DEMONSTRATION OF DAIRY MANURE REMEDIATION USING IBR TECHNOLOGY

[1]C.S. Hansen and [2]C.L. Hansen
[1]*College of Agriculture, Department of Nutrition and Food Science, Utah State University, Logan, UT 84322; Phone: (435)760-1973; Fax: (435)797-2379.*
[2]*College of Engineering, Center for Profitable Uses of Agricultural Byproducts, Utah State University, Logan, UT 84322; Phone: (435)797-2188; Fax: (435)797-2379.*

ABSTRACT

This paper is a report of the performance of a new design of an aerobic bioreactor called the induced blanket reactor or IBR. The IBR appears to treat high-solids organic matter (manure) effectively in a relatively short time without plugging. A 28 m^3 (7500 gal.), heated IBR has been in operation at Utah State University's dairy farm, the Caine Dairy, since the summer of 2000. The bioreactor, an upflow sludge blanket type, features a method to build and maintain a sludge blanket without plugging. Up to 80% of the VSS were removed from dairy manure in the IBR with less than a 10-day HRT. Biogas was collected and burned to produce hot water. Parameters for the system that were reported include pH, temperature, influent and effluent totals, soluble COD, total and volatile solids, and suspended solids. All these parameters were recorded at different loading rates. Biogas quality with percent of methane content was also reported.

Key words: anaerobic, dairy, manure, bioenergy

PROBLEM

The livestock industry in the United States continues to move in the direction of fewer and larger facilities. This trend has been continuous for many decades. The USDA reported that in 2001, pig facilities with less than 500 pigs decreased by 4538 and dairy facilities with less than 100 cows decreased by 7045 (USDA, 2002). Government programs designed to help save the family farm have not been very successful in curbing this trend. Large factory farms, especially in pork production, continue to increase, and the resulting concentration of manure continues to increase. Ever since passage of the Clean Water Act in 1972, there has been a concern as to the detrimental effect livestock operations have on the environment. For example, if a nutrient in manure such as phosphorus enters surface water, eutrophication is usually accelerated. Phosphorus is often the limiting nutrient in fresh water. When phosphorus is enriched in fresh water, the plants in the water, including algae, respond with increased growth. When these plants die, microbes consume oxygen from the water in the decomposition process. This depletes the oxygen, resulting in a deficiency for aquatic animal life. In addition, oxygen deficiency results in incomplete decomposition, which tends to impart turbidity, and foul tastes and odors to the water. Other potential pollutants from animal manures may be an excess of nitrogen, carbon, or ammonia. Fecal coliform and fecal matter that contain pathogens may also be potential pollutants.

Confined animal feeding operations (facilities with more than 1000 animal units in one place for 45 days or more) are required to have a comprehensive nutrient management plan (CNMP) to help protect the environment from the pollutants generated. Proper disposal of the large quantities of manure generated is becoming more and more critical. The pollution of surface and ground water has been the main concern; however, air pollution is also becoming a major concern. Methane gas generated in lagoon systems and decomposing manure has been determined to be a greenhouse gas 21 times more detrimental than carbon dioxide (Lusk, 1998). Some states are implementing regulations for confined animal feeding operations (CAFO's) that are in addition to federal EPA regulations. Both Idaho (the fifth largest milk producer in the U.S.) and Iowa have drafted odor ordinances (Bernick, 2002).

SOLUTION

Anaerobic digestion (AD) of the liquid waste stream and subsequent collection and utilization of the methane gas is the best solution available at this time. AD of animal manure not only prevents air and water pollution, but can convert a manure problem into a profitable resource by generating electricity and/or heat with the methane gas that it produces. AD also greatly reduces the odor problem.

ANAEROBIC DIGESTION

Anaerobic digestion has been around for thousands of years. Biogas was known to have been used to heat bath water in Assyria during the tenth century BC. In 1895 in Exeter, England, biogas was recovered from a "carefully designed" sewage treatment facility and used to fuel street lamps (McCabe, 1957). In Europe during and after World War II, the process was used quite extensively when energy supplies were reduced. Millions of small anaerobic digesters are used as home septic systems to digest waste. Although the process of anaerobic digestion may appear simple, it is actually a very complex process. A symbiotic relationship has to exist between consortiums of bacteria. Figure 1 shows a simple outline of this complicated process.

