Problem of the Day

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The rock media in three, 80-ft diameter trickling filters is 5 feet deep. The BOD concentration in the primary effluent is 105 mg/L. The recirculation flow is set at a constant 100% of the influent flow, which averages 4.5 MGD. The BOD concentration in the secondary clarifier effluent is 17.5 mg/L, with a soluble BOD concentration of 4.1 mg/L. Calculate the organic loading to these trickling filters.

Introduction

There are two very important things to remember when calculating the organic loading to trickling filters and many operator certification exams expect that operators know these:

1. the units on organic loading rate to trickling filters are **always** pounds of BOD per day per 1,000 cubic feet of media volume (**lb BOD/d·1,000 ft^3**);
2. whatever is going on in the recirculation flow, it is ignored when calculating the organic loading; in other words, even though certification exam questions, like this one, will often give you the organic concentration (BOD, sBOD, COD, etc.) in the recirculation flow (i.e., the secondary effluent), it is **not** used in calculating the organic loading (think "O" for organic loading and "NO" to **not** use the organic concentration in the recirculation flow); don't feel like you have to use it just because they gave it to you!

There are basically two things you have to calculate to determine the organic loading to trickling filters: the lb BOD/d in the primary effluent flow going to the trickling filters and the volume of the media. The units that organic loading is expressed in (No. 1 above) tell you this. Both "steps" can be included in a single solution bridge.

Solution

The question does not ask the answer to be in any specific units, but all wastewater treatment plant operators should know that the units on organic loading to trickling filters are always lb BOD/d·1,000 ft^3. Always. 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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$$\left|\frac{\text{lb BOD}}{\text{d·1,000 ft}^3}\right| = \frac{\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad}{}$$

The units needed in the answer tell us that we are going to calculate the lb BOD/d going to the trickling filters and divide that by the volume of the media expressed as "1,000 ft^3." WWTT likes to start the solution bridge for pounds and pounds-per-day calculations with the concentration of the constituent of interest, in this case BOD, as shown in bold.

$$\left|\frac{\text{lb } \mathbf{BOD}}{\text{d·1,000 ft}^3}\right| = \left|\frac{\text{105 mg } \mathbf{BOD}}{\text{L}}\right| \frac{\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad}{}$$

So as not to forget, whenever mg/L are entered on the solution bridge, they are immediately canceled.

$$\left|\frac{\text{lb } \mathbf{BOD}}{\text{d·1,000 ft}^3}\right| = \left|\frac{\text{105 } \cancel{\text{mg}} \text{ } \mathbf{BOD}}{\cancel{\text{L}}}\right| \left|\frac{\cancel{\text{L}}}{\text{M·}\cancel{\text{mg}}}\right| \frac{\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad}{}$$

The units d are needed in the denominator of the answer, so the flow rate is entered because it is the only place d occurs as shown in bold. Notice the Ms cancel as an added benefit.

$$\left|\frac{\text{lb } \mathbf{BOD}}{\mathbf{d}\text{·1,000 ft}^3}\right| = \left|\frac{\text{105 } \cancel{\text{mg}} \text{ } \mathbf{BOD}}{\cancel{\text{L}}}\right| \left|\frac{\cancel{\text{L}}}{\cancel{\text{M}}\text{·mg}}\right| \left|\frac{\text{4.5 } \cancel{\text{M}}\text{gal}}{\mathbf{d}}\right| \frac{\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad}{}$$

The density of water is entered to get the units lb in the numerator as shown in bold. As an added benefit, the units gal cancel, numerator and denominator.

$$\frac{\textbf{lb BOD}}{\textbf{d}\cdot 1{,}000\ ft^3} = \frac{105\ \cancel{mg}\ \textbf{BOD}}{\cancel{L}} \times \frac{\cancel{L}}{\cancel{M}\cdot\cancel{mg}} \times \frac{4.5\ \cancel{Mgal}}{\textbf{d}} \times \frac{8.34\ \textbf{lb}}{\cancel{gal}}$$

I hope you recognize that what we've done to this point is simply a pounds-per-day calculation. We still need the units 1,000 ft^3 in the denominator of the answer. Where do these units come from? Here is WWTT's trick so you will not even have to think about whether you might have divide or multiply by 1,000. First, multiply the solution bridge by 1,000 ft^3/1,000 ft^3 , which is just multiplying by 1 so it doesn't change the arithmetic at all. This gets the units 1,000 ft^3 needed in the denominator of the answer on the solution bridge as shown in bold.

