Problem of the Day

2015.Aug.18

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A rectangular DAF thickener is 22 feet wide and 75 feet long. Waste activated sludge is being pumped to the DAF thickener at 700 gpm at an average TSS concentration of 5,500 mg/L. Calculate the solids loading rate (lb/hr·ft^2) to this DAF thickener.

Introduction

This, obviously, is a very straightforward pounds-per-day calculation. I am behind on Problems of the Day so I'm actually writing the 2015.Aug.18 Problem of the Day on September 25, 2015, the day after WasteWater Technology Trainers finished the summer certification review season with a Grades I and II Operator Certification and Math Review class in Oceanside, California sponsored by the City of Oceanside.

I've always had this niggling in the back of my head that I approach pounds and pounds-per-day calculations a little differently whether the concentration for whatever pollutant of interest is given in mg/L or percent (%). I have always been very consistent in my approach to both, but they are just a little bit different and that difference has always bothered me a little.

Today I woke up thinking about that difference. So I tried something new in yesterday's Problem of the Day and continuing with today's Problem of the Day.

In the water and wastewater treatment business, a mg/L is equivalent to a part per million parts, or ppM. This is because the density of water is equal to 1 gram per milliliter (1g/mL) in metric units. This leads to the fact that 1 L of water weighs 1,000,000 mg, so 1 mg in a L of water is 1 ppM. Even though most operators are told very early on in their careers that a mg/L is equivalent to a ppM, there are a lot of folks that get this wrong on certification exams.

In contrast to a mg/L, percent (%) is equivalent to a part per hundred parts, or ppH. There is a big difference between a ppH and a ppM. This is best appreciated by example: What would you rather have, a hundred dollars or a million dollars? Big, big difference!

In our classes I've always told folks that if concentration is given in mg/L, you will use the pounds or pounds-per-day calculation. If concentration is given in %, I teach people to label things in a very specific way to let the units "do the math for you." The solution given below to today's Problem of the Day is presented a little differently. Let me what you think.

Solution

The following information is given in the problem statement or assumed. Note the manner in which I have modified the way I express mg/L and others.

1. WAS flow = 700 gal WAS/min
2. TSS concentration = 5,500 mg/L = 5,500 ppM = 5,500 lb TSS/M lb WAS
3. Density of WAS = 8.34 lb WAS/gal WAS (assumed since not given)
4. DAF thickener length = 75 ft
5. DAF thickener width = 22 ft

Today's problem asks to calculate the solids loading rate to the DAF thickener in units of lb TSS/hr·ft^2. These units, then, are put between heavy vertical lines, as always, followed by an equals sign and the blank solution bridge.

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$$\left|\frac{\text{lb TSS}}{\text{hr}\cdot\text{ft}^2}\right| = \frac{\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad}{}$$

The only place the units lb TSS appear in the list is in the numerator of No. 2. This, then, is entered to start the solution bridge to get the units needed in the numerator of the answer as shown in bold.

$$\frac{\textbf{lb TSS}}{\text{hr}\cdot\text{ft}^2} = \frac{5{,}500\ \textbf{lb TSS}}{\text{M lb WAS}}$$

There is nothing in the list with units of hr. The only time unit given in the list is min in the denominator of No. 1. The well known conversion factor is entered to get the units hr in the denominator (knowing that min will be canceled eventually).

$$\frac{\textbf{lb TSS}}{\textbf{hr}\cdot\text{ft}^2} = \frac{5{,}500\ \textbf{lb TSS}}{\text{M lb WAS}} \times \frac{60\ \text{min}}{\textbf{hr}}$$

Entering the surface area of the DAF thickener (No. 4 x No. 5) in the denominator of the solution bridge gives the units ft^2 needed in the answer.

$$\frac{\textbf{lb TSS}}{\textbf{hr}\cdot\textbf{ft}^2} = \frac{5{,}500\ \textbf{lb TSS}}{\text{M lb WAS}} \times \frac{60\ \text{min}}{\textbf{hr}} \times \frac{}{75\ \textbf{ft} \times 22\ \textbf{ft}}$$

