Full Scale Digester Mixing Performance – Nozzle, Linear Motion, or NONE

CSWEA
88th Annual Meeting
Oakbrook Terrace, IL
May 19, 2015
Presentation Outline

➢ Background
  ▪ South Shore WRF
  ▪ South Shore Digesters
    • Mixing & Digestion Performance

➢ Evaluation
  ▪ Screening Alternatives
  ▪ Test Plan
  ▪ Results

➢ Plans for the Future
Milwaukee Metropolitan Sewerage District (MMSD)

- Regional Water Resources & Wastewater Utility
- Service Population = 900,000
- Two Water Reclamation Facilities
  - Jones Island WRF (80 mgd Avg, 390 mgd Peak)
  - South Shore WRF (100 mgd Avg, 300 mgd Peak)
  - Interconnected by 12-mile Solids Pipeline System
South Shore Water Resources Facility (WRF)

- Located on Shore of Lake Michigan in Oak Creek, WI
- Constructed 1965
- Processes Include
  - Preliminary Treatment, Primary Clarification
  - Nitrifying Activated Sludge, Effluent Disinfection
  - Waste Activated Sludge Transferred to Jones Island for Milorganite Production
  - Anaerobic Digestion, Normally of Primary Sludge
  - Digested Sludge Transferred to Jones Island for Milorganite Production
Interplant Solids Pipeline

Primary Sludge

WAS & Digested Sludge

Thickening

Digestion

Milorganite
South Shore WRF

Sludge Treatment

Liquid Treatment
South Shore Digesters

- Four Large, 125’ Diameter, 37’ SWD, ~3.25 MG Digesters (#9-12)
- Eight Older 110’ Diameter, 20’ SWD, 1.5 MG Digesters (#1-8)
- Six of eight older digesters converted to thickened sludge storage
South Shore Digesters #9-12

- Buried with Concrete Covers Including 16 Support Columns
- Operated in Mesophilic Temperature Range Using Sludge Recirculation Heating
- Digester Gas Utilization Includes:
  - 5 Engine-Driven Generators with Heat Recovery (5.2 MW)
  - Dual Fuel Hot Water Boilers
SS Digesters Original Mixing

- Digesters 1-4 Lance Type Gas Mixing Systems
- Digesters 5-8 Internal Draft Tube Mechanical Mixers
- Digesters 9-12 Atara Gas Cannon Mixers Installed in 1988
SS Digester Mixing & Performance

- Experience With Each System Relatively Poor
  - Ineffective Mixing, Solids Stratification
  - Debris/Grit Accumulations found to Occupy Approximately 1/3 of Digester Volume during digester cleaning

- 2010/2011 Digestion Results
  - SRT/HRT Ranged from 8-15 days
  - Volatile Solids Reduction/Destruction (VSR) Average 40%

- Well Operated Digestion of **Primary Sludge** Should Be Able to Achieve 50-60% VSR
SS Digester Mixing Evaluation

- Decision Made to Investigate Improved Mixing
- Key Goals/Aims
  - Reliable, Efficient, and Cost-Effective (PW Basis)
  - Improved Mixing/Reclaiming Dead Digester Volume Should
    - Increase SRT to Minimum 15 Days
    - Decrease Solids Mass for Disposal
    - Increase Biogas Production
  - Capacity Regained may be Used for Accepting High Strength Wastes to Further Boost Biogas Production
## Mixing Technology Screening

<table>
<thead>
<tr>
<th></th>
<th>Pump and Nozzle</th>
<th>Draft Tube</th>
<th>Linear Motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Installations</td>
<td>Many</td>
<td>Many</td>
<td>Few</td>
</tr>
<tr>
<td>Equipment Manufacturers</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Number of Units per Tank</td>
<td>2 pumps, 11 nozzles</td>
<td>6 draft tubes</td>
<td>3 mixers</td>
</tr>
<tr>
<td>Horsepower per Unit</td>
<td>100 hp</td>
<td>15 hp</td>
<td>15 hp</td>
</tr>
<tr>
<td>Energy Input</td>
<td>0.4 hp/1,000 ft³</td>
<td>0.2 hp/1,000 ft³</td>
<td>0.1 hp/1,000 ft³</td>
</tr>
<tr>
<td>Install in “Buried” Tanks</td>
<td>Yes</td>
<td>Internal draft tube only</td>
<td>Yes</td>
</tr>
<tr>
<td>Install in Large Tanks</td>
<td>Yes</td>
<td>Yes</td>
<td>Few</td>
</tr>
<tr>
<td>Moving Parts in Tank</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Empty Tank to Maintain</td>
<td>Yes/No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Potential for rags to collect on system</td>
<td>No</td>
<td>Yes</td>
<td>No?</td>
</tr>
<tr>
<td>Preliminary Capital Cost for SSWRF Digesters</td>
<td>$6,184,000</td>
<td>$10,460,000</td>
<td>$6,426,000</td>
</tr>
<tr>
<td>Considered for the SSWRF Digesters</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
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</table>
Technologies Selected for Evaluation

Linear Motion Mixing

Pump and Nozzle Mixing
Key SSWRF Digester Challenges

- **Pump and Nozzle Mixing**
  - Digester Size Required Dual Pump System
  - Concern Over Potential Vivianite Formation in mixing system

- **Linear Motion Mixing**
  - No Installations of This Size/Volume
  - None with Interior Support Columns
  - CFD Analysis Results in Need for 3 LM Mixers, No Existing Installations with Multiple Mixers
  - Some mechanical issues at existing installations
Mixing Technologies Bidding

