# Sludge Digestion and Solids Handling

BayWork Operator Certification Prep 2019

Instructor: Monte Hamamoto

# Sludge Digestion

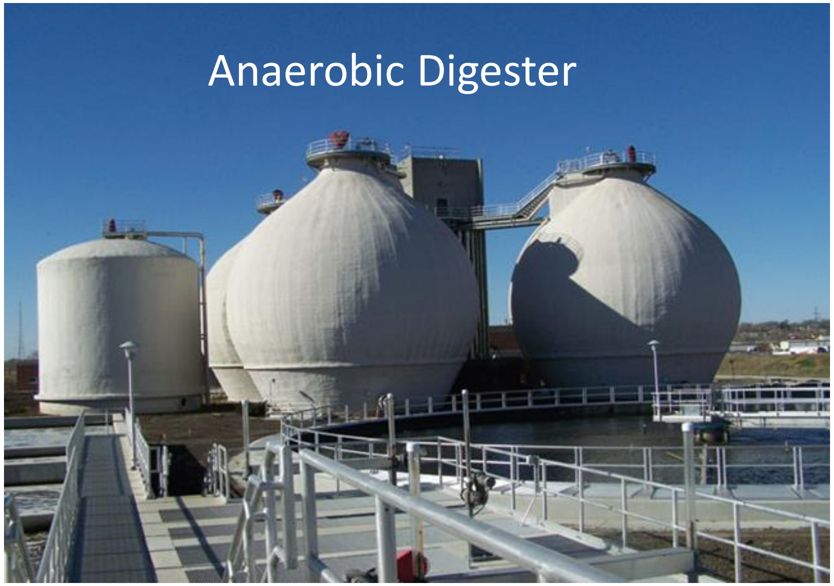
- Need for Sludge Digestion
  - In the Primary Sedimentation Process
    - Settled solids (Primary Sludge)
    - Floating solids (Scum-FOG)
  - In the Secondary Treatment Processes
    - Trickling filter sloughing
    - Activated Sludge WAS

Bacteria decompose the solids to simpler forms that are stable for final disposal.

# Sludge Digestion

Sludge digesters can be ANAEROBIC or AEROBIC

- ANAEROBIC -The breakdown of wastes by microorganisms in the <u>absence</u> of dissolved oxygen
- AEROBIC – The breakdown of wastes by microorganisms in the <u>presence</u> of dissolved oxygen

# Sludge Digestion

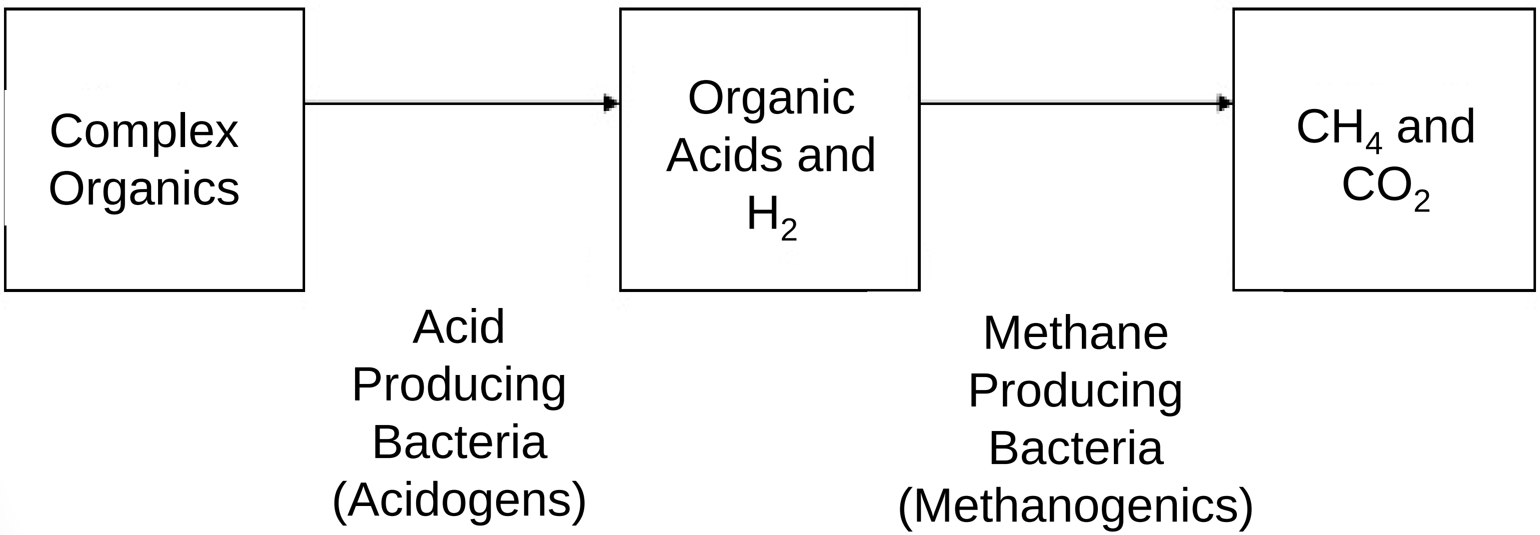
- ANAERBIC DIGESTION
    - Organic solids are decomposed by anaerobic microorganisms producing methane gas
    - 2 different bacteria in the anaerobic digestion process
        - <u>SAPROPHYTIC ORGANISMS</u> (**Acid Formers**) break down organic solids into "volatile acids"
        - <u>METHANE FERMENTERS</u> – convert the "volatile acids" to " methane gas". The Methane Fermenters are sensitive to pH and reproduce in a pH range of 6.6 to 7.6

