Activated Sludge Math

1. Find the surface overflow rate for a secondary clarifier that is 120 feet in diameter when the influent flow is 120 gpm. Then, find the weir loading rate.

2. The liquid train for a 4.0 MGD WWTP consists of screening, grit removal, primary clarification, activated sludge, secondary clarifiers, and chlorine disinfection. The influent contains 350 mg/L of BOD. If the primary clarifiers removed 35% of the influent BOD, what is the organic load to the secondary treatment process?

3. Calculate the Sludge Volume Index (SVI) for two different operating conditions. In situation one, the MLSS concentration is 3,000 mg/L and the settled sludge volume after 30 minutes (SSV_{30}) is 250 mL. In situation two, the MLSS concentration is 8,000 mg/L and the SSV30 is 980 mL.

4. A treatment plant has one aeration basin and one clarifier. The aeration basin holds 300,000 gallons and the clarifier holds 60,000 gallons. The MLSS concentration is 2500 mg/L, the RAS and WAS concentrations are 7,000 mg/L, and the clarifier core concentration is 600 mg/L. Find the SRT if the WAS pump operates continuously at 10 gpm.

5. A treatment plant does not have flow monitoring on their Return Activated Sludge line. The operator wants to know what the percent RAS rate is relative to the influent flow. Calculate the RAS rate given the following information: MLSS concentration is 2500 mg/L, influent flow is 4.0 mgd, RAS concentration is 7,000 mg/L, WAS concentration is 7,200 mg/L, WAS pump rate is 60 gpm.

6. An activated sludge process has three aeration basins. Each basin is 100 feet long, 35 feet wide, and 12 feet deep. The MLSS concentration is 2800 mg/L. There are two clarifiers. Each clarifier is 55 feet in diameter and 12 feet deep. A clarifier core sample indicates that the solids concentration in the clarifier is equivalent to 500 mg/L. If the RAS/WAS concentration is 6000 mg/L, find the WAS pumping rate in gallons per day to maintain a sludge age of 15 days.

7. For the plant described in problem #6, assume an influent BOD concentration of 325 mg/L and and influent flow of 2.5 MGD. If the desired F:M ratio is 0.20, should wasting be increased or decreased?

8. Estimate the sludge pumping time in minutes per day for a primary sludge pump removing 100 gpm of sludge at 5% total solids from a primary tank receiving a flow of 5.0 MGD. The primary influent contains 250 mg/L of TSS and the primary effluent contains 70 mg/L of TSS.

9. Given the following information, find the solids loading rate to the secondary clarifier.
   a. Influent flow = 2 MGD
   b. MLSS = 2500 mg/L
   c. RAS = 6000 mg/L
   d. RAS flow is 70% of influent flow
   e. Secondary clarifier is 65 feet in diameter and 12 feet deep.

1. A. Surface Overflow Rate $= \frac{\text{flow, gpd}}{\text{area, sf}}$

$$\frac{120 \text{ gal}}{\text{min}} \bigg| \frac{1440 \text{min}}{1 \text{ day}} \bigg| = 172800 \frac{\text{gal}}{\text{d}}$$

$$\text{Area} = (0.785)(\text{diameter})^2$$
$$\text{Area} = (0.785)(120 \text{ ft})(120 \text{ ft})$$
$$\text{Area} = 11304 \text{ ft}^2$$

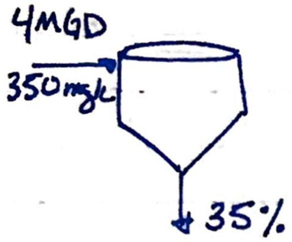
$$\text{SOR} = \frac{\text{flow}}{\text{area}}$$
$$\text{SOR} = \frac{172800 \text{ gal/d}}{11304 \text{ ft}^2}$$
$$\text{SOR} = 15.3 \text{ gal/d/sf}$$

B. Weir Loading Rate $= \frac{\text{Flow, gpd}}{\text{Linear feet of Weir}}$

$$\text{Weir} = \text{Perimeter} = \pi d$$
$$\text{Perimeter} = (3.14)(120 \text{ ft})$$
$$\text{Perimeter} = 376.8 \text{ ft}$$

$$\text{Weir Loading Rate} = \frac{172{,}800 \text{ gpd}}{376.8 \text{ ft}}$$
$$\text{Weir Loading Rate} = 458.6 \text{ gpd/sf}$$

2.



