



## 20. Solids Stabilization - Digestion

- Sludge digestion is a microbiological process to treat - stabilize, the wastewater solids
- As part of digestion, the organic material present is biodegraded by microorganisms. It is the most common sludge stabilization method.
- There are two major sludge digestion processes - aerobic digestion which utilizes aerobic microorganisms and anaerobic digestion which utilizes anaerobic microorganisms.

Comparison of aerobic and anaerobic digestion:

Methane production (fuel use potential)	Unlike anaerobic digestion, aerobic digestion does not produce methane
Energy consumption	Aerobic digestion has higher energy needs as air supply is required to support the aerobic activity. The energy needs for an anaerobic digester is limited to mixing the digester and maintaining digester temperatures
Biomass production	Anaerobic digestion produces only about 20% of the biomass produced by aerobic digestion
Dewaterability of sludge produced	Compared to anaerobic digestion, aerobic digestion produces sludge with poor dewaterability which leads to producing cake with lower solids content and therefore more expensive to haul
Ammonia concentration	Significant ammonia is produced as part of anaerobic digestion which imposes additional ammonia removal needs particularly for plants with nitrogen discharge thresholds
Sludge odors	Aerobic digestion has much less odor issues compared to anaerobic digestion
Capital cost	Initial capital costs are higher for anaerobic digesters due to higher SRT requirements is higher - methanogens are slower growing
Weather impacts	Process efficiency of aerobic digester drops in cold weather. The anaerobic digestion is not affected by weather as the sludge in the digester is maintained at the desired temperature

For this class we will focus only on anaerobic digestion - the most common method - as anaerobic digestion generates digester gas which can be used as fuel and also due to its lower energy demands.

### 20.1 Digester design

- The anaerobic digester is typically a large cylindrical concrete tank
- The digester is operated as a continuous process at a fixed volume

- As sludge is fed into the digester it displaces an equal amount of sludge which leaves the digester through the digester overflow system - see the digester overflow system design diagram below
- The digester overflow system is designed to allow for selecting the level from which the sludge overflows
- The sludge typically occupies 70 - 90% of the total digester volume and the methane carbon dioxide gas mixture occupies the headspace from where it is withdrawn also on a continuous basis.
- The digester can be constructed with either a fixed or floating roof.