ANAEROBIC DIGESTERS USED ON THE FARM

Almost three decades of recent research in the U.S. has provided much information about how manure can be converted into an energy source. Several different types of digesters have evolved over this period of time. The most common types are the plug flow, complete mix, and covered lagoons. The plug flow is a bioreactor where manure moves laterally as a plug through an elongated vessel or underground

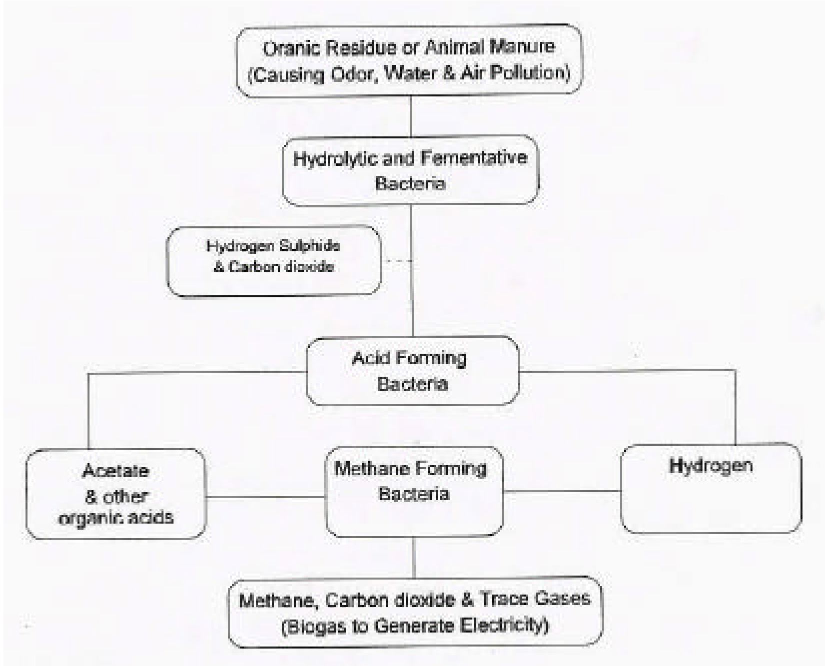

Figure 1. Anaerobic digestion process.

conduit. It is usually built using a 5 to 1 ratio (5 feet of length for 1 foot of width). The plug flow can usually handle thick manure with up to 13% solids. The complete mixed system is usually an aboveground tank in which manure is mixed completely, using some kind of internal mixing device. The covered lagoon can be a lagoon that is fully covered or a lagoon only partially covered with cells covering the most productive part of the lagoon. All of these systems can collect biogas.

FAILURES OF FARM DIGESTERS

According to a 1998 study sponsored by the U.S. Department of Energy, failure rates among these types of farm-based digesters which are actually built are staggering: plug flow failures – 63%, complete mix failures – 70%, and even covered lagoons have a failure rate of 22% (Lusk, 1998). This is totally unacceptable, especially on a family farm that is struggling to survive. The failure rates for the plugflow digester were even higher during the 1980's; however, some plug flows that were put in during that time are actually still in operation and working very well. The same design could be successful on one farm and then fail on others. Bad design is, however, still the leading cause of digester failures. Experience over the years has answered some of the questions, while others still need more research. According to P. Lusk, "The role of farm management is key; not only must digesters be well engineered and built with high-quality components, they must also be sited at farms willing to incorporate the uncertainties of a new technology" (Lusk, 1998).

