EVALUATION OF PROCESSES TO REDUCE ACTIVATED SLUDGE SOLIDS GENERATION AND DISPOSAL
05-CTS3
Acknowledgements

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• Royce Hammitt (Des Moines)
WSR Affect Waste Solids Fractionation

Waste Solids

Biodegradable

- Fast
- Slow
- Very Slow

Non-Biodegradable

- Organic
- Inorganic
Sludge Reduction Mechanism Hypotheses

• Physical/Chemical Sludge Reduction Technologies
  – Solubilize sludge solids and lyse cells, thereby increasing the rate of degradation
  – Render the non-degradable organic fraction degradable, thereby increasing the extent of degradation

• Biological Sludge Reduction Technologies
  – Cycling of decay products through variable environmental conditions to increase overall organic conversion to gas
The Sludge Reduction Technology Marketplace is Very Active

- Extended Aeration
- Cannibal™
- Ozonation

- Homogenization
- Pressure Release
- Sonication
- Thermal Hydrolysis
- Pulsed Electric Field

- Thermophilic Digestion
- Phased Digestion
- Acid/Enzymatic Hydrolysis
- Post Aerobic Digestion
Cannibal™

- Siemens Cannibal™ builds on the “extended aeration” concept
- Versions in operation since 1998
Cannibal Step 1 – Physical

Solids separation module (SSM)
- Fine drum screen (250 um)
  - treats part of RAS continuously
- Hydrocyclones
  - intermittent use
  - classifier produces grit/inert material
- Total inerts
  - 0.2 to 0.3 kg/kg BOD
  - dewatered to 30-40% TS
  - is 90% volatile
  - disposed in landfill
Cannibal Step 2 – Biological

- **Interchange Reactor**
  - WAS (<1% TS) sent to reactor
  - WAS set by AS SRT 8 to 15 d
  - Interchange reactor SRT 10-12 d
  - Intermittent aeration (SBR) controlled by ORP (anoxic/anaerobic)
  - Portion returned to aeration basins daily

- **Annual Solids Purge**
  - < 0.1 kg/kg BOD
Soluble COD data from Cannibal™ WWTPs
Physical Cell Lysis Processes
Cambi – Thermal Hydrolysis

**RAW SLUDGE**
- Living bacteria
- Dead bacteria
- Inert suspended solids (SS)
- EPS

**THERMAL HYDROLYSIS**
- Raw sludge 16 - 17% DS
- PULPER
  - Preheated to ~97°C, homogenized and reduction of viscosity.
  - Retention time ~1.5 h
- REACTOR
  - Batch process 165°C / 6 bar.
  - Retention time 20 min.
- FLASH TANK
  - Temp 102°C
  - Retention time ~1.5 h
- Process gases are cooled and compressed before sent to digesters to be broken down
  - Homogenized material 14 - 15% DS
  - Steam 11 bar
  - Reuse of steam
  - Hydrolyzed material 12 - 13% DS (1.5 - 2 bar)
  - Hydrolyzed material to digesters 8 - 12% DS
  - Dilution water

**HYDROLYZED SLUDGE**
- Hydrolyzed SS
- Cell content
- Cell wall
- Inert suspended solids (SS)
- Hydrolyzed EPS
Kruger Exelys – Thermal Hydrolysis

Primary + Secondary sludge

Steam mixer + condenser

Reactor

Sludge: 165°C, 9 bar, ~20%DS, t ≥ 30 min

Steam Generator

Heat exchanger

Dilution water

To digester
Hydrolyzed Sludge

35-40°C
8-10%DS

Recovered heat

Biogas

CHP unit

Electricity + Heat

+100% capacity

1st dewatering

Sludge: ≥ 20%DS

Final dewatering

Energy recovery

Digester
## Cambi Claimed Performance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mesophilic AD</th>
<th>CAMBI + Meso AD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digester Feed (%TS)</td>
<td>4-6</td>
<td>12-15</td>
</tr>
<tr>
<td>VSLR (kg VS/m$^3$/d)</td>
<td>1.5</td>
<td>3.5</td>
</tr>
<tr>
<td>VS Destruction (%)</td>
<td>40-55</td>
<td>55-65</td>
</tr>
<tr>
<td>Pathogen content</td>
<td>Class B</td>
<td>Class A</td>
</tr>
<tr>
<td>Dewatered Cake TS (%)</td>
<td>20-25</td>
<td>30-35</td>
</tr>
</tbody>
</table>
## DCWASA Performance Data Summary for the Cambi Pilot Study