# Sludge Digestion

- ANAEROBIC DIGESTION
  - The object of good anaerobic digester operation is to maintain a suitable environment to sustain a growing population of both Saprophytic (acid formers) and methane fermenters.
  - A properly operating anaerobic digester:
    - Reduces the raw feed volatile (organic) solids by 40-60%
    - Most anaerobic digesters require a minimum of 15-days to reach this reduction

# Sludge Digestion

- Anaerobic Digestion Process



# Sludge Digestion

**ANAEROBIC DIGESTION STANDARD DESIGN PARAMETERS**

| Process Parameter | Condition | Standard Design Ranges |
|---|---|---|
| Volatile Solids Loading | Standard<br>High Rate | 0.03 – 0.1 lbs VS/day ft3<br>0.1 – 0.4 lbs VS/day/ft3 |
| Detention Time | | 15 – 25 days |
| VS Reduction | | 40 – 60% |
| Gassification of Solids | Good Digestion | 90 – 95% |
| Digester Gas Production | | 12 – 18 ft3/lb VS destructed |
| Gas Make Up | Methane<br>CO2<br>H2S<br>Other Gases | 65 – 70%<br>30 – 35%<br>< 1.0%<br>< 1.0% |
| Digester Gas Heat Value | Average | 500 -600 BTU/ft3 |
| Digester Gas Pressure | Under Cover | 6 – 11 Inches of Water |
| Digester pH | Normal Operating Range | 6.8 – 7.2 pH |
| Digester Working Temperature | Psychrophilic<br>Mesophilic<br>Thermophilic | < 80 F<br>80 – 113 F (Optimum 95 F)<br>> 113 F |
| Temperature Change | Rule of Thumb | 1.0 F per day |
| VA/ALK Ratio | Stable Operation | 0.1 – 0.5 |

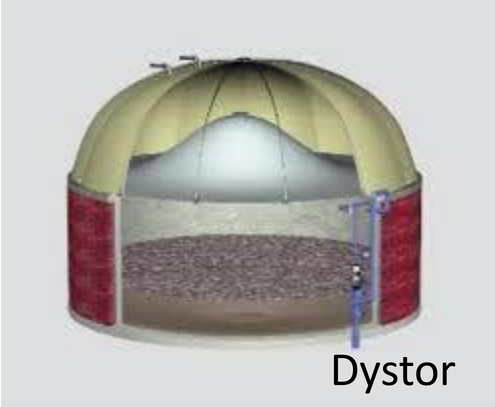
# Sludge Digestion

- ANAEROBIC DIGESTION
  - Mixing is the most important factor in the high-rate digestion process:
    - Uses most of the digester volume
    - Quickly distributes food throughout the volume
    - Puts microorganisms in contact with food
    - Achieves good pH control by distributing the BUFFERING ALKALINITY
    - Distributes heat throughout the tank volume
    - Minimizes the separation of heavy grit and floatables

# Sludge Digestion

- ANAEROBIC DIGESTION
  - Three (3) Anaerobic Digestion Process Operating Temperatures:
    1. **PSYCHROPHILIC** – lowest temperature, unheated digester. Dependent on ambient temperature. No bacterial activity at temperatures below $50^0$F
    2. **MESOPHYLIC** – Medium temperature (most popular), $80^0$F to $113^0$F. The optimum range is $85^0$F to $100^0$F. Most popular set-point $95^0$F
    3. **THERMOPHYLIC** – hot temperature, above $113^0$F. Optimum range $120^0$F to $135^0$F.

