Problem of the Day

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Two trickling filters, each 60 feet in diameter, receive a total average flow of 2,900,000 gal/d (2.9 MGD). The total recirculation flow is 125% of the influent flow or 3,625,000 gal/d. The media depth in each filter is 15 feet. The BOD concentration in the primary clarifier effluent is 130 mg/L. Calculate (a) the hydraulic loading and (b) the organic loading to these trickling filters.

Introduction

When doing trickling filter math problems, operators must remember that the calculation for hydraulic loading **does** include the recirculation flow, whereas the calculation for organic loading **does not** include the recirculation flow or the BOD in the recirculation flow.

The way to remember this is to write down a big O for “organic:”

O

In front of the big O for “organic” but a big N:

NO

What does this mean? NO, you do **not** use the recirculation flow or the BOD in it to calculate the organic loading to trickling filters.

Solution—Part a

As with most problems, the solution bridge starts with identifying the units needed in the answer. But the question doesn’t indicate what the units are for the hydraulic loading. Yesterday’s problem solved for the hydraulic loading to primary clarifiers. Hydraulic loading to clarifiers is also called surface overflow rate, hydraulic loading rate, surface loading rate, and surface loading. When talking about clarifiers, the hydraulic loading is always expressed in gal/d·ft^2. Always. And guess what? These are the units that hydraulic loading to trickling filters is always in as well. The only thing you have to remember is that you have to add the influent flow and the recirculation flow to the trickling filter—trickling filters (2) in this problem—and then divide by the total trickling filter surface area. Since the units needed for Part a are gal/d·ft^2, these units are entered between heavy vertical lines, as before, followed by an equals sign and the blank solution bridge.

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$$\left|\frac{\text{gal}}{\text{d}\cdot\text{ft}^2}\right| = \frac{\qquad}{\qquad}$$

As is so often the case, the units needed in the answer tell you what you have to do. To start the solution bridge, we want gal in the numerator, and we get that unit from the flow. It is up to you to remember that you have to add the influent flow and the recirculation flow when calculating the hydraulic loading to trickling filters. When we do this to start the solution bridge, we have both gal in the numerator and d in the denominator that we need in the answer (shown in bold). We know this has to be correct.

$$\left|\frac{\textbf{gal}}{\textbf{d}\cdot\text{ft}^2}\right| = \left|\frac{(2{,}900{,}000 + 3{,}625{,}000)\ \textbf{gal}}{\textbf{d}}\right| \frac{\qquad}{\qquad}$$

In order to get ft^2 needed in the denominator of the answer, the surface area of one trickling filter is entered in the denominator of the solution bridge. Remember the area of a circle: 0.785 x diameter^2 (same thing as 0.785 x diameter x diameter). This is entered in the denominator and it is per trickling filter (TF). When you say “per” in your head as you’re writing, remember you go to the other side of the solution bridge as shown.

$$\left|\frac{\textbf{gal}}{\textbf{d}\cdot\textbf{ft}^2}\right| = \left|\frac{(2{,}900{,}000 + 3{,}625{,}000)\ \textbf{gal}}{\textbf{d}}\right| \frac{\text{TF}}{0.785 \quad 60\ \textbf{ft} \quad 60\ \textbf{ft}}$$

We're almost there, only one unwanted unit on the solution bridge that needs to be canceled, TF. How many trickling filters (TF) are there? Since this cancels out all the unwanted units leaving only the units needed in the answer, we know the solution bridge is complete. The arithmetic gives the answer to Part a.

$$\frac{\textbf{gal}}{\textbf{d}\cdot\textbf{ft}^2} = \frac{(2{,}900{,}000 + 3{,}625{,}000)\ \textbf{gal}}{\textbf{d}} \times \frac{\cancel{\text{TF}}}{0.785} \times \frac{}{60\ \textbf{ft}} \times \frac{}{60\ \textbf{ft}} \times \frac{}{2\ \cancel{\text{TF}}}$$

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$$\frac{\textbf{gal}}{\textbf{d}\cdot\textbf{ft}^2} = \frac{(2{,}900{,}000 + 3{,}625{,}000)\ \textbf{gal}}{\textbf{d}} \times \frac{\cancel{\text{TF}}}{0.785} \times \frac{}{60\ \textbf{ft}} \times \frac{}{60\ \textbf{ft}} \times \frac{}{2\ \cancel{\text{TF}}}$$

(2,900,000 + 3,625,000) ÷ 0.785 ÷ 60 ÷ 60 ÷ 2 = **1,154 gal/d·ft²**.

