Anaerobic Digester Microbial Community, Metadata, and Outcomes

Alison Ling, Barr Engineering
in collaboration with Microbe Detectives
Can we give operators more tools to troubleshoot digesters, especially with regard to methane production?
Microbiome and Reactor Performance

- Digester Design
- Digester Operation
- Digester Microbiome
- Digester Performance Outcomes
Outline

• Intro to Digester Microbiology
• Study Objectives
• Study Approach and Some Findings
• Future Steps and Use of Results
A diverse microbial community is needed to support methanogenesis.

Feedstocks (WAS, primary sludge, high-strength wastes)

CH₄, CO₂, and Water
Microbe Meet and Greet: Hydrolyzers

Feedstocks (WAS, primary sludge, high-strength wastes)

Complex Organics

Hydrolyzers
Microbe Meet and Greet: Acidogens and Acetogens
Microbe Meet and Greet: Methanogens

Methanogens

- Hydrogen
- Organic acids

CH₄, CO₂, and Water
Microbiome

Digester Design
- SRT
- Reactor type
- Mesophilic/thermophilic

Digester Operation
- Operating pH and temp
- Feedstocks
- COD and nutrient loading
- Chemical additions
- VFA:Alkalinity
- Mixing

Digester Microbiome
Microbiome and Reactor Performance

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Digester Microbiome

What is important here?

Digester Performance Outcomes
- Biogas production
- COD removal
- VSS destruction
- Other operational issues
Objectives

• Help operators improve operations
  – Optimize methane production
  – Minimize downtime
• Inform full-scale design
21 digesters, 60 samples

Sample for microbial community
- 16S rRNA gene sequencing by Illumina MiSeq, QIIME

Collect operations, design, and performance data
Measurable: Who they are related to

- Taxonomical (ancestry) classification

*Results do not definitively indicate metabolic group*
Measurable: Who they are related to
• Taxonomical (ancestry) classification

*Results do not definitively indicate metabolic group
Methods

Measurable: Who they are related to

- Taxonomical (ancestry) classification

*Results do not definitively indicate metabolic group

Hydrolyzers, Acidogens
Measurable: Who they are related to
- Taxonomical (ancestry) classification

*Results do not definitively indicate metabolic group*
Measurable: Who they are related to
- Taxonomical (ancestry) classification

*Results do not definitively indicate metabolic group*
Interest: What they do

- Methanogens
- Hydrolyzers
- Acidogens and Acetogens
- Methanogens
Digester Microbiome

Bacteria

Hydrolyzers

Acidogens and Acetogens

Archaea

Methanogens
Findings

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What is important here?

Digester Microbiome

Digester Performance Outcomes
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Findings – Archaea and Methane

All Digesters

Percent CH4

Percent Archaea
Findings

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Digester Microbiome

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What is important here?
Findings – Community Groupings
Findings – Community Groupings
Municipal more diverse

Diversity and Industry

Shannon's Evenness Index

Species Observed

- Municipal
- Industry
Findings

Digester Design
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Digester Microbiome

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What is important here?
Findings – Archaea and Digester Type
Findings

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What is important here?
• Thermophilic reactors have higher methane production and archaea
Findings

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What is important here?
• Directly correlates to methane production
Findings

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What is important here?
Micronutrient Addition

Correlates to more archaea . . . but less diversity
Key Performance Indices

- Methane Potential KPI
  - Based on methanogen abundance
- Community Stability and Diversity KPI
  - Based on community diversity and similarity to reactor baseline
- Odor KPI
  - Based on abundance of sulfate-reducing bacteria
Future – Use of Results

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Digester Microbiome
- Bio-methane KPI
- Bio-stability KPI
- Bio-odor KPI

Digester Performance Outcomes
- Biogas production
- COD removal
- VSS destruction

Provide additional performance metrics
Example Key Performance Indicators (KPIs) From Study

Bio-methane KPI

Bio-stability KPI
Future – Use of Results

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Digester Microbiome
- Bio-methane KPI
- Bio-stability KPI
- Bio-odor KPI

Digester Performance Outcomes
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Provide additional performance metrics

Requires accurate and continuous monitoring of operating conditions
• Including
  – Community groupings and relationships to operations and performance parameters
  – Correlations between operations and microbiome
  – Correlations between microbiome and digester performance
  – Description of KPI and how they are derived
Performance Dashboard
Bio-Methane KPI Example

Week or Month

<table>
<thead>
<tr>
<th>Week</th>
<th>Methanobacterium</th>
<th>Methanosarcinales</th>
<th>Methanothermobacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.50%</td>
<td>2.10%</td>
<td>0.00%</td>
</tr>
<tr>
<td>2</td>
<td>0.80%</td>
<td>1.70%</td>
<td>0.00%</td>
</tr>
<tr>
<td>3</td>
<td>0.40%</td>
<td>1.10%</td>
<td>0.00%</td>
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</tbody>
</table>

% Prevalence of Methanogens
Performance Dashboard
Bio-Diversity KPI Example

Week or Month

<table>
<thead>
<tr>
<th>Week</th>
<th>Bio-Diversity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.8</td>
</tr>
<tr>
<td>2</td>
<td>3.7</td>
</tr>
<tr>
<td>3</td>
<td>3.8</td>
</tr>
</tbody>
</table>
## Performance Dashboard
### AD Output Example

<table>
<thead>
<tr>
<th>Week or Month</th>
<th>CH4 Production</th>
<th>COD Removal</th>
<th>VSS Destruction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normalized KPI</td>
<td>Efficiency KPI</td>
<td>Efficiency KPI</td>
</tr>
<tr>
<td>1</td>
<td>0.60</td>
<td>73%</td>
<td>78%</td>
</tr>
<tr>
<td>2</td>
<td>0.58</td>
<td>69%</td>
<td>73%</td>
</tr>
<tr>
<td>3</td>
<td>0.64</td>
<td>71%</td>
<td>74%</td>
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Performance Dashboard Example

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Bio-Odor KPI Planned
Future Work

• Additional data from more digesters
• Further develop KPIs
• Work with operators to implement lessons learned