METHANE GENERATION FROM LIVESTOCK WASTES

Methane generation has recently become a popular topic for treatment of livestock wastes. It is labeled as the solution to pollution problems and the energy crisis all wrapped into one. Some potential exists for some operators in certain situations. But it is not a practical solution for many other operators.

Advantages

Advantages of methane generation are basically three. First, energy is harvested from waste which would otherwise be lost. Second, odors which would otherwise escape and cause problems, are contained in digestors. They are not eliminated, but merely held in the closed digestor until the gas is used. Third, valuable nutrients are retained. Significant losses, especially of nitrogen, occur from open lagoons, deep pits, and aerobic systems. Methane generators retain the nitrogen, though it still may be lost in storage after leaving the generator.

Disadvantages

There are three disadvantages of methane digestion. First, digestors are expensive. Second, anaerobic digestion is complex and sensitive to environmental conditions. Careful management is required. Third, digestion is not a disposal system. Over 90 percent of the waste going in (including the additional dilution water that must be added for all but dairy wastes) comes back out as liquids and solids, and must then be disposed of.

Basic Anaerobic Digestor Process

Anaerobic digestion is a two-part process, and each part is performed by a specific group of organisms. The first part is the breakdown of complex organic matter (manure) into simple organic compounds by acid-forming bacteria. Several species of acid-forming bacteria grow and reproduce rapidly and are not very sensitive to their environment. They essentially break down complex organics and produce primarily acetic acid and propionic acid, along with some ammonia, and carbon dioxide.

The second group of microorganisms, the methane-formers, break down the acids into methane and carbon dioxide. This group is composed of a relatively few species of bacteria that grow and reproduce slowly and are quite sensitive to their environment.

In a properly functioning digestor, the two groups of bacteria must be balanced so that the methane-formers just use the acids produced by the acid-formers. If the acid-formers get ahead of the methane-formers, acids begin to accumulate, the pH drops, the methane-formers are inhibited, and ultimately digestion ceases. The balance of the two groups of bacteria is affected by several factors including loading quantity, quality, and frequency, as well as temperature, toxic elements, and pH.

Temperature

Anaerobic digestors for livestock waste treatment are normally operated in a temperature range of 86 to 95 degrees F. The temperature most commonly used is 95 degrees F. Other temperatures can be used, if the temperature is held constant. For each 20-degree F drop, gas production will be cut approximately in half, or will take twice as long. Likewise, for each 20-degree F rise, activity will double. The factors to be considered are the energy required to maintain the digestor temperature and the gas production.

A constant temperature is very critical. Variation should not exceed ±3 degrees F. A rapid temperature drop of 5 degrees F will inhibit the methane-formers enough to cause an acid accumulation and a possible digestor failure. Once a digestor starts to fail, reestablishing the proper temperature may not prevent complete failure.

Tank Size

Tank size is controlled by the number, size, and type of animals served, dilution water added, and detention time. Table 1 shows some recommended sizes.

The factor that can be most easily changed with regard to tank size is detention time. Ten days is the minimum, but any number larger can be used. The longer the detention time, the larger the tank must be. Longer detention times allow more decomposition of wastes. Fifteen days is a frequently used detention time.

Toxicities

Heavy metal toxicities are possible, but they generally are not a problem. Copper sulfate is sometimes used as a swine supplement, but the copper

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Pm-593
July 1974

Table 1. Loading rate guidelines for heated, mixed anaerobic digestors at 95°F being fed fresh livestock manures.

Factor	Swine, Growing-finishing	Dairy	Beef, under 700 lbs.	Poultry, Layer	Poultry, Broiler
Dilution ratio (Manure) : (manure + water)	1:2.9	Undiluted	1:2.5	1:8.3	1:10.2
Estimated dilution water, gal. water/ 1000 lb. body wt.	15	0	11	47	79
Hydraulic detention time, days	12.5	17.5	12.5	10	10
Loading rate, lb. volatile solids per cubic foot per day	0.14	0.37	0.37	0.13	0.1
Digestor volume, cubic feet/1000 lb. animal	30	24	14	72	120

This data is designed to avoid ammonia toxicity (total ammonia < 1200 milligrams/liter) and excess acid production (loaded < 0.37 pounds volatile solids per cubic foot per day).

From R.J. Smith, The Anaerobic Digestion of Livestock Wastes and the Prospects for Methane Production. Presented at Midwest Livestock Waste Management Conference, ISU, Ames, IA. Nov. 27-29, 1973.

is tied up by sulfides in the sludge so it doesn't create a problem.

Excess ammonia is the most serious problem. Ammonia levels of 1500 to 3000 milligrams per liter (mg/l) are inhibitory, and levels over 3000 mg/l cause complete failure. This is especially critical with poultry and swine waste. Dilution rates directly affect tank size. Three times the volume requires three times as large a tank to maintain the desired detention time. Table 1 shows dilution rates required to control ammonia toxicities.

