Problem of the Day

2015.Jun.10

Problem of the Day

The VSR averages 60.1% (from yesterday's Problem of the Day). The digester gas production ranges from 12.5 to 17.8 ft^3 of gas produced per pound of VS destroyed. For a VS loading of 15,500 lb/d, calculate the ft^3 of gas produced daily for the low and high gas production rates (12.5 and 17.8 ft^3 gas/lb $VS_{destroyed}$, respectively).

Introduction

For a well operating anaerobic digester, gas production typically varies between 12 and 18 ft^3 gas/lb $VS_{destroyed}$. The objective of today's problem is to see what impact gas production on a VS destroyed basis has on the amount of gas produced per day.

Solution

There are obviously two parts to this question: on calculation at the low gas production rate, the other at the high rate. In both calculations the units desired in the answer are ft^3 gas/d so these are entered between heavy vertical lines followed by an equals sign and the blank solution bridge.

Problem of the Day: The VSR averages 60.1% (from yesterday's Problem of the Day). The digester gas production ranges from 12.5 to 17.8 ft^3 of gas produced per pound of VS destroyed. For a VS loading of 15,500 lb/d, calculate the ft^3 of gas produced daily for the low and high gas production rates (12.5 and 17.8 ft^3 gas/lb $VS_{destroyed}$, respectively).

$$\left| \frac{ft^3 \text{ gas}}{d} \right| = \text{\_\_\_\_\_}$$

The information given in the problem statement is summarized here with the appropriate units (especially note units on VSR):

1. VSR = 60.1% = 60.1 lb $VS_{destroyed}$/100 lb $VS_{applied}$
2. Gas production, low = 12.5 ft^3 gas/lb $VS_{destroyed}$
3. Gas production, high = 17.8 ft^3 gas/lb $VS_{destroyed}$
4. VS loading = 15,500 lb $VS_{applied}$/d

The first part of the question calculates the ft^3 of gas produced per day using the low $VS_{destroyed}$-based gas production. Since it (No. 2) has the units needed in the answer, ft^3 gas (shown in bold), it starts the solution bridge.

$$\left| \frac{\mathbf{ft^3 \text{ gas}}}{d} \right| = \left| \frac{12.5 \ \mathbf{ft^3 \text{ gas}}}{\text{lb } VS_{destroyed}} \right| \text{\_\_\_\_\_}$$

The units in the denominator, lb $VS_{destroyed}$, need to be canceled. The VSR is the only other given in the list (No. 1) with these units so it is entered next on the solution bridge. The unwanted units cancel, denominator and numerator.

$$\left| \frac{\mathbf{ft^3 \text{ gas}}}{d} \right| = \left| \frac{12.5 \ \mathbf{ft^3 \text{ gas}}}{\cancel{\text{lb } VS_{destroyed}}} \right| \left| \frac{60.1 \ \cancel{\text{lb } VS_{destroyed}}}{100 \text{ lb } VS_{applied}} \right| \text{\_\_\_\_\_}$$

The units in the denominator, lb $VS_{applied}$, need to be canceled. The VS loading is the only other given in the list (No. 4) with these units so it is entered next on the solution bridge. The unwanted units cancel, denominator and numerator. Since all the units have canceled except those needed in the answer, the solution bridge is complete. The arithmetic gives the answer to the first part of the problem.

$$\left| \frac{\mathbf{ft^3 \text{ gas}}}{\mathbf{d}} \right| = \left| \frac{12.5 \ \mathbf{ft^3 \text{ gas}}}{\cancel{\text{lb } VS_{destroyed}}} \right| \left| \frac{60.1 \ \cancel{\text{lb } VS_{destroyed}}}{100 \ \cancel{\text{lb } VS_{applied}}} \right| \left| \frac{15{,}500 \ \cancel{\text{lb } VS_{applied}}}{\mathbf{d}} \right|$$

12.5 x 60.1 x 15,500 ÷ 100 = **<u>116,444 ft^3 gas/d</u>**.

The second part of the question calculates the ft^3 of gas produced per day using the high $VS_{destroyed}$-based gas production. Since it (No. 3) has the units needed in the answer, ft^3 gas (shown in bold), it starts the solution bridge as before.

ft^3 gas	=	17.8 **ft^3 gas**	
d		lb $VS_{destroyed}$	

The units in the denominator, lb $VS_{destroyed}$, need to be canceled. The VSR is the only other given in the list (No. 1) with these units so it is entered next on the solution bridge. The unwanted units cancel, denominator and numerator.

ft^3 gas	=	17.8 **ft^3 gas**	60.1 ~~lb $VS_{destroyed}$~~	
d		~~lb $VS_{destroyed}$~~	100 lb $VS_{applied}$	

The units in the denominator, lb $VS_{applied}$, need to be canceled. The VS loading is the only other given in the list (No. 4) with these units so it is entered next on the solution bridge. The unwanted units cancel, denominator and numerator. Since all the units have canceled except those needed in the answer, the solution bridge is complete. The arithmetic gives the answer to the second part of the problem.

ft^3 gas	=	17.8 **ft^3 gas**	60.1 ~~lb $VS_{destroyed}$~~	15,500 ~~lb $VS_{applied}$~~
d		~~lb $VS_{destroyed}$~~	100 ~~lb $VS_{applied}$~~	**d**

17.8 x 60.1 x 15,500 ÷ 100 = **<u>165,816 ft^3 gas/d</u>**.

Discussion

Not surprisingly the more volatile solids converted to gas (12.5 to 17.8 ft^3 gas/lb $VS_{destroyed}$), the more gas is produced per day for the same VS load (116,444 to 165,816 ft^3 gas/d). As more emphasis is being placed on increasing gas and energy production in anaerobic digesters and co-generation units, an obvious question arises: Is the conversion of volatile solids to gas controlled by operators?

Richard Jones and Peter Dold of EnviroSim Associates Ltd., presented an interesting paper at Weftec 2013 entitled, “Misconceptions and Realities of Anaerobic Sludge Digestion Process Performance.” What was interesting about their modeling results was the two factors that most strongly influence gas production in anaerobic digesters are essentially characteristics of the wastewater and not in the control of operators: (1) the inorganic suspended solids concentration in the raw influent (they did their work using COD, not TSS), and (2) the performance (i.e., removal efficiency) of primary clarification.

What makes wastewater treatment so interesting is everything is related to everything else!

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.