Problem of the Day

2014.Dec.05

Introduction

We're still keeping with pounds calculations.

Every operator should know how to calculate pounds and pounds per day given concentration (in mg/L or ppM). We will call both calculations the "pounds calculation."

There are two elements that have to come together for the pounds calculation to work. First, volume—whether it's volume to calculate pounds or volume/time (that's flow) to calculate pounds per day—has to be converted to Mgal (million gallons). We can do this very easily in the railroad track so there is no need to convert the volume to Mgal before working the railroad track; in fact, WWTT recommends against doing this conversion "on the side." Second and the reason for the first, is there is an embedded M (million) in mg/L and, of course, ppM (parts per million parts). If concentration is given in ppM, WWTT recommends it be expressed as mg/L because in our business **mg/L = ppM**. This conversion factor tells us why that's so:

$$\frac{M \cdot mg}{L} \quad \text{or} \quad \frac{L}{M \cdot mg}$$

Today's and several previous days' Problems of the Day demonstrate.

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

How many pounds of chlorine are required to super-chlorinate an 18-inch pipeline at the regional wastewater treatment plant if the pipeline is 4,500 feet long? Final effluent will be used to fill the pipeline. The operator wants to dose the water flowing into the pipeline at 65 mg/L. Once full, valves at each end of the pipeline will be closed and the super-chlorinated water allowed to stand overnight.

Discussion

Key words and information: "**How many pounds**" and "**mg/L**." You **know** you're going to be using the "pounds calculation."

I can't tell you how often we calculate pounds and pounds per day in the wastewater treatment business. We do these calculations over and over and over again. Doing them should be second nature to all operators. No matter how comfortable you are doing these calculations, however, WWTT recommends you **always** carry the units **all the way through** the problem so you don't forget anything. Today's problem is another good example of "there's a lot going on here." Remember: units are your friend and they will tell you how to do a problem in almost all instances (the railroad track doesn't work, for example, when calculating the VSR in digester problems). Practice all your problem solving with the units. It will pay off huge.

Solution

A full pipe is really just a cylindrical tank lying on its side. Given diameter and length of a pipe, we can calculate its volume. We know we can convert this volume to Mgal. To begin, we put the units we want the answer to be in, **lb Cl_2**, between heavy vertical lines followed by an equals sign and the blank track.

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Information summary, specifically labeled:

- Diameter of pipe = 18 in
- Length of pipe = 4,500 ft
- Target chlorine dose = 65 mg Cl_2/L
- **Calculate: pounds of chlorine (lb Cl_2) needed**.

$$\left| \text{lb } Cl_2 \right| = \text{———————————————————}$$

The unit, **Cl_2**, needed in the answer only shows up in the list of information given in the problem in one other place, 65 mg **Cl_2**/L. Entering the desired chlorine dose starts the railroad track.

$$\left| \text{lb } \mathbf{Cl_2} \right| = \left| \frac{65 \text{ mg } \mathbf{Cl_2}}{\text{L}} \right| \text{———————}$$

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.

$$\left| \text{lb } \mathbf{Cl_2} \right| = \left| \frac{65 \text{ } \cancel{\text{mg}} \text{ } \mathbf{Cl_2}}{\cancel{\text{L}}} \right| \left| \frac{\cancel{\text{L}}}{\text{M}\cdot\cancel{\text{mg}}} \right| \text{———————}$$

The **M** that remains in the denominator is a reminder that an **Mgal** is needed in the numerator to cancel the **M**, as discussed at the beginning of this post. But there is no **Mgal** in the information given in the problem. What do we do? We know we can calculate volume from the pipe's diameter and length, so we use the conversion factor, **Mgal/10^6 gal**, to enter the **Mgal** needed. Notice, too, that **gal** cancels in the numerator and denominator.

