Fixed-film digesters are designed to have a smaller footprint than conventional suspended-growth digesters, an important factor where land availability is limited.

FIXED-FILM ANAEROBIC DIGESTER

REDUCING DAIRY MANURE ODOR AND PRODUCING ENERGY

Holistic manure treatment system developed at University of Florida offers farmers many practical advantages — from controlling odors to maximizing nutrient and water recovery.

Ann C. Wilkie

A STATE-OF-THE-ART, fixed-film anaerobic digester — designed specifically to meet the needs of the typical Florida dairy farm — has been installed at the Institute of Food and Agricultural Sciences Dairy Research Unit (DRU) at the University of Florida. The DRU is located in Hague, Alachua County, Florida. The goal of the project is to demonstrate use of fixed-film anaerobic digester technology at a working dairy to simultaneously treat wastewater and produce energy in the form of methane gas. This holistic manure treatment system not only stabilizes the wastewater, but also produces energy, controls odors, reduces pathogens, minimizes environmental impact from waste emissions, and maximizes fertilizer and water recovery for reuse.

Florida dairies use large volumes of water for barn flushing, resulting in large amounts of dilute wastewater. The most common manure management system utilizes short-term holding ponds for flushed-manure wastewater storage, with subsequent pumping to sprayfields to supply fertilizer nutrients and irrigation water for production of forage crops. Although effective for nutrient recycling, these systems can produce strong odors. The partial decomposition of organic matter by anaerobic microorganisms is the primary cause of odor in dairy livestock manure. The land application of manure slurry volatilizes the malodorants and creates a high odor nuisance potential.

Being a completely closed system, however, a fixed-film digester allows more complete anaerobic digestion of the odorous organic intermediates found in stored manure to less offensive compounds. Analyses conducted using human odor panels showed a substantial decrease (94 percent) in flushed dairy manure odor after fixed-film anaerobic digestion at three-day hydraulic retention time (HRT). By contrast, short-term storage (three days) of flushed dairy manure was shown to exacerbate manure odor by 77 percent.

Free-stall barns at Florida's Dairy Research Unit are hydraulically flushed on an automated schedule followed by a series of pretreatment steps and eventually flowing into a sump from where the digester is fed.

SYSTEM DESIGN

The basic fixed-film digester design consists of a tank filled with plastic media on which a consortia of bacteria attach and

grow as a slime layer or biofilm — hence the name "fixed-film" digester. The media is fully submerged and wastewater flow can be in either the upflow or downflow mode. As the wastewater passes through the media-filled reactor, the attached and suspended anaerobic biomass convert both soluble and particulate organic matter in the wastewater to biogas, a mixture of mostly methane and carbon dioxide. The biogas produced can be collected and used either directly (e.g. for heating water) or in an engine generator to provide electricity.

Immobilization of the bacteria as a biofilm prevents washout of slower growing cells and provides biomass retention independent of HRT. Since the bacteria are not continuously washed out along with the effluent, a substantial microbial biomass develops within the reactor. Because there are more bacteria for a given reactor volume compared to conventional suspended-growth designs, less time is needed to degrade the wastewater, allowing operation at short HRTs typically in the range of two to six days. Fixed-film digesters are ideally suited for treating large volumes of dilute, low-strength wastewaters such as those generated by Florida dairy operations (< 1 percent total solids), because large numbers of bacteria can be concentrated inside smaller digesters operating at shorter HRTs than would be needed to achieve the same degree of treatment with conventional suspended-growth anaerobic reactors. Also, fixed-film digesters have a smaller footprint than conventional suspended-growth digesters — an important factor where land availability is limited.

INTEGRAL PART OF WASTE MANAGEMENT SYSTEM

The Alachua fixed-film anaerobic digester is designed to be an integral part of the overall waste management system for the 500-milking cow dairy and will serve as a model for the Florida dairy industry. As constructed, the complete digester system consists of a 100,000-gallon, fixed-roof digester tank; a biogas collection and flare system; an influent feed pump; a recycle pump; a desludging pump; a liquid level control structure; and a mechanical building for housing pump controls, an air compressor for powering the pneumatic feed pump, and biogas utilization equipment. Vertically arranged, three-inch diameter corrugated polyethylene drainage pipe, commonly used in septic tank drain fields, is installed as the media in the digester (four zones of 4 ft pipe). This widely available material offers a low-cost solution to providing sufficient surface area in the digester for microbial attachment. By simply changing the position of a damper valve, flow direction through the media-bed can be switched between upflow and downflow modes.

