MICHIGAN STATE UNIVERSITY

BioWorks Energy LLC
Advanced organics processing

QUANTALUX

# 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

| Feedstocks | TS (%) | VS (%) | Tip Fee (typ) | $/load (avg) | relative BMP |
|---|---|---|---|---|---|
| Sludge | 5% | 78% | n/a | n/a | 1 |
| Generic Food | 13% | 92% | $20-$50/ton | $600 - $800 | 2.2 |
| FOG | 4% | 90% | 10₵/gal | $1,000 | 2.0 |
| Dairy Processing | 10% | 70% | 3₵ - 8₵/gal | $500-$600 | 1.7 |
| *Relative BMP based on sludge = 300 Nm3 CH4/ton VS* | | | | | |

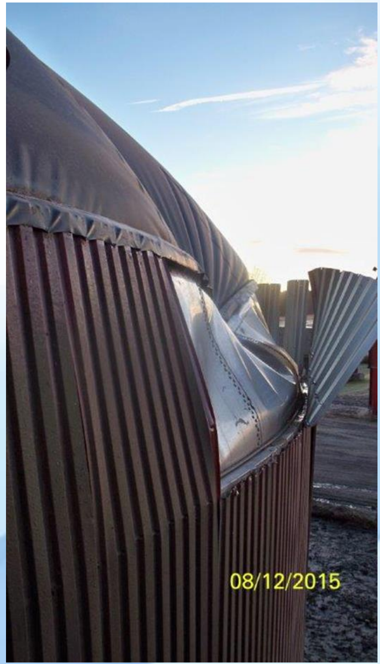
If you have excess capacity, then co-feeds are a smart addition.

*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 $CO_2$ %
- $H_2S$

**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 → Caution is needed when taking high volumes of acid waste
- Sufficient alkalinity → May need to add buffering agent
- High volatile fatty acids (VFAs) → Can your AD handle the conversion of VFAs without buildup?
- Toxic/inhibitory compounds → Know how your feed stocks are generated!
- Adequate N, P and trace metals → 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.

