United States
Environmental Protection
Agency

Industrial Environmental
Research Laboratory
Cincinnati OH 45268

Research and Development

EPA-600/S2-83-119 July 1984

Project Summary

Management of Industrial Pollutants by Anaerobic Processes

Alan W. Obayashi and Joseph M. Gorgan

A study was made of the anaerobic degradation of organic matter to methane, a byproduct which could recommend wider use of the anaerobic waste treatment as a short-term solution for lessening U.S. demand for oil in an energy crisis. The anaerobic process requires less energy than does the aerobic biological process which does not produce a usable byproduct.

The study investigated two major aspects of anaerobic treatment: development of the process, and process control parameters. Other areas of study included biodegradation of organic compounds, toxicity effects, and microbial sulfur recovery.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Anaerobic Treatment Processes

The anaerobic degradation of organic matter to methane is a complex interaction of three groups of bacteria (illustrated in the full report). The first group of bacteria are the fermentative bacteria which hydrolize the complex long chain organics and ferment them to fatty acids, alcohols and other soluble organics. The second group of bacteria are the acetogenic bacteria which degrade propionate and longer chain fatty acids to acetate, H_2 and CO_2. Presently this is the only known pathway for long chain fatty acids and alcohols, since there are no documented cases of a methogenic bacteria being isolated which can degrade these organics directly to methane. For the third group of bacteria, the methanogens, the substrates for growth determined to date are H_2, acetate, formate and methanol.

A review of the literature suggests that the rate limiting step in anaerobic digestion may be the conversion of propionic and acetic acid to methane gas. However, one reference indicated that at high solids retention times (greater than 10 days) the rate limiting step in the digestion of sewage sludge at 35°C is the hydrolysis of organic solids. The same study reports that cellulose hydrolysis is the rate limiting step in the digestion of municipal solid wastes.

In spite of their present significance and future potential, anaerobic waste treatment processes have not enjoyed a favorable reputation. This lack of popularity stems from the many misconceptions held by design engineers concerning the microbiological and biochemical fundamentals of the anaerobic digestion process. Anaerobic waste treatment is thought of by many as a sensitive process which is easily upset and difficult to control. The anaerobic digestion process also has a reputation for producing obnoxious odors and requiring long initial startup periods and high temperatures (35°C) for effective waste stabilization. Another reason may be that direct treatment processes have yet to be proven on specific industrial effluents.

Nevertheless, anaerobic waste treatment does have several fundamental advantages over aerobic biological treatment processes. First, anaerobic treatment attains a high degree of waste stabilization with very little sludge production (less than 5% of the biodegradable organic matter is converted to cell material) which reduces the nutrient requirement in the influent waste stream. A second advantage of the anaerobic process is that 90% of the biodegradable fraction can be converted to a usable end-product in the form of methane (CH_4) gas which can be used to heat the waste stream to give a higher rate of stabilization or to supplement inplant power requirements. Using direct anaerobic digestion processes,high organic loadings along with short hydraulic retention times (three hours and greater) can be achieved.

Because of the current energy situation throughout the country and the need for energy conservation, use of anaerobic processes by industry will undoubtedly increase. Many researchers see energy conservation as the only practical short-term solution for the U.S. to become self-sufficient in energy production. More and more interest is being evinced by the anaerobic processes which require little energy and supply a valuable power source, methane gas. Anaerobic biological processes on the other hand, require a high energy input and produce no usable byproduct.

In the final report, two major aspects of anaerobic treatment are reported in detail: the development of the processes and the process control parameters. In the development aspect, the anaerobic processes are reviewed in a chronological order, i.e., from the simplest to the higher rate processes, e.g., anaerobic sludge blanket process. The final report also summarizes the application of anaerobic processes to a variety of wastewaters. In the process control aspect, three areas are covered (1) pH and alkalinity, (2) nutrient requirements, and (3) temperature effects on biological processes.

Biodegradation of Organic Compounds by Anaerobic Processes

Recent advances in technology have led to the production of many new and potentially dangerous compounds, some of which eventually turn up as a constituent in wastewater. Each of these new substances, representing a wide array of compounds ranging from phenols to pesticides, presents problems for its ultimate disposal. Wastewater treatment plants are experiencing many problems and challenges in dealing with these hazardous wastes. Many new and innovative techniques for their treatment, including anaerobic processes, are being investigated. As is the case in any waste treatment method, anaerobic processes will not breakdown all organic compounds. In the final report, complete details are presented on how anaerobic processes function to breakdown large numbers of organic wastes. Also, the applicability of anaerobic processes to new wastes are evaluated in a three-step evaluation: (1) formulation of a definition of the term biodegradation and setting of standards for the degree of biodegradation; (2) a comparison of tests on aerobic and anaerobic processes to determine relative biodegradability; and (3) a summary of previous work involving the biodegradation of organic by anaerobic processes.

