Measuring Biogas

A number of factors on both the digestion side and the biogas phase need to be monitored for best performance and fault finding, but first a couple of points. This article refers to "biological biogas" – a renewable energy formed from moist, readily degradable organic matter by microbial processes, commonly at body or ambient temperatures. Thermal gasification processes are entirely different, best applied to dry materials, able to handle less degradable material like wood/lignin and produce different gases (including Carbon Monoxide) via gasification (producer gas), pyrolysis and syngas.

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The second point applies to measurement in general – there are a range of accuracies required and many techniques to measure most things. A field operator really only needs to know that today's conditions are similar to yesterdays (or different!) so only needs comparative measurements that are quickly, easily and cheaply obtained. This has received some discussion in the Anaerobic Digestion group on LinkedIn. A scientist, on the other hand, needs to know the absolute value to at least reasonable accuracy and would have the skills and time/technicians to operate more complex equipment. In a biogas operation the field operator does daily monitoring using simple techniques and calls a consultant with access to more sophisticated equipment when monitoring indicates a potential problem.

Anaerobic digestion, the process that produces biogas, is a sequence of steps in which larger organic molecules like proteins and starches are broken down into simpler molecules in a number of steps, each facilitated by a consortium of microbes. The "waste" of each step becomes the "food" of the next step, but too high a concentration of waste/food can become inhibitive to either the previous or following stage of the process. As Carbon Dioxide (CO_2) is produced through the process a carbonate/bicarbonate buffering system develops that keeps a healthy digester close to neutral pH, as long as the symbiotic microbial relationships are all working properly.

Often the first indication of possible failure is a change in the gas phase, so this is a good thing to monitor. At the simplest level if the volume of gas being produced is consistent with the input to the digester and if the gas remains combustible all is well. If the volume of gas is falling while the organic loading rate (or the feed input rate) is increasing or if the percentage of methane is falling below what has been the normal range the digester is heading for trouble and the best action is to cease feeding.

The fact that biogas will self-combust with a pale blue flame (burn without ignition source once ignited) indicates over 50% methane, if the flame goes out when the ignition is off there is less than 50% methane and if the "biogas" extinguishes a flame there is mainly CO_2 present. A "Syringe Protocol", using simple equipment and the fact that Sodium/Potassium Hydroxide absorbs CO_2 but not Methane (CH_4 – the fuel part of biogas known as natural gas or marsh gas), is a step up in accuracy for field measurements – see http://bit.ly/SyringeProtocol.

Other methods of gas analysis, with increasing cost and complexity, include Draeger tubes, hand held gas analysers of various types, mounted continuous monitors and gas chromatographs with the appropriate column and detector. A method of continuously monitoring gas quality, allowing for alarms and/or logging to be implemented, by bubbling biogas through a sodium bicarbonate solution and measuring pH of the solution has also been proposed and successfully demonstrated.

While on the topic of gas it is important to know that biogas may contain small amounts of Hydrogen Sulphide (H_2S), Ammonia (NH_3) and other volatile organics. For safety reasons flammable gas alarms should be installed and H_2S alarms mandatory for personnel working around digesters, with NH_3 also monitored because of health risks.

A variable volume storage or the time that biogas is being used at a set rate (by a burner or flare) may provide sufficient information about gas production, or there are various gas flow meters available for monitoring the volume of biogas produced. In selecting a gas meter the corrosive nature of biogas, which is usually saturated with water unless dried prior to metering, needs to be taken into account.

On the digestion side the main variables to be aware of are the operating temperature, the volume of liquid being fed, the organic content of the input (and output) measured as Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) or Volatile Solids (VS) (which are all interrelated), the alkalinity of the digester and the short chain fatty acid profile.

If a heating system is part of the digester setup (which it often is, depending on ambient conditions and design requirements) a drop in temperature is an indication of heater malfunction. If there is no heating system it may be necessary to reduce the volume fed into the digester during the cooler time of the year to avoid overloading the digester and causing failure. This will depend on the design philosophy adopted for the installation. A range of temperature monitoring options from a thermometer or hand held probe dipped into the digester output as part of the daily check to multiple thermocouples logged every hour are available.

Logging the gas volume, influent volume and temperature can be valuable in fault finding as a change in a variable may be noticed in time to avert failure. If failure does occur the data record may allow determination of the cause when looking back to see what changed first.

Operating temperature determines the minimum Hydraulic Retention Time (HRT) that can be used – the higher the temperature (up to about 60 °C) the faster the microbes reproduce and the shorter the HRT can be. Once the HRT is decided the digester operating volume determines the volume of influent that can be fed into the digester. For example a 100 m³ Continuous Flow Stirred Tank digester operating at 35 °C may have an HRT of 12 days, so would be fed 100/12 or 8.33 m³ of effluent per day. Much shorter HRTs (down to 1 day) are possible with Packed Bed or Suspended Growth digesters, so only an 8.33 m³ digester would be needed to handle the same waste as above. As with gas flow measurement the particular properties of the influent and the purpose of taking measurements will have to be

considered when selecting a measurement system – maybe measuring pump run time or pump electricity consumption will give an adequate idea of liquid volume input under some circumstances.

Volatile Solids is perhaps the easiest way of estimating biological content of the influent, requiring just a muffle furnace and accurate scales, but takes some time for drying the sample. BOD and COD are standard procedures with various instruments now available to help facilitate the processes. It is important not to push too much organic matter into the digester, as organic overloading can lead to digester failure by inhibiting microbial action.

Because the digester system is well buffered pH on its own usually only indicates failure after the damage is done, but may be a useful adjunct to field measurements by the operator. A drop in Alkalinity, indicating a loss of buffering capacity caused by an increase in acid concentration, gives much better warning of impending failure as it can be observed before pH itself changes. Alkalinity can be determined in the field by titration to two end points, using sulphuric acid as the titrant. A simple calculation gives the Alkalinity value.

A FOS/TAC evaluation has been developed to determine the ratio between alkalinity and total fatty acids and can be automated for determination within 30 minutes. A paper by Anderson and Yang (1992) gives some details.

Since complex organic molecules are broken down into simpler molecules in the anaerobic digestion process, passing through short chain fatty acids to methane and carbon dioxide, it may prove useful to monitor the relative levels of valeric, butyric, propionic and acetic acid that occur towards the end of this process. Acetic acid should always have double the value of propionic acid and increasing propionic acid is an alarm that the process is becoming unstable (Stockl et al., 2012). Titration, spectrophotometer and chromatograph methods can be used to determine relative amounts of short chain fatty acids.

References

Anderson, G. and G. Yang (1992). "Determination of bicarbonate and total volatile acid concentration in anaerobic digesters using a simple titration." Water Environment Research 64(1): 53-9.

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