- Construction Bid Documents Provided Three Bid Alternates
  1. Pump and Nozzle Mixing in Two Digesters $3.6M
  2. Linear Motion Mixing in Two Digesters $3.3M
  3. Pump and Nozzle Mixing in One Digester + Linear Motion Mixing in One Digester $3.7M
- MMSD Selected Alternate 3 for Construction and Evaluation
Digester 12: Pump & Nozzle
Digester 10: Linear Motion
Evaluation Criteria

- Full Scale Evaluation of the Mixing Technologies to Assess Future Improvements
- Capital Cost
- Digestion Test Performance
  - VSR
  - Digester Volume Utilization/Cleaning Requirements
- Mixing Energy
- Maintenance/Reliability
Evaluation Performance Testing

Test Digesters
- Digester 10 – Linear Motion Mixing System
- Digester 12 – Pump and Nozzle Mixing System

Test Parameters
- Maintain 15 Day SRT @ 95 Deg F

Evaluation Monitoring Criteria
- VSR
- Gas Production
- Mixing Energy
Evaluation Period 1

- August 4-September 19, 2014
  - Test Flow/Loading Control Problems
    - SRT Varied, Averaged 22 Days
  - Issue with IPS Pipeline Resulted in Need to Digest SS WAS
  - Individual digesters sampler problems
  - Inconclusive
Evaluation Period 2

November 17-December 19, 2014

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Digester 10 (LM)</th>
<th>Digester 12 (P&amp;N)</th>
</tr>
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<tbody>
<tr>
<td>SRT</td>
<td>Days</td>
<td>15.6</td>
<td>15.8</td>
</tr>
<tr>
<td>VA/Alk Ratio</td>
<td>---</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>VSR</td>
<td>%</td>
<td>57.8</td>
<td>56.6</td>
</tr>
<tr>
<td>Gas Production</td>
<td>cf/lb VS Removed</td>
<td>20.7</td>
<td>21.3</td>
</tr>
<tr>
<td>Mixing Energy</td>
<td>kW/1,000 lb VS Destroyed</td>
<td>1.15</td>
<td>5.62*</td>
</tr>
</tbody>
</table>

*Pump & Nozzle system operated with On/Off operation and VFD speed control.
Testing Conclusions

- **Pump & Nozzle**
  - More research needed to evaluate optimal use of VFD and On/Off controls to minimize energy while providing consistent & reliable performance.

- **Linear Motion**
  - Achieved equal digestion performance at significantly less energy consumption.
  - LMM mixers have operated without mechanical issue for 1.5 years. Winter 2013/14 was very cold.
Overall Evaluation Results

- **Capital Cost: Linear Motion System Favored**
  - Pump & Nozzle: Based on Project Bidding ~$260,000 higher installed cost per large digester.
  - Full implementation of Pump and Nozzle requires increased electrical capacity at MCC (~$1M).

- **O&M Cost: Linear Motion System Favored**
  - Equivalent maintenance costs, No LMM issues to date.
  - Linear Motion energy ~80% lower than Pump & Nozzle

- **Digestion Performance: Considered Equal**

- **Conclusion: Linear Motion Selected for Future**
# Overall Evaluation Results

<table>
<thead>
<tr>
<th></th>
<th>Unmixed Digester</th>
<th>Pump and Nozzle</th>
<th>Linear Motion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mixing System Cost</strong></td>
<td>$0</td>
<td>$208,000</td>
<td>$542,000</td>
</tr>
<tr>
<td><strong>Installed Cost</strong></td>
<td>$0</td>
<td>$1,526,000</td>
<td>$1,346,000</td>
</tr>
<tr>
<td><strong>Cleaning Cost</strong></td>
<td>$325,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Average HP Demand</strong></td>
<td>0</td>
<td>150</td>
<td>45</td>
</tr>
<tr>
<td><strong>Annual Energy Cost</strong></td>
<td>0</td>
<td>$75,000</td>
<td>$24,000</td>
</tr>
<tr>
<td><strong>SRT</strong></td>
<td>21 days</td>
<td>15 days</td>
<td>15 days</td>
</tr>
<tr>
<td><strong>Volatile Solids Destr.</strong></td>
<td>62%</td>
<td>57%</td>
<td>58%</td>
</tr>
<tr>
<td><strong>Unit Gas Production</strong></td>
<td>20 ft³/lb VSd</td>
<td>21 ft³/lb VSd</td>
<td>21 ft³/lb VSd</td>
</tr>
</tbody>
</table>
Current Status

- Overall SSWRF Digestion Performance Has Improved
  - Digesters 10 & 12 Getting Majority of Feed Sludge
    - Maintained at 15 day SRT or greater with full active volume
    - Unmixed Digesters true SRT >15 days due to decreased loadings
  - VSR Has Increased from 48% to 61%
  - Current Operations (Digesters 10/12 mixed, 9/11 unmixed) Provide Adequate Capacity for Near Term Requirements
    - Adding mixing to other digesters not currently required
Current Status

➢ Linear Motion Mixing is Preferred Technology if Decision is Made to Add Mixing to Other Digesters in the Future
   ▪ Significant energy savings compared to P&N
   ▪ Have been very reliable for 1.5 years including 2 winters (winter 2013-2014 was very cold).

➢ District is Now Pursuing additional HSW to Increase Digester Loadings, Biogas Production and Energy Recovery via Engine Generators.
Acknowledgements

- MMSD
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  - Todd Schwingle
Thanks for Your Attention!

- Dennis Dineen
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