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

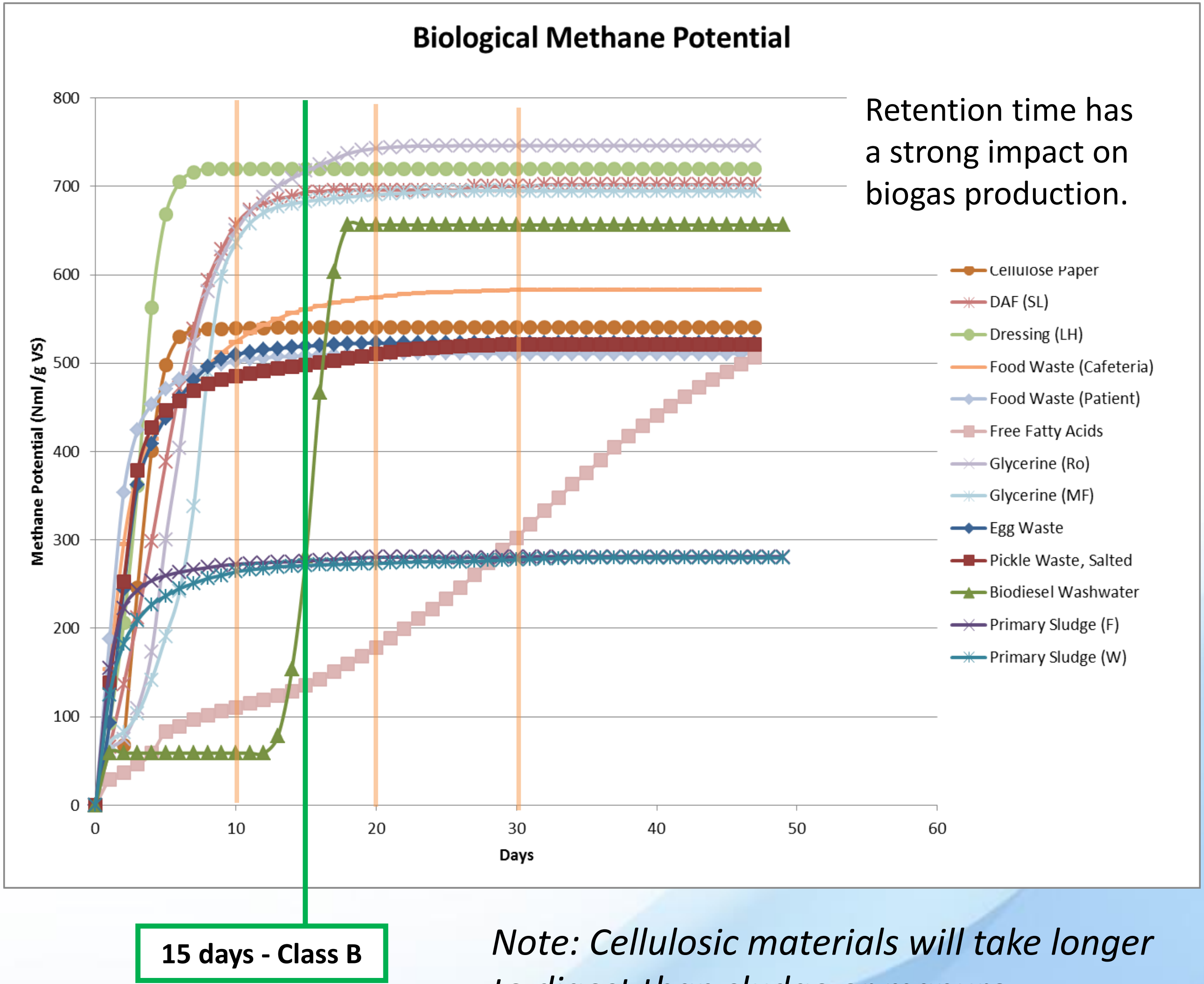
SRT – Sludge Retention Time

=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*

# HRT/SRT




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.

*VFA/ALK = 0.35, Warning .....*
*VFA/ALK = 0.5, 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

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

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

For completely mixed systems

OLR = 80 lbs-VS per 1000 $ft^3$ per day

= 1.3 kg-VS per $m^3$ 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:

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

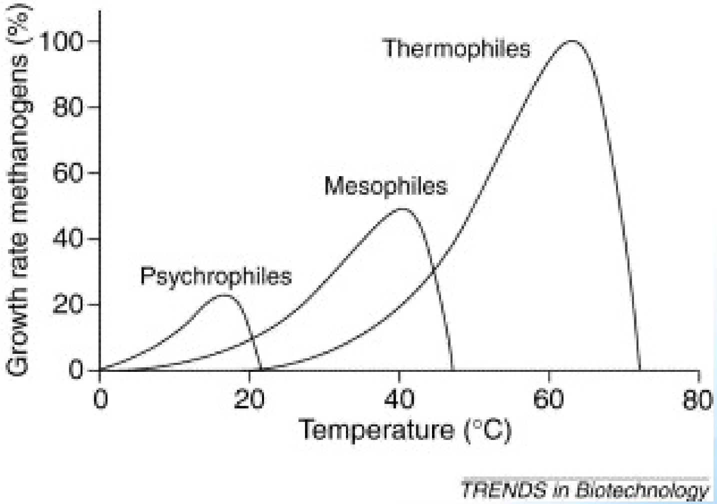
$$= \frac{\text{lbs-VS sludge} + \text{lbs-VS food waste} + \text{lbs-VS FOG}}{\text{Reactor Volume}/1000\ \text{ft}^3}$$

*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 ΔT to less than 1 deg C/day.




