Problem of the Day

2015.Aug.06

Problem of the Day

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. The digested sludge has a VS content of 53.2%. The VSR is 60.5%. If each pound of VS destroyed in the digesters yields 16.4 ft^3 of digester gas, calculate the amount of gas produced daily.

Introduction

This is the sixth 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.

The process objective of digesters, anaerobic or aerobic, is the reduction of volatile solids (VS). "Reduction" isn't the greatest choice of words nor is "destruction" because the organic carbon in the VS isn't reduced or destroyed but **converted** to methane (CH_4) and carbon dioxide (CO_2). Because the carbon in digester gas (typically about **65% CH_4, 34% CO_2 and 1% other inert gases**) comes from the organic carbon in the VS influent to anaerobic digesters, it shouldn't be surprising that a key operational performance indicator is how many ft^3 of digester gas are produced per pound of VS "destroyed," which ranges from 12 to 18 ft^3 gas/lb $VS_{destroyed}$ for well operated anaerobic digesters. Indeed, in today's Problem of the Day, gas production is given as 16.4 ft^3 gas/lb $VS_{destroyed}$.

As discussed in previous Problems of the Day, WWTT labels things in a very specific way. This labeling approach significantly eases the computations that operators have to do for certification exams. Done properly, it makes problem solving failsafe (i.e., mistakes are hard to make) and foolproof (i.e., you don't have to have tremendous math skills to do the problems correctly). For example, WWTT labels the VSR very specifically. The VSR for this series of Problems of the Day was calculated yesterday and found equal to 60.5%. WWTT labels this: 60.5 lb $VS_{destroyed}$/100 lb $VS_{applied}$. With this labeling convention, one can appreciate that the VSR ties together what's coming down the pipe to the digester ($VS_{applied}$) with what's going "up in smoke" in the digester gas ($VS_{destroyed}$).

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
10. VS content in digested sludge = 53.2% VS
11. VSR = 60.5% = 60.5 lb $VS_{destroyed}$/100 lb $VS_{applied}$
12. Gas production = 16.4 ft^3 gas/lb $VS_{destroyed}$

Today's problem asks to calculate "amount of gas produced daily." What is meant by that? Certainly "daily" means "per day." Then, one has to know that the "amount of gas" produced by anaerobic digesters is measured in cubic feet (ft^3). Putting these together, we see that the units needed in the answer are ft^3 gas/d. These units, then, are put between heavy vertical lines, as always, followed by an equals sign and the blank solution bridge.

Problem of the Day: 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. The digested sludge has a VS content of 53.2%. The VSR is 60.5%. If each pound of VS destroyed in the digesters yields 16.4 ft^3 of digester gas, calculate the amount of gas produced daily.

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

The only place the units ft^3 gas appear in the list is in the numerator of No. 12. This, then, is entered to start the solution bridge.

$$\frac{\mathbf{ft^3\ gas}}{d} = \frac{16.4\ \mathbf{ft^3\ gas}}{lb\ VS_{destroyed}} \text{\_\_\_\_\_}$$

As mentioned above, the VSR, labeled specifically the way WWTT recommends it be labeled, ties together what is entering the digester (lb $VS_{applied}$) to what is being converted in the digester to gas (lb $VS_{destroyed}$). In order to cancel the units lb $VS_{destroyed}$, the VSR is entered exactly the way it is given in the list (No. 11). This is the only item listed that has the units $VS_{destroyed}$ in it, which cancel.

$$\frac{\mathbf{ft^3\ gas}}{d} = \frac{16.4\ \mathbf{ft^3\ gas}}{\cancel{lb\ VS_{destroyed}}} \frac{60.5\ \cancel{lb\ VS_{destroyed}}}{100\ lb\ VS_{applied}} \text{\_\_\_\_\_}$$

