Problem of the Day

2014.Oct.17

Discussion

Wastewater treatment plant operators often use different chemicals in both liquid and solids treatment processes. Polymer solutions or emulsions, for example, are frequently used to improve solids recovery and performance in either thickening or dewatering units. Alum, ferric chloride or lime may be added to primary or secondary clarifiers or to a secondary effluent to remove phosphorus by formation and precipitation of an insoluble phosphorus compound. Ferric chloride is added to raw influent to improve the settling of suspended solids, called chemically enhanced primary treatment or CEPT, typically including a small dose of anionic polymer. Doses of chlorine, in gaseous, liquid or solid form, are, of course, used to disinfect final plant effluent. Chlorine also may be applied to RAS to control sludge settleability. All of these situations involve dosages of chemicals to either wastewater or sludge. Wastewater treatment plant operators need to be able to perform chemical dosing problems or understand how automatic dosing systems work.

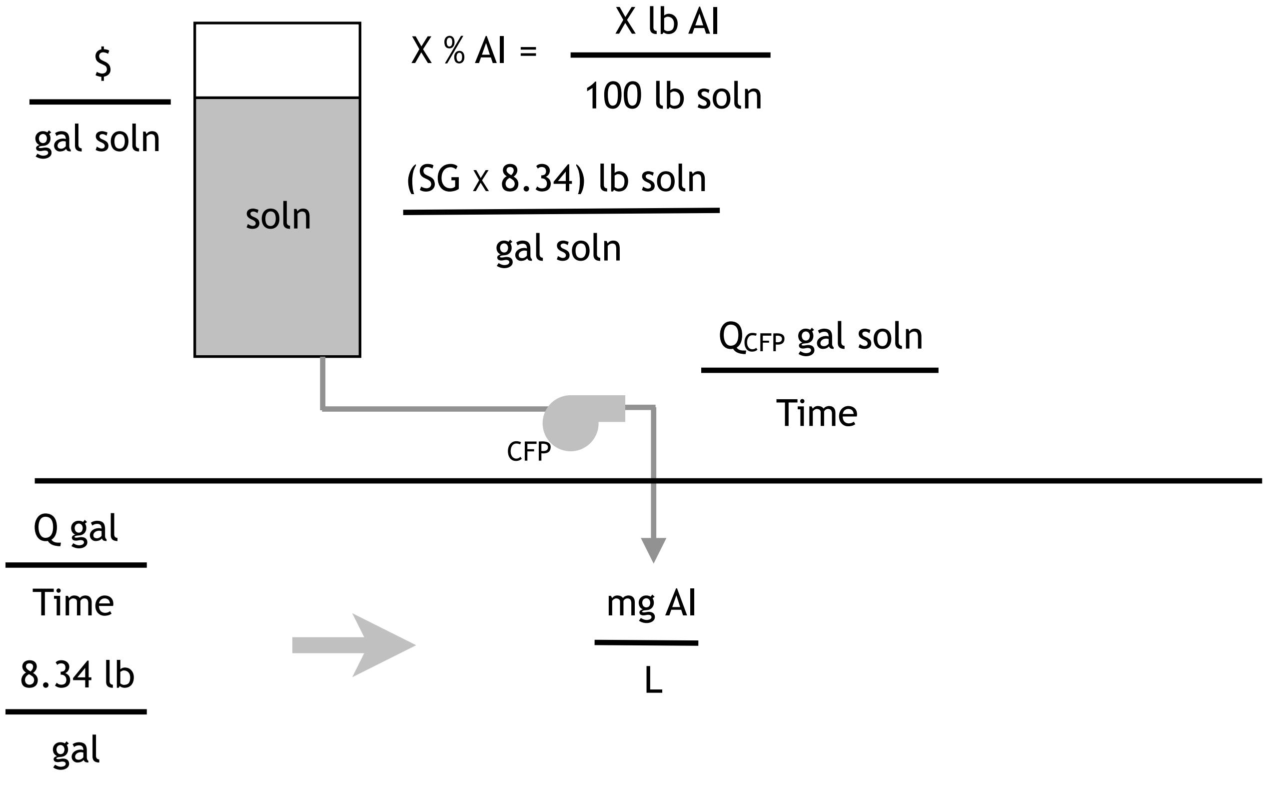
Often chemical dosages are expressed in mg/L. However, the operator should know that in wastewater calculations **mg/L and ppM** (parts per million) are taken to be equivalent because a liter of water weighs a million milligrams. The conversion factor, M·mg/L, is used to cancel mg, L, and the million (M) in Mgal/d. By using this conversion factor operators are reminded when doing problems to express flow in Mgal/time or volume in Mgal. Note, it is not necessary to convert all flows to Mgal/d, as taught by many trainers. In fact, converting all flows to Mgal/d often requires additional steps be taken to solve a problem because the time unit required is not day, rather than decreasing the number of steps.

