Assessment of Operating Challenges of Digester Foaming

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Brown and Caldwell
Based Partially on a Survey and Workshops by the
Central States Water Environment Association

Acknowledgements

Jeff Brochtrup, Madison MSD
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Eric Lecuyer, Northern Moraine WRD (previously, Central States Executive Director)

Initial results presented at WEF Residuals and Biosolids Conference, May 2011, Sacramento, CA
Background
Formation of Ad Hoc Committee

• Concerns Expressed at 2009 Annual Meeting
• CSWEA Objective to Better Engage and Serve Operators

• Ad Hoc Committee Developed
  • Selected Chair and Nominated Members
  • Developed Committee Charge

• Committee Developed Survey and Workshop as Goals

• Survey Developed and Performed in Late 2009/Early 2010
  • Web Based
  • Follow Up by Committee Members
History of the CSWEA Digester Foaming Committee’s Efforts

- Committee established after 2009 annual conference
- Initial groundwork in late 2009
- Survey sent out in early 2010
- 1st Workshop – April 2010
- Follow Up Survey
- 2nd Workshop – April 2011
- 3rd Workshop – February 2012
Initial Workshop - April 21, 2010 Identified Typical Causes of Excessive Foaming

• Varying Sludge Loadings
  • Total Sludge Quantity
  • Ratio of Primary Sludge to WAS

• High Ratio of WAS

• Inadequate Mixing

• Nocardia and Microthrix Parvecella

• Inconsistent or High VFAs

• Low Influent Solids Concentration

• Excessive or Fine Bubble Mixing
Survey Results
Brief Survey Summary

• About 216 WWTPs have anaerobic digestion:
  • Illinois: 64
  • Minnesota: 56
  • Wisconsin: 96

• Ad hoc committee developed questionnaire to gauge the extent of anaerobic digester foaming problems at WWTPs

• Follow-up calls and e-mails
Survey – 94 Responses (44%)

- Significant Digester Foaming in Last 10 Years?

- 50 of the 94 Responses
  - 23% (min) of the 216 WWTPs
Survey Responses

• Was Cause of Digester Foaming Determined?

- Yes: 55%
- No: 45%
Survey Trends

- Size of WWTPs

<table>
<thead>
<tr>
<th>Size of WWTPs</th>
<th>Percent of Plants w/ Digester Foaming</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1.0 mgd</td>
<td>6 of 19 (32%)</td>
</tr>
<tr>
<td>1 to 5 mgd</td>
<td>27 of 45 (60%)</td>
</tr>
<tr>
<td>5 to 20 mgd</td>
<td>12 of 24 (50%)</td>
</tr>
<tr>
<td>&gt; 20 mgd</td>
<td>6 of 7 (86%)</td>
</tr>
</tbody>
</table>
Survey Trends

- Type of Biological Treatment

<table>
<thead>
<tr>
<th>Percent of Plants w/ Digester Foaming</th>
<th>Activated Sludge</th>
<th>Trickling Filters</th>
<th>RBCs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>59%</td>
<td>40%</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>43 of 73</td>
<td>10 of 25</td>
<td>3 of 10</td>
</tr>
</tbody>
</table>
Survey Trends

- Foaming in Activated Sludge?

<table>
<thead>
<tr>
<th>Percent of Plants w/ Digester Foaming</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70%</td>
<td>58%</td>
</tr>
<tr>
<td></td>
<td>14 of 20</td>
<td>32 of 55</td>
</tr>
</tbody>
</table>
Survey Trends

- Phosphorus Removal

<table>
<thead>
<tr>
<th>Plant Type</th>
<th>Percent of Plants w/ Digester Foaming</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPR</td>
<td>30 of 49 (61%)</td>
</tr>
<tr>
<td>BPR</td>
<td>14 of 22 (64%)</td>
</tr>
<tr>
<td>No P Removal</td>
<td>8 of 26 (31%)</td>
</tr>
</tbody>
</table>
Survey Trends

- Nitrogen Removal

<table>
<thead>
<tr>
<th>Percent of Plants w/ Digester Foaming</th>
<th>NH3 Removal</th>
<th>Total N Removal</th>
<th>No N Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>60%</td>
<td>2 of 4</td>
<td>9 of 24</td>
<td></td>
</tr>
</tbody>
</table>
Survey Trends

