Side Stream Nutrient Considerations and Nutrient Harvesting

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CDM Smith

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Agenda

• High Strength Side Streams
• Drivers
  – Permit, Cost to treat, O&M and equipment
• Nitrogen Treatment Alternatives
• Phosphorus Treatment Alternatives
  – Treat or Harvest
• Summary and Conclusions
### Side Stream Characterization

<table>
<thead>
<tr>
<th></th>
<th>Primary Sludge Thickening Return</th>
<th>Secondary Sludge Thickening Return</th>
<th>Dewatering Return</th>
<th>Digestate Return</th>
</tr>
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<tr>
<td>TSS - Conc., mg/L</td>
<td>557</td>
<td>444</td>
<td>330</td>
<td>2000</td>
</tr>
<tr>
<td>BOD - Conc., mg/L</td>
<td>300</td>
<td>300</td>
<td>200</td>
<td>50</td>
</tr>
<tr>
<td>Ammonia - Conc., mg NH3-N/L</td>
<td>15</td>
<td>15</td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>Total Phosphorus - Conc., mg TP/L</td>
<td></td>
<td></td>
<td>13</td>
<td>200</td>
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- Predict BOD and Ammonia from typical wastewater (MOP8) and CDM Smith Clients
Nitrogen Side Stream Treatment Options

- Non-proprietary
  - Equalization
  - High Rate Nitrifying Activated Sludge Process
- Proprietary
  - InNitri® ("Inexpensive Nitrification")
  - SHARON® ("Single Reactor High Activity Ammonia Removal Over Nitrite") Process
    - AOx-DN ("Ammonia Oxidation-Denitrification Over Nitrite") – similar to SHARON®
  - Anammox® ("Anaerobic Ammonium Oxidation") Process
    - DEMON (suspended growth)
    - ANITA Mox (fixed film)
  - Other Nitrogen Removal Processes
    - AT-3 ("Aeration Tank 3", NYCDEP – 26th Ward)
    - BABE® ("Bio-Augmentation Batch Enhanced")
    - CaRRB ("Centrate and RAS Reaeration Basin")
Nitrification

\[
\text{NH}_4^+ + 1.5\text{O}_2 \rightarrow \text{NO}_2^- + 2\text{H}^+ + \text{H}_2\text{O}
\]

\[
\text{NO}_2^- + \frac{1}{2} \text{O}_2 \rightarrow \text{NO}_3^-
\]
## Side Stream Process Alternatives

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<td>Equalization</td>
<td>EQ flow over 24 hr period, or only at night; need mixing</td>
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<td>Aerated Equalization</td>
<td>Aerate the centrate only; At 1 day SRT, should get most ammonia removed</td>
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<td>High rate nitrifying activated sludge</td>
<td>Activated sludge plant for dewatering Side Stream (aeration tank and clarifier); Can be done in an SBR</td>
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<td>Treats Side Stream in a separate activated sludge system (with clarifier), produces an enriched population of nitrifying bacteria, which is used to seed the mainstream reactor, no denite step</td>
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| Equalization                               | EQ flow over 24 hr period, or only at night; need mixing                     | • Easy, low cost solution  
• Distributes load throughout day                                                                                     | • Load still treated in main process  
• Large storage tank needed                                                                                               |
| Aerated Equalization                        | Aerate the centrate only; At 1 day SRT, should get most ammonia removed      | • Thousand Oaks example – achieve 50% ammonia removal                                                                  | • More equipment and operational costs than EQ only  
• No denite of Side Stream                                                                                               |
| High rate nitrifying activated sludge      | Activated sludge plant for dewatering Side Stream (aeration tank and clarifier); Can be done in an SBR | • Non-proprietary  
• Uses high temp of dewatering Side Stream  
• Dallas example - ~800 mg/L ammonia down to <10 mg/L with 3 day SRT; saved $400K & double equipment cost compared with SHARON® | • Separate Side Stream process  
• No denite of Side Stream                                                                                               |
| InNitri® (m²t technologies)                | Treats Side Stream in a separate activated sludge system (with clarifier), produces an enriched population of nitrifying bacteria, which is used to seed the mainstream reactor, no denite step | • Increased capacity of mainstream nitrification process  
• Uses high temp of dewatering Side Stream to speed reaction                                                             | • No denite of Side Stream  
• Alkalinity needed  
• Poor settling of Side Stream → hard to maintain SRT                                                                   |
## Side Stream Process Alternatives – SHARON®/Annamox®