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conventional Mesophilic Digestion (20-day SRT)</th>
<th>Cambi™ – 15-day SRT</th>
<th>Cambi™ – 20-day SRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>VSr</td>
<td>50%</td>
<td>58%</td>
<td>60%</td>
</tr>
<tr>
<td>Ammonia</td>
<td>1,430 mg/L</td>
<td>2,446 mg/L</td>
<td>2,134 mg/L</td>
</tr>
<tr>
<td>Dewatered %DS</td>
<td>24%</td>
<td>34–36%</td>
<td>34–36%</td>
</tr>
<tr>
<td>Cake Odor</td>
<td>N/A</td>
<td>Improved by 80–90%</td>
<td>Improved by 80–90%</td>
</tr>
</tbody>
</table>
## The Thermal Hydrolysis Market

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Full-Scale Facilities</th>
<th>Capacities dtpy</th>
<th>Since</th>
<th>Intent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambi - THP</td>
<td>&gt;20</td>
<td>2,200 to 163,000</td>
<td>1995</td>
<td>Digester pretreatment for Class A</td>
</tr>
<tr>
<td>Kruger - Exelys</td>
<td>1 (+2)</td>
<td>2,400 to 22,000</td>
<td>2010</td>
<td>Digester pretreatment for Class A</td>
</tr>
<tr>
<td>Kruger - Biothelys</td>
<td>&gt;4 (+2)</td>
<td>1,000 to 30,000</td>
<td>2004</td>
<td>Digester pretreatment for Class A</td>
</tr>
<tr>
<td>EnerTech - SlurryCarb</td>
<td>1</td>
<td>56,000</td>
<td>2009</td>
<td>Bio-fuel</td>
</tr>
</tbody>
</table>
Pressure Release

Vendor claims

• A minimum 20% increase in Biogas production.
• A minimum 15% reduction in dehydrated sludge volume
• Carbon augmentation for BNR

Siemens Crown Disintegrator
Wiesbaden WWTP - 60m3/hr
<table>
<thead>
<tr>
<th>Site Name</th>
<th>VSr %</th>
<th>% inc</th>
<th>Biogas yield cf/lb VS des</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>% inc</td>
</tr>
<tr>
<td>Wiesbaden Biebrich</td>
<td>32%</td>
<td>38%</td>
<td>20.0%</td>
</tr>
<tr>
<td>Taunusstein</td>
<td>32%</td>
<td>44%</td>
<td>38.9%</td>
</tr>
<tr>
<td>Ingelheim</td>
<td>36%</td>
<td>49%</td>
<td>34.1%</td>
</tr>
<tr>
<td>Ginsheim</td>
<td>45%</td>
<td>54%</td>
<td>19.9%</td>
</tr>
<tr>
<td>Münchwilen</td>
<td>32%</td>
<td>43%</td>
<td>32.0%</td>
</tr>
<tr>
<td>Rosedale WWTP</td>
<td>51%</td>
<td>62%</td>
<td>21.6%</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>38.1%</strong></td>
<td><strong>48.3%</strong></td>
<td><strong>27.7%</strong></td>
</tr>
</tbody>
</table>
## Crown Claimed Performance

<table>
<thead>
<tr>
<th>Site Name</th>
<th>DS after dewatering %</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>% increase</td>
<td></td>
</tr>
<tr>
<td>Wiesbaden Biebrich</td>
<td>31</td>
<td>36</td>
<td>16.1%</td>
<td></td>
</tr>
<tr>
<td>Taunusstein</td>
<td>31</td>
<td>36</td>
<td>16.1%</td>
<td></td>
</tr>
<tr>
<td>Ingelheim</td>
<td>28</td>
<td>34</td>
<td>21.4%</td>
<td></td>
</tr>
<tr>
<td>Ginsheim</td>
<td>20</td>
<td>23.4</td>
<td>17.0%</td>
<td></td>
</tr>
<tr>
<td>Münchwilen</td>
<td>22</td>
<td>26.4</td>
<td>20.0%</td>
<td></td>
</tr>
<tr>
<td>Rosedale WWTP</td>
<td>18.5</td>
<td>22.2</td>
<td>20.0%</td>
<td></td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>25.1</strong></td>
<td><strong>29.7</strong></td>
<td><strong>18.4%</strong></td>
<td></td>
</tr>
</tbody>
</table>
• NaOH to weaken cell membranes and reduce viscosity (pH 9 to 10)
• Chopper pump to break up agglomerates
• Screen to 800 μm to remove non-cellular debris
• Homogenizer pressure 82,700 kPa (12,000 psig) for cell lysis
## Des Moines WRF Study

