Anaerobic Digestors:
The Role of Bioaugmentation

Bioscience, Inc.
Environmental Products & Services
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The Digestion Process

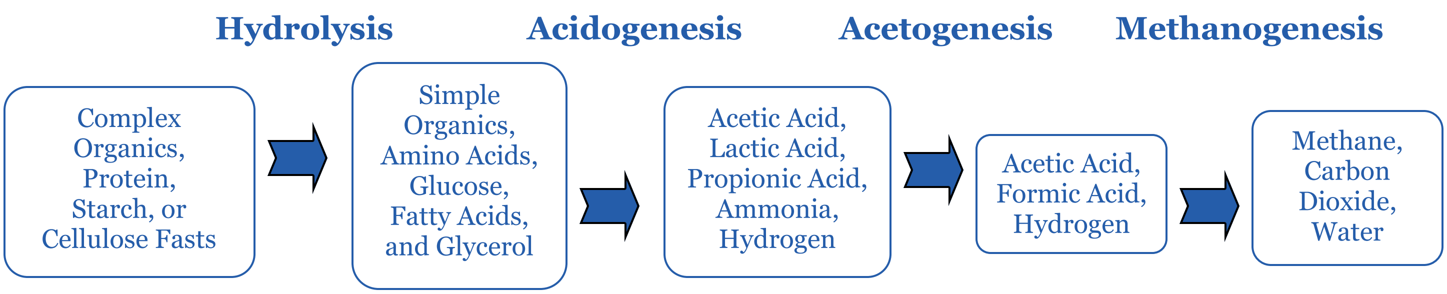
Anaerobic sludge digesters are very commonly found in both municipal and industrial wastewater treatment settings around the world. The digester is typically a completely enclosed tank that excludes oxygen from the digester liquids. The objectives of such digesters are to:

- Reduce the mass of biosolids,
- Stabilize the resulting suspension, and
- Produce a usable gas (methane).

The importance of these objectives varies from country to country and site to site depending on the local cost of sludge disposal and the economic value of the gas that is produced. Currently fats, oils, and greases (FOG) and/or septage may also be added to the sludge digester to increase gas production and revenue (by charging for the disposal of these residues).

The Biology

A wide range of process configurations are found in the field, but the core anaerobic process generally involves a two-stage process (hydrolysis, acidogenesis, acetogenesis and methanogenesis) mediated by two distinct groups of microbes that must operate in concert in order for the process to produce the desired results enumerated above. The growth rate and optimal growth conditions for these two groups of microbes is quite different. In particular, one of these groups (the methanogens that do the final conversion of organic acids to methane gas) is relatively slow growing and is quite sensitive to a range of commonly-encountered operating conditions. The simplified process follows this sequence:



Stage 1: Hydrolysis converts complex polymeric organic compounds to simple compounds which can be absorbed and metabolized. Acidogenesis breaks these compounds down to volatile fatty acids, carbon dioxide and other low molecular weight compouts. Acetogenesis further converst a variety of simple metabolic products to acetic and formic acids and hydrogen.

Stage 2: Methanogenesis converts hydrogen, formate, acetate and other simple substrates to methane and carbon dioxide.

In Stage 1, microbial respiration occurs using any residual dissolved oxygen, nitrate, ferric iron and sulfate as electron acceptors. Various hydrolysis reactions occur, depolymerizing proteins, starch, cellulose and other carbohydrates. Fats are hydrolyzed to glycerol and fatty acids. Fermentation reactions then dominate as these electron acceptors are consumed. The products formed include ammonia, hydrogen sulfide, ferrous iron, hydrogen, propionic, acetic and formic acids. In the absence of further degradation, the pH decreases. These reactions are carried out by facultative and obligate anaerobic bacteria. In some digester designs, the Stage 1 process is carried out in a separate reactor.

