CONTROL OF ANAEROBIC DIGESTION

I. INTRODUCTION.

Although the anaerobic digestion process has many advantages such as a low production of waste sludge, low power requirements for operation, and production of a useful product, methane, it has a poor record with respect to process stability as evidenced by the many reports of "sour" or failing digesters. Adequate control is therefore essential to the success of the process. Some of the key factors of importance are:

A. Uniform and Continuous Loading. Since the process involves reactions occuring in series with inhibitory intermediates (volatile acids) it is important to prevent too high a concentration of volatile acids in the reactor. Uniform and continuous loading is very beneficial in this respect.

B. Concentration of Feed Sludge. The pumping of too much water with the organic solids can result in too low a retention time in the digester with subsequent failure of the process.

C. Mixing. Good mixing will insure that segregation does not take place which can have the effect of reducing the volume of digester available for reaction. In addition, mixing will distribute any toxic substances in the feed throughout the tank volume thereby reducing their concentration. Good mixing is also essential to increase reaction rates.

D. Grit Removal. Grit should be removed before sludge is pumped to the digester. Otherwise, it will accumulate in the bottom of the tank and over a period of time greatly decrease the volume available for digestion.

E. Records & Laboratory Analyses. The proper measurements and analyses must be made at sufficiently frequent intervals to insure adequate process control. Material balances should be established for all components entering and leaving the digester and the efficiency of operation calculated. These values should be plotted vs. time and displayed as graphs in the plant control room.

II. OPERATIONAL PARAMETERS.

A. Process Loading. A constant record should be maintained of digester loading. This can be calculated from the volume of raw sludge pumped per day, the total and volatile solids in the raw sludge, and the tank volume. Loading should be expressed as both lb. of volatile solids per cu ft of digester per day (0.2-0.4) and as retention time (10-15 days). Loadings are simple to calculate, let the operator know when he is reaching capacity, and often help to explain "upsets".

B. Process Efficiency. A constant record should also be maintained of process efficiency. This may be expressed as percentage destruction of volatile solids or percentage removal of input COD. The amount of COD removed can be calculated from the rate of methane production.

C. Temperature. The temperature in the digester should be maintained between 90-95°F. The methane bacteria are considered to be quite sensitive to sudden changes in temperature.

D. Gas Production Rate. For domestic sewage sludge, the gas produced should average between 16 and 18 cu ft (STP) per lb of volatile solids destroyed. Decreasing gas production rates sometimes indicate that the process is not operating properly; however, this can also be caused by non-uniform feeding or changes in carbon dioxide content of the gas due to chemical reactions instead of biological reactions. The percentage of carbon dioxide in the gas can be increased or decreased by chemical reactions.

E. Methane Production Rate. This should be one of the better indicators of impending operational problems since the methane bacteria represent the rate limiting step in the process. Also, methane does not participate in any chemical reactions in the digester as does carbon dioxide. The % CH_4 in gas from digesting sewage sludge is 65-70%.

F. Alkalinity. The alkalinity in the digester serves to buffer the system thus preventing sudden changes in pH. The buffering system is the carbon dioxide-bicarbonate-carbonate system with the ammonium ion as the major cation. The alkalinity is dependent on, among other things, the composition and concentration of the feed sludge. Typical values are 2,000 to 4,000 mg/l as $CaCO_3$.

G. pH. The methane bacteria are relatively sensitive to pH and pH control is therefore an important aspect of anaerobic digestion. The process operates best at pH values between 6.6 and 7.4.

H. Volatile Acids. The concentration of volatile acids in the digester is considered to be the best indicator of digester condition. A sudden increase in volatile acid concentration is frequently one of the first indications of impending operational problems. Volatile acid concentrations found in well operated sewage sludge digesters vary from 50 to 300 mg/l expressed as acetic acid.

I. Interactions Betweem Variables. There are strong interactions between several of the parameters mentioned and for this reason no single parameter is adequate for digester control. Examples of some of the more important interactions are:

1. An increase in volatile acid concentration will:

   a. Decrease alkalinity through conversion of bicarbonate to carbon dioxide.
   b. Increase the percentage of carbon dioxide in the gas produced.
   c. Decrease the pH.

2. It is believed that inhibition of the methane bacteria by volatile acids is due to the unionized fraction of the acid. A decrease in pH will increase the unionized fraction.

III. MEASUREMENTS AND ANALYSES.

The control of anaerobic digestion requires frequent measurements and analyses of the raw, intermediate, and end products of digestion. Standard Methods for Examination of Water & Wastewater or Simplified Lab Procedures for Wastewater Examinations should be consulted as to the specific procedures for making the analyses. Whenever possible continuous recording instruments should be used for the measurement or analysis.

A. Raw Sludge

1. Total and volatile solids concentrations
2. Volume of sludge pumped to the digester per day
3. pH
4. Alkalinity

B. Sludge in Digester

1. Temperature
2. pH
3. Total and volatile solids concentrations
4. Volatile acids
5. Alkalinity
6. Quantity transferred to second stage or other points

C. Digested Sludge Withdrawn

1. Quantity
2. Total and volatile solids concentration

D. Gas

1. Rate of gas production
2. Composition of gas (CH_4, CO_2, H_2S)
3. Temperature

III. E. Supernatent

1. Quantity removed
2. pH
3. Volatile acids
4. Total and volatile solids concentration
5. Suspended solids
6. BOD or COD

F. Other (as needed)

1. Temperature throughout the tank to indicate the effectiveness of mixing.
2. Sounding of the tank to detect the presence of scum or grit deposits
3. N_2 and O_2 analysis of digester gas to detect the presence of leaks.