# Sludge Digestion




- ANAEROBIC DIGESTION
  - **<u>Secondary Digesters</u>**
    - No mixing
    - Allows solids/liquid (SUPERNATE) to separate
    - Gas storage
    - Floating cover
    - Seed Sludge

# Sludge Digestion

- ANAEROBIC DIGESTER GAS SYSTEM
  - Digester Gas has a heat value = 500 to 600 BTU
  - Natural Gas has a heat value = 900 to 1200 BTU

**DIGESTER GAS + OXYGEN = EXPLOSIVE**

- Digester Gas is used for:
  - Co-generation Internal Combustion (I/C)Engines
  - Boilers to heat digesters and buildings
  - I/C Engines to operate blower for aeration
  - Biosolids drying
  - Natural gas for vehicles
  - Production of Biodegradable Plastics

# Sludge Digestion

Electricity Co-Generation

Boilers for digester heating


Biodegradable Plastic


Natural Gas Vehicles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# Sludge Digestion

- ANAEROBIC DIGESTER GAS SYSTEM
  - Digester Dome for Gas Storage
    - Must be kept at positive pressure, <11 in Water
      - Higher than 11 inches of water column pressure could result in gas escaping from the dome water seals
    - Must be kept out of a vacuum situation
      - Withdrawing solids too quickly
      - can collapse dome
      - Could draw in air and cause an explosive atmosphere
    - Pressure/Vacuum Relief Valves
      - Pressure Relief generally have a flame arrestor attached to them

