Problem of the Day

2015.Jul.20

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Maintaining a 8.5 day MCRT with less than a foot of sludge blanket in the secondary clarifiers results in excellent sludge quality throughout the year and a secondary effluent with consistently less than 10 mg TSS/L. The chief plant operator wants to check the F:M ratio. The primary effluent composite sample collected six days ago had a BOD concentration of 110 mg/L. The MLVSS concentration in the aeration basins the same day was 1,650 mg/L. The plant treated 11.6 MGD that day. The total on-line aeration basin volume was 3.1 Mgal. Calculate the F:M ratio.

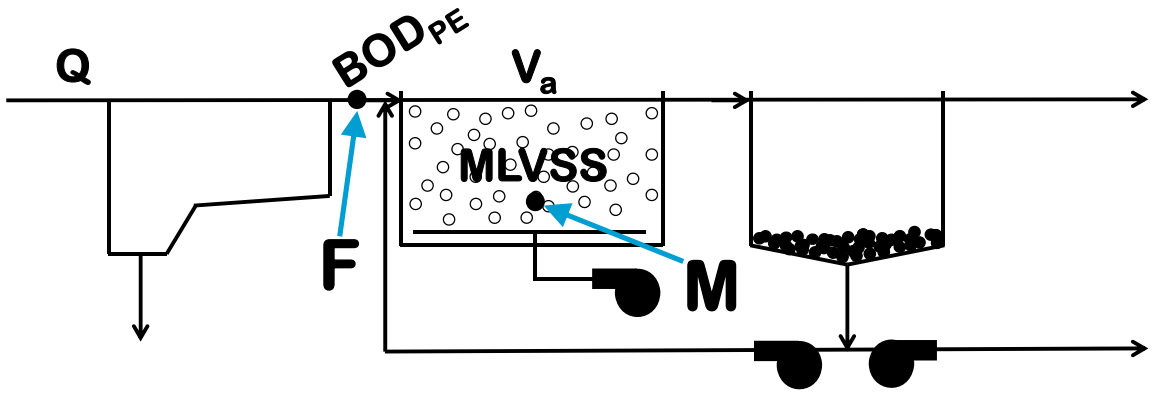
Introduction

I am not quite sure where the operations profession got the idea that activated sludge can be controlled using the F:M ratio, but it was a sad day for our business. From there, controlling using the F:M morphed into controlling the mass of microbes in the system (M) to controlling the MLVSS concentration to controlling the solids inventory in the system to controlling the MLSS concentration. **The sooner all operators and process control engineers understand that the MCRT/SRT controls all of these and that the MCRT/SRT is the control variable of paramount importance, the better and more consistently all activated sludge plants will perform**. As Spandau Ballet's song lyric and Wally Lam's book title say, "I know this much is true." Trust me.

The chief plant operator in today's problem has it right: she is maintaining **a constant MCRT with minimal secondary clarifier sludge blankets** and is just **checking** the F:M.

Solution

The following graphic shows where the F and M in the F:M ratio are calculated: F is the lb BOD/d in the primary effluent (PE), and M is the lb MLVSS in the aeration basin. Note: if the plant doesn't have primary clarifiers, F is the lb BOD/d in the influent.



Schematic of activated sludge treatment train used for F:M problems (Q = plant flow, BOD_{PE} = concentration of BOD in the primary effluent, V_a = on-line aeration basin volume, MLVSS = MLVSS concentration in aeration basin)

The list of "givens" expressed with units as used by WasteWater Technology Trainers:

1. Plant flow, Q = 11.6 Mgal/d
2. Primary effluent BOD concentration, BOD_{PE} = 110 mg BOD/L
3. On-line aeration basin volume, V_a = 3.1 Mgal
4. MLVSS concentration = 1,650 mg MLVSS/L

The question asks to calculate the F:M ratio but doesn't give the units needed in the answer. **All operators should know that the units on the F:M ratio, even though it is frequently given as if it has no units, are lb BOD/d·lb MLVSS**. These units, lb BOD/d·lb MLVSS, are put between heavy vertical lines, as always, followed by an equals sign and the blank solution bridge.

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$$\left| \frac{\text{lb BOD}}{\text{d·lb MLVSS}} \right| = \underline{\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad}$$

The F:M ratio is a pounds-per-day calculation (F) divided by a pounds calculation (M). Although WWTT advocates the two calculations be done separately, they are done here in one solution bridge. From the units of the F:M ratio, we know F (lb BOD/d) goes in the numerator. WWTT likes to start out the solution bridge for pounds and pounds-per-day calculations with the concentration of the constituent of interest, in this case BOD.

lb **BOD**	=	110 mg **BOD**	
d·lb MLVSS		L	

The next entry cancels the mg and L just entered with the BOD concentration.

