

DIGESTERS

Sludge digestion is the primary means of stabilizing the volatile organic material in the sludge. Biologically degradable organics account for 60-65% of the total solids in the sludge. The organic sludge contains bound water molecules within it. Digestion releases most of the bound water in the sludge. As the sludge decomposes the organic material is converted into gases. This results in a reduction in the volume of sludge that will ultimately have to be disposed. If the digestion process is anaerobic the gases produced will be carbon dioxide (CO₂), methane (CH₄) and hydrogen sulfide (H₂S). If it is aerobic, the only gas that is produced is carbon dioxide.

ANAEROBIC DIGESTION

Anaerobic digestion requires an absence of dissolved oxygen. The bacteria that digest the organics in the sludge still need oxygen to live. They use oxygen that is chemically bound in organic compounds like sugars and starches. The gases that result from this process are present in different ratios depending on the operating temperature and ratio of volatile acids to alkalinity in the digester. There are two groups of bacteria involved in anaerobic decomposition. One group is called "acid formers." They take complex raw organic compounds, like sugars and starches, and break them down into organic acids and release some carbon dioxide in the process. The second group of bacteria takes the organic acids from the acid formers and converts them into methane, carbon dioxide and hydrogen sulfide. They are called the "methane fermenters." Methane fermenters will not work in a pH less than 6.6 or greater than 7.6. They work best when the pH is 7.0-7.2.

Since the acids that are being produced in the first part of the process will lower the pH, it is important to maintain enough alkalinity in the digester to buffer the effect of the acids. This is necessary to keep the pH above 7.0 and will result in maximum methane production. Running volatile acids and alkalinity tests on the digester is an important part of efficient digester operations. The acid/alkalinity ratio will change before the pH begins to drop. If the acids increase and drive the ratio out of the normal operating range, the digester may become upset. The volatile acid to alkalinity ratio should be kept below 0.4 and the alkalinity should not fall below 1000 mg/l.

Using the pH as the control parameter is not a good idea. By the time the pH drops it may be too late to avoid the upset. When this happens, the methane production will drop dramatically and foaming may occur. Most of us have had a case of heartburn or indigestion before; it's basically the same thing. Losing methane production can compound the problem if methane is used to heat the digester. If the temperature drops it can compound the problem.

TEMPERATURE RANGES FOR ANAEROBIC DIGESTION

There are three groups of anaerobic bacteria that are used in wastewater anaerobic digesters. Each group is temperature sensitive and can only survive in a very narrow temper range. The temperature of an anaerobic digester must never be changed more than 1°F per day. Foaming and upsets will occur when the temperature rises or falls too quickly.

Psychrophilic (cold-loving) anaerobic bacteria operate in a range from 50-68 degrees F. They are found in unheated Imhoff tank digesters. They are not efficient and it takes from 50-120 days to stabilize the sludge. The off gases contain very little methane and are high in hydrogen sulfide. Odor problems are associated with this process.

Mesophilic (medium temperature loving) bacteria operate in a range from 68-113 degrees F. Optimum temperatures are from 85-100 degrees and most digesters operate at 95-98 degrees. At that temperature it normally takes 25-30 days to digest the sludge. When operating efficiently at this temperature, digesters will produce 8-12 cubic feet of digester gas for every pound of organics. The gas should be 65-70% methane and 30% carbon dioxide. It will have a heat value of 500-800 BTU's per cubic foot.

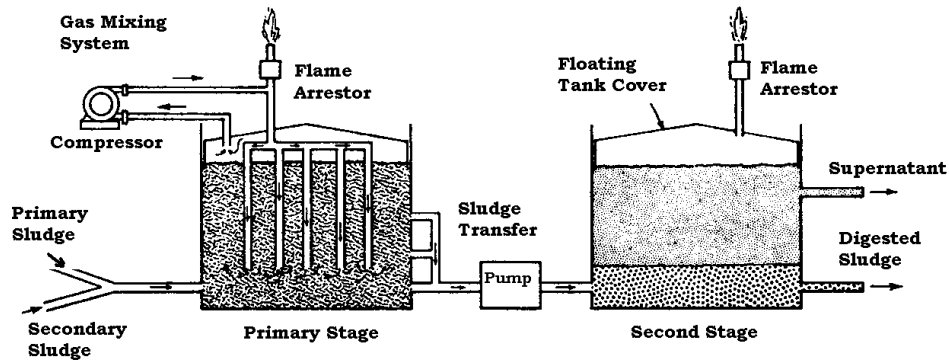
Thermophilic (heat-loving) bacteria have an operating temperature range of 120-135 degrees F. Larger percentages of methane are produced at these temperatures, but the higher temperatures require more heating and negate the increase. Sludge can be digested in 5-12 days though. These bacteria are very sensitive to temperature changes and are easily upset. There is another issue regarding heating a digester to these temperatures. When heat exchangers or heating coil temperature approach 130 degrees F, sludge begins to cake on the piping. This clogs the heat exchangers and insulates the heating coils.

