ciency is 60%

Solution:



$$\frac{Out}{In} \ : \ \frac{Actual\ \ Outlet(X)}{80} = \frac{100-60}{100}$$
$$\implies \frac{Actual\ \ Outlet(X)}{80} = 0.4$$
$$\implies Actual\ \ Outlet(X) = 0.4 * 80 = \boxed{32mg/l}$$

5. Calculate the primary clarifier influent solids concentration if its outlet concentration is 60 mg/l and the known clarifier removal efficiency is 75%?

$$\frac{Actual\ \ inlet\ \ (X)}{Actual\ \ outlet} = \frac{100}{100 - Removal\ \ efficiency}$$
$$\frac{Actual\ \ inlet\ \ (X)}{60} = \frac{100}{100-75} = 4$$
$$\implies Actual\ \ inlet\ \ (X) = 4 * 60 = \boxed{240mg/l}$$

8 Activated Sludge

8.1 Example Problems

1. Calculate F/M ratio based on the following data:

   Secondary influent BOD - 156 mg/l

   Four (4) aeration basins - 30 ft x 70 ft x 10 ft. deep

   Influent flow - 0.65 MGD

   MLSS - 3600 mg/l

   MLSS average % volatile - 72%

   Solution:

$$F:M = \frac{(lbs/day)\ \ primary\ \ effluent\ \ BOD\ \ entering\ \ the\ \ aeration\ \ tank}{(lbs)\ \ MLVSS\ \ in\ \ the\ \ aeration\ \ tank}$$

$$F:M = \frac{156 * 0.65 * 8.34}{3600 * 0.72 * 4 * (30 * 70 * 10)ft^3 * \frac{7.48gal}{ft^3} * \frac{MG}{1000000gal} * 8.34} = \boxed{0.06}$$

2. Calculate the MCRT of an activated sludge plant given the following information.
   Plant flow- 4.25 MGD
   WAS conc-7980 mg/l
   Waste flow- 0.055 MGD
   RAS conc.- 7980 mg/l
   Aeration tank vol-1MG
   Clarifier vol- 0.25 MG
   Final eff TSS conc. - 21.2 mg/l
   MLSS conc.- 2050 mg/l

   Solution:

   $$MCRT(days) = \frac{MLSS\ in\ aeration\ tank\ (lbs) + MLSS\ in\ clarifier\ (lbs)}{SS\ effluent\ (lbs/day) + SS\ WAS\ (lbs/day)}$$

   $$MLSS\ in\ aeration\ tank\ (lbs) = 1 * 2050 * 8.34 = 17097 lbs$$

   $$MLSS\ in\ clarifier\ (lbs) = 0.25 * 2050 * 8.34 = 4274.3 lbs$$

   $$SS\ effluent\ (lbs/day) = 4.25 MGD * 21.2 mg/l * 8.34 = 751.4 lbs/day$$

   $$SS\ WAS\ (lbs/day) = 0.055 MGD * 7980 mg/l * 8.34 = 3660.4 lbs/day$$

   Plugging in the values calculated above: $MCRT(days) = \frac{17097.6 + 4274.3}{751.4 + 3660.4} = 4.8 = \boxed{5 days}$

3. A sludge settleability test shows a reading 220 ml after 30 minutes of settling in a one liter graduated cylinder. Lab testing on this mixed liquor shows a MLSS concentration of 1850 mg/L and a MLVSS concentration of 1440 mg/L. Calculate SVI for this mixed liquor sample.

   *a. 119
   b. 108
   c. 153
   d. 138

   Solution:
   SVI (ml/g)= $\frac{Settled\ sludge\ volume\ in\ ml/l\ after\ 30\ min}{MLSS\ mg/l} * 1000\frac{mg}{g}$

