Cold Weather Nitrification/Denitrification in Lagoons

October 13, 2016

Marc W. Salmi, P.E.
Environmental Dynamics International
Agenda

• Overview & Background
• IDEAL Bioreactor
• Performance Data (Round 1)
• Nutrient Removal in Lagoons
  – Phosphorous & Nitrogen Pathways
  – Treatment Philosophies
• Performance Data (Round 2)
• Nutrient Rebound
• Configurations
• Q&A
Overview & Background
Overview & Background

• Leader in aerated lagoons for 40 years
  – Introduced retrievable panel technology for aerated lagoons in 1970s
  – Continued innovative aeration and treatment design

Complete Mix Lagoon

Partial Mix Lagoon
Overview & Background

• Applying design expertise to advanced biological processes for 35+ years
  – Activated sludge and extended aeration plants
  – Over 3,500 installations world-wide

Botina, Paraguay
Millbury, MA
Overview & Background

- 25 Years of Sequencing Batch Reactor Systems
  – Over 300 international installations

Greater Noida, India – 72 MGD
Zywiec, Poland – 27 MGD
Overview & Background

• Integrated Fixed-Film System (IFAS) Innovation and Lagoon Installation
  – 50+ domestic MBBR installations
The IDEAL Bioreactor
The IDEAL Bioreactor

- **Intermittently Decanted Extended Aeration Lagoon (IDEAL)**
  - An advanced upgrade for lagoon-based treatment processes
    - Especially nutrient (ammonia, nitrogen, phosphorous) removal
  - Incorporates proven technologies across 40 years of wastewater treatment experience
What is the IDEAL Bioreactor?

Intermittently Decanted Extended Aeration Lagoon (IDEAL)
IDEAL® Solution

Phases

Phase 1: Fill and Aeration *(2 hours)*

Phase 2: Fill and Settle *(1 hour)*

Phase 3: Fill and Decant *(1 hour)*

*operating sequence adjustable*
Performance Data (Round 1)
Performance Data – Grantsville, UT
Performance Data – Grantsville, UT

BOD Concentration (mg/L) vs. Time

Date

Concentration (mg/L)
Performance Data – Grantsville, UT

TSS Concentration (mg/L) vs. Time

Date
## Performance Data – Grantsville, UT

### Process Data Summary (48+ Month Concentrations)

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Influent</th>
<th>Effluent</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>147 ± 40</td>
<td>2.1 ± 4.1</td>
<td>mg/L</td>
</tr>
<tr>
<td>TSS</td>
<td>180 ± 60</td>
<td>11 ± 12</td>
<td>mg/L</td>
</tr>
<tr>
<td>Minimum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow Rate (MGD)</td>
<td>.004</td>
<td>0.7</td>
<td>1.99</td>
</tr>
</tbody>
</table>
Performance Data – Miner, MO
Performance Data – Miner, MO

BOD Concentration (mg/L) vs. Time

- Influent
- Effluent

Graph showing BOD concentration (mg/L) over time from June 2012 to September 2015.
Performance Data – Miner, MO

TSS Concentration (mg/L) vs. Time

- Influent
- Effluent
## Performance Data – Miner, MO

### Process Data Summary (24 Month Concentrations)

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Influent</th>
<th>Effluent</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>260 +/- 90</td>
<td>8.6 +/- 7.3</td>
<td>mg/L</td>
</tr>
<tr>
<td>TSS</td>
<td>90 +/- 40</td>
<td>14 +/- 10</td>
<td>mg/L</td>
</tr>
</tbody>
</table>
Performance Data – New Madrid, MO

(Photo Not Available)
Performance Data – New Madrid, MO

BOD Concentration (mg/L) vs. Time

Date

Concentration (mg/L)


Inf

Eff
Performance Data – New Madrid, MO

TSS Concentration (mg/L) vs. Time

Concentration (mg/L)

Date


Inf
Eff
# Performance Data – New Madrid, MO

## Process Data Summary

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Influent</th>
<th>Effluent</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>210 +/- 70</td>
<td>5 +/- 2.7</td>
<td>mg/L</td>
</tr>
<tr>
<td>TSS</td>
<td>110 +/- 40</td>
<td>12 +/- 7</td>
<td>mg/L</td>
</tr>
</tbody>
</table>
Nutrient Removal in Lagoons
Nutrient Removal in Lagoons

- Phosphorous
- Nitrogen
  - Ammonia/Ammonium
  - Nitrate/Nitrite
  - Cellular/Biomass/Sludge
Nutrient Removal in Lagoons
Nutrient Removal in Lagoons

Missouri Department of Natural Resources

Changes to the Water Quality Standard for Ammonia

Water Protection Program fact sheet
Division of Environmental Quality, Leanne Tippett Mosby, Director

10/2013

Ammonia toxicity varies by temperature and by pH of the water. Assuming a stable pH value, but taking into account winter and summer temperatures, Missouri includes two seasons of ammonia effluent limitations. Typical ammonia effluent limitations for a facility discharging to a stream with no dilution allowances, under the current water quality standard, are:

- Summer – 3.6 mg/L daily maximum, 1.4 mg/L monthly average.
- Winter – 7.5 mg/L daily maximum, 2.9 mg/L monthly average.

