Optimization of Biological Nutrient Removal Wastewater Treatment Systems

ACWA Nutrients Permitting Workshop
June 5, 2018

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Division of Environmental and Financial Assistance
Compliance Assistance Unit
The Plan

• What goes wrong

• Troubleshooting systems

• Case studies

• Questions and Comments
What goes wrong...

Permit Limits change, and the WWPT doesn’t

Land Application of Treated Wastewater Rules Implemented 2014

- WWTPs encouraged to avoid discharging to Waters of the State
- Eased limits since they discharged to impoundments
- WWTPs not designed to meet 10 mg/L TIN in effluent
What goes wrong...

Effluent limits tighten statewide

Tighter TP limits for some dischargers to Ohio River

Nitrate limits on the horizon?
What goes wrong...

Design is important

But often design is by the book (and bacteria can’t read)

Inattention to influent waste streams will create havoc with BNR

Especially influents with weak organic loadings
What goes wrong...

Disconnect between design and operation

Design is important
But when design doesn’t include operational flexibility,
the hands of the operator are tied

(operators don’t get to chose what comes down the pipe)
Troubleshooting Systems

Process Control is an essential

- Check the chemical trails that the biology leaves behind
- Field test equipment
- Grab samples, sometimes lots of grab samples
- Cheap, easy, and effective
Troubleshooting Systems
Troubleshooting Systems
Troubleshooting Systems

If the conditions are right, the bacteria will perform

Ammonia, nitrate, and orthophosphate in the inputs to the tanks

Ammonia, nitrate, and orthophosphate in the tanks

Measure, don’t guess...
Troubleshooting Systems

Cedarville WWTP
Nutrient Profile
08/24/2004

<table>
<thead>
<tr>
<th>Location</th>
<th>NH3-N (mg/L)</th>
<th>NO3-N (mg/L)</th>
<th>PO4 (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preair effluent box</td>
<td>30</td>
<td>7.0</td>
<td>2.1</td>
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<tr>
<td>Pre-anaerobic eff</td>
<td>16</td>
<td>0.9</td>
<td>10.8</td>
</tr>
<tr>
<td>Anaerobic eff</td>
<td>14.7</td>
<td>0.0</td>
<td>10.8</td>
</tr>
<tr>
<td>Anoxic eff</td>
<td>13</td>
<td>0.7</td>
<td>1.3</td>
</tr>
<tr>
<td>Oxic eff</td>
<td>0.01</td>
<td>1.4</td>
<td>1.1</td>
</tr>
<tr>
<td>Clarifier eff</td>
<td>0.38</td>
<td>1.3</td>
<td>0.9</td>
</tr>
</tbody>
</table>
Case Study: Firestone Trace WWTP
Case Study: Firestone Trace WWTP
Firestone Trace WWTP

We found:

Nitrates are high (anoxic and effluent)
  • Turn the Nitrate Recycle Pump down to 15 min ON, 45 min OFF (96 pin timer!)
Influent COD is low
Aeration tanks are very aerobic (NH$_3$-N ~ 0)
Expand the Anoxic Tank?
Troubleshooting Systems

Clarifiers

Oxic Tank

Oxic Tank

An-Oxic Tank

Anoxic Tank

EQ Basin

NO3-N Recycle
Firestone Trace WWTP
s::can Data
01/05 - 01/13
Firestone Trace WWTP

Continued to run with two anoxic tanks for through the summer of 2011

Flirted with Noncompliance for TIN all summer

Pretty certain that carbon was the limiting factor
Firestone Trace WWTP

9/12/2011

A 55 gallon drum of Glycerin began to drip into the Anoxic Tank
Firestone Trace WWTP
Effluent Total Inorganic Nitrogen
Individual Samples (2 per month)
9/12/2011 - 4/30/2014

TIN (mg/L)
Firestone Trace WWTP
Monthly Total Inorganic Nitrogen

TIN (mg/L)
Process Control Flow Chart for Denitrification in Anoxic Tank

Clarifier Effluent Ammonia and Nitrate Test

- Ammonia Low
  - Nitrates Low
    - System in Compliance
  - Nitrates High
    - Check Anoxic Tank Nitrates
- Ammonia Low
  - Nitrates High
  - Ammonia High
  - Nitrates Low
    - Incomplete Nitrification

