

DIGESTER FOAMING PROBLEMS AND SOLUTIONS BASED ON US EXPERIENCES

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Abstract

In the US, there is increasing interest in anaerobic digester (AD) foaming. Various groups have recently initiated research programs. These include the Water Environment Research Foundation (WERF), the Central States Water Environment Association (CSWEA), and several universities including the University of Wisconsin and Illinois Institute of Technology. This paper looks at AD foaming in terms of “true” foaming and the recently developed concept of “rapid volume expansion”. It primarily focuses on recent, on-going and completed research by WERF and CSWEA. Various causes and mechanisms are identified, including physical causes, biological causes, and chemical causes as well as operational and design causes. The most effective operational, design, and chemical “cures” observed to date are also presented.

Keywords

Anaerobic digestion, foaming, rapid volume expansion, Digester foaming, digestion survey

Introduction

Biogas energy from anaerobic digesters (AD) is the energy production center of wastewater treatment plants (WWTPs). With rising costs of energy and green concerns, more and more focus is being placed on AD problems. Foaming is one of these. It is associated with:

- Upsets of Anaerobic Digesters
- Gas Piping and Handling Equipment Impacts
- Making Unsightly and Unsafe Conditions
- Damage Tanks and Equipment

There is lot of, sometimes contradictory, information in the literature as to what causes foaming are and how to cure it. Often what solves the problem in one case can cause or aggravate it elsewhere. In the following, the basics of the problem and potential cures are presented, focusing primarily on recent work done by WERF and CSWEA.



Figure 1: Impacts of AD Foaming
clogged gas handling equipment

Impacts of AD Foaming

There are both economic and non-economic impacts of AD foaming. Economic impacts include:

- Personnel Time
- Equipment
- Supplies
- Process Performance
- Biogas & Energy
- Outside Contract Services

Non-Economic impacts include:

- Health and Safety
- Aesthetic Effects
- Odor Problems

Rivers of AD Foam....



Kankakee, Illinois



....to exploding digesters)

Figure 2: Extreme Impacts of AD Foaming

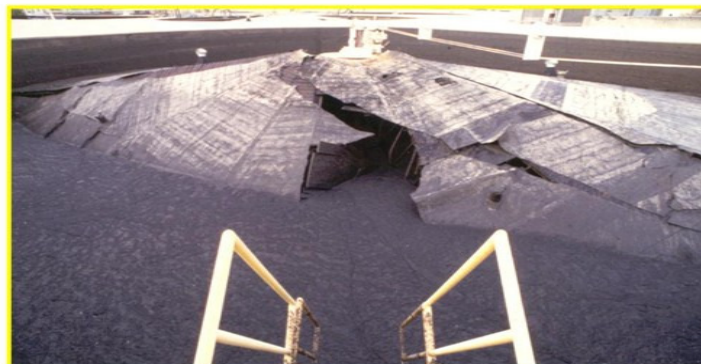


Figure 3: Extreme Impacts of AD Foaming - Floating Cover Failure

Basics -Two types of Foaming

Two types of foaming are discussed in this paper:

- “True foaming”
- “Rapid volume expansion”

It is important to distinguish between these, since what helps one may actually aggravate the other. For example: decreasing mixing or using intermittent mixing seem to have major benefits in terms of reducing true foaming, but just the opposite, increasing mixing and continuous mixing, seem to have major benefits with respect to decreasing rapid volume expansion.

