Problem of the Day

2015.Dec.26

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The Clear Springs wastewater treatment plant receives an average dry weather flow of 5 MGD. The peak wet weather flow is 16 MGD. There are four primary clarifiers, each is 60 feet in diameter with an average depth of 18 feet. There is a single effluent weir around the periphery of each primary clarifier. The average influent TSS and BOD concentrations during dry weather flow are 285 and 290 mg/L, respectively. The influent TSS are 72% volatile. The average primary effluent TSS and BOD concentrations during dry weather flow are 95 and 145 mg/L, respectively. Each primary sludge pump pumps 35 gpm. Calculate the pounds of TSS per day removed in the primary clarifiers.

Introduction

I've said it many times before, but I'm going to say it again: **It is a good time to be in the water business**. We really can live without oil. **It's impossible to live without water**.

But wastewater treatment is getting more and more sophisticated. So much of protecting the public's health rests on the shoulders of water and wastewater treatment plant operators. We also must do our jobs as cost effectively as possible to protect our ratepayers' hard earned money. Our jobs aren't just about "meeting permit." Consider this, or something like it, as the professional operator's credo:

> **The mission of wastewater treatment plant operators is to remove pollutants from the incoming water while complying with all permit requirements—water, land and air—and convert them to safe disposable biosolids as sustainably and cost effectively as possible.**

How do we prove to our ratepayers, regulators and ourselves that we're up for the task: **by attaining increasing levels of certification**.

We indirectly measure the presence, or absence, of organic carbon by a number of different analytical tests: BOD, cBOD, COD, TOC (total organic carbon), VSS and VS. All of these tests measure "organics" in a sample. "Organic" is synonymous with "organic carbon."

Primary clarifiers remove more organics for less money than any other process unit at a wastewater treatment plant. The process objective of primary clarification is the removal of settleable solids. The BOD (or COD) associated with those solids is removed when the solids are removed. This is important because a lot of people are confused and think that the TSS removal efficiency across a primary clarifier (for municipal wastewater treatment, TSS removal across primary clarifiers ranges from approximately 40 to 60%) is different than the BOD removal efficiency across a primary clarifier (for municipal wastewater treatment, BOD removal across primary clarifiers ranges from approximately 25 to 40%). Yes, computationally they are different numbers, but what all operators have to understand is that it is the same material being removed, we're just measuring it differently.

I loath the monicker "settleable solids." For one, I think it is terribly confusing, especially for operators just starting out in the business. For another, referring to these as "settleable solids" belies the fact that all settleable solids are TSS but not all TSS are settelable. It is for this reason that WWTT uses the following nomenclature: settleable solids = TSS_{set}; non-settleable solids = TSS_{non}. Similarly, BOD in wastewater is either soluble/dissolved (sBOD) or particulate (pBOD). Some of the particulate BOD is associated with TSS_{set} ($pBOD_{set}$) and the rest of the particulate BOD is associated with TSS_{non} ($pBOD_{non}$).It is important to understand the distinctions being made here as it negates some confusion.

Indeed, wastewater treatment **is** expensive but it is our job to treat wastewater "as cost effectively as possible." The organic carbon captured by primary clarifiers can be converted to methane in anaerobic digesters that can then be combusted in engines driving electrical generators. Augmenting the organic carbon captured in primary clarifiers, some plants feed fats, oils and grease (FOG) and other feedstocks to their digesters (if they have the capacity available) to increase methane production and electricity generation. East Bay Municipal Utilities District (EBMUD) has been so successful doing exactly this, they produce more electricity than the wastewater treatment plant uses. **This is the future**.

Solution

In today's problem we are asked to calculate how many pounds of TSS per day (lb TSS/d) are removed in the primary clarifier. As always, the units needed in the answer, **lb TSS/d**, are shown between heavy vertical lines followed by the equals sign and the blank solution bridge to get the problem started.

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lb TSS	=	
d		L

There is a lot of information given in this problem. Underlining the numbers and their descriptors might look like this.