   SVI=$\frac{220ml/l}{1,850mg/l} * 1000\frac{mg}{g} = \boxed{119ml/g}$

8.2 Practice Problems

1. What is the food/microorganism ratio given the following conditions:
   MLSS = 2500 mg/L
   Secondary Influent BOD_5 = 210 mg/L
   Aeration Tank Volume = 125,000 gallons
   Primary Effluent BOD_5 = 102 mg/L
   Influent Flow = 235,000 gallons per day
   Mixed Liquor is 75% volatile
   Solution:

   $$F:M = \frac{(lbs/day)\ primary\ effluent\ BOD\ entering\ the\ aeration\ tank}{(lbs)\ MLVSS\ in\ the\ aeration\ tank}$$

   $$F:M = \frac{210\ mg/l * 0.235\ MGD * 8.34}{(2500\ mg/l * 0.75) * \left(125,000\ gal * \frac{MG}{1,000,000\ gal}\right) * 8.34} = \boxed{0.21}$$

2. Calculate the MCRT given the following.
   Plant flow - 1.8 MGD
   MLSS conc - 2800 mg/l
   WAS flow - 0.04 MGD
   MLVSS conc. - 2190 mg/l
   Aerator vol - 0.3 MG
   Reactor vol. - 0.2 MG
   RAS conc. - 8150 mg/l
   Effluent SS conc.-18 mg/l
   Solution:

   $$MCRT(days) = \frac{MLSS\ in\ aeration\ tank\ (lbs) + MLSS\ in\ clarifier\ (lbs)}{SS\ effluent\ (lbs/day) + SS\ WAS\ (lbs/day)}$$

$MLSS\ in\ aeration\ tank\ (lbs) = 0.3 * 2800 * 8.34 = 7005.6lbs$

$MLSS\ in\ clarifier\ (lbs) = 0.2 * 2800 * 8.34 = 4670.4lbs$

$SS\ effluent\ (lbs/day) = 1.8MGD * 18mg/l * 8.34 = 270.2lbs/day$

$SS\ WAS\ (lbs/day) = 0.04MGD * 8150mg/l * 8.34 = 2718.8lbs/day$

Plugging in the values calculated above: $MCRT(days) = \dfrac{7005.6 + 4670.4}{270.2 + 2718.8} = 3.9 = \boxed{4days}$

3. In an aeration tank, the MLSS is 2650 mg/l and recorded 30-minute settling test indicates 221 ml/L. What is the sludge volume index?

   Solution:
   SVI (ml/g)= $\dfrac{Settled\ sludge\ volume\ in\ ml/l\ after\ 30\ min}{MLSS\ mg/l} * 1000\dfrac{mg}{g}$

   SVI=$\dfrac{221ml/l}{2650mg/l} * 1000\dfrac{mg}{g} = \boxed{83ml/g}$

4. The desired F/M ratio is .35 lbs BOD/day/lb MLVSS. If 2,100 lbs of BOD enter the aerator daily, how many lbs of MLVSS should be maintained in the aeration tank?
   Solution:
   $F : M = \dfrac{(lbs/day)\ primary\ effluent\ BOD\ entering\ the\ aeration\ tank}{(lbs)\ MLVSS\ in\ the\ aeration\ tank}$

   $\implies 0.35 = \dfrac{2100}{x} \implies x = \boxed{6000lbs\ MLVSS}$

9 Activated Sludge

9.1 Example Problems

1. 1

9.2 Practice Problems

1. 1

10 Stabilization Ponds

10.1 Example Problems

1. What is the surface area in acres of a pond that is 4 feet deep, if it holds 30 million gallons?
   Solution:
   $Pond\ Volume = Surface\ Area * Depth \implies 30MG = Surface\ Area * 4ft$
   $\implies Surface\ Area\ (acres) = \dfrac{30MG * 3.069\dfrac{acre - ft}{MG}}{4ft} = \boxed{23\ acre}$

2. The influent flow to a pond is 10,000 gallons/hour with a suspended solids concentration of 142mg/L in the raw wastewater. How many lbs of suspended solids are sent to the pond daily?