If it takes out 35%, then 65% went on to the secondary treatment process.

$$lbs/d = (mg/L)(MGD)(8.34)(0.65)$$
$$lb/d = (350\ mg/L)(4\ mgd)(8.34)(0.65)$$
$$lb/d = 7589.4$$

3. A.
$$SVI,\ mL/g = \frac{(SSV_{30},\ mL)(1000\ mg/g)}{MLSS,\ mg/L}$$
$$SVI,\ mL/g = \frac{(250\ mL)(1000\ mg/g)}{3000\ mg/L}$$
$$SVI,\ mL/g = 83.3$$

$$SVI,\ mL/g = \frac{(SSV_{30},\ mL)(1000\ mg/g)}{MLSS,\ mg/L}$$
$$SVI,\ mL/g = \frac{(980\ mL)(1000\ mg/g)}{8{,}000\ mg/L}$$
$$SVI,\ mL/g = 122.5$$

4. $$\text{MCRT} = \frac{\text{lbs MLSS} + \text{lbs Clarifier}}{\text{lbs WAS} + \underbrace{\text{lbs Effluent}}_{\text{you can usually ignore lbs in effluent}}}$$

* Find lbs for each area.

$$\text{lbs A-Basin} = (\text{mg/L})(\text{MGD})(8.34)$$
$$= (2500\ \text{mg/L})(0.3\ \text{mgd})(8.34)$$
$$= 6255$$

$$\text{lbs Clarifier} = (\text{mg/L})(\text{MGD})(8.34)$$
$$= (600\ \text{mg/L})(0.06\ \text{MGD})(8.34)$$
$$= 300.24$$

for WAS, we first have to convert the flow rate to MGD.

$$\frac{10\ \text{gal}}{\text{min}} \left| \frac{1440\ \text{min}}{1\ \text{day}} \right| \frac{1\ \text{MG}}{1000000\ \text{gal}} \Big| = 0.0144\ \text{MGD}$$

$$\text{lbs WAS} = (\text{mg/L})(\text{MGD})(8.34)$$
$$= (7{,}000\ \text{mg/L})(0.0144\ \text{MGD})(8.34)$$
$$= 840.672$$

Now, we have all the pieces.

$$\text{MCRT} = \frac{\text{lbs MLSS} + \text{lbs Clarifier}}{\text{lbs WAS}}$$

$$\text{MCRT} = \frac{6255 + 300.24}{840.672}$$

← DO THIS TOP BIT FIRST. THERE IS AN [illegible]

$$MCRT = \frac{6555.24 \text{ lbs}}{840.672 \text{ lbs/d}}$$

$$MCRT = 7.8 \text{ days}$$

5. Many people think that if you leave the solids in the clarifier, they will thicken and compact. This is only true to a limited extent.
The settleometer doesn't keep compacting all day. Does it? Nope. RAS/WAS concentration is easily predicted.

$$X_{RAS} = \left(\frac{Q}{Q_{RAS}} + 1\right) X_{MLSS}$$

$$\frac{7000^{mg/L}}{2500} = \left(\frac{4 \text{ MGD}}{Q_{RAS}} + 1\right) \frac{2500^{mg/L}}{2500}$$