“True” foaming is what everyone thinks they are most familiar with:

- A separate foam phase is formed at digester liquid surface
- Usually foam is a semi stable or semi stable low-density material – like the head of foam on a glass of beer.
- Gas bubble size is about same or smaller than sludge particle size (stable foam)
- Liquid-Solids-Gas (see Figure 4)
- Solids and liquid constituents
- Bubbles stabilized by filaments and surfactants
- Dissolved flotation effects of biogas
- Sludge particles are accumulated in foam
- Dense foam
- Accumulates in AD tanks

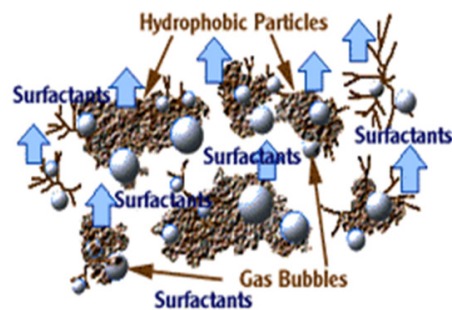


Figure 4: True foam

“Rapid Volume Expansion” is a recent recognition of a problem formerly called foaming that actually is something a bit different:

- The entire liquid volume of the digester has a rapidly dropping density, due to gas
- This is what happens when a bottle of beer is opened and the sudden pressure reduction allows gas to come out of solution and expands the volume of the beer; however the head that forms on top of the glass is true a foam.
- Holdup of gas within the liquid mass, with corresponding liquid expansion of entire liquid contents
- Sometimes causes a true foam layer on top to be pushed out of digester
- Often results in actual digested solids (not just foam) moving up and out of digester



Figure 5: Glass of beer (Chapman and Krugel 2011)

WERF INFR1SG10

A common problem cited in WWTPs is AD foaming, with many reported causes and numerous anecdotal prevention/control methods. Single-plant, specific cause-effect, investigations make up much of the available information. As WWTPs have started to implement processes such as biological nutrient removal and membrane bioreactors, AD foaming problems continue to persist and have been documented. WERF has commissioned this on-going, targeted collaborative research study (WERF INFR1SG10) to better understand the causes and impacts of AD foaming, identify and fill gaps in literature, and to identify successful methods for AD foam prevention and control (Pagilla, 2012).

Project Goals

- Literature Study to Identify State-of-the-Art and Gaps/Needs in Knowledge
- Plant Survey – Reconcile Literature Gaps with Survey Responses
- Full Scale Demonstrations to Address Gaps and Needs
- Develop a Guidance Document for the WWTP Industry on AD Foaming Prevention/Control

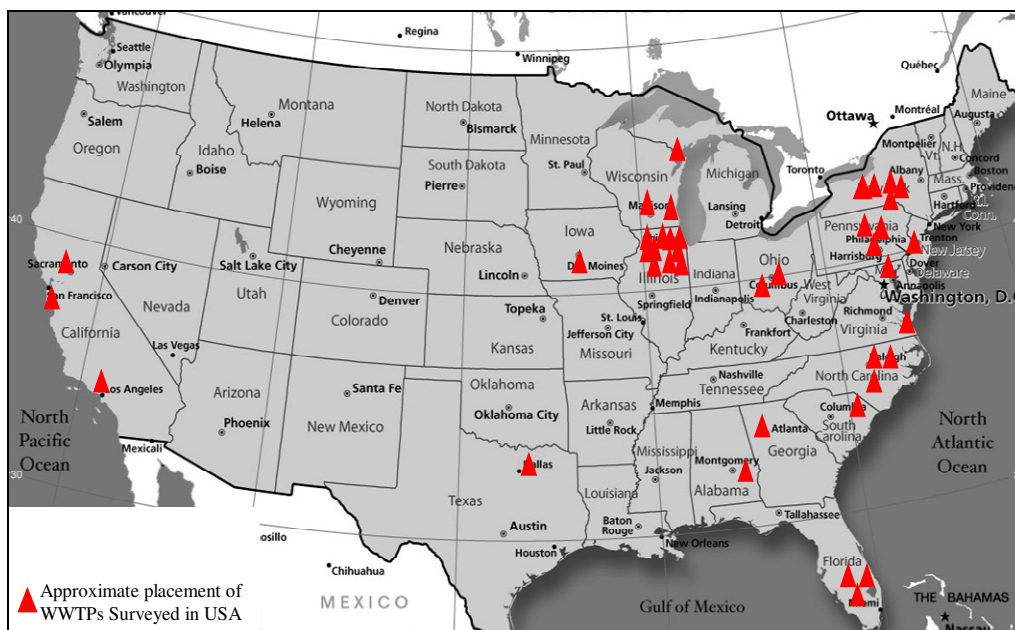


Figure 6: Location of WWTPs in Survey

Findings

39 wwtps were initially surveyed. Results show:

- 32 out the 39 WWTPs have AD foaming
- Foam occurs during all seasons
- Foam can be both intermittent and persistent
- Foam occurs for all activated sludge configurations
- Filaments are commonly associated with foaming incidents
- Surfactants/FOG can be associated with foaming incidents
- Foaming ADs are usually mixed continuously
- Top solutions tried include:
 - Defoaming chemicals
 - Uniform Loading
 - “Optimum Mixing”
 - WAS Chlorination may work in some cases
 - Thickening may work in some cases

There are still gaps and further needs. These are being addressed by conducting focused, full-scale investigations at select plants.

CSWEA Studies

The following is extracted from Schroedel et al 2011.

The Central States Water Environment Association, in response to member interest, formed an Ad Hoc Committee to help assess the occurrence, causes, and solutions to anaerobic digester foaming. Through an on-line survey and workshops, it was determined that foaming was relatively common, could have a variety of causes, may have a variety of solutions, and was worth further investigation.

Web Based Survey

A relatively brief survey was created and specifically designed so responding operators could complete the survey within a very few minutes without the need to reference a lot of technical information. Using the Survey tool available from the Associations’ web based email marketing service resulted in the development of simple, multi-choice response survey, along with the ability to add comments if desired in text boxes. Of the responses received, most included comments providing additional information on their specific process or their own insights into the digester foaming phenomenon.

Web Based Survey Results

It should be noted that the data were not evaluated for statistical relevance, and data verification was not conducted to determine data validity. The purpose of the survey was to collect “grass-roots” type information from plant operators to begin to demonstrate the extent of the problem, to garner interest by affected plant operators, and to assess whether obvious digester foaming trends could be identified based on the following parameters:

- Size of WWTP
- Type of liquid biological treatment (activated sludge, trickling filters, RBCs)
- Whether foaming in the activated sludge was present
- Whether the plant was operated to remove nutrients (ammonia, TN, P)
- Type of anaerobic digestion (conventional, thermophile, TPAD, acid-gas)
- Digester detention time
- Digester mixing system

Of the plants contacted, 94 plants (46%) completed the survey and provided useful data and information. Raw data results (including all comments) were downloaded into an Excel format file and analyzed by the survey results sub-committee. This committee published initial survey results in the spring issue of Central States Water magazine as part of an article announcing an upcoming Digester Foaming Workshop sponsored. The data indicated the following trends (among others):

