Columbus Southerly WWTP Anaerobic Digestion Optimization and Foam Abatement Investigation

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August 28, 2014
Presentation Objectives

• Gain an appreciation for the complexity of the anaerobic digestion process at a basic level

• Gain an appreciation for how digester foaming occurs and how it may be controlled

• Understand importance of optimizing the process to produce more gas to generate energy

• Where is the City going from here?
Background

- This presentation is intended for a wide audience.

- As an industry and culture, we are growing more concerned about environmental sustainability, which includes energy conservation and recovery.

- Many larger wastewater treatment plants (WWTPs) in the United States and Canada employ anaerobic digestion.

- Interest in the process will continue to grow.
A key benefit of anaerobic digestion is methane.

Methane gas typically has a heating value of approximately 650 BTU/CF, compared to 1,000 BTU/CF for natural gas.

Digesters gas is a potential fuel source that can be used for heating boilers in lieu of natural gas. It may be also cleaned and converted into electricity.

This trend is expected to continue as utilities seek to develop energy efficient solutions to offset operational costs.
What is Anaerobic Digestion?

• The term is based on Latin for “life without air”
  Ana: No
  Aero: Air
  Bic: Life

• Since the process involves sludge and volume reduction/stabilization, the term that we use is Anaerobic Digestion.
The Digestion Process

Three classes of reactions occur:

- **Hydrolysis:** breaking apart complex organics and solids into simple, liquid-phase organics. Kinetically, this reaction occurs in hours.

- **Acid Forming:** Conversion of simple organics and acetate. Some gas is formed. Kinetically, this reaction is also fast, and occurs in about 1-2 days.

- **Methane Forming:** Conversion of acetate, carbon dioxide, and hydrogen into methane gas. Kinetically, this reaction is slow and occurs over >10 days.
Process Design Considerations

Design and operational requirements include:

- System loaded within design limits
- Adequate residence time (SRT) for methanogens to develop
- Even temporal loading
- Steady temperature ~98°F
- Good mixing
- No toxicants
- Sufficient alkalinity
Columbus Southerly WWTP Dual Phase Anaerobic Digestion System Looking North. The 3 Acid Phase Digesters and 6 Methane Phase Digesters are visible.
Project History

- Project initiated in 1998 to rehabilitate 6 existing tanks constructed in the 1960s.

- Value engineering was performed on the preliminary design in 2001 and then shelved.

- Project re-activated in late 2004 with design revisions including “dual phase”.

- Construction began in March 2006 and was substantially complete in May 2009.

- Digester optimization study was initiated in 2010. The final summary report was issued in March 2013.
Columbus Southerly WWTP

- The Southerly WWTP is the larger of two WWTPs operated by the City of Columbus.

- Rated capacity is 114 MGD.

- Sewer system is mostly separate but with some combined areas.
Columbus Southerly WWTP Dual Phase Digestion Objectives

- Provide energy from methane gas for building and process boilers.
- Reduce mass of solids for dewatering and disposal.
- Reuse existing tanks and buildings.
Project Features

• Two digester feedwells mix Thickened Waste Activated Sludge (TWAS) with Thickened Primary Sludge (TPS).

• New 31 ft. diameter concrete tanks with fixed insulated steel covers.

• Gas piped to waste gas burners.

• This is the “front” of the digestion process.
Project Features

• Three Acid Phase Digesters (APDs), first phase of dual phase digestion provides detention time of approximately 2 days.

• New 33 foot diameter concrete tanks with fixed insulated covers and insulated side walls.

• (Acid) Gas piped to waste gas burners.

Columbus Southerly WWTP
Acid Phase Digesters
Project Features

• Six “conventional” Methane Phase Digesters (MPDs).

• Retrofitted existing 85-foot diameter concrete tanks with insulated steel floating covers, which hold gas.

• MPDs are fed evenly through the day.

• Gas piped to boilers under normal operational conditions. This is the “better quality” (methane rich) gas.
Project Features

• Vaughn Rotamix pumped mixing system for Feedwells, APDs, and MPDs.

• A Computational Fluid Dynamics (CFD) study was conducted by vendor during design to determine mixing nozzle placement.

• Mixing pumps are located next to the tanks in the tunnel area. No moving parts are within the tanks themselves.

Columbus Southerly WWTP
Mixing System Piping
Project Features

- Sludge heated by hydrothermal using direct steam injectors.
- Steam supplied from boilers, which are fueled by digester gas.
- Main (“raw”) steam injectors located upstream of APDs.
- Additional steam injectors are located on the MPD mixing system to maintain constant temperature in MPDs.
Project Features

• Digester gas handling system includes waste gas burner, sediment traps, foam separators, and digester gas compressors.

• Digester gas is used to fuel steam boilers and plant incinerators.

• At this point there is no other gas cleaning to remove “siloxanes” for electrical generation.
Process Schematic Diagram

1. TWA
2. Flow Diversion Valves
3. S
4. Well
5. Pumps
6. S
7. Flow Meter
8. Acid Digester Feed Sludge Automatic Sampler
9. Raw Steam Injector System
10. Flow Meters & Control Valves
11. Acid Phase Digestion System
12. Pumping
13. Flow Meter
14. S
15. Flow Meters & Control Valves
16. Recirculation Steam Injection System
17. Methane Phase Digestion System
18. Pumping
19. Digester 6 Liquid Loadout
20. Biosolids Automatic Sampler
21. FeCl₃
22. De-watering Feed Wells
23. To De-watering

Values are in GPD at 5% Total Solids.
Digester Foaming Begins

- The Methane Phase Digesters have foamed periodically since the system was started in 2009.

- Foam builds up in the annular space between the digester covers and the tank wall.

- During severe foaming episodes, foam spills over the tank walls.

