Lecture 6: Digestion

Basics of digestion

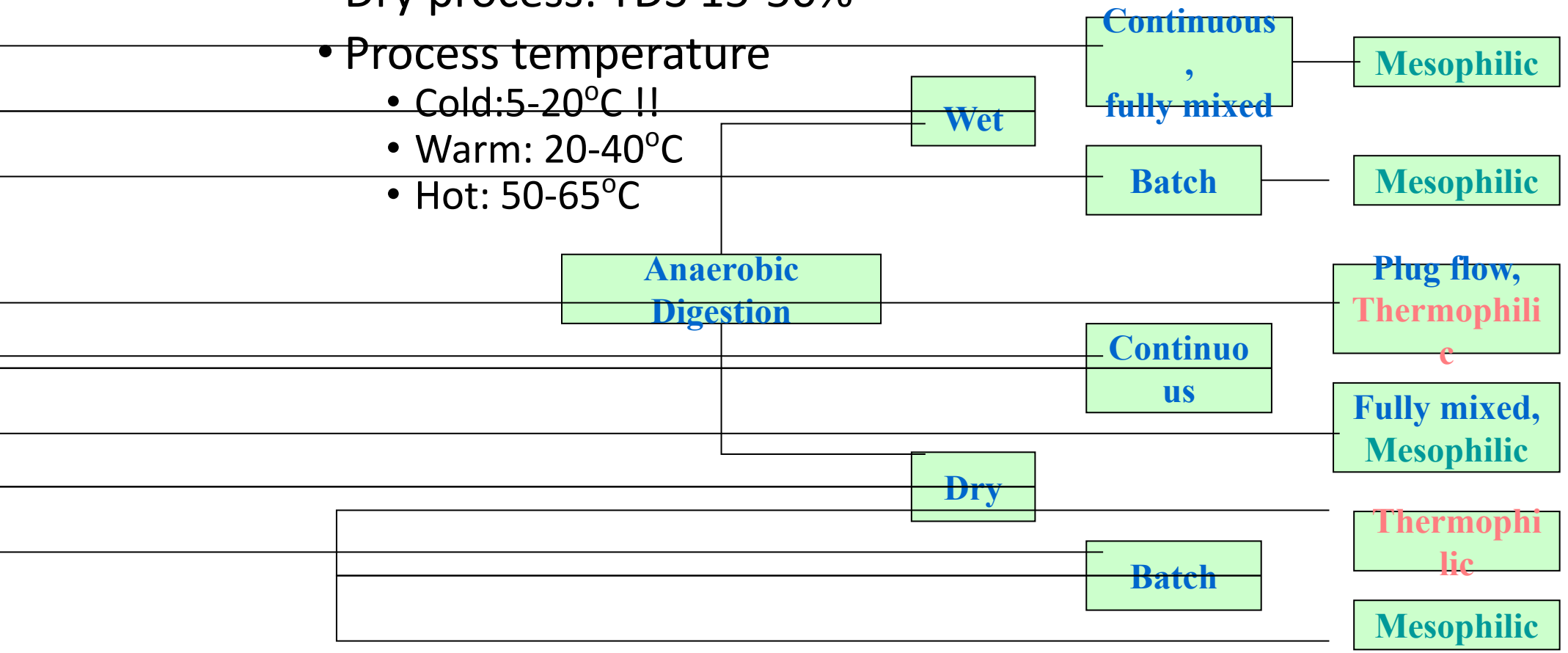
- **Treatment** for biological waste that cannot be disposed of at a landfill
  - 2006 biodegradable waste could be placed to landfills 75%
  - 2016 only 35%
    - other methods have to be developed

- **Digestion facilities in** Finland
  - Mainly at waste water plants for sludge treatment (~ 15 facilities)
  - A few facilities for municipal bio-waste treatment (Stormossen, Laihia)
  - A few industrial waste facilities
  - A few large facilities for farm waste (Close to Turku, Juva….)
  - Several facilities for farm waste treatment
  - The facilities in Finland produce over 25 mill. m^3 biogas
  - Biogas can be used for energy production or fuel for vehicles

- **Facility sizes** vary from private farm reactors (< 100 m^3) to Helsinki Water reactor (10 000 m^3)

Classification of anaerobic processes

- Wet process: total dry solids (TDS) 5 -15%
- Dry process: TDS 15-50%
- Process temperature
  - Cold:5-20°C !!
  - Warm: 20-40°C
  - Hot: 50-65°C



Digestion process

Biological reactions in the digestion are similar to those in anaerobic landfill

Hydrolysis: fermentative bacteria hydrolyze complicated organic compounds into soluble organics more available for the next stage

- Enzymes produced by hydrolytic bacteria decompose and liquefy carbohydrates, cellulose, proteins and fats
- Rate limited: decomposing the complex compounds like cellulose
- Rate governed by
  - Substrate availability
  - Bacterial population density
  - Temperature and pH

Acidogenesis (acidogenesis and acetogenesis): products of the hydrolysis are further processed by bacteria

- Main products: acetic, lactic and propionic acids
  - Acetic acid is produced from monomers
  - Volatile fatty acids (VFA) are produced from protein, fat and carbohydrate components
- Some gases (CO_2, H_2) and methanol are produced
- pH falls
- Products depend on feedstock, bacteria species and environmental conditions

