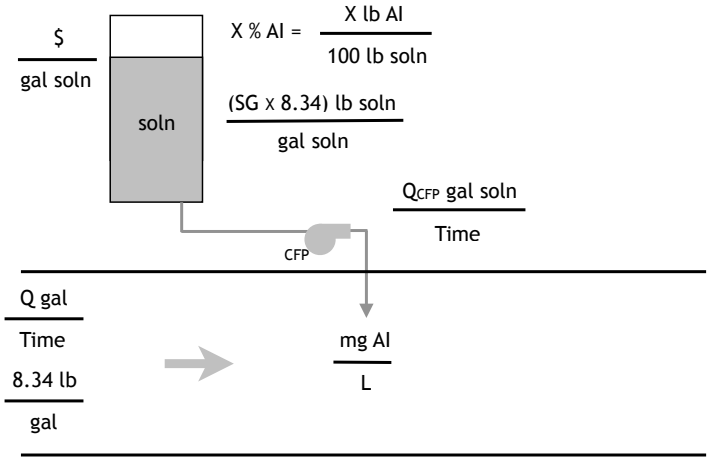
# Problem of the Day
# 2014.Oct.26

## Discussion

WWTT's approach to solving chemical dosing problems was introduced in the 2014.Oct.17 Problem of the Day. Chemical usage at wastewater treatment plants (WWTPs) is typically the third greatest operating expense, after labor and power (electricity), so being able to calculate and accurately control chemical dosing and the cost associated with it are important skills for operators to master.

WWTT approaches all chemical dosing problems the same way. The generic graphic for setting up these problems given in the 2014.Oct.17 Problem of the Day is repeated here (this is a really cool graphic):




*Generic graphic for setting up chemical dosing problems (AI = active ingredient, soln = solution containing active ingredient, SG = specific gravity, CFP = chemical feed pump, $Q_{CFP}$ = flow rate of chemical feed pump, Q = flow (or volume) to which chemical is being dosed).*

As discussed 2014.Oct.17, there are six key pieces of information in this graphic:

1. Percent concentration of active ingredient (AI) in the feed solution
2. Density or specific gravity (SG) of the feed solution
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
6. Resulting concentration of AI in the water either in ppM AI or mg AI/L.

On certification exam problems, five of these six factors will be given, or can be calculated, and the operator is required to calculate the sixth.

## Problem

**Problem of the Day**: The ferric chloride solution (FCS) delivered to the Big Bend WWTP is 47% ferric chloride (FC). FCS is pumped at 0.5 gpm to a primary influent flow of 7 MGD for chemically enhanced primary treatment. FCS has a specific gravity of 1.45 and FC is 34.4% iron (Fe). What is the iron dose in the primary influent flow in mg Fe/L?

## Solution

Iron, Fe, is the active ingredient. Two pieces of information (1A and 1B) are needed to get to the active ingredient in the ferric chloride solution (FCS) being pumped into the primary influent flow:

1A. Percent concentration ferric chloride (FC) in FCS = 47% FC = 47 lb FC/100 lb FCS
1B. Percent concentration Fe in FC = 34.4% Fe = 34.4 lb Fe/100 lb FC
2. Density of feed solution (FCS) = 1.45 x 8.34 lb/gal = 12 lb FCS/gal FCS
3. Chemical feed rate = 0.5 gal FCS/min
4. Flow rate of water to which the chemical is being dosed, Q = 7 Mgal/d
5. Density of water = 8.34 lb/gal
6. Resulting concentration of Fe in primary influent = **unknown**.

It is very important to concentrate on the way things are being labeled here. The solution being dosed to the primary influent flow is **ferric chloride solution, abbreviated FCS**. The ferric chloride solution (FCS) contains 47% **ferric chloride, abbreviated FC**. The ferric chloride (FC) contains 34.4% **iron, chemical symbol Fe**. These abbreviations and labeling must be strictly adhere to as the railroad track is populated to ensure the right units are canceled.

The problem asks to calculate the iron dose, in **mg Fe/L**, to the primary influent flow. 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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$$\left|\frac{\text{mg Fe}}{\text{L}}\right| = \frac{\qquad\qquad}{\qquad\qquad}$$

Whenever a question asks to solve for concentration, either **mg/L or ppM** (parts per million), **the railroad track is always started with the conversion factor, M•mg/L**. Doing so enters mg and L into the railroad track needed in the answer, shown in **bold** on both sides of the equals sign.

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$$\left|\frac{\textbf{mg Fe}}{\textbf{L}}\right| = \left|\frac{\text{M}\cdot\textbf{mg}}{\textbf{L}}\right| \frac{\qquad\qquad}{\qquad\qquad}$$

The M could be canceled out by putting the flow, 7 Mgal/d, in the denominator. That would be fine. WWTT likes to enter the unit, Fe, into the railroad track. Looking at the list above, Fe only shows up in the concentration of Fe in FC (No. 1B in the list), so this is entered into the railroad track.

