1. Two, circular primary clarifiers are to be designed to treat domestic wastewater following preliminary treatment. The state regulatory requirements stipulate the overflow rate must be 600 gpd/ft\(^2\) at the average daily flow and 1000 gpd/ft\(^2\) at the peak hourly flow. The detention time should be between 1 and 2 hours for all flows. The minimum weir loading rate at peak hourly flow can not exceed 30,000 gpd/ft. The average daily flow to the primary clarifiers is 9 MGD. The peaking factor for the PHF:ADF is 2.5:1. Determine the minimum diameter clarifier to the nearest 5-ft interval for two clarifiers operating in parallel to meet the criteria. Determine the side water depth (SWD) to meet the detention time requirements. Calculate the weir length necessary to meet the weir loading condition established by the regulatory agency.

\[ \text{PHF} = 2.5 \times 9 \text{ MGD} = 22.5 \text{ MGD or 11.25 MGD/clarifier} \]

Calculate the surface area based on clarification by rearranging Equation (10.3).

\[ A_s = \frac{Q}{V_o} = \frac{4.5 \times 10^6 \text{ gpd}}{600 \text{ gpd/ft}^2} = 7500 \text{ ft}^2 \text{ @ ADF} \]

\[ A_s = \frac{Q}{V_o} = \frac{11.25 \times 10^6 \text{ gpd}}{1000 \text{ gpd/ft}^2} = 11,250 \text{ ft}^2 \text{ @ PHF Controls} \]

\[ A_s = \frac{\pi D^2}{4} = 11,250 \text{ ft}^2 \quad D = \left( \frac{11,250 \text{ ft}^2 \times 4}{\pi} \right) = 119.68 \text{ ft} \quad \text{Use 120 ft} \]

Calculate the volume of the clarifier assuming a detention time of 1 hour at PHF.

\[ \theta = \frac{V}{Q} \quad V = \theta \times Q = 1 \text{ h} \left( \frac{1 \text{ d}}{24 \text{ h}} \right) \left( 11.25 \times 10^6 \text{ gpd} \right) \left( \frac{1 \text{ ft}^3}{7.48 \text{ gal}} \right) = 62,667 \text{ ft}^3 \]

Actual surface of clarifier is equal to: \[ A_s = \frac{\pi (120 \text{ ft})^2}{4} = 11,310 \text{ ft}^2 \]

\[ \text{Depth} = \frac{V}{A_s} = \frac{62667 \text{ ft}^3}{11,310 \text{ ft}^2} = 5.54 \text{ ft} \quad \text{go with 5 ft 7 in.} \]

Calculate the weir length assuming peripheral weir = \( \pi D = \pi (120 \text{ ft}) = 377 \text{ ft} \)

Calculate the weir loading rate:
Two, rectangular primary settling basins operating in parallel are to be designed to treat domestic wastewater following preliminary treatment. The average daily flow coming into the treatment plant is 10,000 m$^3$/d and the PHF:ADF ratio is 3:1. Each basin is expected to treat 75% of the peak hourly flow with one unit out of service. The state regulatory requirements stipulate the maximum overflow rate must not exceed 100 m$^3$/d⋅m$^2$. The detention time should be between 1 and 2 hours at the average daily flow. The maximum weir loading rate at peak flow can not exceed 350 m$^3$/d⋅m. Determine the dimensions (L, W, D) of the settling basins using a L:W ratio of 4:1 to meet the design criteria. Determine the side water depth (SWD) to meet the detention time requirements. Calculate the weir length necessary to meet the weir loading condition established by the regulatory agency.

