Anaerobic digestion

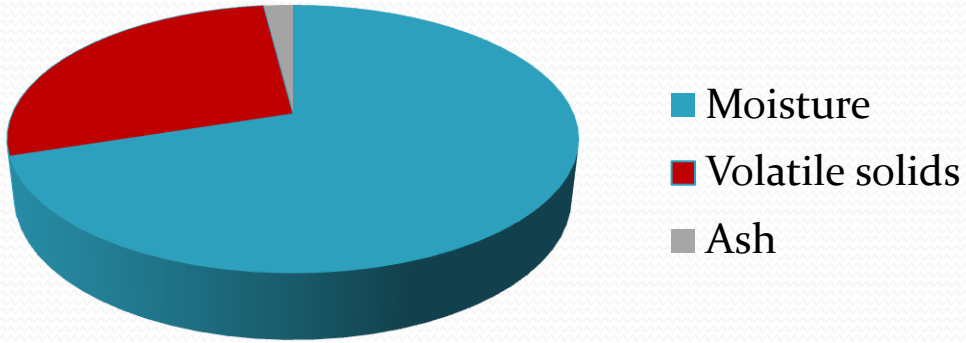
Technical overview and benefits

Overview

- Terms used in anaerobic digestion
- Different types of digesters
- Benefits of anaerobic digestion

Total Solids, Volatile Solids

- Total Solids (TS)= Dry matter content of substrate (very important as water does not produce methane)
- Volatile Solids (VS)= Combustible proportion of TS, organic matter
- Non-volatile Solids (Ash)= Inorganic material (Minerals, salts), also not a source of methane



Total Solids, Volatile Solids

Total Solids

Ash

COD (Chemical oxygen demand)

- Chemical oxidant used to completely oxidize substrate
- Color indicator used to determine oxidant consumed
- Represents total oxidative potential of substrate
- Used widely in aerobic water treatment to determine aeration requirement
- Stoichiometrically related to methane potential
  - $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
  - Therefore 1 g COD = 0.35 L methane @ STP
- This is the theoretical maximum

BOD (Biochemical oxygen demand)

- Similar to COD, but uses aerobic microbes to oxidize substrate
- Measures oxygen consumed during process
- Requires several days (commonly 5 days = BOD_5)
- More realistic representation of microbially-available organic material

BMP (Biochemical methane potential)

- Biochemical Methane Potential Assay
  - Developed as correlative test of BOD in anaerobic systems
  - Measures actual methane production
  - Determines kinetics of methane production (lag phase, stationary phase, etc.)
  - Can determine non-biodegradable materials in feedstock through residues

Organic loading rate (OLR)

- Rate at which feedstock is fed to the digester
- Units in kg VS (or COD)/m^3/day
- Varies by feedstock, reactor type, microbial population, temperature, etc.
- Too low= too large of reactor
- Too high= overload reactor, acidification

Hydraulic Retention Time (HRT)

- Turn-over rate in digestion (i.e. amount of time substrate remains in active volume)
- Optimized for higher biogas/reactor volume ratio
- Too high= Unnecessarily large reactor
- Too low= Reduced biogas output, washout microbes

Temperature

- Anaerobic metabolism more sensitive to temperature than aerobic
- Three primary temperature ranges = three different anaerobic ecologies
  - Ambient: 10-25° C (50-77 °F)
  - Mesophilic: 25-45 °C (77-113 °F)
  - Thermophilic: 45-60 °C (113-140 °F)
- Biogas output is greater at higher temps, but not linearly
- Each range has optimum temp for that microbial population

pH

- Very important parameter
- Optimum 7.0, acceptable 6.0-8.0
- Methanogens cannot function at low pH
- Ammonia toxicity above 8.0
- Slow recovery after sustained drop in pH
- pH can be maintained through addition of buffering agents (sodium bicarbonate, etc.), if required
- Dependent upon alkalinity of feedstock

Batch vs. continuously fed

- Batch – Digester loaded once, emptied once fully degraded
- Continuously fed – Digester loaded on a continuous basis, effluent produced at each loading