RESEARCH AT UTAH STATE UNIVERSITY

Dr. Conly L. Hansen has been doing research in anaerobic digestion for more than 25 years. During the 1990s he developed what he called a cluster system. This system also included an innovative process for ammonia removal. More recently he has concentrated on a process known as the up flow anaerobic sludge blanket (UASB). This process has a high rate of digestion with a short hydraulic retention time (HRT). It has been used with success in some applications but is limited with animal manures because of plugging problems. Dr. Carl S. Hansen joined the research team in 1999. It was felt that if the plugging problem could be solved, the result would be a high-rate digestion system that was fairly simple to operate. In 2000, Dr. Conly Hansen was awarded a center of excellence from the state of Utah to continue research in anaerobic digestion. The center is called the C*enter for Profitable Uses of Agriculture By-products*. Continued research in this area led to development of a new process called the induced blanket reactor (IBR).

DEVELOPMENT OF THE IBR PROCESS

There were three goals for the development a new anaerobic digester: First, it had to be reliable; second, it needed to be a simple design and easy to operate; and third, it needed to be affordable. The resulting IBR process is a tank with a septum in the top that also contains a plugging control mechanism. A blanket of bacteria develops under this septum that the influent has to travel through in order to reach the exit at the top of the tank.

SUCCESS OF THE IBR PROCESS

In the process of meeting our original goals, we concluded that reliability, simple design, and affordability are all inter-related. If a digester shuts down for any reason, the farmer loses money. The simpler the design, the less chances there are for failure. The smaller the digester, the lower the cost is the original investment. The only way to make a digester smaller is to reduce the HRT, and the only way to reduce the HRT is to make a digester more efficient. Anaerobic bacteria are slow to multiply. One way to make the digester more efficient is to retain and reuse these bacteria. The IBR process is able to accomplish this with the use of a septum in the top of the tank. Clusters of methanogenic bacteria, with methane attached, float to the top where they hit this septum. This separates the methane from the bacteria. The bacteria then sink back to the sludge and are retained for more digestion, while the methane continues on and exits the tank. The bacteria that do escape to the top of the septum are captured and returned to the bottom of the tank with a recirculation system.