Peak flow per clarifier = 10,000 m$^3$/d × (3) × (0.75)/2 =11,250 m$^3$/d

Calculate the surface area based on clarification by rearranging Equation (10.3).

\[ A_s = \frac{Q}{V_o} = \frac{11,250 \text{ m}^3/\text{d}}{100 \text{ m}^3/\text{d} \cdot \text{m}^2} = 112.5 \text{ m}^2 \text{ @ 75%PHF} \]

\[ A_s = L \times W = 4 W^2 = 112.5 \text{ m}^2 \quad W = 5.3 \text{ m and } L = 4(5.3) = 21.2 \text{ m} \]

Calculate the volume of each clarifier. Assume a detention time of 1 h @ 75%PHF.

\[ V = 0 \times Q = 1 h \left( \frac{1 \text{ d}}{24 \text{ h}} \right) \left( \frac{11,250 \text{ m}^3}{\text{d}} \right) = 469 \text{ m}^3 \]

\[ \text{Depth} = \frac{V}{A_s} = \frac{469 \text{ m}^3}{5.3 \text{ m} \times 21.2 \text{ m} \text{ m}^2} = 4.17 \text{ m} \]

Calculate the weir length:

\[ \frac{11,250 \text{ m}^3/\text{d}}{350 \text{ m}^3/\text{d} \cdot \text{m}} = 32.1 \text{ m} \]

3. Design a completely-mixed activated sludge process using three different design approaches (i.e., calculate the volume of the aeration basin). For the first approach, base your design on detention time, the second one on BOD loading, and the third one on kinetics. The influent design flow rate to the activated sludge
process is 10,000 m$^3$/day with a BOD$_5$ concentration of 200 mg/L. Completely-mixed activated sludge processes typically have detention times ranging from 3 to 6 hours and BOD$_5$ loadings ranging from 50 to 120 lb BOD$_5$/(day·1000 ft$^3$). Typical biokinetic coefficients (Reynolds and Richards, 1996) used in design are: $Y = 0.6$ mg VSS/mg BOD$_5$, $k = 3$ d$^{-1}$, $K_S = 60$ mg/L, and $k_d = 0.06$ d$^{-1}$. Use a MCRT=10 days and $X = 2500$ mg/L VSS.

Pick a detention time of 4.5 hours.

$$V = \theta \times Q = 4.5 \times \left(\frac{1 \text{d}}{24 \text{h}}\right) \left(10,000 \frac{\text{m}^3}{\text{d}}\right) = 1875 \text{m}^3$$

Pick a BOD Loading Rate of 85 lb/1000 ft$^3$.d.

Actual BOD Loading Rate =

$$10,000 \frac{\text{m}^3}{\text{d}} \left(\frac{1000 \text{L}}{\text{m}^3}\right) \left(\frac{200 \text{mg}}{\text{L}}\right) \left(\frac{1 \text{g}}{1000 \text{mg}}\right) \left(\frac{1 \text{kg}}{1000 \text{g}}\right) = 2000 \text{kg/d}$$

Volume = \[\frac{2000 \text{kg/d}}{85 \text{lb BOD} \left(\frac{454 \text{g}}{\text{lb}}\right) \left(\frac{1 \text{kg}}{1000 \text{g}}\right) \left(\frac{(3.281 \text{ft})^3}{\text{m}^3}\right) = 1470 \text{m}^3\]

Calculate volume based on kinetics: \[
\frac{1}{\theta_c} = Y \frac{(dS/dt)}{X} - k_d
\]

First, determine the effluent substrate concentration using Equation (10.15).

\[
S_e = \frac{K_s (1 + k_d \theta_c)}{\theta_c (Y k - k_d) - 1} = \frac{60 \text{mg/L} \left(1 + 0.06 \text{d}^{-1} \times 10 \text{d}\right)}{10 \text{d} \left(0.6 \text{mg/mg} \times 3 \text{d}^{-1} - 0.06 \text{d}^{-1}\right) - 1} = 5.85 \text{mg/L}
\]

Next, determine the volume of the aeration basin using Equation (10.17).

\[
V = \frac{Y Q (S_o - S_e) \theta_c}{1 + k_d \theta_c} = \frac{0.6 \text{mg/mg} \left(10000 \text{m}^3/\text{d}\right) \left(200 - 5.85\right) \text{mg/L} \left(\frac{10 \text{d}}{2500 \text{mg VSS/L}}\right)}{1 + 0.06 \text{d}^{-1} \times 10 \text{d}} = 2910 \text{m}^3
\]
4. A completely-mixed activated sludge process is to be designed to treat 10 MGD of domestic wastewater containing 200 mg/L of COD. Use the following design parameters in the design process: \( X = 2500 \text{ mg/L MLVSS}, \) influent TKN = 20 mg/L. The following biokinetic coefficients (Lawrence, 1975) should be used: \( Y = 0.40 \text{ mg VSS/mg COD}, \) \( k = 7 \text{ d}^{-1}, \) \( K_S = 75 \text{ mg/L}, \) and \( k_d = 0.06 \text{ d}^{-1}. \) Determine the volume and oxygen required at a MCRT = 15 days.

