Operation and Control of Multiple BNR Processes in One WWTP

Williamsport Sanitary Authority’s Chesapeake Bay and CSO Compliance Program

Presented by: Phil Anderson  
June 24, 2015
Purpose of Presentation

• Understand the operation and control of multiple the Biological Nutrient Removal (BNR) Systems.

• Review the Components of the Systems
  • Design criteria
  • Operation and process control
  • Target parameters

• Process Optimization
Agenda

• Overview of Central Plant
• Flow Pattern
• Biological Nutrient Removal
  • Design Criteria
    • Total Phosphorus Removal
    • Total Nitrogen Removal
• Operation & Monitoring
• Optimization
Where is Williamsport?
Agenda

• Overview of Central Plant
• Flow Pattern
• Biological Nutrient Removal
  • Design Criteria
    • Total Phosphorus Removal
    • Total Nitrogen Removal
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• Optimization
Central Plant Overview of Existing
Central Plant Overview of Existing

The Central Plant:
• Initially constructed in 1955

• Upgraded to secondary treatment in 1974.

• Fine bubble air diffusers were installed in 1994 to provide improved air distribution and mixing in the activated sludge system.

• WSA is a CSO community serving 63,000.
Central Plant Overview of Existing

Since 2004 WSA was in negotiations with USEPA and PADEP:

• Final effluent discharges to the West Branch of the Susquehanna River (Chesapeake Bay Watershed).

• In addition to NPDES permit requirements, the Chesapeake Bay Nutrient Reduction program requires the removal of nitrogen and phosphorus...
Central Plant Overview

- USEPA and PADEP’s Combined Sewer Overflow Regulations
- PADEP’s Chesapeake Bay Strategy
Central Plant

Nutrient Credit Trading:

- **DEP Requires Evaluation**: Credit purchase to be considered for PENNVEST funding.
- **DEP Favors Trading**: Encourages POTWs to fund non-point BMPs if more cost-effective.
- **Premise**: Buying credits may be less expensive than building and operating new infrastructure.
- **“Truing-up”**: Defer upgrades, use for permit year shortfalls.
Central Plant Nutrient Credit Trading

Nutrient Credit Trading (cont):

- **Credit Program**: Rules and policies not settled
- **Credit Supply/Price**: Availability uncertain; price subject to market variation.
- **Cost Comparison**: Current credit price is close to the cost of building some increments of treatment facilities.
Central Plant

In the end WSA:

• Evaluated the Nutrient Trading Program
• Determined the plant upgrades and expansion served the community better.
• Construction in addition to meeting the nutrient goals also provided capacity to reduce CSOs
• CP design started in 2005
• CP upgraded in 2009-2014
## Central Plant Overview NPDES Permit

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Daily Average (mg/l)</th>
<th>Daily Average (ppd)</th>
<th>Annual (Pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow (8.4 MGD)</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>CBOD</td>
<td>25</td>
<td>1,750</td>
<td>na</td>
</tr>
<tr>
<td>Nitrate</td>
<td>2.0</td>
<td>140</td>
<td>na</td>
</tr>
<tr>
<td>TKN</td>
<td>4.0</td>
<td>280</td>
<td>na</td>
</tr>
<tr>
<td>TN</td>
<td>6.0 (4.5)</td>
<td>420</td>
<td>153,423</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>0.8 (0.5)</td>
<td>56</td>
<td>20,456</td>
</tr>
</tbody>
</table>
## Central Plant Overview Process Modeling

