Rapid Volume Expansion of Digester Contents

November 2014
What is rapid volume expansion? Is it foaming or something else?

What factors can influence events?

Case Study at the Brightwater WWTP in Woodinville, WA.

Design modifications to manage events.

Take homes
Tennessee Case - 2012
Events Can Be Serious
What is Foam?

• Gas bubbles entrapped in the liquid matrix
• Surface tension and capillary forces stabilize foam bubbles
• Foaming increases when the surface tension of the liquid is reduced (increased bubble stability)
• Foaming agents (surfactants) increase foam formation
• Foam bubbles collapse when liquid drains by gravity
What is Foam?
Why is digester volume expansion not foaming?

- Digester volume expansion is caused by changes in digester gas holdup
  - Production rate greater than release rate
- In some cases, an apparent foaming event is actually caused by expansion of the digester contents
- Rapid volume expansion can present a significant risk to digester and operator safety
During normal digester operations gas generation and evolution to the headspace are at equilibrium.

Diagram showing gas generation and evolution to the headspace with the following gas representations:
- CH\(_4\)
- CO\(_2\)
- H\(_2\)
- CO\(_2\)

The digester headspace is shown on top with arrows indicating gas movement, and the digesting sludge is shown on the bottom with corresponding gas arrows.
The Principal of Gas Holdup

Typical Digester Operation: Gas production and conveyance to headspace is at steady state.

When conveyance and production are out of balance.
Examples of gas hold up in liquids
Bubble Hydrodynamics – The Science of Gas Holdup

- Sludge Characteristics that impact/result in slow bubble rise rates
  - **Size**: Small bubbles rise slower than large ones
  - **Viscosity**: Digester sludge is viscous, behaves as a viscoplastic
    - Reduced viscosity with increase shear stress (mixing)
  - **Yield Stress**: Bubbles must overcome this
  - **Surface tension**: Surfactants present in digesters reduce surface tension
  - **Pressure**: Tall digesters have higher pressures near the bottom
  - **Particles**: Grit and solids in the digester will impact bubble size
Improved digester design, increased process efficiency has made this an issue
WAS and Filaments

- Foam trapping allows accumulation of Nocardioforms
- Hydrophobic surface causes attachment to air bubbles

(Source: Parker et al, WER, Vol 86, No 6, 2014)
Digester Operation Influences Gas Holdup

• Changes in gas holdup impact the volume of digester contents

• Common causes of volume expansion are related to digester operation:
  • Digester feed rates
  • Digester mixing intensity
  • Power outages
  • Scum / Fog addition
  • And more...

• It is unlikely we can eliminate or prevent all volume expansion events
Example - Sudden Changes in Mixing can Cause Volume Expansion

• Several documented cases of volume expansion following a sudden change in mixing

• Changes in mixing direction can cause a sudden shift in gas holdup resulting in a dramatic change in liquid level
Case Study: Brightwater Digesters

• Modern digester design

• Similar to an egg shaped digester but lower construction cost (Modified Silo)
  • 3 digesters, 1.25 Mgal each
  • 1 storage tank, 790kgal
  • Diameter 59 ft
  • Digester SWD 65 ft
Brightwater WWTP digestion process
Test Results

• Density change due to gas holdup
  • Start density near water: SG = 0.92
  • End density lower than water: SG = 0.77

• Volume transferred:
  • 140,000 gal, 11% of digester active volume transferred to Blending Storage tank
  • 400-500 gpm transfer rate
New Research: Laboratory scale supports the full scale observations

Digester Modifications During Commissioning

• Verified existing overflow capacity was sufficient – Yes, it was!

• VFD operation of digester mixers - slow changes in mixer speed and direction

• Radar level monitoring – accurate surface/liquid level monitoring
Surface Level measurement
Radar shows the true digester level

~10 ft = 204 kgal or about 26% of the tank volume
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>
Take Home Message

• DESIGNERS:
  • Consider rapid volume expansion in future digester designs

• OPERATORS:
  • Be aware of rapid volume expansion during operations and maintenance activities

• I would be interested in hearing about experiences from your plants
Acknowledgements

- Chris Muller – Brown and Caldwell – Andover, MA
- Tom Chapman – Brown and Caldwell- Tucson, AZ
- Steve Krugel –Brown and Caldwell- Seattle, WA