Moving Bed Biofilm Reactor
MBBR
for Nitrification/Denitrification

By
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Nitrogen Sources

- Natural Decomposition of Organics

- Non-point Sources (fertilizers)

- Point Sources
  1) Industry
  2) Wastewater
Negative Impacts of Nitrogen on the Environment

- Nitrate in drinking water can cause Blue Baby Syndrome
- Increased levels of nitrate in water supplies can increase the acidity of the water and make toxic metals such as mercury more soluble
- Growth of nuisance algae blooms can cause decreased water quality and cause fish kills
Nitrification

• Two Step Biological Process

\[ \text{NH}_4^-\text{N} \xrightarrow{\text{oxidized}} \text{NO}_2^-\text{N} \xrightarrow{\text{oxidized}} \text{NO}_3^-\text{N} \]

• Aerobic Autotrophic Bacteria

\[ \text{NH}_4^-\text{N} \xrightarrow{\text{oxidized}} \text{NO}_2^-\text{N} \quad \text{(Nitrosomonas)} \]

\[ \text{NO}_2^-\text{N} \xrightarrow{\text{oxidized}} \text{NO}_3^-\text{N} \quad \text{(Nitrobacter)} \]

• Note these are documented as dominate bacteria but others exist in each step
Denitrification

$\text{NO}_3^- \rightarrow \text{NO}_2^- \rightarrow \text{NO} \rightarrow \text{N}_2\text{O} \rightarrow \text{N}_2$

- **Anaerobic Conditions**
- **Heterotrophic and Autotrophic Bacteria**
- **Nitrite or Nitrate is electron acceptor**
- **Carbon Source Required** (Methanol)

$$5\text{CH}_3\text{OH} + 6\text{NO}_3^- \rightarrow 3\text{N}_2 + 5\text{CO}_2 + 7\text{H}_2\text{O} + 6\text{OH}^-$$
Moving Bed Biofilm Reactor

- Activated Sludge
- Trickling Filter
- MBBR
Advantages of MBBR

- Smaller Footprint
- Utilize whole tank volume for biomass
- Less Sludge Produced (Better Settling)
- No Return Activated Sludge
- Easy Expansion (more media)
- No Media Clogging
- Reliability and Ease of Operation
- Easy to Retrofit Existing Basins
Design Example

Outline

- Nitrogen Removal
- Tertiary Treatment
- Nitrification
- Denitrification
- Municipal Wastewater

Goals

- Ammonia-N $< 5$ mg/L
- Nitrate-N $< 5$ mg/L
- Total N $< 15$ mg/L

Municipal Wastewater Goals

Ammonia-N $< 5$ mg/L

Nitrate-N $< 5$ mg/L

Total N $< 15$ mg/L
Basic Design

Nitrification

\[ \text{Influent} \rightarrow \text{NH}_4^+ \rightarrow \text{NO}_3^- \rightarrow \text{Effluent} \]

- Media Fill
- Aeration
- Carbon Source (Methanol)
- Alkalinity

Denitrification

\[ \text{NO}_3^- \rightarrow \text{N}_2 \text{ (gas)} \rightarrow \text{Effluent} \]

- Media Fill
- Mechanical Mixing
Design Parameters

- Primary Clarifier Effluent used as Basin Influent
- Typical Values Taken From Moorhead WWTF
- Process Design for 20°C
- Steady State Conditions
- Completely Mixed Reactor
- Kaldnes Parameters

<table>
<thead>
<tr>
<th>Influent Water Characteristics</th>
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<tbody>
<tr>
<td>Flow</td>
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<tr>
<td>6 mgd</td>
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<tr>
<td>Flow</td>
</tr>
<tr>
<td>9.3 cfs</td>
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<tr>
<td>NH₄⁺-N</td>
</tr>
<tr>
<td>25 mg/L</td>
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<tr>
<td>NH₄⁺-N</td>
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<tr>
<td>1251.9 lb/d</td>
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<tr>
<td>BOD</td>
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<tr>
<td>6.7 mg/L</td>
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<tr>
<td>pH</td>
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<tr>
<td>6.6</td>
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<tr>
<td>DO</td>
</tr>
<tr>
<td>6.9 mg/L</td>
</tr>
<tr>
<td>TKN</td>
</tr>
<tr>
<td>30 mg/L</td>
</tr>
<tr>
<td>TSS</td>
</tr>
<tr>
<td>6.9 mg/L</td>
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</table>
Nitrification Tank Design

