Performance Optimization with Co-Feeds

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WWRFs can benefit by anaerobically digesting other organic materials

FACTS!

• More organic waste is becoming available due to organic waste bans
• Feed-in tariffs can be attractive for bio-based electricity
• More Co-Feeds = More biogas + tipping fees !!! = untapped revenues

<table>
<thead>
<tr>
<th>Feedstocks</th>
<th>TS (%)</th>
<th>VS (%)</th>
<th>Tip Fee (typ)</th>
<th>$/load (avg)</th>
<th>relative BMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sludge</td>
<td>5%</td>
<td>78%</td>
<td>n/a</td>
<td>n/a</td>
<td>1</td>
</tr>
<tr>
<td>Generic Food</td>
<td>13%</td>
<td>92%</td>
<td>$20-$50/ton</td>
<td>$600 - $800</td>
<td>2.2</td>
</tr>
<tr>
<td>FOG</td>
<td>4%</td>
<td>90%</td>
<td>10₵/gal</td>
<td>$1,000</td>
<td>2.0</td>
</tr>
<tr>
<td>Dairy Processing</td>
<td>10%</td>
<td>70%</td>
<td>3₵ - 8₵/gal</td>
<td>$500-$600</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Relative BMP based on sludge = 300 Nm3 CH4/ton VS

If you have excess capacity, then co-feeds are a smart addition.

Sources of extra revenue for WWTP
What are the barriers?

Co-feedstocks can deliver more revenue to the plant, BUT ....

• More biological activity requires better monitoring
• More biogas production - How do you capture the most value?
• Do you have the capacity to handle the increased biogas production?
• Co-feedstocks can result in biochemical imbalance
Monitoring digester biochemistry

- When accepting co-feedstocks, regular monitoring is essential.
- Key biochemical parameters tell the operator about current digester health.
- Future performance can also be predicted if the historical data is valued.

**Gas Quality**
- CH$_4$ and CO$_2$ %
- H$_2$S

**Gas Quantity**
- How much gas?
- Specific Gas Production

**Reactor Chemistry**
- VFA
- Alkalinity (bicarbonate)
- pH

**OLR**
- Total solids in
- Volatile solids in
- VSR

**Physical**
- VS in, VS out
- Color, Odor,
Typical guidelines for a healthy AD

A stable and productive digester has:

- A pH between 6.8 – 7.8
- Sufficient alkalinity
- Low volatile fatty acids (VFAs)
- No rapid changes in temperature
- No toxic/inhibitory compounds present in the influent
- Enough nutrients (N & P) and trace metals - esp. Fe, Co, Ni, etc.
- All key biochemical ratios within range
How does this change with co-feeds?

A digester with co-feedstocks:

- A pH between 6.8 – 7.8
- Sufficient alkalinity
- High volatile fatty acids (VFAs)
- Toxic/inhibitory compounds
- Adequate N, P and trace metals

Caution is needed when taking high volumes of acid waste
May need to add buffering agent
Can your AD handle the conversion of VFAs without buildup?
Know how your feed stocks are generated!
Sewage sludge provides macro- and micro-nutrients... may need to augment
What you know today

HRT – Hydraulic Retention Time
   = Retention time for feedstock in reactor vessel.

HRT (days) = \frac{\text{Reactor volume}}{\text{Daily feed rate}}

SRT – Sludge Retention Time
   = Retention time for active biomass in the reactor vessel.

For most WWTP AD systems, HRT = SRT

*Tracking of HRT is typically performed for Biosolids compliance*
Retention time has a strong impact on biogas production.

Note: Cellulosic materials will take longer to digest than sludge or manure.
Example of Mass Loading to Reactor

Inputs
• Feed Rate – 75,000 gpd
• Total solids – 5%
• Volatile Solids - 75% (VS of TS)

Mass Loading
• Total Solids = 75,000 gpd x 0.05*8.34lb/gal = 31,275lb/day
  = 15.6 tons/day
• Volatile Solids = 0.75 x 15.6 tons/day = 12.5 tons/day
Example of Mass Loading to Reactor with co-feeds

**Inputs**
- Feed Rate of Co-feeds 30,000 gpd
- Total solids – 12%
- Volatile Solids - 83% (VS of TS)

**Mass Loading**
- Total Solids = 30,000 gpd x 0.12*8.34lb/gal
  = 30,024 lbs/day
  = 15 tons/day
- Volatile Solids = 0.83 x 15 tons/day = 12.46 tons/day

Large increase of solids loading to the reactor – do you have the biomass to stabilize?
Total Volatile Solids loading to Reactor

• A high/low feed rate can lead to poor performance
• The operator needs to carefully control the %VS/day added
• Total volatile solids (mass) will impact:
  – VFA/ALK ratio (a rapid change is undesirable)
  – OLR (depending on the organic content of the feedstock)
  – Volume of gas production
  – Volatile Solids Reduction
VFA/ALK Ratio

