Post Aerobic Digestion
Full scale example, and comparison to Anammox for sidestream treatment.

Matt Berg

Thanks to:
Heidi Bauer, Tom Johnson, Bruce Johnson, Dave Oerke, Steve Graziano
What is Post Aerobic Digestion?

- Aerobic Digestion after Anaerobic Digestion
- Aeration Operation:
  - Full Time: Nitrification Only (requires alkalinity addition)
  - Intermittent: Nitrification, Denitrification
  - Continuous Low DO: Simultaneous Nitrification, Denitrification
PAD Purpose and Challenges

• Advantages:
  – Reduction of N without chems.
  – VSS reduction
  – Odor reduction
  – Struvite stabilization

• Challenges:
  – Biological heat
  – Foam
Spokane County Regional Water Reclamation Facility (SCRWRF)

- Greenfield, 8 MGD Avg., MBR, Scalping plant
- First started treating wastewater in late 2011
- First full scale plant to use PAD in North America
- Motivated by TN limit (10mg/L), 8 days storage pre-dewatering, and reduced solids hauling (30-60 miles)
Spokane Solids Handling System

- Anaerobic Digestion, 15 day SRT
- Thickening & Dewatering
- Post Aerobic Digestion, 5-10 day SRT
- CoGen & Gas Storage
Volatile Solids Destruction Comparison

<table>
<thead>
<tr>
<th>Digestion Technology</th>
<th>VSR Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mesophilic Anaerobic Digestion</td>
<td>40%-50%</td>
</tr>
<tr>
<td>ATAD</td>
<td>55%-65%</td>
</tr>
<tr>
<td>Thermal Hydrolysis + MAD</td>
<td>50%-60%</td>
</tr>
<tr>
<td>MAD + PAD</td>
<td>60%-80%</td>
</tr>
</tbody>
</table>
Nitrogen Performance, Sidestream

• Spokane Acceptance Test
• Ammonia
  – Average PAD influent: ~1,000 mg/L
  – Average Removal: 98.6%, 14.0 mg/L effluent
• TIN (measured as ammonia + nitrate)
  – Average PAD influent TIN >1,000 mg/L
  – Average Removal: 95%, 27.6 mg/L effluent
• Very effective for sidestream treatment
Nitrification Challenges

• Heat – Above 40°C, nitrification becomes unstable
  – Driven primarily by VSS reduction

• Nitrification failure results in both high ammonia and higher pH’s
  – Ammonia Toxicity accelerates failure
Overcoming Challenges - Design

• Temperature:
  – Air cooling system
  – Sprinklers (evaporative cooling) on aluminum lid
    • Reduced by 4 degrees C
  – Automation and controls

• Foam:
  – Control temperature & process stability
  – Foam overflow system
  – Refining control over aeration cycles

• pH control – sulfuric acid addition
Overcoming Challenges - Operations

• If optimum performance is desired:
  – Close control of pH and DO are critical
  – Operator attention is important when starting up
  – DO, temperature, pH monitoring (6.9-7.6 for min dewatering polymer)
  – Air control: Blower intensity and on/off timing, tank levels

• Automation & instrumentation
  – Automate optimum balance between nitrification and denitrification
PAD & Anammox Comparison: Similarities

- Sidestream Treatment Technologies (high concentration)
- Reduction of nitrogen
- No supplemental carbon or alkalinity

WEF Webcast 12/9/2009: Sidestream Treatment for Nutrient Removal and Recovery
What is Anammox

Anaerobic Ammonium Oxidation

- Advantages:
  - Reduction of N without chems.
  - Lower energy

- Challenges:
  - Slow growth
  - Competition with nitrite oxidizing bacteria

Diagram:

- Autotrophs
  - Nitritation-Aerobic
  - Nitrite (NO$_2^-$)
  - 25% O$_2$
  - 75% O$_2$
  - AOB's
  - 50%

- ANAMMOX
  - Ammonia (NH$_3$/ NH$_4^+$)
  -Nitrite (NO$_2^-$)
  -Nitrate (NO$_3^-$)
  - 40% Carbon
  - 60% Carbon