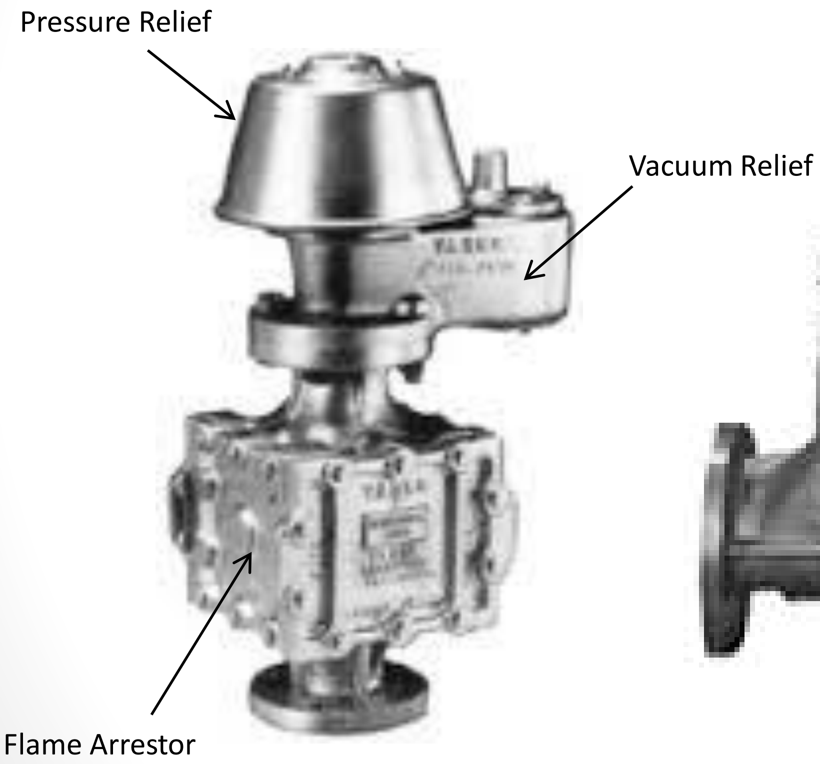
# Sludge Digestion

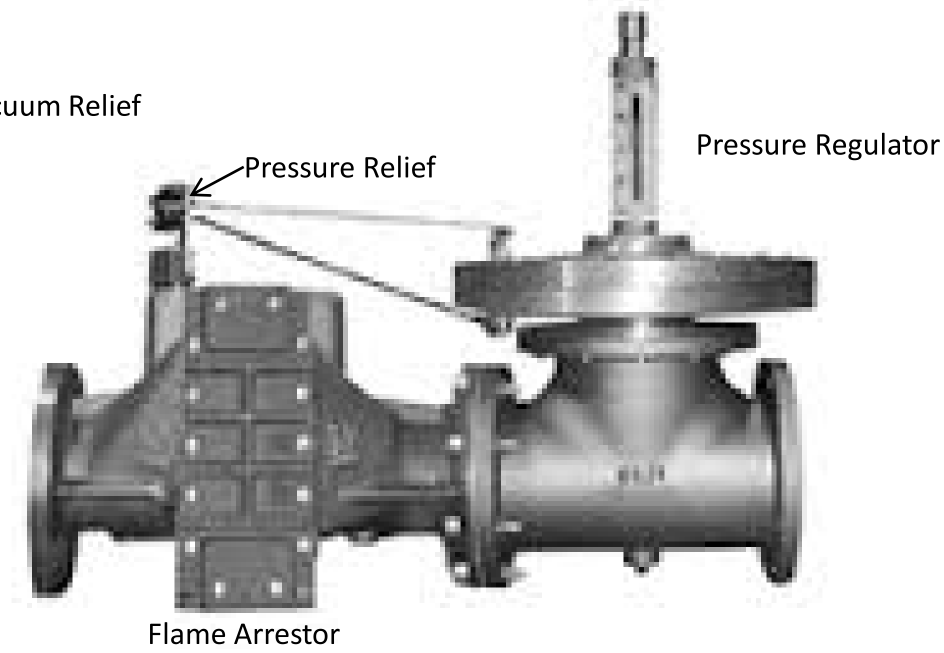
- ANAEROBIC DIGESTER GAS SYSTEM

Anaerobic Digester Explosions

# Sludge Digestion

- ANAEROBIC DIGESTER GAS SYSTEM
  - Digester Dome for Gas Storage



# Sludge Digestion

- ANAEROBIC DIGESTER GAS SYSTEM
- Excess gas produced that cannot be utilized is prohibited from discharge to the atmosphere (GHG)
- Removed via a
  WASTE GAS BURNER

Waste gas burner full enclosed with catalytic converter

# Sludge Digestion

- ANAEROBIC DIGESTER HEATING SYSTEM

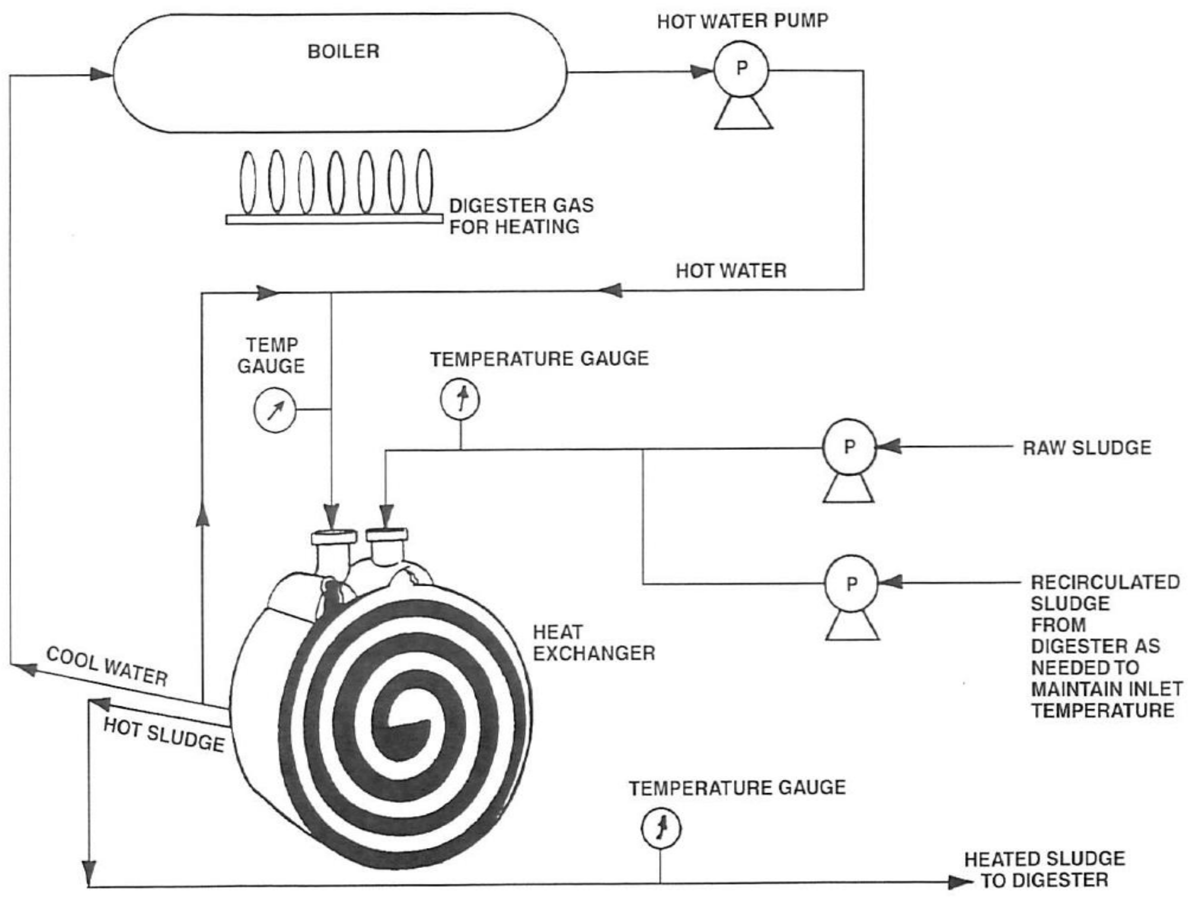
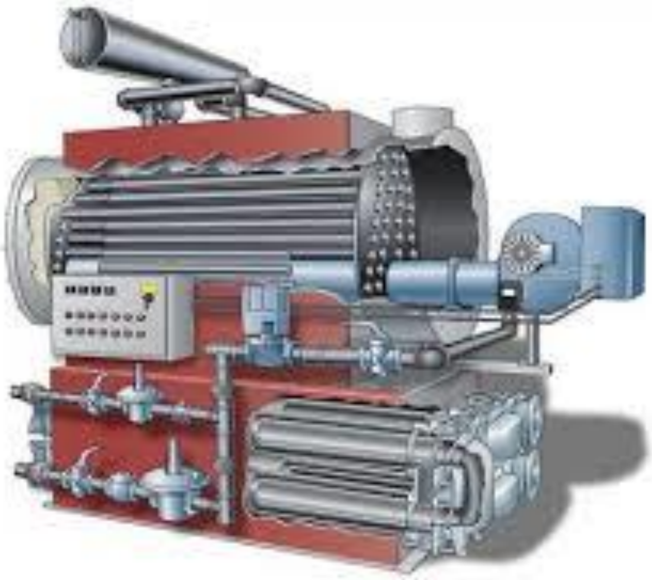



