Problem of the Day
2014.Nov.24

Discussion

The Water Environment Federation is the trade organization for water professionals, including wastewater treatment operations professionals (http://wefcom.wef.org/home). Individual states, or groups of states, sponsor local chapters. On October 29, 2014, I gave a 6-hour Math for Operators Workshop at the annual conference of the Pacific Northwest Clean Water Association (PNCWA). PNCWA represents Idaho, Oregon and Washington (http://www.pncwa.org/). All operators should seriously consider joining their local association. In California it is the California Water Environment Association (http://www.cwea.org/).

Long story short: I randomly covered a series of math problems in the PNCWA workshop, and I have been requested by several attendees to send them the problems. Instead, I am going to post them here (starting with the 2014.Nov.04 Problem of the Day). They are good practice for all visitors to WWTT's Problem of the Day.

For those of you who may be new to WWTT's Problem of the Day, we insert a page break before and after the problem statement so you can print it without looking at the solution. **See what you can do to solve the problem before looking at the solution**.

Wastewater treatment is very expensive and getting more so at the same time ratepayers are demanding cost containment. Electricity is the second biggest O&M cost at most WWTPs. Methane from anaerobic digesters can be used to power engines that drive electrical generators, and the heat from the engines can be used to maintain mesophilic temperatures in the digesters. The methane-powered generators are called cogeneration, or "**cogen**," units and also combined heat and power (**CHP**) units. **As electricity gets more and more expensive, the methane produced in anaerobic digesters gets more and more valuable**.

Today's Problem of the Day looks at digester gas production. In doing these kinds of problems it is useful to remember that the organic carbon in the volatile solids destroyed in anaerobic digesters isn't really destroyed but converted, primarily, to **methane** (**CH_4**) and **carbon dioxide** (**CO_2**), both of which are gases that are removed. For those of you just entering the wastewater treatment profession, you should remember that digester gas is typically reported as having:

65% CH_4

34% CO_2

1% other gases (including hydrogen sulfide)

Problem of the Day

Given the following information, calculate the cubic feet (ft^3) of gas produced per pound of volatile solids destroyed:

- Primary sludge flow = 275,000 gal/d
- Primary sludge TS concentration = 5.3%
- Primary sludge VS concentration = 72.5%
- Digested sludge VS concentration = 55.6%
- Gas production = 760,000 ft^3/d
- **Calculate: ft^3 gas produced per lb VS destroyed**.

Discussion

All digester gas problems are started by calculating the VSR, which stands for **volatile solids reduction** (think "destruction"), even if the question does not ask for the VSR to be calculated.

Following is a list of the information given in the problem and needed to find the solution, labeled the way WWTT advocates so the units will do the math for you:

- 275,000 gal sldg/d
- 5.3% TS = 5.3 lb TS/100 lb sldg
- Sludge density = 8.34 lb sldg/gal sldg (assumed)
- 72.5% TS = 72.5 lb VS/100 lb TS (note: these are VS influent to the digester or applied, $VS_{applied}$)
- 72.5% influent VS = 0.725 (for VSR calculation)
- 55.6% digested VS = 0.556 (for VSR calculation)
- Gas production = 760,000 ft^3 gas/d

The problem statement does not give the density of the sludge. Generally speaking, if the TS concentration is less than approximately 7%, the density of water can be confidently assumed. If the reader forgets that density is required, it is helpful to note that both gallons of sludge (gal sldg) and pounds of sludge (lb sldg) appear in the list of information given (275,000 **gallons of sludge**/day and 5.3 pounds of TS/100 **pounds of sludge**, respectively). The physical constant that allows gallons to be converted to pounds and pounds converted to gallons is the density. Note, however, it is very important to label the density of the sludge as shown. You would never want to mistake primary sludge, for example, for water, so label it accordingly!

Solution

In all digester-gas type problems, the first step will always be to calculate the VSR.

$$\textbf{VSR (\%)} = \frac{(0.725 - 0.556)}{0.725 - (0.725 \times 0.556)} \times 100$$

VSR = 52.5%.

As discussed in the 2014.Sept.28 Problem of the Day (http://wastewatertechnologytrainers.com/wp-content/uploads/2014/09/2014.Sep_.281.pdf), the VSR is expressed in the following manner.

$$52.5\%\ \text{VSR} = \frac{52.5\ \text{lb}\ VS_{destroyed}}{100\ \text{lb}\ VS_{applied}}$$

Labeling the VSR in this manner will basically do the problem for you, as demonstrated below. Note, "destroyed" and "applied" are abbreviated "**dest**" and "**app**" below, respectively.

Problem of the Day: Given the following information, calculate the cubic feet (ft^3) of gas produced per pound of volatile solids destroyed:

- Primary sludge flow = 275,000 gal sldg/d
- Primary sludge TS concentration = 5.3% = 5.3 lb TS/100 lb sldg
- Primary sludge density = 8.34 lb sldg/gal sldg (assumed)
- Primary sludge VS concentration = 72.5% = 72.5 lb VS$_{app}$/100 lb TS
- Digested sludge VS concentration = 55.6% (only used in VSR calculation)
- Gas production = 760,000 ft^3 gas/d
- **Calculate: ft^3 gas/lb VS$_{dest}$.**

ft^3 gas	=	760,000 **ft^3 gas**	~~d~~	~~gal sldg~~	100 ~~lb sldg~~	100 ~~lb TS~~	100 ~~lb VS$_{app}$~~
lb VS$_{dest}$		~~d~~	275,000 ~~gal sldg~~	8.34 ~~lb sldg~~	5.3 ~~lb TS~~	72.5 ~~lb VS$_{app}$~~	52.5 **lb VS$_{dest}$**

All the units have canceled except those needed in the answer, **ft^3 gas/lb VS$_{dest}$**, so the math is done. The arithmetic completes the problem:

760,000 x 100 x 100 x 100 ÷ 275,000 ÷ 8.34 ÷ 5.3 ÷ 72.5 ÷ 52.5 = **16.4 ft^3 gas/lb VS$_{dest}$**.

Label everything the way we have shown, and then it is a simple matter of working down the railroad track canceling out the units you don't want and keeping the units you do want!

Happy calculating!