Under the new EPA criteria, where mussels are present or expected to be present, typical effluent limitations for a facility discharging to a stream with no dilution allowance would be:

- Summer – 1.7 mg/L daily maximum, 0.6 mg/L monthly average.
- Winter – 5.6 mg/L daily maximum, 2.1 mg/L monthly average.
Nutrient Removal in Lagoons

Wastewater Treatment Technologies

Key:
A – Preferred when feasible
B – Has demonstrated capability in meeting ammonia when designed appropriately
C – Shows potential for meeting ammonia limitations.
D – Unlikely to meet ammonia limitations, or data inconclusive

<table>
<thead>
<tr>
<th>Wastewater Technology</th>
<th>Ammonia Effluent Limit (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 0.7</td>
</tr>
<tr>
<td>Land Application</td>
<td>A</td>
</tr>
<tr>
<td>Wetland</td>
<td>D</td>
</tr>
<tr>
<td>Facultative Lagoon</td>
<td>D</td>
</tr>
<tr>
<td>Aerated, Partial Mix Lagoon</td>
<td>D</td>
</tr>
<tr>
<td>Lagoons with Approved Retrofits</td>
<td>C</td>
</tr>
<tr>
<td>Recirculating Sand Filter</td>
<td>C</td>
</tr>
<tr>
<td>Trickling Filter</td>
<td>D</td>
</tr>
<tr>
<td>Oxidation Ditch</td>
<td>B</td>
</tr>
<tr>
<td>Extended Aeration Package Plant</td>
<td>D</td>
</tr>
<tr>
<td>Sequencing Batch Reactor</td>
<td>B</td>
</tr>
<tr>
<td>Biological Nutrient Removal</td>
<td>B</td>
</tr>
<tr>
<td>Enhanced Biological Nutrient Removal</td>
<td>B</td>
</tr>
<tr>
<td>Membrane Bioreactors</td>
<td>B</td>
</tr>
<tr>
<td>Breakpoint Chlorination</td>
<td>D</td>
</tr>
<tr>
<td>Moving Bed Biofilm Reactor</td>
<td>B</td>
</tr>
<tr>
<td>Integrated Fix Film Activated Sludge</td>
<td>B</td>
</tr>
<tr>
<td>Side Stream Nutrient Removal</td>
<td>B</td>
</tr>
</tbody>
</table>
Nutrient Removal in Lagoons

• Solution to Challenges:
  – Increase Biomass
    • Back-of-the-Plant
    • Middle-of-the-Plant
    • Front-of-the-Plant

Complete Mix → Partial Mix Cell with Quiescent Zone
Nutrient Removal in Lagoons

- Select a Selector
  - Back of the Plant
    - Attached growth “filters”
    - Must address variable loading (temperature induced)
Nutrient Removal in Lagoons

- Select a Selector
  - Back of the Plant
    - Attached growth “filters”
    - Must address variable loading (temperature induced)

**Summer**

30 mg/L, in 2 mg/L, out

- Complete Mix
- Partial Mix Cell with Quiescent Zone
- Post-QZ Polishing Filter
Nutrient Removal in Lagoons

- Select a Selector
  - Back of the Plant
    - Attached growth “filters”
    - Must address variable loading (temperature induced)

**Winter**

30 mg/L, in 25 mg/L, out
Nutrient Removal in Lagoons

- Select a Selector
  - Back of the Plant
    - Attached growth “filters”
    - Must address variable loading (temperature induced)
    - Possible BOD & TSS management needs

Diagram:
- Complete Mix
- Partial Mix Cell with Quiescent Zone
- Post-QZ Polishing Filter
Nutrient Removal in Lagoons

- Select a Selector
  - Back-of-the-Plant
  - Middle-of-the-Plant
    - Must address variable loading (temperature induced)
    - Short-circuiting potential (PM Units)
    - Down-stream rebound (Package Units)
Nutrient Removal in Lagoons

- Select a Selector
  - Back-of-the-Plant
  - Middle-of-the-Plant
  - Front-of-the-Plant
    - Down-stream rebound potential
    - Denitrification