*Fig. 12.19 Gas-fired external hot water heat exchanger*

# Sludge Digestion

- ANAEROBIC DIGESTER HEATING SYSTEM

Spiral Heat Exchanger



Boiler Hot Water Box with
Heat Exchanger

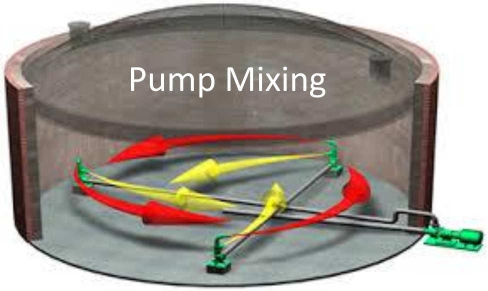
# Sludge Digestion

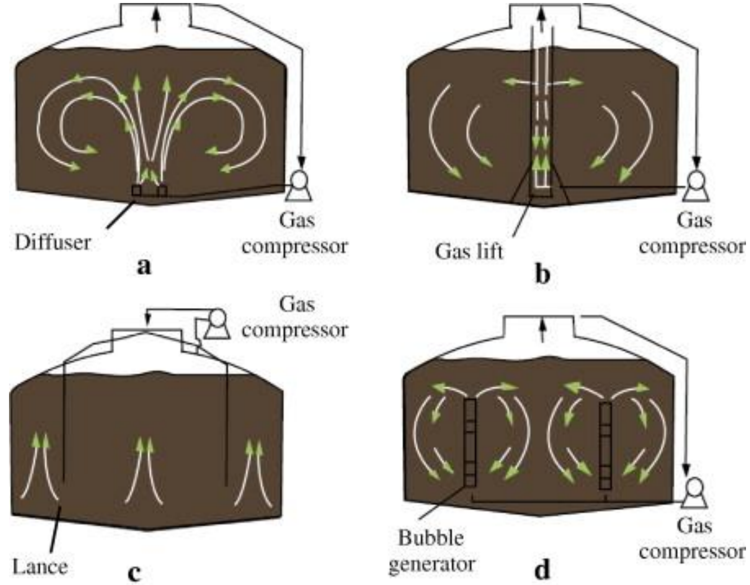
- ANAEROBIC DIGESTER MIXING SYSTEM
  - Mechanical Mixing
    - Prop mixing
    - Pump Mixing
  - Gas Mixing
    - Pump digester gas back into bottom of digester to provide gas lift mixing

# Sludge Digestion

- ANAEROBIC DIGESTER MIXING SYSTEM






Digester Gas Mixing

# Sludge Digestion

- ANAERODIC DIGESTER OPERATION
  - Three main operation controls of an Anaerobic Digester:
    1. Temperature (Heating)
    2. Feeding (Volatile organic feed)
    3. Mixing (Maintaining good contact with food and microorganisms)