We have all the units on the solution bridge needed in the answer, **lb TSS/hr·ft²**, so now the "solution" is to cancel unwanted units. WAS flow (No. 1) is entered so min cancel numerator and denominator.

$$\frac{\textbf{lb TSS}}{\textbf{hr}\cdot\textbf{ft}^2} = \frac{5{,}500\ \textbf{lb TSS}}{\text{M lb WAS}} \times \frac{60\ \cancel{\text{min}}}{\textbf{hr}} \times \frac{}{75\ \textbf{ft} \times 22\ \textbf{ft}} \times \frac{700\ \text{gal WAS}}{\cancel{\text{min}}}$$

The M in M lb WAS reminds us, as did L/M·mg, that an Mgal is needed. Because there isn't an Mgal in the list, we enter one using a conversion factor and the Ms cancel denominator and numerator; as well gal cancel.

$$\frac{\textbf{lb TSS}}{\textbf{hr}\cdot\textbf{ft}^2} = \frac{5{,}500\ \textbf{lb TSS}}{\cancel{\text{M}}\ \text{lb WAS}} \times \frac{60\ \cancel{\text{min}}}{\textbf{hr}} \times \frac{}{75\ \textbf{ft} \times 22\ \textbf{ft}} \times \frac{700\ \text{gal WAS}}{\cancel{\text{min}}} \times \frac{\cancel{\text{Mgal}}}{10^6\ \cancel{\text{gal}}}$$

Entering the density of the WAS cancels lb WAS and gal WAS.

$$\frac{\textbf{lb TSS}}{\textbf{hr}\cdot\textbf{ft}^2} = \frac{5{,}500\ \textbf{lb TSS}}{\cancel{\text{M lb WAS}}} \times \frac{60\ \cancel{\text{min}}}{\textbf{hr}} \times \frac{}{75\ \textbf{ft} \times 22\ \textbf{ft}} \times \frac{700\ \cancel{\text{gal WAS}}}{\cancel{\text{min}}} \times \frac{\cancel{\text{Mgal}}}{10^6\ \cancel{\text{gal}}} \times \frac{8.34\ \cancel{\text{lb WAS}}}{\cancel{\text{gal WAS}}}$$

Since all the units have now canceled except those needed in the answer, **lb TSS/hr·ft²**, we know the solution bridge is complete. The arithmetic gives the answer.

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$$\frac{\textbf{lb TSS}}{\textbf{hr}\cdot\textbf{ft}^2} = \frac{5{,}500\ \textbf{lb TSS}}{\cancel{\text{M lb WAS}}} \times \frac{60\ \cancel{\text{min}}}{\textbf{hr}} \times \frac{}{75\ \textbf{ft} \times 22\ \textbf{ft}} \times \frac{700\ \cancel{\text{gal WAS}}}{\cancel{\text{min}}} \times \frac{\cancel{\text{Mgal}}}{10^6\ \cancel{\text{gal}}} \times \frac{8.34\ \cancel{\text{lb WAS}}}{\cancel{\text{gal WAS}}}$$

5,500 x 60 x 700 x 8.34 ÷ 75 ÷ 22 ÷ 1,000,000 = **1.17 lb TSS/hr·ft^2**.

Discussion

Again, this is no more than the pounds-per-day calculation, but with a slightly different "solution bridging" approach. Note by representing the mg/L concentration as ppM and expressing it in terms of "lb per M lb," I don't have to use the conversion factor L/M·mg. In this particular problem I can also label, as I have been doing when concentration is given in percent, the TSS concentration in the WAS "5,500 lb TSS/M lb WAS" and the density of the WAS as "8.34 lb WAS/gal WAS." This seems much more descriptive to me, I guess because it never "felt" right to assume that WAS is the same thing as water, if you know what I mean. Note, too, that my general strategy has become, based on the recommendation of one of WWTT's students, that we get all units needed in the answer on the solution bridge before we start canceling unwanted units. I'm liking this strategy. How about you?

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.