Anaerobic Fixed-Film Digester
System for Dairy manure

Stanley A. Weeks, Stanley A. Weeks, LLC
4 Ashlor Drive
Middle Grove, NY 12850

Abstract. This paper is a summary of 20 months of operation of a fixed-film digester designed for a 4-day retention time for separated dairy manure. Biogas production, odor control, and pathogen reduction were evaluated, as well as a compost/dryer system for separated manure solids.

Keywords. Anaerobic digestion, manure treatment, fixed-film, biogas, manure separation, manure handling, dairy manure.

For presentation at
NABEC 2003
Northeast Agricultural & Biological Engineering Conference
Storrs, Connecticut, USA
August 2003
Introduction

Methane production from manure on a dairy farm has the advantage of a nearly constant feed stock supply. This is a major benefit when compared to alternative energy sources such as solar and wind. Dairy cow manure can be used to produce useful energy in the form of biogas (approximately 60 percent methane) through oxygen-free digestion of the manure. The process can be thought of as an extension of the cow’s digestive process. One major challenge associated with anaerobic digestion systems is to use the energy effectively at the dairy farm.

Fertilizer value of manure is essentially unchanged by the anaerobic digestion process. Effluent from the digester will have slightly lower dry matter content than as produced manure. Odor is substantially reduced, as volatile acids are consumed by bacteria during the process. Overall volume of effluent is basically the same as the influent.

Manure as produced by dairy cows may be used directly in the digester with no need for additional water. If large amounts of bedding are used, however, it may be necessary to add water to provide proper moisture content within the digester. Some additional water will also have to be added if manure will be pumped to the digester. Most digesters have been designed for a twenty to twenty five day retention time in order to optimize gas production and odor control.

Only about one third of installed on-farm digester systems have been successful over the long term. Reasons for this record include; poor design, incorrect installation, inadequate management, and energy economics. The goal of this three year project, which includes a fixed film digester, is to design, install, operate and monitor a dairy manure treatment and processing system. Performance will be evaluated based on equipment reliability, economic analysis, and managerial needs.

Liquid/Solid Separator

Removal of fresh solids from slurry manure is a primary step in many treatment systems designed to reduce the pollution content of manure, prolong the life of storage facilities, improve the effectiveness of biological treatment, and minimize environmental nuisance. Work with separators was begun with the goals of improving manure handling efficiency, reducing purchased bedding cost, and producing a soil amendment product as a potential cash crop.
Initially, the idea was to use the separator for the effluent, or outflow, from an anaerobic digester at the Agway Research Farm, located at Tully, NY. That concept has changed over time. It is now suggested that slurry manure be run through a separator prior to storage, digestion, or land application.

There are several design concepts now used for separators. Separators with no moving parts, such as inclined screens, work well only if large amounts of water are added, such as in flushing systems. At the complex end of the scale, belt presses—such as those used with sewage sludge—are priced too high for on-farm applications. Screw press design is simple (an auger being the only moving part), cost effective, and would produce solids of the desired dryness (28 to 30 percent dry matter).

With separated manure solids dry matter of 28 percent or greater, composting of solids begins almost immediately. Wetter solids will slump in a pile, forcing air from the pile and thus limiting the aerobic composting process. Compost piles need to reach a temperature of approximately 130 degrees F for a period of three days in order to kill off undesirable bacteria. Experience has shown that manure from one dairy cow will produce about one cubic foot of separated solids per day, and that is more than enough volume to provide recycled bedding. Depending on farm location, purchased bedding cost ranges from $50 to $100 per cow per year.

Some farms are successfully using solids for bedding directly from the separator (“raw”), with no composting, but bacteria concern remains an issue. Others may mix some amount of sawdust with the “raw” solids, and perhaps add some lime as well. From a materials handling standpoint, solids may be used either “raw” or well composted, but partially composted solids are a materials handling problem, as cell walls have begun to break down and material becomes wet and difficult to handle. To date, the main reason for not fully composting solids are the time, space, and labor requirements for proper composting.

Approximately 20 percent of the manure stream will be in the solids fraction, along with 20 percent of the nutrients. The liquid, with most of the fertilizer value, can now be pumped long distances, irrigated, or injected into the ground. There will be no crust formation in storage, so poly liners for earthen storages may be used. One operation that creates an odor issue with slurry manure is top agitation that may be required to break up a crust. That agitation releases undesirable volatile compounds into the air. Handling separated liquid manure becomes almost like handling water. Also, any treatment system dealing with the liquid becomes easier, as the difficult to deal with large solids have been removed.