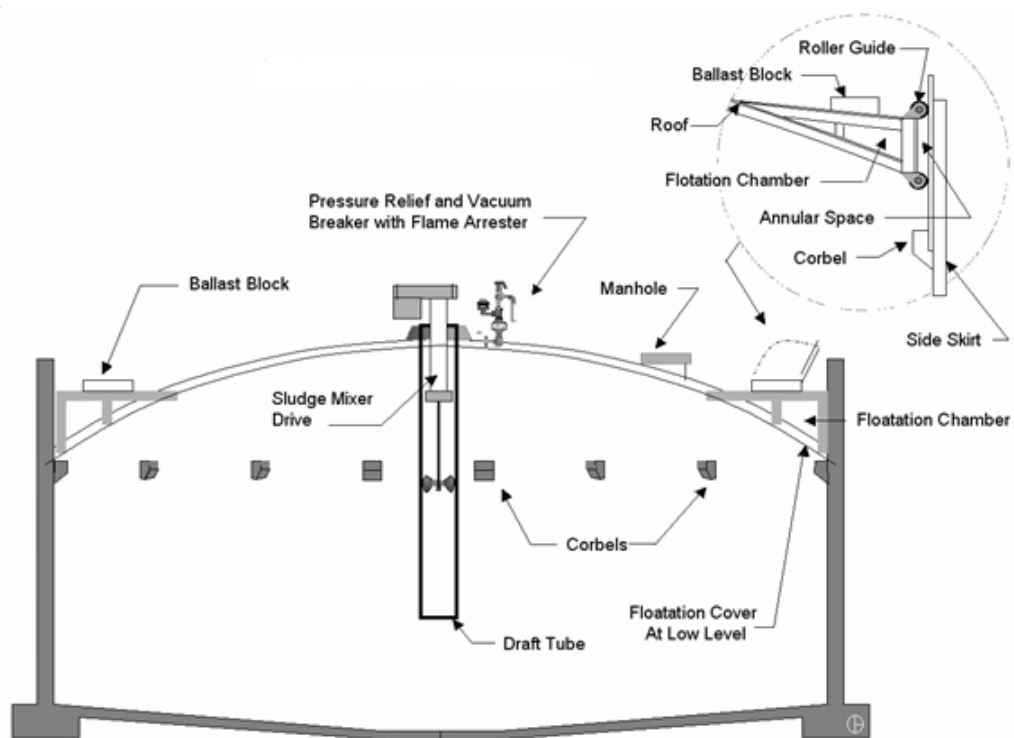


Figure 20.1: Floating Dome Anaerobic Digestion

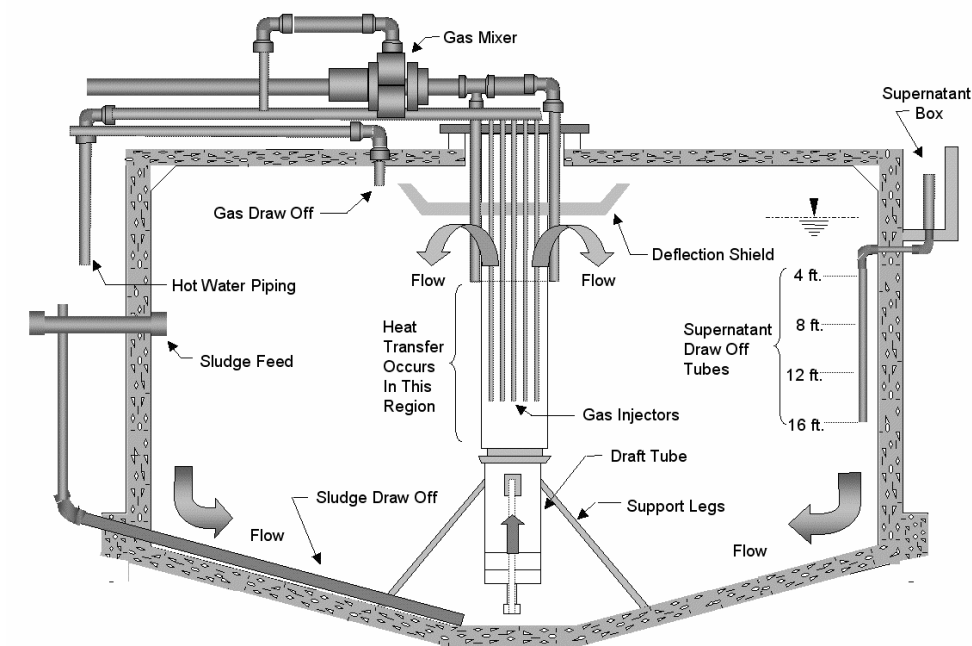


Figure 20.2: Fixed Dome Anaerobic Digestion

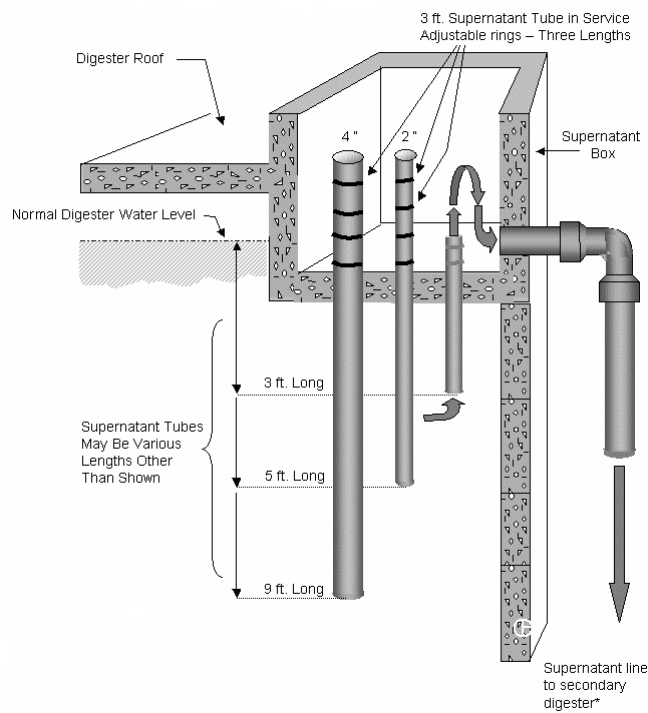
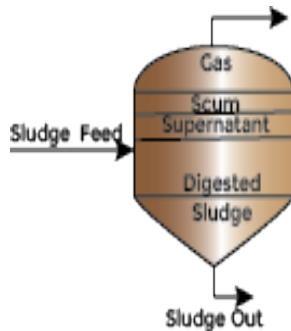