The operator should understand the concept of **concentration expressed as a percent**. Whereas mg/L is parts per million parts, percent concentration is parts per hundred parts. In all wastewater calculations, with one exception, percent concentration is expressed on a weight-to-weight basis, typically lb/100 lb. Thus, a 0.33% polymer solution should be expressed in units of 0.33 lb of polymer (understood to be "dry" polymer) per 100 lb of polymer solution, or simply solution. A sodium hypochlorite solution reported to be 12.5% available chlorine would be expressed as 12.5 pounds of chlorine per 100 lb of solution. Similarly, the concentration of TS in a primary sludge reported to be 5% TS would be expressed as 5 lb of TS per 100 lb of sludge. Since TS are, by definition, understood to be "dry" (i.e., the solids in the TS test are dried at 103˚C to constant weight) and the sludge is "wet," the units "5 lb TS/100 lb sludge," avoids the confusion inherent in the expression of "dry solids" in "wet sludge."

In most dosage calculations, the mass or weight of the chemical being dosed is delivered by pumping a specific volume of solution containing the chemical over time, **not** always days. It is necessary, therefore, in these calculations to be able to move freely between units of weight and volume and back again. Density, expressed in units of mass per unit volume, is the physical characteristic that allows the operator to do so.

The definition and use of the concept of **specific gravity (SG)** also should be understood by the wastewater treatment plant operator. The SG of a substance is the ratio of its density to the density of water. Water, of course, has a SG of 1. The SG of other substances can be either greater than or less than 1. Liquid alum, for example, has a SG of 1.32, and thus weighs 11.00 pounds per gallon (1.32 x 8.34 lb/gal = 11.00 lb liquid alum/gal liquid alum). Some liquids, like aqueous ammonia, have SGs less than 1. Wastewater sludges have SGs greater than 1 due to the solids in the sludges. For example, a sludge with a SG of 1.05 would weigh 8.757 lb/gal (1.05 x 8.34 lb/gal = 8.757 lb sldg/gal sldg). If a wastewater math problem gives SG, it is very likely it will be used in the calculation. **Note, SG has no units**.

The basic set-up for almost all chemical dosing problems should use this schematic, where "AI" stands for "active ingredient," "CFP" stands for "chemical feed pump," "Q_{CFP}" stands for "chemical feed pump flow rate," and "SG" stands for "specific gravity."



In this schematic, AI ("Active Ingredient") is the **chemical of interest**, be it chlorine, polymer, ferric chloride, iron, or whatever. Often the concentration of the AI in the feed solution (**abbreviated** "**soln**") is given as a percentage. Chemical dosing calculations are hugely simplified if the operator expresses this percentage as pounds of AI per 100 pounds of solution (as discussed above). For example, a 2.5% polymer feed solution means there are 2.5 pounds of polymer (i.e., "dry" polymer) per 100 pounds of solution (i.e., "wet" polymer) pumped by the chemical feed pump. However, keep in mind that chemical feed pumping rates are typically given in units of, for example, gal/min, not in pounds/min. Therefore, the density of the feed solution containing the AI is needed to convert gallons of solution to pounds of solution and vice versa. If neither the density nor the SG of the solution is given, the operator can assume the density of the feed solution equals that of water (i.e., 8.34 lb/gal), but since it's not water, **the solution density is expressed in units of pounds of solution per gallon of solution (i.e., 8.34 lb soln/gal soln)**.