Wet vs. dry digestion

Wet

- Used for low TS feedstocks
- Allows pumping of material
- Generally faster than dry digestion

Dry

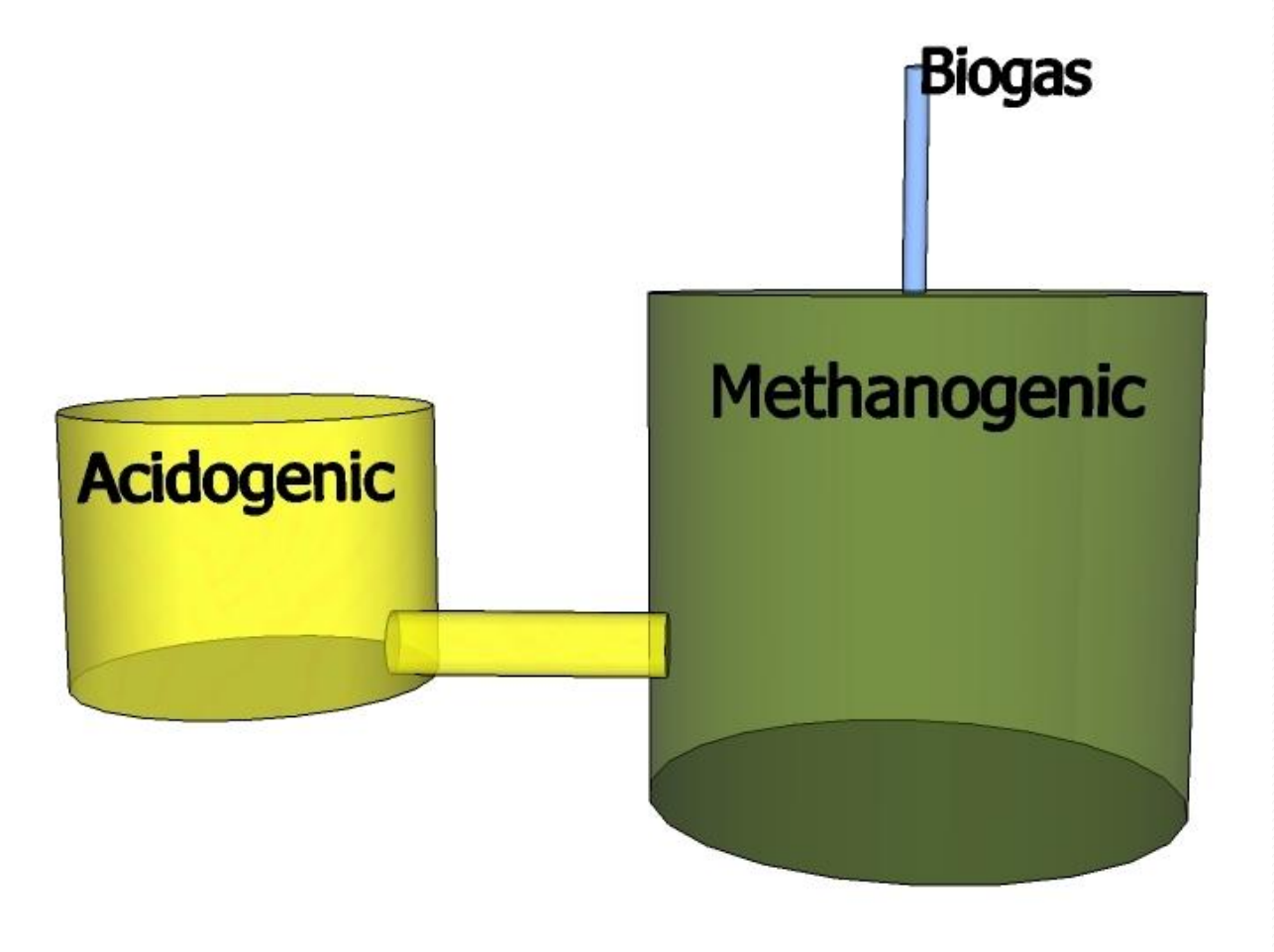
- AKA high solids digestion
- Used for high solid materials (e.g. MSW)
- Leachate recycling usually employed
- Typically a batch system

