

UPSET CONDITIONS IN ANAEROBIC DIGESTERS IN WASTEWATER TREATMENT PLANTS CAUSE DEGRADATION OF PROTECTIVE LININGS

Robert A. (Randy) Nixon, *President*
Corrosion Probe, Inc. / Corrosion Testing Laboratories, Inc.

Abstract

Both mesophilic and thermophilic anaerobic digesters are currently being utilized to treat sludge derived from more than typical municipal sewerage sources. Wastewater treatment plants are accepting septage and sludge from food waste and industrial contributors routinely today. Receiving these other sources of waste which are extremely high in volatile solids is a source of significant income for the utilities. However, high volatile solids loading into the digesters can cause out-of-balance biochemical conditions in the digesters. High volatile fatty acid to alkalinity ratios and low methane production are but a few of the repercussions of these imbalanced conditions. These process upsets result in high acetic, propionic and other intermediate fatty acids. These exposures, when sufficiently prolonged, can cause degradation to the polymers in some protective coating systems commonly used successfully in the past.

This paper will present evidence of this type of attack based on both field experience and laboratory testing data. Recommendations will be made for future material selection criteria and testing to avoid premature lining failures in anaerobic digesters in the future.

Keywords

anaerobic digesters; methanogens; volatile fatty acids; alkalinity; mesophilic; thermophilic; biogas

BACKGROUND ON ANAEROBIC SLUDGE TREATMENT IN DIGESTERS

The reader is likely familiar with the Activated Sludge Process used by the majority of wastewater treatment plants to convert dissolved organic solids to suspended solids so those solids can be settled out of solution as sludge or biosolids. This is accomplished in conventional treatment plants consisting of primary clarifiers, some form of aeration such as ambient aeration basins, pure oxygen reactors, or trickling filters. The wastewater is mixed with large quantities of microorganisms and air. The microorganisms utilize the organic waste matter for food and the oxygen in the air to burn a portion of this food to form carbon dioxide and water. This provides energy to the microorganisms. Because the microorganisms take on so much energy from this oxidation, they grow rapidly. This results in a large percentage of the organic cells to be converted into different cellular forms. This portion of the converted waste is not stabilized, but takes on the form of settleable solids or sludge. This sludge then presents a disposal challenge as it contains pathogens and other organic substances which are reactive and unstable. The activated sludge process obtains its name from the activated sludge called return activated

sludge or RAS (taken from the secondary clarifiers and pumped into the aeration tanks) to make sludge collectible so it can be handled while the water is made cleaner. Activated means active with bacteria.

Perhaps the best way to explain Anaerobic Digestion is to contrast its process with the aerobic Activated Sludge Process. In anaerobic treatment, the wastewater is also mixed with a great deal of microorganisms, but no air is added. In these conditions, bacteria grow which convert the organic waste to carbon dioxide (CO₂) and methane (CH₄) which produces very little energy in the microorganisms. Hence, their growth rate is very slow. So only a small percentage of the cells are converted to new cellular forms. The lion's share of the degradable organics are therefore converted to methane gas and are stabilized because the gas is not soluble. The methane gas therefore escapes from the sludge and can be burned to create energy. When it is burned, it forms CO₂ and water.¹ In anaerobic digestion, 80 plus percent of the degradable organics are stabilized. In aerobic treatment by contrast, approximately 50 percent or less of the organic waste is stabilized. When we say stabilized, we mean destruction of pathogens and other reactive substances.

Besides producing energy, the other main advantages for anaerobic digestion are very low production of waste biological sludge and no oxygen requirements. Perhaps its greatest disadvantages are relatively higher temperatures are necessary for it to work and the very slow rate of bacterial growth. This slow growth significantly limits the rate at which the process can be adjusted to changing waste composition, waste loads to the digesters, and changes in sludge temperature in the digester.

As you will see later in this discussion, this slow rate of growth for methane producing bacteria can have a critical influence on the development of upset conditions in an anaerobic digester which can result in the chemical attack of the substrate and/or the polymers in certain coating materials.

A conventional anaerobic digester consists of a tank containing municipal wastewater sludge and the bacteria which promote anaerobic treatment. The mixed treatment waste along with the microorganisms are removed together for final disposal or use. In some cases, the mixture of the sludge and bacteria are introduced into a second tank where the suspended solids can settle and the sludge becomes more concentrated for disposal.