Solution—Part b

As with most problems, the solution bridge starts with identifying the units needed in the answer. But the question doesn't indicate what the units are for the organic loading. Operators need to know what the units are for organic loading to trickling filters: the units are always pounds of BOD/d per 1,000 ft³ of media volume, or lb BOD/d·1,000 ft³. And remember: for the trickling filter organic loading calculation, you do **not** use the recirculation flow or the BOD in it. Since the units needed for Part b are lb BOD/d·1,000ft³, they are entered between heavy vertical lines, as before, followed by an equals sign and the blank solution bridge.

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$$\frac{\text{lb BOD}}{\text{d}\cdot 1{,}000\ \text{ft}^3} = \frac{\quad}{\quad}$$

Obviously, we need to use a pounds-per-day calculation to calculate the lb BOD/d. Here's how the units work for doing so in the solution bridge given the information in the problem statement.

$$\frac{\textbf{lb BOD}}{\textbf{d}\cdot 1{,}000\ \text{ft}^3} = \frac{130\ \cancel{\text{mg}}\ \textbf{BOD}}{\cancel{\text{L}}} \times \frac{\cancel{\text{L}}}{2.9\ \cancel{\text{Mgal}}} \times \frac{8.34\ \textbf{lb}}{\textbf{d}} \times \frac{}{\cancel{\text{gal}}} \times \frac{}{\quad}$$

Next, the volume of the media in each trickling filter ("per trickling filter") is entered in the denominator of the solution bridge. Volume of a cylinder is the area of the circle times the height, 0.785 x diameter² x h.

$$\frac{\textbf{lb BOD}}{\textbf{d}\cdot 1{,}000\ \text{ft}^3} = \frac{130\ \cancel{\text{mg}}\ \textbf{BOD}}{\cancel{\text{L}}} \times \frac{\cancel{\text{L}}}{2.9\ \cancel{\text{Mgal}}} \times \frac{8.34\ \textbf{lb}}{\textbf{d}} \times \frac{\text{TF}}{\cancel{\text{gal}}} \times \frac{0.785}{} \times \frac{60^2\ \text{ft}^2}{} \times \frac{15\ \text{ft}}{\quad}$$

As before, there are two trickling filters (TF).

lb BOD	=	130 ~~mg~~ **BOD**	~~L~~	2.9 ~~Mgal~~	8.34 **lb**	~~TF~~				
d·1,000 ft^3		~~L~~	~~M·mg~~	**d**	~~gal~~	0.785	60^2 ft^2	15 ft	2 ~~TF~~	

The next step is a little Wahlberg trick. We currently have the units ft^3 needed in the answer in the denominator of the solution bridge. But what about the units 1,000 ft^3? I guarantee you that this is going to confuse you when under the pressure of a certification exam: Do I multiply or divide by 1,000? So, first I put the factor 1,000 ft^3/1,000 ft^3, which is obviously equal to 1, in the solution bridge.

lb BOD	=	130 ~~mg~~ **BOD**	~~L~~	2.9 ~~Mgal~~	8.34 **lb**	~~TF~~				1,000 ft^3
d·1,000 ft^3		~~L~~	~~M·mg~~	**d**	~~gal~~	0.785	60^2 ft^2	15 ft	2 ~~TF~~	1,000 ft^3

Now, the trick is to put the 1,000 ft^3 in the denominator in square brackets so that it stays together as a unit (shown in bold), and we do **not** put the 1,000 in the brackets into our calculator when doing the arithmetic. Since all the units have cancelled except the units needed in the answer, lb BOD/d·1,000 ft^3, we know the solution bridge is complete. The arithmetic gives the answer to Part b.

lb BOD	=	130 ~~mg~~ **BOD**	~~L~~	2.9 ~~Mgal~~	8.34 **lb**	~~TF~~				1,000 ~~ft^3~~
d·1,000 ft^3		~~L~~	~~M·mg~~	**d**	~~gal~~	0.785	60^2 ~~ft^2~~	15 ~~ft~~	2 ~~TF~~	[**1,000 ft^3**]

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lb BOD	=	130 ~~mg~~ **BOD**	~~L~~	2.9 ~~Mgal~~	8.34 **lb**	~~TF~~				1,000 ~~ft^3~~
d·1,000 ft^3		~~L~~	~~M·mg~~	**d**	~~gal~~	0.785	60^2 ~~ft^2~~	15 ~~ft~~	2 ~~TF~~	[**1,000 ft^3**]

130 x 2.9 x 8.34 x 1,000 ÷ 0.785 ÷ 60 ÷ 60 ÷ 15 ÷ 2 = **37.1 lb BOD/d·1,000 ft^3**.

Discussion

Besides how these kinds of problems are laid out on the solution bridge, the other takeaway here is knowing when and when not to use the recirculation in trickling filter problems. All operators need to keep this straight when doing certification exam math problems.

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.