Food waste can go either way

Two phase digestion

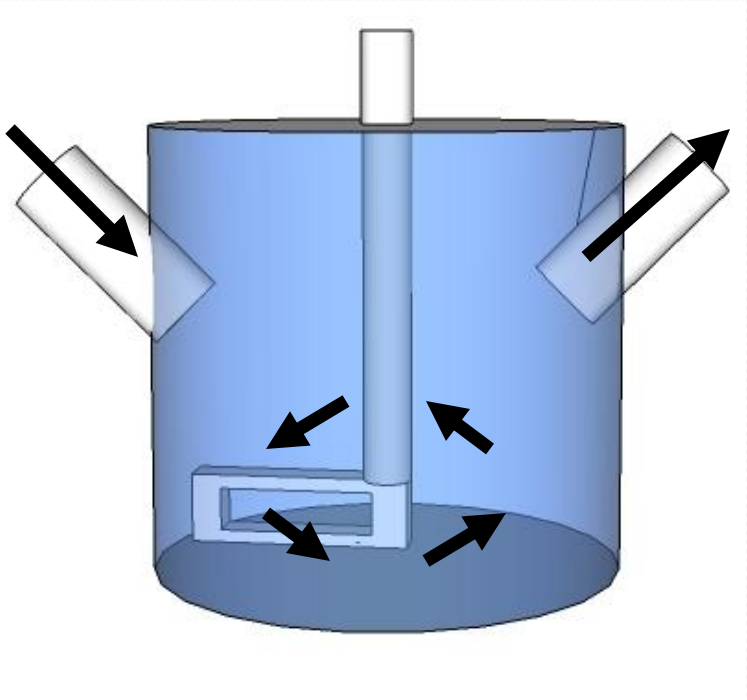
- Single phase- all in one reactor
- Two phase- acidogenesis and methanogenesis separated
- Benefits
  - Increased over-all efficiency (short HRT of acidogenic reactor)
  - More pH control of methanogenic reactor

Two phase digestion



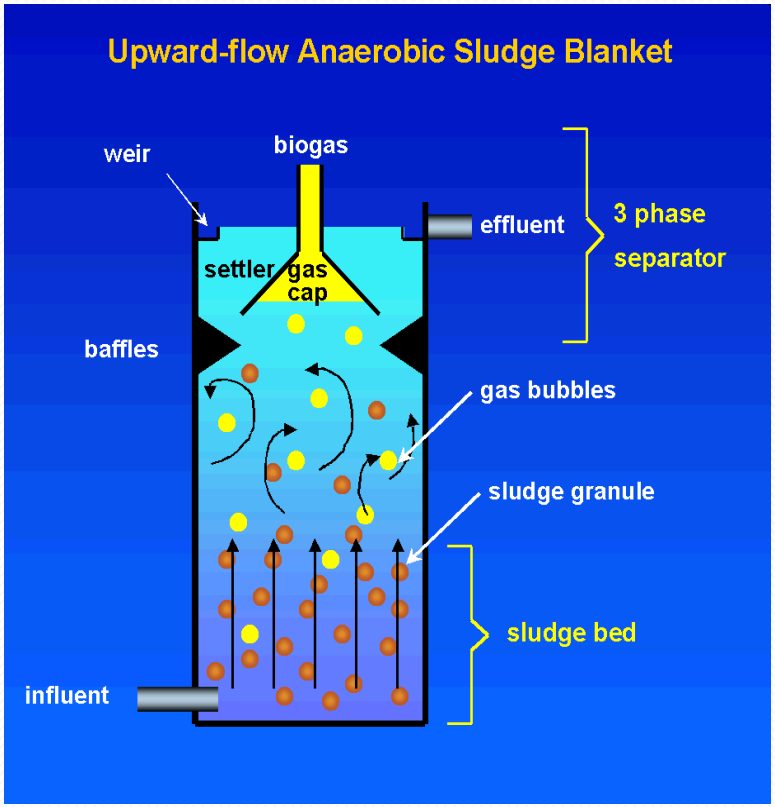
CSTR

- Continuously-Stirred Tank Reactor
- Simple but effective design



UASB

- Up-flow Anaerobic Sludge Blanket
- Frequently used for activated sludge digestion