Calculate the effluent soluble COD concentration using Equation (10.15).

\[
S_e = \frac{K_s (1 + k_d \theta_c)}{\theta_c (Y k - k_d)} - 1 = \frac{75 \text{ mg/L} \left[ (1 + 0.06 \text{ d}^{-1} \times 15 \text{ d}) \right]}{15 \text{ d} \left[ 0.4 \text{ mg/mg} \times 7 \text{ d}^{-1} - 0.06 \text{ d}^{-1} \right] - 1} = 3.55 \text{ mg/L}
\]

Calculate the volume of the completely-mixed basin by using Equation (10.17).

\[
V = \frac{Y Q (S_e - S_c) \theta_c}{1 + k_d \theta_c} X = \frac{0.4 \text{ mg/mg} \left( 10 \text{ MGD} \right) \left( 200 - 3.55 \text{ mg/L} / 1 \right) \left( 15 \text{ d} / 2500 \text{ mg VSS/L} \right)}{1 + 0.06 \text{ d}^{-1} \times 15 \text{ d}} = 2.48 \text{ MG}
\]

\[
V = 2.48 \text{ MG} \left( \frac{10^6 \text{ gal}}{1 \text{ MG}} \right) \left( \frac{\text{ft}^3}{7.48 \text{ gal}} \right) = 331,551 \text{ ft}^3 \approx 332,000 \text{ ft}^3
\]

Calculate the oxygen requirements using Equations (10.19) and (10.20).

\[
O_2 = Q \left( S_e - S_c \right) (1 - 1.42 Y) + 1.42 k_d X V + Q(TKN_o) (4.57)
\]

\[
O_2 = 1.0 \left( 200 - 3.55 \text{ mg/L} \right) \left( 1 - 1.42 \times 0.4 \text{ mg/mg} \right) \times 8.34 + 1.42 \left( 0.06 \text{ d}^{-1} \right) \left( 2500 \text{ mg/L} \right) \left( 2.48 \text{ MG} \right) \times 8.34
\]

\[
+ 1.0 \left( \frac{20 \text{ mg}}{\text{L}} \right) \left( 4.57 \times 8.34 \right) = 19,100 \text{ ppd O}_2
\]

5. A circular secondary is to be designed for a pure oxygen activated sludge process. The state’s regulatory agency design criteria are as follows: peak overflow rate of 50 m$^3$/d·m$^2$, average overflow rate = 20 m$^3$/d·m$^2$, peak solids loading rate = 245 kg/d·m$^2$, peak weir loading rate = 375 m$^3$/d·m, and depth = 3.5 to 4.5 meters. The average daily flow to the aeration basin prior to the junction with the recycle flow is 6800 m$^3$/day. The maximum recycled sludge flow is 100% of the average daily flow. The design mixed liquor suspended solids concentration is 5,000 mg/L, and the ratio of the peak hourly to average daily flow is 2.8. Determine the diameter, detention time at peak hourly flow, and peak weir loading assuming a peripheral weir is used.

\[
Q @ PHF = 2.8(6800 \text{ m}^3/\text{d}) = 19,040 \text{ m}^3/\text{d}
\]

Calculate the surface area based on clarification as follows using Equation (10.24).
Calculate the surface area based on thickening as follows using Equation (10.25).

\[
A_c = \frac{Q}{V_o} = \frac{6800 \text{ m}^3/\text{d}}{20 \text{ m}^3/\text{d} \cdot \text{m}^2} = 340 \text{ m}^2 \quad \text{@ ADF}
\]

\[
A_c = \frac{Q}{V_o} = \frac{19,040 \text{ m}^3/\text{d}}{50 \text{ m}^3/\text{d} \cdot \text{m}^2} = 380.8 \text{ m}^2 \quad \text{@ PHF}
\]

Calculate the surface area based on thickening as follows using Equation (10.25).

\[
A_T = \frac{(Q + Q_R) \text{MLSS}}{\text{SLR}}
\]

\[
A_T = \frac{(19,040 + 6,800 \text{ m}^3/\text{d})(5000 \text{ mg/L})(1 \text{ kg/10^6 mg})(1000 \text{ L/m}^3)}{245 \text{ kg/d} \cdot \text{m}^2} = 527 \text{ m}^2
\]

Thickening controls the design since it yields the largest surface area.