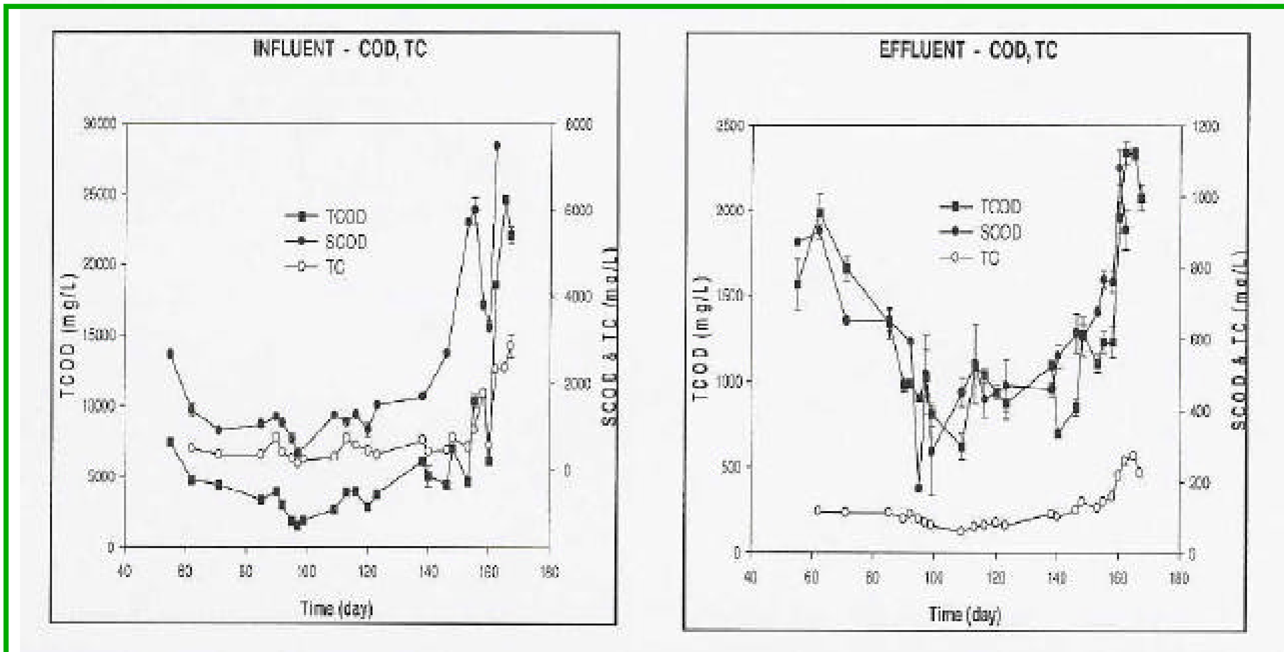

Figure 2a. Graphical representation of loading rates showing differences in HRT.

Another way to improve efficiency is to put the food (influent) and bacteria in contact with each other in an ideal environment. The IBR process is able to do this by the use of relatively small diameter tanks in comparison to their height, and by controlling precisely what goes in and what comes out.

Plugging and poor design are two main reasons for digester failures. The IBR process is able to control plugging with a mechanism that is presently being patented. The simple design of the IBR process makes it user friendly and easy to operate.

Finally, because the biogas is used for energy production, its quality is also a factor in affordability. The IBR process has been producing biogas with a methane content of 80%.

HOW THE IBR PROCESS COMPARES TO OTHER TREATMENT SYSTEMS

Table 1 lists some of the practices that farmers are using to handle their manure problems and compares them with the IBR process.

RESEARCH DATA

Figure 2 uses a hydraulic retention time (HRT) of 10 days. We are presently collecting data using an HRT of 4 days, and the results so far look very similar. These graphs indicate a total C.O.D. destruction of over 75%, a soluble C.O.D. destruction of over 85%, a total suspended-solids destruction of over 80%, and a volatile suspended-solids destruction of over 80%. As the graphs indicate, different loading rates were used and the temperature varied some but averaged around 34 degrees C. The Ph averaged about

