Myths and Misconceptions of Digesters
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Presentation Outline

• Anaerobic digestion fundamentals
• Anaerobic digestion applications
• Myths and misconceptions of digesters

Uses of Anaerobic Biotechnology

• Renewable Energy Generation
  – Greenhouse gas reduction
  – Economically viable in Europe due green energy incentives
  – Typically not economically viable in North America at present

• Waste Treatment
  – Odor reduction
  – COD and volatile solids removal
  – Pathogen inactivation
  – Some renewable energy generation
### Requirements for Anaerobic Digestion

**Proper:**

1. Substrate
2. Temperature
3. pH
4. Macronutrients
5. Micronutrients
6. Microorganisms
7. Microbe/Substrate contact
8. Toxicity accommodation
9. Reaction time
10. Water availability

### (1) Substrate

1 gram VS = 1 to 2 grams chemical oxygen demand (COD)

Often, nearly all COD removed is released as an equivalent amount of methane

1 gram COD = 395 mL methane @ 35°C, 1 atm

### (2) Temperature

1. **Optimum Temperature:**
   - **Mesophilic:** 30-38°C
   - **Thermophilic:** 50-57°C

2. **Real world:** 5-70°C?

FOG solubility higher at higher T
Gas (e.g. NH₃, H₂S) solubility lower at higher T
(3) pH

Required pH range for methanogenesis approximately 6.4 - 8.2

\[ \text{pH} = -\log [H^+] \text{ and } [H^+] = \text{moles H}^+ \text{ per liter} \]

Soluble carbonic acid from CO$_2$ in the biogas and transient increases in intermediate volatile acids concentrations tend to decrease the pH unless there is sufficient alkalinity (i.e. buffering capacity)

(4) Macronutrients

(1) Nitrogen

Required: 3-6 mg N per gram COD removed

Optimum: 40 to about 2000 mg soluble TKN/L in reactor for highest rate of methane production

(2) Phosphorous

Required: 0.5 - 1 mg P per gram COD removed

Optimum: At least 0.1- 4 mg/L PO$_4$$^{3-}$-P in reactor for highest rate of methane production
Macronutrients

(3) Iron Requirements

- Approximately 0.3 mg Fe per gram COD removed
- Approximately 0.5 mg soluble Fe/L in reactor for optimum rate of methane production

(5) Micronutrients

1. Nickel
2. Cobalt
3. Molybdenum
4. Calcium
5. Sulfide
6. Magnesium
7. Potassium
8. Zinc
9. Others inorganics (e.g., Cu, Mn, Se, B, W)
10. Organic micronutrients (cysteine)

Anaerobic Biotechnology
Example 1:
Monchevre Cheese
Belmont, WI
• Largest goat cheese producer in US
• 6 million gallons of goat milk per year
• 8 million pounds of cheese per year
• 47,000 gallons per day of wastewater
• 5,270 kWh/day electricity generated
• Enough electricity to power 210 homes
• Watch video at:
  http://www.youtube.com/watch?v=QzpmOTIQH4

Anaerobic Biotechnology
Example 2:
Upstate Niagara Cooperative
(formerly Breyers Yogurt)
East Lawrence, NY
• Yogurt and cottage cheese production
• 54,100 gallons per day of process wastewater
• 20,000 gallons per day of other industrial waste
• 180 million Btu/day biogas to boiler
MFT = Media fixed-film technology anaerobic bioreactor

- Municipal wastewater solids digestion
- Treat approx. 200 million gallons per day wastewater
- Treat approx. 2 million gallons per day biosolids slurry
- Produce 1.2 million ft³/day biogas
- Generate electricity (combustion engines/generators)
Myths and Misconceptions

• Anaerobic digestion is:
  – Good to go with any seed biomass
  – Slow
  – Susceptible to toxic chemicals
  – Ruined by oxygen
  – Can’t achieve final COD < 30 mg/L

Not Good to Go With Any Biomass Available!

Biomass activities actually differ greatly

Different Digester Organisms Result in Different Biogas Yields

15% more methane

Control = Seed biomass microbial community
Active = Different microbial community (bioaugmented)
Source: Kaushik Venkiteshwaran, Ph.D. Student, Marquette University
Anaerobic is Not Slow!

Anaerobic reactor has smaller volume and can be faster than aerobic reactor:

Both aerobic and anaerobic organisms can process a maximum of about 1 gram of COD per gram of active microbes (as VSS) per day.

Typical WWTP loadings:

- Aerobic loading: 0.5 to 3.2 g COD/L-d
- Anaerobic loading: 2.0 to 40 g COD/L-d

Anaerobic is Not More Susceptible to Toxicants!

“…if the chlorinated aliphatics are excluded, the IC\textsubscript{50} concentrations for methanogens and aerobic heterotrophs remain statistically the same…”

Dr. R. E. Speece
(Anaerobic Biotechnology & Odor/Corrosion Control, 2008, p. 472)

Anaerobic is Not More Susceptible to Toxicants!

- Methanol: Anaerobic IC\textsubscript{50} = 22,000 mg/L, Aerobic IC\textsubscript{50} = 20,000 mg/L
- Ethyl Benzene: Anaerobic IC\textsubscript{50} = 160 mg/L, Aerobic IC\textsubscript{50} = 130 mg/L
Anaerobic Biomass is Not Ruined by a Little Oxygen!

Waste Management 18 (1998)
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WASTE MANAGEMENT
Feasibility and benefits of methanogenesis under oxygen-limited conditions

Methanogenic and aerobic (or microaerophilic) biological processes are often considered mutually exclusive and separated as biological wastewater treatment options. However, under oxygen-limited conditions, both aerobic respiration and methanogenesis can be practically accomplished by a single mixed culture. Rather than that of a strictly anaerobic culture maintained in parallel...


Anaerobic Systems CAN Achieve COD < 30 mg/L and BOD₅ < 30 mg/l!

Anaerobic Membrane Bioreactor
Anaerobic Systems Can Achieve Average COD < 10 mg/L!


Influent COD = 500 mg/L  
Effluent COD = 7 mg/L  
HRT = 2.2 hrs  
Synthetic domestic wastewater

Daisy Brands, Garland, TX - Anaerobic Membrane Bioreactor

Common Results

Courtesy of Vincent Taylor, President, Daisy Brand, Inc.

**DAISY BRANDS, GARLAND, TX**  
**FULL-SCALE ANAEROBIC MEMBRANE BIOREACTOR OPERATIONS HISTORY**

- Startup with Municipal Seed
- Initial Results (2-4 weeks) 88-90% COD Reduction
- COD Reduction improved steadily over the next 6 weeks
- COD Reduction consistent at >99.5% since November of 2007
- Average Performance Values:
  - Influent COD = 44,000 mg/L: Range 22,000 – 85,000 mg/L
  - Effluent COD = 220 mg/L: Range 20 – 750 mg/L
  - BOD’s are rarely tested. The few tests run have been < 10 mg/L
Questions?

Upflow Anaerobic Sludge Blanket Reactor (UASB)
City Brewery, LaCrosse, WI
ca. 1982 (first UASB in USA)