$$\left| \text{lb } \mathbf{Cl_2} \right| = \left| \frac{65 \text{ } \cancel{\text{mg}} \text{ } \mathbf{Cl_2}}{\cancel{\text{L}}} \right| \left| \frac{\cancel{\text{L}}}{\text{M}\cdot\cancel{\text{mg}}} \right| \left| \frac{\cancel{\text{Mgal}}}{10^6 \text{ } \cancel{\text{gal}}} \right| \text{———————}$$

It looks like we're in trouble because we've canceled all the units in the railroad track except **Cl_2**. But we still need **lb** in the answer, so it has to be entered in the railroad track. We do this by entering the density of water. Notice that the unit, **lb**, has to go in the numerator because that's where it needs to be in the answer.

$$\text{lb } Cl_2 = \frac{65\ \cancel{mg}\ Cl_2 \quad \cancel{L} \quad \cancel{Mgal} \quad 8.34\ \text{lb}}{\cancel{L} \quad \cancel{M \cdot mg} \quad 10^6\ \cancel{gal} \quad \text{gal}}$$

Now we have the units needed in the answer, **lb Cl_2**, but we've added, and need to cancel, **gal**, in the denominator, but we don't have gal. Gallons (gal) are a unit of volume. We know we can calculate volume of the pipe, but it will be in ft^3 (ultimately), so we enter a well known conversion factor allowing **gal** to be canceled.

$$\text{lb } Cl_2 = \frac{65\ \cancel{mg}\ Cl_2 \quad \cancel{L} \quad \cancel{Mgal} \quad 8.34\ \text{lb} \quad 7.48\ \cancel{gal}}{\cancel{L} \quad \cancel{M \cdot mg} \quad 10^6\ \cancel{gal} \quad \cancel{gal} \quad ft^3}$$

The units, ft^3, in the denominator are telling us we now need to enter the volume of water that the pipe, when full, will contain. Again, when a pipe is full, it is basically a cylindrical "tank" lying on its side. To calculate the volume of a cylinder, we multiply the surface area, which is a circle ($A = 0.785 \times \text{diameter}^2$), by depth. In this case, we have to find the surface area of the pipe and multiply it by its length.

$$\text{lb } Cl_2 = \frac{65\ \cancel{mg}\ Cl_2 \quad \cancel{L} \quad \cancel{Mgal} \quad 8.34\ \text{lb} \quad 7.48\ \cancel{gal} \quad 0.785 \quad 18\ \text{in} \quad 18\ \text{in} \quad 4{,}500\ \text{ft}}{\cancel{L} \quad \cancel{M \cdot mg} \quad 10^6\ \cancel{gal} \quad \cancel{gal} \quad ft^3}$$

Now we have mixed units. Looking at what we need to cancel, we conclude we have to convert the in^2 (in x in) to ft^2. No problem! We know there are 12 in/ft. What we need, though, is ft^2, so we have to "square" the entire conversion factor, $(12\ in/ft)^2$. We need to expand this and, in doing so, the 2 in the superscript applies to everything inside the parentheses, $12^2\ in^2/ft^2$. Since 12 x 12 = 144, our "new" conversion factor becomes $144\ in^2/ft^2$, which is entered into the railroad track so the in x in cancel. Notice, too, that the ft x ft^2 in the numerator (ft^3) cancels with the ft^3 in the denominator.

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Whoa! Everything has canceled except the units we need in the answer, **lb Cl_2**, so **we know** the math is done. The arithmetic gives the answer:

65 x 8.34 x 7.48 x 0.785 x 18 x 18 x 4,500 ÷ 1,000,000 ÷ 144 = **32.2 lb Cl_2**.

Many of you in California may have heard that **water** treatment plant certification has been moved from the California Department of Health Services to the Office of Operator Certification in the State Water Resources Control Board. We think our approach to doing math problems is so sound and can help so

many operators, water and wastewater, WWTT is going to start doing math review classes for water treatment plant operators. If you know of anybody who is pursuing water treatment plant or distribution operator certification, or if you are, visit WWTT's courses webpage here. The water classes aren't up as of this writing, but they will be soon!

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