March 18-19, 2015

Anaerobic MBR: Challenges & Opportunities

Symposium:
Hydrogen, Hydrocarbons, and Bioproduct Precursors from Wastewaters
National Renewable Energy Laboratory
Washington, DC

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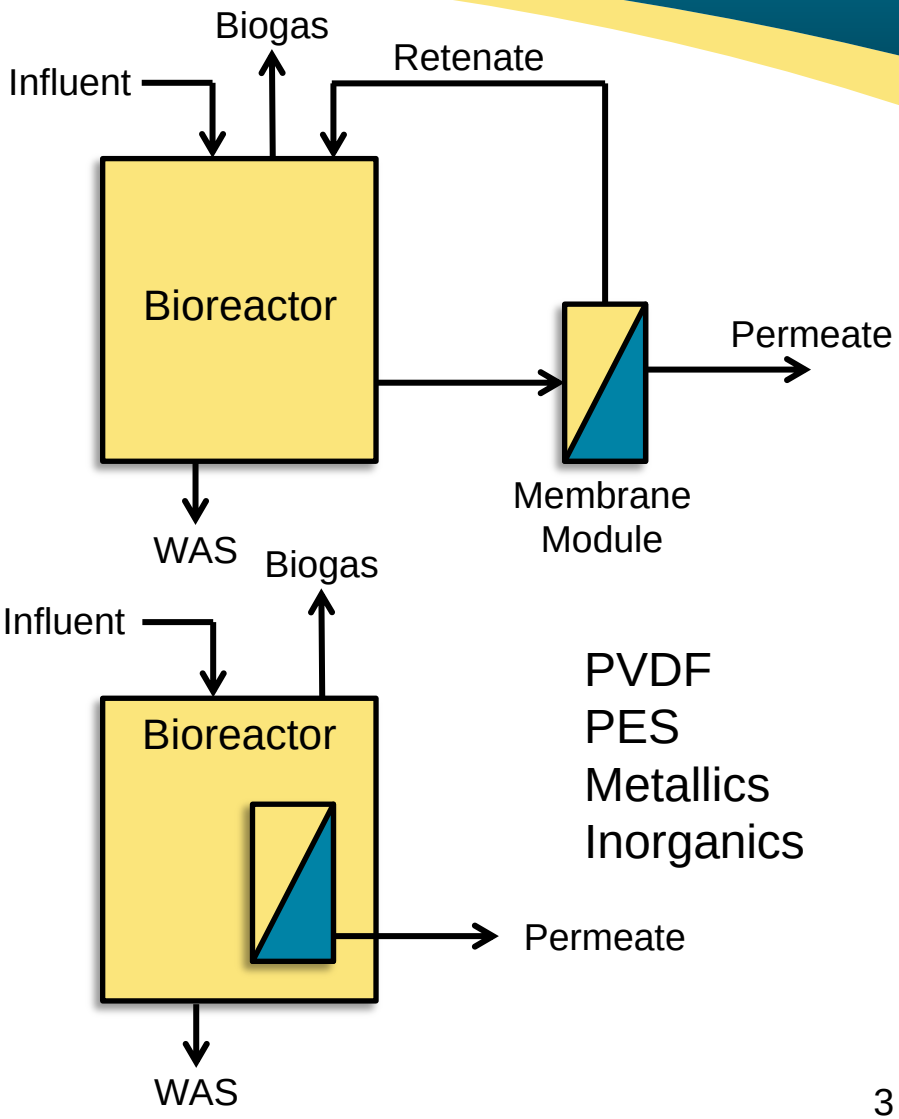
Outline

- Challenge for Municipal Wastewater
- Membrane Fouling
- Energy Potential
- System Economics
- Research Needs

Challenges: Municipal Wastewater Treatment Using AnMBR

- Low temperatures in municipal wastewaters
- Low strength municipal wastewaters
- Bioreactors must be heated
- Long SRTs are required
- Post-treatment is required for direct discharge
- High SO4 reduces methane production
- Methane solubility at low temperatures limits recovery
- GHG emissions