$$\frac{\textbf{lb BOD}}{\textbf{d}\cdot\textbf{1,000 ft}^3} = \frac{105\ \cancel{mg}\ \textbf{BOD}}{\cancel{L}} \times \frac{\cancel{L}}{\cancel{M}\cdot\cancel{mg}} \times \frac{4.5\ \cancel{Mgal}}{\textbf{d}} \times \frac{8.34\ \textbf{lb}}{\cancel{gal}} \times \frac{1{,}000\ ft^3}{\textbf{1,000 ft}^3}$$

Second, the 1,000 ft^3 in the denominator is bracketed, [ ], so that it is kept together as a standalone unit, the unit we need in the answer. The brackets also mean that when you get to the 1,000 in the brackets, it is **not** entered into your calculator when doing the arithmetic, but the 1,000 in the numerator, which is not in brackets, is.

$$\frac{\textbf{lb BOD}}{\textbf{d}\cdot\textbf{1,000 ft}^3} = \frac{105\ \cancel{mg}\ \textbf{BOD}}{\cancel{L}} \times \frac{\cancel{L}}{\cancel{M}\cdot\cancel{mg}} \times \frac{4.5\ \cancel{Mgal}}{\textbf{d}} \times \frac{8.34\ \textbf{lb}}{\cancel{gal}} \times \frac{1{,}000\ ft^3}{[\textbf{1,000 ft}^3]}$$

We have all the units on the solution bridge that we need in the answer so now we continue canceling units until we only have what we need. We have to divide by the volume of the media in each trickling filter (TF). The shape of a trickling filter is that of a can. To calculate the volume of a can, we multiply the area of the circle (0.785 x diameter^2) by the depth. This calculation is entered in the denominator of the solution bridge because we have to divide by volume and we have to cancel the units ft^3 in the numerator. Also, remember. the volume entered is per TF and whenever the word "per" comes across your lips, you go to the other side of the solution bridge.

$$\frac{\textbf{lb BOD}}{\textbf{d}\cdot\textbf{1,000 ft}^3} = \frac{105\ \cancel{mg}\ \textbf{BOD}}{\cancel{L}} \times \frac{\cancel{L}}{\cancel{M}\cdot\cancel{mg}} \times \frac{4.5\ \cancel{Mgal}}{\textbf{d}} \times \frac{8.34\ \textbf{lb}}{\cancel{gal}} \times \frac{1{,}000\ \cancel{ft^3}}{[\textbf{1,000 ft}^3]} \times \frac{TF}{0.785 \times 80^2\ \cancel{ft^2} \times 5\ \cancel{ft}}$$

There are 3 trickling filters (3 TF), so this is entered in the denominator to cancel out TF in the numerator.

$$\frac{\textbf{lb BOD}}{\textbf{d}\cdot\textbf{1,000 ft}^3} = \frac{105\ \cancel{mg}\ \textbf{BOD}}{\cancel{L}} \times \frac{\cancel{L}}{\cancel{M}\cdot\cancel{mg}} \times \frac{4.5\ \cancel{Mgal}}{\textbf{d}} \times \frac{8.34\ \textbf{lb}}{\cancel{gal}} \times \frac{1{,}000\ \cancel{ft^3}}{[\textbf{1,000 ft}^3]} \times \frac{\cancel{TF}}{0.785 \times 80^2\ \cancel{ft^2} \times 5\ \cancel{ft} \times 3\ \cancel{TF}}$$

Since all the units have now canceled except those needed in the answer, **lb BOD/d•1,000 ft^3**,we know the solution bridge is complete. The arithmetic gives the answer.

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lb BOD	=	105 ~~mg~~ **BOD**	~~L~~	4.5 ~~Mgal~~	8.34 **lb**	1,000 ~~ft^3~~	~~TF~~			
d·1,000 ft^3		~~L~~	~~M·mg~~	**d**	~~gal~~	[**1,000 ft^3**]	0.785	80^2 ~~ft^2~~	5 ~~ft~~	3 ~~TF~~

105 x 4.5 x 8.34 x 1,000 ÷ 0.785 ÷ 80 ÷ 80 ÷ 5 ÷ 3 = **52.3 lb BOD/d·1,000 ft^3**.

Discussion

Notice when doing the arithmetic, as discussed, the 1,000 in the numerator is entered in your calculator but the 1,000 in brackets in the denominator is not. This little trick is real helpful under the pressure of an exam.

This is a very important calculation to master for certification exams. Invariably, you will have to calculate the organic loading to trickling filters somewhere in the progression of exams you will take as you better your credentials with higher and higher levels of certification. Wastewater treatment plant operation is a noble and much needed profession. As I believe that a wastewater treatment operator protects more lives in a day than a doctor will save in his or her lifetime, it is a profession as worthy as the medical profession.

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.