<table>
<thead>
<tr>
<th>Influent Parameters (Including Recycle Streams)</th>
<th>Annual Average - Average Flows, Average Loads</th>
<th>Annual Average - Average Flows, Max. Month Loads</th>
<th>Max Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow</td>
<td>8.4</td>
<td>8.4</td>
<td>21</td>
</tr>
<tr>
<td>cBOD5 (mg/L)</td>
<td>112</td>
<td>162</td>
<td>77</td>
</tr>
<tr>
<td>cBOD5 (lb/d)</td>
<td>7,860</td>
<td>11,374</td>
<td>13,485</td>
</tr>
<tr>
<td>TSS (mg/L)</td>
<td>101</td>
<td>179</td>
<td>89</td>
</tr>
<tr>
<td>TSS (lb/d)</td>
<td>7,098</td>
<td>12,509</td>
<td>15,646</td>
</tr>
<tr>
<td>TKN (mg/L)</td>
<td>24</td>
<td>34</td>
<td>13</td>
</tr>
<tr>
<td>TKN (lb/d)</td>
<td>1,660</td>
<td>2,358</td>
<td>2,358</td>
</tr>
<tr>
<td>TP (mg/L)</td>
<td>3.8</td>
<td>7</td>
<td>2.6</td>
</tr>
<tr>
<td>TP (lb/d)</td>
<td>267</td>
<td>457</td>
<td>457¹</td>
</tr>
</tbody>
</table>
Modeled 3 Different Conditions:

1. Average flows and average loads (to assess year-round performance)
2. Maximum month loads at average flow
3. Maximum month flows at max month loads (design condition to meet nutrient requirements)
Central Plant Overview Improvements
Central Plant Overview Improvements to Existing

- **Activated Sludge**
  - Improved Air Flow and DO Control (Aerobic)
  - Changed AS to Modified Ludzak-Ettinger (MLE) Process for the removal of Nitrate.
  - Added IMLR Pumps – Return Nitrates to Influent Zones (Anoxic)
  - Anoxic Zones – Mixing only
  - Swing Zones – Mixing for Anoxic/Aerobic and Air Diffusers for Aerobic
  - Anaerobic Zone for phosphorus removal

- **Secondary Clarifiers converted to Bioreactors**
- **CCT converted to Reaeration Tanks**
Central Plant Overview

New Facilities:

• CSO Tank
• Headworks
• Secondary Clarifiers
• Chemical Feed – Polymer, FeCl2 & NaOH
• Denitrification Filters – Carbon Feed
• Chlorine Contact Tank
• Sidestream Treatment – for recycle loading
• Gravity Belt Thickener
• SCADA
Central Plant Overview of Existing
Central Plant Overview
Agenda

• Overview of Central Plant
• Flow Pattern
• Biological Nutrient Removal
  • Design Criteria
    • Total Phosphorus Removal
    • Total Nitrogen Removal
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• Optimization
Flow Pattern

- HDW (21 MGD)
  - FeCl₃ / Polymer
  - PRE AIR
  - PSTs (22 MGD)
  - NaOH

- BNR (MLE)
  - FeCl₃ / Polymer
  - RAS

- Sec. Clarifiers
  - WAS
  - Sidestream Treatment
    - GT
    - GT
    - GBT
    - RECYCLE

- PSA
  - 1 MGD

- Filter Press
  - Belt Filter Press
    - SLUDGE CAKE TO LANDFILL

- Disinfection
  - UP TO 22 MGD
  - 0 TO 8.9 MGD
  - BACKWASH (RECYCLE)

- CSO
  - 2 MG Tank
  - 0 – 25 MGD
  - RECYCLE

- Anaerobic Digestion
  - RECYCLE
Flow Pattern
Agenda

- Overview of Central Plant
- Flow Pattern
- **Biological Nutrient Removal**
  - Design Criteria
    - Total Phosphorus Removal
    - Total Nitrogen Removal
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Biological Nutrient Removal Overview
Biological Nutrient Removal Overview

BNR by Activated Sludge using three zones (aerobic, anoxic & anaerobic):

• Aerobic to remove:
  ✓ CBOD and Ammonia - Nitrification (produces nitrates)
• Anoxic to remove:
  ✓ Nitrates using Denitrification
• Anaerobic to remove:
  ✓ Phosphorus

• Permit Goal
  ✓ Total Nitrogen (Nitrate Plus TKN)
  ✓ Total Phosphorus
Agenda

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## Operation & Monitoring - MOPO

