DIGESTER OVERFLOWS
Causes, Control Measures, and A Case Study
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Today’s Goals

• Identify primary causes for anaerobic digester overflows
• Improve understanding of mechanisms involved
• Build appreciation for what caused the overflow

First priority – chronology of events
New Frontiers for Anaerobic Digestion

- Thermal hydrolysis pretreatment
- Co-digestion, adding new feeds with sludge
- Sludge rheology impacting bubble hold-up
- Greater loading rates/less conservative design

All increase the possibility of a Rapid Rise Volume Expansion (RRVE)
Gas Holdup and Volume Expansion

![Diagram showing Gas Holdup and Volume Expansion](image)

- **NO GAS**
- **WITH GAS**
Important Considerations

- Fermentations > dissolved gases > bubbles > frothy sludges and foams
- Density variation can be extreme due to bubbles
- Mixing can mitigate feed, density & thermal gradients
- Too little or too much mixing can be problematic, because

  *Volume Expansion is directly related to mixing energy input*
Types of Foaming

• Nocardial foam formation
  – *from biological processing*

• Chronic or nuisance foaming
  – *common with digestion operation*

• Rapid Rise Volume Expansion
  – *rapid surge of frothy sludge (not foam)*

*The key is to avoid those rapid surges*
Uncontainable Frothy Sludge
Volume Expansion

- Caused by changes in digester gas holdup
- Overflow results from expansion exceeding digester capacity
- Rapid rise volume expansion can present a significant risk to digester and operator safety
Sludge Characteristics Impacting Gas Holdup

- **Size**: small bubbles rise slower than large ones
- **Viscosity**: sludge is viscous & thixotropic
- **Surface tension**: surfactants reduce surface tension
- **Pressure**: taller digesters have greater gradients
- **Particles**: grit and solids will impact bubble size
Digester Operations Impacting Gas Holdup

• Digester feed rate consistency
• Digester mixing and heating intensity
• Power outages that interrupt mixing/pumping/heating
• Scum addition
• High-strength organic waste addition
Sudden Changes in Mixing Rate & Direction Can Cause Volume Expansion

• Several documented cases of volume expansion followed 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
Potential Safeguards in Rapid Rise Volume Expansion

- Pressure relief valves*
- Emergency overflows*
- Foam suppression sprays
- Increased headspace for foam storage in gas plenum
- Rapid transfer piping to lower the liquid level

*Pressure relief valves & some emergency overflows are impacted by fluid density. Frothy sludge is less dense than water.
Viscosity versus Shear Rate and Mixing

Viscosity Data

Shear Rate (1/sec)

Viscosity (mPa-s)

28 rpm
G ≈ 1/s

100 rpm
G ≈ 4/s

156 rpm
G ≈ 6/s
How Much Mixing Energy Input (MEI) Is Needed?

• Too little MEI promotes gas entrainment, reducing density, causing volume expansion

• Too much MEI promotes gas production as well as release of gas bubbles again changing density

• Density change and volume expansion between these boundaries will depend on which is dominant – enhanced gas production or enhanced gas release

Mixing system design should provide for flexibility to adjust for operating experience
Containment or Overflow vs. Mixing

Volume Expansion

- Entrainment dominates
- Gas production dominates

Hydraulic Capacity for volume expansion

Mixing Energy Input
Case Study

City of Spokane

Egg-Shaped Digesters (ESDs)
New ESDs – Two 2.85 MG External Pump Mixed, Steam Injection Heated
Major ESD Foaming Event
July 2009

• A 45-min. power outage resulted in a 120-min. foaming event that ejected 150,000 gallons from the primary ESD with zero inflow.

• Mixing system was shut down - no backup power

• Heating from steam lance was intensified

• Foam collection tank and gas scrubber system were totally inundated within minutes

• EOF (emergency overflow) of 600 gpm capacity was overwhelmed
Profile of Rapid Rise Volume Expansion Event

Flow Rate vs. Duration, hours

- Rising Leg of Event
- Declining Leg of Event
- Flow Reduction starts after Shutoff of Feed
Unwanted Scenes!
Uncontained Overflows
Considerations for Digester Design and Operation

- Consider using headspace to manage volume expansion
- Recognize that the density of frothy sludge is less than that of water
- Consider multiple depth sensor technologies to monitor volume
- Consider emergency gravity sludge transfer capability
- Provide redundant power to maintain mixing
- Develop SOPs for atypical events like power outages
- Provide operator training for atypical events
- Have an emergency response plan for overflow control
Questions?

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Mixing ‘Budget’ in Digesters

• MEI or Mixing Energy Input – energy input/volume-time

• ‘Free’ MEI is provided by rising biogas:
  • Area-specific as gas always rises (mixing energy/area-time)
  • Increases with greater height to diameter ratio

• Added MEI can be at high end from pumped hydraulic jet mixing, or at low end from linear motion mixing

• Total mixing is the sum of the base plus added MEI
Effect of Mixing Speed on Gas Production and Volume Change

Effect of Mixing Speed

- Gas Production Rate (mL/min)
- Volume Change (%)

Elapsed Time (min)

- 156 rpm
- 100 rpm
- 28 rpm
- 3 rpm
- 0 rpm
- 156 rpm

Graph showing the effect of mixing speed on gas production rate and volume change over elapsed time.
Conclusions from ESD Event

- Provide high capacity, non-isolatable EOF’s with external P-Traps
- Add multiple depth sensor technologies
- Be aware that ESDs can provide optimal mixing, but also can result in increased exposure to catastrophic RRVE events
- Operator confusion from excessive sludge piping alternatives (human factor)
- Significant changes should occur only with manual operator control (human factor)
- Add an emergency digester sludge gravity transfer capability (with gas equalization)
- Provide blow-off hatches (ones that don’t leak digester gas)
- Provide an electrical power redundancy to maintain mixing at all times
- Observed that foam scavenging systems that may work well in pancake digesters were completely inadequate for ESD’s