Monitoring and control of anaerobic digestion*

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Abstract

Digesters treating industrial wastes are frequently subjected to fluctuations in both waste composition and organic load, thus necessitating special precautions on the part of the operator to prevent metabolic overloading of the micro-organisms. This paper describes various sensitive indices of digester stability relevant to effective process control and operating reliability at high load rates.

Introduction

Anaerobic treatment of soluble organic industrial wastes is often regarded as an unstable process by engineers, especially when compared with aerobic sewage treatment. Given the particularly complex, concentrated and fluctuating nature of anaerobic substrates and the higher space loading rates required by these systems, it is clear that anaerobic digestion will be a sensitive process. However, it need not be unreliable if properly controlled.

Aside from mechanical failure, the two principal causes of digester failure are:

- metabolic overloading of the micro-organisms and consequent pH drop; and
- loss of biomass.

Whatever the cause of failure, the ultimate result is a retardation or even complete cessation of gasification. Subsequent reactivation is often time-consuming owing to the slow growth rate of rate-limiting bacteria, such as the methanogens. The onus therefore rests both on the designer to provide reliable control arrangements and on the operator to devise overall control strategies to minimise an overload risk.

The present paper examines a number of sensitive indices of imminent overload and consequent performance loss. These parameters have proved effective for process control. While the emphasis has been laid upon suspended-growth systems for soluble waste treatment, the concepts discussed are also of relevance for anaerobic systems treating solid wastes such as sewage sludge and manures.

Relationship between cation availability and substrate buffer potential

The degree of process control required for treating a given industrial waste is largely governed by its chemical composition. Cation availability is particularly important since it determines the alkalinity of pH of the digester system. Thus, e.g. nitrogenous compounds are decomposed and reduced to ammonia, a proportion of which is metabolised by the process organisms while the remainder is combined with the liberated carbon dioxide to produce stable inorganic compounds which act as buffers, e.g. NH_4HCO_3.

The influence of cation availability on buffer potential is illustrated in Figure 1 which gives data from anaerobic studies on various wastes of different COD. Thus, e.g. the low availability of nitrogen and other cations in brewery wastes (total cations, 2 me/l) results in a digester effluent of low buffer capacity - insufficient to allow an acceptable safety factor for a high-rate process. Addition of alkali for pH control is therefore essential for systems with a natural alkalinity below 1 000 *mg/l* as $CaCO_3$. If a sodium salt is used for pH control care must be taken not to exceed the reported sodium-ion inhibitory concentration of 3 500 to 5 500 mg/l Na(McCarty, 1964).

In contrast, digesters treating wine distillery wastes (total cations, 160 me/l) develop an alkalinity of 6 000 *mg/l* as $CaCO_3$. This is due to the high potassium bitartrate feed concentrations and consequent release of potassium ions, available for buffering during digestion.

Volatile acid: alkalinity: pH ratios for digester control

As mentioned above, ammonium ion concentration plays an important part in determining the bicarbonate alkalinity or buffering capacity of the digester system. Increasing volatile acid levels are neutralised by the bicarbonate alkalinity and give rise instead to, as it were, 'volatile acid-salts' alkalinity. Under these conditions bicarbonate alkalinity can be approximated by means of the following formula (McCarty, 1964):

$$BA = TA - (0{,}85)(0{,}833)\,VA$$

Where:

BA = bicarbonate alkalinity (mg/l $CaCO_3$)
TA = total alkalinity (mg/l $CaCO_3$)
VA = volatile acid (mg/l CH_3COOH)
0,85 = Only 85% of volatile acid-alkalinity is measured by titration of total alkalinity to pH 4.
0,833 = Convert volatile acid units to equivalent alkalinity units.

An increase in volatile acids over and above the available cation component of the alkalinity results in the formation of free volatile acids and partial destruction of buffering potential, accompanied by pH drop and decreased gas production.

The relationship between volatile acid level, alkalinity and pH determined in the course of a recent study on anaerobic digestion of brewery waste is illustrated in Figure 2 (Ross, 1985). It will be seen that a bicarbonate alkalinity deficit occurs at pH less than 5,8. Although probably the principal parameter governing the stability of the digestion process, pH is not a sensitive indicator since by the time the pH falls, alkalinity has already declined. Digester pH should if possible be held within the 6,8 to 7,2 range.

Relationship between pH and volatile acids dissociation index

A pH-dependent equilibrium exists between the ionised and un-

*Revised paper. Originally presented at the Symposium on Anaerobic Digestion, Bloemfontein, 1986.
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Received 19 February 1987.