Shorter retention times in anaerobic digesters cause an increased proportion of the bacteria to be removed from the digester with the effluent sludge. The limit to the retention time is reached when the bacteria being removed exceeds the bacteria that can reproduce itself. At a 95°F temperature, this develops after about 3 to 5 days of operation. This is why the detention time for conventional digesters is increased to between 10 and 30 days to assure that reliable treatment and practical control of the process can be achieved. This retention time for solids in the digester is referred to as Solids Retention Time or SRT. This is an important parameter in the proper control of the process.²

Generally, at operating digester temperatures of around 95°F, the SRT needs to be at least 10 days for efficient digestion of sludge. Hydraulic Retention Time (HRT) is another way of expressing and monitoring digestion. HRT and SRT are the same when no sludge recycling occurs in digesters.

BASIC UNDERSTANDING OF THE ANAEROBIC DIGESTER (AD) PROCESS BIO- CHEMISTRY

There are three (3) principal stages of chemical reactions which occur in the AD process as follows:

1. Hydrolysis – The addition of water causes the cleavage of H-O bonds when cations and anions in the waste react with water molecules. This alters the pH of the waste while those H-O bonds are cleaved. These reactions form complex organics including glucose from the hydrolysis of cellulose and give off hydrogen. In hydrolysis, reactions mainly cause insoluble organic compounds to be converted to soluble compounds which are highly fermentable. In short, the hydrolysis stage makes soluble compounds that

can be further hydrolyzed to simple monomers used by certain bacteria that perform fermentation. In the main, hydrolysis forms complex organic waste that is largely soluble.

2. **Fermentation Stage** – In this stage the soluble compounds formed in the hydrolysis stage are degraded and are converted to mainly carbon dioxide (CO_2) and hydrogen (H_2) through bacterial action. The bacteria in this stage are acid forming. The major acid formed is acetic acid with its conjugate base being acetate. The second most prominent acid formed is propionic acid. In this stage, amino acids, sugars, and some volatile fatty acids are degraded further to form the acetic and propionic acids plus other intermediate volatile fatty acids. In these reactions, ammonia is also formed which raises the pH and adds buffering capacity to the amino acids formed. These organic acids include formic acid, butyric acid, valeric acid, and caproic acid.
3. **Methanogenesis Stage** – In this stage, a group of organisms known collectively as methanogens or methane forming bacteria convert the organic acids to methane and carbon dioxide. One group of methanogenic bacteria split acetate into methane and carbon dioxide. A second group, call hydrogen-utilizing methanogens, utilize hydrogen as an electron donor and carbon dioxide as an electron receptor to produce methane. Another bacteria present within the AD process, called acetogens, are also capable of using CO_2 to oxidize hydrogen to form acetic acid. The acetic acid formed will then be converted to methane as well. Acetate formation is responsible for nearly 75% of methane production in the AD process.³

Figure 1 below depicts the major AD chemical reactions discussed above.

