Nutrient Removal Optimization
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November 2017
Agenda

• Purpose
• Case Studies
• Summary
Purpose

The purpose of this presentation is to provide quantitative examples of nutrient optimization strategies that different North Carolina municipalities have used to optimize nutrient removal and reduce operating costs.
Case Study 1

Western Wake Water Reclamation Facility
Cary, NC
Western Wake Regional Water Reclamation Facility – 18 MGD

- Headworks
- Administration & Maintenance
- Switchyard
- Generators
- Clarifiers
- Filters
- Post Aeration
- Disinfection
- Bulk Chemicals
- Biological Reactor Basins
- Odor Control
- Effluent Pump Station
- Solids Handling
Western Wake WRF – Simplified Process Flow

Screens → Grit Removal → BRB Basins → Clarifiers → Flow Metering → Post Aeration → Effluent Filters → UV → Cape Fear

Drying → Dewatering → Thickening → Disposal
Process Configuration

Diagram showing the process configuration with stages labeled as Fermenter, Anaerobic, Anoxic, Anoxic, Aerobic, Aerobic, Post Anoxic, and Aerobic. Arrows indicate flow paths between these stages.
Timeline – Major operation changes since startup

- August 2014 – Facility placed into service
- Dec 2015 – Facility begins decreasing supplemental carbon dose
- Feb 2016 – Facility begins optimizing BRB DO concentrations
- August 2014 – Facility meets permit limits on first day of discharge
- July 2016 – Facility completely discontinues the use of supplemental carbon and ferric sulfate
Performance – Historical Effluent Data

Effluent Nitrogen

- After DO Control Improvements:
  - Effluent TN typically below 3.0 mg/L
  - Effluent TP typically below 0.3 mg/L
Chemical Dosing – July 2016 Facility discontinued the used of supplemental carbon and ferric sulfate

- Facility no longer needs chemical to achieve effluent TN below 3.0 mg/L and TP below 0.3 mg/L
Optimized DO Concentrations

- Low DO conditions in Cell 7 promote SND conditions
  - Also reduces DO returned back to the head of the anoxic zone for improved denitrification with influent carbon

DO setpoints:
- Cell 5: 1.75 mg/L
- Cell 6: 1.25 mg/L
- Cell 7: 0.25 mg/L
Optimized DO Concentrations → Lower nitrate concentrations in Cell 4 and Cell 8

- Clarifier channel nitrate has decreased to below 3.0 mg/L
Mixed Liquor Fermentation

- Small fermentation recycle pump – 75 GPM
- Creates an HRT of 50 hours at current flows
Mixed Liquor Fermentation

- Zone intended to release rbCOD and VFAs to be used for phosphorus and nitrogen removal
- Special sampling:
  - RAS sCOD = 28 mg/L
  - Cell 1 sCOD = 44 mg/L
  - Suggests fermentation is occurring in the ML Ferm Zone
- Cell 1 also has phosphorus release, supporting that there is an active PAO population uptaking sCOD in Cell 1
WWRWRF is achieving low effluent TN and TP limits, without the use of supplemental carbon or ferric sulfate.

The facility has optimized DO concentrations in the BRB basins for SND and nitrogen removal.

The ML fermentation zone is critical for meeting low effluent TP limits, and for a healthy Bio-P population.
Case Study 2
South Durham Water Reclamation Facility
Durham, NC
The SDWRF is One of Two 20 mgd Plants Owned and Operated by the City of Durham

- SDWRF had to meet TN limits of 3 mg/L
- Has 5-stage BNR
- Effluent TN averaged 8-9 mg/L
Kruger ANITA Mox MBBR is a Continuous Flow-Through Process with Biofilm on Media and Was Installed April 2015
Insert slide on baffle wall improvements
Insert slide on DO setpoints
SD has an operating budget of $1.960 M. Personnel costs are another $915,000.

For FY 16 we spent $547,400 on electricity and $85,420 on natural gas. It looks like we’ll be at $463,000 and $78,300 for FY17. We did not use any carbon in calendar year 2016 and ended up below the proposed N limit of 185,345 Lbs (173,244 Lbs). 2015 had 217,544 Lbs discharged.

