Problem of the Day

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The influent to the Oxbow Water Reclamation Facility averages 46.5 MGD. The influent TSS concentration is 385 mg/L, 74.2% of which is volatile. Using small dosages of ferric chloride and anionic polymer for chemically enhanced primary treatment (CEPT), the operators keep the primary effluent TSS concentration to a fairly stable 106 mg/L. In the previous two Problems of the Day it was found that 108,199 lb TSS/d and 80,284 lb VSS/d are removed in the primary clarifiers. If the primary sludge is withdrawn at a solids concentration of 5.2% TS, calculate how many gallons of primary sludge per day are pumped to the anaerobic digesters.

Introduction

This is the third in a series of Problems of the Day that will lead up to the daily heat content in the anaerobic digester gas. This series of problems deals only with the primary sludge that is directed to the anaerobic digesters.

As previously discussed, with a little CEPT, the operators at the Oxbow Water Reclamation Facility are getting 72.5% TSS removal (you should be able to calculate this for yourself). Not bad for what we'd expect is a modest chemical cost ("... small dosages of ferric chloride and anionic polymer...").

The process objective of primary clarifiers is the removal of settleable solids. While the Imhoff cone is used to measure the volumetric concentration (mL/L) of settleable solids, they can also be determined gravimetrically by measuring the TSS concentration and then performing a non-settleable TSS test. There is no "standard method" to do so, but the test advanced by yours truly (that is, Eric J. Wahlberg) is gaining popularity. Operators need to know that all settleable solids are TSS (designated TSS_{set}), but not all TSS are settleable because some TSS are non settleable (designated TSS_{non}).

In contrast, the process objective of digesters, anaerobic or aerobic, is the reduction of volatile solids (VS). "Reduction" isn't the best choice of words because the organic carbon in the VS isn't reduced or destroyed but converted to methane (CH_4) and carbon dioxide (CO_2). This is why it is so important to calculate how many pounds of VS are being applied to digesters. It also is why the organic loading rate to anaerobic digesters is expressed in units of lb VS/d per ft^3 of digester volume (lb VS/d·ft^3), the subject of tomorrow's Problem of the Day.

While it is not often specifically stated so, operators should understand and appreciate that TSS **and** VSS are removed at same rate in primary clarifiers. In other words, if the TSS removal efficiency, calculated above, is 72.5%, than the VSS removal efficiency also is 72.5%. What this means is that if the percent volatile solids in the influent is 74.2%, then the TSS in the primary effluent is 74.2% volatile and the TSS —and TS, as discussed below—in the primary sludge also is 74.2% volatile.

Solution

The following information is given, expressed in the units recommended by WWTT (sludge is abbreviated "sldg"):

1. Influent flow = 46.5 Mgal/d
2. Influent TSS concentration = 385 mg TSS/L
3. Influent VSS concentration = 74.2% = 74.2 lb VSS/100 lb TSS
4. Primary effluent TSS concentration = 106 mg TSS/L
5. Pounds TSS per day removed = 108,199 lb TSS/d
6. Pounds VSS per day removed = 80,284 lb VSS/d
7. Primary sludge solids concentration = 5.2% TS = 5.2 lb TS/100 lb sldg

The question is asking to calculate gallons of primary sludge per day going to the digesters. In the list above, note the units lb sldg in No. 7. In order to convert back and forth between gal and lb, we need the density of the sludge. Because it is not given, it needs to be assumed.

8. Primary sludge density (assumed) = 8.34 lb sldg/gal sldg

The units gal sldg/d are put between heavy vertical lines, as always, followed by an equals sign and the blank solution bridge.

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$$\left|\frac{\text{gal sldg}}{\text{d}}\right| = \frac{\qquad\qquad\qquad\qquad}{}$$

In the information listed, given and assumed, there is only one place the units gal sldg appear: No. 8. This is used, "upside down," to start the solution bridge. Doing so enters the units gal sldg needed in the numerator of the answer in the solution bridge (shown in **bold**). This is how the solution bridge is started in most problems.

$$\left|\frac{\textbf{gal sldg}}{\text{d}}\right| = \left|\frac{\textbf{gal sldg}}{\text{8.34 lb sldg}}\right| \frac{\qquad\qquad\qquad\qquad}{}$$

The units lb sldg need to be canceled from the solution bridge. There is only one other place in the list where the units lb sldg occur: in the denominator of No. 7. This is entered next in the solution bridge, again, "upside down" so like units can be canceled in the denominator and numerator.

$$\left|\frac{\textbf{gal sldg}}{\text{d}}\right| = \left|\frac{\textbf{gal sldg}}{\text{8.34 }\cancel{\text{lb sldg}}}\right| \frac{\text{100 }\cancel{\text{lb sldg}}}{\text{5.2 lb TS}} \frac{\qquad\qquad\qquad\qquad}{}$$

The units lb TS don't show up in the list again. This is where an important point has to be made, and understood, about TS and TSS. TS and TSS are **not** the same thing. TS are the sum of the TSS and the TDS (total dissolved solids):

TS = TSS + TDS

For our purposes, however, we can treat them as the same when doing sludge problems. In fact, we have to in order to do these kinds of problems. With that said, we enter the lb TSS/d removed in the primary clarifiers. As kind of a reminder that TS and TSS are not the same thing, WWTT puts the second S in TSS in parentheses, TS(S) as shown. The unit lb TS and lb TS(S) cancel.

$$\left|\frac{\textbf{gal sldg}}{\textbf{d}}\right| = \left|\frac{\textbf{gal sldg}}{\text{8.34 }\cancel{\text{lb sldg}}}\right| \frac{\text{100 }\cancel{\text{lb sldg}}}{\text{5.2 }\cancel{\text{lb TS}}} \frac{\text{108,199 }\cancel{\text{lb TS(S)}}}{\textbf{d}}$$

Since all the units have now canceled except those needed in the answer, gal sldg/d, we know the solution bridge is complete. The arithmetic gives the answer.

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$$\frac{\text{gal sldg}}{\text{d}} = \frac{\text{gal sldg}}{8.34\ \cancel{\text{lb sldg}}} \cdot \frac{100\ \cancel{\text{lb sldg}}}{5.2\ \cancel{\text{lb TS}}} \cdot \frac{108{,}199\ \cancel{\text{lb TS(S)}}}{\text{d}}$$

100 x 108,199 ÷ 8.34 ÷ 5.2 = **249,490 gal sldg/d**.

Discussion

I know I say this all the time, but the solution bridge is a pretty amazing why to do these problems. I understand the “trick” is in the labeling and this is what you should be practicing. But WWTT has refined the labeling to such a degree, once you have it down, the units do the problems for you. And they do them correctly!

Happy calculating! Let us know, by leaving a comment, if you want us to do a specific problem, if you see a mistake, or if you have a question on any of the Problems of the Day you are looking at.