THE DEMON® ANAMMOX PROCESS: RESOURCE SAVINGS THROUGH SIDE STREAM TREATMENT, AND THE STEPS TOWARDS AN ENERGY NEUTRAL WWTP

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PRESENTED BY: CHANDLER JOHNSON
Co-Authors

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Bernhard Wett – ARA Consult

Amanda Summers – Pierce County / Chambers Creek WWTP
Agenda

Section I: DEMON / ANAMMOX TECHNOLOGY

Section II: PIERCE COUNTY WWTP

Section III: STRASS WWTP

Section IV: CONCLUSIONS
The DEMON® / Anammox - Process
Anaerobic sludge digestion is very beneficial; however, recycling of high ammonia stream has many “bad” effects:

- Reduction in C/N ratio which minimizes denitrification potential – thus requiring external carbon for meeting effluent Nitrogen limits
- Shock loads to system due to infrequent dewatering
- Alkalinity sometimes insufficient for complete nitrification

Represents up to 40% TN Load to Plant
1 process cycle of the DEMON involves multiple time-controlled phases:

- Aeration phase (Nitritation)
- Mix phase (Deammonification)
- Fill & Mix Phase (NH₃-N Addition)

Settling phase

Discharge phase
**DEMON® 2.0 - Anammox Treatment**

**Continuous Mode**

- **Process Benefits**
  - Lower installed Feed pump HP
  - Lower installed Blower HP

- **Higher Loading Rates**
  - Smaller EQ Tank Volume
  - Higher Anammox Retainment
Fundamentals of Nitrification – Denitrification

**Autotrophic Nitrification**
Aerobic Environment

- 75% O₂
- 100% Alkalinity
- 1 mol Ammonia (NH₃/ NH₄⁺)
- Oxygen demand 4.57 g / g NH₄⁺-N oxidized
- Carbon demand 4.77 g COD / g NO₃⁻-N reduced

**Heterotrophic Denitrification**
Anoxic Environment

- 25% O₂
- 40% Carbon
- 60% Carbon
- 1 mol Nitrite (NO₂⁻)
- ½ mol Nitrogen Gas (N₂)
- 1.8 – 2.7 kW hr / lb N
- 4 – 6 kW hr / kg N

**Oxygen demand**
- 4.57 g / g NH₄⁺-N oxidized

**Carbon demand**
- 4.77 g COD / g NO₃⁻-N reduced
**Fundamentals of Deammonification**

### Aerobic Ammonium Oxidation (AerAOB)

- > 60% reduction in Oxygen
- Eliminate demand for supplemental carbon
- 50% of the alkalinity demand

### Anaerobic Ammonium Oxidation (Anammox or AnAOB)

0.45 – 0.79 kW hr / lb N
1 – 1.75 kW hr / kg N

- **Partial Nitritation**
  - 40% O₂
  - 50% Alkalinity

**Chemical Reactions:**

- \[\text{NH}_4^+ + 1.32 \text{NO}_2^- + 0.066 \text{HCO}_3^- + 0.13 \text{H}^+ \rightarrow 0.26 \text{NO}_3^- + 1.02\text{N}_2 + 0.066 \text{CH}_2\text{O}_{0.5}\text{N}_{0.15} + 2.03 \text{H}_2\text{O} \]

- **Oxygen demand**
  - 1.9 g / g NH₄⁺-N oxidized
Comparison of Consumables

- Conventional
- DEMON+

Legend:
- Green: Energy
- Blue: Methanol
- Red: Sludge
Nitrogen Cycle

Methanol

N\textsubscript{2}

\text{NO\textsubscript{3}}

\text{NH}_{4}\textsuperscript{+}

\text{NO\textsubscript{2}}

\text{O}_2

\text{O}_2 \, 50\%

\text{O}_2
## Demon® Projects for North America

<table>
<thead>
<tr>
<th>Location</th>
<th>Operational Year</th>
<th>Daily Output</th>
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<tbody>
<tr>
<td>York River, VA</td>
<td>2012</td>
<td>554 lb/day</td>
</tr>
<tr>
<td>Biogas plant, FL</td>
<td>2013</td>
<td>1,500 lb/day</td>
</tr>
<tr>
<td>Alexandria, VA</td>
<td>2015</td>
<td>2,826 lb/day</td>
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<tr>
<td>City of Greeley, CO</td>
<td>2015</td>
<td>781 lb/day</td>
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<tr>
<td>City of Guelph, Ontario</td>
<td>2015</td>
<td>921 lb/day</td>
</tr>
<tr>
<td>Pierce County, WA</td>
<td>2017</td>
<td>4,147 lb/day</td>
</tr>
<tr>
<td>DC Water, DC</td>
<td>2017</td>
<td>27,338 lb/day</td>
</tr>
</tbody>
</table>
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Pierce County DEMON® Process Flowchart

