Anaerobic digestion – opportunities to optimize and enhance digestion

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Looking to get more out of your digester(s) can take many forms.
In a fixed volume digester the rate of digestion is a means of enhancing digester performance and increasing capacity
Example: conversion from conventional mesophilic digestion to temperature phased AD
You don’t always have to move to a new process to get more from your system.

![Graph showing Volatile Solids Destruction vs Retention Time with four lines representing advanced digestion, optimized mesophilic digestion, and sub-optimal mesophilic digestion.]
Some changes in your operation can improve the overall performance and stability

- Digester Mixing
- Tank Sequencing
- Digester Feed
- Process Stress Testing
- Sludge Withdrawal
- Sludge Pretreatment
- Operating Temperature
- Supplemental Feedstock
- Micro-nutrients
How hot is too hot?- Temperature Considerations
Digester Operating Temperature

• What is best?
  • Reference Manuals
  • Grady, Diagger, Lim (1999) mesophilic (77-104°F), thermophilic (122 -140 °F)
  • Metcalf and Eddy (2003) mesophilic (77-104°F), thermophilic (122 -134°F)
  • WEF MOP 8 – maintain temperatures +/- 1 °C of target at all times

USEPA 1979 indicates avoiding range between 104 to 122 °F
Temperature instability can lead to process deterioration and instability

Fig. 1. Process performance during step-wise temperature increase in operational temperature (Reactor A) during the anaerobic digestion of a mixture of primary- and activated-sludge: (a) Biogas production in mL of biogas produced per day, (b) Biogas composition in % of methane in biogas, (c) VFA concentration in mM. ■—acetate, ▲—propionate, ■—iso-butyrate, ◊—butyrate; ◇—iso-valerate, ◇—valerate.

Many of known methanogens are optimal in mesophilic conditions

Operating temperature can also impact toxicity levels in the digester (ex. Ammonia)

- Increasing temperature decreases the pKa which increases the unionized ammonia concentration

\[ \text{NH}_4^+ \rightleftharpoons \text{NH}_3 + H^+ \]

Process Considerations
- Thermal hydrolysis (high solids)
- Thermophilic digestion
- Co-digestion of high nitrogen content wastes (ex. blood wastes)
- High solids digestion process
Considerations for variable temperature operations

- Increase heating or heat transfer capacity
  - New boilers or heat exchangers, etc.
- Increase heat loop temperature
  - Avoid cooking sludge on walls
- Increase feed solids thickness
  - Reduces sludge heating demands
  - Need to evaluate impacts of changed sludge rheology on your system (pumping and heat exchange)
  - Consider additional capacity and performance benefits

New HEX at Rockland, MA WWTP

Tuning HEX for Tacoma’s dual digestion process (ATAD-TPAD)
Surface Wasting: Get that low specific gravity sludge out of my digester!
Some wasting configurations may trap low specific gravity sludge. Why should I care?
For some Tanks, the “Fix” is easy and **FREE**
For some Tanks, the “Fix” is easy and **FREE**
Solution at Owls Head
Owls Head Conversion Performance

Cautioned that **surface wasting** was **NOT** the only digester enhancement
Owls Head Conversion Performance
Research in to factors impacting digester efficiency. The future of optimization?
Synergistic digestion- artifact or reality

- Original observations came from Millbrae, CA with introduction of FOG,
- Aichinger (2015) – noted reduction in sludge production with organic waste addition up to 20 percent of VS load
- Hypothesis is that the carbon to nitrogen ratio is improved making the process more effective.

Fig. 4. Specific biogas production, cake production and ammonia return load based on co-substrate addition for Zirl WWTP and Strass WWTP.

Citation: Aichinger et al (2015). Synergistic co-digestion of solid-organic-waste and municipal sewage-sludge: 1 plus 1 equals more than 2 in terms of biogas and solids reduction” Water Research, 87, 2015, 416-423.
Is synergy a C:N issue, or is it more complex?

• Zitomer (2008) – noted enhanced methane production with the digestion of yeast waste with sewage sludge, 4-18 percent additional COD destruction needed to balance.

• Attributed the improved digestion to supplemental nutrients and co-factors in yeast from production process

• Produced more gas than is theoretically possible without digestion of the sludge

Table 3—BMP results.

<table>
<thead>
<tr>
<th>Waste</th>
<th>Concentration range tested (g COD/L)</th>
<th>BMP (mL CH₄/g COD)</th>
<th>Biogas methane (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADF</td>
<td>0.50 to 2.2ᵃ</td>
<td>350 ± 30</td>
<td>61 ± 15</td>
</tr>
<tr>
<td>Yeast production</td>
<td>0.50 to 2.5</td>
<td>2270 ± 340ᵇ</td>
<td>60 ± 3</td>
</tr>
<tr>
<td>Food flavorings production</td>
<td>0.05 to 0.25</td>
<td>940 ± 450ᵇ</td>
<td>69 ± 1</td>
</tr>
<tr>
<td>Restaurant</td>
<td>0.60 to 12</td>
<td>490 ± 260</td>
<td>68 ± 2</td>
</tr>
<tr>
<td>Brewery</td>
<td>0.50 to 2.5</td>
<td>410 ± 20</td>
<td>58 ± 6</td>
</tr>
</tbody>
</table>

ᵃ Higher concentrations caused inhibition and lower BMP values (Zitomer et al., 2001).
ᵇ Suspect value that is significantly greater than the theoretical maximum of 400 mL CH₄/g COD.

Iron addition enhances TPAD operation in laboratory study. Is the assumption micronutrients are not an issue for muni AD correct?

- Speece identified a cocktail of trace metals can stimulate digestion.

- Hao et al (2017)- investigated adding waste iron shavings to acid and gas phases of an acid gas system
  - Analysis based on waste activated sludge digestion
  - Observed strongest stimulatory effect when added to the methane phase.
  - Methanogens in acid phase enhanced with the addition of WIS

**Fig. 3.** VSS removal ratios in the main experiments.

**Citation:** Hao et al (2017), “Analyzing the mechanisms of sludge digestion enhanced by iron” Water Research, 117, 2015, 58-67.
Population dynamics with process changes

- Mah (2017) looked at population profiles of mesophilic and THP enhanced digestion.
- Showed distinct population shifts between the processes.
- Others have suggested THP increases hydrogen utilizing methanogenesis.
- TPAD shows different population profiles depending on operating conditions.
- **Research Question**: Is there a distinct population profile that equates to optimized digestion operation for each process?

**Figure 4: NMDS Plot of Bray-Curtis Dissimilarity Metrics**

Citation: Mah et al (2017), Proceedings of the WEF Residuals and Biosolids Conference 2017, Seattle, WA
QUESTIONS?

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