The milking herd at the DRU is confined to free-stall barns, which are hydraulically flushed on an automated schedule. The milking parlor apron is equipped with an "udder washer" which, together with the milking parlor wash-down wastewater, flows to a wastewater channel. In summer, misters in the free-stall barns help to keep the cows cool and also contribute additional water to the waste stream. Currently, the cows in the barns are bedded on sand. The wastewater initially flows down the collection channel to a sand-trap, where some of the sand is recovered for reuse. After the sand-trap, the wastewater flows through a channel to a mechanical separator, which removes large fibrous solids. The wastewater flows across a settling basin and then over a weir into a sump from where the digester is fed. Solids removed by the separator and from the settling basin are land applied.

Being a completely closed system, a fixed-film digester allows more complete anaerobic digestion of the odorous organic intermediates found in stored manure to less offensive compounds.

DIGESTER OPERATION

The digester tank is set on a custom-designed slab that has a conical bottom for easy removal/recycling of sludge. The influent wastewater is pumped from the sump using a pneumatic pump. The influent flow is monitored by the number of actuations of the influent pump. The influent line runs through the wall of the tank and into a central feed duct. In upflow mode, the wastewater flows down through the feed duct into the area below the media bed, then up through the media zones and back to the feed duct, where it flows out the effluent line into the level control structure.

A portion of the effluent is recycled through an open impeller centrifugal pump back to the influent line. The digested effluent flows down through an exterior culvert that houses the level control structure and to a storage pond to be land applied in accordance with the farm's nutrient management plan. A desludging pump removes sludge via a line leading from the apex of the conical bottom and recycles it back to the influent line through the recycle pump. The recycle line is equipped with a meter for continuous flow monitoring.

Biogas leaves the top of the digester tank through a two-inch PVC line and passes through a sediment trap to a mass-flow meter, prior to flowing through a pressure relief valve and on to the flare. Both pressure and vacuum emergency relief valves are located on top of the tank. The tank also has several sampling ports for obtaining mixed-liquor samples at various radii from above, below and within each media zone.

BIOGAS PRODUCTION

The unit is operating at a three-day HRT at ambient temperature and producing 6,000 ft^3 of biogas per day at 80 percent CH_4:20% CO_2. The biogas produced from the digester is being flared to reduce odors and emissions of methane, which is a potent greenhouse gas.

Potential options for biogas utilization at the DRU include: Production of hot water for use in the milking parlor; Generation of electricity for on-farm use; Absorption refrigeration for milk cooling; and Vehicular fuel. However, the total amount of biogas

that can be reliably produced in winter conditions is not yet known. For now, the biogas will continue to be flared until the best energy recovery option can be selected based on accurate biogas production information.

ADDITIONAL BENEFITS

In addition to minimizing offensive odors and producing usable energy, anaerobic digestion has several other important benefits. One advantage is nearly complete retention in the effluent of the fertilizer nutrients (N, P and K) that were in the raw manure entering the digester. Also, a broad spectrum of microbial pathogens can be destroyed by anaerobic digestion. This may have particular significance for animal health in recycle flush systems. The ability of the fixed-film digester to provide recyclable water for barn flushing is especially valuable as water becomes an increasingly precious limited resource.

Pretreatment by mechanical screening followed by high-rate methanogenesis in a fixed-film reactor is a novel concept in animal waste management. The primary benefit of separation of solids from liquids is the production of two fractions that are inherently more manageable than the original slurry. Minimizing waste stream solids avoids clogging problems and/or impaired biofilm activity. The benefits in terms of ease of materials handling, production of a high-fiber by-product, and reduction in digester volume requirements are substantial. Although digested wastewater solids produce biogas, fixed-film digesters achieve the highest treatment efficiency with diluted wastewater, or low-solids concentrations. Fibrous solids have potential use for bedding, refeeding and horticultural applications.

Produced at the rate of 6,000 cu. ft./day, digester biogas is currently being flared to reduce odors and methane emissions.

BOTTOM LINE

The financial attractiveness of on-farm anaerobic digestion is likely to improve considerably as environmental concerns assume greater importance. A complete assessment of economic feasibility must take account of all avoided costs and the value of intangible environmental externals, such as odor control and reduction of volatile emissions. Environmentally sound, sustainable practices are essential for staying in business over the long run. In order to coexist with their neighbors, intensive livestock operations must manage both effluents: the odors as well as the manure. The alternative may be to relocate the enterprise, or cease operations entirely. The fixed-film anaerobic digester offers an innovative technology option for waste management without limiting the enterprise. The process can be adapted to an individual situation and incorporated into the existing manure management scheme. The Alachua digester is destined to play a significant role in promoting the use of fixed-film anaerobic systems for processing of flushed dairy and swine manures. ■

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