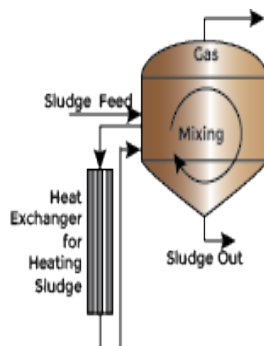
Figure 20.3: Digestion Overflow System

## 20.2 Types of anaerobic digestion systems



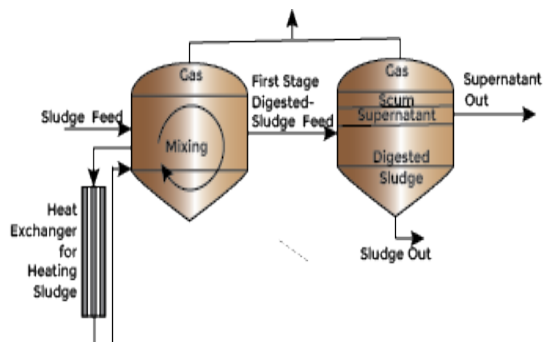
### Low-Rate

- No mixing provided
- Long detention time of 30 to 60 days
- Suitable for low organic loading
- Intermittent sludge feed
- Stabilized solids settle to the bottom and are removed periodically
- Suitable for small wastewater treatment plants



### High-Rate

- Mixing and external heating provided
- Uniform feeding
- Typical detention times of 10 to 20 days
- Most common



### Two-stage

- Digestion occurs in the heated and mixed primary digester vessel
- The unheated secondary tank serves as storage for digested solids and as a source of seed

Summary Conditions for Anaerobic Sludge Digestion		
Temperature and detention time	Psychrophillic Mesophilic - Normal range Mesophilic Most common	50 - 65 F 50 - 180 days 68 - 113 F 95 - 98 F 15 - 30 days
pH	Thermophillic Optimal General Range	113 - 135 F 5 - 12 days 7.0 to 7.1 6.4 to 7.4
VS loading rate (high rate digester) Gas production	Optimal	0.1 and 0.2 lbs VS/day/ ft <sup>3</sup> 8-12 cu. ft 16-18 cu. ft.
Gas Composition	Methane Carbon dioxide Hydrogen sulfide	65% 35% Trace
Volatile acid concentration (as acetic acid)	Normal Maximum	200-800 mg/L 2000 mg/L
Alkalinity Concentration	Normal	2,000-3,500 mg/L (as calcium carbonate) 3,000-5,000 mg/L (as bicarbonate)
Volatile acids to alkalinity ratio	Desirable Upset condition	< 0.25 > 0.4

## 20.3 Digestion parameters and control

### 20.3.1 Digestion temperature

- The anaerobic digestion is temperature sensitive and temperature of the sludge in the digester needs to be controlled to ensure proper operation.
- The activity and type of bacteria present in the digester is dictated by the operating temperature of the digester.
- Anaerobic digestion can be in the following three temperature ranges, each of which has its own unique microbiology.

#### i. PSYCHROPHILIC DIGESTION

If operating in this temperature regime, the digesters are maintained between 50 - 65 F. This regimen is not commonly used. Digestion in this range requires 50 to 180 days depending on the target volatile matter reduction

#### ii. MESOPHILIC DIGESTION:

These digesters operate between 68 - 113 F. Most common operating temperatures for mesophilic digesters is between 95 – 98 F and the typical number of days required for digestion is between 15 to 30 days.

#### iii. THERMOHILLIC DIGESTION:

These digesters' optimal operating temperatures range is between 113 - 135 F and it typically requires 5 to 12 days.