① move this by dividing both sides by 2500

$$2.8 - 1 = \frac{4 \text{ MGD}}{Q_{RAS}} + 1 - 1$$

② move the 1 by subtracting it from both sides

$$1.8 = \frac{4 \text{ MGD}}{Q_{RAS}}$$

THESE TWO NUMBERS CAN TRADE PLACES

$$Q_{RAS} = \frac{4 \text{ MGD}}{1.8}$$

$$Q_{RAS} = 2.22 \text{ MGD} \quad \text{or} \quad \frac{2.22}{4} \times 100 = 56\%$$

of influent flow

6. THIS IS AS HARD AS THE MATH EVER GETS

$$\underset{\text{given}}{\underset{\uparrow}{MCRT}} = \frac{\overbrace{lb\ A\text{-}Basin + lbs\ clarifier}^{\text{find}}}{\underset{\text{unknown}}{lbs\ WAS}}$$

$$lbs\ A\text{-}basin = (mg/L)(\underset{\text{need volume}}{MGD})(8.34)$$

$$\begin{aligned}Volume &= (Length)(Width)(Depth)(\#\,basins)\\ &= (100\,ft)(35\,ft)(12\,ft)(3)\\ &= 126000\ cf\end{aligned}$$

BUT, I NEED MILLION GALLONS

$$\frac{126000\ cf}{} \cdot \frac{7.48\ gallons}{1\ cf} \cdot \frac{1\ MG}{1000000\ gal} = 0.942\ mg$$

$$\begin{aligned}lbs\ A\text{-}basin &= (mg/L)(MGD)(8.34)\\ &= (2800\ mg/L)(0.942\ mg)(8.34)\\ &= 21997.6\ lbs\end{aligned}$$

NOW, WE NEED TO DO THE SAME THING FOR THE CLARIFIERS.

$$\begin{aligned}Volume &= (0.785)(diameter)^2(\#\,of\ clarifiers)(depth)\\ Volume &= (0.785)(55\,ft)(55\,ft)(12\,ft)(2)\\ Volume &= 56991\ cf\end{aligned}$$

$$\frac{56991\ cf}{} \cdot \frac{7.48\ gallons}{1\ cf} \cdot \frac{1\ MG}{1{,}000{,}000\ gal} = 0.426\ mg$$

$$\text{lbs CLARIFIER} = (\text{mg/L})(\text{MG})(8.34)$$

$$\text{lbs CLARIFIER} = (500\ \text{mg/L})(0.426\ \text{mg})(8.34)$$

$$\downarrow \quad = 1776.42$$

NOW, WE ARE READY TO GO BACK TO THE MCRT FORMULA.

$$\text{MCRT} = \frac{\text{lbs A-basin} + \text{lbs Clarifier}}{\text{lbs WAS}}$$

$$15\ \text{day} = \frac{(21997.6\ \text{lbs} + 1776.42\ \text{lbs})}{\text{lbs WAS}}$$

THIS DIVIDING LINE ACTS JUST LIKE A PARENTHESIS

$$15\ \text{days} = \frac{23{,}774.02\ \text{lbs}}{\text{lbs WAS}}$$

change places

$$\text{lbs WAS} = \frac{23{,}774.02\ \text{lbs}}{15\ \text{days}}$$

$$\text{lbs WAS} = 1584.9$$

great! we found pounds, BUT I need gallons

$$\text{lbs/d WAS} = (\text{mg/L})(\text{MGD})(8.34)$$

$$1584.9\ \text{lbs/d} = (6000\ \text{mg/L})(\text{MGD})(8.34)$$

*simplify!

$$\frac{1584.9}{50040} = \frac{(50040)(\text{MGD})}{50040}$$

to move this, divide both sides

$$0.03167 = \text{mgd}$$

* not quite there...

$$\frac{0.03167\ \text{mg}}{\text{d}} \left| \frac{1000000\ \text{gal}}{1\ \text{mg}} \right| = \boxed{31{,}673\ \text{gallons/day}}$$

THE ANSWER!