The diameter of the clarifier is calculated as follows:

\[
A_s = \frac{\pi D^2}{4} = 527 \text{ m}^2 \quad D = 25.9 \text{ m} \text{ use 26.0 meters}
\]

Next calculate the volume so that the detention time can be calculated. Select a depth of 4 meters. Other depths will yield different volumes.

\[
V = \frac{\pi D^2}{4} \times \text{Depth} = \frac{\pi (26 \text{ m})^2}{4} \times 4 \text{ m} = 2,124 \text{ m}^3
\]

Calculate the detention time using Equation (10.4).

\[
\theta = \frac{V}{Q} = \frac{2,124 \text{ m}^3}{19,040 \text{ m}^3/\text{d}} = 0.112 \text{ d}
\]

\[
\theta = 0.112 \text{ d} \left( \frac{24 \text{ h}}{\text{d}} \right) = 2.7 \text{ h}
\]

Calculate the weir loading rate; first calculate the weir length = \( \pi D = \pi (26 \text{ m}) = 81.68 \text{ m.} \)

Calculate the weir loading rate using Equation (10.5).
6. A rectangular settling basin is to be designed for a conventional, plug-flow activated sludge process. The flow is 10 MGD, the overflow rate \((V_o)\) is 700 gpd/ft\(^2\), the detention time \((\theta)\) is 5 hours, and the weir loading rate is 22,000 gpd/ft. The settling basin sludge rake mechanisms that will be used are for square basins, therefore, two will be used in tandem to provide a length to width ratio of 2:1. Determine the dimensions of the settling basin \((L, W, \text{ and } D)\) and the total length of the effluent weir.

Calculate the surface area as follows by rearranging Equation (10.3).

\[
V_o = \frac{Q}{A_s}, \quad A_s = \frac{Q}{V_o} = \frac{10 \times 10^6 \text{ gpd}}{700 \text{ gpd/ft}^2} = 14,286 \text{ ft}^2
\]

Next calculate the dimensions of the settling basin.

\[
A_s = L \times W = 2 W^2 = 14,286 \text{ ft}^2 \quad W = 84.5 \text{ ft use } 85 \text{ ft}; \quad L = 2(85 \text{ ft}) = 170 \text{ ft}
\]

Calculate the volume of the settling basin by rearranging Equation (10.4).

\[
\theta = \frac{V}{Q} \quad V = \theta Q = 5h \left( \frac{1 \text{ d}}{24 \text{ h}} \right) \left( 10 \times 10^6 \text{ gal/d} \right) \left( \frac{1 \text{ ft}^3}{7.48 \text{ gal}} \right) = 278,520 \text{ ft}^3
\]

Calculate the depth by dividing the volume by the surface area.

\[
\text{Depth} = \frac{V}{A_s} = \frac{278,520 \text{ ft}^3}{170 \text{ ft} \times 85 \text{ ft}} = 19.3 \text{ ft} \quad \text{Use a depth of } 19.5 \text{ ft}
\]

Calculate the weir length by dividing the flow rate by the weir loading rate; rearranging Equation (10.5).

\[
q = \frac{Q}{\text{Weir length}} \quad \text{Weir Length} = \frac{Q}{q} = \frac{10 \times 10^6 \text{ gpd}}{22,000 \text{ gpd/ft}} = 455 \text{ ft}
\]

7. Compute the volume \((\text{m}^3)\) of 1000 kg of waste activated sludge if the moisture content is 96%. What volume will it occupy if the solids content is increased to 8% by gravity thickening?
Use Equation (10.27), Part A. Assume the specific gravity of wet sludge (S) is equal to 1.0.

