Anaerobic Digesters Control Odors, Reduce Pathogens, Improve Nutrient Manageability, Can be Cost Competitive with Lagoons, and Provide Energy Too!

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Abstract

There has been quite a bit of discussion and information published about energy production from anaerobic digesters. The basic design concepts proven by successful digesters built in the 1980's are applicable today. Additional benefits from anaerobic digestion have not been emphasized. Anaerobic digestion is more extensively used outside of the US where concern for treatment of animal waste has been a concern for a longer time. In todays world, odor and pathogen control are important. The first pig manure digester systems in the US were installed principally to control manure odors. The odor control goal was successfully met. It has been suggested that recent US episodes of surface water contamination with E. coli, cryptosporidia, and pfiesteria blooms are linked with manure discharges. It can be expected that future legislation will address pathogen control. Pathogen reduction using anaerobic digesters has been extensively studied in Denmark, where many centralized animal waste digesters with strict requirements for pathogen reduction are in place. Anaerobic digestion will eliminate >99% of most pathogens. Recent regulatory changes require significantly more investment in manure treatment and storage systems. A one cell anaerobic lagoon designed for treatment and storage of pig manure under Natural Resources Conservation Service (NRCS) or American Society of Agricultural Engineers (ASAE) standards can be a very large lagoon. A two cell lagoon designed for methane recovery from the first cell can reduce the total lagoon volume requirement by 10 - 25% per NRCS Conservation Practice Standard 360. A two part manure treatment system including a heated, mixed anaerobic digester preceding a storage structure reduces total volume requirements by 50 - 80%. The construction cost savings from reduced volumes can be significant and may pay for digester substitution in the manure system. Substituting a digester for a lagoon at the same planned investment level results in a very low cost supply of methane for use on the farm and biologically stabile and virtually odorless manure. During anaerobic digestion much of the manure organic N is converted to ammonia. Ammonia application for crop growth can be more accurately managed than organic N application. Methane recovery and use reduces the effect of direct methane release to the atmosphere, where it is considered a problem as a greenhouse gas. Full scale, long term operating digester systems are described. References and calculations supporting conclusions are included.

Keywords: Biogas, methane, odor, anaerobic digestion, digester, covered lagoon, nutrient management, pathogens

Introduction

Some of the first comments from farmers and their friends when RCM began building on-farm anaerobic digesters were: " HEY, IT DOESN'T SMELL MUCH AROUND HERE ANYMORE", and "YOU KNOW, WE DON'T SEEM TO HAVE ALL THE FLIES WE USED TO". These were the first clues that non-energy benefits were appreciated.

Anaerobic digestion is widely applied in the treatment of high strength municipal sludges and industrial wastes. Transferring this technology to US farms has experienced limited success due to costs and a number of non-operational units. Anaerobic digestion is more extensively used outside of the US where biological stabilization of animal waste has been a concern for a longer time. The major on-farm interest has been energy production. Additional benefits from anaerobic digestion have not been emphasized.

Mother Nature has a Game Plan - Biological Stabilization

Manure is partially digested feed. The remaining partially degraded and unused materials continue to decompose upon leaving the animal. Bacterial decomposition begins in any manure containment and continues until the manure is removed or it is stabilized. The process can be simplified into two steps: Step 1 - Anaerobic bacteria degrade wet, unfrozen manure into the odiferous compounds associated with "that nasty manure smell"; Step 2 - Methane bacteria consume Step 1 compounds, given adequate time at a temperature above freezing, substantially eliminating the odors.(1,2) Manure completing Step 2 is "biologically stabilized" and is no longer manure but is treated effluent.

In todays world, odor control, pathogen control, costs and nutrient management are important when selecting manure management system components. See The AgSTAR Handbook(1) for descriptions of digesters.

Odor Control Benefit - Never Having to Say You're Sorry

An anaerobic digester is a structure where the goal is continuous methane production and a biologically stabilized effluent. Digesters reduce odor generation and migration. Digester effluent does not release effusive objectionable odors. The effluent of a digester has an earthy smell with some ammonia present. A paper by Wilkie et al (2) summarizes odor control benefits of anaerobic digestion.

The primary goal of digesters at Rocky Knoll Farms of Lancaster, PA (800 sows farrow to finish) and Valley Pork in 7 Valleys, Pennsylvania (1,500 sows, farrow-to finish) was to reduce manure odors. Both farms were located within sight of clusters of non-farm residences. Both were located within a mile of towns and subdivisions. Valley Pork had an acute odor problem prior to installation of the digester system. The digester stabilized the manure, collected usable gas and satisfied the objections of the neighbors, town council and state regulators.