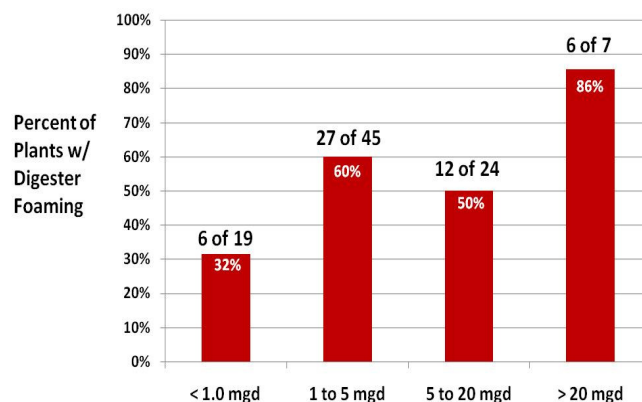


Figure 7: Foaming vs. WWTP capacity

- 50 WWTPs (53% of replies) had significant digester foaming problems within the last 10 years.
- In about half of the foaming cases, the cause of the problem was not determined.
- Nearly all of the larger WWTPs (> 20 mgd) experienced foaming problems (6 of 7 plants), whereas only 6 of 19 small plants (< 1 mgd) experienced foaming problems [Figure 7].
- WWTPs with activated sludge treatment were more likely to have digester foaming (59%) than WWTPs with trickling filters (40%) or RBCs (30%).
- Digester detention time appeared to have limited impact on digester foaming. Foaming was observed in approximately 60% of the WWTPs that had detention times of less than 10 days as well as in plants with detention times of great than 30 days.
- More than 60% of the plants that remove phosphorus experienced digester foaming, whereas about 30% of the plants with no phosphorus removal experienced foaming [Figure 8].
- Approximately 60% of the plants that remove ammonia experienced digester foaming compared to 38% of plants without ammonia removal.
- A slightly higher percentage of plants that have activated sludge foaming problems experience digester foaming problems compared to plants without activated sludge foaming problems (70% vs. 58%).
- The majority of respondents have conventional hemophilic digestion facilities, and 56% of conventional

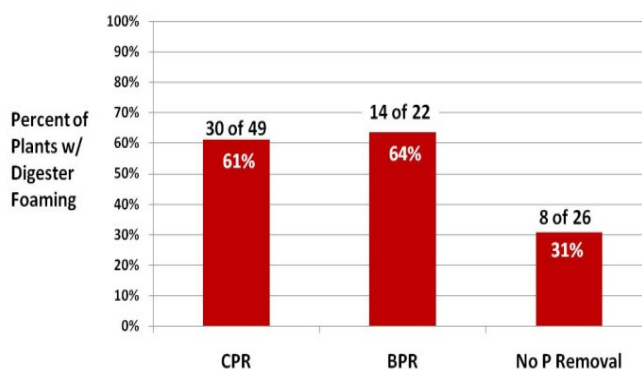


Figure 8: Foaming vs. P removal

systems experienced digester foaming. One plant has a thermophile-only digestion system (no foaming) and two plants have acid-gas digestion (also no foaming in either plant). TPAD system operators reported foaming in 3 of the 7 installations (43%).

- Digester mixing type appears to favor the liquid draft tube style [Figure 9].

Other data graphs are provided in the Appendix.

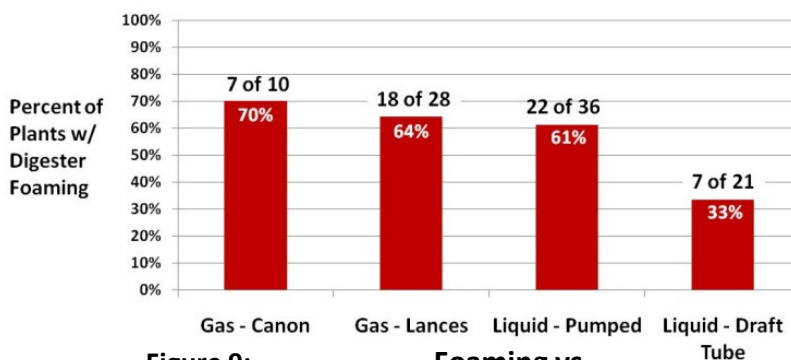


Figure 9:

Foaming vs.

Typical Causes of “True” Foaming

- *Nocardia* and *Microthrix Parvecella*
 - Thresholds for AS and AD Foaming are Different
 - Stable Foam (Stable for Hours)
 - High Solids Content
 - Definite Primary Cause of AD Foaming

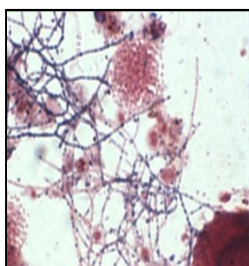


Figure 10: *Gordonia (Nocardia) amarae*

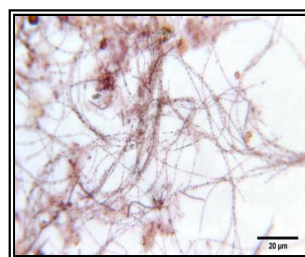


Figure 11: *Microthrix parvicella*

- Varying Feed Sludge Loadings (Quality & Quantity)
- VS Loading Rate and Variation
- Ratio of Primary Sludge to WAS
- High Ratio of WAS
- Surfactants
- Inconsistent or High VFAs (?)
- Low Influent Solids Concentration
- Mixing
 - Too little
 - Too much
 - Gas or mechanical
 - Continuous or intermittent
 - Fine bubble mixing