\[ V = \frac{W_s}{(s/100)\gamma S} = \frac{1000\text{ kg}}{(4/100)(1000\text{ kg/m}^3)(1.0)} = 25\text{ m}^3 \]

Use Equation (10.27), Part B. Assume that S = 1.0

\[ V = \frac{W_s}{(s/100)\gamma S} = \frac{1000\text{ kg}}{(8/100)(1000\text{ kg/m}^3)(1.0)} = 12.5\text{ m}^3 \]

8. A gravity belt thickener (GBT) is proposed for thickening 7000 kg/day of waste activated sludge containing 1% solids. The hydraulic loading rate to the GBT will be 200 gpm/meter and the solids loading rate will be between 200 to 600 kg/m·h. The anticipated concentration of solids in the thickened sludge is 6%. Five kg of dry polymer are required per Mg of dry solids fed to the GBT. Determine the effective width of the belt assuming that 25 gpm of washwater are required per meter of belt and determine the suspended solids concentration in the centrate. Assume that the solids capture rate is 95%.

Must perform material balances on mass of solids and flows entering and exiting the gravity belt thickener.

\[ M_{\text{Sludge}} + M_{\text{Polymer}} = M_{\text{Cake}} + M_{\text{Centrate}} \quad \text{Q}_{\text{Sludge}} + \text{Q}_{\text{Wash Water}} = \text{Q}_{\text{Cake}} + \text{Q}_{\text{Centrate}} \]

Polymer added is calculated as follows:

\[ \frac{5\text{ kg polymer}}{\text{Mg}} \left( \frac{1\text{ Mg}}{10^6 \text{ g}} \right) \left( \frac{1000\text{ g}}{\text{kg}} \right) = 0.005 \text{ kg/kg} \]

Total polymer added is:
0.005 \frac{\text{kg}}{\text{d}} \left( \frac{7000 \text{ kg}}{\text{d}} \right) = 35 \frac{\text{kg}}{\text{d}}

Solids in Cake.

(7000 + \frac{35 \text{ kg}}{\text{d}}) \times (0.95) = 6683.25 \frac{\text{kg}}{\text{d}}

Calculate the mass of solids in the centrate.

\[ M_{\text{centrate}} = M_{\text{sludge}} + M_{\text{polymer}} - M_{\text{cake}} \]

\[ M_{\text{centrate}} = 7000 + 35 - 6683.25 = 351.75 \text{ kg/d} \]

Calculate the volume of sludge fed to the GBT. Assume that \( S = 1.0 \)

\[ Q = \frac{W_s}{(s/100) \gamma S} = \frac{7000 \text{ kg/d}}{(1/100)(1000 \text{ kg/m}^3)(1.0)} = 700 \text{ m}^3/\text{d} \]

Convert this flow into gallon per minute.

\[ Q = 700 \frac{\text{m}^3}{\text{d}} \left( \frac{1000 \text{ L}}{\text{m}^3} \right) \left( \frac{1 \text{ gal}}{3.785 \text{ L}} \right) \left( \frac{1 \text{ d}}{8 \text{ h}} \right) \left( \frac{1 \text{ h}}{60 \text{ min}} \right) = 385 \text{ gpm} \]

Determine the width of the belt by dividing the sludge flow by the design hydraulic loading rate of 200 gpm/meter.

\[ \text{Belt Width} = \frac{385 \text{ gpm}}{200 \text{ gpm/m}} = 1.97 \text{ meters} \quad \text{Use} \quad 2 \text{ meters} \]

\[ Q_{\text{wash water}} = 25 \text{ gpm/m} \times 2 \text{ meters} = 50 \text{ gpm} \]

Calculate the flow of the cake. Assume that \( S = 1.0 \)

\[ Q_{\text{cake}} = \frac{6683.25 \text{ kg/d}}{(6/100)(1000 \text{ kg/m}^3)(1.0)} = 111.38 \text{ m}^3/\text{d} \]

\[ Q_{\text{cake}} = 111.38 \frac{\text{m}^3}{\text{d}} \left( \frac{1000 \text{ L}}{\text{m}^3} \right) \left( \frac{1 \text{ gal}}{3.785 \text{ L}} \right) \left( \frac{1 \text{ d}}{8 \text{ h}} \right) \left( \frac{1 \text{ h}}{60 \text{ min}} \right) = 61.3 \text{ gpm} \]

\[ Q_{\text{centrate}} = Q_{\text{sludge}} + Q_{\text{wash water}} - Q_{\text{cake}} \]
\[ Q_{\text{Centrate}} = 385 + 50 - 61.3 = 373.7 \text{ gpm} \]

