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 previous 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 and that 249,490 gallons of primary sludge are pumped to the digesters each day at a solids concentration of 5.2% TS. There are four primary digesters at the plant, each holds 750,000 gallons. Calculate the organic loading to these anaerobic digesters.

Introduction

This is the fourth in a series of Problems of the Day that will lead up to calculating 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" for this test, 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 today'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
8. Number of anaerobic digesters = 4 DIG
9. Volume of each anaerobic digester = 750,000 gal

Today's problem doesn't indicate the units needed in the answer. However, operators should know that the **organic loading to an anaerobic digester is always in units of lb VS/d·ft^3**. These units, lb VS/d·ft^3, are put between heavy vertical lines, as always, followed by an equals sign and the blank solution bridge.

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$$\frac{\text{lb VS}}{\text{d}\cdot\text{ft}^3} = \frac{\quad}{\quad}$$

The units lb VS do not appear in the list. In yesterday's Problem of the Day, the assumption that TS is equal to TSS in sludges was discussed. Indeed, this allows us to assume that VS and VSS are the same as well, even though we know they are not (i.e., VS = VSS + VDS). But now we see that the units lb VSS appear in two places in the list: Nos. 3 and 6. But in No. 6 the units are lb VS(S)/d (we put the second S in VS(S) in parenthesis to indicate we know VS and VSS are not really the same thing), which is what we need. Keep in mind, too, that if the VS(S) are "removed in the primary clarifiers," these solids are going to the digesters.

$$\frac{\textbf{lb VS}}{\textbf{d}\cdot\text{ft}^3} = \frac{80{,}284\ \textbf{lb VS(S)}}{\textbf{d}} \times \frac{\quad}{\quad}$$

We now need ft^3 in the denominator of the solution bridge, but nothing in the list has these units either. We add the well know conversion factor to get ft^3 in the denominator of the solution bridge.

$$\frac{\textbf{lb VS}}{\textbf{d}\cdot\textbf{ft}^3} = \frac{80{,}284\ \textbf{lb VS(S)}}{\textbf{d}} \times \frac{7.48\ \text{gal}}{\textbf{ft}^3} \times \frac{\quad}{\quad}$$

Remembering that the units ft^3 needed in the denominator of the answer are volume in the digesters, so the volume of each digester is entered so the units gal cancel.

$$\frac{\textbf{lb VS}}{\textbf{d}\cdot\textbf{ft}^3} = \frac{80{,}284\ \textbf{lb VS(S)}}{\textbf{d}} \times \frac{7.48\ \cancel{\text{gal}}}{\textbf{ft}^3} \times \frac{\text{DIG}}{750{,}000\ \cancel{\text{gal}}} \times \frac{\quad}{\quad}$$

And there are four digesters (DIG) so this is entered next so like units cancel, numerator and denominator.

$$\frac{\textbf{lb VS}}{\textbf{d}\cdot\textbf{ft}^3} = \frac{80{,}284\ \textbf{lb VS(S)}}{\textbf{d}} \times \frac{7.48\ \cancel{\text{gal}}}{\textbf{ft}^3} \times \frac{\cancel{\text{DIG}}}{750{,}000\ \cancel{\text{gal}}} \times \frac{}{4\ \cancel{\text{DIG}}}$$

Since all the units have now canceled except those needed in the answer, lb VS/d·ft^3, we know the solution bridge is complete. The arithmetic gives the answer.

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lb VS	=	80,284 **lb VS(S)**	7.48 ~~gal~~	~~DIG~~	
d·ft^3		**d**	**ft^3**	750,000 ~~gal~~	4 ~~DIG~~

80,284 x 7.48 ÷ 750,000 ÷ 4 = **<u>0.20 lb VS/d·ft^3</u>**.

Discussion

The organic loading rate to an anaerobic digester is a very important operational consideration. The range typically cited is 0.15 to 0.40 lb VS/d·ft^3, but around 0.20 lb VS/d·ft^3, is considered optimum. And this is becoming increasingly important as many resource recovery facilities emphasize greater methane and energy production, use advanced anaerobic digester systems that are loaded more aggressively, and many facilities are co-digesting sludge with other feedstocks like FOG (fats, oils and grease) and food wastes.

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.