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| SHARON® (m²t technologies) | Nitrifies ammonia to nitrite then reduces the nitrite to nitrogen gas in a continuous-flow, completely mixed reactor without sludge recycle at the temperature of centrate | • Decrease nitrogen load to mainstream  
• Decrease oxygen & carbon | • Additional process to maintain  
• Proprietary, can be costly |
| AOX-DN (f.r.mahony & associates, inc.) | Similar to SHARON® in fixed film reactor; controls nitrification by intermittently aerating the reactor; at high temp of centrate | • Decrease nitrogen load to mainstream  
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| ANITA Mox (Kruger, Inc.) | Anammox in continuous flow reactor, Fixed Film Growth (MBBR) or combined Fixed Film and Suspended Growth (IFAS) | • Decrease nitrogen load to mainstream  
• Decrease oxygen & carbon | • Proprietary, can be costly |
| SHARON®/Annamox (m²t technologies) | Anammox downstream of SHARON®, with SHARON® operated to provide approximately equal parts of ammonia and nitrite | • Decreases oxygen use by ~63% compared to conventional nitrification  
• Does not consume COD | • Additional process to maintain  
• Heat generated by Anammox, may need cooling |
Biological Nitrogen Removal

**Nitrification**
- Aerobic (with oxygen)
- Autotrophs (AOBs and NOBs)
  - Ammonia
  - Nitrite
  - Nitrate
  - Oxygen
  - Oxygen Alkalinity

**Denitrification**
- Anoxic (no oxygen)
- Heterotrophs
  - Nitrite
  - Nitrogen gas, Carbon dioxide
  - Carbon
  - Carbon Alkalinity
SHARON® Process Short-cuts Nitrification to Reduce Energy and Carbon Requirements

**Nitrification**
- Aerobic (with oxygen)
- Autotrophs (AOBs and NOBs)

**Denitrification**
- Anoxic (no oxygen)
- Heterotrophs

**Ammonia**
- Oxygen
- Alkalinity

**Nitrite**
- Oxygen

**Nitrate**
- Carbon

**Nitrogen gas,**
- Carbon dioxide
- Alkalinity

**SHARON**
- High temp
Anammox® Process Achieves Shortest Route to Remove Nitrogen at Low Operating Cost (low oxygen, no carbon)

**Nitrification**
- Aerobic (with oxygen)
- Autotrophs (AOBs and NOBs)

**Denitrification**
- Anoxic (no oxygen)
- Heterotrophs

**Anammox**
- Autotrophs (anammox bacteria)

1. **Ammonia** → **Oxygen Alkalinity**
2. **Nitrite** → **Nitrate**
3. **Nitrate** → **Carbon**
4. **Nitrite → Nitrogen gas, Carbon dioxide Alkalinity**
5. **Oxygen → Nitrite**
High Rate Nitrifying Activated Sludge

- Side Stream
- Nitrification
- Air
- Lime
- NO₃⁻
- To WML thickening
- To Headworks

SHARON®/Anammox

- Side Stream
- Nitrification to NO₂⁻
- Methanol
- Denitrification to N₂ Gas
- To Headworks
# Side Stream Process Alternatives - Other