Columbus Southerly WWTP
Residue from Foaming Episode
Importance of Foam Control

• Foam is a byproduct of the surface chemistry of how gas, liquid, and solids interact in solution.

• There have been many explanations given as to the cause of foam and is not well understood.

• All agree that the potential for foaming robs a system of capacity, which in turn hinders the production of methane gas.
Importance of Foam Control

- Can all foaming be eliminated from a system? The answer: probably not.

- But, performance can be improved to optimize the system.

- Foaming incidences can be better predicted, mitigated and reduced.
Digester Optimization Study

• Commissioned by the City of Columbus in 2010.

• Purpose was to determine the likely cause or causes of foaming and to make recommendations.

• Initial focus was on improving the function of the Acid Phase Digesters.
Sludge samples were taken periodically from October 2010 through October 2011.

Initial testing parameters on the system included percent total solids, percent volatile solids, pH, volatile fatty acids, alkalinity, oxygen reduction potential, and temperature.

These tests were performed to help eliminate some possible foaming causes.

The results did not pinpoint the exact cause (or causes).
Possible Causes of Foaming

The following possible causes for foaming were considered for initial evaluation:

- Excessive mixing
- pH
- Toxicants
- Sludge temperature
- Latent toxicity from boiler chemicals
- Gas pressure
- Volatile Fatty Acids concentration
- Intermittent feeding
- Filaments (Nocardia and Microthrix Parvacella)
- Short circuiting
- Inadequate pre-mixing of sludges
- Volatile loading variation
## Possible Causes of Foaming

<table>
<thead>
<tr>
<th>Possible Issue</th>
<th>Comments</th>
<th>Determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excessive Mixing</td>
<td>Could contribute to frothing.</td>
<td>One mixing pump impeller was changed out to reduce the applied mixing energy with no difference noted.</td>
</tr>
<tr>
<td>Sludge Temperature</td>
<td>Variations &gt;1º C per day can upset the process.</td>
<td>While problems were noted during start up, temperature fluctuations did not appear.</td>
</tr>
<tr>
<td>Intermittent or Slug Feeding</td>
<td>Interruptions to the feed can lead to foaming.</td>
<td>The &quot;most open valve&quot; fed system feeds all tanks evenly.</td>
</tr>
<tr>
<td>Filaments: Nocardia and Microthrix Pavacella</td>
<td>Hydrophobic composition of filaments may alter surface chemistry at foam interface.</td>
<td>Possible minor or contributing factor.</td>
</tr>
<tr>
<td>Volatile Solids Loading Variation</td>
<td>Recommended daily variation in volatile solids load (organic load) stay within ±5-10 percent of the previous day's loadings.</td>
<td>Daily Variations in volatile solids loading are noted to exceed 30% on a daily basis. This is far outside of the desired range of 5-10%. A strong correlation was discovered between high volatile solids variation and foaming events.</td>
</tr>
<tr>
<td>Short-Circuiting</td>
<td>Short-circuiting of sludge within the digester by inadequate mixing or poor pipe placement.</td>
<td>There are no obvious flaws in the piping arrangement to support this as a likely cause.</td>
</tr>
</tbody>
</table>
Previous papers at WEFTEC including WERF included much focus on filamentous bacteria in the activated sludge process.

The emphasis of our study ultimately settled on a different possible cause: variability of volatile solids loading.

Most of this loading variation can be attributed to wet weather activity in the sewer system.
Wet Weather Generates Different Solids Loadings for Treatment

This USEPA illustration shows a combined sewer system in dry and wet weather. Many WWTPs in the United States and Canada experience wet weather challenges.
Figure 1: Histogram of TPS Daily Flows to Digestion
1/1/2006 - 9/16/2012 (2,308 days)
Primary Solids Loading

• Data from previous figure is from 2006 – 2012.

• Solids fed to digestion are pre-thickened to 5% TS.

• The 50% percentile pumping rate was 186,784 GPD.

• The 90th percentile flow rate was 365,621 GPD.

• Elevated values may occur over several weeks.
Primary Solids Loading

• High values occur through scour of interceptor sewers during wet weather conditions.

• The City has had two OEPA Consent Orders and has spent significant resources on wet weather compliance.

• Wet weather compliance has impacted solids generation.

• During peak wet weather periods, TPS is sent directly to dewatering.
Primary Solids Loading

• While TPS is variable, biological sludge wasted from the activated sludge system varies little.

• Previous studies on the subject of foaming have indicated that the percentage of TWAS should be maintained at <40% of the total amount.

• We recommend maintaining Volatile Solids (VS) loading within 5-10% per day.
Primary Solids Loading

Columbus Southerly WWTP Primary Sludge Loading Data
January 1-31, 2011

Daily Variability of TPS Flow during January 2011. This is based on 5% TS.
Loading Summary Points

• As was mentioned, the end point objective would be to maintain a relatively even feed based on the previously daily loading.

• At the present time, this is difficult to accomplish.

• Other than feed wells, there is little solids storage ahead of digestion.

• Operationally, the plant attempts to hold back solids in the primary clarifiers and gravity thickener.
Solution Considerations

The solution must recognize the following:

• Ohio’s changing wet weather patterns and climate change may be a factor.

• It is unlikely that the City will reduce or eliminate all wet weather flows in its collection system.

• Unlike many other WWTPs, Columbus Southerly WWTP does not experience significant amounts of filamentous bacteria.
Solution Considerations

Major Elements:

• Implement a load leveling system to handle TPS.

• Implement a process control strategy to maintain a feed rate of TPS within the desired range.

• Use a de-foaming agent to help combat potential foaming outbreaks.
Proposed Location for a new TPS Load Leveling Tank

Proposed Location for New Load Leveling Tank, Upstream of Feed Wells
Questions?

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