Underlying Mechanistic Principles and Proposed Modeling Approach for Waste Activated Sludge Reduction Technologies

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Acknowledgements

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  – Bruce Johnson, P.E., B.C.E.E.
  – Lauren Fillmore (WERF)
Biosolids Minimization Strategies

Headworks

Plant Influent

Primary Treatment

PS to Digestion

Activated Sludge

Secondary Treatment

WAS to Digestion

Plant Effluent

Solids Handling

Dewatering/Disposal

- Extended Aeration
- Cannibal™
- Biolysis®

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

- Thermophilic Digestion
- Phased Digestion
- Acid/Enzymatic Hydrolysis
- Post Aerobic Digestion
Sludge Reduction Mechanism Hypotheses

- 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
- result in the generation of less sludge by process modification
Very Active Marketplace

Industry needs:

• A better understanding of fundamental mechanisms.
• A critical evaluation of performance.
• A method to evaluate technologies for their technical and economic applicability to specific wastewaters
WERF 05-CTS 3 Approach

- Conduct a literature search of known technologies and processes used to reduce sludge mass. Only those with full-scale testing and/or operating installations considered.
- Select 3-4 technologies (primarily non-financial basis) representative of main mechanistic principles.
- Develop general evaluation model based on selected technologies, relying on actual field data and additional laboratory testing
- Validate model based on field data from other installations.
Getting Data and Info
Plants that agreed to participate

- Peru, IN Utilities - Cannibal
- Bulgarograsso, Italy - Praxair
- Brisbane, AUS Water - CAMBI
- Næstved, Denmark - CAMBI
- Rosedale WWTP, NZ – Crown
- Viby, Denmark - Crown
Data and Samples Received

• **Cambi Process:**
  – Naestved, Denmark
  – DC Water and Sewer Authority pilot plant operated at Virginia Tech.

• **Crown Press:**
  – Rosedale WWTP, New Zealand

• **Cannibal System:**
  – Peru, IN
  – Emporia, VA
  – Big Bear, CA
  – Morongo, CA
## Protocol Full-Scale Sample Collection and Analysis

<table>
<thead>
<tr>
<th>Sample Location</th>
<th>pH</th>
<th>TS/TSS VS/VSS</th>
<th>COD/ SCOD</th>
<th>Soluble Cations/Anions</th>
<th>VFAs</th>
<th>Total Fe/Al</th>
<th>Protein Polysaccharides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Influent</td>
<td>X</td>
<td>TSS/VSS</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Primary Sludge</td>
<td>X</td>
<td>TS/VS</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Mixed Liquor</td>
<td>X</td>
<td>TSS/VSS</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>WAS/Process Feed</td>
<td>X</td>
<td>TS/VS</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Post Process</td>
<td>X</td>
<td>TS/VS</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Digested Sludge</td>
<td>X</td>
<td>TS/VS</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Dewatering Centrate/Filtrate</td>
<td>X</td>
<td>TSS/VSS</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Effluent</td>
<td>X</td>
<td>TSS/VSS</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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 (anox/anaer.)
  – Portion returned to aeration basins every day - odor control

• Annual Solids Purge
  – < 0.1 kg/kg BOD
Soluble COD data from Cannibal™ WWTPs

![Graph showing Soluble COD over Incubation Time](image)

- **SCOD (mg/L)**
- **Incubation Time (days)**
- **Soluble COD**

- **Poor performance**
- **Good solids reduction**
- **Poor performance**

**Notes:**
- Poor performance is indicated by the yellow diamond line.
- Good solids reduction is indicated by the green triangle line.
- Poor performance is indicated by the purple square line.

**Source:**
- WERF
- CH2M HILL
1. Solids are dewatered to ~15%.

2. Solids mixed with return steam and water, so about 12%.

3. Solids are heated by direct steam addition to 320°F and 90 psi for 45 minutes.
   - Class A time v. temp.
   - Organic compounds are solubilized.