<table>
<thead>
<tr>
<th>Schedule</th>
<th>System Startup</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 2012</td>
<td>Headworks; Influent and CSO Pumping, Screening and Grit Removal</td>
</tr>
<tr>
<td>September 2012</td>
<td>Primary Sludge Pumping</td>
</tr>
<tr>
<td>October 2012</td>
<td>Aeration Tanks (MLE)</td>
</tr>
<tr>
<td>January 2013</td>
<td>Secondary Clarifiers, RAS, Disinfection and CCT, Final Scum Pumping</td>
</tr>
<tr>
<td>March 2013</td>
<td>Denitrification Filters and Methanol System</td>
</tr>
<tr>
<td></td>
<td>BFP Sludge Cake Conveyor and Cake Pumps</td>
</tr>
<tr>
<td>May 2013</td>
<td>Chemical Feed Systems (Ferric Chloride &amp; Sodium Hydroxide)</td>
</tr>
<tr>
<td>August 2013</td>
<td>Side Stream Treatment (SST)</td>
</tr>
<tr>
<td>September 2013</td>
<td>Gravity Belt Thickener (GBT)</td>
</tr>
<tr>
<td>October 2013</td>
<td>Bio-reactors and Re-aeration Tanks</td>
</tr>
</tbody>
</table>
Operation & Monitoring - MOPO

- WWTP Staff - Who are they? What is their experience?
- Formed the WSA Process Control Team (PCT)
  - WSA Operations Manager
  - WSA WW Operations Manager
  - WSA CP Superintendent
  - WSA CP Assistant Superintendent
  - ARCADIS RPR (Resident Engineer)
  - ARCADIS Operations Specialist
  - ARCADIS Liaison Engineer
  - Gannett Fleming Construction Manager
Operation & Monitoring - MOPO

Operational Goals:

• Meet the limits of the NPDES
  • TN
  • TP
• Manage peak flows
  • Flow Controls
  • Maintain Bio Mass
• Well established operating procedures
• SCADA and process control
Operation & Monitoring

- The BNR Process has three types of zones:
  - Selector anoxic zones (A) for selection against filamentous microorganisms and for denitrification (nitrate removal).
  - Swing zones anoxic/anaerobic/aerobic (B) and (Bioreactors – anoxic/aerobic).
  - Aerobic zones (C & D) for CBOD/COD removal and nitrification and reaeration (Reaeration Tanks).
Operation & Monitoring

Warm weather operation:

- Zone A and the bioreactors are operated in anoxic mode
- Zone B anaerobic for P removal
  - Plus RAS and Primary Effluent
- Zones C and D, and the reaeration tanks in aerobic mode.
Operation & Monitoring

Internal Recycle

A ANOXIC

B AN - AEROBIC

C OX

D OX

Bio-Reactors ANOXIC

Reaeration OX

Sec. Clar.

RAS

(typ. of 2 trains)

Anoxic

Aerobic

Anoxic

Aerobic

Nitrate

Denite Filters

Operation & Monitoring

Internal Recycle

A ANOXIC

B AN - AEROBIC

C OX

D OX

Bio-Reactors ANOXIC

Reaeration OX

Sec. Clar.

RAS

(typ. of 2 trains)

Anoxic

Aerobic

Anoxic

Aerobic

Nitrate

Denite Filters
Operation & Monitoring
Operation & Monitoring

Fall & Spring Conditions:

• Maintain warm weather operation as long as possible to maintain P removal
• Zone B and the Bio-Reactors are operated in anoxic or aerobic modes in the transition seasons of fall and spring as necessary to achieve nitrification and denitrification.
• Any remaining nitrate removal is achieved in the denitrification filters.
Operation & Monitoring

Internal Recycle


(typ. of 2 trains) RAS

Anoxic Aerobic Anoxic Aerobic

Denite Filters

Nitrate
Operation & Monitoring

Cold weather conditions:

- Low wastewater temperatures (< 12°C) slow microbial activity.
- Zones A and B operated in anoxic mode
- Any phosphorus is passed on to the denitrification filters.
- Zones C and D, and bioreactors are operated in aerobic mode.
Operation & Monitoring

Cold weather conditions (continued):

- This maximizes the volume available for nitrification, while still achieving partial denitrification in Zone A and B.
- Any remaining nitrate and phosphorus removal is achieved in the denitrification filters.
Operation & Monitoring
Cold Weather

Internal Recycle

A
AX

B
AX

C
OX

D
OX

RAS

(typ. of 2 trains)

Bio-Reactor
OX

Reaeration
OX

Sec. Clar.