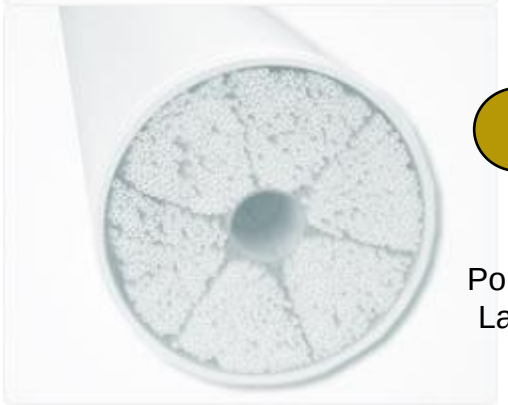


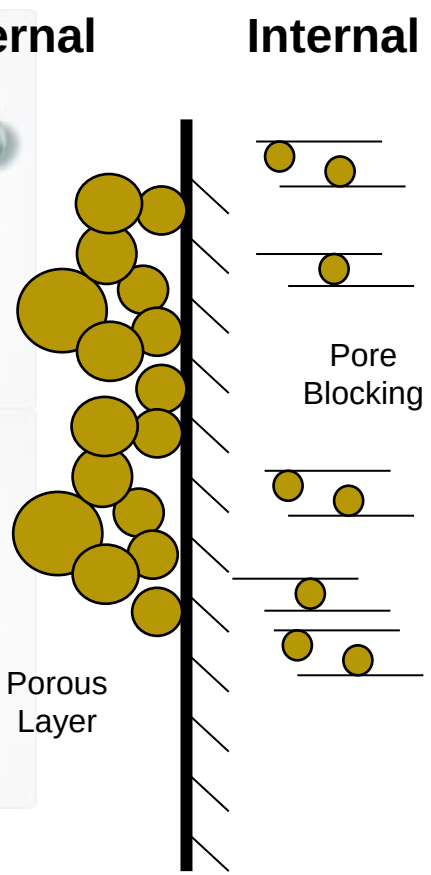
Challenges: Municipal Wastewater Treatment Using AnMBR

- Limited Development Realized Since Early 2000s
  - Anaerobic processes are complex
  - Methanogens highly sensitive to wastewater toxicity
  - Difficulty in managing variable conditions
  - Membrane fouling
  - Relatively low flux
- Necessity of Operating at Ambient Temperatures
  - Low organic strength → low methane production
  - Low methane production → limited heating potential
  - Long SRTs → increases membrane fouling

Challenges with Membrane Fouling

- Internal fouling generally irreversible
- External fouling generally reversible
- Internal deposits generally more inorganic
- Long SRT operation promotes internal pore blocking
- Fouling → higher costs & membrane replacement





Suspended biomass, colloidal solids, SMP, EPS, Attached cells, inorganics (e.g., struvite)

Fouling Control Methods

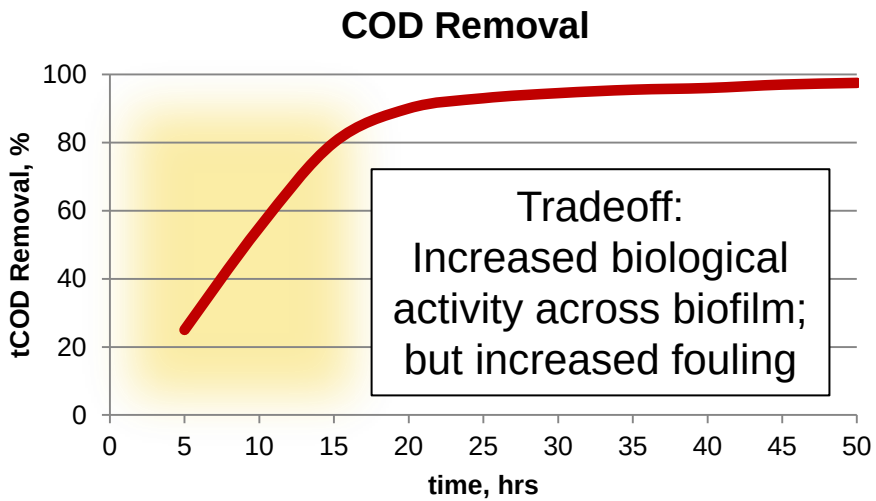
- Biogas sparging
- Backflushing
- Periodic membrane relaxation
- PAC/GAC addition
- Combinations

Operational/Performance Considerations

- OLR: >10 kg COD/m3/d
- HRT: ~ 8-12 hours
- Sustainable flux rate:

< 15 LMH

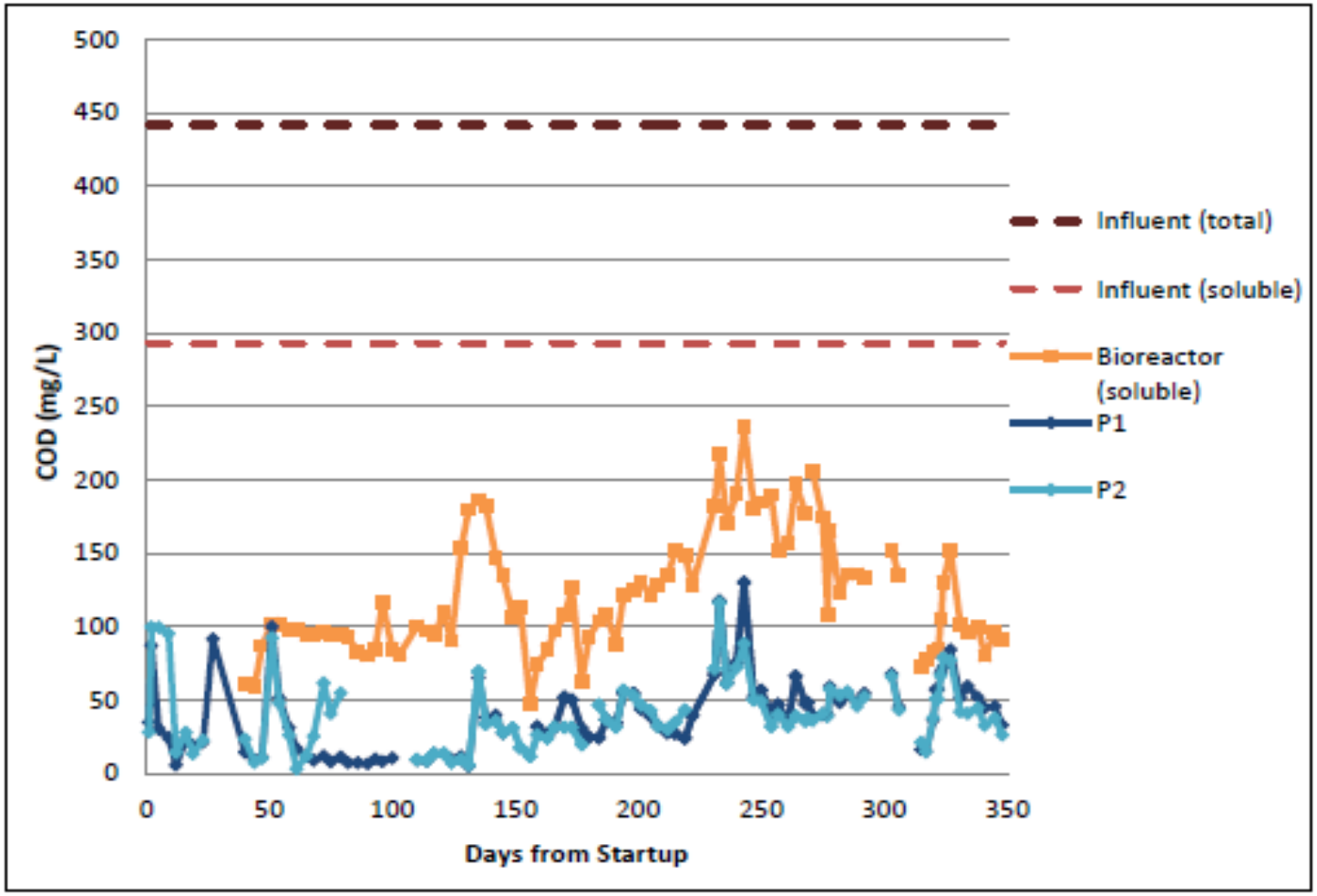
- Temperature
- Methane solubility



Adapted from: Smith, et al. Bioresource Technology 122 (2012)

- >85% COD removal
- >99% TSS removal
- TN and TP removals negligible
- Effluent COD/N & COD/P unfavorable for downstream BNR