In Stage 2, methane producing archea convert the simple substrates from Step 1 to methane using carbon dioxide as the electron acceptor. Bacteria which produce hydrogen may be closely associated with the archea and these organisms are sometimes described as syntrophic or cross-feeding, enabling both to grow in an otherwise non-ideal environment. These archea are slow growing, generally require neutral pH, and extract small amounts of energy from the methane production. Thus, they are easily inhibited by low pH (if the acidogenesis reactions occur too fast for the methanogens to convert the acids to methane and carbon dioxide), dissolved oxygen which is toxic to obligate anaerobes, and various organics or heavy metals. Due to the unique enzymes involved in methogenesis, certain trace metals such as iron, nickel and cobalt may be limiting. Most heavy metals form insoluble compounds with the hydrogen sulfide and are not readily available for incorporation into biomass.

Electron Acceptors for Respiration and Methanogenesis in Prokaryotes.

(from Todar's Online Textbook of Bacteriology)

Electron Acceptor	Reduced End Product	Name of Process	Example Species
O_2	H_2O	Aerobic respiration	Escherichia, Streptomyces
NO_3	NO_2, N_2O, or N_2	Anaerobic respiration: denitrification	Bacillus, Pseudomonas
SO_4	S or H_2S	Anaerobic respiration: sulfate reduction	Desulfovibrio
Fumarate	Succinate	Anaerobic respiration: using an organic electron acceptor	Escherichia
CO_2	CH_4	Methanogenesis	Methanococcus

Common Problems

Anaerobic sludge digesters often suffer from a series of operating problems including:

Sour Digestion Syndrome: Caused by acid buildup with simultaneous slowing or cessation of gas production. This problem occurs when the acid forming microbes in the biomass that convert the organics present in the sludge into organic acids outgrow the slower growing, more finicky methanogens. As a result, the pH of the reacting mixture begins to drop, further slowing the growth of the methanogens even more in a feed forward destructive cycle. Gas production, along with the other desirable outcomes of the process, can be reduced or may cease.

Common Problems (cont.)

Grease Blankets: Caused by the buildup of insoluble (primarily FOG) on the surface of the digester. The amount of relatively insoluble materials in the sludge depends to a degree on the design of the upstream process that is generating the sludge and the amount of FOG and/or septage deliberately added. In particular, if that system does not have any form of primary removal of solids (typically both floating and sinking solids are removed in such a treatment step) then the amount of the insolubles increases. In addition, many digesters receive both primary and secondary clarifier sludges. Over time, the floating insolubles form a cap on the top of the digester that must eventually be removed. This requires that the process be shut down and cleaned. This is a difficult, expensive (in terms of the process downtime), and potentially dangerous process. Proper design of a digester mixing process can prevent this cap formation.

Nutrient Imbalance: Caused by a lack of certain key micronutrients. It is well documented that certain micronutrients (including several metal ions in the proper balance with the sludge being degraded) can significantly accelerate the overall process of anaerobic sludge digestion and stabilize it. This leads to greater and more consistent gas production along with sludge mass reduction and ultimate stabilization. In many cases, no steps are taken to ensure that such micronutrients are present in the proper balance to yield optimal sludge processing. This problem is made worse if FOG or septage is added, as it is typically high in carbon and low in nitrogen, phosphorus and trace minerals.

Foam and Scum: Filamentous bacteria present in the sludge coming from the aeration basin ahead of the digester may generate a foam or scum layer that can overflow the digester cover.

Incomplete hydrolysis of polymers and complex organics: Caused by insufficient residence time or low production of hydrolytic enzymes.

Bioaugmentation

Specialty blends of micronutrients, microbial cultures, microbial growth enhancers and neutralizing agents when added to systems experiencing such problems can be effective in stimulating (and re-establishing, if necessary) properly balanced biological activity in anaerobic sludge digesters. Such blends re-establish the proper nutrient balance, introduce cultures capable of performing the desired tasks, stimulate the growth of the indigenous microbes, and assist in buffering the pH of the system to minimize the tendency of the pH to drop. Bioaugmentation of poorly operating sludge digesters can show significant benefits, particularly where gas production has a high value.

Such products are usually mixed with warm water and applied at the rate of 0.5 to 5 pounds per 1000 gallons of digester or system volume. The amount and frequency of addition depend on the frequency and severity of the problem at hand. Appropriate application rates for specific problems may be determined by laboratory treatability testing.

966 Postal Road, Suite 200 · Allentown, PA 18109 · (484) 245-5232 ·Fax (484) 245-5236
E-mail: bioscience@bioscienceinc.com · Website: www.bioscienceinc.com