- A digester does not tolerate temperature fluctuations and need to be maintained at stable temperatures for a significant duration.
- As a rule of thumb temperature of a digester should not be changed more than 1 per day.
- Temperature fluctuations will destroy the microbiological balance leading to digester failure.
- External heating is provided to maintain sludge temperatures in the digester.
- Temperature fluctuations also can be minimized by feeding the system at frequent intervals.
- An external or internal heat exchanger or direct steam injection is typically used for maintaining the sludge temperature

### 20.3.2 Digestion mixing

A sludge mixing system is integral to the digester design. It performs three main functions:

- It allows for the bacteria to properly come in contact with the food.
- It prevents accumulation of grit and scum in the digester which could lead to dead zones.

3. It allows for maintaining uniform temperature. Typical mixing system designs achieve a turnover time of 30 to 45 minutes.

### 20.3.3 Digestion feed

- The sludge feed to the digester has a total solids content of about 3 – 6%.
- 70% of the total solids fed are organic solids.
- These organic solids are measured as volatile solids (VS)
- Hydraulic or Sludge retention time (SRT) is calculated by dividing the digester volume by the daily sludge flow

$$\text{Digester SRT (days)} = \frac{\text{Digester Volume (ft}^3 \text{ or gallons)}}{\text{Sludge Feed (ft}^3 \text{ or gallons per day)}}$$

- The SRT in an anaerobic digester typically ranges from 10 to 20 days.
- A minimum SRT is essential to the digestion process to ensure that the necessary microorganisms are being produced at the same rate as they are removed from the system each day
- Accumulation of grit in the bottom or scum at the top of the digester would effectively reduce the working volume of the digester
- The amount of digester influent being pumped and the percent VS of the waste are a measure of the digester's organic loading rate (influent mass per time)
- Control of the amount of volatile solids loading is one of the key critical operational control parameter.
- Volatile solids loading rate of the digester is the mass of VS added to the digester each day divided by the operating volume of the digester – lbs VS/day/ft<sup>3</sup>
- Typical high rate digesters VS loading range between 0.1 and 0.2 lbs VS/day/ ft<sup>3</sup>
- The rate of digestion depends on the type of organic material present.
- The constituents of the organic material in primary sludge is typically feces, and plant and animal origin material. This organic material is relatively easy to digest compared to the organics in the secondary sludge which is primarily living and dead microorganisms and metabolic byproducts associated with microbiological growth and decay.
- Typical primary sludge from a treatment plant with preliminary treatment contains approximately 65% organic material. 80% of this organic material is typically destroyed in the digester. Whereas, the secondary sludge typically contains 90% organics and only 60% of the secondary sludge organics is destroyed.

### 20.3.4 Volatile solids breakdown

- The volatile solids content of the sludge entering and leaving the digester are measured to quantify the solids removal in the digester
- The expected reduction of volatile solids of a properly operating digester is 40-60% of the total volatile solids present in raw sludge feed.
- The volatile solids in the feed sludge would be about 70% to 75% while the digested sludge would be 45% to 50% volatile solids
- The expected reduction of volatile solids of a properly operating digester is 40-60% of the total volatile solids present in raw sludge feed
- The volatile solids reduction of the digester is provided by the Van Kleeck equation

$$\text{Digester VS reduction(\%)} = \frac{VS_{in} - VS_{out}}{VS_{in} - VS_{in} * VS_{out}} * 100$$

- Digester volatile solids concentration is typically expressed as a percentage of the sludge total solids
- 70% VS which means that 70% of the total solids is volatile solids
- The value of  $VS_{in}$  and  $VS_{out}$  for the digester VS reduction (Van Kleeck) equation above should be in fraction and not as a percentage.
- For example: for a 70% VS content use 0.7 in the equation. Likewise 0.525 is used for 52.5% VS concentration
- Higher volatile solids reduction implies higher gas production and lower biosolids hauling costs

- Breakdown of volatile matter in the sludge ultimately into methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>) occurs in multiple steps involving different groups of microorganisms.  
 Step 1. This is the hydrolysis step where the complex organic matter in the sludge including carbohydrates, proteins, lignin, and lipids are converted to simpler compounds including sugars, soluble fatty acids and amines.  
 Step 2. This involves formation of volatile acids from the products from Step 1. This is the acid formation step.  
 Step 3. The acid formed in Step 2 is converted into methane and carbon dioxide. This step is accomplished by a group of methane forming bacteria.
- The digester conditions are maintained to ensure optimal conditions conducive to the activity of the methane formers. Good digester operations requires ensuring that conditions are kept favorable for the methane formers