Nitrates High

- Increase Soluble Carbon Feed
- Or Reduce Nitrate Recycle Pump Rate

Nitrate Low

- Increase Nitrate Recycle Pump Rate

Check and Correct Nitrification Inhibition:
- Low DO
- Low Alkalinity
- Low Temp
- Low MLSS
- Low Time
Firestone Trace WWTP

Optimize Anoxic Zone

- Control Nitrate Recycle
- Control Soluble Carbon

Process Control

- Anoxic Tank NH3-N and NO3-N
- Aeration Tank NH3-N and NO3-N
Case Study: Scioto Reserve WWTP

Aeration Tank

EQ

RAW

RAS
Scioto Reserve WWTP

0.423 MDG Design Flow

Operates at 50% design flow at 100+% of capacity

Land applies treated wastewater to an impoundment for irrigation of golf course

In 2012, rules for land application change and implementation of tight limits begins. Effluent limits required 10 mg/L TIN by April 2014

Scioto Reserve WWTP original design does not provide for denitrification
Scioto Reserve WWTP

Initially, tried to ON/OFF blower operation to denitrify in the aeration tanks

Occasionally TIN would be within permit, but no consistency, no room for safety

December 2013: Drastic measures
Scioto Reserve WWTP
Effluent Total Inorganic Nitrogen
2013

[Graph showing weekly sampling of TIN (mg/L) from 1/2/2013 to 12/18/2013.]

Weekly Sampling
Process Control Flow Chart for Denitrification in Anoxic Tank

Clarifier Effluent Ammonia and Nitrate Test:
- Ammonia Low Nitrate Low
  - System in Compliance
- Ammonia Low Nitrates High
- Ammonia High
  - Incomplete Nitrification

Nitrates High
- Increase Soluble Carbon Feed Or Reduce Nitrate Recycle Pump Rate

Nitrate Low
- Increase Nitrate Recycle Pump Rate

Check and Correct Nitrification Inhibition:
1. Low DO
2. Low Alkalinity
3. Low Temp
4. Low MLSS
5. Low Time
<table>
<thead>
<tr>
<th>Sensor</th>
<th>Value</th>
<th>Parameter</th>
<th>Temperature</th>
<th>Notes</th>
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<tbody>
<tr>
<td>01</td>
<td>0.6 mg/l</td>
<td>O2</td>
<td>16.2 °C</td>
<td>AT DO</td>
</tr>
<tr>
<td>02</td>
<td>1.5 mg/l</td>
<td>NH4-N</td>
<td>16.2 °C</td>
<td>AT NH3</td>
</tr>
<tr>
<td>03</td>
<td>5.5 mg/l</td>
<td>NO3-N</td>
<td>16.2 °C</td>
<td>AT NO3</td>
</tr>
<tr>
<td>04</td>
<td>6.58</td>
<td>pH</td>
<td>16.1 °C</td>
<td>AT pH</td>
</tr>
<tr>
<td>05</td>
<td>0.1 mg/l</td>
<td>O2</td>
<td>16.0 °C</td>
<td>AX DO</td>
</tr>
<tr>
<td>06</td>
<td>6.7 mg/l</td>
<td>NH4-N</td>
<td>16.0 °C</td>
<td>AX NH3</td>
</tr>
<tr>
<td>07</td>
<td>4.0 mg/l</td>
<td>NO3-N</td>
<td>16.0 °C</td>
<td>AX NO3</td>
</tr>
<tr>
<td>08</td>
<td>6.78</td>
<td>pH</td>
<td>16.1 °C</td>
<td>AX pH</td>
</tr>
</tbody>
</table>
Scioto Reserve WWTP

• 1) created a mixed Anoxic Zone
• 2) relied on RAS for nitrate recycle
• 3) relied on raw wastewater for carbon source
• 4) Ran blowers ON/OFF during the week
• 5) Ran full aeration during the weekend

• TIN < 10 mg/L
Scioto Reserve WWTP
VARiON Data
Weekly Sampling TIN
February 12 - September 9, 2014
Scioto Reserve WWTP
VARiON Data
Weekly Sampling TIN
February 12 - September 9, 2014