ANAEROBIC DIGESTERS

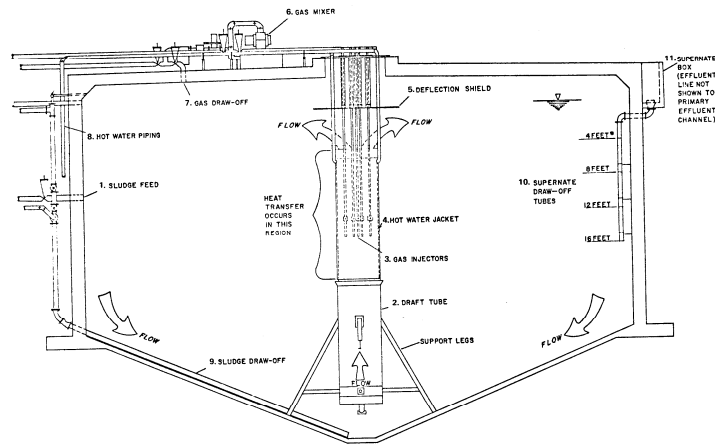
Anaerobic digesters are sized based on a solids loading rate of 0.15-0.35lbs per day/cuft. Anaerobic digester systems are usually built with two digesters. The primary digester receives the thickened sludge. It is heated and is equipped with mixing equipment to keep the sludge stirred and temperatures uniform. The mixers can be mechanical units or gas bubbleers that mix by pumping digester gas into the sludge. A heat exchanger system will also assist in mixing the contents of the digester as sludge is pumped through the exchanger. The sludge passes from the primary digester to the secondary digester.



Primary digester with mechanical mixers



Two Stage Anaerobic Digester



Primary Digester

The secondary digester may not be mixed. It is used to settle digested sludge and finish the digestion process prior to drawing the sludge off to be dried in drying beds or thickened using other processes. The overflow from the secondary digester is returned to the head of the plant. With no DO and a high BOD strength this flow can have an impact on the secondary processes. The BOD strength and flow must be known so that it can be added to the calculation of secondary organic loading. Secondary digesters also store most of the digester gas that is produced. They can have a floating top that rises and falls with changes in the digester level and gas production or removal.



Secondary Digester with Floating Cover

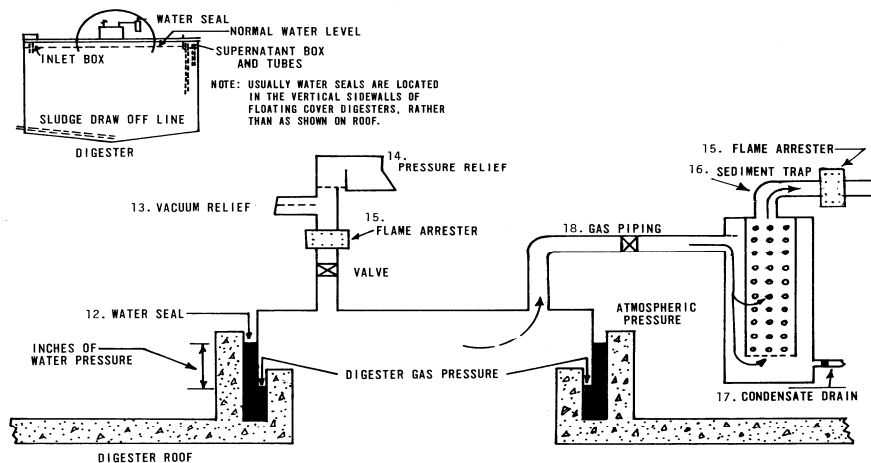
A water seal around the edge of the floating top prevents gas from escaping. It is designed to maintain about 8-12 inches of water in the seal. The gas pressure in the system must be less than 8 inches of water to prevent the water seal from blowing out. If the gas is not removed fast enough the pressure will rise and threaten the integrity of the water seal. If sludge is removed too quickly the water seal will collapse and let air into the digester. This will prevent the floating cover from collapsing. But the introduction of air in the digester can create a potential for explosion. Great care must be taken to maintain the water seal on the floating cover.

