Farm Digesters and Digestion 101

by Mark Moser

A Promising Solution - Anaerobic Digestion Technology

Anaerobic digestion is one of the few manure treatment options that reduces the environmental impact of manure and produces savings and revenues. Anaerobic digestion will not solve all of the problems of manure. However, it will result in a return on the manure management investment and stop the manure from managing the owner.

Environmental Benefits

Much information has been published about energy production from anaerobic digesters. Equally important, however, a properly designed and operated digester biologically stabilizes organic wastes, reduces odor, improves fertilizer value, and reduces pathogens. It can be expected that future regulations will address pathogen control. Anaerobic digestion is more extensively used in Taiwan and Europe where animal waste pollution has been regulated for a longer time. The US and Pacific Rim countries have seen a recent increase in the use of digesters due to tighter enforcement of regulations.

General Effect of Digestion on BOD, Nutrient, Pathogen and Weed Seed

Anaerobic digestion in a digester will reduce BOD and TSS by 80-90%. Odor is virtually eliminated. The digester will have minimal effect on the nutrient content of the digested manure. Pathogen reduction is greater than 99% in a 20 day HRT mesophilic digester (100 degree F). Half or more of the organic nitrogen (Org-N) is mineralized to ammonia (NH3-N). A small amount of the P and K will settle as sludge in most digesters. 30 - 40 % of P and K are retained in covered lagoon digesters. Digesters are very effective in killing weed seeds.

General Technical Description - Overview of Anaerobic Digestion

Manure consists of partially decomposed feed, waste feed, and water. Manure alone or mixed with process water and flush water is generally too concentrated to be decomposed aerobically in a manure treatment or storage structure, because oxygen cannot diffuse into solution fast enough to support aerobic bacteria. Therefore, manure is broken down sequentially by groups of anaerobic bacteria. An anaerobic digester is a vessel sized to grow and maintain a population of methane bacteria that feed on organic wastes placed in the unit. The bacteria grow without oxygen, decompose the waste, and produce methane as a useable fuel byproduct. Methane bacteria are slow growing, environmentally sensitive bacteria. These bacteria require a pH greater than 6.5 and adequate time to convert organic acids into biogas. Methane production is reduced as water temperature decreases.

Anaerobic digestion can be simply grouped into two steps. The first step is easy to recognize because the decomposition results in bad manure odors. The second stage methane bacteria consume the products of the first step and produce biogas - a mixture of methane and carbon dioxide. Biogas from a stable digester contains 60% - 80% methane. Biogas is virtually odorless but contains a small amount of mercaptans such as hydrogen sulfide.

Biogas Production Potential

Table 1 shows the expected ranges of biogas production from typical US farm raised animals. The last column lists the animal population to support a 40 kW engine, as it is the smallest suitable engine-generator in the US.

Table 1. Biogas Production Potential

	kWh/ head/day	Biogas Production ft3/d	Population for 40 kW continuous output generator
Cow	2.5-3.7	**6**	4
Sow	0.2 - 0.3	**5-7.5**	3
Nursery	0.06 - .09	**1**	1
Finisher	0.15 – 0.22	**3**	4
Beef Feeder	1.8 – 2.2	**4**	6
Laying hen	.01	**0.25**	72,000

Anaerobic Digester System Components

An anaerobic digester system includes manure collection, pretreatment, an anaerobic digester, biogas recovery, biogas handling and biogas use.

- **Manure** must be collected fresh on a regular schedule for digestion. A very important design consideration is the amount of process water included in the manure collection. Process water includes all water from all sources that mixes with manure.
- **Pretreatment** is used to adjust the manure or slurry contents to meet process requirements of the selected digestion technology. A mixing tank or solids separator are pretreatment options.
- **An anaerobic digester** is an engineered containment vessel designed to promote the growth of methane bacteria. The digester may be heated or unheated, mixed or unmixed, a simple tank or a very complicated media packed column. Manure characteristics and collection technique determine the type of anaerobic digestion technology that can be used.
- **Biogas** formed in a digester bubbles to the surface and may be collected by a fixed rigid top, a flexible inflatable top or a floating cover depending on the type of digester. The collection system directs biogas to gas handling components.
- **Biogas** may be filtered for mercaptan and moisture removal. Biogas is usually pumped or compressed to operating pressure and then metered to the gas use equipment.
- **Biogas** that is pressurized and metered can be used as fuel for heating, adsorption cooling, electrical generation and cogeneration. Biogas can be substituted for low pressure natural gas or propane in the equipment listed in Table 2.

Table 2. Biogas Use Options

Biogas Fueled Engine

- Electrical generator - electricity for use or sale, heat recovery optional
- Refrigeration compressors - cooling, heat recovery optional
- Irrigation pumps - pumping, heat recovery optional

Direct Combustion Options

- Hot water boiler - for space heat, process and cleanup hot water
- Hot air furnace - for space heat
- Direct fire room heater - for space heat
  Adsorption chiller - for cold water production, heat recovery optional

Available Anaerobic Digestion Technologies

Many configurations of anaerobic digesters have been developed but may or may not be commercially available for farms. Table 3 lists the operating characteristics of digester technologies. Covered lagoons and complete mix digesters are commercially available.