Material handling advantages are thus substantial when using a liquid/solid separator system. The separator does need to be part of a system, with proper consideration
being given to manure collection, mixing, pumping, and solids removal. One of the most important considerations is proper mixing of the collection tank such that the separator feed pump will deliver well-mixed, consistent slurry to the separator.

**USDA Separator/Digester System**

A manure separator and anaerobic digester system was installed by Agway at the USDA Dairy Research Facility at Beltsville, MD in 1994. Odor control was the main issue, rather than maximum biogas production. Past experiences with other digester designs had shown that crust formation could take place in the digester tank, depending on type of bedding used and amount of water added to the manure. To eliminate this concern regarding crusting, it was decided to operate a liquid/solid separator prior to the digester. Thus, only the liquid fraction would be fed to the digester. USDA, as a result of their investigations of other digester systems, required that a propeller mixer be installed inside the digester as a safety measure to protect against crusting.

Liquid fraction (5-6% dry matter) from the separator flowed to a 10,000 gallon collection tank, and was then pumped each hour into the digester, using a 3 HP pump controlled by a time clock. Since large fibers had been removed, a mechanical check valve could be used to prevent back flow through the in feed line. Digester effluent flowed directly into long term storage. Digested liquid was applied as fertilizer. There was no crust formation on the surface of the storage.

The digester tank was a 30' diameter x 28' high poured concrete silo, designed for a 23 day retention time. Insulation was placed on the exterior of the tank. It was designed for a herd size was 225 mature cows and 225 replacement animals. All biogas produced was burned in a boiler, and hot water from the boiler used to maintain the digester at 100 degrees F. Heating system consisted of PVC pipe buried in the concrete floor and encapsulated in a concrete divider wall. Excess heat from the boiler was dumped with a fan-radiator set. Separated solids were moved to a separate facility for composting research.

Operating experience with this separator/digester concept indicated that biogas production was reduced approximately 30% when compared with digestion of produced dairy manure. Gas quality averaged 70% methane, compared to 60% experienced with conventional digester designs.
Fixed-Film Digester Research

Conventional digester designs require a long (20 to 30 days) retention time because many of the active bacteria are flushed from the digester vessel at each feeding. Bacteria population reaches a certain level, and steady state operation results. Recent designs rely on the fact that active bacteria cling to surfaces within a digester, and as surface area increases so does the bacteria population. A fixed-film anaerobic digester, developed and being evaluated at the University of Florida is one such design (Wilkie, 1998).

Active biomass retention within a digester can dramatically reduce retention time, from 20 days to 4 days. This will result in greatly reduced capital cost, as the digester tank is the single largest cost of the total system.

The fixed-film design would not be possible without separation, as large manure fibers would clog the fixed-film media. Removal of large solids also eliminates the need for heat pipes within the digester, as external heat exchangers may be used. Crusting on the exterior of heat pipes, as well as corrosion, has been an ongoing concern in conventional digesters.

One choice of media is corrugated plastic drainage pipe, packed within a circular tank such that flow will be vertical and upward through the pipes. Some method should be provided for removing settled solids from the bottom, should this settling occur. Influent and effluent lines, gas withdrawal line, and heating circulation lines with temperature sensors need to be installed.

Experience at the University of Florida, with very dilute dairy waste (0.4% solids), and a three day retention time fixed-film digester were excellent. COD reduction, biogas production, and biogas quality were reported, and methane content of the biogas was 78%, compared to the 60% expected in conventional digesters. Additional tests were conducted with 1.3% and 2.0% solids dairy manure in fixed-film digesters, with 1.5 and 2.3 day retention times, with significant odor reduction (Powers, et al, 1999).

ANFF Treatment System

A three year project involving liquid/solid separation, anaerobic fixed-film digestion, and heated air drying of solids is in progress at the J. J. Farber Farm, located at East Jewett, NY. This is a New York State Energy Research and Development Authority (NYSERDA) project, with the Watershed Agricultural Council (WAC) for the New York City Watersheds, Inc. acting as the Contractor as well as providing partial funding for
the project. Additional funding is provided by Niagara Mohawk Power Corporation and New York State Electric and Gas Corporation.

This project was designed to demonstrate a system for: manure odor control, reduction of pathogenic organisms, methane energy production, and production of manure solids for bedding/soil amendment use. It combines many of the concepts previously discussed regarding manure treatment systems.