lb **BOD**	=	110 ~~mg~~ **BOD**	~~L~~	
d·lb MLVSS		~~L~~	M·~~mg~~	

The M in the conversion factor just entered reminds us that an Mgal is needed, but we have two! Which one do we use, No. 1 or No. 3 in our list? Since we are calculating lb BOD **per day**, we enter the flow (No. 1), not the volume (No. 3).

lb **BOD**	=	110 ~~mg~~ **BOD**	~~L~~	11.6 ~~M~~gal	
d·lb MLVSS		~~L~~	~~M·mg~~	**d**	

We have to convert gal to lb, which we do by entering the density of water.

lb BOD	=	110 ~~mg~~ **BOD**	~~L~~	11.6 ~~Mgal~~	8.34 **lb**	
d·lb MLVSS		~~L~~	~~M·mg~~	**d**	~~gal~~	

Currently, the solution bridge has units of lb BOD/d remaining. This completes the F calculation. The M calculation goes in the denominator and starts out with the concentration of MLVSS.

lb BOD	=	110 ~~mg~~ **BOD**	~~L~~	11.6 ~~Mgal~~	8.34 **lb**	L	
d·lb **MLVSS**		~~L~~	~~M·mg~~	**d**	~~gal~~	1,650 mg **MLVSS**	

The next entry, a conversion factor, cancels the mg and L just entered with the MLVSS concentration. Be careful to enter it so like units cancel in the numerator and denominator.

lb BOD	=	110 ~~mg~~ **BOD**	~~L~~	11.6 ~~Mgal~~	8.34 **lb**	~~L~~	M·~~mg~~	
d·lb **MLVSS**		~~L~~	~~M·mg~~	**d**	~~gal~~	1,650 ~~mg~~ **MLVSS**	~~L~~	

The M in the conversion factor just entered reminds us that an Mgal is needed, but we have two! Which one do we use, No. 1 or No. 3 in our list? We've already used No. 1, so can't use it again, but we're also calculating lb MLVSS **not** lb MLVSS per day, so we enter the volume (No. 3), not the flow (No. 1).

lb BOD	=	110 ~~mg~~ **BOD**	~~L~~	11.6 ~~Mgal~~	8.34 **lb**	~~L~~	~~M·mg~~		
d·lb **MLVSS**		~~L~~	~~M·mg~~	**d**	~~gal~~	1,650 ~~mg~~ **MLVSS**	~~L~~	3.1 ~~M~~gal	

We have to convert gal to lb, which we do by entering the density of water.

lb BOD	=	110 ~~mg~~ **BOD**	~~L~~	11.6 ~~Mgal~~	8.34 **lb**	~~L~~	~~M·mg~~		~~gal~~
d·lb MLVSS		~~L~~	~~M·mg~~	**d**	~~gal~~	1,650 ~~mg~~ **MLVSS**	~~L~~	3.1 ~~Mgal~~	8.34 **lb**

To save us a little calculator time, we notice we can cancel 8.34 in the numerator and denominator (if you didn't notice this, you'd still get the same answer).

lb BOD	=	110 ~~mg~~ **BOD**	~~L~~	11.6 ~~Mgal~~	~~8.34~~ **lb**	~~L~~	~~M·mg~~		~~gal~~
d·~~lb~~ MLVSS		~~L~~	~~M·mg~~	**d**	~~gal~~	1,650 ~~mg~~ **MLVSS**	~~L~~	3.1 ~~Mgal~~	~~8.34~~ **lb**

Since all the units have now canceled except those needed in the answer, we know the solution bridge is complete. The arithmetic gives the answer.

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d·~~lb~~ MLVSS		~~L~~	~~M·mg~~	**d**	~~gal~~	1,650 ~~mg~~ **MLVSS**	~~L~~	3.1 ~~Mgal~~	~~8.34~~ **lb**

110 x 11.6 ÷ 1,650 ÷ 3.1 = **<u>0.25 lb BOD/d•lb MLVSS</u>**.

Discussion

The growth rate of the microorganisms in an activated sludge system and the temperature of the wastewater will determine how many microorganisms will be present for the amount of BOD entering the aeration basin. Operators must know this: **we control the growth rate by controlling the MCRT**. Said slightly differently: the MCRT (and temperature) will determine how many microorganisms will be present for the amount of BOD entering the aeration basin. The microbes know how many microbes the incoming BOD will support so they control how many microorganisms will be in the system not the operators and engineers.

The long solution bridge shown above the answer boils down to:

F:M = [BOD conc. (mg/L) x flow (Mgal/d)]/[MLVSS conc. (mg/L) x aeration basin volume (Mgal)]

This would be a shortcut to calculating the F:M ratio. But be careful: don't use a shortcut unless you know where it came from and how it works.

Happy calculating! Let us know, by leaving a comment, if you want us to do a specific problem, if you see a mistake, or if you have a question on any of the Problems of the Day you are looking at.