Centrate Treatment: Lessons Learned in the Full-Scale AnitaMOX™ Startup at Denver MWRD

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March 23, 2018
Outline

• First Principles: Deammonification
• Project Overview
• Startup Sequence
• Modes of Operation
• Performance Data
Conventional Nitrification/Denitrification

**Autotrophic Bacteria**
Aerobic Environment

- 1 mole Nitrite (NO$_2^-$)
- 25% O$_2$ (energy)
- 75% O$_2$ (energy) ~100% Alkalinity
- 1 mole Ammonia (NH$_3$/NH$_4^+$)

**Heterotrophic Bacteria**
Anoxic Environment

- 1 mole Nitrate (NO$_3^-$)
- 40% Carbon (BOD)
- 60% Carbon (BOD)
- ½ mol Nitrogen Gas (N$_2$)

**Nitrite Shunt**

**NITRIFICATION**

**DENITRIFICATION**
Deammonification

- Oxygen Requirement Reduction
- External rbCOD Requirement Eliminated

Autotrophic Bacteria
Aerobic Environment

- 0.5 mole Nitrite ($\text{NO}_2^-$)
- 37% $\text{O}_2$ (energy)
- ~50% Alkalinity

Ammonia Oxidizing Bacteria (AOB)

1 mole Ammonia ($\text{NH}_3 / \text{NH}_4^+$)

Anammox

Autotrophic Anoxic Environment

½ mol Nitrogen Gas ($\text{N}_2$) + a little bit of nitrate ($\text{NO}_3^-$)
Deammonification Configurations

• Sequencing Batch Reactor (SBR)
  • World Water Works DEMON®
  • Suez Cleargreen™

• Moving-bed Bioreactor (MBBR)
  • Kruger ANITAmox™

• Granulated Sludge
  • Paques Anammox®
Metro Wastewater Reclamation District

District Information

- ~1.7 million population
- Serves 49 entities
- Two treatment facilities

Northern Treatment Plant - 24 mgd

Robert W. Hite Treatment Facility (RWHTF) - 220 MGD
Breaking the Nitrogen Recycle Load

Regulatory Limits:
Barr-Milton TMDL
Reg. 31: TN = 2.1 mg/L
Sidestream Deammonification: ANITAmox™
## Baseline Design Criteria

### AnitaMOX Design

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centrate Flow (Peak)</td>
<td>1.1</td>
<td>MGD</td>
</tr>
<tr>
<td>Centrate Flow (Average)</td>
<td>0.9</td>
<td>MGD</td>
</tr>
<tr>
<td>Design Surface Area NH₄ Load</td>
<td>2.66</td>
<td>gN/m²/day</td>
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<tr>
<td>Total Media Fill</td>
<td>36.5</td>
<td>%</td>
</tr>
<tr>
<td>Seed Media</td>
<td>5</td>
<td>%</td>
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</table>

### Average Centrate Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>TKN</td>
<td>1,300</td>
<td>mg/L</td>
</tr>
<tr>
<td>NH₄-N</td>
<td>1,200</td>
<td>mg/L</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>3,900</td>
<td>mg/L</td>
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<tr>
<td>BOD₅</td>
<td>130</td>
<td>mg/L</td>
</tr>
<tr>
<td>TSS</td>
<td>300</td>
<td>mg/L</td>
</tr>
</tbody>
</table>
Project Overview

Scope

- Convert one Centrate and RAS Reaeration Basin (CaRRB) into two deammonification basins
- Treat 100% of the centrate to the following goals:
  - 80% ammonia oxidation
  - 70% TIN reduction
- AnitaMOX™ MBBR was selected
Sidestream Deammonification: Retrofit of CaRRB Reactor

Cylindrical Screen

Dewatering Centrate

AK-K5 Media

Sidestream Deammonification Reactors

AnitaMOX™

DMX1

DMX2

CaRRB

Stantec
Retrofitting & Repurposing Existing CaRRB

- Media Retention Screens
- Medium Bubble Diffuser Grids
- Stamo Mixers (Sweden)
Startup Sequence

1. Load unseeded media into reactors
2. Pump Primary Effluent for 4-6 week duration
3. Load seeded media into reactors
   - Temporary heating of centrate
Startup Sequence: Initial Seed at 5%
Startup Sequence

Goal:

• Keep ammonia concentration between 250-350 mg/L
• Keep nitrite below 60 mg/L
  • High nitrite is inhibitory to anammox
• Slowly increase centrate flow
• Slowly decrease duration of air OFF; more air ON
Startup Sequence

• Phase 1 – Batch feed with intermittent aeration (goal: NH3-N = 350 mg/L; end after 1-2 days)
• Phase 2 – Continuous feed with intermittent aeration
• Phase 3 – Increasing the feed load with reduction of air-OFF periods (keep NO2-N < 40 mg/L)
• Phase 4 – Increasing/maintaining the feed load with continuous aeration
Keys to Success

• Daily meetings to discuss analysis and make process decisions
• Trending is key to monitoring the process, just looking at a snapshot doesn’t give the whole picture
• NH3-N primary parameter for process control
• Don’t go backwards on air ON/OFF durations
Modes of Operation

• Aeration Control
• Intermittent Aeration
• Continuous Aeration
  • Airflow input value
  • DO control
  • pH control*
• Idle Mode (maintenance)
Startup Summary

- Unseeded media loaded in mid-June 2017
- Loaded Seeded Media – mid-August 2017
- Switched to continuous aeration – October 9, 2017
- 100% of Centrate Flow to Deammonification – November 21, 2017
Performance During Startup

Reactor 1

- Ammonia Oxidation Rate
- Nitrite Oxidation Rate
- Nitrogen Oxidation Rate by Anammox

Nitrate production aligns with stoichiometry

Accelerated Anammox Growth

Full Nitrite Oxidation
Surface Area Loading and TIN Removal Rates @ 36.5% Fill

SARR (g N/m²-d)
SALR (g N/m²-d)

Design SARR
Design SALR

DMX1
DMX2
Design Removal
Design Loading
Design HRT = 2.4 days

No Digested Solids EQ

Centrate Dilution

Design NH3 Load

Average Daily Flow and Load

Rapid Recovery

Stable

Digester Upset

Average Daily Influent Ammonia Concentration

1,100

Dilution

Average Daily Load

Design NH3 Load

Flow (mgd), HRT (days)

Total NH4-N Load  ---  Design Load  ---  Total Flow  ---  Observed HRT  ---  Design HRT

%NH4-N Removed  ---  %TIN Removed  ---  NH4 Guarantee

%NH4-N Removed  ---  %TIN Removed  ---  NH4 Guarantee

Temperature

Influent concentration  ---  Min 30-day avg NH4 Conc

Reactor 1  ---  Reactor 2  ---  30-day Avg Design Min

Min 30-day avg NH4 Conc

Reactor 1

Reactor 2

30-day Avg Design Min

Temperature (°C)
Challenges

- “Projectile” Media
- Foam
- Centrate Dilution
- Variable Centrate Flows
Takeaways

• Anamox is a proven technology for sidestream treatment
• Retrofitting and repurposing existing infrastructure is huge cost advantage
• Metro realizing significant cost savings on aeration
• Minimal seed percentages will continue until more "bio-farms" are on line
• Startup to full loading is achievable within 3 months
• Anamox seems relatively robust against perturbations upstream
• Retrofits always have their downsides