   Solution:

   $$\frac{lbsSS}{day} = 10000\frac{gal}{hr} * \frac{24hrs}{day} * \frac{MG}{1000000gal} * 142\frac{mg}{l} * 8.34 = \boxed{284\frac{lbs\ SS}{day}}$$

3. A pond is 260 ft. long and 80 ft. wide. What is the area of this pond in acres?

   Solution:

   $$(260 * 80)ft^2 * \frac{acre}{43,560ft^2} = \boxed{0.48acre}$$

4. A pond has a volume of 1,800,000 ft^3. If the flow to the pond is 425 gpm, what is the pond detention time in days?

   Solution:

   $$DT = \frac{volume}{flow} = 1,800,000ft^3 * \frac{1}{425\frac{gal}{min}} * \frac{day}{1440min} * \frac{7.48gal}{ft^3} = \boxed{22days}$$

5. Find pond hydraulic loading in inches/day when the depth of the pond is 6 ft. and the detention time is 30 days.

   Solution:

   $$Hydraulic\ Loading\ (HL) = \frac{flow}{area}$$

   $$Detention\ time\ (DT) = \frac{vol}{flow} \implies flow = \frac{vol}{DT}$$

   Substituting for flow in the HL formula above:

   $$HL = \frac{\frac{vol}{DT}}{area} \text{ or } \frac{vol}{area * DT} \implies \boxed{HL = \frac{pond\ depth}{DT}}\ as\ \frac{vol}{area} = pond\ depth$$

   $$Pond\ hydraulic\ loading\ rate = \frac{Pond\ depth\ (in)}{Pond\ detention\ time\ \frac{Volume}{Flow}} = \frac{6 * 12\ inches}{30\ days} = \boxed{\frac{2.4in}{day}}$$

6. The flow to a pond is 750,000 gpd. If the pond diameter is 100 ft and the BOD in the pond influent is 300 mg/L, what is the organic loading to this pond in lbs BOD/day/acre?

   Solution:

   $$Organic\ loading = \frac{lbs\ BOD\ per\ day}{area\ (acres)} = \frac{0.75MGD\ *\ 300mg/l\ *\ 8.34}{0.785 * 100^2ft^2} * \frac{43,560ft^2}{acre} = \boxed{\frac{10,413lbs\ BOD}{day - acre}}$$

10.2 Practice Problems

1. A stabilization pond is 1100 ft. long, 600 ft wide, and is operated at a depth of 5 ft. It receives a flow of 500,000 gpd and which has an influent BOD of 185mg/L. Using this information do the following:

   (a) Convert the flow to the pond in units of acre-ft/day.

   (b) Find the area of this pond in units of acres.

   (c) Find the volume of pond in units of acre-feet.

   (d) Calculate the pond detention time in days.

(e) Calculate the hydraulic loading to the pond in units of inches per day.

(f) Calculate the organic loading to the pond (lbs of BOD/day/acre).

Solution:

(a) $\frac{500,000gal}{day} * \frac{ft^3}{7.48gal} * \frac{acre-ft}{43,560ft^3} = \boxed{1.53\frac{acre-ft}{day}}$

(b) $(1,100*600)ft^2 * \frac{acres}{43,560ft^2} = \boxed{15.2acres}$

(c) $(1,100*600*5)ft^3 * \frac{acres-ft}{43,560ft^3} = \boxed{75.8acre-ft}$

(d) $DT = \frac{volume}{flow} = (1,100*600*5)ft^3 * \frac{1}{500,000\frac{gal}{day}} \frac{7.48gal}{ft^3} = \boxed{49.4days}$

(e) $Pond\ hydraulic\ loading\ rate\left[\frac{in}{day}\right] = \frac{Pond\ depth\ (in)}{Pond\ detention\ time\ \frac{Volume}{Flow}} = \frac{5*12in}{49.4} = \boxed{1.2\frac{in}{day}}$

(f) $Organic\ loading = \frac{lbs\ BOD\ per\ day}{area\ (acres)}$

$\implies \frac{0.5MGD\ *\ 185mg/l\ *\ 8.34}{1,100*600ft^2} * \frac{43,560ft^2}{acre} = \boxed{\frac{50.9lbs\ BOD}{day-acre}}$

2. A 2.5 acre stabilization pond is operated at a depth of five (5) ft. What is the pond detention time if the flow to the pond is 18,000 ft^3/day?