- Nitrification rate of 1 gNH$_4^+$-N/m$^2$d (Kaldnes)
- Decided on 30% Fill
- Resultant SA of 150 m$^2$/m
- Ammonia-N Load of 1250 lb/d
- Reactor Volume of 130,000 ft$^3$
- Depth of 12 ft
- Length to Width 2:1 used
- HRT 3.9 hrs

Media Design and Characteristics
- 7 mm Long and 10 mm Diameter
- Density of 0.96 g/cm$^3$
- Surface Area of 500 m$^2$/m$^3$
- Typical Fill of 30-50%
Aeration Requirements

- Course Bubble Diffusers used to Suspend Media and Oxygen Requirements
- Oxygen Transfer Rate of 1%/ft depth Results in 11% Oxygen Transfer Rate (Kaldnes)
- Based on earlier stoichiometry \(4.6 \text{ gO}_2/\text{gNH}_4^+ - \text{N (Nitrification)}\)
- Ammonia Loading used to determine 110 kgO₂/hr
- Standard Oxygen Transfer Rate Determined

\[
SOTR = AOTR \left[ \frac{C_{s,20}}{\alpha F(\beta \times C_{s,T,H} - C)} \right] =
\]

- Air Flow Rate then Determined 4000 ft³/min

\[
\text{Air flow} = \frac{SOTR}{SOTE(60 \text{ min/h})((0.270 \text{ kgO}_2 / \text{m}^3 \text{ air})}
\]

- Diffuser Grid Pattern Design
Alkalinity Requirements

Stoichiometry
\[ \text{NH}_4^+ + 2\text{HCO}_3^- + 2\text{O}_2 \rightarrow \text{NO}_3^- + 2\text{CO}_2 + 3\text{H}_2\text{O} \]

7.14 g Alkalinity as CaCO3/g N is required

Design Considerations
• Assumed Influent Alkalinity of 120 mg/L as CaCO3
• Desired Effluent Alkalinity of 80 mg/L as CaCO3
• Alkalinity Required used for Nitrification is 164 mg/L as CaCO3
• Alkalinity Addition Needed is 124 mg/L as CaCO3

• Total Alkalinity Required 6,200 lbs/d
• Strictly Based on Stoichiometry (Further Investigation Needed)
Denitrification Tank Design

• Denitrification rate of 2 gNH$_4^+$-N/m$^2$/d (Kaldnes)
• Decided on 30% Fill
• Resultant SA of 150 m$^2$/m
• Nitrate-N Load of 1,050 lb/d
• Reactor Volume of 56,000 ft$^3$
• Depth of 12 ft (Kaldnes)
• Length to Width 2:1 used
• HRT 1.7 hrs

Media Design and Characteristics
- 7 mm Long and 10 mm Diameter
- Density of 0.96 g/cm$^3$
- Surface Area of 500 m$^2$/m$^3$
- Typical Fill of 30-50%

Mechanical Mixing
Methanol (CH₃OH) Requirements

• Carbon Source for Denitrification

• Typical dose of 3.2 kg of methanol/kg NO₃-N (Metcalf & Eddy)

• Based on Nitrate-N Loading of 480 kg/d

• Dose of 510 gal/d of Methanol Required
Resultant Design

**Nitrification**
- HRT = 3.9 hrs
- Volume of 130,000 ft³
- Media Fill (30%)
- Alkalinity 6200 lbs/d
- Aeration 4000 ft³/min

**Denitrification**
- HRT = 1.7 hrs
- Volume of 56,000 ft³
- Media Fill (30%)
- Mechanical Mixing

Carbon Source (Methanol) 510 gal/d
Biowin Schematic (Steady State)

<table>
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<tr>
<th>Element</th>
<th>Total N mg/L</th>
<th>Ammonia N mg/L</th>
<th>TKN mg/L</th>
<th>Nitrate-N mg/L</th>
<th>Nitrite-N mg/L</th>
<th>pH</th>
<th>cBOD mg/L</th>
<th>TSS mg/L</th>
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<tr>
<td>Effluent</td>
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<td>0.2</td>
<td>7.6</td>
<td>2.7</td>
<td>0.4</td>
<td>6.9</td>
<td>25.7</td>
<td>34.7</td>
</tr>
</tbody>
</table>

Biowin Results For Nitrification/Denitrification
Goals accomplished (NH$_4^+$-N, NO$_3^-$-N<5mg/L, Total N<15 mg/L)
Other Considerations

• Simultaneous Removal of Carbon and Nitrogen
• Sedimentation Tank due to Increased Solids
• More Detailed Design for Alkalinity
• Ability to Utilize Existing Infrastructure
• Variable Temperature, Flow, and Loading Conditions
Thank You!

Questions???