Table 3: Types of Digesters and their Characteristics

Type of Digester	Tech Level	Influent Solids Concentration	Solids Allowable	Supplemental Heat	HRT (days)[1]
Ambient temperature covered lagoon	low	0.1 - 2%	fine	no	40+
Complete mix	medium	2.0 -10%	coarse	yes	15+
Packed reactor[2]	medium	0.5 - 2%	soluble	yes	2+
Plug Flow[3]	low	11 - 13%	coarse	yes	20+

(1) HRT = Hydraulic Retention Time = digester volume/daily influent volume
(2) Attached growth reactors
(3) Dairies only

Cost Effectiveness of Anaerobic Digestion

There are no simple answers to the question of cost effectiveness. The economics depend on the cost of electricity or heat energy. Digester projects will meet this requirement for farms with electricity costs of greater than $0.06/kWh that can use most of the electricity on site.

If there is value to fertilizer improvement, pathogen reduction or odor control and it can be accounted for in the farm balance sheet, then a digester may be more profitable. If a farm has to meet government regulations on wastemanagement and a digester may be substituted for another management option, the added costs of a digester may have a very high return over spending money on a non-revenue alternative.

Most projects rely on a multitude of benefits to recover the investment. Heat that improves production, disease control that keeps animals and people healthy, and odor control that keeps people happy and productive are benefits that are seldom assigned their true worth. In some cases, a digester has recovered its cost by avoiding penalty fines and neighbor complaints or lawsuits. In other cases, particularly for dairies, the digester improves the handling capability of the material and saves the farm money on materials handling. At dairies, digested solids can be recovered and used for bedding.

Financial Structuring

Many digester systems are built with a combination of public and private funding. Most countries that are serious about pollution control offer the private farms a cost sharing arrangement, with 20-60% of a digester funding coming from the government. It is in the public interest to keep farms open, the farmers employed, farm products inexpensive to society, and to reduce or eliminate animal waste pollution of drinking water sources. Some “subsidy” is offered worldwide, either financial or through limited enforcement, based on the assumption that a farmer with little or no investment in manure management will not reduce pollution if the costs exceed the profits from animal production.

General Economic Effect

Digesters are considered expensive because of the time and capital costs involved in most projects. However, farms have been the rapidly consolidating into larger units with larger pollution potential. The large pollution potential results in more people wanting to take advantage of digester technology to benefit from production of energy while reducing pollution.

Critical Points of the Adoption of Alternatives

Technical Challenges and Organizational Adjustments

In general, there are no technical barriers to anaerobic digestion. The economics are such that many

large farms could have favorable returns on investment. Large farms are often targeted for regulation and required to manage manure, therefore those farms are more likely to invest in a digester. Still, many farms would rather not spend any money on pollution control regardless of the return because the farms prefer to target their time and investment in animal production. As a technology, digestion is superficially known. Another barrier to the use of the technology is the lack of knowledge in the areas of design by engineers and regulators.

Economic and Finance Aspects - Investment Recovery

Digesters are cost competitive with other manure treatment technologies. Surprisingly, farms or farm advisors do not regularly consider return on investment. Farmers assume that pollution control is a cost item and chose a lesser-cost alternative. Farm banks are reluctant to finance digesters because the technology is still not widely used. Government encouragement has had the most effect in implementing digesters. There are thousands of digesters in Taiwan and hundreds in Europe where the environmental benefits of anaerobic digestion are recognized and promoted.

Incentives - Disincentives

In general, there are few incentives for regulatory compliance and investment. A majority of farms prefer to minimize investment in manure management. Some incentives may be necessary to encourage farms to install and maintain manure management systems as has been done in Europe and Taiwan. Recently the United States has adopted a punitive and restrictive approach for farm manure management. The Attorney General of Illinois recently sued a farm for odor. Thus, the economics of manure change dramatically. Disincentives are now driving owners. More regulation and enforcement has forced US farms to consider the options more carefully. Several have reached the conclusion that if they have to spend money on manure management, then a digester is a viable option in recovering their costs.

Market Advantages

In the longer-term analysis, an anaerobic digester will improve the profitability of most, but not all farms. In the future, the advantages of the systems will be more fully appreciated. There are hundreds more digesters today than there were 10 years ago. Industry has embraced the technology as a lower cost alternative for pollution control and many farms will also. When the technology is compared with alternatives, farmers realize that the advantages exist. If farms in all countries must meet similar pollution control regulations, then they will all consider their options and many will select digestion for the edge it will give them in profitability.

Does Anaerobic Digestion Solve the Problem?

A problem must be recognized before it can be solved. Farms and governments are recognizing the need for control of point source and non-point discharge from animal production. Controls cost money. Digesters make money for the farm from heat or electricity, reduced odor, reduced flies, reduced pathogens, killed weed seeds, and improved fertilizer values. Therefore; anaerobic digestion can be a solution to the problem.

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