Calculate the solids concentration in the centrate.

\[
M_{\text{Centrate}} = \frac{351.75 \text{ kg/d}}{373.7 \text{ gal/min} \left( \frac{60 \text{ min}}{8 \text{ h}} \cdot \frac{3.785 \text{ L}}{\text{gal}} \right)} \left( \frac{10^6 \text{ mg}}{\text{kg}} \right) = 518 \text{ mg/L} \]

Check the solids loading rate (SLR) to the gravity belt thickener.

\[
\text{SLR} = \frac{\left(7000 + 35 \text{ kg/d} \right) \left( \frac{1 \text{ d}}{8 \text{ h}} \right)}{2 \text{ meters}} = 440 \frac{\text{kg}}{\text{m} \cdot \text{h}} \text{ between } \left(200 - 600 \frac{\text{kg}}{\text{m} \cdot \text{h}}\right) \text{ OK} \]

9. Design a conventional, single-stage anaerobic digester based on the following parameters: daily raw sludge production = 650 kg; volatile solids in undigested sludge = 70%; solids content in raw sludge = 5%; digestion period = 30 days; storage volume for digested sludge = 90 days; volatile solids destruction during digestion = 50%; and solids content of thickened, digested sludge = 7%.

Calculate the volume of raw sludge fed daily, \( V_1 \), using Equation (10.27) and assuming \( S=1.0 \)

\[
V_1 = \frac{W_s}{(s/100)\gamma S} = \frac{650 \text{ kg}}{(5/100)(1000 \text{ kg/m}^3)(1.0)} = 13 \text{ m}^3 / \text{d} \]

\[
\text{TS} = \text{FS} + \text{VS} \quad \text{VS} = 0.70 \times (650 \text{ kg/d}) = 455 \text{ kg/d} \]

\[
\text{FS} = \text{TS} - \text{VS} = 650 - 455 = 195 \text{ kg/d} \]

\[
\text{VS Remaining after Digestion} = 0.50 \times (455) = 227.5 \text{ kg/d} \]

\[
\text{TS Remaining after Digestion} = \text{FS} + \text{VS}_{\text{remaining}} = 195 + 227.5 = 422.5 \text{ kg/d} \]

Calculate the volume of daily digested sludge accumulation, \( V_2 \), assume \( S=1.0 \), and \( s = 7\% \)

\[
V_2 = \frac{W_s}{(s/100)\gamma S} = \frac{422.5 \text{ kg}}{(7/100)(1000 \text{ kg/m}^3)(1.0)} = 6.04 \text{ m}^3 / \text{d} \]

Now, determine the volume of a conventional, single-stage anaerobic digester using Equation (10.28).
10. An aerobic digester is to be designed to treat the waste activated sludge (WAS) from a completely-mixed activated sludge process that does not have primary clarifiers. Approximately 1,300 kg of dry solids (WAS) are produced daily containing 0.6% solids, 70% volatile solids and a wet specific gravity of 1.10. The minimum design temperature is 60°F and a temperature correction factor of 1.065 will be used in design. The detention time in the digester should be between 18 and 22 days at a temperature of 20°C.

Determine the following:

a) design detention time (days) at 60°F;

\[ ^{\circ}C = \frac{5}{9} (F - 32) = \frac{5}{9} (60 - 32) = 15.6 \]

Use Equation (10.34) to calculate the required detention time.