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$$\left|\frac{\textbf{mg Fe}}{\textbf{L}}\right| = \left|\frac{\text{M}\cdot\textbf{mg}}{\textbf{L}}\right| \left|\frac{34.4\text{ lb }\textbf{Fe}}{100\text{ lb FC}}\right| \frac{\qquad\qquad}{\qquad\qquad}$$

Every unit needed in the answer is now in the railroad track, indicated in **bold**. To solve the problem the

unwanted units are canceled out as you work down the railroad track. Currently, the units, M, lb, and lb FC, are unwanted and need to be canceled. Any one could be canceled by entering the same unit from the list above into the railroad track. From the list above, there is only one other place where the units, lb FC, show up: the concentration of FC in the FCS (No. 1A above). This is entered into the railroad track so lb FC cancel out.

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| **mg Fe** | = | M·**mg** | 34.4 lb **Fe** | 47 ~~lb FC~~ | |
|---|---|---|---|---|---|
| **L** | | **L** | 100 ~~lb FC~~ | 100 lb FCS | |

Next, there is only one other place that the units, lb FCS, show up, the density of the feed solution (No. 2) calculated in the list above by multiplying the SG (specific gravity) given in the problem statement by 8.34 lb/gal.

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| **mg Fe** | = | M·**mg** | 34.4 lb **Fe** | 47 ~~lb FC~~ | 12 ~~lb FCS~~ | |
|---|---|---|---|---|---|---|
| **L** | | **L** | 100 ~~lb FC~~ | 100 ~~lb FCS~~ | gal FCS | |

Next, there is only one other place the units, gal FCS, show up, the pumping rate of the chemical feed pump (No. 3). It is entered so gal FCS cancel.

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| **mg Fe** | = | M·**mg** | 34.4 lb **Fe** | 47 ~~lb FC~~ | 12 ~~lb FCS~~ | 0.5 ~~gal FCS~~ | |
|---|---|---|---|---|---|---|---|
| **L** | | **L** | 100 ~~lb FC~~ | 100 ~~lb FCS~~ | ~~gal FCS~~ | min | |

Minutes (min) are a unit of time. The only other unit of time, days (d), in the list above shows up in the primary influent flow rate (No. 4), so this flow rate has to be entered into the railroad track so the d is in the numerator. The M in Mgal also cancels the M in M·mg, as shown.

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| **mg Fe** | = | ~~M~~·**mg** | 34.4 lb **Fe** | 47 ~~lb FC~~ | 12 ~~lb FCS~~ | 0.5 ~~gal FCS~~ | d | |
|---|---|---|---|---|---|---|---|---|
| **L** | | **L** | 100 ~~lb FC~~ | 100 ~~lb FCS~~ | ~~gal FCS~~ | min | 7 ~~M~~gal | |

Although we can't forget to convert minutes to days, we now have lb and gal that need to be canceled and this is done by entering the water density given in the list above (No. 5).

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **mg Fe** | = | ~~M~~**mg** | 34.4 ~~lb~~ **Fe** | 47 ~~lb FC~~ | 12 ~~lb FCS~~ | 0.5 ~~gal FCS~~ | d | ~~gal~~ | |
| **L** | | **L** | 100 ~~lb FC~~ | 100 ~~lb FCS~~ | ~~gal FCS~~ | min | 7 ~~M~~gal | 8.34 ~~lb~~ | |

Finally, the only units that remain are min and d which are canceled with a well known conversion factor.

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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **mg Fe** | = | ~~M~~**mg** | 34.4 ~~lb~~ **Fe** | 47 ~~lb FC~~ | 12 ~~lb FCS~~ | 0.5 ~~gal FCS~~ | ~~d~~ | ~~gal~~ | 1,440 ~~min~~ |
| **L** | | **L** | 100 ~~lb FC~~ | 100 ~~lb FCS~~ | ~~gal FCS~~ | ~~min~~ | 7 ~~M~~gal | 8.34 ~~lb~~ | ~~d~~ |

Since all the units have canceled except the ones needed in the answer, **mg Fe/L**, the math is done and the arithmetic gives the answer:

34.4 x 47 x 12 x 0.5 x 1,440 ÷ 100 ÷ 100 ÷ 7 ÷ 8.34 = **24 mg Fe/L**.

The labeling used by WWTT takes some practice to get used to. With practice, though, problem solutions are very straightforward: enter the units needed in the answer and cancel all unwanted units. **It is emphasized that the units have to work out; if the units don't work out, the answer will be incorrect**. Today's Problem of the Day was a good example of this approach.