Anaerobic Woodchip Bioreactors Under Minnesota Conditions

Andry Ranaivoson, John Moncrief, Mark Dittrich\(^{(1)}\), Yogesh Chander, and Pam Rice\(^{(2)}\)

University of Minnesota, St. Paul
Minnesota Department of Agriculture\(^{(1)}\)
ARS-USDA, St. Paul \(^{(2)}\)
Trench with Woodchip
Bioreactor Site (240 ft x 4 ft x 6 ft)
Flow Control Box

INLET

Field InFlow Compt 1

To Bioreactor Compt 2

To Bypass Compt 3

OUTLET

Bioreactor Outlet Compt 4

To Ditch Compt 5

Pressure Transducer

Woodchip

Top Soil

6.0 ft
Denitrifier Community in Anaerobic Biofilter Reactor

• More than 100 species of (heterotrophic) bacteria can reduce nitrate to nitrogen gas
• Under anaerobic conditions, microorganism use nitrogen oxides as electron acceptors
  \[ \text{NO}_3^- \rightarrow \text{NO}_2^- \rightarrow \text{NO} \rightarrow \text{N}_2\text{O} \rightarrow \text{N}_2 \]
• Denitrifying bacteria also have the ability to degrade toxic organic compounds
Field Operations of Current Study

- **Claremont-Bioreactor installed 2007**
  - Corn-Corn-Soybean rotation (lbsN/acre)
  - Anhydrous Ammonia, Fall Applied

- **Dundas-Bioreactor installed 2007**
  - Corn-Soybean rotation (lbsN/acre)
    - 2008: 100, 2009: 0, 2010: 100, 2011: 0
  - Anhydrous Ammonia, Fall Applied
Monitored Parameters Bioreactor

• Physico-Chemical
  • Hydraulic Residence Time (HRT)
  • Temperature Profile
  • pH, Redox Potential, Dissolved Oxygen

• Longevity
  • C/N Ratio change over time
Site Monitoring
Temperature Monitoring Layout

TOP VIEW

VERTICAL PROFILE

INLET

1

WOODCHIP

3

4

SOIL

7

2: Air

5

6

OUTLET

TOP SOIL 2 ft

WOODCHIP 4 ft

thermocouples every 8 in.
Sampling Scheme
Pollutants Monitored

- Nitrate
- Total & Soluble Phosphorus
- Herbicides: Acetochlor & Atrazine
Results from Sites:
Dodge County
Two Sites: Longevity of Woodchip by C/N Ratio

<table>
<thead>
<tr>
<th>2009 WOODCHIP % RATIO CHANGE</th>
<th>ORIGINAL*</th>
<th>DEPTH, IN.</th>
<th>CLAREMONT</th>
<th>DEPTH, IN.</th>
<th>DUNDAS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 - 18</td>
<td>24.5%</td>
<td>0 - 29</td>
<td>15.1%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18 - 37</td>
<td>5.5%</td>
<td>29 - 48</td>
<td>6.8%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>37 - 48</td>
<td>1.5%</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Claremont 2009: inflow head & nitrate concentration
Claremont 2010: inflow head & nitrate removal rate
### Claremont Site: 2009

<table>
<thead>
<tr>
<th></th>
<th>Fallling Limb</th>
<th>Rising Limb</th>
<th>Reduction Difference</th>
<th>Total Norm Load Red.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fallling Limb</strong></td>
<td>1.50</td>
<td>1.43</td>
<td></td>
<td>1.48</td>
</tr>
<tr>
<td><strong>Rising Limb</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Reduction Difference</strong></td>
<td></td>
<td></td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td><strong>Total Norm Load Red.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Claremont Site: 2010

<table>
<thead>
<tr>
<th></th>
<th>Fallling Limb</th>
<th>Rising Limb</th>
<th>Reduction Difference</th>
<th>Total Norm Load Red.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fallling Limb</strong></td>
<td>0.97</td>
<td>0.66</td>
<td></td>
<td>0.77</td>
</tr>
<tr>
<td><strong>Rising Limb</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Reduction Difference</strong></td>
<td></td>
<td></td>
<td>31.2%</td>
<td></td>
</tr>
<tr>
<td><strong>Total Norm Load Red.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Summary of Results

- Nitrate concentration in pattern tile water ranged from 11 to 22 mg/l.
- During snowmelt, nitrate load reduction (through bioreactor) ranged from 7% to 26%
- During spring and summer time,
  - At Claremont, nitrate load reduction reached an average of 48% and 21% in 2009 and in 2010, respectively.
  - Amount of water flowing into bioreactor decreases nitrate removal
  - At Claremont, hydraulic residence time was 14 hours and 21 hours in 2009 and in 2010, respectively.
- Most of the Phosphorus was in the soluble form (>75%). Phosphorus load reduction can reach up to 80%
Results from Sites:
Rice County
Herbicide Experiment

• Acetochlor & Atrazine

• “Controlled” Conditions in the Field:
  • Increasing and fixed concentrations of herbicides: 2.0 ppb, 3.5 ppb, & 7.5 ppb
  • 3 runs of 6-day cycle
  • Fixed concentrations: 1.0 NO$_3$–N ppm
  • Ditch water concentrations for total phosphorus

• Flow Rate: 4 GPM (equiv. to 24-hr residence time)
AVERAGE DISSIPATION: 69% ACETOCHLOR
AVERAGE DISSIPATION: 53% FOR ATRAZINE
Atrazine adsorbed by sugar cane mulch residue
Ratio residue:solution is 1:30
# Load of contaminants

<table>
<thead>
<tr>
<th>Load</th>
<th>IN</th>
<th>OUT</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetochlor, oz.</td>
<td>0.051</td>
<td>0.015</td>
<td>70%</td>
</tr>
<tr>
<td>Atrazine, oz.</td>
<td>0.034</td>
<td>0.016</td>
<td>54%</td>
</tr>
<tr>
<td>Nitrate, lbs</td>
<td>9.66</td>
<td>5.62</td>
<td>42%</td>
</tr>
<tr>
<td>Total Phosphorus, oz.</td>
<td>2.71</td>
<td>0.57</td>
<td>79%</td>
</tr>
</tbody>
</table>

**Soluble P > 75%**

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</thead>
<tbody>
<tr>
<td>Flow Depth, in.</td>
<td>0.83</td>
</tr>
<tr>
<td>Flow Rate Average, gpm</td>
<td>4.42</td>
</tr>
</tbody>
</table>
Summary

- Anaerobic bioreactor is capable of reducing pollutant load from pattern tile.
- They can last up to more than 10 years.
- The amount of nitrate reduced will depend on the season (snowmelt vs. growing season) and inflow of water.
- The pollutant list includes:
  - Nitrate
  - Phosphorus, total and soluble
  - Herbicides
- Adequate HRT & bioreactor design will help achieve pollutant removal.