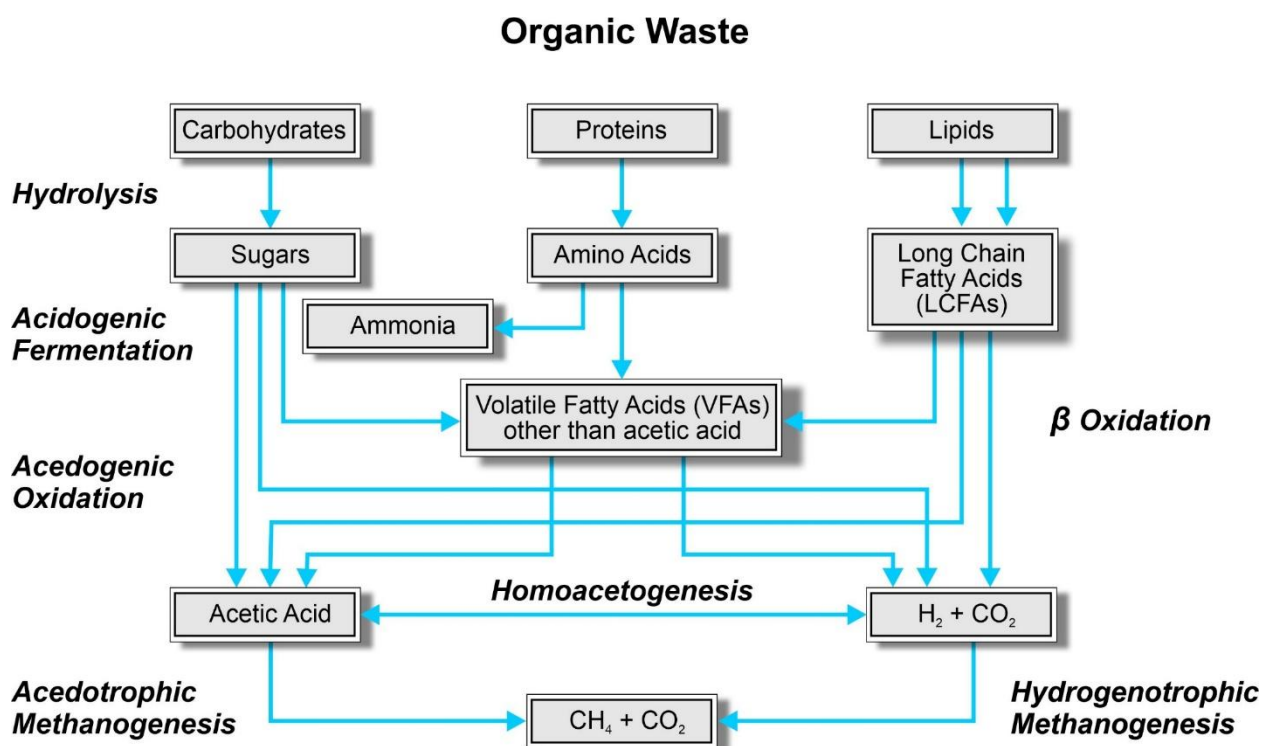


Figure 1
Methane Gas Formation in AD Process

Figure 2 presents the two stages of Bacterial Reactions in anaerobic treatment discussed above.

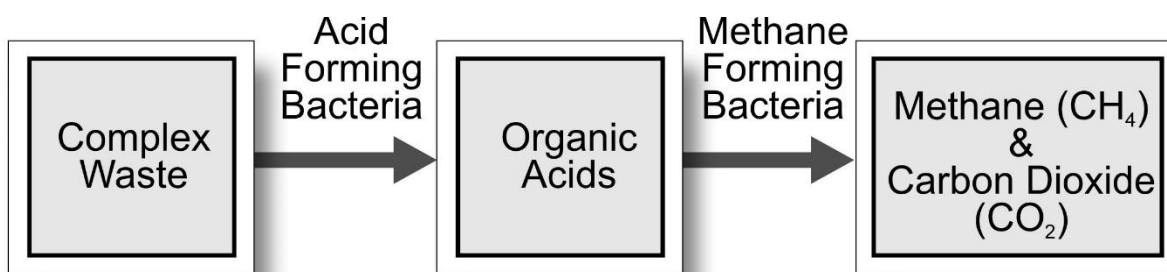


Figure 2
Two Stages of Bacterial Reactions in Anaerobic Treatment

AN ANAEROBIC DIGESTER IS A REACTOR

A reactor is a process vessel in which typically multiple chemical and/or biochemical reactions occur simultaneously. An anaerobic digester is in every way a reactor. Within that tank, whether cylindrical with a floating or a fixed cover or egg shaped, all of the stages of reactions discussed above are occurring at the same time once the process has been established from initial start-up. This assumes the digester is operating in a balanced way. There are many methane forming bacteria present in an AD. There are also many acid forming bacteria present. When the system is in balance, the methane bacteria use the acid intermediates as rapidly as they develop and are present in the sludge. But if the methane bacteria are not available in sufficient numbers, or their growth is being stymied (growth slowed down) by unfavorable environmental conditions in the digester, they will not be able to utilize the acids as quickly as those acids are produced by acid-forming bacteria. This means the volatile fatty acids increase in concentration. This increase in acid content reveals that the methane forming bacteria are not in balance with the acid forming bacteria. This causes acidic conditions to develop in the process and the pH of the sludge is reduced to levels which prevent healthy bacteria growth for the methane forming bacteria. When these volatile fatty acid intermediates become too prominent, aggressive acidic attack of certain polymers in coatings can occur. These conditions are often short lived as digester control parameters are monitored and adjustments are made to correct the out of balance conditions. However, these corrections can take several days to a month to fully solve. Therefore, aggressive attack of the substrate and of certain polymers in coatings can occur during these out-of-balance digester operating episodes. This is largely due to exposure of those coatings to acetic and propionic acids when these unbalanced conditions occur. The CO₂ gas formed by the methanogens in the digester (in the sludge and gas phases) reacts with moisture and forms carbonic acid. When carbonic acid reacts with the iron in steel tank substrates, it forms iron carbonate. When carbonic acid reacts with the cement paste in concrete digester tank substrates, it forms calcium carbonate. These are the common reaction compounds which are formed on the substrate when coatings are penetrated by CO₂ following break down of the polymer in certain coatings used in digesters.

MESOPHILIC AND THERMOPHILIC DIGESTERS

While there are other newer anaerobic digester processes such as pre-hydrolyzing vessels with downstream staged mesophilic digesters and other technologies, conventional mesophilic digesters are the most common AD process you will encounter. Mesophilic Digesters which make up the majority of AD processes at wastewater treatment plants in North America operate in the temperature range of 85°F to 100°F with 94°F to 95°F being commonplace.

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