[Bar chart showing weekly sampling data for TIN from February 12 to September 9, 2014. The chart includes dates from 3/16/2014 to 9/6/2014 and indicates concentration levels.]
Scioto Reserve WWTP
VARiON Data
Aeration Tank NH3-N and NO3-N
9/20 - 10/06
Scioto Reserve WWTP
VARiON Data
Anoxic Tank NH3-N and NO3-N
9/20 - 10/06
Troubleshooting Systems: Bradford WWTP

New WWTP came online November 2013

Constructed a Carrousel Type BNR System

Designed for 0.480 MGD

2017 average flow: ~0.550 MGD (big clarifiers!)
Troubleshooting Systems: Bradford WWTP

BNR (Carrousel type)

RAS (NO3-N) -> OXIC -> NO3-N Recycle -> RAW (Carbon)
Bradford Wastewater Treatment Plant
Effluent Total Phosphorus
1/1/2014 to 4/25/2018
## Nitrate Analysis

<table>
<thead>
<tr>
<th>Nitrate (mg/L)</th>
<th>RAS</th>
<th>Anaerobic</th>
<th>Anoxic</th>
<th>Digester</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/15/2018</td>
<td>14.3</td>
<td>11.9</td>
<td>14.6</td>
<td>14.6</td>
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<tr>
<td>3/19/2018</td>
<td>8.7</td>
<td>12.5</td>
<td>11.9</td>
<td>11.9</td>
</tr>
<tr>
<td>3/20/2018</td>
<td>11.6</td>
<td>7.9</td>
<td>11.8</td>
<td>55.9</td>
</tr>
<tr>
<td>3/21/2018</td>
<td>11.5</td>
<td>7.5</td>
<td>12.0</td>
<td>12.0</td>
</tr>
<tr>
<td>3/22/2018</td>
<td>8.6</td>
<td>8.2</td>
<td>11.1</td>
<td>131.5</td>
</tr>
</tbody>
</table>
Case Study: Bradford WWTP

Too much Nitrate everywhere

Solution:

1) Close the nitrate recycle gate
2) Run vertical rotor at 30 hertz
3) Turn Anaerobic Zone Mixer OFF for 3 hours, ON for 15 minutes
4) Turn Anoxic Zone Mixer OFF for 3 hours, ON for 15 minutes
5) Profile Ammonia, Nitrate, and Orthophosphate in each zone
Bradford WWTP
Nutrient Profile
Nitrate Grab Sampling

Concentration (mg/L)

Date

Anaerobic - NO3-N
Anoxic - NO3-N
Bradford WWTP
Nutrient Profile Grab Sampling

Concentration (mg/L)

<table>
<thead>
<tr>
<th>Date</th>
<th>Final Effluent - NO3-N</th>
<th>Final Effluent - PO4-P</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/11/2018</td>
<td>0.64</td>
<td>0.11</td>
</tr>
<tr>
<td>4/12/2018</td>
<td>0.72</td>
<td>0.27</td>
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<tr>
<td>4/19/2018</td>
<td>0.43</td>
<td>0.11</td>
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<tr>
<td>4/30/2018</td>
<td>0.36</td>
<td>0.27</td>
</tr>
<tr>
<td>5/2/2018</td>
<td>0.11</td>
<td>0.13</td>
</tr>
<tr>
<td>5/7/2018</td>
<td>0.72</td>
<td>0.51</td>
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<tr>
<td>5/8/2018</td>
<td>0.36</td>
<td>0.17</td>
</tr>
<tr>
<td>5/15/2018</td>
<td>0.37</td>
<td>0.37</td>
</tr>
<tr>
<td>5/16/2018</td>
<td>0.16</td>
<td>0.2</td>
</tr>
<tr>
<td>5/22/2018</td>
<td>0.2</td>
<td>0.18</td>
</tr>
<tr>
<td>5/23/2018</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Case Study: Bradford WWTP

First April sample was high (1.25 mg/L), but the rest of the samples brought the monthly down to 0.66 mg/L

Alum feed was shut down 5/2

May 2018 another consecutive month of compliance for TP

In addition, the village was spending $1200/month for alum previously.

Electricity demand should also be reduced due to mixer turndown
Case Study: Bradford WWTP

Keys to BPR:

Process Control!

1) Monitor the nutrients in the Inputs to each zone
2) Monitor the nutrients in Internal Recycles (Digester Supernatant)
3) If the Chemistry is correct in the zones, the bacterial response will be compliant.
4) Know the chemical environment in each zone of the WWTP.
Questions?

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