Problem of the Day
2014.Oct.09

Discussion

Velocity plays a important role in wastewater collection and treatment. In a gravity sewer, for example, it is desired to keep the velocity of the wastewater flow 2 ft/s or greater in order to keep all solids in suspension. In grit chambers at the wastewater treatment plant, the velocity of the wastewater flow is slowed to approximately 1 ft/s in order for inorganic, or fixed, solids to settle, but organic, or volatile, solids to pass through to primary or secondary treatment.

Velocity also is very important in clarifiers, primary, secondary or tertiary. Velocity is calculated by a very simple equation:

$$v = \frac{Q}{A}$$

where v = velocity, Q = flow, and A = the area through which the flow is passing.

The velocity of interest in a clarifier is the velocity of the flow exiting the clarifier. This velocity is so important it has its own special name: surface overflow rate, sometimes called the hydraulic loading rate and the hydraulic loading:

$$SOR = \frac{Q}{A}$$

where SOR = surface over flow rate, Q = effluent flow, and A = the clarifier surface area which is the area through which the flow is passing.

The units on SOR are always: gal/d•ft^2. Always. But, you're asking, gal/d•ft^2 don't look like units of velocity (think miles/hour), what's up with that? This is the subject of today's Problem of the Day.

Problem

Now for today's problem.

Problem of the Day: In municipal wastewater treatment, the SOR for primary clarifiers typically ranges, by design, from 600 to 1,200 gal/d•ft^2. SOR is calculated by dividing the flow exiting the clarifier by the clarifier surface area. The two primary clarifiers at the Clearwater WWTP have a SOR of 875 gal/d•ft^2 during the diurnal peak flow. How many ft/s is this?

Solution

As always, the first thing we have to do is identify the units needed in the answer. The question asks for "ft/s." In fact, this problem is only converting from one set of units, gal/d·ft^2, to another set of units, ft/s. As before, we put the units needed in the answer between heavy vertical lines followed by the equals sign and the blank track.

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$$\left| \frac{\text{ft}}{\text{s}} \right| = \underline{\qquad\qquad\qquad\qquad\qquad\qquad}$$

When doing a conversion problem such as this, the railroad track is started with what is being converted, in this case 875 gal/d·ft^2.

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$$\left| \frac{\text{ft}}{\text{s}} \right| = \left| \frac{875\ \text{gal}}{\text{d·ft}^2} \right| \underline{\qquad\qquad\qquad\qquad}$$

Notice that seconds (s) and days (d) are in the denominator on either side of the equals sign. This is an important observation to make. **Seconds and days are both units of time**. The reader should know that if time units were in the denominator on the left-hand side of the equals sign and time units were in the numerator on the right-hand side of the equals sign, there is no conversion factor known to humankind that will get the numerator time units into the denominator (or vice versa). In other words, even though the time units are different, they have to start out on the same side of the railroad track. Always be looking for what the units can tell you.

Let's say for the moment I have forgotten that there are 86,000 seconds/day, but do remember there are 1,440 minutes/day (1,440 min/d) and 60 seconds/minute (60 s/min). These are entered into the railroad track to cancel out unwanted units. Doing so gets s needed in the answer into the railroad track, shown in bold.

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$$\left| \frac{\text{ft}}{\textbf{s}} \right| = \left| \frac{875\ \text{gal}}{\cancel{\text{d}}\cdot\text{ft}^2} \right| \left| \frac{\cancel{\text{d}}}{1{,}440\ \cancel{\text{min}}} \right| \left| \frac{\cancel{\text{min}}}{60\ \textbf{s}} \right| \underline{\qquad\qquad}$$

Let the units talk to you: gallons (gal) are a unit of volume. Volume can always be converted to units of length x length x length. If gal can be converted to ft^3, two of those ft would cancel with the ft^2 in the denominator. Can we convert gal to ft^3? Absolutely!

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$$\frac{\textbf{ft}}{\textbf{s}} = \frac{875\ \cancel{\text{gal}}}{\cancel{\text{d}}\cdot\cancel{\text{ft}^2}} \times \frac{\cancel{\text{d}}}{1{,}440\ \cancel{\text{min}}} \times \frac{\cancel{\text{min}}}{60\ \textbf{s}} \times \frac{\textbf{ft}^3}{7.48\ \cancel{\text{gal}}}$$

All the units have canceled now except those needed in the answer, ft/s, so the math is complete. The arithmetic gives the answer:

875 ÷ 1,440 ÷ 60 ÷ 7.48 = <u>0.0012 ft/s</u>.

So let's think about what this answer is telling us. We said earlier that we like to see the velocity of flow in a gravity sewer 2 ft/s or greater to keep solids in suspension. We said earlier that we like to see the velocity of flow in a grit chamber to be approximately 1 ft/s to let inorganic solids settle out but organic solids to pass through to primary or secondary treatment. In the primary clarifier downstream of the grit chamber, as just calculated, the velocity of flow is 0.0012 ft/s, **a thousand times slower** than the velocity in the grit chamber! This is why things settle out in clarifiers and why we describe them as "quiescent." It should be noted that particles that have a settling velocity less than 0.0012 ft/s will not settle in this clarifier so will be carried out in the effluent. Don't let the units on SOR, gal/d·ft^2, fool you: they really are units of velocity and it is a very important velocity indeed!