Pathogen Reduction Benefit - A Future Issue

Pathogen reduction has not been a topic of much concern in manure management in the US. However, it has been suggested that recent US episodes of surface water contamination with E. coli, cryptosporidia, and pfiesteria blooms are linked with manure discharges. It can be expected that future legislation will address pathogen control. Pathogen survival times have been extensively studied in Denmark where many centralized animal waste digesters with strict requirements for pathogen reduction are in place. (3)

Pathogens survive weeks or months in unheated manure storage structures. Fresh manure mixed in a storage may be inadvertently field applied with minimal reduction of pathogens. Pathogens are reduced in heated mesophilic digesters (37^{o} C) in days and thermophilic digesters (55^{o} C) in a matter of hours.(3) Separating digestion from storage will provide adequate time to reduce most pathogens and viruses.

Improved Nutrient Manageability - An Underappreciated Benefit

Most manure application is managed based on the nitrogen application rate. 30 - 50 % of the nitrogen in raw manure is in the organic form and the rest in the ammonia form. Ammonia can be converted to nitrate for plant uptake, while some plants may use ammonia directly. Use of ammonia for plant fertilization is well known and predictable. Organic N must be freed from organic molecules (mineralized) into soil solution to be either used by plants or converted for use. Mineralization occurs when the soil is not frozen. A problem can arise when organic N is mineralized in the spring and fall when soils are unfrozen, but minimal plant growth is occurring. Mineralized N can be converted to nitrate and leached from the soil when plants are unable to take it up, contributing to ground water pollution.

Anaerobic digestion converts much of the organic N into ammonia yielding an effluent with 60 - 80% ammonia. Ammonia availability is a predictable fertilizer, whereas organic N availability is unpredictable. The higher the percentage of N in the ammonia form, the less uncontrolled release of N from organic compounds to the soil. To maximize the benefit of manure fertilization and minimize leaching losses, ammonia is preferred.

Costs of Digester Benefit - May be Competitive with Lagooning

In the cooler regions of the US, heated tank digesters may substitute for the treatment volume of a lagoon at a cost near the cost normally invested in that volume. However, a digester does not replace the need for storage.

Lagoons are used to biologically stabilize and minimize odors from manure. For Ames, Iowa, the Natural Resource Conservation Service(4) recommends sizing a lagoon to receive 4 pounds of volatile solids (VS) per 1000 ft3 of dedicated lagoon treatment volume per day. This is a loading rate of 0.004 lb/ft3.

Digesters are used to biologically stabilize and minimize odors from manure. A heated digester performs the same biological function as a lagoon in a much shorter time because of the higher temperature. For a heated anaerobic digester, the minimum total solids concentration to sustain self heating is 3% with a VS concentration of 2.4% or 1.5 lb VS/ ft^3. This concentration can be achieved by underfloor scrapers or managed pull plug manure collection. A conservatively designed heated mixed digester is sized for a 20 day retention time. Therefore, the loading rate is 0.075 lb VS/ ft^3 (1.5 lb/ft^3/20 days).

By comparison of the loading rates above one can see that a heated digester requires about 1/20 of the treatment volume needed in a lagoon to perform the same function.

Per unit of volume, digester construction will cost more than lagoon construction. However, a heated digester requires a much smaller volume than a lagoon. Costs vary between regions, soil types and digester types. Costs from recent AgSTAR projects(4) were reviewed, and gas use costs such as generators were removed. Unlined lagoon construction cost \$0.07/ft^3(4) while a HDPE lined lagoon cost about \$ 0.16/ft^3.(5) Concrete tank digesters including boilers to maintain digester temperature cost \$1.90 to \$2.25/ft^3.(4) A digester project under construction using a clay lined, partially concrete lined lagoon will cost about \$1.09/ ft^3. (5)

A lagoon system requires 20 times the volume as a heated digester to get the same treatment and that investment could be transferred into a digester construction. Therefore, for comparable levels of biological stabilization one would spend about \$1.40 in unlined lagoon; \$ 3.20 in an HDPE lined lagoon; \$2.25 in a structural tank, heated, mixed digester; or \$ 1.09 in a heated, mixed, covered, lined lagoon digester.

Substitution of a digester investment for lagoon treatment volume investment yields excess methane which is essentially a free energy source. Further investment in gas use equipment such as an engine generator should have a very rapid payback. Additional savings are realized by reduction of lagoon surface area, thereby reducing rainwater collection and land application costs. Also, the stored effluent is of uniform quality and will not be an odor source when land applied.

References

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