Solution:

$Pond\ detention\ time = \frac{Volume}{Flow} = \frac{(2.5*5)acre-ft}{18,000\frac{ft^3}{day} * \frac{acre-ft}{43,560ft^3}} = \boxed{30\ days}$

3. The flow to a pond is 7.2MGD. If the pond diameter is 350 ft and the BOD in the pond influent is 170mg/L, what is the organic loading to this pond in lbs BOD/day/acre?

Solution:

$Organic\ loading = \frac{lbs\ BOD\ per\ day}{area\ (acres)} = \frac{7.2MGD\ *\ 170mg/l\ *\ 8.34}{0.785*350^2ft^2} * \frac{43,560ft^2}{acre} = \boxed{\frac{4,624lbs\ BOD}{day-acre}}$

11 Trickling Filters

11.1 Example Problems

1. The total influent flow (including recirculation) to a trickling filter is 1.89 MGD. If the trickling filter is 80 ft in diameter, what is the hydraulic loading in gpd/sq ft on the trickling filter?

Solution:

$Hydraulic\ loading\ \frac{gpd}{ft^2} = \frac{(1.89*10^6)gpd}{(0.785*80^2)ft^2} = \boxed{376\frac{gpd}{ft^2}}$

2. A trickling filter, 70 ft in diameter with a media depth of 6 ft, receives a flow of 0.78 MGD. If the BOD concentration of the primary effluent is 167 mg/L, what is the organic loading on the trickling filter in lbs BOD/day/1000 cu ft?

Solution: $Organic\ loading: \dfrac{lbs\ \ BOD}{day - 1000ft^3} = \dfrac{lbs\ \ BOD\ \ feed\ to\ TF\ \ per\ \ day}{volume\ \ in\ \ 1000ft^3}$

$$= \frac{\dfrac{(0.78 * 167 * 8.34) lbs\ \ BOD}{day}}{(0.785 * 70^2 * 6) ft^3 * \dfrac{1000 ft^3}{1000 ft^3}} = \boxed{\frac{47 lbs\ \ BOD}{day - 1000 ft^3}}$$

3. The suspended solids concentration entering a trickling filter is 236 mg/l. If the suspended solids concentration of the trickling filter effluent is 33 mg/l, what is the suspended solids removal efficiency of the trickling filter?

   Solution:

   $$\%Removal = \frac{236 mg/l - 33 mg/l}{236 mg/l} * 100 = \boxed{86\%}$$

4. A trickling filter, 70 ft in diameter with a media depth of 6 ft, receives a flow of 0.78 MGD. If the BOD concentration of the primary effluent is 167 mg/L, what is the organic loading on the trickling filter in lbs BOD/day/1000 cu ft?

   Solution:

   $Organic\ loading: \dfrac{lbs\ \ BOD}{day - 1000ft^3} = \dfrac{lbs\ \ BOD\ \ feed\ to\ TF\ \ per\ \ day}{volume\ \ in\ \ 1000ft^3}$

   $$= \frac{\dfrac{(0.78 * 167 * 8.34) lbs\ \ BOD}{day}}{(0.785 * 70^2 * 6) ft^3 * \dfrac{1000 ft^3}{1000 ft^3}} = \boxed{\frac{47 lbs\ \ BOD}{day - 1000 ft^3}}$$

5. The influent to the trickling filter is 1.61 MGD. If the recirculated flow is 2.27 MGD, what is the recirculation ratio?

   Solution: $R_R = \dfrac{Q_R}{Q_I} = \dfrac{2.27}{1.61} = \boxed{1.4}$

11.2 Practice Problems

1. A trickling filter has a total flow of 32 MGD. If the recirculation ratio is 0.8, what is the primary effluent flow to the TF?