Diagram:
- Complete Mix
- Partial Mix Cell with Quiescent Zone
Performance Data (Round 2)
Miner, MO Ammonia Data
**Miner, MO Ammonia Data**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Influent</th>
<th>Effluent</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia-N</td>
<td>28 +/- 6</td>
<td>0.66 +/- 1.3</td>
<td>mg/L</td>
</tr>
<tr>
<td>(April-September)</td>
<td>27 +/- 6</td>
<td>1.9 +/- 2.4</td>
<td>mg/L</td>
</tr>
<tr>
<td>(October-March)</td>
<td>28 +/- 7</td>
<td>0.5 +/- 0.8</td>
<td>mg/L</td>
</tr>
</tbody>
</table>
Miner, MO Ammonia Data
Miner, MO Ammonia Data
Miner, MO Ammonia Data

NH3-N Concentration (mg/L) vs. Time

- Influent
- Effluent

Begin Intensive → End Intensive
Miner, MO Ammonia Rebound Data

(IDEAL Bioreactor vs. PM/QZ Effluent)
Miner, MO Ammonia Rebound Data

(IDEAL Bioreactor vs. PM/QZ Effluent)

NH$_3$-N and Temperature vs. Time

Graph showing NH$_3$-N concentration and temperature trends over time from December to June.
## Miner, MO Ammonia Rebound Data

*(IDEAL Bioreactor vs. PM/QZ Effluent)*

**Process Data Summary (30 Month Concentrations)**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Influent</th>
<th>Effluent</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia-N</td>
<td>28 +/- 6</td>
<td>0.24 +/- 0.39</td>
<td>mg/L</td>
</tr>
<tr>
<td>(April-September)</td>
<td>27 +/- 6</td>
<td>0.15 +/- 0.26</td>
<td>mg/L</td>
</tr>
<tr>
<td>(October-March)</td>
<td>28 +/- 7</td>
<td>0.28 +/- 0.43</td>
<td>mg/L</td>
</tr>
</tbody>
</table>
# IDEAL Miner, MO Case Study

## Ideal Process Data Summary (2013-2014 Winter) a/ Warm Up

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Influent (mg/L)</th>
<th>Effluent (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD</td>
<td>275 +/- 75</td>
<td>13 +/- 6</td>
</tr>
<tr>
<td>TSS</td>
<td>75 +/- 23</td>
<td>25 +/- 9.8</td>
</tr>
<tr>
<td>Ammonia-N</td>
<td>31 +/- 4</td>
<td>0.05 +/- 0</td>
</tr>
<tr>
<td>Nitrate-N</td>
<td>0.05 +/- 0.06</td>
<td>11 +/- 4</td>
</tr>
<tr>
<td>Nitrite-N</td>
<td>0.12 +/- 0.18</td>
<td>0.91 +/- 0.86</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>42 +/- 10</td>
<td>15 +/- 4</td>
</tr>
</tbody>
</table>

## IDEAL Bioreactor Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow (MGD)</td>
<td>0.18 +/- 0.02</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>11 avg (16 max, 4.4 min)</td>
</tr>
<tr>
<td>MLSS (mg/L)</td>
<td>1300 +/- 300</td>
</tr>
<tr>
<td>F:M Ratio</td>
<td>0.045</td>
</tr>
</tbody>
</table>

Note I: Error calculated using Student’s T with a 98% confidence interval

Note II: Effluent Ammonia-N consistently below method detection limit of 0.05 mg/L
Grantsville, UT Ammonia Rebound Data
(IDEAL Bioreactor vs. PM/QZ Effluent)
Grantsville, UT Ammonia Rebound Data

(IDEAL Bioreactor vs. PM/QZ Effluent)
NH₃-N Concentration (mg/L) vs. Time

- **DBBR Cell #1 Effluent**
- **PM Cell #2 Effluent**
- **PM Cell #3 Effluent**
- **PM Cell #4 (Final) Effluent**

IDEAL Performance Data – Grantsville, UT
New Madrid, MO Ammonia Data

Note: Miner, MO shown as example; layout similar
**New Madrid, MO Ammonia Data**

![NH₃-N Concentration vs. Time Graph](image)

- **NH₃-N Concentration (mg/L) vs. Time**

- **Date Range:** Jul-15 to Jun-16

- **Concentration (mg/L):**
  - Inf: Black dots
  - Eff: White dots

- **Data Points:**
  - Jul-15: 40 mg/L
  - Aug-15: 35 mg/L
  - Sep-15: 30 mg/L
  - Oct-15: 25 mg/L
  - Nov-15: 20 mg/L
  - Dec-15: 15 mg/L
  - Jan-16: 10 mg/L
  - Feb-16: 5 mg/L
  - Mar-16: 0 mg/L
  - Apr-16: 0 mg/L
  - May-16: 0 mg/L
  - Jun-16: 0 mg/L
# New Madrid, MO Ammonia Data