In almost all cases in wastewater treatment, the chemical feed is pumped into water, either a specified volume of water or a specified flow of water, to achieve a target concentration. Because many get confused, it should be noted that the concentration of AI either targeted or achieved in the volume or flow of water is mg AI/L not mg soln/L. Do not be confused by this. Note, also that "AI" occurs in only two places in the schematic: X lb AI/100 lb soln and mg AI/L. In summary, there are six factors to be considered when solving chemical dosing problems (refer to figure above):

1. Percent concentration of AI in the feed solution
2. Density or SG of the feed solution (assume equal to water if not given, 8.34 gal soln/lb soln)
3. Solution feed rate delivered by the chemical feed pump (Q_{CFP}) or the cost per gallon of solution

4. Volume or flow rate of water to which the chemical is being dosed
5. Density of the water to which the chemical is being dosed (this will always be 8.34 lb/gal and you will not be asked to calculate it)
6. Resulting concentration of AI in the water either in ppM AI or mg AI/L.

Typically, five of these six factors will be given, or can be calculated, and the operator is required to calculate the sixth. In most instances, the operator will be asked to calculate either: (1) the concentration of AI in the water, (2) the pumping rate of the chemical feed pump, or (3) the daily (or weekly, monthly, or annual) cost of the feed solution. WWTT's approach to chemical dosing problems uses units to "do the algebra" for you. Labeling the various elements of each problem exactly as shown in the figure on the previous page is the key to success. If asked to calculate the concentration of AI in the water, the railroad track will always be started with M·mg/L and expressed as ppM at the end of the problem if that is what the question asks for.

Problem

Learn to label chemical dosing problems the way WWTT teaches and the units will do the problem for you!

Problem of the Day: It is desired to dose the primary influent flow at the Little River WWTP at 1.5 milligrams of polymer per liter (1.5 mg poly/L) to enhance suspended solids removal. The influent flow rate is 5.3 MGD (Mgal/d). The polymer solution dosed to the influent flow has a polymer concentration of 0.5%. What should the pumping rate be of the chemical feed pump in gal/hr?

Solution

Polymer, or poly, is the active ingredient. Listing the information given in the problem in the same sequence as listed above:

1. Percent concentration of AI in the feed solution = 0.5% poly = 0.5 lb **poly**/100 lb soln
2. Density of feed solution = 8.34 lb soln/gal soln (assumed since not given)
3. Solution feed rate delivered by the chemical feed pump = **unknown**
4. Flow rate of water to which the chemical is being dosed, Q = 5.3 Mgal/d
5. Density of water = 8.34 lb/gal
6. Resulting concentration of AI in the water = 1.5 mg **poly**/L.

The problem asks to calculate the feed rate of the chemical feed pump in gal/hr. Notice in the schematic above that the suction line to the chemical feed pump goes to the solution (soln) tank. Therefore, the chemical feed pump pumps gallons of solution per hour. This needs to be label exactly like this: gal soln/hr. These are the units needed in the answer so they are entered between heavy vertical lines followed by an equals sign and the blank track.

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gal soln	=	
hr		

As before, WWTT likes to start the railroad track out with the units in the numerator that the question asks the answer to be in, in this case, gal soln.

Look at the list above. There is only one entry that has the unit “gal soln” in it. Which is it?

The only place this unit shows up is in the density of the solution: 8.34 lb soln/gal soln. In order to get the unit, gal soln, in the numerator, it has to be inverted when we enter it into the railroad track, as shown. Again, we do this because this unit is needed in the answer, as shown in bold.