Select a detention time of 20 days at 20°C.

\[ t_{20^\circ C} = t_{20^\circ C} (1.065)^{(20^\circ C - 15.6)} = 20 \text{ d} (1.065)^{(20^\circ C - 15.6)} = 26.4 \text{ d} \]

Calculate the volume of waste activated sludge before thickening using Equation (10.27).

\[ V_{WAS} = \frac{W_S}{(s/100) \gamma S} = \frac{1,300 \text{ kg/d}}{(0.6/100)(1000 \text{ kg/m}^3)(1.0)} = 216.7 \text{ m}^3/\text{d} \]

b) volume of the aerobic digester (m³) if the sludge is thickened to 2.5% solids prior to digestion;

Calculate the volume of waste activated sludge after thickening using Equation (10.27).

\[ V_{WAS} = \frac{W_S}{(s/100) \gamma S} = \frac{1,300 \text{ kg/d}}{(2.5/100)(1000 \text{ kg/m}^3)(1.0)} = 52 \text{ m}^3/\text{d} \]

\[ V = 26.4 \text{ d} \times \left( 52 \frac{\text{ m}^3}{\text{ d}} \right) = 1373 \text{ m}^3 \]

c) the quantity of oxygen (kg) required daily if 2.0 kg of O₂ are required per kg of volatile solids destroyed. Assume that 60% of the volatile solids are destroyed during aerobic digestion;

\[ \text{VS Destroyed} = 1300 \frac{\text{ kg}}{\text{ d}} \times (0.70 \text{ volatiles}) \times (0.60 \text{ destroyed}) = 546 \frac{\text{ kg}}{\text{ d}} \]
\[ \text{O}_2 \text{ Required} = 546 \text{ kg/d} \times \left( \frac{2.0 \text{ kg O}_2}{\text{kg VS destroyed}} \right) = 1092 \frac{\text{kg O}_2}{\text{d}} \]

d) the air flow rate in (m³/min) if air contains 0.281 kg of oxygen per m³ and the efficiency of the diffused aeration system is 5%. See Example 10.7.

\[ \text{Air Required} = \frac{1092 \text{ kg O}_2/\text{d}}{[0.281 \text{ kg O}_2/\text{m}^3](0.05)} \left( \frac{1 \text{ d}}{24 \text{ h}} \right) \left( \frac{1 \text{ h}}{60 \text{ m}} \right) = 54 \frac{\text{m}^3}{\text{min}} \]

e) the volatile solids loading rate on the digester (kg VS/m³·day); and

\[ \text{VS Loading Rate} = \frac{1300 \text{ kg/d} \times (0.70)}{1373 \text{ m}^3} = 0.66 \frac{\text{kg VS}}{\text{m}^3} \]

f) the volume of air required for mixing (m³/1000 m³·min).

\[ \text{Volume of Air for Mixing} = \frac{54 \text{ m}^3/\text{min} \times (1000 \text{ m}^3)}{1373 \text{ m}^3} = 39.3 \frac{\text{m}^3}{\text{m} \cdot 10^3 \text{ m}^3} \]

Only need 25-35 m³/1000 m³·min, however, must provide more air to meet the process oxygen requirements.

11. A belt filter press (BFP) with an effective belt width of 2.0 meters is used for dewatering 100 gpm of anaerobically digested sludge with a solids content of 7.0%. The polymer dosage is 6.5 gpm containing 0.20% powdered polymer by weight. The washwater consumption is 30 gpm per meter of effective belt width. The cake solids content is 30% and the suspended solids concentration in the filtrate is 1,800 mg/L. Calculate the hydraulic loading rate, solids loading rate, and polymer dosage and estimate the solids recovery.

Calculate the sludge loading rate to the BFP.
\[
100 \frac{\text{gal}}{\min} \left( \frac{60 \text{ min}}{\text{h}} \right) \left( \frac{24 \text{ h}}{\text{d}} \right) \left( 1 \text{MG} \frac{\text{lb}}{10^6 \text{ gal}} \right) \left( 8.34 \text{ lb/MG} \frac{\text{mg/L}}{} \right) \left( 7 \times 10,000 \frac{\text{mg/L}}{\text{L}} \right) = 84067.2 \frac{\text{lb}}{\text{d}}
\]

Calculate the solids loading rate (SLR) as follows:

\[
\text{SLR} = \frac{84067.2 \frac{\text{lb}}{\text{d}}}{2 \text{ meters}} \left( \frac{1 \text{ d}}{24 \text{ h}} \right) = 1751 \frac{\text{lb}}{\text{h} \cdot \text{m}}
\]