Duration and Temperature are related:

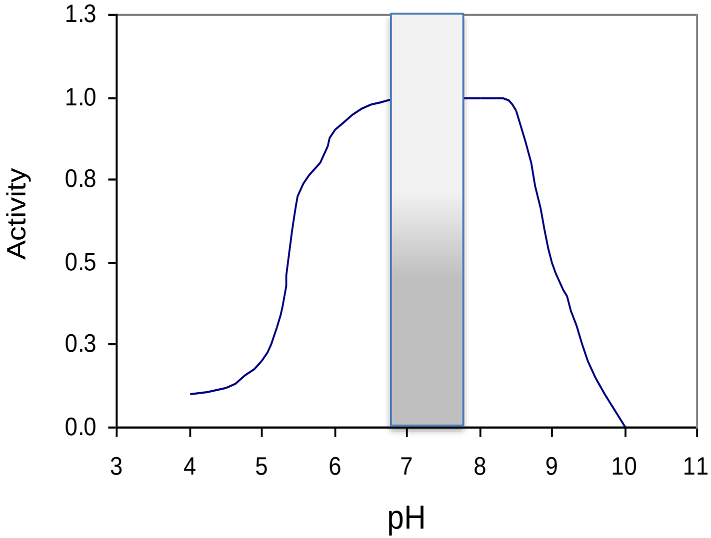
- Class B pathogen reduction: @ 95 F for 15 days
- Class A pathogen reduction: @122 F for 30 min (typ).

*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 $H^2$ production

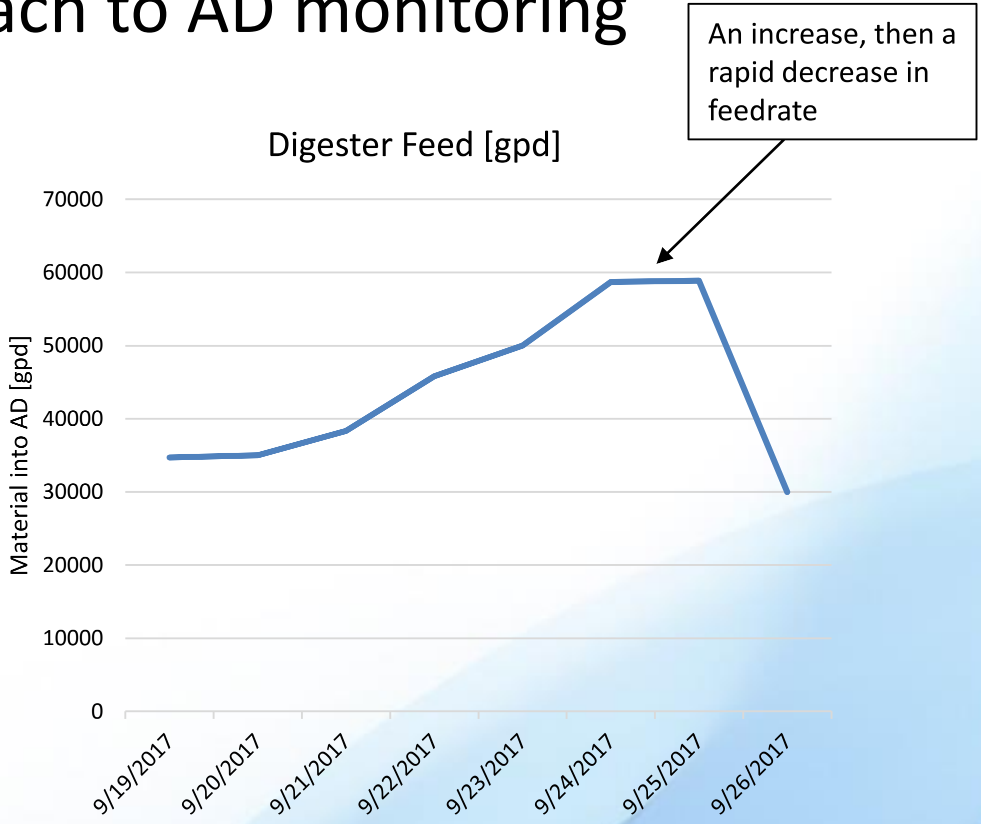
Relative activity of methanogens to pH




*Depending on alkalinity concentration, pH reduction could by delayed. By the time pH is out-of-range, the digester has already "soured".*

