Problem of the Day

2014.Oct. 06

Discussion

As discussed in the 2014.Sept.21 Problem of the Day, the primary objective of wastewater treatment is to protect public health. Disinfection is the killing of microorganisms that cause disease in human beings. Chlorine is widely used for disinfection at water and wastewater treatment plants. The impact chlorination has had on public health is nothing short of miraculous (see the graphic in WWTT's blog "Raising the Bar"). When it comes to chlorination problems, all operators should remember:

Dose = Demand + Residual

From this simple equation, two other equations are derived:

Demand = Dose − Residual

and

Residual = Dose − Demand

Today's Problem of the day uses the second of these equations. The dose concentration has to be calculated first in a "reverse" pounds equation. This type of question shows up on many operator certification exams.

Problem of the Day: Over the last three months, the average chlorine use at the Muddy River WWTP was 540 pounds per day. During this time the influent flow averaged 3.6 MGD and the chlorine residual averaged 2.5 mg/L. Calculate the average chlorine demand in mg/L.

Solution

Listing the information given in the problem statement, with appropriate units:

- Q = 3.6 Mgal/d
- Chlorine dose = 540 lb Cl_2/d
- Chlorine residual = 2.5 mg Cl_2/L

While it is understood that demand is equal to the dose minus the residual, in the information given, the dose and residual are in different units (lb Cl_2/d and mg Cl_2/L, respectively) so they cannot be subtracted. **Remember: to add or subtract two or more numbers, they must have the same units**.

We have to calculate the dose concentration, in mg Cl_2/L, given the dose and flow in a "reverse" pounds calculation. Therefore, we enter the units for concentration we are seeking (mg Cl_2/L) between heavy vertical lines followed by an equals sign and the blank track.

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$$\left|\frac{\text{mg } Cl_2}{\text{L}}\right| = \_\_\_\_\_$$

Whenever the problem is asking to find the answer in either mg/L or ppM, which is equivalent to mg/L, the railroad track is **always** started with M·mg/L. Doing so gets the units mg and L, needed in the answer, into the railroad track.

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$$\left|\frac{\textbf{mg } Cl_2}{\textbf{L}}\right| = \left|\frac{\text{M}\cdot\textbf{mg}}{\textbf{L}}\right| \_\_\_\_\_$$

Entered next into the railroad track is 540 lb Cl_2/d because it gets the unit, Cl_2, into the railroad track.

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$$\left|\frac{\textbf{mg } \textbf{Cl}_2}{\textbf{L}}\right| = \left|\frac{\text{M}\cdot\textbf{mg}}{\textbf{L}}\right| \left|\frac{540 \text{ lb } \textbf{Cl}_2}{\text{d}}\right| \_\_\_\_\_$$

All the units needed in the answer are now entered in the railroad track, but there are several units that need to be canceled, M, lb and d. Entering flow into the denominator cancels M and d.

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$$\left|\frac{\textbf{mg } \textbf{Cl}_2}{\textbf{L}}\right| = \left|\frac{\cancel{\text{M}}\cdot\textbf{mg}}{\textbf{L}}\right| \left|\frac{540 \text{ lb } \textbf{Cl}_2}{\cancel{\text{d}}}\right| \left|\frac{\cancel{\text{d}}}{3.6 \cancel{\text{M}}\text{gal}}\right| \_\_\_\_\_$$

The units lb and gal are canceled by dividing by the density of water.

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$$\frac{\textbf{mg } \textbf{Cl}_2}{\textbf{L}} = \frac{\cancel{\text{M}}\cdot\textbf{mg}}{\textbf{L}} \; \frac{540 \cancel{\text{lb}}\ \textbf{Cl}_2}{\cancel{\text{d}}} \; \frac{\cancel{\text{d}}}{3.6\ \cancel{\text{M}}\cancel{\text{gal}}} \; \frac{\cancel{\text{gal}}}{8.34\ \cancel{\text{lb}}}$$

Because all the units have been cancelled except for those needed in the answer, the solution is found by doing the arithmetic:

$$540 \div 3.6 \div 8.34 = 18.0 \text{ mg } Cl_2/L.$$

This isn't the answer so it is not underlined. What we just calculated was the dose concentration. To calculated the demand, the residual is subtracted from the dose:

$$\text{Demand} = (18.0 - 2.5) \text{ mg } Cl_2/L = \underline{15.5 \text{ mg } Cl_2/L}.$$