Sequencing Batch Digester. An ***Anaerobic Sequencing Batch Reactor*** (Figure 12), or ***ASBR digester***, is a variation on an intermittently mixed digester. Methane forming microorganisms are kept in the digester by settling solids and decanting liquid. An ASBR operates in a cycle of four phases (Figure 13). The digester is fed during the fill stage, manure and microbes are mixed during the react phase, solids are settled during the settle stage, and effluent is drawn off during the decant stage. The cycle is repeated up to four times a day for nearly constant gas production. Liquid retention times can be as short as 5 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 12. ASBR digester located on the Oklahoma State University Swine Research and Education Center.

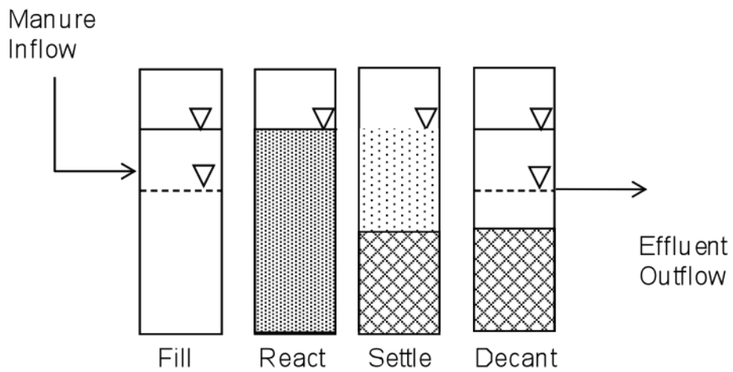

Figure 13. Four phases of an ASBR digester cycle.

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Anaerobic Digestion of Animal Manures: Types of Digesters

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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 to grow. There are a wide variety of anaerobic digesters, each performing this basic function in a subtly different way. Seven of the most common digesters are described in this document. Construction and material handling techniques can vary greatly within the main categories.

For clarity, we can divide digesters into three categories:

Passive Systems: Biogas recovery is added to an existing treatment component.

Low Rate Systems: Manure flowing through the digester is the main source of methane forming microorganisms.

High Rate Systems: Methane forming microorganisms are trapped in the digester to increase efficiency.

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 efficiently. A lagoon provides storage, as well as treatment; the liquid level on the second cell must rise and fall to create storage, while the level on the first cell remains constant to promote manure breakdown. Since they are not heated, the temperature of covered lagoons follows seasonal patterns. Methane production drops when lagoon temperatures dip below 20 C. A covered lagoon located in the tropics will produce gas year-round, but gas production will drop considerably during the winter as you move further north. Since sludge is stored in lagoons for up to 20 years, methane forming microorganisms also remain in the covered lagoon for up to 20 years. This means that much of the fertilizer nutrients, particularly phosphorus, also remain trapped in the covered lagoon for a long time. If lagoon effluent is recycled to remove manure from buildings, liquid retention time is generally 30 days to 60 days—depending on the size and age of the lagoon.

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

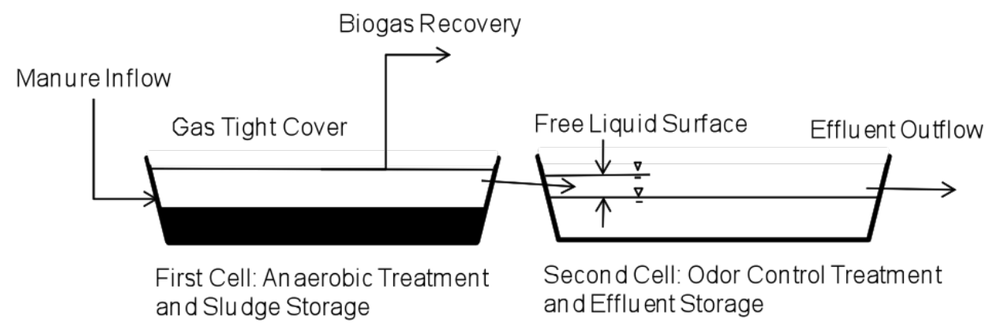

Figure 2. Schematic drawing of covered lagoon digestion system.

Low Rate Systems

Complete Mix Digester: A complete mix digester (Figure 3) is basically 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. Methane forming microorganisms 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 thermophyllic systems. The digester can be continuously mixed or intermittently mixed. Intermittent mixing means the tank is stirred during feeding and only occasionally between feedings. Sometimes the process takes place in more than one tank. For instance, acid formers break down manure in one tank, then methane formers 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.

Figure 3. Complete mix digester located on the Cave Brothers Farm in Waterloo, Wis. (Photo courtesy of Cave Brothers Farm/USEPA).

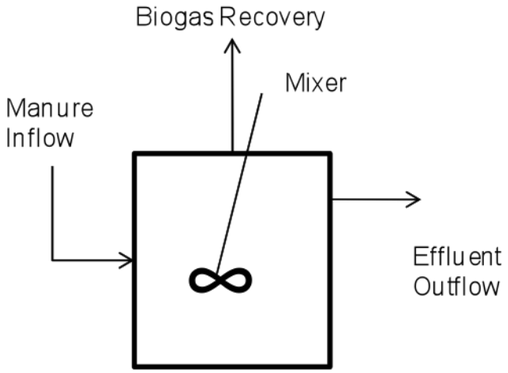

Figure 4. Schematic drawing of a complete mix digester.