### 20.3.5 Digester pH and alkalinity

- The anaerobic digestion requires a symbiotic relationship between the different groups of microorganisms involved.
- Each group of organisms involved in the anaerobic digestion process have an optimal pH for maximum rate of reaction –  
 Hydrolysis: pH 5-7 optimal  
 Acid formation: pH 5-7 optimal –  
 Methane formation: pH 7-8 optimal, pH 6.5-8.5 operational
- In a healthy digester the volatile acids produced in Step 2 are used in Step 3 as food by the methane formers at about the same rate as they are produced.
- As the methane forming microorganisms in the digesters are very sensitive to the digester conditions including organic content, pH, temperature and toxins and also grow very slowly, it is necessary to maintain the digester pH close to neutral
- The conversion of the volatile fatty acids to methane by methane formers allow for controlling the accumulation of volatile acids
- If the activity of methane formers is suppressed due to conditions such as low pH, volatile acids will accumulate potentially causing the digester to become "sour"
- In a normally operating digester, the alkalinity present in the sludge prevents the pH from dropping due to the formation of volatile acids during Step 2.
- The alkalinity consumed due to the acids formed in Step 2 is replenished in Step 3 by the formation of bicarbonate from the CO<sub>2</sub> and ammonia produced during digestion.



- Unlike the acid formers, Thus, if the digester condition such as the pH was to change – drop because of the formation of acids and a lack of alkalinity, Step 3 will not happen resulting in the digester pH dropping even further resulting in a “sour” digester condition.
- When acid formers out produce the methane formers the volatile acids increase sharply
- The methane formers are the key to digester operation and are very vulnerable to low pH There needs to be sufficient alkalinity present to prevent pH changes as the volatile fatty acids are being formed.
- If sufficient alkalinity is not present the pH will drop further inhibiting the activity of methane formers and the digester will turn “sour”
- The bicarbonate ion (HCO<sub>3</sub><sup>-</sup>) is the main source of buffering capacity to maintain the system’s pH in the range of 6.5 – 7.6. The concentration of HCO<sub>3</sub><sup>-</sup> in solution is related to the percent of carbon dioxide in the gas phase
- Alkalinity consumed by the acid production is offset by alkalinity produced as part of the methanogenic activity
- Regular monitoring the digester alkalinity and volatile acids is vital in ensuring a stable digestion process.
- In a well operating digester the volatile acids expressed as acetic acid would be in the range of 50 to 500 mg/L and the alkalinity expressed as calcium carbonate would be in the range of 2,000 to 3,000 mg/L (bicarbonate alkalinity of 2,500mg/L and 5,000mg/L)

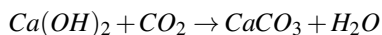


- The volatile acid-to-alkalinity ratio indicates if the digester has enough buffering capacity for the volatile acids being produced.
- Increase in volatile acid to-alkalinity ratio will increase the potential for pH decrease which would result in an upset digester.
- In general keeping the volatile acids to alkalinity ratio at 0.25 or less is desirable for good operations.
- Ratios above 0.4 indicate upset and the need for corrective action.

### 20.3.6 Digester pH control

- Following chemicals: calcium oxide, calcium hydroxide, anhydrous ammonia, Ammonia (liquid), ammonium hydroxide, sodium carbonate, sodium bicarbonate, and sodium hydroxide have been used for increasing the pH of a sour digester.
- The use of calcium oxide (quicklime) or calcium hydroxide (slaked or hydrated lime) is probably the most dangerous if mixed with water prior to feeding. If instead of adding these two chemicals to water for digester feeding, adding water to these chemicals would pose the threat of a violent reaction and splattering of this strong caustic.

Excess lime should be avoided as lime reacts with carbon dioxide to form calcium carbonate.



If carbon dioxide is removed too rapidly or in too large a quantity from the sludge, then carbon dioxide from the biogas will replace the carbon dioxide lost from the sludge. When carbon dioxide is lost from the biogas, a partial vacuum condition develops under the digester dome. This condition may cause the digester cover to collapse. Also, as the concentration of alkalinity increases in the anaerobic digester, the continued use of quick lime results in the precipitation of calcium carbonate.