4. Pressure in reactor is reduced to 60 psi.
   - Steam is returned to Pre-Heat.

5. Reactor pressure is rapidly released, flashing solids to the flash tank.
   - Flashing causes cells to rupture.
   - Steam is returned to Pre-Heat.
   - Hydrolyzed solids have reduced viscosity.

- Class A biosolids
- Reduced volume
  - >35% solids
  - 60 V.S. destruction

- Pre-Heat Tank
- Reactor
- Flash Tank
- Methane
- Anaerobic Digester

- 8-10% solids digester feed at 100°F

- 60% C.O.D. conversion
- 50% reduction in digester volume
- Increased gas production
- Foaming eliminated

- Dewatering 30-37% DS
## Cambi Reported 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/m³/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>CMD</th>
<th>15d SRT</th>
<th>20d SRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>VSR</td>
<td>50%</td>
<td>57.7%</td>
<td>59.6%</td>
</tr>
<tr>
<td>Ammonia</td>
<td></td>
<td>2,446 mg/L</td>
<td>2,134 mg/L</td>
</tr>
<tr>
<td>Dewatered %TS</td>
<td>24.4%</td>
<td>33.5%</td>
<td>33.5%</td>
</tr>
<tr>
<td>Cake Odor*</td>
<td></td>
<td>10%</td>
<td>10%</td>
</tr>
</tbody>
</table>

* measured as volatile organic sulfur compounds
Pressure Release

- Macerate sludge to homogenize
- Increase pressure (12 Bar) with PD pump
- High pressure mixer, flow into disintegration nozzle.
- As the flow exits the nozzle, cavitation occurs rupturing cell structure
- Sludge can be passed through system three times before discharge to the digesters.
Cell Disruption

- **Impact Ring**: Forces Sheer to lyse cells.
- **12,000 psi 700 mph**: Sheer forces liquefy WAS into lyzed cells.
- **Valve Seat**: Interior of valve that remains intact.
- **WAS (Intact Cells)**: Contains intact cells that are not disrupted.
- **Lyzed Cells**: Cells that are liquefied and disrupted.

Overall, the diagram illustrates the disruption of cells under shear forces, leading to liquefaction and cell lysis.
## Crown Reported Performance

<table>
<thead>
<tr>
<th>Site Name</th>
<th>VSr %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
</tr>
<tr>
<td>Wiesbaden Biebrich</td>
<td>32%</td>
</tr>
<tr>
<td>Taunusstein</td>
<td>32%</td>
</tr>
<tr>
<td>Ingelheim</td>
<td>36%</td>
</tr>
<tr>
<td>Ginsheim</td>
<td>45%</td>
</tr>
<tr>
<td>Münchwilen</td>
<td>32%</td>
</tr>
<tr>
<td>Rosedale WWTP</td>
<td>51%</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>38.1%</strong></td>
</tr>
</tbody>
</table>
# Crown Reported Performance

<table>
<thead>
<tr>
<th>Site Name</th>
<th>TS after dewatering %</th>
<th>% increase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>Wiesbaden Biebrich</td>
<td>31</td>
<td>36</td>
</tr>
<tr>
<td>Taunusstein</td>
<td>31</td>
<td>36</td>
</tr>
<tr>
<td>Ingelheim</td>
<td>28</td>
<td>34</td>
</tr>
<tr>
<td>Ginsheim</td>
<td>20</td>
<td>23.4</td>
</tr>
<tr>
<td>Münchwilen</td>
<td>22</td>
<td>26.4</td>
</tr>
<tr>
<td>Rosedale WWTP</td>
<td>18.5</td>
<td>22.2</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>25.1</strong></td>
<td><strong>29.7</strong></td>
</tr>
</tbody>
</table>
Important Questions

• how does the performance of these processes vary from plant to plant?
• can we predict performance without extensive piloting?
Summary and Conclusions

- Many new products in the market
- Few full-scale installations; many OUS
- Little definitive information known about raw feed characteristics and/or process operational parameters
- Some hypotheses about modeling and mechanisms, but no/little data to support theories
- Need for the development of an evaluation methodology confirmed
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