Sludge Digestion and Solids Handling
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 absence of dissolved oxygen
- AEROBIC – The breakdown of wastes by microorganisms in the presence of dissolved oxygen
Sludge Digestion

- ANAEROBIC DIGESTION
  - Organic solids are decomposed by anaerobic microorganisms producing methane gas
  - 2 different bacteria in the anaerobic digestion process
    - SAPROPHYTIC ORGANISMS (Acid Formers) break down organic solids into “volatile acids”
    - METHANE FERMENTERS – 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

1. Complex Organics
2. Organic Acids and $\text{H}_2$
3. $\text{CH}_4$ and $\text{CO}_2$

- Acid Producing Bacteria (Acidogens)
- Methane Producing Bacteria (Methanogenics)
**Sludge Digestion**

**ANAEROBIC DIGESTION STANDARD DESIGN PARAMETERS**

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

2. **MESOPHYLIC** – Medium temperature (most popular), 80°F to 113°F. The optimum range is 85°F to 100°F. Most popular set-point 95°F

3. **THERMOPHYLIC** – hot temperature, above 113°F. Optimum range 120°F to 135°F.
Sludge Digestion

- ANAEROBIC DIGESTION
- **Secondary Digesters**
  - 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

- Pressure Relief
- Vacuum Relief
- Flame Arrestor
- Pressure Regulator

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- 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

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Sludge Digestion

- ANAEROBIC DIGESTER HEATING SYSTEM

![Diagram of 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

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Sludge Digestion

• ANAEROBIC 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. TEMPERATURE
  • Maintain optimum temperature for operating range to properly reduce volatile organic solids and generate methane gas
Sludge Digestion

• ANAEROBIC 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

• ANAEROBIC 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
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*
- *Van der Waal's forces* 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 (AGGLOMERATION)
  • Rapid mixing during the flocculation process would cause the floc particles to fall apart or SHEAR due to the mixing energy
Sludge Digestion

COAGULATION

Van der Waal's forces

Coagulation
- Water particles
  - Attract each other
  - Repeal each other
- Coagulant
  - Neutral particles

Coagulation
Flocculation/Sedimentation
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
Sludge Digestion

- DIGESTED SOLIDS DEWATERING
- Mechanical dewatering

Belt Press
Plate and Frame Press

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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

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Sludge Digestion

- DIGESTED SOLIDS DEWATERING
- Solar dewatering

Traditional Sludge Drying Beds

Solar Greenhouse
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?
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**

\[
= (\text{VM added, lbs/day}) \\
\text{Volume of digester, ft}^3
\]
ANAEROBIC DIGESTER MATH

**Anaerobic Digester Loading**

Digester Loading, Volatile Matter/ft\(^3\)/day

\[
\text{Loading} = \frac{\text{VM added, lbs/day}}{\text{Volume of digester, ft}^3}
\]

VM added = 1.032 lbs

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

\[
= (40\text{ft})^2 (0.785)(20\text{ft})
= (1,600 \text{ ft}^2)(0.785)(20\text{ft})
= (1,256 \text{ ft}^2)(20\text{ft})
= 25,120 \text{ ft}^3
\]
Sludge Digestion

ANAEROBIC DIGESTER MATH

Anaerobic Digester Loading

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

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

\[
= \frac{1,032 \text{ lbs VM}}{25,120 \text{ ft}^3}
\]

\[
= 0.041 \text{ Volatile Matter/ft}^3/\text{day}
\]
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

\[
\text{\% volatile solids reduction} = \frac{\text{in} - \text{out}}{\text{in} - (\text{in} \times \text{out})} \times 100\%
\]

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

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

\[
= \frac{0.25}{0.39} \times 100\%
\]

\[
= 0.64 \times 100\%
\]

\[
= 64\% \text{ volatile solids reduction}
\]