- Pumped mixing (too much nozzle velocity)
- Digester Configuration
 - Shape
 - Cover
 - Head space
- Operating Parameters
 - pH/Alkalinity
 - VA concentration
 - Temperature
 - Headspace Pressure
 - Gas Withdrawal Rate

Typical Causes –Rapid Volume Expansion

Chapman and Krugel (2011) list the following as being typically associated with rapid volume expansion:

- Digester startup
- Batch feeding
- Starting digester mixing
- Stopping digester mixing
- Changing direction of digester mixing
- Changing the intensity of digester mixing

Cure -Prevention and Control of True Foaming

- Physical Break-up by Sludge Sprays
- Chemical Addition (Defoamants, No Cl₂)
- Sludge Pre-Treatment Technologies
- Prevention
 - Uniform Sludge Feeding (flow and load)
 - Optimized Mixing (Not More Mixing!)
 - Control of Foaming in Liquid Treatment
 - Change in Digester Cover/Piping/Shape
- 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

Key Gaps and Needs – Full Scale Focus

WERF (Pagilla 2012) lists the following key gaps and needs:

- PS: WAS Solids Ratio Effects
- VSLR and VSLR variation Effects
- Biological versus Non-Biological Foaming
- Feed Sludge Holding Effects
- Defoamer Application Effectiveness
- Sludge Pre-Treatment Effectiveness
- Other Strategies (Foam Destroyer, Level Control, etc.)
- Methods (Foam Sensing, Potential, etc.)
- Fundamental Mechanisms
- Quantification of Impacts

Cures-Rapid Volume Expansion

The following is excerpted from Chapman and Krugel (2011):

- During startup digester feed should be at a reduced volume and gradually increased over time.
- Digesters should include a means to accommodate volume expansion to ensure the digester has the capability to safely remove sludge during a rapid expansion event.
- Appropriate digester gas system operating protocol and gas system safety features should be in place to prevent a rapid drop in pressure.
- A robust digester mixing system should be utilized to minimize dead volume. In addition, the mixing system should operate continuously.
- Changes in digester mixing direction should occur slowly to prevent a rapid change in gas holdup and a corresponding rapid change in the digester volume.
- When planning for a digester shutdown, the digester mixing system should be gradually reduced in speed and stopped over a period of time to prevent sudden changes in gas holdup
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- When planning for a digester shutdown, the digester mixing system should be gradually reduced in speed and stopped over a period of time to prevent sudden changes in gas holdup

A Few Last Words from Professor Pagilla

Foaming probably happens all the time because there is dissolved gas (biogas) flotation in the digesters all the time. Foaming problems happen when the physical system cannot handle the amount of foam generated. For example, a foam trap and drainage system on the gas collection piping eliminates the problems in gas treatment systems (scrubbers, etc.)

The issue of rapid collapse of foam is serious issue. We believe that this happens due to too high solids content in the foam progressively, making it unstable at some point (goes back to the fundamental foam formation mechanisms).

As long as the AD is maintained with relatively uniform solids concentration throughout the volume and uniform temperature, there is no need for mixing above and beyond that. At the bottom, you need supplemental mixing because the "natural" gas mixing due to biogas production is not sufficient to keep the solids in suspension. But at the top, there is plenty of gas escaping into the gas dome, and should be sufficient to keep the solids in suspension. Lastly, the use of pumped mixing is common and is important to understand it in terms more than number of turnovers. The location of the inlet and the nozzle velocity are important.