7. $\frac{F}{m} = \frac{\text{lbs BOD}}{\text{lbs MLVSS}}$ ★← if % volatile is unknown, use MLSS insted of MLVSS

$\text{lbs BOD} = (\text{mg/L})(\text{mgd})(8.34)$

$\downarrow \; = (325 \text{ mg/L})(2.5 \text{ mgd})(8.34)$

$= 6776.25$

$\frac{F}{m} = \frac{\text{lbs BOD}}{\text{lbs MLSS}}$

$\frac{F}{\mu} = \frac{6776.25 \text{ lbs}}{21997.6 \text{ lbs}}$ ← figured this out in problem #6

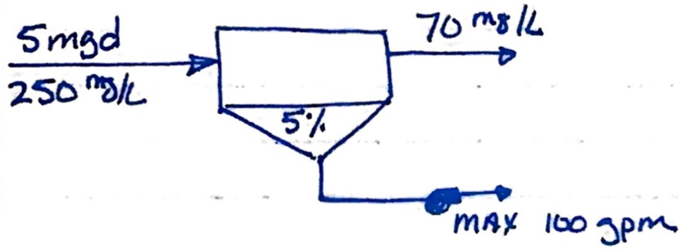
$\frac{F}{m} = 0.31$

↑ for this number to get smaller, either BOD must decrease OR MLSS must increase.

to increase MLSS, Decrease wasting

↓ DECREASE

8. DRAW A PICTURE



SOLIDS CAN ONLY GO TWO PLACES. FIND TOTAL POUNDS GOING TO THE BLANKET.

$$\text{lbs} = (\text{mg/L})(\text{mgd})(8.34)$$
$$\text{lbs} = (250 - 70\ \text{mg/L})(5\ \text{mgd})(8.34)$$
$$\text{lbs} = 7506$$

BUT.... THOSE SOLIDS GOT CONCENTRATED TO 5% IN THE BLANKET.

$1\% = 10{,}000$ mg/L AS LONG AS WE ARE UNDER ABOUT 7% SOLIDS

$$5\% \left| \frac{10.000\ \text{mg/L}}{1\%} \right| = 50{,}000\ \text{mg/L}$$

$$\text{lbs BLANKET} = (\text{mg/L})(\text{MGD})(8.34)$$
$$7506\ \text{lbs} = (50.000\ \text{mg/L})(\text{MGD})(8.34)$$ SIMPLIFY
$$\frac{7506\ \text{lbs}}{417000} = \frac{(417000 \times \text{MGD})}{417000}$$
$$0.018 = \text{MGD}$$

or

18,000 gallons per day.

SOLIDS PUMP DOES 100 gpm

$$\frac{18000\ \text{gallons}}{} \left| \frac{1\ \text{min}}{100\ \text{gal}} \right| = \boxed{180\ \text{minutes total run time}}$$

DONE!

9. $$\text{lbs/sf}\cdot d = \frac{(Q_{INF} + Q_{RAS})(\text{MLSS, mg/L})(8.34)}{\text{AREA, sf}}$$

FIND THIS FIRST

$$\text{AREA} = (0.785)(\text{diameter})^2$$
$$\text{AREA} = (0.785)(65\text{ ft})(65\text{ ft})$$
$$\text{AREA} = 3316.625\text{ ft}^2$$

RAS FLOW IS 70% OF INFLUENT FLOW

$$(2\text{ MGD})(70\%) = 1.4\text{ mgd}$$

$$\text{lbs/sf}\cdot d = \frac{(Q_{INF} + Q_{RAS})(\text{MLSS, mg/L})(8.34)}{\text{AREA, sf}}$$
$$\text{lbs/sf}\cdot d = \frac{(2\text{mgd} + 1.4\text{mgd})(2500\text{ mg/L})(8.34)}{3316.625\text{ ft}^2}$$

$$\text{lbs/sf}\cdot d = \frac{(3.4)(2500)(8.34)}{3316.625}$$

$$\text{lbs/sf}\cdot d = 21.4$$