Problem of the Day
2014.Dec.26

Introduction
I have always heard that the Chinese character meaning "crisis" is two characters superimposed on each other. The first, taken by itself, means "danger." The second, taken by itself, means "opportunity." With the drought in California, we have certainly been in crisis mode. But what amazing opportunity! **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 the water business 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**.

At the heart of wastewater treatment is **nutrient and pathogen removal**. Let's talk about nutrients. Today when we hear "nutrients," most of us think about nitrogen (N) and phosphorus (P), but there is a third nutrient that has defined wastewater treatment from the beginning: carbon (C). Yes, carbon. The massive, indiscriminate release of carbon into our waterways—specifically, organic carbon—during the 100+ years leading up to the passage of the Clean Water Act in 1972 in the United States didn't lead to the algae blooms and euthrophication we associate with N and P pollution. Instead, the oxidation of all that carbon by resident microorganisms led to dissolved oxygen (DO) "sag," and fish suffocated.

We indirectly measure the presence, or absence, of organic carbon by a number of 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 total suspended solids (TSS_{set}). The BOD (or COD) associated with those solids is removed when the solids are removed. This is important. The reason it is important is because secondary treatment, where the remaining BOD is "removed" (I will explain "removed" in a subsequent post), is expensive, so **the more BOD removed in the primary clarifiers, the better**.

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) to their digesters to increase methane production and electricity generation. East Bay Municipal Utilities District (EBMUD) has been so successful doing so, they produce more electricity than they use. **This is the future**.

For those of you who may be new to WWTT's Problem of the Day, we insert a page break before and after the problem statement so you can print it without looking at the solution. **See what you can do to solve the problem before looking at the solution**.

Problem of the Day

The Running Springs wastewater treatment plant receives an average dry weather flow of 2.5 MGD. The peak wet weather flow is 8 MGD. There are two primary clarifiers, each is 60 feet in diameter with an average depth of 16.5 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 325 and 350 mg/L, respectively. The influent TSS are 72% volatile. The average primary effluent TSS and BOD concentrations during dry weather flow are 105 and 205 mg/L, respectively. Each primary sludge pump pumps 30 gpm. Calculate the pounds of TSS per day removed in the primary clarifiers.

Discussion

Because primary clarifiers are such treatment plant workhorses, operators really need to “get their heads around them.” We’re going to use this same problem statement and do every primary clarifier type problem we can think of, maybe even make up a few! We’ll keep track of the types of problems in the following list so you can refer back to individual Problems of the Day if you have a question on a specific type of primary clarifier problem.

- 2014.Dec.16—TSS removal efficiency
- 2014.Dec.17—BOD removal efficiency
- 2014.Dec.18—VSS removal efficiency
- 2014.Dec.19—influent VSS concentration
- 2014.Dec.20—primary effluent VSS concentration
- 2014.Dec.21—primary sludge volatile content (VS and VSS)
- 2014.Dec.22—influent TSS pounds per day
- 2014.Dec.23—influent VSS pounds per day
- 2014.Dec.24—influent BOD pounds per day
- 2014.Dec.25—happy holidays
- 2014.Dec.26—TSS pounds per day removed

In today’s problem we are asked to calculate how many pounds of TSS per day are removed in the primary clarifier.

Solution

The units needed in the answer, **lb TSS/d**, are shown between heavy vertical lines followed by the equals sign and the blank track to get the problem started.

Problem of the Day: The Running Springs wastewater treatment plant receives an average dry weather flow of 2.5 MGD. The peak wet weather flow is 8 MGD. There are two primary clarifiers, each is 60 feet in diameter with an average depth of 16.5 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 325 and 350 mg/L, respectively. The influent TSS are 72% volatile. The average primary effluent TSS and BOD concentrations during dry weather flow are 105 and 205 mg/L, respectively. Each primary sludge pump pumps 30 gpm. Calculate the pounds of TSS per day removed in the primary clarifiers.

Information summary, specifically labeled (**bold** indicates used in today’s problem):

- **Average dry weather flow = 2.5 Mgal/d**
- Peak wet weather flow = 8 Mgal/d
- Number of primary clarifiers = 2 PC
- Primary clarifier diameter = 60 ft
- Primary clarifier depth = 16.5 ft
- **Primary influent dry weather TSS = 325 mg TSS/L**
- Primary influent dry weather BOD = 350 mg BOD/L
- Primary influent TSS = 72% VSS = 72 mg VSS/100 mg TSS
- **Primary effluent dry weather TSS = 105 mg TSS/L**
- Primary effluent dry weather BOD = 205 mg BOD/L
- Primary sludge pumps, each = 30 gal sldg/min
- Calculate: **lb TSS/d removed in the primary clarifiers**.

$$\left| \frac{\text{lb TSS}}{\text{d}} \right| = \frac{(325 - 105)\ \text{mg TSS}}{\text{L}}$$

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The railroad track is started with the unit, **TSS**, needed in the answer, but it shows up in the list of information given in the problem in two places, primary influent TSS concentration and primary effluent TSS concentration. Which one do we use? Answer: we use both of them.

If 325 mg TSS/L are entering the primary clarifiers and 105 mg TSS/L are leaving the primary clarifiers, how many mg/L are removed in the primary sludge? The concentration of TSS going into the sludge hoppers is the difference (325 − 105) mg TSS/L, so this is what is used to start the railroad track.

$$\left.\frac{\text{lb }\mathbf{TSS}}{\text{d}}\right| = \left|\frac{(325-105)\text{ mg }\mathbf{TSS}}{\text{L}}\right|$$

Whenever **mg/L** are entered into the railroad track, 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 into the railroad track to cancel **mg** and **L**.

$$\left.\frac{\text{lb }\mathbf{TSS}}{\text{d}}\right| = \left|\frac{(325-105)\ \cancel{\text{mg}}\ \mathbf{TSS}}{\cancel{\text{L}}}\right|\frac{\cancel{\text{L}}}{\text{M}\cdot\cancel{\text{mg}}}\right|$$

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. 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.

$$\left.\frac{\text{lb }\mathbf{TSS}}{\mathbf{d}}\right| = \left|\frac{(325-105)\ \cancel{\text{mg}}\ \mathbf{TSS}}{\cancel{\text{L}}}\right|\frac{\cancel{\text{L}}}{\cancel{\text{M}\cdot\text{mg}}}\right|\frac{2.5\ \cancel{\text{M}}\text{gal}}{\mathbf{d}}\right|$$

We have **gal** to cancel and we need **lb** in the numerator of the answer so it has to be entered in the railroad track. We do both by entering the density of water. 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 into the railroad track, 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.

$$\left.\frac{\text{lb }\mathbf{TSS}}{\mathbf{d}}\right| = \left|\frac{(325-105)\ \cancel{\text{mg}}\ \mathbf{TSS}}{\cancel{\text{L}}}\right|\frac{\cancel{\text{L}}}{\cancel{\text{M}\cdot\text{mg}}}\right|\frac{2.5\ \cancel{\text{Mgal}}}{\mathbf{d}}\right|\frac{8.34\ \mathbf{lb}}{\cancel{\text{gal}}}\right|$$

In the railroad track we now have only the units needed in the answer, **lb TSS/d**, so we **know** the math is done.

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- Calculate: **lb TSS/d removed in the primary clarifiers**.

lb **TSS**	=	(325 − 105) ~~mg~~ **TSS**	~~L~~	2.5 ~~Mgal~~	8.34 **lb**
d		~~L~~	~~Mmg~~	**d**	~~gal~~

The arithmetic gives the answer:

(325 − 105) x 2.5 x 8.34 = **4,587 lb TSS/d**.

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

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