1. <u>TEMPERATURE</u>
   - Maintain optimum temperature for operating range to properly reduce volatile organic solids and generate methane gas

# Sludge Digestion

- ANAERÓBIC DIGESTER OPERATION
  2. FEEDING
     - Maintain proper balance of Volatile Acids and Methane Fermentation
     - Maintain optimal % solids of feed solids of approximately 3.5%
       - Thinner solids contain higher concentrations of water
         - Water requires additional heat to maintain optimal temperature
         - Water reduces the working volume and influences the detention time
         - Water can dilute the Alkalinity or buffering
         - Water will increase the digester supernate going back into the plant

# Sludge Digestion

- ANAERBIC DIGESTER OPERATION
  3. MIXING
     - Maintain optimum contact between food and microorganisms
     - Provide good heat distribution of heated sludge
     - Provides suspension of heavy solids that would settle without mixing
     - Can break up the scum layer that floats on top of the digester volume

# Sludge Digestion

- DIGESTED SOLIDS DEWATERING
  - Process and equipment that removes water from the stable digested solids
  - Generally uses a cationic polymer for solids conditioning and floc formation prior to dewatering
    - Mechanical dewatering
    - Heat dewatering
    - Solar dewatering

# Sludge Digestion

## COAGULATION

- Coagulants tend to be positively charged.
- Due to their positive charge, they are attracted to the negative particles in the water
- ***The combination of positive and negative charge results in a neutral , or lack, of charge***
- *<u>Van der Waal's forces</u>* refer to the tendency of particles in nature to attract each other weakly if they have no charge.

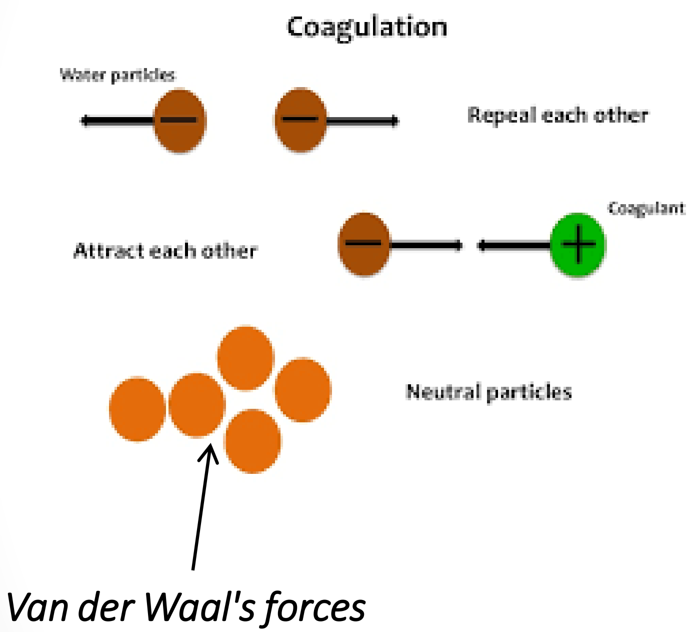
# Sludge Digestion

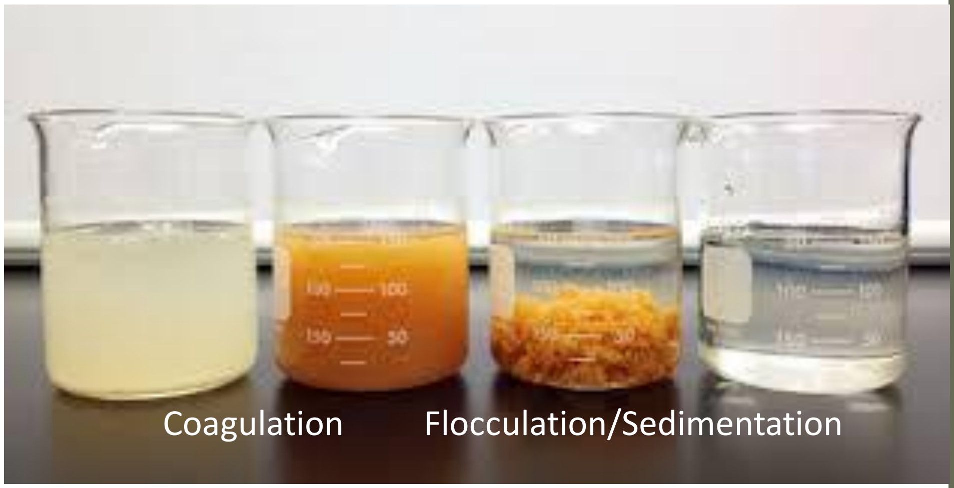
OPERATION

- Coagulation
  - Requires the addition of a coagulant chemical
  - Requires a rapid or FLASH MIX to thoroughly mix the coagulant and charged particles to neutralize the charges
- Flocculation
  - The clumping of particles as the result of coagulation
  - Requires slow mixing to allow particles to softly collide and stick together (<u>AGGLOMERATION</u>)
  - Rapid mixing during the flocculation process would cause the floc particles to fall apart or <u>SHEAR</u> due to the mixing energy

