Problem of the Day
2014.Dec.06

Introduction

How about one more pounds calculation?

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.

More and more wastewater treatment plants are having to oxidize ammonia (nitrification), remove nitrogen (nitrification + denitrification) and remove phosphorus. Ammonium (NH_4^+) and ammonia (NH_3) are in chemical equilibrium:

$$NH_4^+ \leftrightharpoons H^+ + NH_3$$

The analytical measurement of "ammonia" includes both NH_4^+ and NH_3. The amount of ammonium and ammonia that exists at any given moment is governed by the pH and temperature of the water. This is important because **un-ionized ammonia** (NH_3) is significantly more toxic to fish and other aquatic organisms than **ionized ammonium** (NH_4^+). Some dischargers are required to calculate the amount of NH_3 that would be expected in the receiving water from the plant effluent.

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 per day of ammonia are discharged in a plant effluent flow of 3.5 MGD? The ammonium/ammonia concentration in the effluent averages 1.6 mg/L. Based on today's measurement of the receiving water pH and temperature, it is expected that 4.5% of the ammonium/ammonia will be in the form of the more toxic NH_3 (ammonia).

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

Based on the pH and temperature of the receiving water, 4.5% of the ammonium/ammonia (NH_4^+/NH_3) discharged will be in the more toxic form of ammonia (NH_3). This will need to be factored into the pounds calculation. Often when a percent is given, WWTT will express it in units of parts per hundred parts. In this instance:

4.5% NH_3 = 4.5 lb NH_3/100 lb NH_4^+/NH_3.

The question asks specifically for "... pounds per day of ammonia ..." These units, **lb NH_3/d**, are put between heavy vertical lines followed by the equals sign and the blank track.

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Information summary, specifically labeled:

- Plant flow = 3.5 Mgal/d
- Effluent ammonium/ammonia concentration = 1.6 mg NH_4^+/NH_3/L
- Ammonia concentration = 4.5% = 4.5 lb NH_3/100 lb NH_4^+/NH_3
- **Calculate: pounds of ammonia discharged per day (lb NH_3/d)**.

$$\left| \frac{\text{lb } NH_3}{\text{d}} \right| = \frac{\quad}{\quad}$$

The unit, **lb NH_3**, needed in the numerator of the answer only shows up in the list of information given in the problem in one other place, 4.5 **lb NH_3**/100 lb NH_4^+/NH_3. Entering this information starts the railroad track.

$$\left| \frac{\textbf{lb } NH_3}{\text{d}} \right| = \left| \frac{4.5 \textbf{ lb } NH_3}{100 \text{ lb } NH_4^+/NH_3} \right| \frac{\quad}{\quad}$$

There is no information given in the problem in units of **lb NH_4^+/NH_3**. There is, however, the effluent concentration, 1.6 mg **NH_4^+/NH_3**, that will allow us to cancel the unit **NH_4^+/NH_3**.

$$\left| \frac{\textbf{lb } NH_3}{\text{d}} \right| = \left| \frac{4.5 \textbf{ lb } NH_3}{100 \text{ lb } \cancel{NH_4^+/NH_3}} \right| \frac{1.6 \text{ mg } \cancel{NH_4^+/NH_3}}{\text{L}} \left| \frac{\quad}{\quad} \right|$$

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.

lb NH_3	=	4.5 **lb NH_3**	1.6 ~~mg~~ ~~NH_4^+/NH_3~~	~~L~~	
d		100 lb ~~NH_4^+/NH_3~~	~~L~~	M·~~mg~~	

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, so we enter the plant flow. Entering the flow also gets **d**, needed in the answer, in the railroad track.

lb NH_3	=	4.5 **lb NH_3**	1.6 ~~mg~~ ~~NH_4^+/NH_3~~	~~L~~	3.5 ~~M~~gal	
d		100 lb ~~NH_4^+/NH_3~~	~~L~~	~~M·mg~~	**d**	

We have the units in the railroad track that we need in the answer, **lb NH_3/d**. But we also have an extra **lb** and a **gal** we have to cancel. We do this by entering the density of water. This can be entered into the railroad track only one way to allow cancelation of the unwanted units.

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- **Calculate: pounds of ammonia discharged per day (lb NH_3/d)**.

lb NH_3	=	4.5 **lb NH_3**	1.6 ~~mg~~ ~~NH_4^+/NH_3~~	~~L~~	3.5 ~~Mgal~~	8.34 ~~lb~~
d		100 ~~lb~~ ~~NH_4^+/NH_3~~	~~L~~	~~M·mg~~	**d**	~~gal~~

Nice! Everything has canceled except the units we need in the answer, **lb NH_3/d**, so **we know** the math is done. The arithmetic gives the answer:

4.5 x 1.6 x 3.5 x 8.34 ÷ 100 = **2.1 lb NH_3/d**.

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.