“Bag” digester

- Low materials and infrastructure input
- Ideal for developing nations

Covered lagoon

- Plastic cover over new or existing manure lagoon
- Plumbing on and through cover captures biogas

“Egg-shaped” digester

- Shape optimized for footprint space, sludge accumulation, mixing, and heating
- Generally used for activated sludge digestion

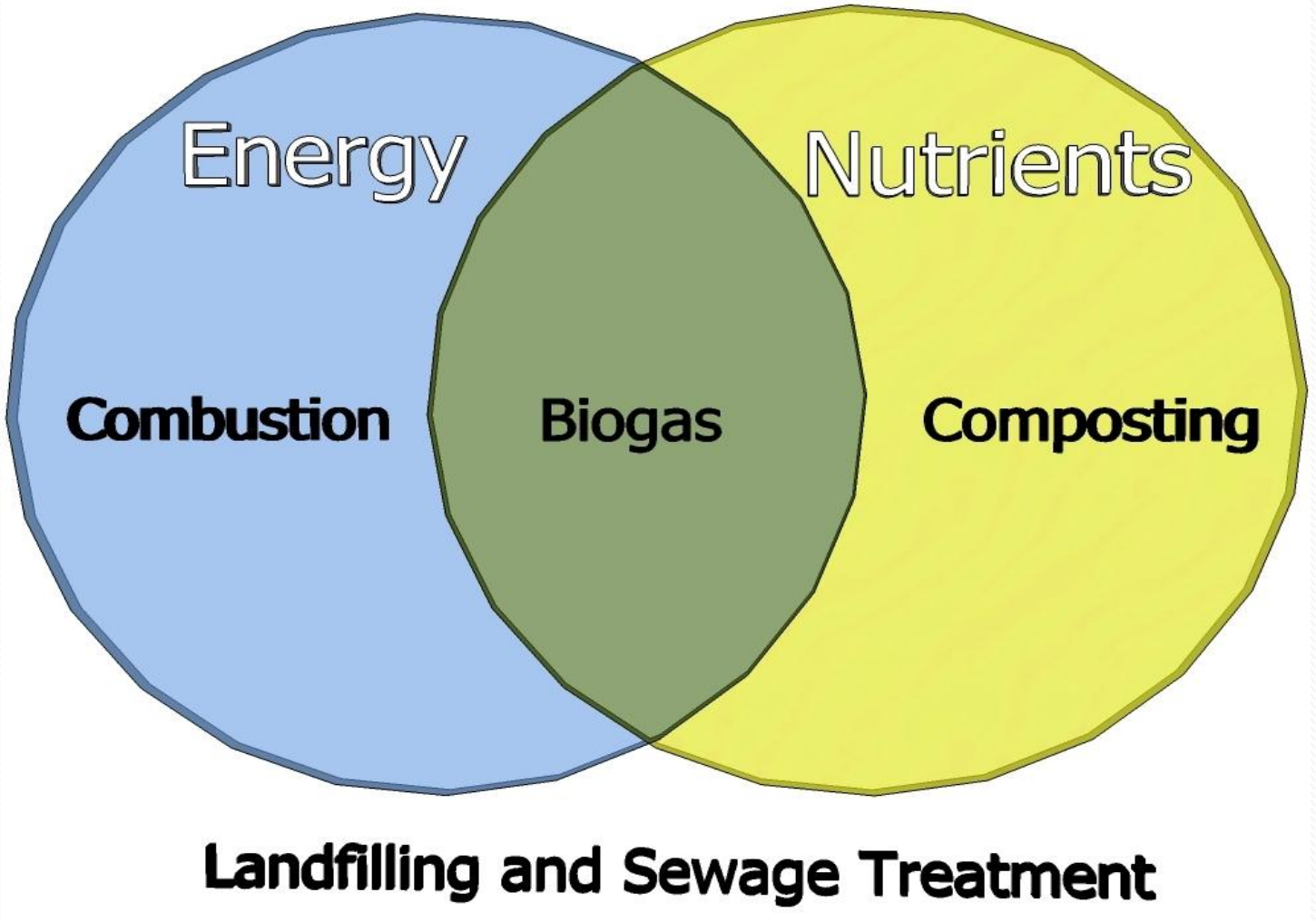
Fixed Film Reactor

- Increased substrate-bacteria contact
- Utilizes biofilms
- Short HRT
- Decreased size
- Used as DRU

Benefits of biogas

- Sustainable energy
- Sustainable nutrients
- Scalable and local
- Reduces pathogens
- Diverts waste from aerobic treatment plants and landfills

Benefits of Biogas



Sustainable energy

- Carbon neutral
  - Combats global warming
- Captures energy from waste
  - No need for energy crops
- Offsets fossil fuel use
  - Stretches energy reserves

Sustainable energy

- Uses of biogas
  - Cooking
  - Heating (water/air)
  - Electricity
  - Gas lighting
  - Vehicle fuel
  - Hydrogen fuel cells

Sustainable nutrients

- Effluent is a nutrient-rich organic fertilizer
- Nutrients mineralized for better plant availability
- Content depends on feedstock

  (e.g. high protein=high N)

Sustainable nutrients

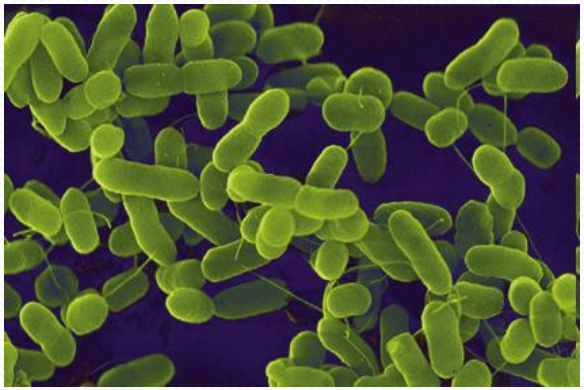
