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. The digested sludge has a VS content of 53.2%. Calculate the VSR.

Introduction

This is the fifth 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 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." Whenever a calculation is being made to determine gas production or heat value in the gas, the VSR calculation must be done first. This calculation is the subject of today's Problem of the Day.

The volatile solids reduction (VSR, some say "removal" instead of "reduction") is a very important calculation for both anaerobic and aerobic digesters. For example, the "503 Regs," which regulate biosolids disposal, require a VSR in the plant's digesters of at least 38% for land application of either Class A or Class B biosolids. I worked with one operator who ran such a high SRT in his oxidation ditch (greater than 60 days!) that he was unable to meet this 38%-VSR requirement through his aerobic digester: the volatile solids in the WAS was already low before getting to the digester, and as far as EPA is concerned, you can't take credit for volatile solids destroyed upstream of digestion. Also, for any certification exam problem that has anything to do with anaerobic digester gas, the VSR will have to be calculated first as stated above.

The VSR calculation is simple enough when looking at the equation:

$$\text{VSR, \%} = \frac{(.VS_{in} - .VS_{out}) \times 100}{.VS_{in} - (.VS_{in} \times .VS_{out})}$$

where $.VS_{in}$ is the **decimal** percent of the sludge influent to the digester and $.VS_{out}$ is the **decimal** percent of the digested sludge, which, to be politically correct, should be called biosolids since it is post digestion. VSR is always reported as a percent.

At least in California, the calculators allowed into certification exams don't like this equation very much. As a result, examinees tend to do the calculation in the numerator and write down the number, then do the calculation in the denominator and write down the number, and then divide the numerator by the denominator. This is an okay strategy, but not one that WWTT recommends. The reason: every time you write a number down from the display of your calculator and every time you punch in a number from the page into your calculator, you risk transposing numbers, especially under the pressure of a certification exam. Be careful. WWTT always emphasizes the following when calculating the VSR using this equation:

1. The volatile solids percentages must be expressed as decimals.
2. Do not round any numbers as you work through this calculation until the end; the calculation is sensitive to rounding.
3. Practice, practice, practice doing the VSR calculation before the exam (practice means getting the correct answer).

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

The VSR calculation doesn't work very well using the solution bridge; it's one of those calculations operators do that they just have to plug the numbers into the equation and turn the crank.

But wait a second, the problem didn't give us the %VS in the primary sludge going to the digester. Or did it?

There are a couple of very important assumptions that have already been discussed in the last few days having to do with solids removal in primary clarifiers and primary sludge concentrations. All operators need to fully understand these assumptions and the impacts of them on downstream processes, both in the liquid and solids treatment trains. Reviewing these:

1. TSS and VSS are removed in primary clarifiers at the exact same rate.
2. TSS and VSS removed from primary clarifiers are treated as TS and VS in primary sludge.

The first of these assumptions means that the percent volatile solids in the primary influent is the same percent volatile solids in the primary effluent and the percent volatile solids in the primary sludge. The second of these assumptions means that the TSS and VSS removed from the influent are the TS and VS applied to the digesters in the primary sludge flow.

Again, all operators need to fully understand these assumptions and the impacts of them on downstream processes, both in the liquid and solids treatment trains.

So the numbers we need to do the VSR calculation are (remember decimals!):

1. $.VS_{in} = 0.742$
2. $.VS_{out} = 0.532$

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$$\text{VSR, \%} = \frac{(0.742 - 0.532) \times 100}{0.742 - (0.742 \times 0.532)}$$

VSR = **<u>60.5%</u>**.

Discussion

What does the VSR mean? A VSR of 60.5%, for example, means that for every 100 pounds of VS applied or fed to the digester, 60.5 pounds are destroyed. Well, not really "destroyed" because the carbon in the VS that are destroyed (reduced) is CH_4 and CO_2 in the digester gas. The reason we use the word "destroyed" is because digester gas production is often expressed as cubic feet of gas produced per pound of volatile solids destroyed. The way WWTT expresses the VSR when doing digester gas

problems is, for example, 60.5 lb $VS_{destroyed}$/100 lb $VS_{applied}$. This labeling is very, very useful when doing digester gas problems.

The quest at more and more wastewater treatment plants and resource recovery facilities to reduce energy expenditures has put great emphasis on anaerobic digester performance as the methane digesters produced, burned in combined heat and power units, becomes more and more valuable. Through the use of advanced anaerobic digestion systems that are loaded more aggressively and co-digestion of carbon-rich feedstocks such as FOG (fats, oils and grease) and food wastes, facilities are substantially reducing the amount of energy they buy off the grid. The East Bay Municipal Utilities District's wastewater treatment plant in Oakland, California, has become an energy producer by generating more electricity than it uses (http://www.epa.gov/region9/waste/features/foodtoenergy/).

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.