- De-ammonification-Anaerobic
  - Nitrite (NO$_2^-$)
  - Nitrogen Gas (N$_2$)
  - 50%
Comparison Methodology

Pro2D$^2$ whole plant simulator:
- Baseline (No SSTP)  
- PAD  
- Anammox

CPES cost estimating system

Assumptions:
- 20 mgd
- Greenfield
- Aeration Basins:
  - 5-stage Bardenpho
- Biosolids facilities:
  - 24/7 operation
  - Disposal via land application

<table>
<thead>
<tr>
<th></th>
<th>Influent</th>
<th>Effluent Limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>250</td>
<td>10</td>
</tr>
<tr>
<td>TSS</td>
<td>240</td>
<td>10</td>
</tr>
<tr>
<td>VSS</td>
<td>192</td>
<td></td>
</tr>
<tr>
<td>TKN</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>NH3</td>
<td>30</td>
<td>1</td>
</tr>
<tr>
<td>TN</td>
<td>39</td>
<td>5.0</td>
</tr>
<tr>
<td>TP</td>
<td>6</td>
<td>1.0</td>
</tr>
</tbody>
</table>
## Results-Mass Balance -Filtrate Quality

<table>
<thead>
<tr>
<th></th>
<th>Baseline (No Sidestream Treatment)</th>
<th>Sidestream Treatment with PAD</th>
<th>Sidestream Treatment with Anammox</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg/L (kg/d)</td>
<td>mg/L (kg/d)</td>
<td>% Decrease from Baseline</td>
</tr>
<tr>
<td>NH3</td>
<td>440 (390)</td>
<td>4.5 (4.0)</td>
<td>99%</td>
</tr>
<tr>
<td>TKN</td>
<td>490 (430)</td>
<td>45 (40)</td>
<td>91%</td>
</tr>
<tr>
<td>TIN</td>
<td>440 (390)</td>
<td>25 (23)</td>
<td>94%</td>
</tr>
<tr>
<td>TN</td>
<td>490 (430)</td>
<td>66 (59)</td>
<td>86%</td>
</tr>
</tbody>
</table>

Both sidestream treatment technologies remove significant amounts of nitrogen from the filtrate compared to the baseline.
## Results - Annual Costs
- Total Energy, Chemical, & Biosolids

<table>
<thead>
<tr>
<th></th>
<th>Baseline (No Sidestream Treatment)</th>
<th>Sidestream Treatment with PAD</th>
<th>Sidestream Treatment with Anammox</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Use, $/yr</td>
<td>$215,000</td>
<td>$245,000</td>
<td>$214,000</td>
</tr>
<tr>
<td>Chemical Use, $/yr</td>
<td>$139,000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Biosolids Production, $/yr</td>
<td>$651,000</td>
<td>$568,000</td>
<td>$643,000</td>
</tr>
<tr>
<td><strong>Total Annual Costs for Energy, Methanol, &amp; Biosolids Disposal, $/yr</strong></td>
<td><strong>$1,005,000</strong></td>
<td><strong>$813,000</strong></td>
<td><strong>$857,000</strong></td>
</tr>
<tr>
<td>Total Cost Compared to Baseline, $/yr</td>
<td>-$192,000</td>
<td></td>
<td>-$148,000</td>
</tr>
<tr>
<td>Total Cost Compared to Baseline, %</td>
<td>-19.1%</td>
<td></td>
<td>-14.7%</td>
</tr>
</tbody>
</table>
## Results-Capital Costs

