Problem of the Day

2015.Jul.21

Problem of the Day

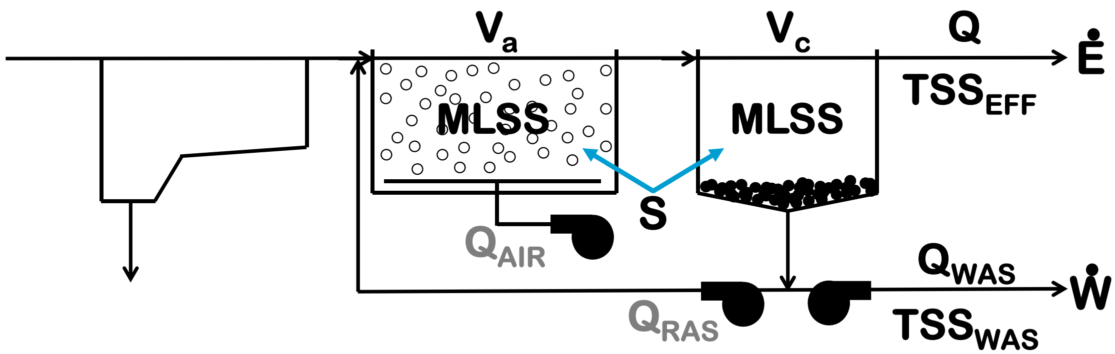
An oxidation ditch is operated in the extended aeration mode of the activated sludge process. The raw wastewater flows to the ditch after screening and grit removal at a rate of 1.1 MGD. The ditch holds 1.5 MG. The MLSS concentration is 2,850 mg/L. The operator maintains a minimal sludge blanket in the secondary clarifier that has a volume of 0.2 Mgal. The effluent TSS concentration averages 7.5 mg/L. Waste activated sludge is removed continuously at a flow of 0.055 MGD and an average TSS concentration of 5,700 mg/L. Calculate the MCRT for this plant.

Introduction

The F:M ratio was calculated in yesterday's Problem of the Day. Most state certification exams require operators to be able to calculate the F:M ratio and 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. **Contrary to what readers will hear from almost everybody except WWTT, the reality is 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 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. **For any activated sludge system, the MCRT/SRT is the control parameter of paramount importance**.

Solution

The following graphic shows where Ė, Ẇ and S are calculated to calculate the MCRT.



Schematic of activated sludge treatment train used for MCRT problems (Q = plant flow, TSS_{EFF} = effluent TSS concentration, Q_{WAS} = WAS flow rate, TSSWAS = WAS TSS concentration, V_a and V_c = on-line aeration basin and secondary clarifier volume, respectively, MLSS = MLSS concentration)

The list of "givens" expressed in the units used by WWTT:

1. Q = 1.1 Mgal/d
2. TSS_{EFF} = 7.5 mg TSS/L
3. Q_{WAS} = 0.055 Mgal/d
4. TSS_{WAS} = 5,700 mg TSS/L
5. V_a = 1.5 Mgal
6. V_c = 0.2 Mgal
7. $V_a + V_c$ = 1.7 Mgal
8. MLSS = 2,850 mg MLSS/L

Under the pressure of a certification exam, operators tend to "freak out" when it comes to MCRT calculations. The main reason for this is because there are so many computations to do. Just remember: all you're doing are three pounds calculations.

WWTT recommends that each pounds calculation be done separately. Referring to the schematic above, 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:

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

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

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

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

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

It is important to note that the State of California, on its wastewater treatment plant operator certification exams, assumes that if you could pick up the secondary clarifier and mix the sludge blanket solids throughout the secondary clarifier volume, then the solids concentration 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, as in today’s problem), so they are not even included in the 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.

Problem of the Day: An oxidation ditch is operated in the extended aeration mode of the activated sludge process. The raw wastewater flows to the ditch after screening and grit removal at a rate of 1.1 MGD. The ditch holds 1.5 MG. The MLSS concentration is 2,850 mg/L. The operator maintains a minimal sludge blanket in the secondary clarifier that has a volume of 0.2 Mgal. The effluent TSS concentration averages 7.5 mg/L. Waste activated sludge is removed continuously at a flow of 0.055 MGD and an average TSS concentration of 5,700 mg/L. Calculate the MCRT for this plant.

