Anaerobic Digestion of Animal Manures: Types of Digesters

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This Fact Sheet covers anaerobic digesters used on farms with liquid, slurry, or semi-solid manure handling systems. For solid-state digestion, digesters that process stackable, high solids materials, such as cotton gin trash, yard waste, food waste, feedlot scappings, and municipal solid wastes, see Extension Fact Sheet BAE 1764, Solid-State Anaerobic Digestion.

Categories of Digesters
All anaerobic digesters perform the same basic function. They hold manure in the absence of oxygen and maintain the proper conditions for methane forming microorganisms (methanogens) to grow. There are a wide variety of anaerobic digesters, each performing this basic function in a subtly different way. Eight of the most common digesters are described in this document. Construction and material handling techniques can vary greatly within the main categories.

1. Passive Systems: Biogas recovery is added to an existing treatment component, and little control is exercised over the reactor environment.
2. Low Rate Systems: Manure added to a digester is the main source of methanogens. Solids retention time (SRT) of the digester, or the length of time solid particles are held in the digester, equals hydraulic retention time (HRT) – the length of time liquid is held in the digester.
3. High Rate Systems: Methane forming microorganisms are trapped in the digester to increase efficiency, and SRT is greater than HRT.

Summary
Livestock producers are faced with a dizzying selection of reactor types when choosing an anaerobic digester to produce biogas on-farm. Digesters can be classified as passive (covered lagoons), low rate (complete mix, plug flow, mixed plug flow), and high rate (contact stabilization, fixed film, suspended media, and sequencing batch). All reactors perform the same basic function, but each type operates at an optimal manure consistency. Levels of efficiency also vary between reactor types. More efficient reactors are generally more complicated and expensive at a given farm size.

Figure 12. ASBR digester located on the Oklahoma State University Swine Research and Education Center.

Figure 11. Schematic drawing of an Induced Bed Reactor (IBR) Digester (Courtesy of Coryl Hansen, Utah State University).

During the react phase, solids are settled during the settle phase, and effluent is drawn off during the decant phase. The cycle is repeated up to four times a day for nearly constant gas production. Hydraulic retention times can be as short as five days. These digesters work well with very dilute manures, and if filled with active microbes during start-up, can even produce biogas with completely soluble organic liquids. Sludge must be removed from the ASBR digester periodically. Concentrated nutrients are harvested during sludge removal.

Figure 13. Four phases of an ASBR Cycle.

Categories of Digesters

Passive Systems
Covered lagoon: This system takes advantage of the low maintenance requirement of a lagoon while capturing biogas under an impermeable cover (Figure 1). The first cell of a two-cell lagoon is covered, and the second cell is uncovered (Figure 2). Both cells are needed for the system to operate properly. A lagoon provides storage, as well as treatment. The liquid level of the second cell must rise and fall to create

Figure 1. First covered cell of a lagoon located on the Oklahoma State University Swine Research and Education Center.

Figure 2. Schematic drawing of covered lagoon digestion system.

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The level of the first cell remains constant to promote efficient manure breakdown. If lagoon effluent is recycled to remove manure from buildings, HRT of the covered cell is usually 30 to 60 days. When lagoons are used for high solids manure, the SRT can be as long as 20 years. This long SRT means that a lot of microorganisms are retained in the lagoon. However, this can be a problem at lower solids concentrations. Lower solids mean that there is a lower number of microorganisms in the lagoon, which can lead to an imbalance in the microbial population. This can cause problems such as reduced biogas production or increased methane emissions.

**Low Rate Systems**

**Complete Mix Digesters:** A complete mix digester (Figure 3) is a tank in which manure is heated and mixed with an active mass of microorganisms (Figure 4). Incoming liquid displaces volume in the digester, and an equal amount of liquid flows out. Methanogens flow out of the digester with the displaced liquid. Biogas production is maintained by adjusting volume so that liquids remain in the digester for 20 days to 30 days. Retention times can be shorter for thermophilic systems. The digester can be continuously or intermittently mixed. Intermittent mixing means the tank is stirred during feeding and only occasionally between feedings. Sometimes digestion takes place in more than one tank. For instance, acid formers break down manure in one tank, and methanogens convert organic acids to biogas in a second tank. Complete mix digesters work best when manure contains 3 percent to 6 percent solids. Digester size can be an issue at lower solids concentrations. Lower solids mean greater volume, which means you need a larger digester to retain the microbes in the digester for 20 days to 30 days.

**Plug Flow Digestor:** The idea behind a plug flow digester (Figure 5) is the same as a complete mix digester – manure flowing into the digester displaces digester volume, and an equal amount of material flows out. However, the contents of a plug flow digester are thick enough to keep particles from settling. Manure moves through the digester as a plug, hence the name “plug flow.” Plug flow digesters do not require mechanical mixing. Total solids content of manure should be at least 15 percent, and some operators recommend feeding manure with solids as high as 20 percent. This means you may need to add extra material to manure to use a plug flow digester. This is not always a bad thing if you consider the added material may also be biodegradable. More degradable material means more biogas. Plug flow digesters are usually five times longer than they are wide. Recommended retention time is 15 days to 20 days.

**Fixed Film Digesters:** In these digesters, microbes are suspended in a constant upward flow of liquid. Flow is adjusted to allow smaller particles to wash out, while allowing larger ones to remain in the digester. Microorganisms form biofilms around the larger particles, and methanogens stay in the digester. Effluent is sometimes recycled to provide steady upward flow. Some designs incorporate artificial support media, such as sand, for microbes to form a biofilm.

**UASB Digesters:** In this digester, methane forming microorganisms grow on supporting media such as wood chips or small plastic rings filling a digestion column (Figures 8 and 9). These digesters are also called Attached Growth Digesters or Anaerobic Filters. The slimy growth coating the media is called a biofilm. Hydraulic retention times of fixed film reactors can be shorter than five days, making it suitable for small digesters. Usually, effluent is recycled to maintain a constant upward flow. One drawback to fixed film digesters is that manure solids can plug the voids between the media, preventing solids from flowing out. A solid separator is needed to remove particles from the manure before feeding it to the digester. Some potential biogas is lost due to removing manure solids.

**Batch Reactor:** Batch digesters are those that rely on manure particles to provide attachment surfaces for microorganisms in the reactor column. Some common types of suspended media digesters are the Upflow Anaerobic Sludge Blanket Reactor or UASB Digester (Figure 10) and the Induced Blanket Reactor or IBR Digester (Figure 11). UASB digesters work best with low solids influent. IBR digesters require high solids manure to function properly.

**Sequencing Batch Reactor:** A sequencing batch reactor (SBR) is a variation on an intermittently mixed digester. Microorganisms are kept in the digester by setting solids and decanting liquid. An SBR operates in a cycle of four phases (Figure 13). The digester is fed during the fill phase, manure and microbes are mixed...