Problem of the Day

2014.Nov.01

Discussion

As the methane produced during anaerobic digestion gets more and more valuable and wastewater treatment plant personnel strive to make their plants energy neutral, more anaerobic digesters will be constructed and more focus will be given to optimizing their performance. Today's Problem of the Day looks at an important anaerobic digester performance criterion: the organic loading rate. The organic loading rate to digesters is always given in units of **lb VS/d·ft^3**. To perform this calculation the pounds of volatile solids per day (lb VS/d) fed to the digester(s) is divided by the their volume expressed in units of ft^3.

There are at least two reasons the organic loading to anaerobic digesters is so important: (1) the process objective of anaerobic digestion is the destruction, or reduction, of volatile solids, and (2) drastic changes to the organic loading can lead to upsets in anaerobic digesters. Operators need to be able to calculate the organic loading to anaerobic digesters.

Problem

The organic loading rate to anaerobic digesters is an important operating parameter.

Problem of the Day: The primary sludge flow to the Springdale WWTP is 45,000 gallons per day. The TS concentration of the primary sludge is 4.7%, of which 72.8% are volatile. The two anaerobic digesters at the plant have a total volume of 418,000 gallons. Calculate the organic loading from the primary sludge to these digesters.

Solution

The following summarizes the information given in the problem statement. Again, WWTT puts this information in very specific units.

- Primary sludge flow = 45,000 gal sldg/d
- TS concentration = 4.7% = 4.7 lb TS/100 lb sldg
- VS concentration = 72.8% = 72.8 lb VS/100 lb TS
- Primary sludge density = 8.34 lb sldg/gal sldg
- Total anaerobic digester volume = 418,000 gal
- **Calculate: organic loading rate**.

While the units wanted in the answer are not given in the problem statement, operators should know that the organic loading rate to anaerobic digesters is always given in units of pounds of volatile solids fed to the digester per day per cubic foot of digester volume, **lb VS/d•ft^3**. Since these are the units wanted in the answer, they are entered between heavy vertical lines followed by an equals sign and the blank track.

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$$\left|\frac{\text{lb VS}}{\text{d}\cdot\text{ft}^3}\right| = \frac{\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad}{}$$

When doing most problems, WWTT likes to start the railroad track out on the right-hand side of the equals sign with the units needed in the answer in the numerator. In the list above, the units, lb VS, only appear in one place, 72.8 **lb VS**/100 lb of TS, which is the way WWTT expresses the information given in the problem statement that the TS are 72.8% volatile, meaning 72.8% VS. Because the units, lb VS, need to be in the answer, they are shown in **bold** on both sides of the equals sign.

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$$\left|\frac{\textbf{lb VS}}{\text{d}\cdot\text{ft}^3}\right| = \left|\frac{72.8\ \textbf{lb VS}}{100\ \text{lb TS}}\right| \frac{\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad}{}$$

Once the railroad track is started, all that the required is to cancel out unwanted units, provided, of course, the information has been properly labeled as in the list above. To cancel out lb TS in the denominator, lb TS are entered into the numerator. There is only one other place where lb TS show up in the list above, 4.7 lb TS/100 lb sludge.

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$$\left|\frac{\textbf{lb VS}}{\text{d}\cdot\text{ft}^3}\right| = \left|\frac{72.8\ \textbf{lb VS}}{100\ \cancel{\text{lb TS}}}\right| \left|\frac{4.7\ \cancel{\text{lb TS}}}{100\ \text{lb sldg}}\right| \frac{\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad}{}$$

There is only one other place the units, lb sldg, show up. These are entered next so units cancel.

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lb VS	=	72.8 **lb VS**	4.7 ~~lb TS~~	8.34 ~~lb sldg~~	
d·ft^3		100 ~~lb TS~~	100 ~~lb sldg~~	gal sldg	

There is only one other place the units, gal sldg, show up. These are entered next so units cancel. This entry also puts the unit, d, needed in the answer in the railroad track.

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lb VS	=	72.8 **lb VS**	4.7 ~~lb TS~~	8.34 ~~lb sldg~~	45,000 ~~gal sldg~~	
d·ft^3		100 ~~lb TS~~	100 ~~lb sldg~~	~~gal sldg~~	**d**	

At this point, the railroad track includes the units, lb VS/d, needed in the answer. The units, ft^3, needed in the answer tell us that we have to divide by the volume of the digesters, although the volume given is in gal.

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lb VS	=	72.8 **lb VS**	4.7 ~~lb TS~~	8.34 ~~lb sldg~~	45,000 ~~gal sldg~~		
d·ft^3		100 ~~lb TS~~	100 ~~lb sldg~~	~~gal sldg~~	**d**	418,000 gal	

The gal just entered is canceled with the well known conversion factor, 7.48 gal/ft^3, which also puts the units, **ft^3**, needed in the answer, in the railroad track.

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lb VS	=	72.8 **lb VS**	4.7 ~~lb TS~~	8.34 ~~lb sldg~~	45,000 ~~gal sldg~~		7.48 ~~gal~~
d·ft^3		100 ~~lb TS~~	100 ~~lb sldg~~	~~gal sldg~~	**d**	418,000 ~~gal~~	**ft^3**

Since all the units have canceled except the ones needed in the answer, **lb VS/d·ft^3**, the math is done and the arithmetic gives the answer:

72.8 x 4.7 x 8.34 x 45,000 x 7.48 ÷ 100 ÷ 100 ÷ 418,000 = **0.23 lb VS/d·ft^3**.

Anaerobic digesters are organically loaded over a range, 0.15 to 0.40 lb VS/d·ft^3. With that said, most of the time anaerobic digesters are organically loaded around 0.2 lb VS/d·ft^3 as demonstrated in this Problem of the Day.