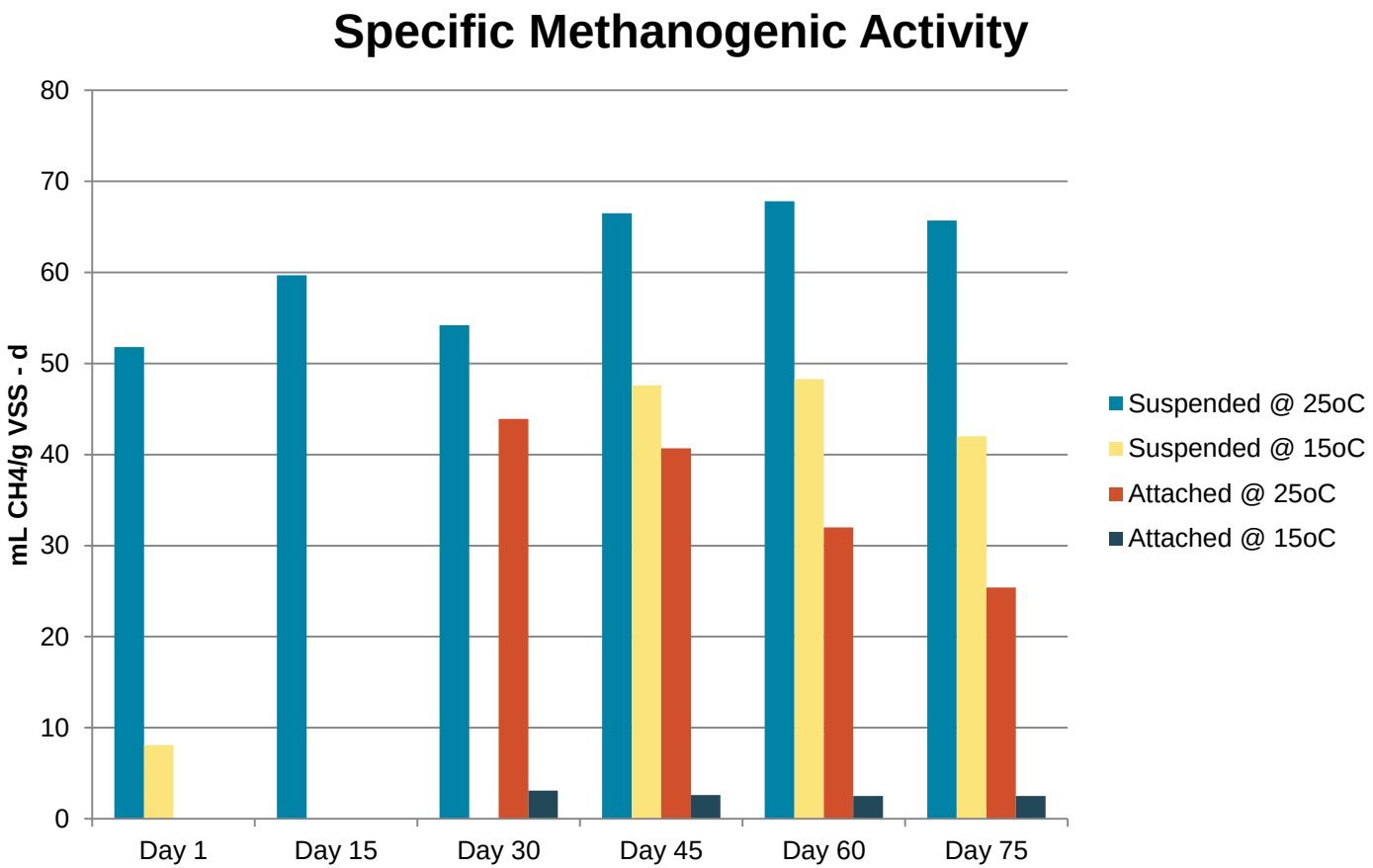
AnMBR Performance – COD Removal



Source: U4R08 WERF; Raskin, et al. (2012)