   Solution:

   $Total\ \ Flow(Q_T) = Influent\ \ Flow(Q_I) * (Recirculation\ \ Ratio(R_R) + 1)$

   $\implies 32MGD = Q_I * (0.8 + 1) \implies Q_I = \dfrac{32}{1.8} = \boxed{17.8MGD}$

2. A 80-ft diameter trickling filter with a media depth of 7 ft receives a primary influent flow of 2,180,000 MGD. If the BOD concentration of the primary effluent is 139 mg/L, what is the organic loading on the trickling filter in lbs BOD/day/1000 cu ft? (Ans: 72 lbs/day-1000 ft3)

   Solution:

   $Organic\ loading: \dfrac{lbs\ \ BOD}{day - 1000ft^3} = \dfrac{lbs\ \ BOD\ \ feed\ to\ TF\ \ per\ \ day}{volume\ \ in\ \ 1000ft^3}$

   $$\implies Organic\ loading = \frac{\dfrac{(2.18 * 139 * 8.34) lbs\ \ BOD}{day}}{(0.785 * 80^2 * 7) ft^3 * \dfrac{1000 ft^3}{1000 ft^3}} = \boxed{\frac{72 lbs\ \ BOD}{day - 1000 ft^3}}$$

3. The desired trickling filter recirculation ratio is 1.4. If the primary effluent flow is 4.4 MGD what is the trickling filter effluent flow that needs to be recirculated.

   Solution:

   $R_R = \frac{Q_R}{Q_I} \implies 1.4 = \frac{Q_R}{4.4} \implies Q_R = 1.4 * 4.4 = \boxed{6.2MGD}$

4. A 90 ft diameter trickling filter treats a 540,000 gpd primary effluent flow. If the recirculated flow to the trickling filter is 120,000 gpd, what is the hydraulic loading on the trickling filter in gpd/ft2.

   Solution:

   $Hydraulic\ loading: \frac{gpd}{ft^2} \implies Hydraulic\ loading\ \frac{gpd}{ft^2} = \frac{(540,000 + 120,000)gpd}{(0.785 * 90^2)ft^2} = \boxed{104\frac{gpd}{ft^2}}$

12 Digestion

12.1 Example Problems

1. Calculate the volatile solids reduction in an anaerobic digester given the following information: Raw sludge feed to digester: 73.7 % VS and digested sludge: 57.2 %VS

   Solution:

   $$Digester\ VS\ reduction(\%) = \frac{VS_{in} - VS_{out}}{VS_{in} - VS_{in} * VS_{out}} * 100$$

   $$Digester\ VS\ reduction(\%) = \frac{0.737 - 0.572}{0.737 - 0.737 * 0.572} * 100 = \boxed{52.3\%}$$

2. 10,000 gallons/day of sludge is pumped to an anaerobic digester/day at 4% solids (70% VS). If 50% of the VS is destroyed, how many lbs of VS is destroyed per day?

   Solution:

   $$\frac{10,000\ Gal}{day} * \frac{8.34\ lbs\ sludge}{Gal} \frac{0.04 * 0.7\ lbs\ VS\ feed}{lb\ sludge} * \frac{0.5\ lbs\ VS\ destroyed}{lbs\ VS\ feed} = \boxed{\frac{1,168\ lbs\ VS\ destroyed}{day}}$$

3. How many pounds of solids are pumped to a digester each day if the digester receives 10,000 gpd of sludge at 5% solids concentration?

   Solution:

   $\frac{lbs\ TS}{day} = \frac{10,000 gal\ \ sludge}{day} * \frac{(8.34 * 0.05 lbsTS)}{gal\ \ sludge} = 4,170\frac{lbs\ \ TS}{day}$

4. Calculate the VS loading to the digester in lbs/day if 10,000 gallons of sludge containing 5% TS with and average VS content of 78%

   Solution:

   Digester VS loading (lbs/day)

   $= \frac{10,000\ \ gallons\ \ sludge}{day} * \frac{8.34 lbs\ \ sludge}{gal} * \frac{0.05 * 0.78 lbsVS}{lb\ \ sludge} = \boxed{3,253 lbs\ \ sludge\ \ per\ \ day}$

12.2 Practice Problems

1. 10,000 gallons/day of sludge is pumped to an anaerobic digester/day at 4% solids (70% VS). If 50% of the VS is destroyed, how many lbs of VS is destroyed per day?