# Sludge Digestion

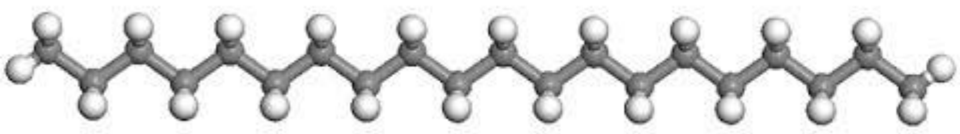
## COAGULATION



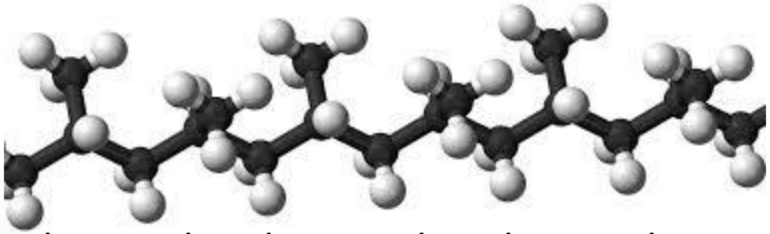



# Sludge Digestion

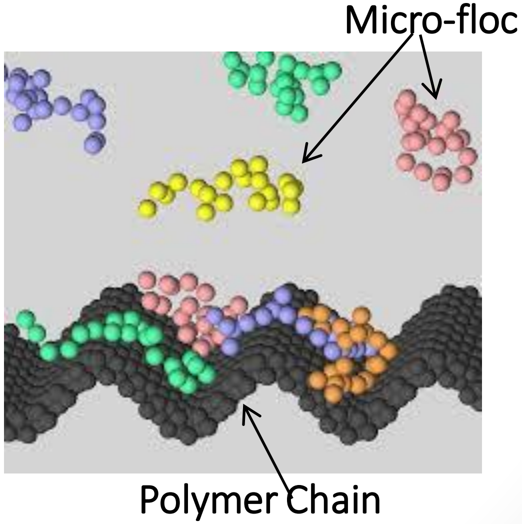
- Polymers
  - Water soluble ,high molecular weight organic compounds that carry electrical charge along a chain of carbon atoms)
  - Polymers help build large floc prior to sedimentation
  - Types of Polymers
    - Non-ionic — no electrical charge
    - Cationic — net positive (+) electrical charge
    - Anionic — net negative(-) electrical charge