- Sodium hydroxide would be the next most dangerous followed by ammonium hydroxide.
- The use of anhydrous ammonia should be limited to facilities that have the equipment to handle gas cylinders and that have feed connections or the ability to make the necessary feed connections.
- The feeding of lime can only raise the digester pH to about 6.8. When lime is added it reacts with carbon dioxide to form calcium bicarbonate. Excessive feeding of lime causes insoluble calcium carbonate to form. In addition excessive lime may remove too much carbon dioxide which could lower gas pressures or even the formation of a vacuum. This could cause air to be drawn into the digester and cause an explosive gas mixture.

### 20.3.7 Digester gas production

- In the anaerobic digestion process microorganisms convert volatile matter into mainly methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>)
- Typical composition of digester gas is about 58 - 65% methane and 30 - 35% CO<sub>2</sub> it also includes traces of ammonia nitrogen, hydrogen sulfide, and other gases.
- Monitoring digester gas production is one of the more important operational parameter.
- Gas production ranges between 10 to 16 cubic feet per pound of volatile matter destroyed and the gas production remains stable over time.
- Low gas production is an indicator of digester issue related to - toxicity, temperature, volatile acid to alkalinity ratio, mixing, or feed rates.

### 20.3.8 Digester failure

- Digester failure conditions are marked by conditions which include increases in:
  - volatile acids
  - volatile acids: alkalinity ratio
  - drop in pH
  - drop in gas production, and
  - an increase in CO<sub>2</sub> concentration
- The failure is typically attributable to factors including overloading, toxicity and temperature control issues.
- Digester failure can be controlled by:
  - stopping or reducing the sludge feed



- exercising pH controls by adding alkaline chemicals, and
- through reseeded the digester with sludge from another healthy digester

### 20.3.9 Digester toxicity issues

- Toxicity could severely impact a digester performance.
- Contributors to toxicity issues include high concentrations of ammonia and toxic metals such as arsenic, cadmium, chromium (hexavalent), copper, nickel, zinc.
- Ammonia toxicity: Ammonia from industrial sources, organic overloading, or from using anhydrous ammonia to correct a digester pH problem can cause a die-off of bacteria; ammonia toxicity begins around 1,500 mg/L and is totally toxic at 3,000 mg/L.

### 20.3.10 Nutrients and trace constituents requirement

The major nutrients required for anaerobic digestion are nitrogen and phosphorus. An average cell contains approximately 12.5 percent nitrogen and 2 percent phosphorus. Sodium, potassium, calcium, magnesium, chloride, and sulfate ions are also required for proper digestion.

## 20.4 Digester safety

### A. Pressure & Vacuum Protection:

- In a digester, as the gas production and sludge withdrawal is continuous, there exists a potential to create pressurized or vacuum conditions within the digester which could jeopardize the structural integrity of the digester.
- Typically the gas in the digester dome is maintained at a pressure of 8-9 inches of water column.
- A pressure relief valve is designed into the digester dome which allows to protect the digester from excessive pressure or vacuum conditions.
- In the event of the digester dome being under excessive pressure, the valve will open to relieve the pressure and likewise if the valve senses a low pressure or vacuum condition, it will open up just enough to let in the air to bring the gas in the digester dome back to normal, set pressure.

### B. Fire and Explosion Protection:

- For a fire or explosion to occur, following three conditions must be met simultaneously:
  - (a) Presence of fuel – combustible material
  - (b) Oxygen (air) must exist in certain proportions, and
  - (c) Ignition source, such as a spark or flame.
- Digester gas contains methane which is a combustible gas.
- The ratio of fuel and oxygen that is required varies with each combustible gas or vapor. The Lower Explosive Limit (LEL) and (UEL) for methane is 5% and 15% respectively.
- A 5% LEL implies that a methane concentration in air of less than 5% is too “lean” to burn and a 15% UEL implies that a concentration of methane exceeding 15% in air would be too “rich” to burn. So for methane, the flammable range is between 5% and 15%. As the digester gas methane content is typically between 60 to 65%, dilution of digester gas with air has the potential to form an explosive mixture.
- A flame arrestor is typically installed at the outlet of the digester gas piping to protect the digester from any external heat or ignition source. The flame arrestor is essentially a heat exchanger which cools down the ignition source or flame entering the digester.