Solution:
$$\frac{10,000\ Gal}{day} * \frac{8.34\ lbs\ sludge}{Gal} \frac{0.04 * 0.7\ lbs\ VS\ feed}{lb\ sludge} * \frac{0.5\ lbs\ VS\ destroyed}{lbs\ VS\ feed} = \boxed{\frac{1,168 lbs\ VS\ destroyed}{day}}$$

2. Primary sludge containing five percent (5%) solids is pumped to a digester continuously at a rate of 25 gpm. How many pounds of volatile solids are added to the digester each day if the volatile solids content is 73% of the total solids?

   Solution:

   Digester VS loading (lbs/day)
   $$= \frac{25 * 1,440\ gallons\ sludge}{day} * \frac{8.34 lbs\ sludge}{gal} * \frac{0.05 * 0.73 lbs VS}{lb\ sludge} = \boxed{10,960\ lbs\ sludge\ per\ day}$$

3. Calculate the % VS reduction in a digester given the volatile solids content of the influent sludge to the digester is 70% and the volatile solids content of the sludge leaving the digester is 52.5%
   Solution: $Digester\ VS\ reduction(\%) = \frac{0.7 - 0.525}{0.7 - 0.7 * 0.525} * 100 = \boxed{53\%}$

13 Chlorine Disinfection

13.1 Example Problems

1. Calculate how many pounds per day of chlorine should be used to maintain a dosage of 12 mg/l at a 5.0 MGD flow.

   Solution:

   $lbs/day = conc.(mg/l) * flow(MGD) * 8.34$

   $lbs/day = 12 * 5 * 8.34 = \boxed{500.4 lbs/day}$

2. What is the chlorine demand if the chlorine dosage is 15 mg/L and the residual is 3 mg/l? Solution:
   Chlorine dosage = chlorine demand + chlorine residual

   $\implies chlorine\ demand = chlorine\ dosage - chlorine\ residual = 15 - 3 = \boxed{12 mg/l}$

3. If 80 pounds of chlorine are applied each day to a flow of 1.5 MGD, what is the dosage in mg/l?

   Solution:

   Applying the pounds formula:

   $lbs/day = conc.(mg/l) * flow(MGD) * 8.34$

   $\implies conc.(mg/l) = \frac{lbs/day}{flow(MGD) * 8.34} = \frac{80}{1.5 * 8.34} = \boxed{6.4 mg/l}$

4. How many pounds per day of chlorine will be required to disinfect a secondary effluent flow of 1.68 MGD if the chlorine demand is found to be 8.5 mg/l and a residual of 3 mg/l is desired? Chlorine dosage = chlorine demand + chlorine residual

   $chlorine\ dosage = 8.5 + 3 = 11.5 mg/l$

   $lbs/day = conc.(mg/l) * flow(MGD) * 8.34 = 1.68 * 11.5 * 8.34 = \boxed{161.2 lbs/day}$

13.2 Practice Problems

1. The chlorine demand is 4.8 mg/l and a chlorine residual is 0.75 mg/l is desired. For a flow of 2.8 MGD, how many pounds per day should the chlorinator be set to deliver.

Solution:

Chlorine dosage = chlorine demand + chlorine residual

$chlorine\ \ dosage = 4.8 + 0.75 = 5.55 mg/l$

To calculate pounds per day, applying the pounds formula:

$lbs/day = conc.(mg/l) * flow(MGD) * 8.34 = 2.8 * 5.55 * 8.34 = \boxed{129.6 lbs/day}$

2. Chlorine is being fed at the rate of 75 pounds per day. Plant flow is 1.2 MGD. The chlorine residual is measured and found to be 2.6 mg/L Calculate chlorine demand.

   Solution:

   $Chlorine\ \ dosage(lbs/day) = conc.(mg/l) * flow(MGD) * 8.34$

   $\implies chlorine\ \ dosage\ \ conc.(mg/l) = \dfrac{lbs/day}{flow(MGD) * 8.34} = \dfrac{75}{1.2 * 8.34} = 7.5 mg/l$

   Chlorine dosage = chlorine demand + chlorine residual

   $\implies chlorine\ \ demand = chlorine\ \ dosage - chlorine\ \ residual = 7.5 - 2.6 = \boxed{4.9 mg/l}$