Presentation Outline

- Objectives and Tasks
- Literature Review
  - Digester Foaming Background
  - Causes of Foaming
  - Impacts of Foaming
  - Control, Prevention and Mitigation
- Identified Gaps
- Survey Study
- Full Scale Case Studies
Major Tasks of WERF INFR1SG10

1. Literature Study to Identify State-of-the-Art and Gaps/Needs in Knowledge
2. Plant Survey – Data and List of Plants for Study
3. Full-Scale Studies at Selected WWTPs
4. Synthesis of Data and Determine Findings
5. Develop a Guidance Document to Outline Successful Foam Mitigation Measures
Foam in Wastewater Applications
Foam in Wastewater Applications

- Three phase foam (liquid-solid-gas)
  - Solids & soluble constituents
  - Floatation effects of gas
- Mechanistic aspects
  - Contribution of each of the phases
  - Bubble sizes
  - Sludge properties
  - Phase interactions
- Classification of foam
- Visual appearance of types of foam
## Foaming Causes & Contributors

<table>
<thead>
<tr>
<th>Classification</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sludge feed characteristics</strong></td>
<td>Surface active agents in feed</td>
</tr>
<tr>
<td></td>
<td>Foam causing filaments in feed sludge</td>
</tr>
<tr>
<td><strong>Digestion process-related characteristics</strong></td>
<td>Organic loading aspects – overload and inconsistent loading</td>
</tr>
<tr>
<td></td>
<td>VFA production - Imbalances between the successive hydrolysis,</td>
</tr>
<tr>
<td></td>
<td>acidogenesis and methanogenesis</td>
</tr>
<tr>
<td></td>
<td>Gas production</td>
</tr>
<tr>
<td><strong>Digester operating conditions</strong></td>
<td>Temperature, pH, Alkalinity</td>
</tr>
<tr>
<td></td>
<td>Mixing</td>
</tr>
<tr>
<td><strong>Digester configuration, shape and physical features</strong></td>
<td>Digester shape and configuration</td>
</tr>
<tr>
<td></td>
<td>Sludge withdrawal and gas piping</td>
</tr>
</tbody>
</table>
Feed-Based Characteristics

- Feed Quality - affect surface activity of digester contents
  - Proteins
  - Lipids (FOG)
  - Detergents
    - Degradation of the nonionic detergents was 27% and anionic was 7%.
- Filaments - *Microthrix parvicella* and *Gordona amarae*
  - Stabilize gas bubbles in the digester due to their surface active nature
  - Produce EPS that add to the total surface active material in the digester.
Digestion Process-Related Causes

- Formation of surface active agents in digester
  - EPS (biosurfactants)
- VFA
- Quantity of feed (OLR) & inconsistent feed
- PS:WAS solids in digester feed
- Gas production

Diagram:
- Complex polymers in feed
  - Proteins
  - Carbohydrates
  - Lipids
  - Hydrolysis
  - Fermentation / Acidogenesis
    - Intermediate products: Eg. Butyric, Propionic acids (SFA/VFA)
  - Beta-oxidation / Acetogenesis
    - Acetic Acid (VFA), CO
  - Methanogenesis
    - Methane, CO₂

* - Possible foam cause/contributor
# Common OLR for Anaerobic Digesters

<table>
<thead>
<tr>
<th>Source</th>
<th>OLR (kg VS m³ d⁻¹)</th>
<th>OLR (lbs VS ft³ d⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handbooks of UK Wastewater Practice (1996)</td>
<td>0.8 – 1.6</td>
<td>0.05 – 0.1</td>
</tr>
<tr>
<td>Metcalf and Eddy (2003)</td>
<td>1.6 – 4.8</td>
<td>0.1 – 0.3</td>
</tr>
<tr>
<td>Brown (2002)</td>
<td>&lt; 4.5</td>
<td>&lt; 0.28</td>
</tr>
<tr>
<td>Gerardi (2003)</td>
<td>designed: 3.2 – 7.2 (usually 0.5 – 0.6)</td>
<td>0.2 – 0.45 (usually 0.03 – 0.04)</td>
</tr>
<tr>
<td>Lamelot (2004)</td>
<td>&lt; 2.5</td>
<td>&lt; 0.15</td>
</tr>
<tr>
<td>Braguglia et al.,</td>
<td>0.7 – 1.4</td>
<td>0.04 – 0.09</td>
</tr>
<tr>
<td>Bolzonella (2005)</td>
<td>~ 1</td>
<td>~ 0.06</td>
</tr>
</tbody>
</table>

**Values for Foaming Digesters in Literature**

<table>
<thead>
<tr>
<th>Source</th>
<th>Value</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moeller et al., 2010</td>
<td>4</td>
<td>0.25</td>
</tr>
<tr>
<td>Ganidi et al., 2011</td>
<td>2.5 - foam initiation ; 5 - persistent foaming</td>
<td>0.15 - foam initiation ; 0.3 - persistent foaming</td>
</tr>
</tbody>
</table>
Digester Physical Features and Operational Causes