Summary

Foaming in Anaerobic Digesters is a significant and widespread problem in the US

- Various US organizations are currently investigating problem
 - This presentation presents information from and about CSWEA and WERF studies
- Two types of foaming identified
 - "True"
 - Rapid Volume Expansion
- Causes and Cures do not completely overlap
- Various causes and mechanisms have been identified, including physical causes, biological causes, and chemical causes as well as operational and design causes.
- The most effective operational, design, and chemical "cures" observed to date are also presented

Acknowledgements

Much of this material was extracted directly from co-authors' and co-authors' organization presentations and previously published/presented elsewhere by IIT, CSWEA, WEF and WERF. Sincere thanks to all.

References

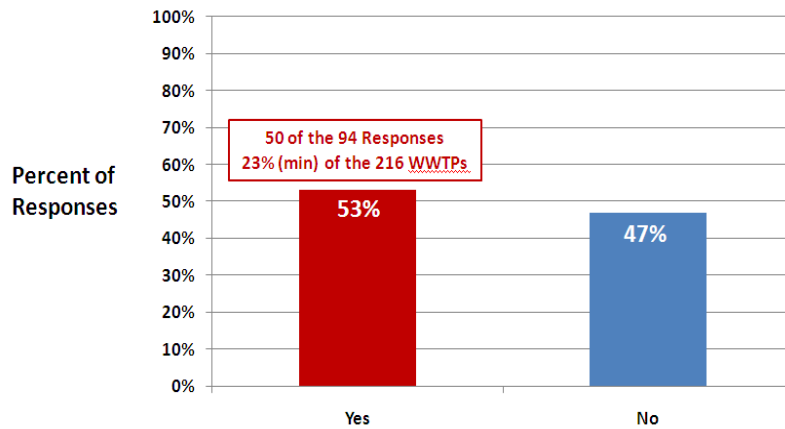
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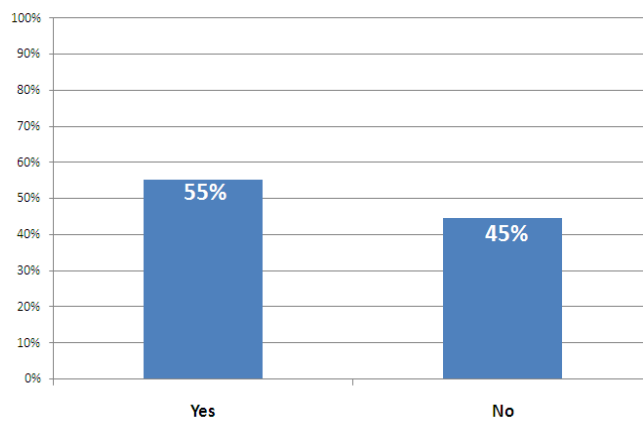
Pagilla, K. (2012) ANAEROBIC DIGESTER FOAMING CAUSES/EFFECTS/PREVENTION/CONTROL. WERF WEBINAR

APPENDIX

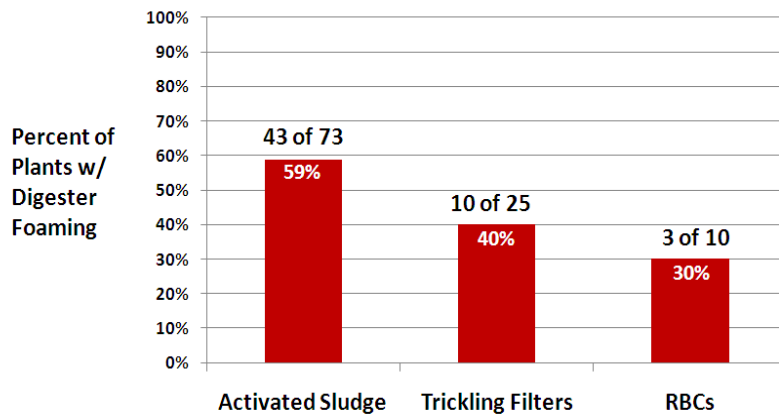
- **Significant Digester Foaming in Last 10 Years?**