One other factor to watch is volatile acids. Excessive acids are caused by overloading the digestor. (Remember the acid-formers work much faster than the methane-formers). Upper loading limits of volatile solids depend on the type of animal and are approximately as shown for loading rates in table 1.

pH

Methane-formers are sensitive to pH. They work best in a range of 6.8 to 7.2, although they will tolerate a range of 6.5 to 7.6. Any over-feeding of the digestor will cause the pH to drop because, with excessive organic matter available, the acid-formers can produce more acid than the methane-formers can use. From this, it is easy to see that batch loading will cause problems. Frequent loading is necessary for good operation—the more frequent, the better. Anaerobic digestors are therefore adapted primarily to automated flushing or scraping systems.

High pH is also toxic and would occur with high ammonia levels. As stated previously, the solution to this problem is proper design for dilution.

Operation

Now that we know some of the problems, how much gas will be produced? A good rule of thumb is 10 cubic feet of gas produced per pound of COD (chemical oxygen demand), or 12 cubic feet of gas per pound of volatile solids digested (destroyed). The gas produced is generally in the range of 60 percent methane (CH_4) and 40 percent carbon dioxide (CO_2). Table 2 summarizes the estimated gas production from various animal wastes.

Anaerobic digestion is not a disposal process; it is a treatment process. The portion of the waste that is decomposed is the volatile solids. With a 15-day detention time, approximately 65 percent of the volatile solids will be broken down. The following calculations are representative of what can be expected from a digestor for most animals:

Assuming 1000 pounds of swine body weight:
- Daily total waste production = 70 lbs.
- Daily total solids @ 15% = 10.5 lbs.
- Daily volatile solids @ 75% total solids = 7.9 lbs.

Dilute 3:1 for ammonia toxicity control
- Total inflow to digestor = 210 lbs/day
- Volatile solids @ 7.9 lbs/day = 3.8% of inflow
- Volatile solids decomposition @ 50% = 3.9 lbs/day

Daily outflow = 210-3.9 = 206.1 lbs/day

$$\text{Daily outflow} = \frac{206.1 \times 100}{210} = 98.1\% \text{ of inflow}$$

This figure will vary primarily according to dilution rate, but in general it will be over 90 percent. You should, therefore, plan to store and dispose of the entire volume of waste after it goes through the digestor.

System Mechanics

Figure 1 shows the basic elements of a single-stage anaerobic digestor. Submerged inflow and outflow lines are needed to prevent gas from escaping. Either a mechanical mixer can be used or the liquid or gas can be recirculated for mixing. Without mixing, a scum will form on top and prevent optimum digestion. A heat exchanger and thermostat are used to maintain the proper temperature. The heat exchanger can be either internal or external. Digestors are sometimes buried to use the soil as insulation, but additional heat will still be needed in the winter for optimum digestion.

A method is needed to transport the wastes from

Table 2. Gas production from animal wastes (60% CH_4 and 40% CO_2) per 1000 pounds body weight.

Animal	Defecated volatile solids lb/day	Expected volatile solids destruction, percent*	Gas cu ft/day	Btu/day**
Swine, growing-finishing	4.8	0.5	29	17,400
Beef	5.9	0.45	30	18,000
Dairy	8.6	0.48	44	26,000
Poultry, Layers	9.4	0.6	72	43,000
Poultry, Broilers	12.0	0.6	92	55,000

*Volatile solids destruction depends primarily on detention time and digestor temperature.

