

Understanding Anaerobic Digestion

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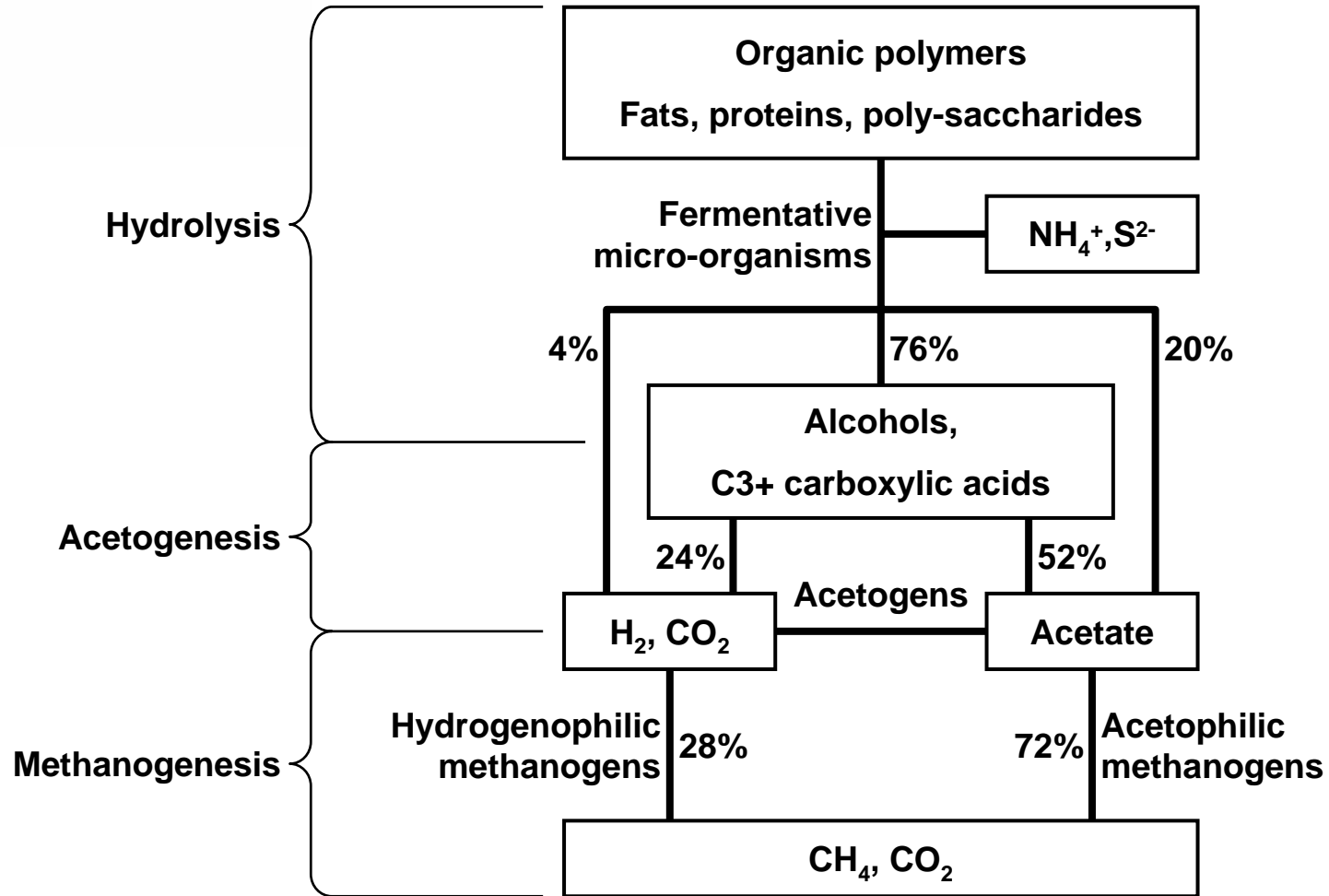


Fundamentals: Descriptions

- **To a Biologist**
 - Genetically diverse eco system
- **To a Civil Engineer**
 - Engineered environment
- **To a chemical engineer**
 - Heterogenous auto catalytic sequence parallel reaction system
 - Reactants in multiple phases typically more than 5
 - Reaction products are catalysts for the continuation of the process
 - Feedstock passes through a sequence of reactions in series
 - Inside a reactor all the reactions are going on at once
 - **Horrendously complex!!**



Fundamentals: Schematic model



Fundamentals: Issues

- **Methanogenesis**
 - Sensitive to both high (>8) and low (<6.5) pH
 - Activity virtually ceases below pH 6
 - Process fails if this becomes rate controlling step
- **Acidogenesis**
 - Rarely rate controlling step
 - Stable activity even below pH4
- **Hydrolysis**
 - Must be rate controlling step
 - Systems must be engineered to maintain this status
 - Catastrophic failure can occur when this ceases to be true
 - Systems vulnerable during turn-up
 - Increasingly vulnerable at higher digestion rates