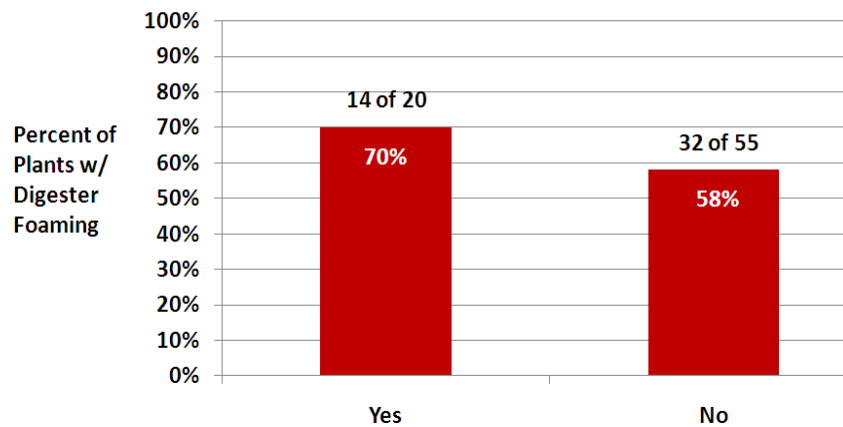
- **Was Cause of Digester Foaming Determined?**



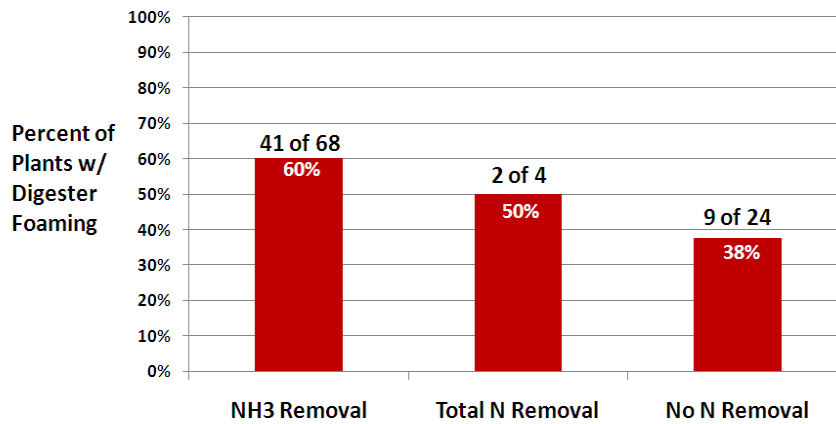
Type of Biological Treatment



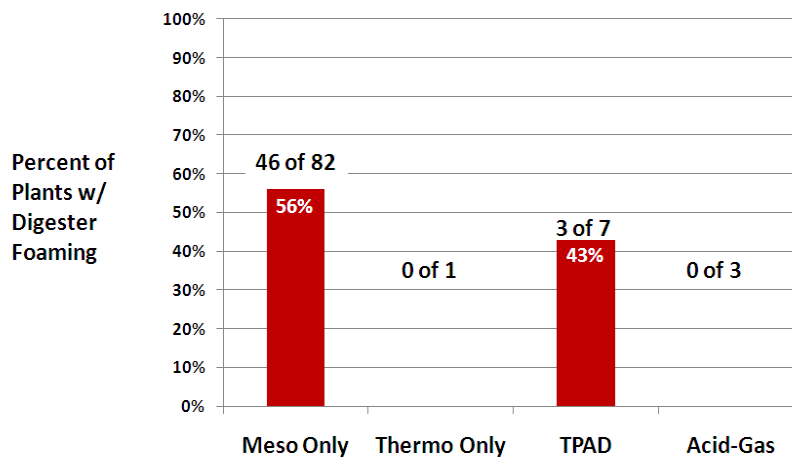
Foaming in Activated Sludge?



Nitrogen Removal



Digestion Process



Digester Detention Time