- Digestion Process

<table>
<thead>
<tr>
<th>Process Type</th>
<th>Percent of Plants w/ Digester Foaming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meso Only</td>
<td>56%</td>
</tr>
<tr>
<td>Thermo Only</td>
<td>0 of 1</td>
</tr>
<tr>
<td>TPAD</td>
<td>3 of 7</td>
</tr>
<tr>
<td>Acid-Gas</td>
<td>0 of 3</td>
</tr>
</tbody>
</table>
Survey Trends

- Digester Detention Time
Survey Trends

- Digester Mixing System

<table>
<thead>
<tr>
<th>Percent of Plants w/ Digester Foaming</th>
<th>Gas - Canon</th>
<th>Gas - Lances</th>
<th>Liquid - Pumped Recirc.</th>
<th>Liquid - Draft Tube</th>
</tr>
</thead>
<tbody>
<tr>
<td>70%</td>
<td>7 of 10</td>
<td>18 of 28</td>
<td>22 of 36</td>
<td>7 of 21</td>
</tr>
<tr>
<td>64%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>61%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0%</td>
<td></td>
<td></td>
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Follow Up Activities
Follow Up Survey

• Attempted to Dig a Little Deeper:
  • Many of the same questions as 2010
  • Mixing times, sequence, etc.
  • Heating equipment and methods
  • Feed sludge type, blending, etc.
  • Feeding times, sequence, etc.
  • Hauled waste acceptance
  • VS loading rates
Second Workshop – Survey Responses – Comments – Dealing with Foam

• Lowered our operating level
• Reduced feed rates when it has foam
• Increase Volatile Acid and Alkalinity testing
• \( \text{H}_2\text{S} / \text{CO}_2 \) testing
• Change mixing intervals
• Reduced feed
• Adjust duration of feed
• Adjust removal rates
• Reduced grease pumping
Third Workshop

- February 2012
- Provided more detailed analysis of specific case studies
  - Causes
  - Solutions
- Further Developed and Refined “Mitigation and Adaptation” Concept
Gas Holdup Expands the Volume

No Gas Holdup/Entrainment

With Gas Holdup/Entrainment
Recent OWASA (NC) data suggest low-specific-gravity can be normal / ongoing

<table>
<thead>
<tr>
<th>Digester Stage</th>
<th>Pressure (ft)</th>
<th>Radar (ft)</th>
<th>Calculated Average Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22.6</td>
<td>30.4</td>
<td>74%</td>
</tr>
<tr>
<td>2</td>
<td>19.2</td>
<td>23.3</td>
<td>82%</td>
</tr>
<tr>
<td>3</td>
<td>16.2</td>
<td>19.0</td>
<td>85%</td>
</tr>
</tbody>
</table>
Case Histories
Video from Hawaii Shows Rapid Rise in Action
Dublin, Ireland Startup Event – 2001

- Very large gas burp or rapid rise event at startup, when mixing finally brought food and microbiology together.

- No structural damage, but significant portion of digester contents overflowed at top relief hatch, spilling DS over significant portion of plant site.
Extreme Events - Digester Overflows at Marquette City

- River of Digester Overflow – Foam/Biosolids

Marquette City, Michigan
Lillehammer, Norway Digester Cover Break

- Fiberglass cover break in 2005 (vacuum) and 2012 (over-pressure)
- Food-waste digester – “hot” fish waste load suspected in Dec 2012
- De-foamer not used during Dec 2012 event
- Resulting burp/rapid rise plugged PRVs and gas lines – also some debris in the digester
Cover Event in Northern Florida, 2012

• Floating cover digester being started up.

• Tank had significant undigested sludge, then temp brought up to meso.