Plug Flow Digester: 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 (Figure 6). However, the contents of a plug flow digester manure are thick enough to keep particles from settling to the bottom. Very little mixing occurs, so 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.

Figure 5. Plug flow digester located on the Emerling Farm in Perry, N.Y. (Photo courtesy of Cornell University/USEPA).

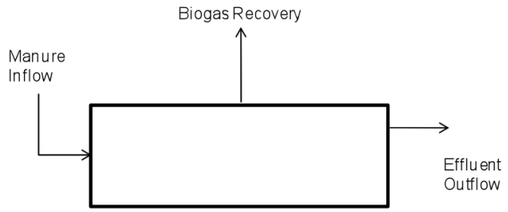

Figure 6. Schematic drawing of a plug flow digester.

High Rate Systems

Solids Recycling: Returning some of the active organisms to the digester decreases digestion time. This is done in plug flow systems by pumping some of the effluent leaving the digester to the front of the digester. In complete mix systems, solids are settled in an external clarifier, and the microbe-rich slurry is recycled back to the digester. The systems are called ***Contact Stabilization Digesters***, or ***Anaerobic Contact Digesters*** (Figure 7).

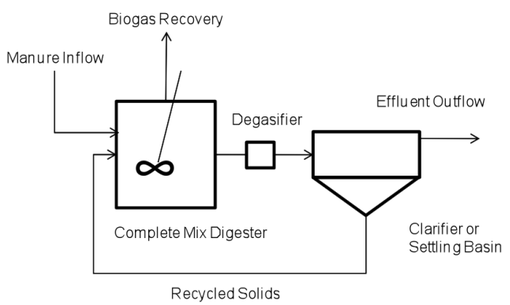

Figure 7. Schematic drawing of contact stabilization digester.

Fixed Film Digester: In this digester, methane forming microorganisms grow on supporting media such as wood chips or small plastic rings that fill a digestion column (Figures 8 and 9). These digesters are also called ***Attached Growth Digesters*** or ***Anaerobic Filters***. The slimy growth coating on the media is called a biofilm. Retention times of fixed film digesters can be lower than 5 days, making for relatively 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 supporting media. 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.

Figure 8. Fixed film digester located on the University of Florida Dairy Research Farm (Photo courtesy of Ann Wilkie, University of Florida) .

Suspended Media Digesters: In these types of 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 methane formers stay in the digester. Effluent is sometimes recycled to provide steady upward flow. Some designs incorporate an artificial supporting media, such as sand, for microbes to form a biofilm; these are called ***Fluidized Bed Digesters***. Suspended media digesters that rely on manure particles to provide attachment surfaces come in many variations. Two common types of suspended media digesters are the ***Upflow Anaerobic Sludge Blanket Digester***, or ***UASB Digester***, and the ***Induced Blanket Reactor***, or ***IBR Digester***. An example and schematic of IBR digesters are shown in Figures 10 and 11.

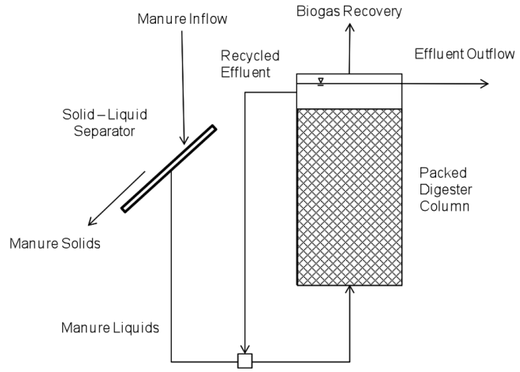

Figure 9. Schematic drawing of a fixed film digestion system.

Figure 10. Battery of IBR digesters (Photo courtesy of Conly Hansen, Utah State University).

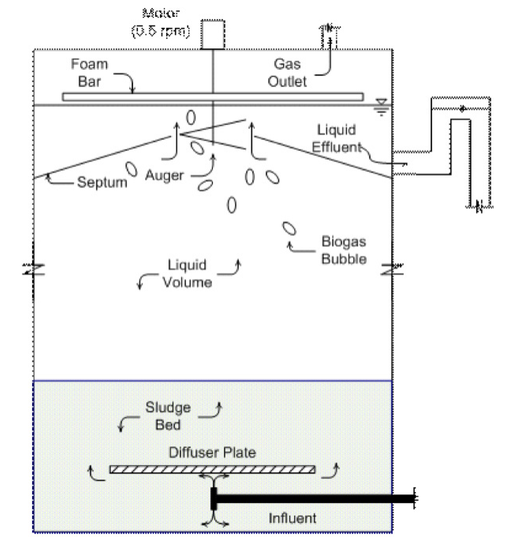

Figure 11. Schematic drawing of IBR digester (Courtesy of Conly Hansen, Utah State University).