Centrifuge/Dewatering

Feed Pump

EQ Basin

Blowers

Mixer

Discharge Cyclone

Waste valve

Enrichment Cyclone

Recycle valve

Decanter

Decanting Valve

Mixers

Enrichment Cyclone pump

Effluent Tank
Pierce County Demon Reactors

Available set points

- Aeration and Fill Phase
  - Fill time and flowrate
  - Blower speed and time
- Aeration Phase
  - Blower speed & time
- Mix/Fill Phase
  - Mixer speed & time
  - Fill time and flowrate
- Fill Phase
  - Flowrate and time
- Enrichment Hydrocyclones
  - Recycle & wasting time
- Settling
  - Time
- Decant
  - Decant mode – decanter/cyclone
  - Time

SBR1: 256,000 gal
SBR2: 253,700 gal
Hi operational level – 21 ft
Low operational level – 18 ft
PIERCE COUNTY START UP DATA

Pierce County Effluent Ammonia, Nitrite, Nitrate Profile

- Effluent NH3-N
- Influent NH3-N

Ammonia-Nitrogen Data (mg/L)

PIERCE COUNTY START UP DATA

Pierce County Effluent Ammonia, Nitrite, Nitrate Profile

- Effluent NH3-N
- Effluent NO3-N
- Effluent NO2-N

Effluent Data (mg/L)

PIERCE COUNTY START UP DATA
PIERCE COUNTY START UP DATA

Pierce County Demon SBR#1 - Alkalinity and % Ammonia Removal Profile

- Alkalinity
- Percent Ammonia Removal
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WWTP Strass, Austria

- 10 MGD Winter, 5 MGD Summer
- Mainstream treatment by an A+B process
- Net energy positive plant since 2005
- DEMON Mainstream & Side stream
WWTP Strauss – Energy Balance

Wett et al., 2014
Hydro-Cyclones Select Granules to De-Couple SRT of MLSS
Strass Resource Requirements of sidestream deammonification
Strass N-removal efficiency of sidestream deammonification
Strass Bioaugmentation to Mainstream WWTP

![Graph showing MLSS DEMON and accumulated seed over time from 01.02.2016 to 21.02.2016.](image-url)
Strass Screen Performance in Retainment of Anammox

screen pass-through

screen retained
A major step towards an energy self-sufficient WWTP

<table>
<thead>
<tr>
<th></th>
<th>Conventional N-removal</th>
<th>A+B &amp; DEMON® in sidestream, mainstream</th>
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<tbody>
<tr>
<td>Aeration</td>
<td>+39.3 Wh /pe d</td>
<td>+16.4 Wh /pe d</td>
</tr>
<tr>
<td>Total</td>
<td>+56.5 Wh /pe d</td>
<td>+33.3 Wh /pe d</td>
</tr>
<tr>
<td>Gas el.</td>
<td>-42.0 Wh /pe d</td>
<td>-64.7 Wh /pe d</td>
</tr>
<tr>
<td>Balance</td>
<td>+14.5 Wh /pe d</td>
<td>-31.4 Wh /pe d</td>
</tr>
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CONCLUSIONS

• Sidestream treatment using the DEMON® / Anammox treatment system is the most cost effective biological treatment solution.

• Seven systems now operational in North America with first system now treating filtrate from Cambi THP + Mesophilic digestion.

• Start up of the Pierce County DEMON® system has gone from 200 lb/day up to over 1,300 lb/day in less than 3 months.

• Strass WWTP in Austria using the A+B concept with both sidestream and mainstream deammonification with aeration control produces 25% more power than uses and is using less and less energy.
Thank you!!!

ANY QUESTIONS????

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