Figure 1 shows the basic process concept; as this system was be added to an existing manure collection and storage operation for a 100 cow dairy. Figure 2 is a schematic of the physical layout at the farm. The large reception pit and long term storage were in place prior to this project. The major concern that the farm had was offensive odors when manure was spread from the long term storage.
Potential Benefits
1. Pathogen control
2. "P" export opportunity
3. Odor control
4. Reduced environmental risk

Figure 1. ANFF treatment system. Liquid-solid separation, anaerobic fixed-film digester, heated air drying solids.
Figure 2. Anaerobic fixed film digestion with drier
Not to scale.  Source: DLtech, Inc.
The system includes using pre-cast concrete for three holding tanks and the digester tank. Holding tank for the digester effluent is for possible heat exchange between effluent and influent liquids. All three holding tanks will overflow into the large reception pit by gravity if necessary.

The digester tank is 10.5' diameter x 16' overall height, insulated on the sides with 4 inches of urethane foam, and is designed for a 4 day retention time. Plastic drainage pipes form the vertical flow fixed-film media, heat exchanger and insulation are external, and a sludge withdrawal pipe is installed at the base.

Biogas is piped to a boiler. Boiler operation is continuous, as no gas storage is provided, except for the top 4' of the digester tank. Some hot water from the boiler is used in conjunction with a heat exchanger to maintain digester temperature, while the excess is run through a fan/radiator unit to produce a stream of warm air for processing of solids.

During operation, separated solids are conveyed either into a dump wagon for storage, or a prototype compost/dryer vessel for processing. Warm air from the fan/radiator is blown into the base of the compost/dryer, encouraging composting activity and removing moisture to create a dried solids product suitable for bedding. It was anticipated that this would be a three day batch process, and bedding production would be a main economic value from the project.

Conclusion

This project was designed to build on previous work by many involving liquid/solid separation, anaerobic digestion, and composting of separated manure solids. Odor control and reduction of pathogenic organisms were the driving issues, as well as reduction of methane emissions to the environment.

Digester operation began in October, 2001, and biogas production reached a steady state level of 28 cubic feet per cow per day. Ten lab test results, over a period of 8 months, indicated a 27% reduction in volatile solids in the digester. Biogas averaged 62% methane, and hydrogen sulfide in the gas was approximately 6,000 ppm. Biogas production averaged 5.79 cubic feet per pound of volatile solids loaded, and 22 cubic feet per pound of volatile solids destroyed.
External shell and tube manure heating system performed well. There was some initial plugging of the 5/8 inch tubes, but a back flush system was installed to provide periodic cleaning. A grinder pump was also installed to feed liquid to the digester in order to ensure that large particles would not plug the tubes.

Liquid was fed to the digester for a calculated time every 30 minutes, for a total of 48 feedings per day. Biogas pressure and production remained very consistent due to this consistent feed method.

Odor control was very good, and stored effluent was spread on hay ground throughout the summer. Prior to this, manure was not spread on many fields due to neighbor or owner complaints.

Biogas boiler consumed all biogas produced. Conversion from gas energy to heat energy efficiency was 80%. The boiler heat exchanger required periodic cleaning due to the high hydrogen sulfide content of the gas.

There were several foaming incidents, mainly related to rapid feed changes for the cows or rapid temperature changes within the digester. Gas line piping was changed to include a positive foam trap prior to the gas meter and boiler gas valve.

There was some pathogen reduction, as fecal coliform in digester in feed liquid averaged 604,000 cfu/gram, and fecal coliform in the effluent averaged 166,000 cfu/gram.

The converted feed mixer did not perform well as a compost/dryer. The mixer reel and augers caused solids to be compacted such that warm air could not be forced through the pile. Some modifications are being considered.

The digester was operated continuously for a twenty month period. On June 30, 2003, the digester was emptied in order to inspect the 4,800 feet of four inch corrugated irrigation tubing that formed the fixed-film media. A large amount of calcified deposits were attached to the media, and approximately 10 inches of grit had settled to the digester floor. The half inch thick deposits threatened to block the media, and had the effect of reducing retention time to 3 days. This reduced retention time is another possible cause of foam production.

Analysis of the fixed-film deposits is in progress. One source of deposit material is the 150 pounds of lime that is added to alley floors to reduce cow slippage. At this point, the fixed-film media has been removed and the digester is being restarted as a five day retention time digester for separated liquid dairy manure.
Disclaimer

“This report was prepared by the Watershed Agricultural Council in the course of performing work contracted for by the New York Energy Research and Development Authority (hereafter NYSERDA). However, any opinions, findings, conclusions or recommendations expressed herein are those of the author and do not necessarily reflect the views of NYSERDA”.

References