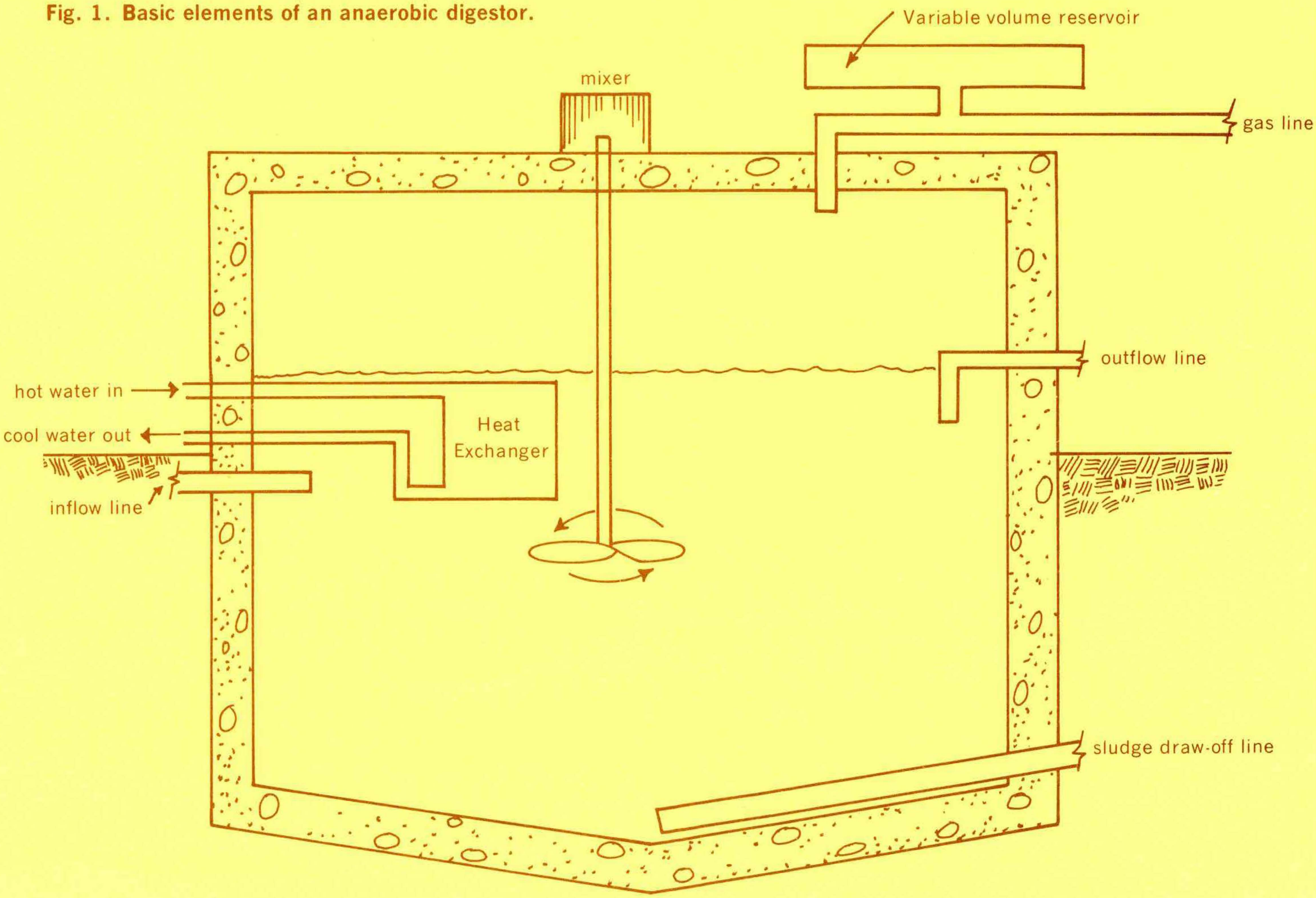
**Calculated at 600 Btu/cubic foot. One Btu is the heat required to raise the temperature of 1 pound of water 1 degree Fahrenheit.

the animals to the digestor. Flushing or scraping systems are well adapted because they can provide frequent waste removal and feeding.

The waste cannot enter a stream after it leaves the digestor because it is still highly polluted. Since most operators do not want to haul liquid manure every day, lagoons are used to hold the waste until it can be disposed of. Final disposal can then be either by hauling or pumping onto agricultural land. Pumping is generally the preferred method because of the high volume of waste due to dilution. Sludge must be periodically removed and disposed of.

Methane is drawn off the top in the digestor. For gas utilization a compressor and storage tank are used, along with the associated plumbing which would include flame traps, pressure gages, regulators, hydrogen sulfide scrubber, and pressure relief valves. A popular facility for gas storage is the floating cover which floats upward while maintaining essentially constant pressure. With a variable volume reservoir such as a floating cover, the compressor is run less frequently. Thus, there is less chance of producing a vacuum in the digestor, which might cause it to collapse.

Fig. 1. Basic elements of an anaerobic digestor.



Methane, unlike propane which can be easily liquefied, can not be liquefied by compression alone. Heating values of various fuels are shown below.

Methane	–1050 Btu/cubic foot
Natural gas	–1050 Btu/cubic feet
Propane	–92,000 Btu/gal.
Gasoline	–128,000 Btu/gal.
Kerosene	–136,000 Btu/gal.

Summary

Anaerobic digestion of animal wastes can produce a usable gas containing a good deal of energy. Unless the system is very large, extra energy will probably have to be added during wintertime operations to maintain the proper temperature in the digestor. Odor containment and nutrient retention are also advantages of digestion.

Primary disadvantages are the amount of management required due to the sensitivity of digestors, the high initial investment required for equipment, and the fact that the wastes must still be disposed of after digestion.

Cooperative Extension Service, Iowa State University of Science and Technology and the United States Department of Agriculture cooperating. Marvin A. Anderson, director, Ames, Iowa. Distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914.