**Pressure Relief Valve – Top
Vacuum Relief Valve – Middle
Flame Arrester - Bottom**



GAS HANDLING SYSTEMS

When handling flammable gases, the danger of explosion is always present. No smoking or sparks can be allowed in the gas handling areas. Most systems require the use of brass tools to minimize the potential for sparks. Digester gas is often used to heat the digesters and sometimes used in co-generation operations. A co-generation process uses digester gas to power electrical generating that can supply electrical power to a portion of the plant. The cooling water for the gas engines is then used to heat the digesters or buildings in the plant. When digester gas is used for these purposes it must be processed after it leaves the digester. Dryers are needed to remove the moisture in the gas. Condensation is a problem in the gas transfer system. Condensate traps are installed in the system prior to drying. These traps collect water that condenses in the piping. They must be manually drained at least once a day. Carbon dioxide can be stripped out using a lime absorption process.



Water Seal and Gas Piping

Safety devices used to protect the gas system include flame arrestors, pressure and vacuum relief valves, and thermal shutoff valves. A flame arrestor has a set of baffles that are designed stop the spread of flame in the piping. The baffles can get clogged over time and must be inspected and serviced every three months. The pressure relief valve is designed to open at about 8 inches of water pressure. It relieves pressure from the digester to prevent the blowout of the water seal. The vacuum relief valve is designed to open at about 8-9 inches of vacuum to prevent the collapse of the water seal. A thermal shutoff valve has a fusible disk that holds the valve stem in the open position. When a flame generates enough heat, the fusible disk melts and the valve seat drops to shut off the gas flow.

SLUDGE FEED AND REMOVAL

Sludge that is pumped to the digester is colder than the digester. It can lower the digester temperature if it is added in large volumes over short periods. The best practice is to feed continuously at low flow rates so that the heating systems can maintain a more constant temperature. Feeding at lower flows for longer periods will help minimize the impact on the digester. Thickening sludge to achieve the highest solids content possible will also minimize the impact on the digester temperature. Thicker sludge means less water is required to move a pound of solids. Don't forget that the secondary digester overflows as the sludge is added to the primary unit. This supernate is returned to the head of the plant. Returning this effluent at high rates on an intermittent basis can result in shock BOD loads on the secondary. If there is no secondary digester, the mixing should be shut down for several hours prior to and during the pumping cycle.

Removing sludge from the secondary digester too fast can create an upset condition. Since secondary digesters are usually not mixed, the sludge at the bottom of the digester will be the most stable. It contains organisms that work on the more unstable "green" sludge that settles as it enters from the primary digester. If too much settled sludge is removed, the population of these organisms may drop to the point that an upset occurs. Well-digested sludge will have a pH between 7.0-7.2. It will not have the septic odors of green sludge and will have a leathery appearance. Green sludges also take a much longer time to dry because much of the cellular bound water isn't released as it is in well-digested sludge.

DIGESTER UPSETS

Digesters get "heartburn" for any number of reasons. If the temperature drops it can shock the methane fermenting bacteria and they will stop fermenting. The volatile acid/alkalinity ratio will increase and the pH will drop. If the temperature is brought back up too quickly it can further shock the bio-system. Never raise or lower digester temperatures by more than 1 degree F per day. A sudden increase in solids loading can also cause an upset. The methane formers will not be able to keep up with the acid production and the VA/Alkalinity ratio will increase. The best thing to do in this case is the same thing you would do for your own acid indigestion, stop eating and rest. If that didn't work you might take some antacids tablet to neutralize the stomach acids. That is the same thing that needs to happen to recover from a digester upset. Rest the unit by not pumping any new sludge for at least 24 hours. If that isn't possible adding calcium carbonate to the sludge flow will increase the alkalinity and help restore the VA/Alkalinity ratio.