<table>
<thead>
<tr>
<th>Digester Number</th>
<th>Digester Feed (TS Basis)</th>
<th>HRT (Days)</th>
<th>Organic Loading Rate (Kilograms Volatile Solids/m³ day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>56% TWAS + 44% PS</td>
<td>20, 15, 10, 7</td>
<td>1.45, 1.76, 2.68, 4.10</td>
</tr>
<tr>
<td>2</td>
<td>56% MicroSludge™ TWAS + 44% PS</td>
<td>20, 15, 10, 7</td>
<td>1.45, 1.76, 2.68, 4.10</td>
</tr>
<tr>
<td>3</td>
<td>100% raw TWAS</td>
<td>15</td>
<td>1.83</td>
</tr>
<tr>
<td>4</td>
<td>100% MicroSludge™ TWAS</td>
<td>15</td>
<td>1.83</td>
</tr>
</tbody>
</table>
Volatile Solids Reduction in Control and Test Digesters

![Graph showing VS Reduction vs. Digester HRT]
## Total Volume of Biogas Produced

<table>
<thead>
<tr>
<th>HRT</th>
<th>No. of days of operation</th>
<th>Total Biogas Production in Control (L)</th>
<th>Total Biogas Production in Test (L)</th>
<th>% Increase in Biogas Production in Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>86</td>
<td>20,392</td>
<td>24,045</td>
<td>15</td>
</tr>
<tr>
<td>15</td>
<td>17</td>
<td>5,376</td>
<td>6,093</td>
<td>12</td>
</tr>
<tr>
<td>10</td>
<td>51</td>
<td>21,954</td>
<td>26,796</td>
<td>18</td>
</tr>
<tr>
<td>7</td>
<td>77</td>
<td>22,619</td>
<td>25,304</td>
<td>11</td>
</tr>
</tbody>
</table>
VFA Production

**TWAS**

<table>
<thead>
<tr>
<th>Incubation day</th>
<th>mg/L as HAc</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>5000</td>
</tr>
<tr>
<td>3</td>
<td>10000</td>
</tr>
<tr>
<td>5</td>
<td>15000</td>
</tr>
</tbody>
</table>

**Micro sludge**

<table>
<thead>
<tr>
<th>Incubation day</th>
<th>mg/L as HAc</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>5000</td>
</tr>
<tr>
<td>3</td>
<td>10000</td>
</tr>
<tr>
<td>5</td>
<td>15000</td>
</tr>
</tbody>
</table>

- HAc
- HPr
- HBu
- Total VFA
Results from Des Moines Study

• Lower odor generation potential for MicroSludge™ treated TWAS.
• Direct formation of VFAs; Higher methanogenic activity for MicroSludge™ treated TWAS.
• Little VSr and CODr improvement at 20d SRT; biggest difference at shorter SRTs.
• Biogas yields higher even with equal VSr and CODr.
• Excellent filament control.
Summary and Conclusions
Physical AD Pre-Treatment

Conclusions

• Thermal hydrolysis is more mature technology
• Better dewatering
• Lower viscosity
• Higher volatile solids loading
• Odor reduction (for some)
• Still recommend piloting
• VFA production
• Reduction in foaming

More research

• Energy balance
• Overall VSr
• Reaction rates
• Biogas yield
• Methane yield
• Recycle stream impacts
Summary and Conclusions
Thermal Hydrolysis for AD Pre-treatment

Conclusions
• Reduced AD reactor size
• Better dewaterability
• Reduced odor
• Reduction in foaming
• Can bypass piloting depending on objectives

More research
• Energy balance
• Overall VSr
• Biogas yield
• Methane yield
• Recycle stream impacts
Summary and Conclusions

Cannibal

Conclusions

• Screening removes non-reactive VS; however, dewatering diminished

• Overall biomass yield varies significantly from plant to plant

More research

• Modeling
• Biomass yield
Next Steps: Issues yet to be Resolved

• How/Why does the performance of these processes vary from plant to plant?
• Can we predict performance without piloting?
• Are there sludge characteristics that the industry has yet to define? If yes, how best to begin defining those characteristics?
Next Steps: Issues yet to be Resolved

• Are AD pre-treatment technologies altering characteristics to significantly change biogas and biomass yields?
• What is the impact of AD pre-treated sludge filtrate/centrate on liquid stream processes?
• Using physical processes, is lysed WAS a good source of VFA for BNR? How much N&P is being returned to the liquid process?