- Reduces use of synthetics
  - Synthetics= fossil fuel derived
- Reduces cost of organic fertilizer
- Increased organic production
- Keeps nutrients within productive cycle
- Reduces runoff/ eutrophication

Scalable and local

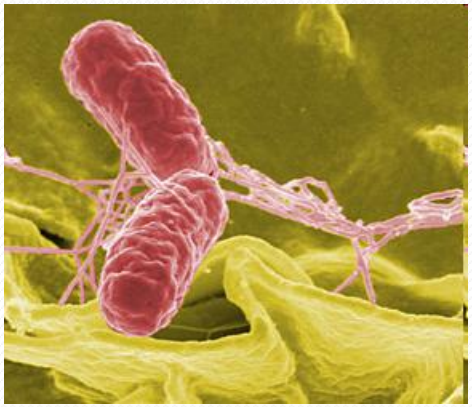
- Applicable to small farm or large city
- Biogas produced on-site or at centralized digester
- Sustainable energy in developing nations

Reduces pathogens

- Anaerobic bacteria out-compete pathogens
- Huge benefit for human waste and manure



Escherichia coli



Salmonella typhimurium

Diverting waste from aerobic treatment

- Problems with aerobic treatment
  - High aeration energy input
  - Loss of nutrients
  - Transportation of biosolids

Diverting waste from landfills

- Problems with organics in landfills
  - Take up space
  - Increased leachate problems
  - Release of methane
  - Lock-up nutrients
  - Cause odor and vermin problems
  - Transportation

Landfill gas vs. biogas

- Landfill gas
  - Slow, passive process
  - Gas contaminated with many pollutants
  - Transportation of waste to landfill
  - Feasible option for existing landfill

- Biogas
  - Fast, active process
  - Gas significantly cleaner
  - Energy AND nutrients
  - Can be produced throughout community
  - Saves landfill space

Questions?