Low molecular weigh polymer chain

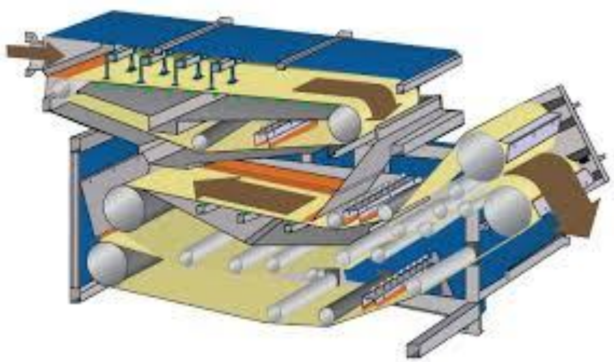


Higher molecular weigh polymer chain



# Sludge Digestion

- DIGESTED SOLIDS DEWATERING
- Mechanical dewatering



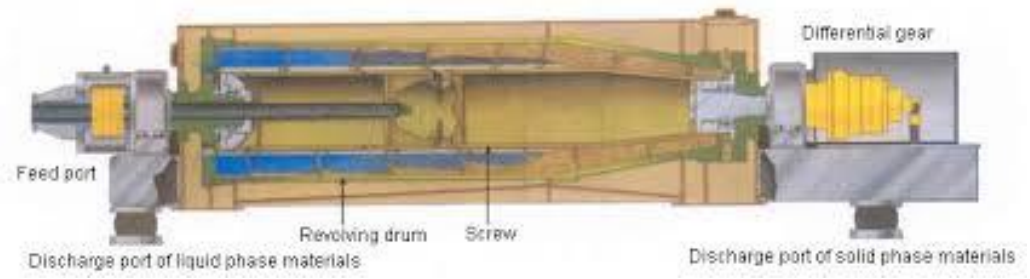
Belt Press

Plate and Frame Press

# Sludge Digestion

- DIGESTED SOLIDS DEWATERING
- Mechanical dewatering

Rotary Fan Press




Centrifuge

# Sludge Digestion

- DIGESTED SOLIDS DEWATERING
- Heat Dewatering

Incinerator

Bioforce Tech
Heat from Biological Activity

# Sludge Digestion

- DIGESTED SOLIDS DEWATERING
- Solar dewatering


Traditional Sludge
Drying Beds

Solar Greenhouse



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# Sludge Digestion

ANAEROBIC DIGESTER MATH

Anaerobic Digester Loading

- During a 24-hour period, 2,800 gallons of 6.5% total sludge solids with a volatile content of 68% was pumped to an anaerobic digester.
  - How many pounds of dry solids were fed to the digester?
  - What portion of the solids are volatile organic that can be readily digested?

# Sludge Digestion

ANAEROBIC DIGESTER MATH

Anaerobic Digester Loading

- Known
  - Sludge pumped = 2,800 gallons
  - % solids = 6.5%
  - % volatile = 68%

Dry Solids, lbs = (flow, gal)(% solids as decimal)(8.34 lbs/gal)

= (2,800, gal)(0.065)(8.34 lbs/gal)

= (182.0 gal)(8.34 lbs/gal)

= 1,518 lbs dry Solids

# Sludge Digestion

ANAEROBIC DIGESTER MATH

Anaerobic Digester Loading

- Known
  - Sludge pumped = 2,800 gallons
  - % solids = 6.5%
  - % volatile = 68%

Volatile Solids, lbs = (total solids, lbs)(% volatile as decimal)

= (1,518 lbs)(0.68)

= **1,032 lbs of Volatile Solids**

# Sludge Digestion

ANAEROBIC DIGESTER MATH

Anaerobic Digester Loading Volatile Matter/$ft^3$/day

- A raw sludge volume of 2,800 gallons was pumped in a 24-hour period to an anaerobic digester with a diameter of 40-ft and a 20 ft water depth. The raw sludge with a 6.5% solid and a volatile solids content of 68% contained 1,032 lbs of volatile solids.
  - Calculate the digester loading in VM/$ft^3$/day

# Sludge Digestion

ANAEROBIC DIGESTER MATH

Anaerobic Digester Loading

- Known
  - Sludge pumped = 2,800 gallons
  - % solids = 6.5%
  - % volatile = 68%
  - Lbs volatile solids = 1,032 lbs
  - Digester diameter = 40 ft
  - Digester water depth = 20 ft

Digester Loading, Volatile Matter/$ft^3$/day

$$= \frac{\text{(VM added, lbs/day)}}{\text{Volume of digester, ft}^3}$$

# Sludge Digestion

ANAEROBIC DIGESTER MATH

Anaerobic Digester Loading

Digester Loading, Volatile Matter/$ft^3$/day

$$= \frac{\text{(VM added, lbs/day)}}{\text{Volume of digester, } ft^3}$$

VM added = 1.032 lbs

Volume of digester, $ft^3$ = (diameter ft)$^2$ (0.785)(depth ft)

= (40ft)$^2$ (0.785)(20ft)

= (1,600 $ft^2$)(0.785)(20ft)

= (1,256 $ft^2$)(20ft)

= 25,120 $ft^3$

# Sludge Digestion

ANAEROBIC DIGESTER MATH

Anaerobic Digester Loading

Digester Loading, Volatile Matter/ft$^3$/day

$$= \frac{\text{(VM added, lbs/day)}}{\text{Volume of digester, ft}^3}$$

$$= \frac{\text{(1,032 lbs VM)}}{\text{(25,120 ft}^3\text{)}}$$

= **0.041 Volatile Matter/ft$^3$/day**

# Sludge Digestion

ANAEROBIC DIGESTER MATH

Anaerobic Digester Volatile Solids % Reduction

- An anaerobic digester has a feed volatile solid content of 68% and a digested sludge overflow that contains a volatile solids content of 43%.
  - Calculate the % volatile solids reduction

$$= \frac{\text{in} - \text{out}}{\text{in} - (\text{in} \times \text{out})} \times 100\%$$

$$= \frac{0.68 - 0.43}{0.68 - (0.68 \times 0.43)} \times 100\%$$

$$= \frac{0.25}{0.68 - 0.29} \times 100\%$$

$$= \frac{0.25}{0.39} \times 100\%$$

$$= 0.64 \times 100\%$$

**= 64% volatile solids reduction**