Problem of the Day

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The plant flow is 36 MGD. On-line aeration basin and secondary clarifier total volumes are 12.6 MG and 3 MG, respectively. The process control operator/engineer maintains exceptional effluent quality (effluent TSS averages 9.5 mg/L) with a 4-day MCRT during the summer. Nitrification is required year round. The MLSS concentration is 2,250 mg/L. Currently, waste activated sludge is directed to a single 50-ft diameter dissolved-air flotation thickener (DAFT). Calculate the solids loading rate, lb TSS/hr·ft^2, to the on-line DAFT.

Introduction

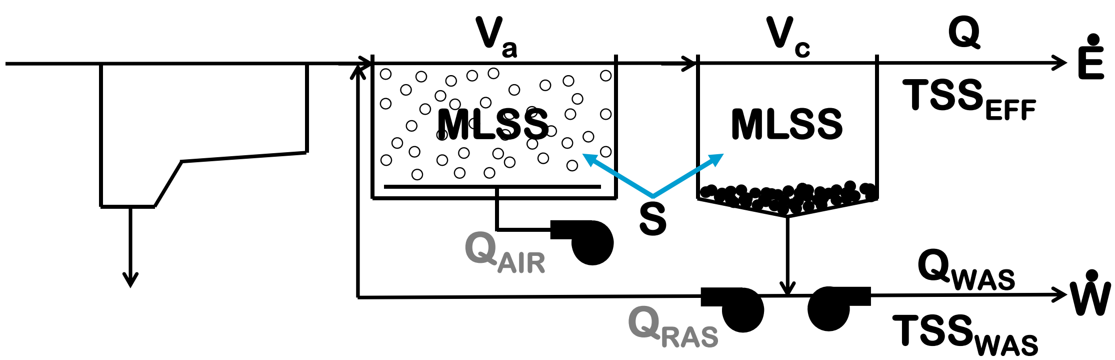
While the question asks to calculate the solids loading rate to the DAFT, there's a lot more going on in this problem. It's really an MCRT problem because you have to calculate how many pounds of solids per day need to be wasted from the activated sludge system in order to maintain the target MCRT of 4 days to determine how many solids are being directed to the DAFT.

In numerous Problems of the Day, the food-to-microorganism (F:M) ratio has been discussed and calculated. Most state certification exams require operators to be able to calculate the F:M ratio and to use it to determine how many pounds of biomass, or "microorganisms," are needed in the aeration basin for the amount of BOD, or "food," per day that is entering the aeration basin.

The reality is, contrary to what readers will hear from almost everybody except WWTT, neither operators nor engineers control the amount of biomass in an activated sludge system, the microbes do.

Absolutely, positively, the most important activated sludge control parameter is the mean cell residence time (MCRT) or the mathematically similar solids residence time (SRT). While many will preach that activated sludge operators have to "keep an eye on many parameters like the MCRT (or SRT), the MLSS concentration, the MLVSS concentration, the system mass, and the F/M ratio," **please, please, please understand that all of these are controlled by the MCRT**. Besides controlling these, the MCRT also controls sludge quality and whether or not the activated sludge system will nitrify.

The following schematic summarizes the information needed to calculate and control the MCRT.



Activated sludge process schematic

Solution

Under the pressure of a certification exam, operators tend to "freak out" when it comes to MCRT calculations. In fact, generally speaking, most operators do not control their activated sludge systems with MCRT because . . . because . . . I'm not sure why. Maybe it's because there is too much to calculate. Just remember: all you're doing is pounds calculations. And know, too, again, absolutely, positively, the most important activated sludge control parameter is the MCRT or the mathematically similar SRT.

WWTT recommends in problems dealing with the MCRT that each pounds calculation been done separately. Referring to the schematic, these are:

Ė = **pounds per day** of TSS unintentionally lost in the **E**ffluent

Ẇ = **pounds per day** of TSS intentionally removed in the **W**AS

S = **pounds** of MLSS in the **S**ystem (aeration basin + secondary clarifier)

The "dot" in Ė and Ẇ (called "E dot" and "W dot," respectively) signifies that both of these are in units of **pounds per day** (i.e., they are **rates** of solids removal), whereas the absence of a dot over the S indicates this is in units of **pounds**. From a solids "accounting" standpoint, it is much easier for the operator to break down MCRT calculations into these three components: Ė, Ẇ and S. The calculations are defined in "equation solution bridges" as follows:

$$\frac{\dot{E}\ \textbf{lb TSS}}{\textbf{d}} = \frac{TSS_{EFF}\ \cancel{\text{mg}}\ \textbf{TSS}}{\cancel{\text{L}}}\cdot\frac{\cancel{\text{L}}}{\cancel{\text{M}\cdot\text{mg}}}\cdot\frac{Q\ \cancel{\text{Mgal}}}{\textbf{d}}\cdot\frac{8.34\ \textbf{lb}}{\cancel{\text{gal}}}$$

$$\frac{\dot{W}\ \textbf{lb TSS}}{\textbf{d}} = \frac{TSS_{WAS}\ \cancel{\text{mg}}\ \textbf{TSS}}{\cancel{\text{L}}}\cdot\frac{\cancel{\text{L}}}{\cancel{\text{M}\cdot\text{mg}}}\cdot\frac{Q_{WAS}\ \cancel{\text{Mgal}}}{\textbf{d}}\cdot\frac{8.34\ \textbf{lb}}{\cancel{\text{gal}}}$$

$$\textbf{S lb MLSS} = \frac{\text{MLSS}\ \cancel{\text{mg}}\ \textbf{MLSS}}{\cancel{\text{L}}}\cdot\frac{\cancel{\text{L}}}{\cancel{\text{M}\cdot\text{mg}}}\cdot\frac{(V_a+V_c)\ \cancel{\text{Mgal}}}{}\cdot\frac{8.34\ \textbf{lb}}{\cancel{\text{gal}}}$$