<table>
<thead>
<tr>
<th>Costs in Million Dollars</th>
<th>Baseline (No Sidestream Treatment)</th>
<th>Sidestream Treatment with PAD</th>
<th>Sidestream Treatment with Anammox</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeration Basins</td>
<td>$19.4</td>
<td>$19.1</td>
<td>$19.1</td>
</tr>
<tr>
<td>Aeration Basin Blowers</td>
<td>$4.4</td>
<td>$4.2</td>
<td>$4.3</td>
</tr>
<tr>
<td>Carbon Feed and Storage Facility</td>
<td>$1.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Anammox Facility</td>
<td>-</td>
<td>-</td>
<td>$3.8</td>
</tr>
<tr>
<td>Post Aerobic Digestion</td>
<td>-</td>
<td>$5.3</td>
<td>-</td>
</tr>
<tr>
<td>Other 11 Facilities</td>
<td>$81.6</td>
<td>$81.6</td>
<td>$81.6</td>
</tr>
<tr>
<td>Additional Project Costs</td>
<td>$15.6</td>
<td>$16.1</td>
<td>$15.9</td>
</tr>
<tr>
<td><strong>Total Construction Cost</strong></td>
<td><strong>$122.5</strong></td>
<td><strong>$126.3</strong></td>
<td><strong>$124.7</strong></td>
</tr>
<tr>
<td>Percent Increase from Lowest Construction Cost</td>
<td>-</td>
<td>3.1%</td>
<td>1.8%</td>
</tr>
</tbody>
</table>
## Results - Life Cycle Costs

<table>
<thead>
<tr>
<th>Costs in Million dollars</th>
<th>Baseline (No Sidestream Treatment)</th>
<th>Sidestream Treatment with PAD</th>
<th>Sidestream Treatment with Anammox</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aeration Basins</td>
<td>$22.3</td>
<td>$22.1</td>
<td>$22.1</td>
</tr>
<tr>
<td>Aeration Basin Blowers</td>
<td>$9.3</td>
<td>$8.6</td>
<td>$8.7</td>
</tr>
<tr>
<td>Carbon Feed and Storage Facility</td>
<td>$4.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Anammox Facility</td>
<td>-</td>
<td>$4.5</td>
<td></td>
</tr>
<tr>
<td>Post Aerobic Digestion</td>
<td>-</td>
<td>$6.5</td>
<td>-</td>
</tr>
<tr>
<td>Biosolids Hauling and Disposal</td>
<td>$17.7</td>
<td>$15.4</td>
<td>$17.4</td>
</tr>
<tr>
<td>Other 11 Facilities</td>
<td>$105.8</td>
<td>$105.8</td>
<td>$105.8</td>
</tr>
<tr>
<td>Standard Items</td>
<td>$18.0</td>
<td>$18.6</td>
<td>$18.4</td>
</tr>
<tr>
<td><strong>Total Net Present Value</strong></td>
<td><strong>$177.6</strong></td>
<td><strong>$177.0</strong></td>
<td><strong>$176.9</strong></td>
</tr>
<tr>
<td><strong>Percent Increase from Lowest Life Cycle Cost</strong></td>
<td>0.40%</td>
<td>0.06%</td>
<td>-</td>
</tr>
</tbody>
</table>
Conclusions-1

• Post Aerobic Digestion and Anammox Similarities:
  – Excellent option for reduction of nitrogen recycled back to the liquid stream
  – Supplemental chemicals not typically required
  – Similar plant effluent quality achieved
  – Significant removal of constituents in filtrate
  – Less energy required for nutrient removal in aeration basins
Conclusions-2

• Post Aerobic Digestion and Anammox Differences:
  – Different sidestream flow streams targeted
  – PAD removes more BOD, VSS, and Nitrogen
    • Driven by VSS destruction
  – Greater net annual cost savings for PAD
    • Driven by VSS destruction
  – Greater net energy savings for Anammox
    • Energy saved in aeration basins exceeds energy for Anammox process
Conclusions-3

• **Overall Costs:**
  – Lowest capital cost: No sidestream treatment
  – Lowest annual cost: PAD
  – Equivalent NPV IN THIS GREENFIELD CASE
  – SITE SPECIFIC
  
  • Consider **PAD** when N removal without chems. desired in addition to **additional VSR (>53/WT)**.
  • Consider **Anammox** when N removal without chems. desired in addition to **energy minimization (>0.07/kWh)**
  • Consider **Baseline if chemical costs are low (<444/DT; and dewatering 24/7)**
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Full scale example, and comparison to Anammox for sidestream treatment.

QUESTIONS?

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