Digester Pressure Relief



Digester Flame Arrestor

## 20.5 Digester math problems

### 20.5.1 Sludge pumping

#### Example Problems:

1. A primary clarifier receives an average flow of 12 MGD containing 280mg/L of TSS. This clarifier typically removes 75% TSS and produces a 3.5% sludge and the sludge pump is rated to pump 35 cu.ft/min.
  - a. How many pounds of TSS is removed in the clarifier?
  - b. How many cu.ft of sludge at the given 3.5% sludge needs to be pumped per day to remove the solids?
  - c. How many minutes would the sludge pump need to be operational each day to pump the required amount of sludge - calculated from ii. above?
  - d. For how many minutes each hour the sludge pump should be programmed to operate (Given the number of minutes the pump need to operate per day calculated from iii. above) ?

Solution:

$$a. \text{ lbs solids removed} = (280 * 0.75) \text{ mg/l} * 12 \text{ MGD} * 8.34 = \boxed{21,017 \text{ lbs solids per day}}$$

$$b. \frac{21,017 \text{ lbs solids}}{\text{day}} = \frac{x \text{ ft}^3 \text{ sludge}}{\text{day}} * \frac{7.48 \text{ gal sludge}}{\text{ft}^3 \text{ sludge}} * \frac{0.035 \text{ lbs solids}}{1 \text{ lb sludge}} * \frac{8.34 \text{ lb sludge}}{\text{gal sludge}}$$

$$\frac{x \text{ ft}^3 \text{ sludge}}{\text{day}} = \frac{21,017}{0.035 * 834 * 7.48} = \boxed{9,626 \frac{\text{ft}^3 \text{ sludge}}{\text{day}}}$$

$$c. \frac{9,626 \text{ ft}^3 \text{ sludge}}{\text{day}} * \frac{\text{min}}{35 \text{ ft}^3 \text{ sludge}} = \boxed{\frac{275 \text{ minutes}}{\text{day}}}$$

$$d. \frac{275 \text{ minutes}}{\text{day}} * \frac{\text{day}}{24 \text{ hrs}} = \boxed{\frac{11.4 \text{ minutes}}{\text{hr}}}$$

### 20.5.2 VS or organic loading

#### Example Problems:

1. How many pounds of TS and VS are pumped to a digester each day if the digester receives 10,000 gpd of sludge at 5% solids concentration with an average VS of 75%?

Solution:

Digester TS loading (lbs/day)

$$\frac{\text{lbs TS}}{\text{day}} = \frac{10,000 \text{ gal sludge}}{\text{day}} * \frac{(8.34 * 0.05) \text{ lbs TS}}{\text{gal sludge}} = 4,170 \frac{\text{lbs TS}}{\text{day}}$$

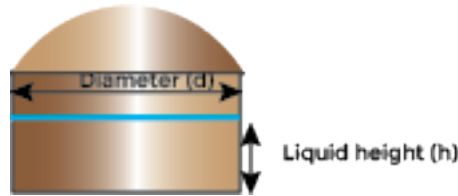
Digester VS loading (lbs/day)

$$= 4,170 \frac{\text{lbs TS}}{\text{day}} * 0.75 \frac{\text{lbs VS}}{\text{lb TS}} = \boxed{3,128 \frac{\text{lbs VS}}{\text{day}}}$$

2. An anaerobic digester is 37' in diameter and 27' deep with a 5,000 gallon daily sludge flow. The sludge is 6% solids and 66% volatile solids. What is the volatile solids loading in pounds per cubic foot per day?

