



**WASTEWATER TECHNOLOGY
T R A I N E R S**

Transforming today's operators into tomorrow's water quality professionals

**Problem of the Day
2015.May.26**

Problem of the Day

Twenty-five thousand gallons per day (25,000 gal/day) of raw sludge is pumped to an anaerobic digester. Lab tests show this sludge to contain 4.6% TS and 75% VS. How many pounds per day of volatile solids are pumped to the anaerobic digester?

Discussion

As you can tell from yesterday's Problem of the Day, the format is somewhat different than it used to be. The problem is given on a blank page so you can print it out and try it on your own before looking at the solution.

Today's problem is a very common "test" question, where the total solids (TS) and volatile solids (VS) concentrations are given in percent not mg/L. Many operators are taught that they can use this equivalent to convert % to mg/L:

$$1\% = 10,000 \text{ mg/L}$$

Let's think about this. For everybody that has visited these pages before or has taken a class from WWTT, one of the most useful conversion factors for doing wastewater math problems is:

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

In words: There are a million milligrams per liter of water. Or: A liter of water weighs a million milligrams.

Notice "of water" in both of these word definitions. That is because this conversion factor uses the density of water (in metric units: 1 g/cm³) in its derivation. It looks like this:

1 L of water	1,000 mL	cm ³	g	1,000 mg	=	1,000,000 mg
	L	mL	cm ³ of water	g		

Since we started this railroad track or solution bridge with "1 L of water," we conclude that 1 L of water has a mass of 1,000,000 mg. Thus, a concentration of 10,000 mg/L can be converted to percent:

10,000 mg	L	100%	=	1%
L	1,000,000 mg			

It is WWTT's contention, addressed in tomorrow's Problem of the Day, that using the equivalent 1% = 10,000 mg/L is only appropriate if the density of whatever solution is being considered in the problem is that of water. In the current problem, the density of the raw sludge is not given nor is the specific gravity. In such situations, the density of sludge has to be assumed equal to water. We will do the problem below with this assumption, whereas tomorrow's problem will be the same problem with the density of the raw sludge other than water. To be clear, though, WWTT does not advocate the use of the 1% = 10,000 mg/L equivalent and, instead, approaches "percent problems" in a unique way. Doing so allows the units to do the problem for us!

Solution

As with most problems, the solution bridge starts with identifying the units needed in the answer. Specifically, the problem states, "[h]ow many pounds per day of volatile solids," so that's how we start things off: The units needed in the answer, lb VS/d, are entered between heavy vertical lines followed by an equals sign and the blank solution bridge.

Problem of the Day: Twenty-five thousand gallons per day (25,000 gal/day) of raw sludge is pumped to an anaerobic digester. Lab tests show this sludge to contain 4.6% TS and 75% VS. How many pounds per day of volatile solids are pumped to the anaerobic digester?

lb VS	=				
d					

The information from the problem statement is repeated here and expressed, with units, the way WWTT teaches:

1. 25,000 gal/d = 25,000 gal sldg/day (sludge is abbreviated sldg)
2. 4.6% TS = 4.6 lb TS/100 lb sldg
3. 75% VS = 75 lb VS/100 lb TS

Notice from this list the units gal sldg and lb sldg. Density is used in many, many wastewater math problems to convert between gal and lb and vice versa. As stated above, neither the density nor the specific gravity of the raw sludge is given so the density of the sludge has to be assume to be that of water, **but labeled very specifically**:

4. 8.34 lb sldg/gal sldg

In most instances, the solution bridge is started on the righthand side of the equals sign with the units needed in the numerator of the answer, in this case lb VS. In the list given, the only place the units lb VS appear is in No. 3 so this starts the solution bridge:

lb VS	=	75 lb VS			
d		100 lb TS			

The units lb VS need to be preserved because they are needed in the answer. This is why they are shown in bold on both sides of the equals sign. From this point, the solution is found by canceling out unwanted units. In order to cancel units, they need to be in the numerator and the denominator. The units lb TS need to be canceled. In the list give, the only other place the units lb TS appear is in No. 2. This factor, then, is entered into the solution bridge so the units lb TS cancel in the numerator and denominator as shown.

lb VS	=	75 lb VS	4.6 lb TS		
d		100 lb TS	100 lb sldg		

Now the units lb sldg need to be cancel. The only other place these units show up in the list is No. 4. This factor, then, is entered into the solution bridge so the units lb sldg cancel in the numerator and denominator as shown.

lb VS	=	75 lb VS	4.6 lb TS	8.34 lb sldg	
d		100 lb TS	100 lb sldg	gal sldg	

Now the units gal sldg need to be cancel. The only other place these units show up in the list is No. 1. This factor, then, is entered into the solution bridge so the units gal sldg cancel in the numerator and denominator as shown. Notice this factor has the units d needed in the answer.

lb VS	=	75 lb VS	4.6 lb TS	8.34 lb sldg	25,000 gal sldg
d		100 lb TS	100 lb sldg	gal sldg	d

Since the only units remaining are the units needed in the answer, lb VS/d, we know the solution bridge is complete. The arithmetic gives the answer:

$$75 \times 4.6 \times 8.34 \times 25,000 \div 100 \div 100 = \mathbf{7,193 \text{ lb VS/d}}$$

Many operators would have tackled this problem by converting 4.6% TS to 46,000 mg TS/L given the equivalent given above. They would have then reasoned that 75% of the TS was VS so would multiply by 0.75:

$$0.75 \times 46,000 = 34,500 \text{ mg VS/L}$$

The raw sludge flow would have to be converted to Mgal/d (25,000 gal/d = 0.025 Mgal/d) to use this VS concentration in the pounds-per-day equation as shown.

lb VS	=	34,500 mg VS	L	0.025 Mgal	8.34 lb
d		L	M mg	d	gal

Since all the units have canceled except those needed in the answer, lb VS/d, the solution bridge is complete. The arithmetic gives the answer:

$$34,500 \times 0.025 \times 8.34 = \underline{\mathbf{7,193 \text{ lb VS/d}}}$$

This is the same answer, obviously. This is because the density of the raw sludge was assumed equal to that of water. In tomorrow's problem the specific gravity of the sludge is given, but otherwise it is the same problem.

Happy calculating! Let us know, by leaving a comment, if you want us to do a specific problem or if you see a mistake or if you have a question.