-Charlie

From: Drummey, Patricia [mailto:pdrummey@hazenandsawyer.com]
Sent: Thursday, May 25, 2017 12:03 PM
To: Montgomery, Lori
Cc: Cocker, Charles; Bilyk, Katya; Wankmuller, David
Subject: RE: Poster for SDWRF ANITA Mox?

Hi Charlie,

We were considering adding an intro that mentions how much it costs to run South Durham per year as well as the typical energy cost per year. I think we have billing data,
Effluent TN for 2016 Lower than Previous Years due to Sidestream Treatment and Other Improvements at this Facility

~ 2 mg/L reduction
Facility Background

20 mgd rated capacity
  Currently 10.5 mgd AA

Stringent nutrient requirements for receiving water
  TN limit of 3 mg/L at current AA
  At 20 mgd TN limit = 1.6 mg/L

Recent upgrade to meet future TN limits
  Included dual-zone DO control, ABAC
Typical Layout for Each Basin

Cells 2-4 typically anoxic

DO Control Zone 1

DO Control Zone 2

Cells 8-9 anoxic

Cell 1 - anaerobic

Cells 5-7 aerobic

Cell 10 aerobic
Probe Types and Locations within BNR Basins – Includes 12 DO probes, 6 ammonia and 6 Nitrate

- DO probes - 12
- Ammonia and Nitrate probes - 12
DO and Ammonia Setpoints Since April 2016

**DO Zone 1**
- High: 4.0 mg/L
- Low: 2.5 mg/L

**DO Zone 2**
- High: 2.5 mg/L
- Low: 1.5 mg/L

**Ammonia**
- 1.0 mg/L

- DO probes - 12
- Ammonia and Nitrate probes - 12
Timeline & Historical PE BOD & TKN Loads Show Similar PE Quality During The Three Time Frames That Will be Compared

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Flow (mgd)</td>
<td>8.9</td>
<td>11.6</td>
<td>9.2</td>
</tr>
<tr>
<td>PE BOD load (lb/d)</td>
<td>13,710</td>
<td>14,870</td>
<td>15,530</td>
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<tr>
<td>PE TKN load (lb/d)</td>
<td>2,710</td>
<td>3,090</td>
<td>3,180</td>
</tr>
<tr>
<td>PE BOD:TKN</td>
<td>5.1</td>
<td>4.8</td>
<td>4.8</td>
</tr>
<tr>
<td>SRT (days)</td>
<td>14</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td>Aerobic SRT (days)</td>
<td>5</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>
ABAC Improved Reliability of Nitrification as Seen by Lower More Consistent Effluent Ammonia

Avg. Eff. NH₃ = 0.25 mg/L

Avg. Eff. NH₃ = 0.15 mg/L

Avg. Eff. NH₃ = 0.03 mg/L

ABAC – NH₃ Setpoint of 2.85 mg/L

ABAC – NH₃ Setpoint of 1.0 mg/L

DO Setpoint Control
Slightly Higher DO in Zone 1 with ABAC Likely Explains Improved Nitrification Efficiency (0.25 to 0.15 to 0.03 mg/L)

Max DO Setpoint 4.0 mg/L

Min DO Setpoint 2.5 mg/L

Before ABAC – least variation and lowest stpt

ABAC 1 mg/L stpt

NH3 conc. Leaving Cell 7
Zone 2 DO Average is Lower with ABAC and Less Variable, Which Improves Denitrification

Max DO Setpoint 2.5 mg/L
Min DO Setpoint 1.5 mg/L

DO typically at lower end of setpoints, suggests DO setpoint can be lowered for additional optimization

- With Zone DO but no ABAC, DO was Higher
- Similar DO profile with ABAC, rise in DO at min loading due to blower turndown

Graph:
- Avg Cell 7 DO - Jan 2015-Oct 2015
- Avg Cell 7 DO - Nov 2015 - March 2016
- Avg Cell 7 DO - April 2016 - Aug 2017

0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Hour
DO Conc. (mg/L)
Effluent Nitrate Consistently lower with ABAC

Effluent nitrate with ABAC setpoint at 1.0 mg/L similar to ABAC setpoint of 2.85 mg/L.
Zone DO control with ABAC has Made Denitrification More Efficient and Resulted in Lower Nitrate/TN