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gal soln	=	**gal soln**	
hr		8.34 lb soln	

If you have labeled the information exactly like is shown in the list above, identified the units the answer as to be in, and started the railroad track as shown, all that remains to do the problem is to cancel unwanted units out while preserving the units needed. Currently, we need to keep gal soln and cancel lb soln. There is only one other entry in the list above that has the unit lb soln. It, too, needs to be inverted when entered into the railroad track to cancel units.

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gal soln	=	**gal soln**	100 ~~lb soln~~	
hr		8.34 ~~lb soln~~	0.5 lb poly	

Continuing, we have to cancel the unit, lb poly. We don't have this unit in the list of information given, but we do have the unit, mg poly. This, then, is entered into the railroad track to cancel out poly.

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gal soln	=	**gal soln**	100 ~~lb soln~~	1.5 mg ~~poly~~	
hr		8.34 ~~lb soln~~	0.5 lb ~~poly~~	~~L~~	

Whenever mg/L are entered into the railroad track and are not needed in the answer, they are canceled with M·mg/L, which also has to be inverted when entered into the railroad track to cancel units out.

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gal soln	=	**gal soln**	100 ~~lb soln~~	1.5 ~~mg poly~~	~~L~~	
hr		8.34 ~~lb soln~~	0.5 lb ~~poly~~	~~L~~	M·~~mg~~	

Currently, we have the unit we need in the numerator, gal soln. We still need hr, and we have to get rid of lb and M. The M reminds us we need an Mgal, so the flow is entered next. Doing so puts d in the denominator. Both hr and d are units of time, so this is progress, too, since we can convert d to hr easily.

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gal soln	=	**gal soln**	100 ~~lb soln~~	1.5 ~~mg poly~~	~~L~~	5.3 ~~M~~gal	
hr		8.34 ~~lb soln~~	0.5 lb ~~poly~~	~~L~~	~~M·mg~~	d	

Now we have lb and gal we need to cancel, and we can't forget we have to convert d to hr. But entering the density of the water gets rid of lb and gal.

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gal soln	=	**gal soln**	100 ~~lb soln~~	1.5 ~~mg poly~~	~~L~~	5.3 ~~Mgal~~	8.34 ~~lb~~	
hr		8.34 ~~lb soln~~	0.5 ~~lb poly~~	~~L~~	~~M·mg~~	d	~~gal~~	

Now we convert d to hr. One of the amazing things about the railroad track and this approach to problem solving, is there is no need to think about whether to divide or multiply by the 24 in 24 hr/d because **the units tell you what to do**. This is hugely important. If you don't use the units like this, you are guaranteed to make the wrong choice—multiplying by 24 rather than dividing—especially under the pressure of a certification exam.

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gal soln	=	**gal soln**	100 ~~lb soln~~	1.5 ~~mg poly~~	~~L~~	5.3 ~~Mgal~~	8.34 ~~lb~~	~~d~~
hr		8.34 ~~lb soln~~	0.5 ~~lb poly~~	~~L~~	~~M·mg~~	~~d~~	~~gal~~	24 **hr**

Since all the units have canceled except the ones needed in the answer, gal soln/hr, the math is done and the arithmetic gives the answer:

100 x 1.5 x 5.3 x 8.34 ÷ 8.34 ÷ 0.5 ÷ 24 = **66.25 gal soln/hr**.

Without units you might look at this solution and say, "Why do I have two 8.34s in my calculation? That can't be right."

The units, as we have labeled them, tell you why: the reason there are two 8.34s is because there are two liquids in the problem—the polymer solution and the water we're adding the polymer solution to—that happen to have the same numeric density. The beauty of the way they have been labeled here—8.34 lb soln/gal soln and 8.34 lb/gal—is that they are distinct and obviously so. Just like we cancel like units when they appear in both the numerator and denominator, the two 8.34s in the railroad track also can be canceled to save yourself a little calculator time on an exam, for instance. Don't worry about it if you don't cancel them, though, you will get the same answer.

Happy calculating!