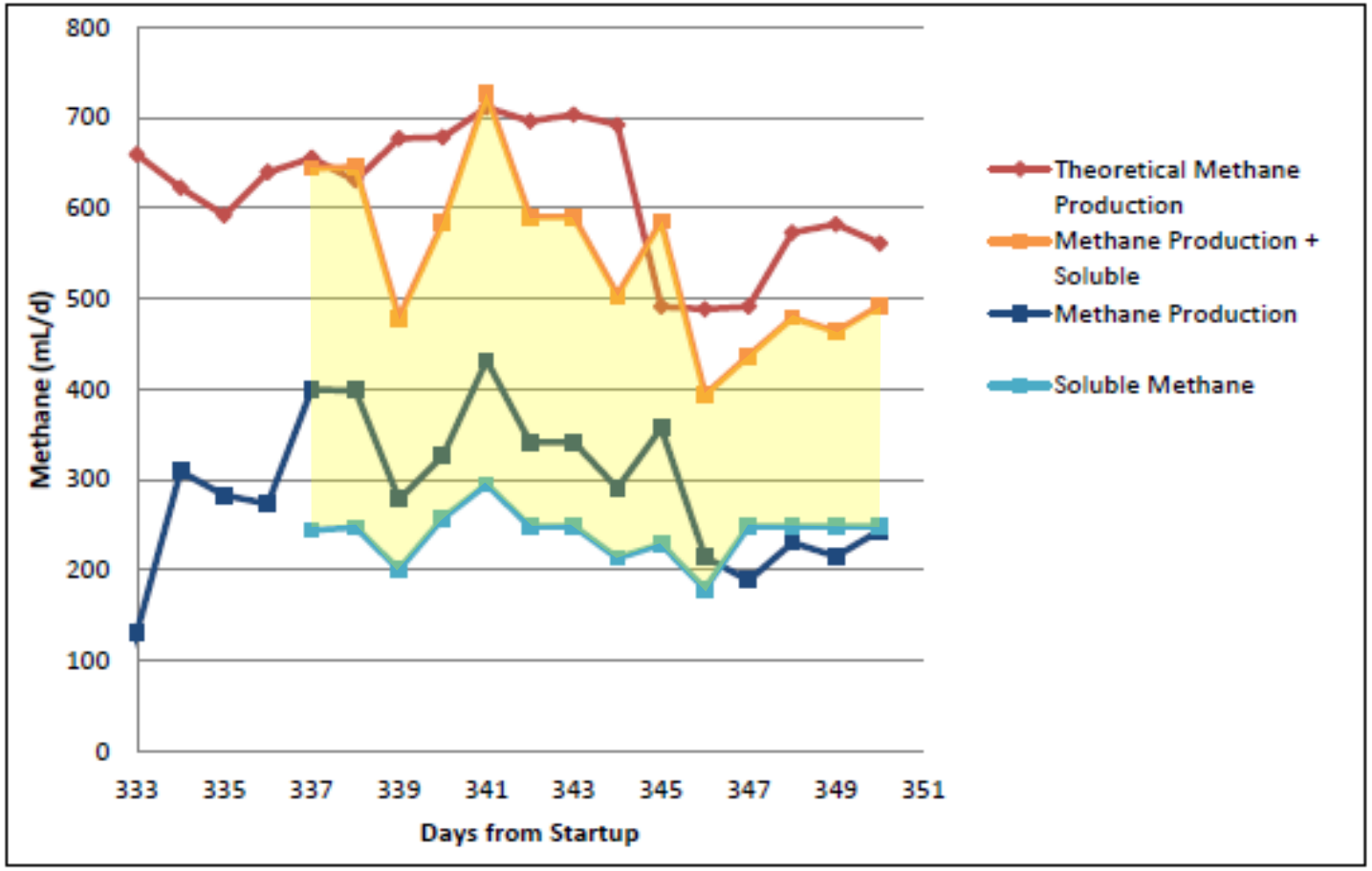
Methane Production Potential

- Colder reactor temperatures result in lower methane production



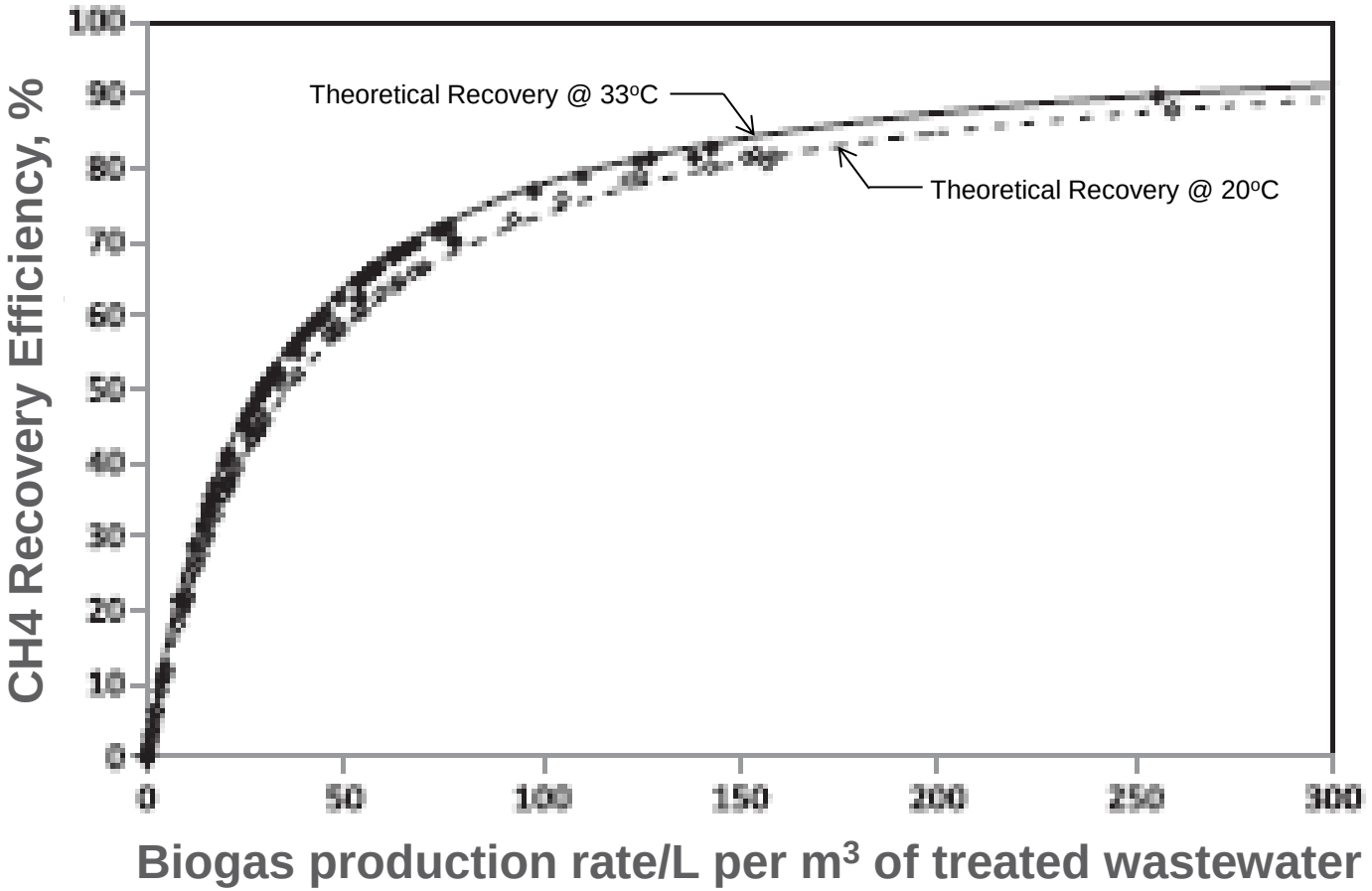
Adapted from: Ho and Sung, Bioresource Technology 101 (2010)