Digestion process

Methanogenesis: methane - forming bacteria produces methane from the products of previous stage (HAc, MeOH, CO_2, H_2)

- Acetic acid + acetate → 75% of CH_4
  - $CH_3COOH \rightarrow CH_4 + CO_2$
- Methanol and hydrogen can be used, too
  - $CH_3OH + H_2 \rightarrow CH_4 + H_2O$
- Carbon dioxide and hydrogen produce methane, too
  - $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

- Converting volatile fatty acids into methane maintains higher pH
  - pH stays at 6,6 – 7,0 (mild acidic)
  - Problems arise if pH <6,4
  - Volatile fatty acids would be harmful for fertilizer use of the final product

Gas formation in anaerobic processes

See anaerobic processes in landfills for more detailed description

- **Phase I**
  - Atmospheric levels of N_2 and O_2
- **Phase II**
  - N_2 falls to 10%
  - Oxygen is depleted
  - Fatty acids and CO_2 formed
- **Phase III**
  - CO_2 falls to 40%
  - CH_4 rises to 60%
- **Phase IV**
  - Plateau: CO_2 40% and CH_4 60%
- **Phase V**
  - CO_2 and CH_4 production to ~0

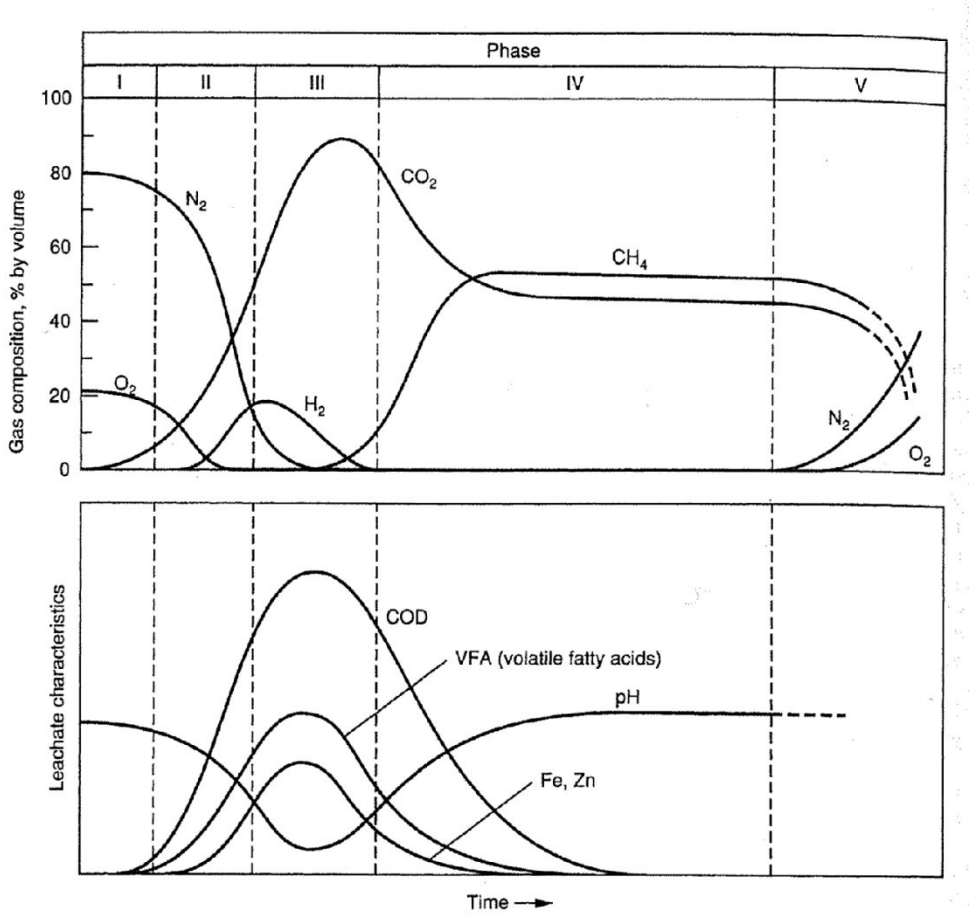


FIGURE 14.6 Generalized phases in the generation of landfill gases (I—Initial Adjustment, II—Transition Phase, III—Acid Phase, IV—Methane Fermentation, and V—Maturation Phase). *(Adapted from Farquhar and Rovers, 1973; Parker, 1983; Pohland, 1987; and Pohland, 1991.)*

Process variables

- Internal environment has to be optimal for fast reactions in reducing the volume of waste and producing biogas effeciently
- Physical conditions
  - Mixing
  - Temperature has to be relatively constant
    - Mesophilic (33-37 °C) more used in Finland
      - 21 days
    - Thermophilic (54 °C)
      - Faster: eg. 14 days
      - Destroys pathogenes better
  - Others: Retention period, wetness, feedstock characteristic, digester loading, bacterial population
- Chemical conditions
  - pH should stay relatively high
  - Alkalinity works as a buffer against acidity
  - Volatile fatty acids concentration affects pH