Objectives

- **Product synthesis**
 - Bio-gas
 - Volatile fatty acids
 - Phosphate
 - Soil conditioner
- **Solids destruction**
- **Energy production**
- **Sanitisation/Pasteurisation**

- **Usually multiple**



Technologies: Wet or Dry

- **Wet**
 - Typically less than 10% solids in the reactor
 - Reasonably homogeneous mobile slurry
 - **Characteristic technologies**
 - Wastewater treatment plant digesters (MAnD)
- **Dry**
 - Typically greater than 20% solids
 - **Heterogeneous fixed bed of solids**
 - Solids “flushed” with liquid digestate
 - **Characteristic technologies**
 - In vessel anaerobic composting
 - Landfill (Flushing bio-reactor)



Technologies: Mesophillic (MAnD)

- **Most common technology**
- **Meso – middling $35 \pm 3^{\circ}\text{C}$**
- **Residence time greater than 10 days**
 - “Stability” issues at low residence time
- **Very large**
 - Continuous stirred tank reactors (CSTR)
 - Batch fed continuous reactors
- **Typically 97% (1.5log) destruction of pathogens**
 - More an issue of hydrodynamics than bio-kinetics



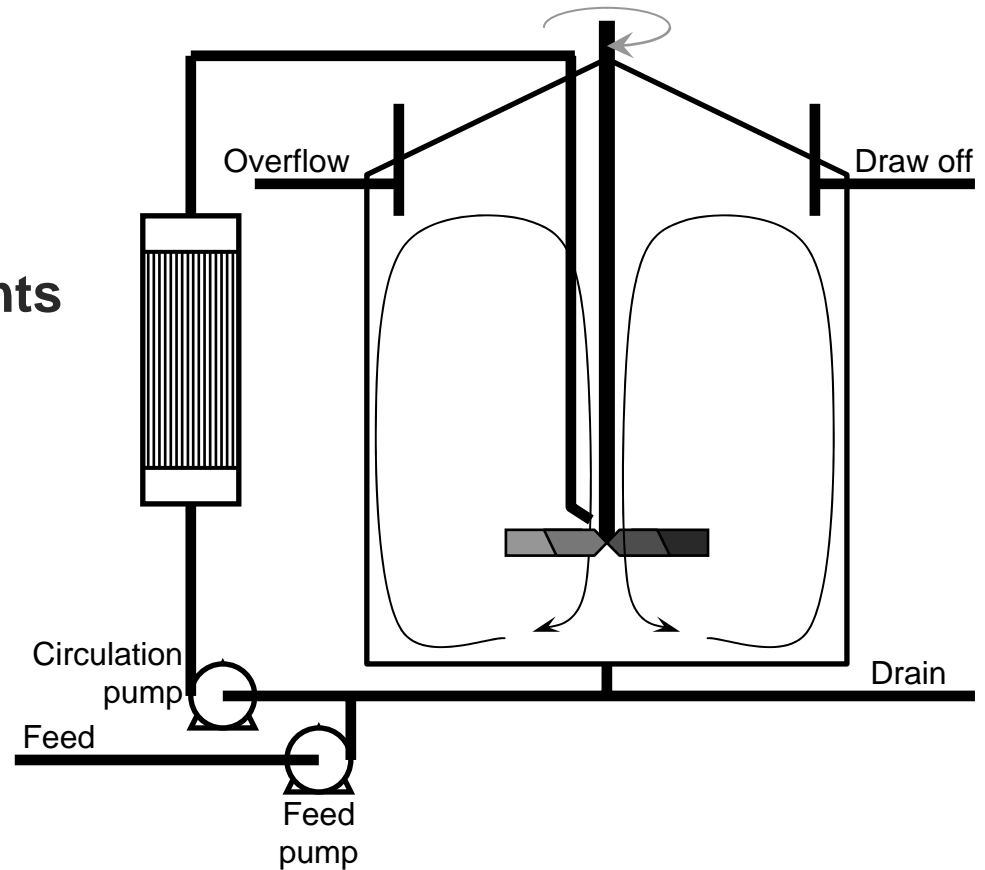
Technologies: Thermophilic (TAnD)

- **As yet uncommon**
- **Thermo – warm $55 \pm 5^\circ\text{C}$**
- **Residence time 5 – 10 days**
 - Fast dynamics may be confused with instability
- **Substantially smaller reactors – to date**
 - Usually batch fed
- **Typically 6log destruction of pathogens**
 - Consistent with reaction rate rules of thumb
- **Energy and odour management significant issues**