Methane Production Potential



Source: U4R08 WERF; Raskin, et al. (2012)

Methane Production Potential

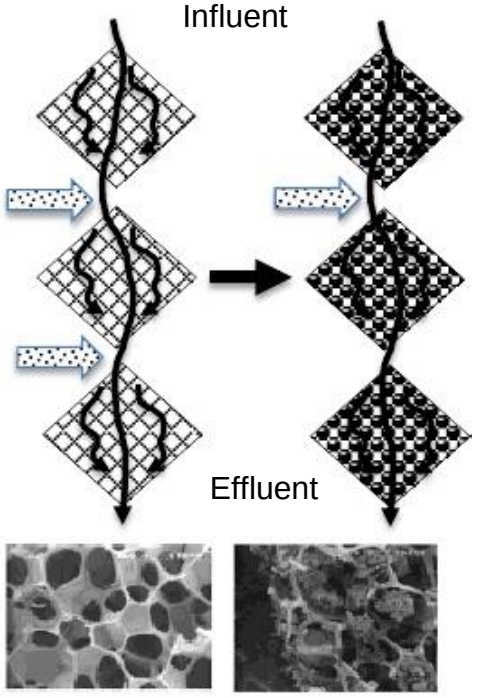


Source: Gimenez, et al. Bioresource Technology; 118 (2012)

Methane Solubility Creates a Challenge

- CH_4 ~ 1.5x more soluble at 15°C than at 35°C
- Dissolved CH_4 leaving process in permeate is significant fraction to total CH_4 generated
- Permeate concentration tends to be oversaturated
- Impact on GHGs

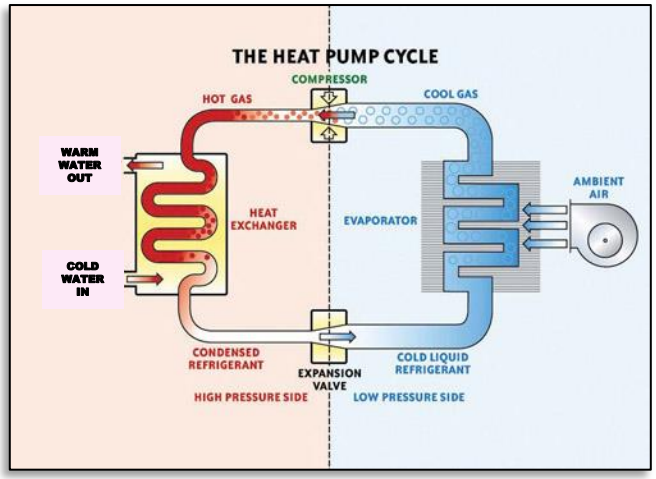
- Post-treatment stripping
- Degassing membrane
- Downflow Hanging Sponge reactor

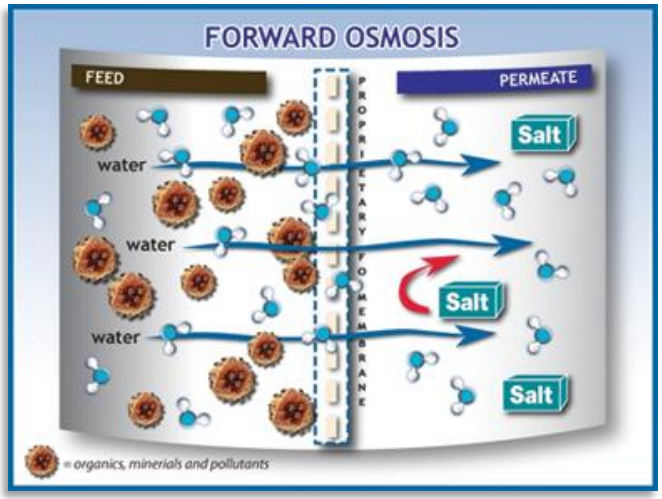


Adapted from Uemura and Harada, (2010)