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From this we list the “givens” and anything we have to assume:

1. Dry weather flow = 5 Mgal/d
2. Wet weather flow = 16 Mgal/d
3. Number of primary clarifiers (PC) = 4 PC
4. PC diameter = 60 ft
5. PC depth = 18 ft
6. Influent TSS = 285 mg TSS/L
7. Influent BOD = 290 mg BOD/L
8. Influent TSS = 72% VSS = 72 lb VSS/100 lb TSS
9. Primary effluent TSS = 95 mg TSS/L
10. Primary effluent BOD = 145 mg BOD/L
11. Density of influent/primary effluent = 8.34 lb/gal (assumed since not given)

The solution bridge is started with the unit, **TSS**, needed in the answer, but it shows up in our list in three places, influent TSS concentration (No. 6), influent VSS percentage (No.8), and primary effluent TSS concentration (No. 9). Which one do we use? Since we are not asked to calculate VSS removal, No. 8 in the list is of no consequence to us. In order to calculate the TSS concentration removed in the primary clarifiers, the primary effluent TSS concentration is subtracted from the influent TSS concentration. The concentration of TSS going into the sludge hoppers is 285 − 95 mg TSS/L, so this is what is used to start the solution bridge.

lb **TSS**	=	(285 − 95) mg **TSS**	
d		L	

Whenever **mg/L** are entered in the solution bridge, WWTT recommends they be canceled with the conversion factor, **M•mg/L**, unless the problem is solving for mg/L. Notice that **M•mg/L** is entered in the solution bridge to cancel **mg** and **L**.

lb **TSS**	=	(285 − 95) ~~mg~~ **TSS**	~~L~~	
d		~~L~~	M·~~mg~~	

The **M** that remains in the denominator is a reminder that an **Mgal** is needed in the numerator to cancel the **M**s. We have two **Mgals** given in the problem, but since we’re calculating the TSS removed per day (**lb TSS/d**) during **dry** weather, we use the dry weather flow (No. 1). Keep in mind that we are calculating the pounds per day of TSS that are removed from the influent flow. The reason this is important to keep in mind is because some folks will ask if the primary sludge flow should be used to calculate the pounds removed. No, remember it is the **pounds per day of TSS that are removed from the influent flow** that we are calculating.

lb **TSS**	=	(285 − 95) ~~mg~~ **TSS**	~~L~~	5 ~~M~~gal	
d		~~L~~	~~Mmg~~	**d**	

We have **gal** to cancel and we need **lb** in the numerator of the answer so it has to be entered in the solution bridge. We do both by entering the density (No. 11). Notice that the unit, **lb**, must go in the numerator and the unit, **gal**, must go in the denominator. By knowing how the units have to be entered in the solution bridge, we don't have to think about whether we need to multiply or divide by the density; the units tell us all we need to know.

lb TSS	=	(285 − 95) ~~mg~~ **TSS**	~~L~~	5 ~~Mgal~~	8.34 **lb**
d		~~L~~	~~Mmg~~	**d**	~~gal~~

Because all the units have canceled except those needed in the answer, **lb TSS/d**,we know the solution bridge is complete and the arithmetic gives the **answer**.

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lb TSS	=	(285 − 95) ~~mg~~ **TSS**	~~L~~	5 ~~Mgal~~	8.34 **lb**
d		~~L~~	~~Mmg~~	**d**	~~gal~~

(285 − 95) × 5 × 8.34 = **7,923 lb TSS/d**.

Discussion

Because primary clarifiers are such treatment plant workhorses, operators really need to "get their heads around them." Keep in mind, though, that operators really don't have a lot of control over primary clarifier performance. This reason this is so is because primary clarifier performance is largely dictated by how much of the influent TSS is settleable (TSS_{set}) and how much is non-settleable (TSS_{non}). In other words, the influent characteristics play a big part in how primary clarifiers will perform.

Happy calculating. Let us know, by leaving a comment, if you want us to do a specific problem or if you see a mistake.