Calculate the hydraulic loading rate (HLR) as follows:

\[
\text{HLR} = \frac{100 \text{ gpm}}{2 \text{ meters}} = 50 \text{ gpm/m}
\]

Calculate the polymer dosage:

\[
\text{Quantity of Polymer} = 6.5 \frac{\text{gal}}{\min} \left( \frac{60 \text{ min}}{\text{h}} \right) \left( \frac{24 \text{ h}}{\text{d}} \right) \left( 8.34 \text{ lb/ gal} \right) \left( 0.002 \right) = 156.12 \frac{\text{lb}}{\text{d}}
\]

\[
\text{Polymer Dosage} = \frac{156.12 \frac{\text{lb}}{\text{d}}}{\left( 84067.2 \frac{\text{lb}}{\text{d}} \right) \left( \frac{1 \text{ ton}}{2000 \text{ lb}} \right)} = 3.71 \frac{\text{lb Polymer}}{\text{ton of sludge}}
\]

Perform materials balance on flows.

\[
Q_{\text{Sludge}} + Q_{\text{WashWater}} + Q_{\text{Polymer}} = Q_{\text{Cake}} + Q_{\text{Centrate}}
\]

\[
Q_{\text{Cake}} + Q_{\text{Centrate}} = Q_{\text{Sludge}} + Q_{\text{WashWater}} + Q_{\text{Polymer}} = 100 + 60 + 6.5 = 166.5 \text{ gpm}
\]

\[
Q_{\text{Cake}} + Q_{\text{Centrate}} = 166.5 \frac{\text{gal}}{\min} \left( \frac{60 \text{ min}}{\text{h}} \right) \left( \frac{24 \text{ h}}{\text{d}} \right) \left( 1 \text{MG} \frac{\text{lb}}{10^6 \text{ gal}} \right) = 2.3976 \times 10^{-1} \text{ MGD}
\]

\[
Q_{\text{Centrate}} = 2.3976 \times 10^{-1} \text{ MGD} - Q_{\text{Cake}}
\]

Perform materials balance on mass of solids.

\[
M_{\text{Sludge}} + M_{\text{Polymer}} = M_{\text{Cake}} + M_{\text{Centrate}}
\]

\[
84067.2 \text{ppd} + 156.12 \text{ppd} = Q_{\text{cake}} \left( 8.34 \right) \left( 30 \times 10,000 \frac{\text{mg/L}}{} \right) + Q_{\text{Centrate}} \left( 8.34 \right) \left( 1800 \frac{\text{mg/L}}{} \right)
\]

\[
84223.32 \text{ppd} = Q_{\text{cake}} \left( 8.34 \right) \left( 30 \times 10,000 \frac{\text{mg/L}}{} \right) + Q_{\text{Centrate}} \left( 8.34 \right) \left( 1800 \frac{\text{mg/L}}{} \right)
\]
84223.32 ppm = 2,502,000 Q_{cake} + 15,012 Q_{Centrate}

\[ 84223.32 \text{ ppm} = 2,502,000 Q_{cake} + 15,012 \left( 2.397 \times 10^{-1} \text{ MGD} - Q_{Cake} \right) \]

\[ Q_{cake} = 0.032418 \text{ MGD} \]

\[ Q_{Centrate} = 2.3976 \times 10^{-1} \text{ MGD} - Q_{Cake} = 2.3976 \times 10^{-1} - 0.032418 = 0.20734 \text{ MGD} \]

Estimate the solids recovery using the following equation, from Example 10.5.

\[ \% \text{ Capture} = \left( \frac{\text{Solids in Feed} - \text{Solids in Centrate}}{\text{Solids in Feed}} \right) \times 100 \]

Calculate the mass of solids in the centrate as follows:

\[ 0.20734 \text{ MGD} \left( \frac{8.34 \text{ lb/MG}}{\text{mg/L}} \right) \left( 1,800 \text{ mg/L} \right) = 3,113 \text{ lb/d} \]

\[ \% \text{ Capture} = \left( \frac{84,223 - 3,113}{84,223} \right) \times 100 = 96.3\% \]