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| AT-3 ("Aeration Tank 3", NYCDEP – 26th Ward) | Treats Side Stream in a separate activated sludge system, plug flow | • Increased capacity of mainstream nitrification process | • Limited full-scale installations  
• No denite of Side Stream |
| BABE ("Bio-Augmentation Batch Enhanced") | Divert portion mainstream RAS and blend with Side Stream to feed into reactor, usually SBR | • Settles better than InNitri® because of RAS addition  
• Can achieve some denite with SBR | • Limited full-scale installations  
• Additional process to maintain |
| CaRRB ("Centrate and RAS Reaeration Basin") | Side Stream (centrate) and RAS in bioreactor with aeration for nitrification before return to mainstream | • Reduced load to mainstream process  
• Can provide biomass storage for wet weather | • Additional process to maintain |
| Ostara PEARL™ Nutrient Recycling | Controlled struvite precipitation for phosphorus & ammonia removal | • Produces struvite, a product that can be sold | • P benefit, not much N benefit  
• Costly |
Faces of Struvite
Faces of Struvite
Drivers for Harvesting Phosphorus

• Struvite Chemical and Cleaning Costs Increasing
  – $170,000/yr and growing at Des Moines
  – $750,000/yr and growing at Deer Island (Ferric only)
• Potential Effluent Nutrient
• Potential Restrictions on Land Applied P at Des Moines
Phosphorus Side Stream Treatment Options

• Non-proprietary
  – Biological
  – Chemical
    • iron salts
    • Alum
    • pH adjustment
  – Carbon Dioxide Injection

• Proprietary
  – Chemical Addition
    • Struvout 2520
  – Harvest
    • DHV – Crystalactor
    • Paques – Phosphaq
    • CNP - Airprex
    • Multiform Harvest
    • Ostara PEARL™
Influent: 72 MGD, 5,200 ppd (8.6 mg/L)

Side Stream: 3,600 ppd, Percent of influent: 69%, Typical: 20-30%

Liquid Treatment Process:
- Primary
- Secondary

Effluent: 3,400 ppd (5.6 mg/L)

Blended Sludge: 5,600 ppd

Biosolids: 2,900 ppd

Special Waste: 1,100 ppd (1.9 mg/L eq.)
Proposed Solution

Side Stream Nutrient Removal

Influent
5,200 ppd (8.6 mg/L)

Liquid Treatment Process
Primary Secondary

Solids Treatment Process

Effluent
≤1 mg/L P

Biosolids
≤2,500 ppd P

Special Waste
1,100 ppd (1.9 mg/L eq.)

Struvite

Side Stream Treatment

5,200 ppd (8.6 mg/L)
Proposed Solution

Side Stream Nutrient Removal

[CNP, PAQUES, OSTARA, MULTIFORM HARVEST, Crystalactor® logos]
\[
\begin{align*}
\text{Mg}^{2+} + \text{NH}_4^+ + \text{PO}_4^{3-} + 6 \text{H}_2\text{O} & \rightarrow \text{MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O} & \text{struvite} \\
3\text{Fe}^{2+} + 2 \text{PO}_4^{3-} & \rightarrow \text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O} & \text{vivianite}
\end{align*}
\]
DHV - Crystalactor
- Phosphaq’s market: >100kg P/d (220 lb P/d)
  - Minimum 50 mg/L PO4-P
  - Minimum 200 mg/L NH4-N
PHOSPAQ Struvite Product

SOURCE: YouTube
CNP – AirPrex®

- Reduce Polymer by up to 30%
- Reduce Disposal Costs by up to 20%
- Reduce Phosphorus Recycle Load by up to 90%
- Reduce Maintenance Costs by up to 50%
- Increase Revenue up to 10% from Fertilizer
Multiform Harvest
Crystal Green® Fertilizer

(Photo removed to reduce file size.)
WASSTRIP™ recommended to protect digester
Struvite Prevention
Electrical Cell Lysis to Aid Struvite Harvesting
Summary

- Compared several nitrogen and phosphorus side stream treatment alternatives
- Evaluated several struvite recovery technologies spanning perceived range from low- to high-tech
- Proposed further study with non Bio-P plants and implications of Iron Salt addition.
Questions

Contact Information:
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