AEROBIC DIGESTERS

Aerobic digesters resemble an extended aeration activated sludge process. Waste activated sludge and trickling filter humus can be mixed with primary sludge and sent to the digester for further decomposition. The aerobic digester acts like an extended aeration plant in that it retains the solids until nearly all of the volatile solids have been stabilized. These digesters are also built with multiple tanks or stages. They are 18-20 feet deep and are aerated by diffuser headers. A DO level of 1-2 mg/l must be maintained and the pH should be between 6.8-7.4.

In order to achieve proper digestion without offensive odors, the organisms that are involved must be kept at their highest level of metabolism. This is known as "endogenous respiration" and it keeps the bugs at their peak operating efficiency. The digestion process may take from 25 to 45 days. If the sludge is to be applied to land it must be kept under aeration for at least 45 days. When sludge is wasted to the digesters the second (or third) stage unit will overflow. This overflow is returned to the head of the plant. While this flow is easier to treat than anaerobic digester overflows, it may still have a high organic strength if the aerators are not shutdown for 30-60 minutes prior to wasting. Shutting off the air will allow settling to occur and will result in lower solids in the supernate.

SLUDGE DRYING BEDS

Sludge that is drawn from the digester is often placed in sludge drying beds. These beds are shallow rectangular basins with a sand bed and underdrain system. Sludge is placed on the bed in 10-12 inch pours. It dries by evaporation and gravity separation of the water. After the sludge is poured onto the bed, the underdrain valve is opened to allow the water that drains out of the bed to return to the head off the plant. The water that drains out of the sludge is collected in the underdrain and sent to the head of the plant. The length of time it takes to dry will depend on the condition of the sludge and degree of digestion, the temperature (colder temperatures mean less evaporation), and compaction of the sand bed.

Drying beds with asphalt bases, instead of sand, make it easier to remove dried sludge with heavy equipment. The dried sludge is removed and taken to a landfill or applied to land. If it is to be applied to public grounds it must be heat treated (flash furnace) or composted so that the temperature rises to 140 degrees for at least 14 days. Never put digester sludge in a drying bed that has dry sludge in it.

BASIC STUDY QUESTIONS

1. What three gases are produced during anaerobic digestion?
2. What are the characteristics of well-digested sludge?
3. How deep should the digested sludge on the drying bed be?
4. Which of the following statements is true regarding pumping sludge to a digester?
 - A. The solids concentration should be as high as possible.
 - B. Pumping smaller volumes more often is easier on the process than pumping lots of sludge all at once.
 - C. The overflow from the digester will return to the headworks of the plant.
 - D. All of the above.

BASIC SAMPLE TEST QUESTIONS

1. Most digesters operate at which temperature range?
 - A. 60-75° F
 - B. 80-85° F
 - C. 95-98° F
 - D. 120-135° F
2. When operating properly a medium range digester will produce gas that is _____ methane.
 - A. 30%
 - B. 70%
 - C. 90%
 - D. 100%
3. The pH of well-digested sludge should be:
 - A. 5.0-5.8
 - B. 6.0-6.5
 - C. 7.0-7.2
 - D. 8.0-9.0

ADVANCED STUDY QUESTIONS

1. What are the digestion times for the three temperature ranges of anaerobic digestion?
2. What is the solids loading rate for an anaerobic digester?
3. Why is it important to concentrate sludge?
4. Why is the volatile acid-to-alkalinity ratio important in digester operations?
5. What is meant by endogenous respiration?

**ADVANCED SAMPLE TEST
QUESTIONS**

1. What is the BTU value of digester gas?
 - A. 100-200 BTU's/cuft
 - B. 500-800 BTU's/cuft
 - C. 900-1600 BTU's/cuft
 - D. 1500-2300 BTU's/cuft
2. The optimum temperature for the mesophilic range is:
 - A. 65-68 degrees F
 - B. 70-75 degrees F
 - C. 95-98 degrees F
 - D. 113-125 degrees F
3. Sludge will cake on the heating coils if the water temperature exceeds.
 - A. 68 degrees F
 - B. 105 degrees F
 - C. 130 degrees F
 - D. 150 degrees F
4. Flame arrestor baffles should be cleaned every:
 - A. 3 months
 - B. 6 months
 - C. Year
 - D. Two years
5. The pH of an aerobic digester should be:
 - A. 3-5
 - B. 5.6-6.2
 - C. 6.8-7.4
 - D. 8.0-8.3