Ė, Ẇ and S are calculated using the equation solution bridges given above.

$$\frac{\dot{E}\ \mathbf{lb\ TSS}}{\mathbf{d}} = \frac{7.5\ \cancel{mg}\ \mathbf{TSS}}{\cancel{L}} \cdot \frac{\cancel{L}}{\cancel{M \cdot mg}} \cdot \frac{1.1\ \cancel{Mgal}}{\mathbf{d}} \cdot \frac{8.34\ \mathbf{lb}}{\cancel{gal}}$$

The arithmetic:

$\dot{E} = 7.5 \times 1.1 \times 8.34 = 68.8$ lb TSS/d.

$$\begin{array}{|c|} \dot{W}\ \textbf{lb TSS} \\ \hline \textbf{d} \end{array} = \begin{array}{|c|c|c|c|} 5{,}700\ \cancel{\text{mg}}\ \textbf{TSS} & \cancel{\text{L}} & 0.055\ \cancel{\text{Mgal}} & 8.34\ \textbf{lb} \\ \hline \cancel{\text{L}} & \cancel{\text{M}\cdot\text{mg}} & \textbf{d} & \cancel{\text{gal}} \end{array}$$

The arithmetic:

$\dot{W}$ = 5,700 x 0.055 x 8.34 = 2,615 lb TSS/d

$$\begin{array}{|c|} \text{S}\ \textbf{lb MLSS} \end{array} = \begin{array}{|c|c|c|c|} 2{,}850\ \cancel{\text{mg}}\ \textbf{MLSS} & \cancel{\text{L}} & (1.5+0.2)\ \cancel{\text{Mgal}} & 8.34\ \text{lb} \\ \hline \cancel{\text{L}} & \cancel{\text{M}\cdot\text{mg}} & & \cancel{\text{gal}} \end{array}$$

The arithmetic:

S = 2,850 x 1.7 x 8.34 = 40,407 lb MLSS.

With $\dot{E}$, $\dot{W}$ and S known, the MCRT calculation is very straightforward using the equation solution bridge given above.

Problem of the Day: An oxidation ditch is operated in the extended aeration mode of the activated sludge process. The raw wastewater flows to the ditch after screening and grit removal at a rate of 1.1 MGD. The ditch holds 1.5 MG. The MLSS concentration is 2,850 mg/L. The operator maintains a minimal sludge blanket in the secondary clarifier that has a volume of 0.2 Mgal. The effluent TSS concentration averages 7.5 mg/L. Waste activated sludge is removed continuously at a flow of 0.055 MGD and an average TSS concentration of 5,700 mg/L. Calculate the MCRT for this plant.

$$\begin{array}{|c|} \text{MCRT}\ \textbf{d} \end{array} = \begin{array}{|c|c|} 40{,}407\ \cancel{\text{lb MLSS}} & \textbf{d} \\ \hline & (68.8 + 2{,}615)\ \cancel{\text{lb TSS}} \end{array}$$

The arithmetic:

MCRT = 40,407 ÷ 2,683.8 = **<u>15.1 d</u>**.

Notice in this last solution bridge that lb MLSS was canceled with lb TSS. It is important to understand that the MLSS is the TSS in the mixed liquor, so MLSS and TSS are the same thing. This should give you no hesitation.

Discussion

In the December 2010 issue of *Water Environment and Technology* there was an article entitled, “Four Steps to Energy Self-Sufficiency.” One of the steps is “process energy conservation,” which is different than energy conservation. It is stated, “In many activated sludge facilities, the traditional approach has been to maintain the MCRT at a relatively high value to ensure good nitrification and minimize the generation of waste activated sludge.” The article goes on to expose the folly (my word) of this approach and argues that maintaining the MCRT as low as possible, while still meeting effluent requirements with respect to ammonia, provides significant process energy savings. I can’t tell you how many operators out there are running their plants at MCRTs that are way too long. I worked with one operator in Pennsylvania who ran his plant at a very high MLSS concentration, reasoning doing so would provide a “cushion” of microbes if the plant received an organic or toxic slug load. The calculated MCRT was over 60 days! And did I mention he violated his discharge permit for four months in a row?

MCRT control is of paramount importance for all activated sludge wastewater treatment plants. It needs to be implemented at all plants now.

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.