## Process Data Summary (5 Month Concentrations)

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Influent</th>
<th>Effluent</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia-N</td>
<td>28 +/- 7</td>
<td>0.33 +/- 0.61</td>
<td>mg/L</td>
</tr>
</tbody>
</table>
Nutrient Rebound
Nutrient Rebound

• Rebound Defined
  – Pollutants (namely nutrients) generated during sludge digestion
Nutrient Rebound

• Rebound in Lagoons
  – Occurs during the sludge digestion process  
    • Always in the background
  – Unsteady State = Major Events
    • Decay is “temperature-dependent”
Lagoon Configurations
Lagoon Configurations

NOTES:
1. SINGLE PROCESS TRAIN SHOWN. PARALLEL OR REDUNDANT SYSTEMS SIMILAR.
2. BASIC CBOD VERSION IN COLD CLIMATES N/DN IN WARM CLIMATES
Lagoon Configurations

INF → SCREENS → IDEAL BIOREACTOR → POST-TREATMENT EQUALIZATION → DISINFECTION → EFF

SUPERNATANT RETURN → WAS → SLUDGE BASIN

IDEAL W/SEPARATE SLUDGE HOLDING & POST-TREATMENT EQ

NOTES:
1. SINGLE PROCESS TRAIN SHOWN. PARALLEL OR REDUNDANT SYSTEMS SIMILAR.
Lagoon Configurations

IDEAL W/SEPARATE SLUDGE HOLDING & DISC FILTRATION (TSS & BOD)
Lagoon Configurations

Flow Bypass

Screens

Ideal Bioreactor

Post-Treatment Equalization

Disc Filter

Disinfection

Inf

Flow Return

Excess Flow Diversion

Supernatant Return

WAS

Sludge Basin

Pre-Treatment Equalization

Notes:
1. Single process train shown, parallel or redundant systems similar.
2. Typical EQ required for control of flow through filter & disinfection units.

Ideal w/excess flow storage, sludge holding, & disc filter
**Final Thought**

**Wastewater Treatment Technologies**

Key:
- A – Preferred when feasible
- B – Has demonstrated capability in meeting ammonia when designed appropriately
- C – Shows potential for meeting ammonia limitations
- D – Unlikely to meet ammonia limitations, or data inconclusive

<table>
<thead>
<tr>
<th>Wastewater Technology</th>
<th>Ammonia Effluent Limit (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 0.7</td>
</tr>
<tr>
<td>Land Application</td>
<td>A</td>
</tr>
<tr>
<td>Wetland</td>
<td>D</td>
</tr>
<tr>
<td>Facultative Lagoon</td>
<td>D</td>
</tr>
<tr>
<td>Aerated, Partial Mix Lagoon</td>
<td>D</td>
</tr>
<tr>
<td>Lagoons with Approved Retrofits</td>
<td>C</td>
</tr>
<tr>
<td>Recirculating Sand Filter</td>
<td>C</td>
</tr>
<tr>
<td>Trickling Filter</td>
<td>D</td>
</tr>
<tr>
<td>Oxidation Ditch</td>
<td>B</td>
</tr>
<tr>
<td>Extended Aeration Package Plant</td>
<td>D</td>
</tr>
<tr>
<td>Sequencing Batch Reactor</td>
<td>B</td>
</tr>
<tr>
<td>Biological Nutrient Removal</td>
<td>B</td>
</tr>
<tr>
<td>Enhanced Biological Nutrient Removal</td>
<td>B</td>
</tr>
<tr>
<td>Membrane Bioreactors</td>
<td>B</td>
</tr>
<tr>
<td>Breakpoint Chlorination</td>
<td>D</td>
</tr>
<tr>
<td>Moving Bed Biofilm Reactor</td>
<td>B</td>
</tr>
<tr>
<td>Integrated Fix Film Activated Sludge</td>
<td>B</td>
</tr>
<tr>
<td>Side Stream Nutrient Removal</td>
<td>B</td>
</tr>
</tbody>
</table>
Summary

• IDEAL Bioreactor is a cost effective solution.
• BOD and TSS < 20 mg/l.
• Ammonia < 0.5 mg/l.
• Total Nitrogen Reduction 66%.
• Separate Solids Digestion.
• Reactor Temperature 2°C.
Final Thought
Q&A
Lagoon Configurations