There is nothing in the list with the units lb $VS_{applied}$. As has been discussed several times in this series of Problems of the Day, VSS removed in the primary clarifiers are taken as the VS fed, or applied, to the digesters in the primary sludge. No. 6 in the list, therefore, is repeated with the appropriate labeling:

6. Pounds VSS/d removed in primaries = pounds VS/d applied to digesters = 80,284 lb $VS_{applied}$/d

This is entered in the solution bridge so like units cancel, denominator and numerator.

$$\frac{\mathbf{ft^3\ gas}}{\mathbf{d}} = \frac{16.4\ \mathbf{ft^3\ gas}}{\cancel{lb\ VS_{destroyed}}} \frac{60.5\ \cancel{lb\ VS_{destroyed}}}{100\ \cancel{lb\ VS_{applied}}} \frac{80{,}284\ \cancel{lb\ VS_{applied}}}{\mathbf{d}}$$

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

Problem of the Day: 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. The digested sludge has a VS content of 53.2%. The VSR is 60.5%. If each pound of VS destroyed in the digesters yields 16.4 ft^3 of digester gas, calculate the amount of gas produced daily.

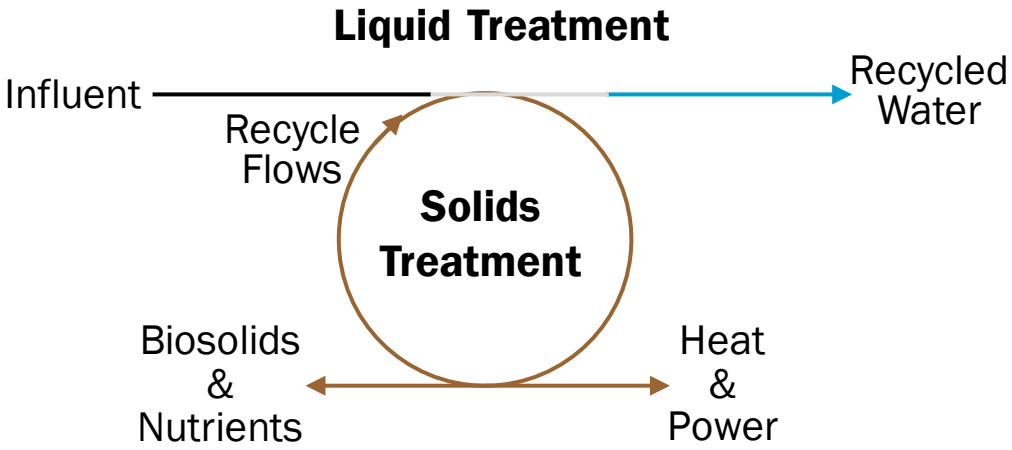
$$\frac{\textbf{ft}^3\ \textbf{gas}}{\textbf{d}} = \frac{16.4\ \textbf{ft}^3\ \textbf{gas}}{\cancel{\text{lb VS}_{\text{destroyed}}}} \times \frac{60.5\ \cancel{\text{lb VS}_{\text{destroyed}}}}{100\ \cancel{\text{lb VS}_{\text{applied}}}} \times \frac{80{,}284\ \cancel{\text{lb VS}_{\text{applied}}}}{\textbf{d}}$$

16.4 x 60.5 x 80,284 ÷ 100 = **796,578 ft^3 gas/d**.

Discussion

"Thar's gold in them thar hills!" (A misquote, according to Wikipedia, from a speech by M.F. Stephenson attempting to dissuade Dahlonega, Georgia gold miners from moving to California for the gold rush there.)

While the overarching objective of wastewater treatment will always be public health and environmental protection, more and more wastewater treatment plants will become resource recovery facilities in the future. It has to be. The essence of resource recovery is captured in this simplified schematic of a resource recovery facility showing the recovery of usable water (recycled water), heat and power (from the gas production calculated in today's Problem of the Day, and biosolids and nutrients (recovering organic carbon, nitrogen and phosphorus).



Schematic of a Resource Recovery Facility

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.