• Rapid expansion of biology and activity brought major overflows plus tilting and jamming the floating cover – damage and major delay.
Spokane Digester Cover Break in 2004

- Sludge digester with fixed concrete cover
- Cover over-pressurized due to several factors
- Entire cover lifted, crashed, and broke apart
- 1 killed, 2 serious injuries
- RR/burp event plugged pipes – DS spilling out PRVs
- Instrument / SCADA failure
- Recent piping changes may have caused confusion in response
Brightwater WWTP Startup (2012) - King County, Washington

• Tall primary digesters – 65 feet side-water depth

• Rapid Rise events documented starting in early 2012, biggest events when mixing stops (power out)

• Extreme specific gravity change over 6 hour event 0.92 $\rightarrow$ 0.77 (gas holdup). 11 % volume expansion, with overflows going to the secondary digester.
Brightwater WWTP Startup (continued)

• Tanks were built with large overflow and surface wasting capacity
• Even tighter controlled feed to digesters has been implemented (no FOG slugs for now)
• Mixer ramping is highly controlled.
• Radar has been added; operator training improved; and capacitance probe for foam level monitoring
Lab Testing at Bucknell University
(Matt Higgins)

Setup:
• Vertical-oriented digester/reactors
• Visually observe liquid rise/foam
• Mixing with paddle mixer

Procedure:
• Turn mixer off, or other changes
• Measure slurry height over time
• Observe characteristics of RR/foam
• Continuously monitor gas production

Ongoing Testing in 2014
Plant Description:

• This is a 60 mgd plant that has preliminary, primary, and secondary treatment. Solids handling facilities includes DAFT’s, anaerobic digestion, dewatering and incineration.

• Solutions
  • Improve feeding
  • Improve mixing
  • Improve temperature control
Digester No. 2 Case Study

**Plant Description:**

- This is an 8 mgd plant consists of preliminary, secondary, and tertiary treatment. The solids handling facilities consists of scum thickening, DAFT’s, anaerobic digestion and dewatering.
Digester No. 2 Case Study

Problems:
• Nocardia

Solution:
• Acid-Gas Phased Digestion
Phased Digestion

- Feed
  - Acid Phase Digestion: 1 day
  - Methane Phase Digestion: 10 days
• Overpressurized the fixed covers, ripping connections between the steel cover and concrete wall.

• All 3 digesters had these events during first 2 years of operation.

• Cause seemed to be accumulation of low-SG sludge in the top portion of tanks.
Digester No. 3 Case Study

**Problems:**
- Feeding methods
- Foam adaptation

**Solution:**
- Improved feeding methods
- Improved mixing methods
- Digester modifications
EXISTING DIGESTER
MODIFIED DIGESTER
Other Research

Draft Final Report in Review

WERF INFR1SG10
Anaerobic Digester Foaming – Prevention and Control
What Have We Learned from All This?

- Agencies are experiencing significant problems from burps, foaming, and rapid rise/gas holdup
- Information is beginning to be shared in the industry.
- Digester foaming, gas holdup and rapid rise depends on many factors:
  - Digester loading rates (and variability of loading)
  - Sludge characteristics/viscosity
  - Tank shape/configuration
  - Mixing system
  - Piping details (in/out, and overflow)
- Digester startups and process/loading changes often create unstable situations - more susceptible to foam and rapid rise events.
Operator Controls

• Control Feeding
• Monitor Sludge Feed
  • Volatile acids (Below 4,000 mg/L)
  • VS loading rate
  • Consistent feed
• Maintain Temperature
• Provide Good Mixing
Digestion Process Monitoring

• Digester Feed
  • Loading rate
  • Types of feed
  • Feeding times

• Temperature

• Digester Gas Production and Consistency

• VA and Alkalinity
Surface Wasting Improvements

Extend piping to normal operating level using 30- or 36-inch pipe
Cost - Cutting, More Effective Designs

Submerged Fixed Covers

- Mimic egg performance
- Last ~ 50 years
- $\frac{1}{2}$ the cost of Eggs
- Concentrated surface wasting in dome
Rapid Rise will Likely Happen in Highly Loaded Digesters

Address the symptom:

- Try to dampen slug loads/force consistent feed
- Passive relief hatches/collection to designed sludge receiving

*Alternative is failed mechanical covers or to fill digester gas piping...*
Mitigation and Adaptation

• Mitigation
  • Minimize Feed of Foaming Organisms
  • Proper Feed Control – quantity, frequency, mixture consistency
  • Good Mixing
  • Consistent Temperature

• Adaptation
  • Surface Discharge
  • Surface Removal
  • Foam Suppressant Chemical Feed
  • Foam Trap on Gas Lines
  • Foam Sensor
  • Protection of Pressure/Vacuum Release Valves
  • Cover Design
Questions?