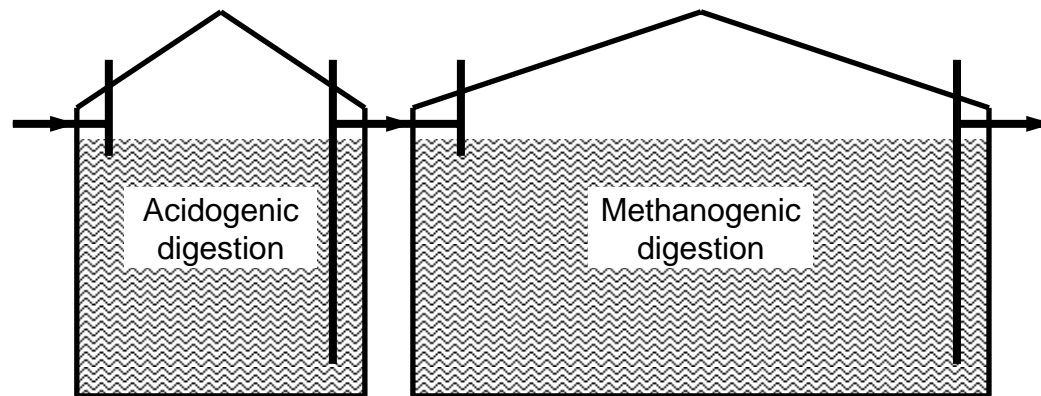
Technologies: Mixing

- **Good mixing is critical!**
- **What is “good mixing”?**
- **Blend feed material with reactor contents**
- **Homogenise reactor contents**
- **Eliminate bypassing**
- **Prevent sedimentation**
- **Tall order in 8000m³ tank**
- **Many subtleties**
- **Beware the snake oil salesman!**



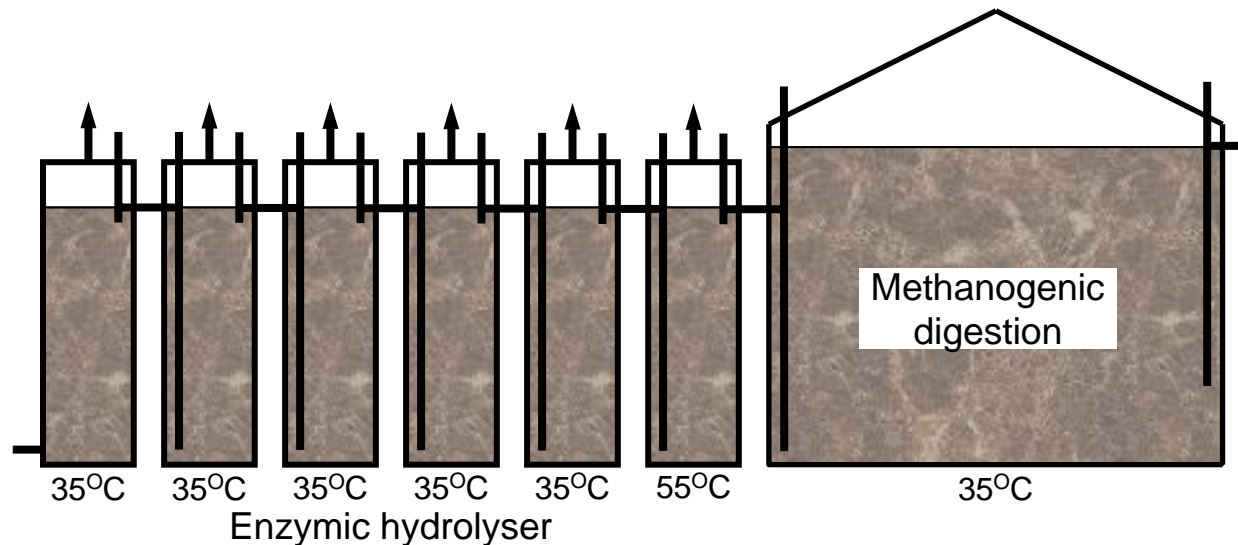
Technologies: Phased digestion

- **Better control**
 - If intermediate storage provided
- **Better pathogen destruction**
- **Greater reactor productivity**
 - Acidogenesis residence time approximately 2 days
 - Acids may be a useful product



Technologies: Hydrolysis

- **Enzymic hydrolysis (UU technology)**
- **Pathogen destruction $>6\log$**
- **Useful VFA solution ex-hydrolysis stages**
- **Hydrolysis residence time less than 5 days**



Conclusions

- **Does Anaerobic Digestion hold the key**
 - Not THE MASTER KEY
 - But an important key in a suite
- **Performance: 1- 5kg/(m³d)**
 - Could do better
 - Must do better to become a practical technology for BMW
10 – 100kg/(m³d)
- **Integration**
 - **Product utilisation**
 - Other bio and/or chemical processes
 - **Energy**
- **Products**
 - **Not just bio-gas**