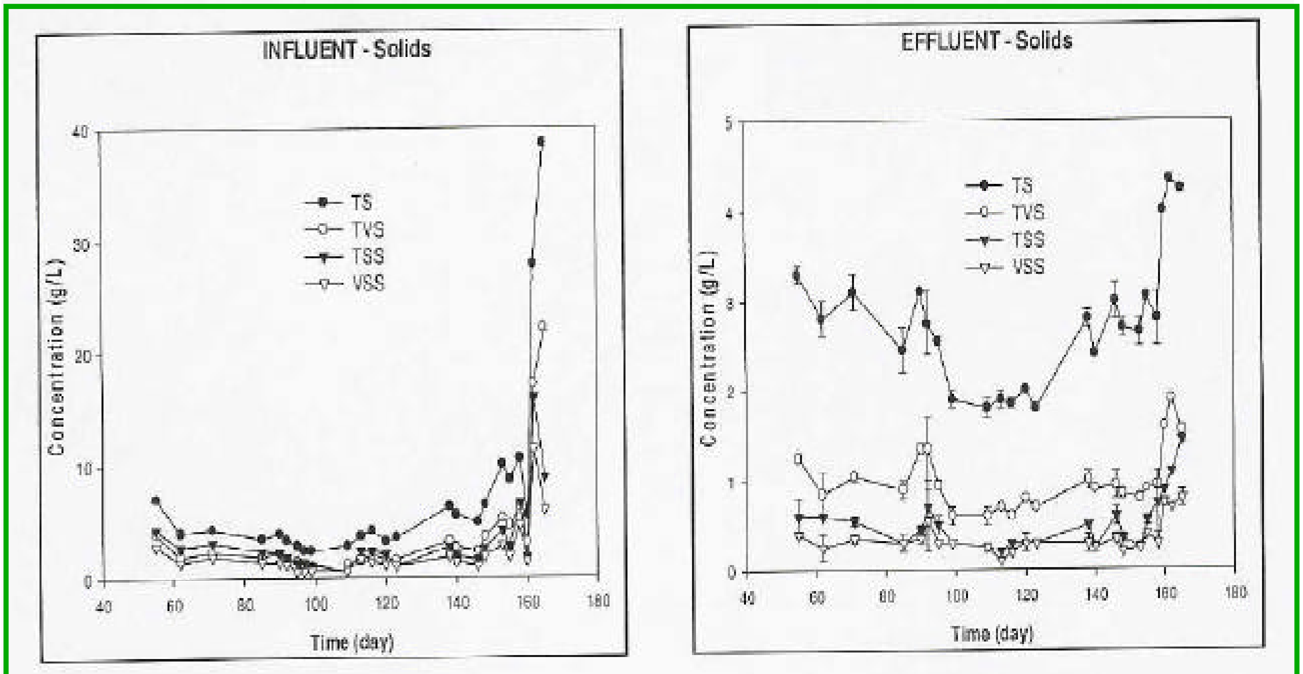

Figure 2b. Graphical representation of loading rates showing differences in HRT.

7.3. All samples of biogas taken indicated a methane content of about 80%, which is on the high end. We are hoping it stays that high with a four-day HRT.

Table 1. Comparison of waste treatment systems.

Agriculture Waste Treatment Method	Efficiency	Energy Production	Reliability	Pollution Control	% Volatile Solids Digested
I.B.R. Process	Outstanding	Outstanding	Outstanding	Outstanding	>60% in 10 days
Traditional Piling and Land Applied	Unsatisfactory	Unsatisfactoy	Outstanding	Unsatisfactory	NA
Traditional Anaerobic Lagoon Followed by Land Application	Unsatisfactory	Unsatisfactory	Outstanding	Unsatisfactory	>60% in 60 days
Traditional Anaerobic Digester (1) - Liquids Digested with Solids	Mediocre	Mediocre	Mediocre	Outstanding	>50% in 20 Days
Plug-flow Anaerobic Digestor with Land Application	Mediocre	Mediocre	Mediocre	Mediocre	>50% in 20 days
New Technology Anaerobic Digestor (2) for Liquid Digested with Solids	Mediocre	Outstanding	Mediocre	Outstanding	>60% in 20 days

(1) Bulk volume fermenter, i.e. large heated tank.
(2) Complete mix tank, anaerobic contact process, or sequencing batch by itself.

The break in data gathering occurred when we tried to increase the solids in the influent to 12%. Although the digester had no problem handling the high solids content, the pump used to load the digester kept plugging. We spent three months experimenting with different types of pumps. Larger pumps will handle higher solids. The two-inch pump we are now using will handle about 8% solids.

CONCLUSIONS

While anaerobic digestion is a proven method for reducing air, water, and ground pollution, there have been too many digesters that have failed when using animal manures. Municipal sewage treatment plants not only have the financial resources to fix their problems, they are also required to do so. Most farmers, on the other hand, are neither required nor have resources available to solve digester problems. If their anaerobic digester fails, it often ends up abandoned and the farmer returns to his old methods of manure management. We feel there are many economic and environmental reasons for animal facilities to use anaerobic digestion. The preliminary data indicates that the IBR process being developed at Utah State University will not only be an affordable system, but a reliable one as well. The new 2002 farm bill, along with improved digester designs, may be the incentives needed to solve manure problems with environmentally sound methods.

REFERENCES

Bernick, J; *Hog-Tied in Iowa*. Farm Journal, May/ June 2002. pp. 31

Lusk, P. (1998). *Methane Recovery from Animal Manures the Current Opportunities Casebook.* pp. 1-3 & 1-5. NTIS. U.S. Dept. of Commerce. This study was prepared for The National Renewable Energy Laboratory, Golden, CO and sponsored by the U.S. Dept. of Energy.

McCabe, J; Eckenfelder, W. eds. (1957). *Biological Treatment of Sewage and Industrial Wastes*. Two volumes. New York: Reinhold Publishing.

USDA Agricultural Statistics 2002. www.usda.gov.