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Myths and Misconceptions of Digesters

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Presentation Outline

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

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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

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(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

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(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. NH_3, H_2S) solubility lower at higher T

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(3) pH

Required pH range for methanogenesis approximately 6.4 - 8.2

pH = -log [H^+] and [H^+] = moles H^+ 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)

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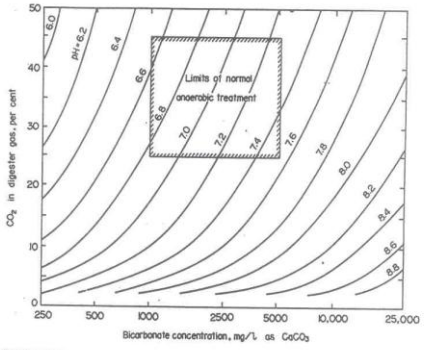

FIGURE 31-2
Relationship between pH, bicarbonate concentration, and carbon dioxide concentration at 35°C. (*P. L. McCarty, Anaerobic Waste Treatment Fundamentals, Public Works*, 123: October 1964.)

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(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

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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

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(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)

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Micronutrients

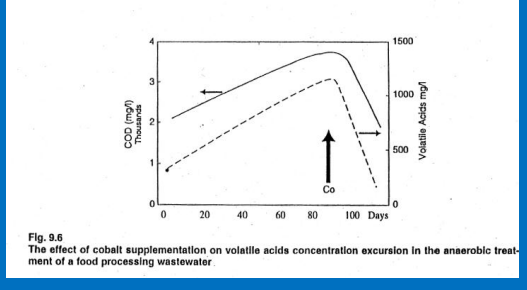

Fig. 9.6
The effect of cobalt supplementation on volatile acids concentration excursion in the anaerobic treatment of a food processing wastewater.

Source: R. E. Speece, *Anaerobic Biotechnology for Industrial Wastewaters* (1996)

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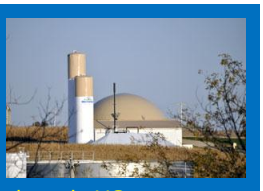
Applications

Anaerobic Biotechnology
Example 1:
Monchevre Cheese
Belmont, WI



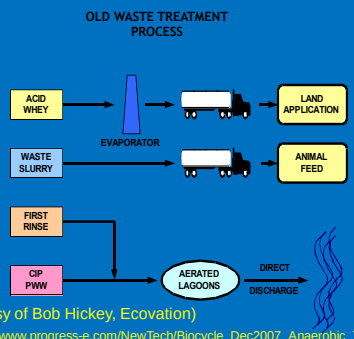
- Largest goat cheese producer in US
- 6 million gallons of goat milk per year
- 8 million pounds of cheese per year
- 47,000 gallons per day of wastewater
- 5,270 kWh/day electricity generated
- Enough electricity to power 210 homes
- Watch video at:

http://www.youtube.com/watch?v=QzpmOTfQQH4

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

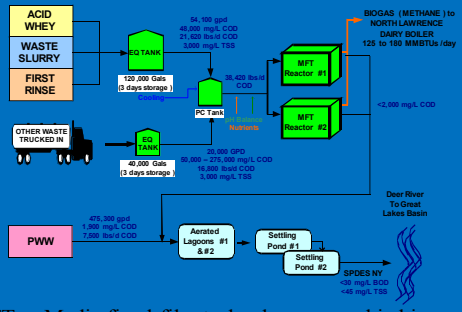
Anaerobic Biotechnology Example 2: Upstate Niagara Cooperative - North Lawrence, New York



(Courtesy of Bob Hickey, Ecovation)

see http://www.progress-e.com/NewTech/Biocycle_Dec2007_Anaerobic_Treatment.pdf

Anaerobic Biotechnology Example 2: Upstate Niagara Cooperative- North Lawrence, New York



MFT = Media fixed-film technology anaerobic bioreactor

Anaerobic Biotechnology Example 3: Milwaukee Metropolitan Sewerage District, Oak Creek, WI

- 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 ft^3/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

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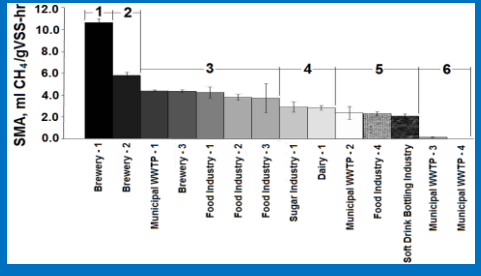
Not Good to Go With Any Biomass Available!



Biomass activities actually differ greatly

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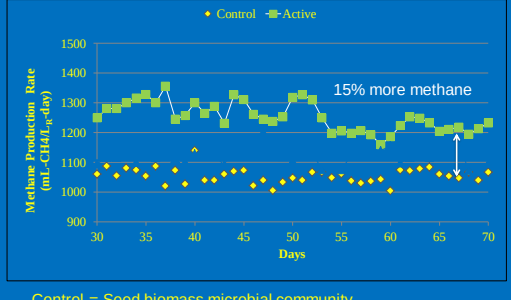
Different Digester Organisms Result in Different Biogas Yields



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

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Anaerobic is Not More Susceptible to Toxicants!

"…if the chlorinated aliphatics are excluded, the IC_{50} concentrations for methanogens and aerobic heterotrophs remain statistically the same…"

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

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Anaerobic is Not More Susceptible to Toxicants!

Methanol

Anaerobic IC_{50}	= 22,000 mg/L
Aerobic IC_{50}	= 20,000 mg/L

Ethyl Benzene

Anaerobic IC_{50}	= 160 mg/L
Aerobic IC_{50}	= 130 mg/L

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Anaerobic Biomass is Not Ruined by a Little Oxygen!

Waste Management 18 (1998)
D.H. Zitomer,*, J.D. Shrout
Civil and Environmental Engineering, Marquette University, Milwaukee, WI 53201, USA

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. r

than that of a strictly anaerobic culture maintained in parallel…

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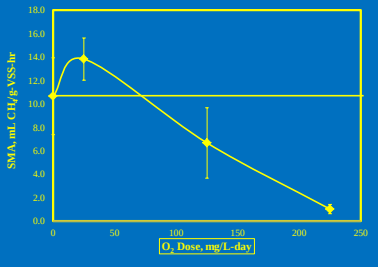
Anaerobic Biomass is Not Ruined by a Little Oxygen!



Source: Tale, V. P., *Bioaugmentation for Recovery of Anaerobic Digesters Subjected to Organic Overload*, Ph.D. dissertation, Marquette University, December 2010.

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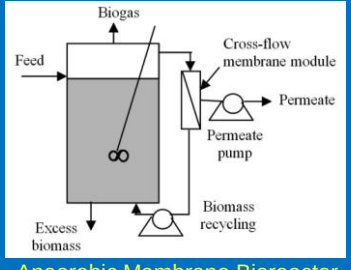
Anaerobic Systems CAN Achieve COD < 30 mg/L and BOD_5 < 30 mg/l!



Anaerobic Membrane Bioreactor

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

Kim Et al. (2011) "Anaerobic Fluidized Bed Membrane Bioreactor for Wastewater Treatment," *ES&T*, 45(2), pp. 576-581.

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

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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 < 10mg/L

Questions?

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