The Basics of Anaerobic Digestion

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Prepared by George Bevington, Senior Project Manager
Why Anaerobic Digestion?

• Stabilize sludge (DEC regulation)
• Reduce solids volume (~30%)
• Produce methane gas
• Can also generate tipping fees from AD
• Can provide safe sustainable disposal method for organic waste generators
Organic Decomposition

- Has occurred naturally for thousands, millions, billions of years
  - Organic material + bacteria = Simple compounds
  - Inorganic material will not break down
- Given time, organics will breakdown but AD equipment and operators help the process move faster
- Activated sludge process (with oxygen)
- Anaerobic Digestion (without oxygen)
Where does Anaerobic Decomposition Occur?

- Landfill, (anaerobic, gas flare or electricity generation)
- Wastewater Anaerobic Digesters (Mesophilic 95 F most widespread)
- Septic Tank (no gas collection!)
- In all of the above, similar bacteria doing the decomposition
Anaerobic Digestion Everywhere...

1. Human Digestion 15 hours
2. Anaerobic Digestion 15 days
3. Landfill Digestion 15+ Years

• Unfortunately, energy recovery occurs only in both 2 & 3!
Why AD at WWTP?

• A 10 MGD activated sludge plant processes wastewater with a BOD concentration @ 228 mg/l. Facility treats 19,015 lbs. BOD/day.
• Dump three 8,000 gallon tankers of Mountain Dew into the headworks. BOD concentration 95,000 mg/l. Additional loading to facility 19,015 lbs. BOD/day
• Low strength waste: treat aerobically
• High strength waste: treat anaerobically, recover energy
• AD: great place to treat sludge, food waste, etc.
Simple Comparison of Processes

**Landfill**
- Solid chunks
  - Less surface area
- No mixing
- No temperature control
- Biogas capture not immediate
- Simple operation
- 15 years to do the job

**Anaerobic Digester**
- Slurry feed (3 – 10% TS)
  - More surface area
- Mixing
- 95 degrees F typical range
- Sealed system captures all biogas
- More complex
- Done in 15 days
Disadvantages of Anaerobic Digestion

- High capital cost
- Produces a poor quality side-stream (digestate)
- Methane-forming bacteria grow slowly
Advantages of Anaerobic Digestion or Co-Digestion

• Significantly reduces amount of end product
• Can process liquid and/or sludge waste
• Stabilizes end product
  • Reduced odors and vector attraction
  • Soil conditioner
• Produces methane (energy efficient)
• Inactivates many pathogens
What Happens inside AD Tank?

**Step 1 – Acid Formation**

Organic Matter + Acid Forming Bacteria = Organic Acids

**Step 2 – Methane Formation**

Organic Acids + Methane Forming Bacteria = Methane (CH4) + CO2
Anaerobic Decomposition

Step 1

- Breakdown of complex organics
- Conversion of organic material in sludge to “Intermediate Degradation Products:” $\text{H}_2\text{O}, \text{CO}_2$, and organic acids by ‘acid formers’
Typical Acid Forming Bacteria

Grow **FAST** and do well in a variety of environments!
Anaerobic Decomposition – Step 2

The Real Work!!

- Breakdown of organic acids formed in step one
- Organic acids converted to CO$_2$ and CH$_4$
- Stabilization accomplished, original intent of AD
What About the Methane Formers?

• Many different methane bacteria
  • Grow much more slowly
  • Sensitive to environment & environmental changes

• WWTP Operators: keep these microbes happy...
  • Anaerobic digester system tailored to meet the needs of methane formers
Controlling the Anaerobic Digester Process

- Keep the slow growing methane formers happy
  - Anaerobic conditions – No oxygen
  - Even feed rate: do not wash out
  - Constant, proper temperature range
  - Good mixing
  - Neutral pH
  - No toxics
Temperature is Important!

• Constant temperature is best
  • Limit daily temperature change to 1° F
• Most digesters run in the mesophilic temperature range
  • 93° F to 100° F textbook range
  • 95° F to 98° F seems like best target
• Stay in recommended temperature range!
Mesophilic vs. Thermophilic

Figure 6

Effect of Digestion Temperature on Gas Production
Based on Data from 23 Studies (6)
pH Control

• Acid forming bacteria work fine down to pH of 5 (or even 3 or 4!)
• Methane formers must have neutral pH
  • 6.8 – 7.2
  • Can go higher, don’t go lower
  • If low pH, methane formation rate dramatically reduced
Anaerobic Digester Mixing

• Provide regular mixing
• Need to bring food into contact with bacteria
• Good mixing, along with heating, will help to assure a good digestion rate
• Mixing critical to good operation
Mixing Systems

• Propellers
• Gas mixing
• Pumped recirculation system
• Linear Motion: low HP disk
Network of Wastewater Digester Locations (NYSERDA)

NYS WWTPs w/Existing Anaerobic Digestion Facilities (145)

KEY TO FEATURES
- NYS Sewerage Treatment Plants
- Anaerobic Digestion (Proportioned by Flow Rate in MGD)
  - 0.015 - 1.0
  - 1.01 - 5.0
  - 5.01 - 20.0
  - 20.01 - 75.0
  - 75.01 - 310.0
- NYS Counties
Enclosed Tanks for AD @ WWTP
Simplified Digester

- Sludge Inlet
- Mixing
- Gas Outlet
- Gas to Storage or engine
- Heating
- Sludge Outlet
Simplified Co-Digester

Sludge Inlet

Food Waste etc. Inlet

Mixing

Gas to Storage or engine

Gas Outlet

Heating

Sludge Outlet
Feeding

• Like us, methane formers prefer several small meals:
  • Best – continuous feed at low rate
  • Okay - Small meals, many times a day
  • Bad - One feeding a day no good
  • Too much food = too much acid
    • Think Thanksgiving dinner
Sludge, Liquid Waste, Food Waste all great AD Feedstock
Biogas Generation

• Biogas mostly methane and CO2
• Biogas plus oxygen and spark = flame or combustion
• Successful AD = maximum methane generation and beneficial use
What does AD have to do with Climate?

- Methane makes up 55 – 75% of Digester Gas
- Methane to atmosphere: not a good thing
- Digesters harvest carbon: create methane molecule
- We can use biogas for beneficial use
Beneficial Uses of Biogas

- Heating
- Electrical Generation
- Renewable Natural Gas (rNG)
- Sludge Drying
Official Score 6,000 to 200:

AD in NYS
- 145 AD at wastewater
- 23 AD at farms
- ?? Industrial AD
- Total: ~200+

AD in Germany
- ~6,000 digesters constructed and operational

Rio 2016
Questions?