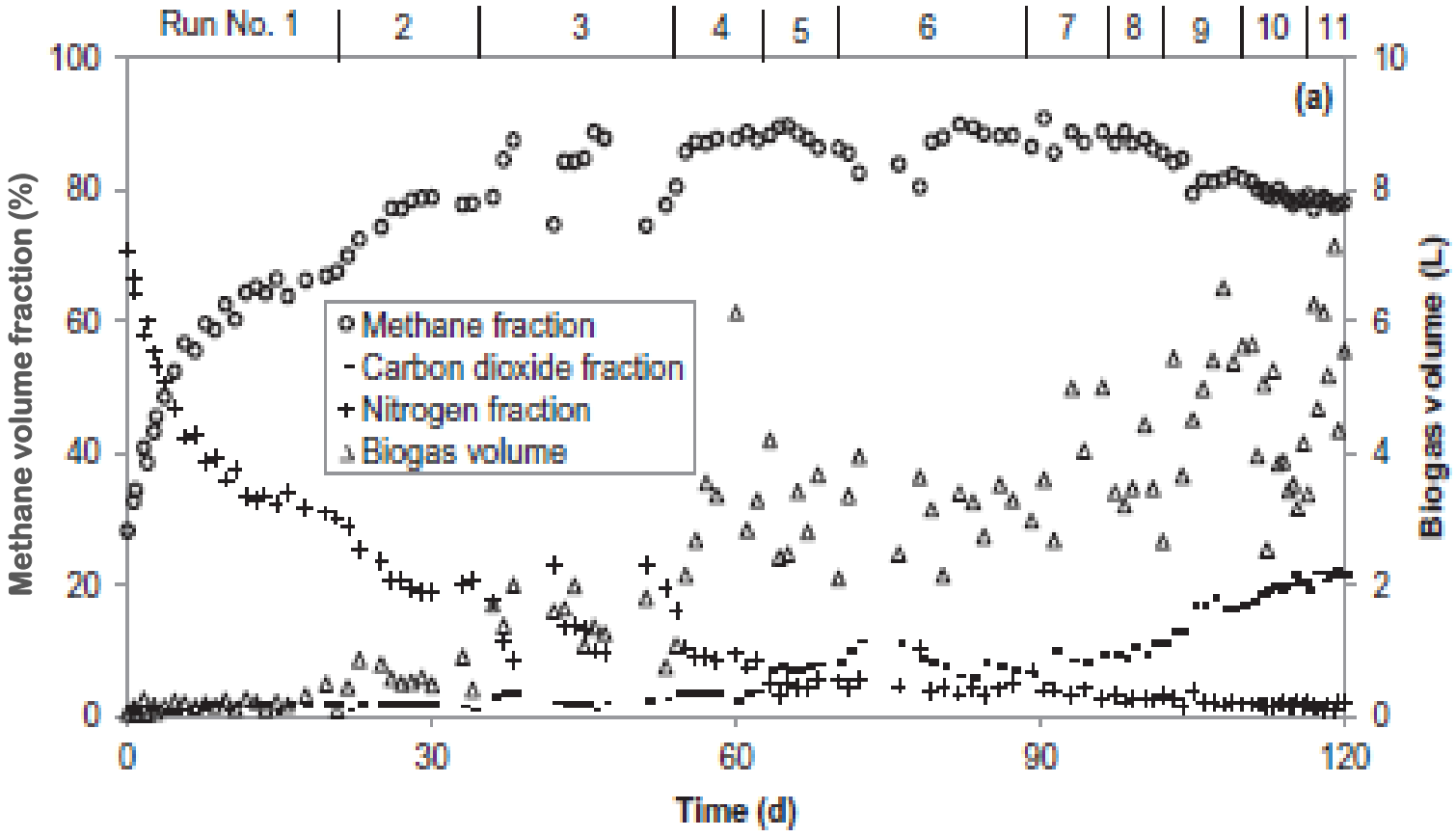
Implications for Energy Recovery

- Production is function of:
  - Temperature
  - Loading rate
  - Operating condition
  - Influent pre-treatment
  - Influent pre-heating
- 110-320 mL CH_4/g COD removed
- Net energy recovery achievable at 9.5 g COD/L or higher