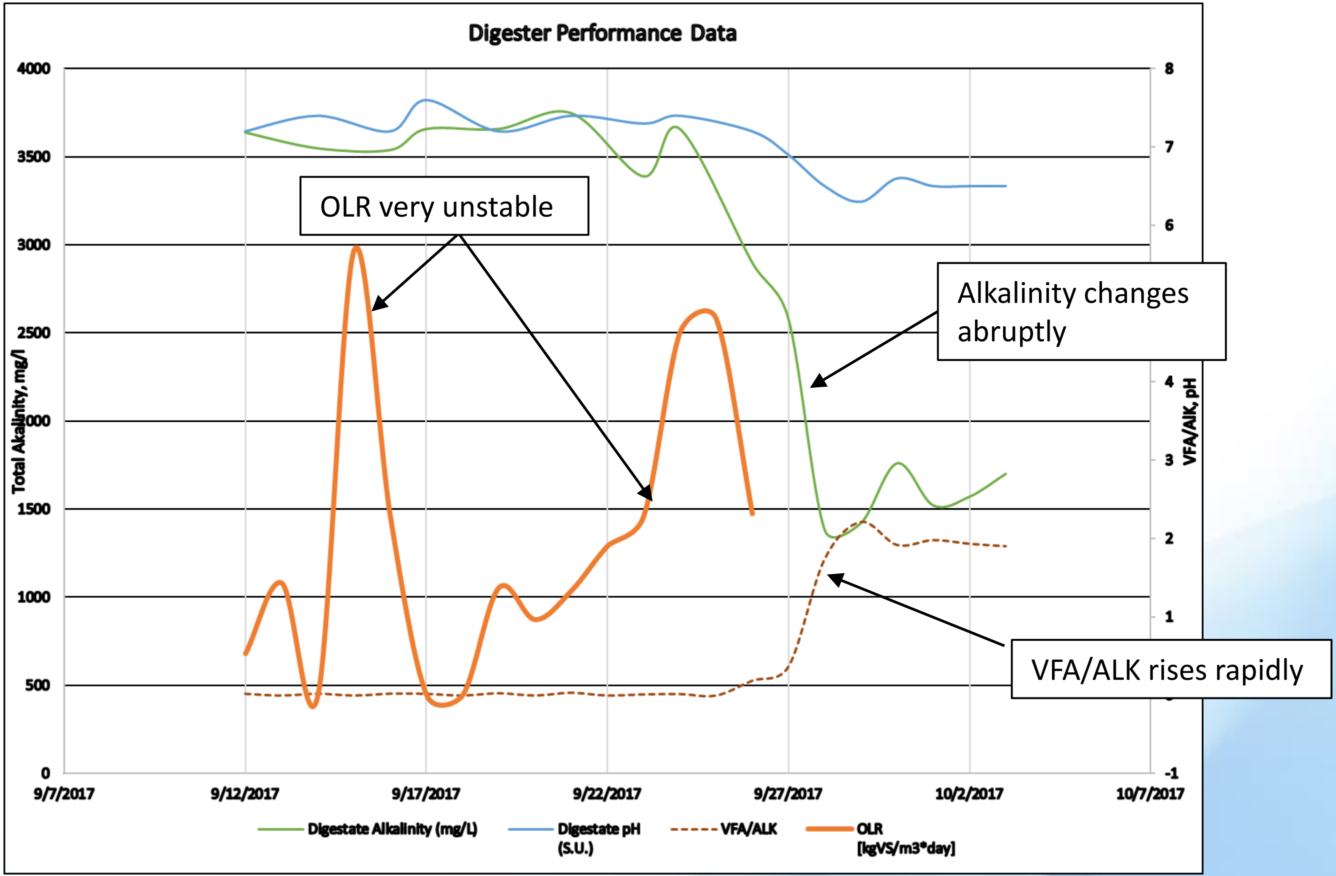
# Step-wise approach to AD monitoring

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



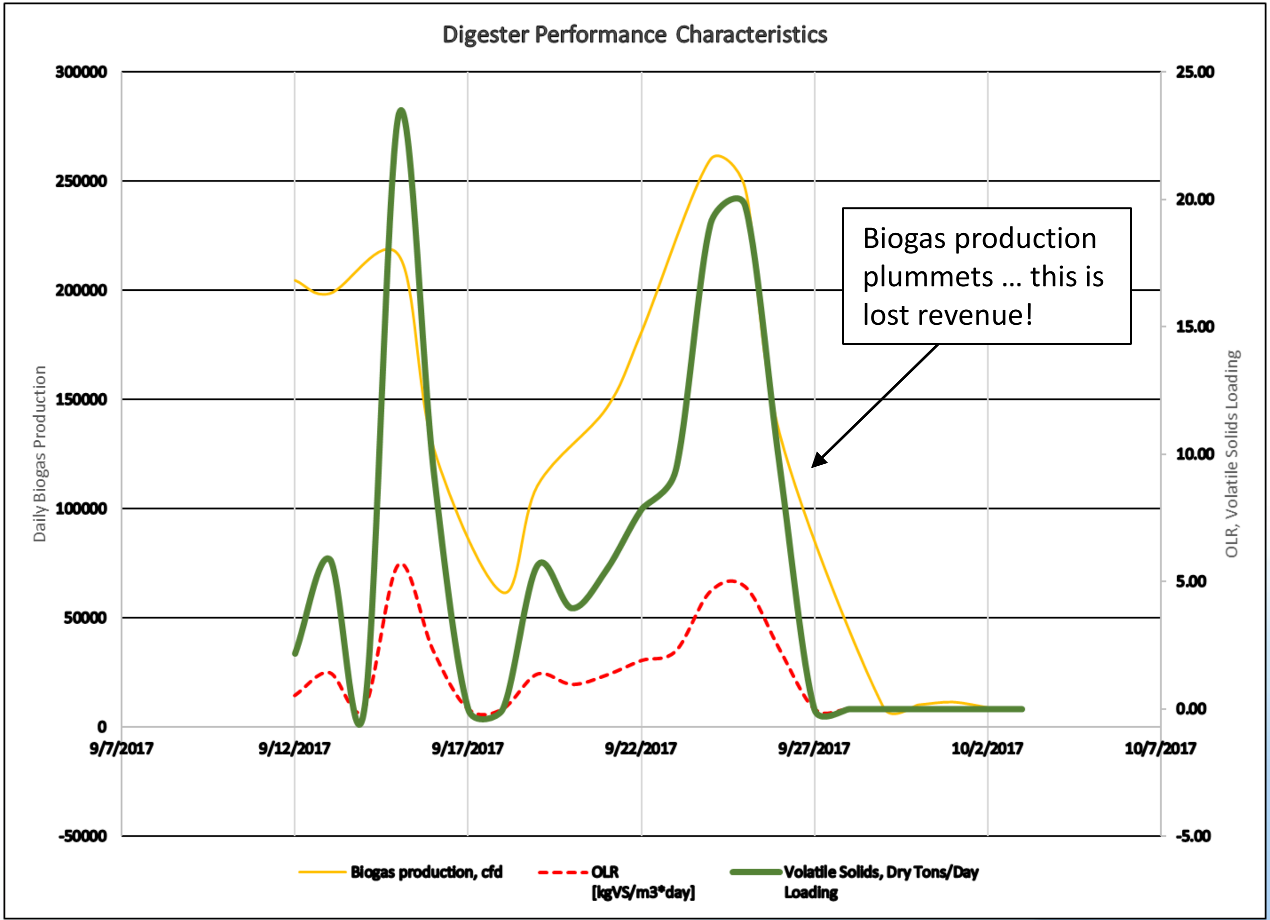

*Example: Rapid changes to the AD feedrate*

# Resulting changes in key biochemical parameters




*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*

# 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
- <u>Why is this a successful partnership?</u>
  - 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

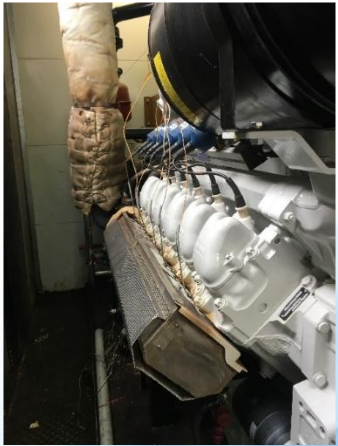
Physical Plant
- Two (2) 1.1 million gallon digesters
- One (1) 1.1 million gallon substrate storage tank
- 600 kW of electrical power generation capacity – and growing
- All power used onsite

- 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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