Solution:

$$\text{Digester volatile solids loading rate} = \frac{\text{Digester Loading} \frac{\text{lbs VS}}{\text{day}}}{\text{Digester volume (V)} \text{ft}^3}$$



$$= \frac{5000 \frac{\text{gal sludge}}{\text{day}} * (8.34 * 0.06 * 0.66) \frac{\text{lbs VS}}{\text{gal sludge}}}{\left(\frac{\pi}{4} * 37^2 * 27\right) \text{ft}^3} = \boxed{0.057 \frac{\text{lbs VS}}{\text{day} - \text{ft}^3}}$$

3. Calculate the VS loading to the digester in lbs/day if 10,000 gallons of sludge containing 5% TS with an average VS content of 78%

Solution:

Digester VS loading (lbs/day)

$$= \frac{10,000 \text{ gallons sludge}}{\text{day}} * \frac{8.34 \text{ lbs sludge}}{\text{gal}} * \frac{0.05 * 0.78 \text{ lbs VS}}{\text{lb sludge}} = \boxed{3,253 \text{ lbs sludge per day}}$$

4. Two sludges are blended together as follows: 15,000 gal. primary sludge at 4.1% solids. 28,000 gal. secondary sludge at 1.3% solids. What is the combined solids concentration? If the primary sludge is 68% VS and the secondary sludge is 63% VS, what is the VS concentration (%) in the combined sludge?

Solution:

Combined solids concentration:  $C_1 * V_1 + C_2 * V_2 = C_3 * V_3$

$$\Rightarrow C_3 = \frac{C_1 * V_1 + C_2 * V_2}{V_3} = \frac{C_1 * V_1 + C_2 * V_2}{V_1 + V_2} = \frac{4.1 * 15,000 + 1.3 * 28,000}{15,000 + 28,000} = \boxed{2.28\%}$$

$C_{VS1} * V_1 + C_{VS2} * V_2 = C_{VS3} * V_3$

$$\Rightarrow C_{VS3} = \frac{C_{VS1} * V_1 + C_{VS2} * V_2}{V_3} = \frac{C_{VS1} * V_1 + C_{VS2} * V_2}{V_1 + V_2}$$

$$\Rightarrow C_{VS3} = \frac{4.1 * 15,000 * 0.68 + 1.3 * 28,000 * 0.63}{15,000 + 28,000} = \boxed{1.50\%}$$

### 20.5.3 Total volatile solids (VS) reduction

1. Calculate the % VS reduction in a digester given the volatile solids content of the influent sludge to the digester is 70% and the volatile solids content of the sludge leaving the digester is 52.5%

$$\text{Solution: Digester VS reduction}(\%) = \frac{0.7 - 0.525}{0.7 - 0.7 * 0.525} * 100 = \boxed{53\%}$$

2. Find lbs VS destroyed per 1000 gal of digester capacity per day if the digester radius is 55 ft with an operating sludge level of 25 ft.

Solution:

$$\text{Digester Volume: } (\pi * 55^2 * 25) \text{ft}^3 * 7.48 \frac{\text{gal}}{\text{ft}^3} = 1,776,220 \text{ gallons} = 1,776.2 \text{ (1000 gallons)}$$

$$\frac{\text{lbs VS reduction}}{\text{day}} = \frac{80,000 \text{ gal} * 8.34 \frac{\text{lbs}}{\text{gal}} * (0.045 * 0.75) \frac{\text{lbs VS}}{\text{lb}} * 0.5 \frac{\text{lbs VS reduction}}{\text{lb VS}}}{\text{day}}$$

$$= 11,259 \frac{\text{lbs VS reduction}}{\text{day}}$$

$$\frac{\text{lbs VS reduction}}{1000 \text{ digester capacity}} = \frac{11,259 \frac{\text{lbs VS reduction}}{\text{day}}}{1,776.2 (1000 \text{ gallons})} = \boxed{6.3 \frac{\text{lbs VS reduction}}{1000 \text{ gallons digester volume}}}$$

3. What is the digester gas production in Btu/day? Assume 14 cu. ft digester gas per lb of VS destroyed and a 650 Btu/cu. ft heating value for the digester gas produced

Solution:

$$\frac{\text{ft}^3 \text{ gas produced}}{\text{day}} = 11,259 \frac{\text{lbs VS reduced}}{\text{day}} * \frac{14 \text{ ft}^3 \text{ gas produced}}{\text{lb VS reduced}} = 157,626 \frac{\text{ft}^3 \text{ digester gas produced}}{\text{day}}$$

$$\frac{\text{BTU produced}}{\text{day}} = 157,626 \frac{\text{ft}^3 \text{ gas produced}}{\text{day}} * \frac{650 \text{ BTU gas produced}}{\text{ft}^3 \text{ gas}} = \boxed{102,456,900 \frac{\text{BTU produced}}{\text{day}}}$$