Toxicity Effects in Anaerobic Processes

Adequate knowledge of the toxicity of relevant toxins and inhibitors in any biological process is essential for an optimal application of the process. Despite the many advantages of anaerobic treatment, the application of methane fermentation is not widely used in this country for treatment of industrial wastewaters.

Much of this reluctance to use anaerobic processes stems from the belief that the methane fermentation systems cannot tolerate the chronic or slug doses of toxic substances found in industrial wastewaters. The presence of toxicants may have caused inhibition which eventually led to failure of the process, particularly in the case of anaerobic sludge digestion. However, it should not be assumed that methanogens are more sensitive to toxicants than facultative organisms.

During the past fifteen years, there have been numerous documented studies of the possible inhibitory effects on the anaerobic digestion process from different compounds commonly found in these systems. In many instances in which digester performance had decreased, the source of the upset could be traced to the presence of a compound that was inhibitory to the microorganisms involved in the digestion process. These compounds originate from waste streams generated by the different industrial processes.

The control of sulfur pollution is a widespread problem associated mainly with hydrocarbon processing and power production. For example, the mining of coal results in acid mine drainage, the burning of coal results in $CaSO_4$ sludges (SO_2 scrubbing) and coal and oil desulfurization results in H_2S waste streams. Of the two forms of sulfur pollution SO^2_4 is a major problem with no reliable method of control.

Microbial Sulfur Recovery

The problem with sulfur disposal are related primarily to energy production and, to a smaller extent, to the mining industry. As more emphasis is placed on the use of hydrocarbons such as oil and coal for energy production, sulfur control and disposal become a more pressing problem.

One form of sulfur pollution is the generation of $CaSO_4$ sludges which is a result of the scrubbing of flue gases from coal fired plants. In addition, H_2S waste streams are generated from the desulfurization of coal and oil. This problem is generally handled by using physical-chemical processes which convert the H_2S to elemental sulfur. Other more limited areas in which high sulfates (acidic wastes) are a problem include acid mine drainage (coal mining), acid wastes from mining operations, and wastes from ethanol distilleries.

Currently, H_2S waste streams are handled by physical-chemical processes, with the major objective being the recovery of elemental sulfur. Presently, when high sulfate wastewaters are neutralized they are either discharged or stored in lagoons where they continue to be a problem.

The biological conversion of high sulfate wastes or hydrogen sulfide waste streams to the more desirable form of elemental sulfur has not been developed beyond the laboratory stage. The kinetics of sulfate reduction and the kinetics of hydrogen sulfide conversion to elemental sulfur have been the subject of very few published studies on the applied bioprocess production of elemental sulfur. These studies are discussed in more detail in the final report. Also, a brief summary of the microbiology of sulfur transformations is presented in the final report.

Microbiology of Sulfur Transformations

All organisms require sulfur with the major need in the incorporation of sulfur in proteins. In addition, microorganisms can use sulfur in a manner similar to the way that organisms use the various forms of nitrogen; that is, as both an energy source and as an electron acceptor. The various oxidation states and the forms in which sulfur exists in the environment are discussed in the final report. Of particular interest is the anaerobic portion of the cycle, the reduction of sulfate to hydrogen sulfide, and the oxidation of sulfides to elemental sulfur.

Alan W. Obayashi and Joseph M. Gorgan are with the Illinois Institute of Technology, Chicago, IL 60616.
***William A. Cawley** is the EPA Project Officer (see below).*

The complete report, entitled "Management of Industrial Pollutants by Anaerobic Processes," (Order No. PB 84-133 024; Cost: $22.00, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Industrial Environmental Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

☆ U S GOVERNMENT PRINTING OFFICE; 1984 — 759-015/7750

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

Official Business
Penalty for Private Use $300

PS 0000329
U S ENVIR PROTECTION AGENCY
REGION 5 LIBRARY
230 S DEARBORN STREET
CHICAGO IL 60604