Denite Filters

Anoxic

Aerobic

Aerobic

Nitrate

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Operation & Monitoring

Analytical Probes and Transmitters:

- Dissolved Oxygen (Zones B, C & D and Reaeration Tanks)
  - Improved Air Flow and DO Control Loop
- ORP (Zones A & B, Bioreactor effluent)
- Nitrate (Zones A, B & D)
- Ammonia (D)
- Phosphorus (Plant Influent Denite Filter Influent & Plant Effluent)
## Target Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Zone A</th>
<th>Zone B: P - Removal</th>
<th>Zone B: Winter</th>
<th>Zone C</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORP</td>
<td>-50 to -450</td>
<td>-300 to -450</td>
<td>-50 to +100</td>
<td>--</td>
</tr>
<tr>
<td>DO</td>
<td>0 to 0.2 mg/l</td>
<td>0 to 0.2 mg/l</td>
<td>2 to 3 mg/l</td>
<td>3 mg/l</td>
</tr>
<tr>
<td>Nitrate</td>
<td>0 to 10 mg/l</td>
<td>0 to 2 mg/l</td>
<td>0 to 10</td>
<td>5 to 20 mg/l</td>
</tr>
<tr>
<td>Ammonia</td>
<td>&gt;20 mg/l</td>
<td>&gt;25 mg/l</td>
<td>&gt;20</td>
<td>0 to 10 mg/l</td>
</tr>
</tbody>
</table>

Imagine the result
## Operation & Monitoring
### DO and Air Flow Control

### Target Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Zone D</th>
<th>Bioreactor</th>
<th>Reaeration Tank</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORP</td>
<td>--</td>
<td>-50 to +100</td>
<td>--</td>
</tr>
<tr>
<td>DO</td>
<td>2 mg/l</td>
<td>0 to 3 mg/l</td>
<td>2 to 3 mg/l</td>
</tr>
<tr>
<td>Nitrate</td>
<td>0 to 4 mg/l</td>
<td>0 to 4 mg/l</td>
<td>0 to 4 mg/l</td>
</tr>
<tr>
<td>Ammonia</td>
<td>&lt;5 mg/l</td>
<td>&lt;5 mg/l</td>
<td>&lt;5 mg/l</td>
</tr>
</tbody>
</table>
## Operation & Monitoring IMLR Control

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMLR Pumps Return Rate</td>
<td>100 to 300%</td>
<td>Influent Flow &lt; 9.0 MGD</td>
</tr>
<tr>
<td>% Return Rate of Plant Influent</td>
<td>0% to 100%</td>
<td>Influent Flow 9.0 to 12.5 MGD</td>
</tr>
<tr>
<td>Flow</td>
<td>Pumps Off</td>
<td>Influent Flow &gt;12.5 MGD</td>
</tr>
</tbody>
</table>
Operation & Monitoring
Aeration Tank Flow Control
Normal Operation – Remote Auto

• All Influent gates operate in Remote Auto and can be controlled from the OPC or WS.
• Gate position is automatically changed to the flow modes below based on maximum flow setpoint adjustable by the Operator:
  • Plug Flow <14.0 MGD
  • Step Feed 14.0 to 18.0 MGD
  • Contact Stabilization >18.0 MGD
Operation & Monitoring
Operation & Monitoring
Operation & Monitoring
Agenda

• Overview of Central Plant
• Flow Pattern
• Biological Nutrient Removal
  • Design Criteria
• Startup Planning
• Operation & Monitoring
• Optimization
Optimization

On Going:

• Created a tiered TN loading target
• Assist with BNR operation
  • Aeration tanks and bioreactors
  • Denitrification filters
• Continue to confirm the Bio Win Model
• Update Normal and Wet Weather BNR Operation and Denitrification SOPs
• Assist WSA in fine-tuning operations and SCADA control schemes
Optimization

TOTAL NITROGEN & STARTUP SCHEDULE

- Total Nitrogen Seasonal Goals
- Primary Effluent Total Nitrogen
- Secondary Effluent Total Nitrogen

- Startup New HDWs
- Startup Aeration Improvements
- Startup Secondary Clataifers
- Startup New Denite Filters
- Denite Filter Performance Test
- Startup Bioreactors
- Shutdown Denite Filter
Questions?