<table>
<thead>
<tr>
<th>Parameter</th>
<th>DO Setpoint Control</th>
<th>ABAC NH3 setpoint 2.85 mg/L</th>
<th>ABAC NH3 setpoint 1 mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effluent Nitrate (mg/L)</td>
<td>2.0</td>
<td>1.2</td>
<td>1.2</td>
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<tr>
<td>Nitrate Removed (lb/d)</td>
<td>267</td>
<td>416</td>
<td>438</td>
</tr>
<tr>
<td>Glycerin Dose (gal/day)</td>
<td>126</td>
<td>154</td>
<td>144</td>
</tr>
<tr>
<td>lb Nitrate Removed/gal Glycerin</td>
<td>2.1</td>
<td>2.7</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Graph: Effluent Nitrogen Species (mg/L) over years 2012-2017 with bars for Ammonia, NOx, and Total Organic TN. The graph shows a 0.7 mg/L TN reduction with ABAC.
Facility B – Operational Lessons Learned and Ongoing Work

Optimizing ABAC setpoints
Adjust DO setpoints based on seasonal variations (e.g. reduce in summer)

Ammonia Based Aeration Control (ABAC) Improved Reliability of Nitrification as Seen by Lower More Consistent Effluent Ammonia

Zone DO control with ABAC has Made Denitrification More Efficient and Resulted in Lower Nitrate/TN
Case Study 4

Hillsborough WWTP
Hillsborough, NC
Insert Hillsborough Aerial
Hillsborough process flow diagram
A Creative Solution was Developed to Convert the Existing Process to More Efficient 5-stage BNR for $1.3 million

- Add anaerobic and anoxic zones.
- Use FRP baffles.
- Convert to 2nd AX and reaer zones. Add MeOH.
- Two parallel trains.
- Fine bubble diffuser grid. PD blowers. Two DO zones.
Basin Views
Effluent TN Since Upgrade has Decreased Significantly

![Graph showing concentration of Effluent TN over time, with a significant decrease after the upgrade.](image-url)
Effluent TP Since Upgrade: BPR has Worked Well for Sustained Periods (No Chemical Addition Yet)
Optimization of BNR Process Led to Further Reductions in TN and TP

Converted 1/3 of aerobic zone to AX volume
Nitrate Leaving 1st Anoxic Zone has Decreased, Suggesting More 1st AX Zone Denitrification

Dissolved Oxygen (mg/L)

- 30 per. Mov. Avg. (Zone 1 Dissolved Oxygen)
- 30 per. Mov. Avg. (Zone 2 Dissolved Oxygen)
- 30 per. Mov. Avg. (Mass of nitrate leaving Aerobic Zone)

Optimization
Phosphorus Uptake Improved with Larger 1st Anoxic Zone

**Graph:**
- **Y-axis:** orthoP Concentration (mg/L)
- **X-axis:** Months from Mar-14 to Aug-14
- **Legend:**
  - orthoP - End of Stage - Conc.
  - 30 per. Mov. Avg. (orthoP - End of Stage - Conc.)

**Note:** Increase in orthoP concentration noted from Jun-14 onwards, indicating improved phosphorus uptake with the larger 1st anoxic zone.
Summary

Substantial increase in NRCY and 1\textsuperscript{st} anoxic zone
HRT reduced TN and need for supplemental carbon
Summary
Key Elements that Lead to Low Level Nutrients Reliably

Mixed liquor fermentation
ABAC
Ammonia-based load EQ
Sidestream treatment
Aerobic SRT control
Nitrate-paced carbon addition
Long 1st anoxic zone w/high NRCY
Optimized DO schemes
## Effluent Performance Summary

<table>
<thead>
<tr>
<th>Facility</th>
<th>TN (mg/L)</th>
<th>TP (mg/L)</th>
<th>Carbon</th>
<th>Metal Salt</th>
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</thead>
<tbody>
<tr>
<td>Western Wake WRF</td>
<td>2.5</td>
<td>0.22</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>North Durham WRF</td>
<td>2.2</td>
<td>0.97</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>South Durham WRF</td>
<td>.62</td>
<td>0.2</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Hillsborough WWTP</td>
<td>1.8</td>
<td>0.6</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
Questions

kbilyk@hazenandsawyer.com