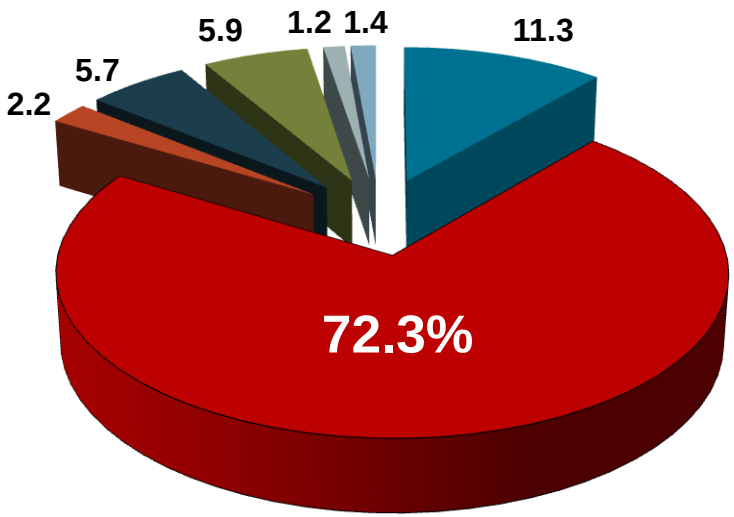
Methane Production



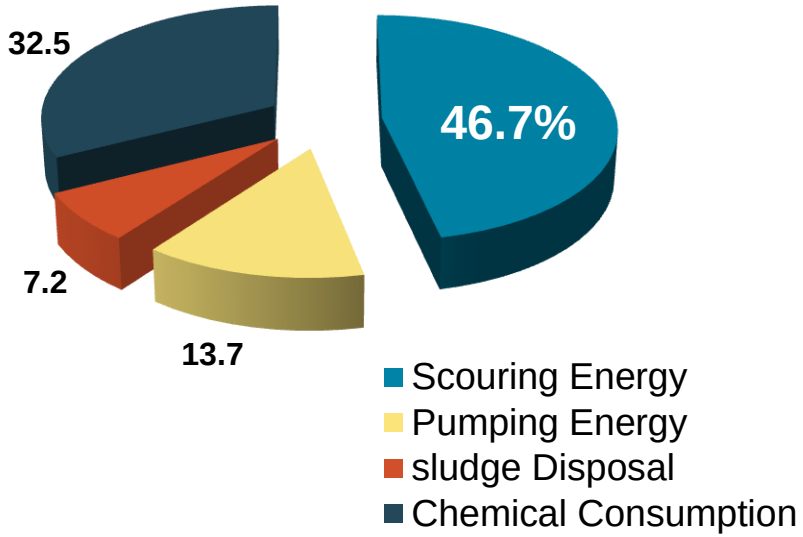
Source: Wei, et. al; Bioresource Technology 166 (2014)

Economic Overview

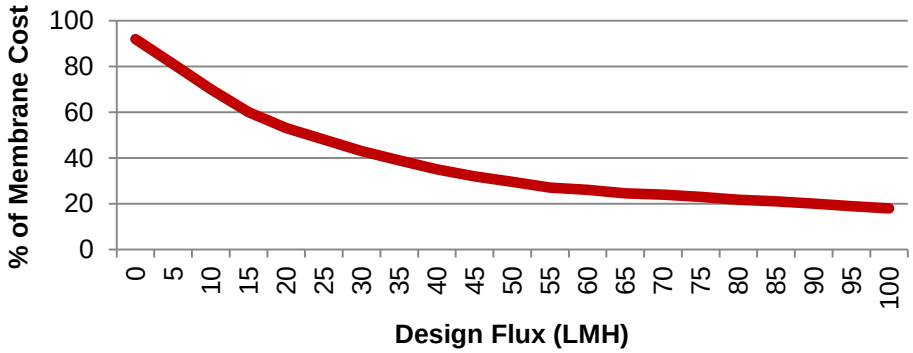
Capital Cost Elements



Operational Cost Elements



Flux Influence on Cost



Adapted from: Lin, et. al; Desalination 280 (2011)

Research Needs for AnMBRs

- Membrane fouling, particularly with low-strength wastewaters
- Consumption and optimization of energy
- Relationship between HRT, SRT, performance and fouling
- Methane solubility at low temperatures.
- Operation at low and high temperatures
- Effects of microbial seeding
- Nutrient removal systems
- Comprehensive effects of OLR on methane production
- Pre-treatment effects

Summary

- AnMBR Remains Challenging for Municipal
- Membrane Fouling Solutions are Elusive
- Significant Impediment is Nutrient Removal
- Methane Solubility a Challenge for Recovery
- Membranes Remain Primary Capital Cost
- Scouring Energy Primary Operational Cost
- Research Opportunities Remain High

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