- **Physical Features**
  - Digester Shape
    - ESD vs. cylindrical
  - Sludge withdrawal
    - Hydraulic vs. valve methods
  - Gas collection piping

- **Operational Causes**
  - Temperature
  - Mixing (intended/unintended)
    - Type – gas or mechanical
    - Power and/or frequency
PREVENTION AND CONTROL OF FOAMING

- Sludge Disintegration Methods
- Operational Modifications to Prevent/Control Foaming
  - Control of the secondary treatment process and associated WAS
  - Control of the feed sludge storage and feeding
  - Control of the digester physical features
- Chemical Antifoaming Agents for Foam Control
  - Antifoams/Defoamers (Eg. Tramfloc, Fibrochem)
  - Coagulating Salts and Polymers (Eg. PAX-14)
  - Chemical Oxidants (Eg. Chlorine, H₂O₂)
Sludge Disintegration Methods

• Thermal hydrolysis (commercial manufacturers Cambi and Kruger (BioTHELSYS))
• Direct steam injection
• Pastuerization (commercial manufacturers Eco-Therm (Ashbrook) and BioPasteur (Kruger))
• Electric-pulsing (OpenCel)
• The Crown sludge disintegration system (Siemens) and Micro Sludge (Paradigm Environmental Technologies)
• Ultrasonic cavitation (Sonolyzer system (EIMCO), the DIRK power ultrasound system, and the Sonix system (Sonico))
How Antifoams Work

Antifoams

(a) Antifoam drop
(b) Entering the surface
(c) Leading to rupture of the film.
Impacts of Foaming

Operational difficulties caused by AD foaming incidents are:

- Reduced active volume resulting in lowered gas production and VS destruction.
- Tank mechanical and structure failure due to foaming.
- Significant maintenance required for cleaning biogas piping and foam overspills.
- Potential short-circuiting of pathogens due to lower active volume in the digester.

Classification of Impacts

- Qualitative Impacts
  - Performance Related Impacts
  - Operational Impacts
  - Regulatory Impacts
- Economic Impacts – Not available
Identified Knowledge Gaps

• Practical foam indication and measurement techniques
• Surface active compound threshold concentrations
• Optimum ratio for PS to WAS in digester feed
• In the case of combined sludge,
  – (a) effect of holding tank residence time on foaming,
  – (b) effects of mixing primary sludge & WAS in storage - increased HRT and VFA production
• Feed microbiological thresholds and generation of surface active compounds by filaments
Identified Knowledge Gaps

• Effects of
  – feed rate on instantaneous gas production and withdrawal rate and foaming
  – defoamers/antifoams on foaming and digester performance

• Quantify economic impacts due to AD foaming in full scale plants, using economic data gathered from various plants.
SURVEY OF FULL SCALE PLANTS

Objectives:

- To determine the current status of full scale AD foaming in WWTPs.
- Obtain information beyond available in the published or grey literature.
- Obtain a list of diverse plants to conduct full scale studies.
- Reconcile gaps found in published literature with these full scale plants.
SURVEY - OVERVIEW

- Total 77 plants
  - 39 in the USA; 38 in Spain
  - Plants in USA - Envirofac's and prior foaming knowledge.
  - Plants in Spain - ACA (Catalan Water Agency) and the rest by DAM (Depuración de Aguas del Mediterráneo).
- Number of plants foaming
  - USA - 32
  - Spain – 22
- Questionnaire based on our literature review
- Knowledge gaps reconciled with survey responses
  - Parameters selected for full scale study
Map of US Utilities Surveyed
Map of Spanish Utilities Surveyed
Interim Observations from Survey Responses

• Most common reported cause is the presence of filaments.
  – Foaming thresholds for the filaments is much lower in the anaerobic digesters than in activated sludge.
• The second most common reported cause of foaming was feed sludge quality and the presence of FOG and other surface active materials in the feed to the digester.
• Relationships between surface active material in feed sludge, point of introduction in the treatment stream and foaming – N/A.
• Differentiate between the causes and contributing factors to the foaming episodes in the plants surveyed – N/A
• No conclusive trend in %WAS in feed could be established.
• No conclusive trend established between mixing types.
Full Scale Study Parameters

• Modifying WAS in digester feed to determine the effect of PS:WAS ratio, particularly in the plants not experiencing filamentous foaming.

• Modifying different OLRs for full scale digesters in an attempt to determine threshold loading rates for each digester is necessary.

• Frequency of feed and mixing of digesters concurrently.
  – Areas of localized overloading near the feed inlets if fed only for a certain period of time in a day, not mixed during the feeding.

• Survey reported utilities were successful in controlling foaming with antifoams, which will be tested in a full scale plant in this study.