Ratio indicates the progress of digestion and stability

\[
\text{VFA/ALK} = \frac{\text{Volatile Acids (mg/l)}}{\text{Alkalinity (mg/l)}}
\]

The healthy range of VFA/ALK is 0.1 to 0.35

If AD is becoming unstable, the VFA/ALK ratio will begin to trend above 0.25.

\[
\text{VFA/ALK} = 0.35, \quad \text{Warning} \ldots.
\]
\[
\text{VFA/ALK} = 0.5, \quad \text{Sour digester (big problems)}
\]
Proper Ratio of VFA/ALK

We know:

• If the VFA/ALK begins to trend past 0.25, the operator can reduce total feed and monitor key metrics
• OR ... add alkaline materials to decrease VFA/ALK ratio
• As the VFA/ALK increases past a healthy range, CO$_2$ goes up and CH$_4$ production goes down.
• The pH of the digester will begin to decrease.

*NOTE: The VFA/ALK ratio is highly dependent on OLR*
Organic Loading Rate

$$\text{OLR} = \frac{\text{kg (or lbs) of Volatile Solids (VS)}}{\text{m}^3 \text{ (or ft}^3\text{) of the reactor}}$$

OLR is a design value for each digester, and varies from system to system (depending on design)....

For completely mixed systems

$$\text{OLR} = 80 \text{ lbs-VS per 1000 ft}^3 \text{ per day}$$

$$= 1.3 \text{ kg-VS per m}^3 \text{ per day}$$

(typical per Ten States Standard)

HIGHER OLR = optimized use of reactor volume .... to a point....

How high can you go???
OLR with multiple co-feeds

Managing OLR is critical when processing co-feeds. With several co-feeds, the OLR is **ADDITIVE**.

Example:

$$\text{OLR total} = \text{OLR sludge} + \text{OLR food waste} + \text{OLR FOG}$$

$$= \frac{\text{lbs-VS sludge} + \text{lbs-VS food waste} + \text{lbs-VS FOG}}{\text{Reactor Volume}/1000 \text{ ft}^3}$$

*Note: OLR is normalized to each 1000 ft$^3$ of reactor volume with units of units of lbs-VS/1000 ft$^3$.*
Temperature & Time

There is no absolute temperature requirement; rather, temperature ranges.

However, it is critical to limit $\Delta T$ to less than 1 deg C/day.

Duration and Temperature are related:

- Class B pathogen reduction: @ 95 F for 15 days
- Class A pathogen reduction: @122 F for 30 min (typ).

Caution: Self-heating of system can occur with high-carbohydrate co-feeds (.... and, BTW, sewage is not a high carbo substrate)
pH

- A good operating pH is 6.8 to 7.8.
- A low pH reduces the activity of methanogens, resulting in an increase in VFA and H\textsuperscript{2} production.

Depending on alkalinity concentration, pH reduction could be delayed. By the time pH is out-of-range, the digester has already “soured”.
Step-wise approach to AD monitoring

- Gather data on key parameters over several days
- Monitor slow changes, react to abrupt changes
- Plot out individual parameter to visualize trends (and performance).

*Example: Rapid changes to the AD feedrate*
Resulting changes in key biochemical parameters

- OLR very unstable
- Alkalinity changes abruptly
- VFA/ALK rises rapidly

Track/evaluate data for alkalinity, pH, VFA/ALK and OLR
A substantial drop in AD performance

Biogas production is a measure of “value” to the plant’s operation

Biogas production plummets ... this is lost revenue!
Case Study: Co-Feeds at a WRRF

- The City of Flint Michigan and BioWorks Energy have a public-private partnership to digest co-feedstocks
- 50 MGD WRRF currently flowing ADF at 15 MGD
- Formerly used sludge incineration as disposal method
- BioWorks Energy developed private-public partnership – 21 year operating agreement
- Project co-digests food waste/byproducts along with WWTP sludges

Why is this a successful partnership?
- Each partner does what they do best; City operates, BioWorks provides service that the City is not configured to perform
- Revenue from project benefits both partners
Case Study: Flint Biogas Plant

Physical Plant
- Two (2) 1.1 million gallon digesters
- One (1) 1.1 million gallon substrate storage tank
- 600 kW of electrical power generation capacity – and growing
- All power used onsite

- 35 to 50k gpd of co-settled sewage sludge
- 20 to 30k gpd of feedstocks

Ability to accept:
- Liquids
- Semi solids
- Packaged goods

List of Co-Feedstocks:
- FOG
- Sugar Waste
- Cucumber waste
- Milk waste
- Biodiesel byproduct
- Food waste

The most desirable co-feed is what pays the best 😊

Successful Private – Public Partnership
A true Win-Win for both parties.
Questions?

Feel free to ask or email us any follow-up questions!

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