Once Ė, Ẇ and S have been determined using these equations, the MCRT is easily calculated:

$$\textbf{MCRT d} = \frac{S\ \cancel{\text{lb MLSS}}}{}\cdot\frac{\textbf{d}}{(\dot{E}+\dot{W})\ \cancel{\text{lb TSS}}}$$

It is important to note that the State of California, on its wastewater treatment plant operator certification exams, assumes that if you could mix the sludge blanket solids throughout the secondary clarifier volume, then the solids concentration in the secondary clarifier would equal the MLSS concentration. There are different techniques used to calculate the mass of solids in secondary clarifiers. The SRT calculation, for example, assumes the mass of solids in the secondary clarifiers is minimal (that is, sludge blankets are kept to a minimum), so they are not even included in the SRT calculation. The State of California's assumption might not be the most accurate. Nevertheless, it is presented here as this is the approach California wants operators to use on certification exams.

It turns out that today's Problem of the Day is a bit different: we need to calculate what Ẇ has to be in order to maintain a target MCRT, which makes this problem much more practical as **this is the most important calculation an operator must know to control all activated sludge systems**. Still, we have to calculate Ė and S, but then to find Ẇ we use the following:

$$\frac{\dot{W}\ \text{lb TSS}}{\text{d}} = \frac{S\ \text{lb TSS}}{}\cdot\frac{}{MCRT_{target}\ \text{d}} - \frac{\dot{E}\ \text{lb TSS}}{\text{d}}$$

Back to the problem:

Problem of the Day: The plant flow is 36 MGD. On-line aeration basin and secondary clarifier total volumes are 12.6 MG and 3 MG, respectively. The process control operator/engineer maintains exceptional effluent quality (effluent TSS averages 9.5 mg/L) with a 4-day MCRT during the summer. Nitrification is required year round. The MLSS concentration is 2,250 mg/L. Currently, waste activated sludge is directed to a single 50-ft diameter dissolved-air flotation thickener (DAFT). Calculate the solids loading rate, lb TSS/hr·ft^2, to the on-line DAFT.

The following list summarizes the information given expressed in the appropriate units:

1. Q = 36 Mgal/d
2. TSS_{EFF} = 9.5 mg TSS/L

3. Target MCRT = 4 d
4. V_a = 12.6 Mgal
5. V_c = 3 Mgal
6. $V_a + V_c$ = 15.6 Mgal
7. MLSS = 2,250 mg MLSS/L
8. Diameter of DAFT = 50 ft

$\dot{E}$, S and $\dot{W}$ are calculated using the equation solution bridges given above.

$\dot{E}$ lb TSS	=	9.5 ~~mg~~ TSS	~~L~~	36 ~~Mgal~~	8.34 lb
d		~~L~~	~~M·mg~~	d	~~gal~~

The arithmetic: $\dot{E}$ = 9.5 x 36 x 8.34 = 2,852 lb TSS/d.

S lb MLSS	=	2,250 ~~mg~~ MLSS	~~L~~	(12.6+3) ~~Mgal~~	8.34 lb
		~~L~~	~~M·mg~~		~~gal~~

The arithmetic: S = 2,250 x 15.6 x 8.34 = 292,734 lb MLSS.

$\dot{W}$ lb TSS	=	292,734 lb MLSS		−	2,852 lb TSS
d			4 d		d

The arithmetic: $\dot{W}$ = (292,734 ÷ 4) − 2,852 = 70,332 lb TSS/d.

But we're not there yet!

What we just calculated for $\dot{W}$, 70,332 lb TSS/d, is what is being directed to the DAFT. We now have to calculate the solids loading rate to the DAFT in lb TSS/hr·ft^2. This is done in the final solution bridge. Note, the area needed in the denominator of the answer (ft^2) is the surface area of the DAFT.

lb TSS	=	70,332 **lb TSS**	~~d~~			
hr·ft^2		~~d~~	24 **hr**	0.785	50 **ft**	50 **ft**

70,332 ÷ 24 ÷ 0.785 ÷ 50 ÷ 50 = <u>**1.49 lb TSS/hr·ft^2**</u>.

Discussion

If you can remember the units on solids loading rate to DAFTs, lb TSS/hr·ft^2 (remember: **per hour**), it is easy to remember the range that is typical in municipal wastewater treatment practice:

1 to 2 lb TSS/hr·ft^2

Obviously, our answer is in this range so we have confidence it is correct.

But remember:

The MCRT, or SRT, is the most important parameter that an activated sludge operator controls.

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.