Organic substrate dosing strategies to nitrate removing bioreactors

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#209
Diffuse nitrate pollution: still a major problem

Total N leaching (kg N/ha)
- 0 - 10
- 10 - 20
- 20 - 50
- > 50

2014 DEAD ZONE
Area of oxygen-deprived bottom-water

Sources: Nancy Rabalais, Louisiana Universities Marine Consortium; Eugene Turner, Louisiana State University; NOAA Center for Sponsored Coastal Ocean Research

NOLA.com | The Times-Picayune
Stimulated denitrification as a solution

Example: woodchip bioreactors

Figure 5. Filling an excavation with woodchips for a bioreactor installation (courtesy of the Iowa Soybean Association Environmental Programs and Services)

Laura Christiansson, Iowa State University

Hungry Bacteria Magically Remove Nitrates

Tile Drained Row Crop Field

Inflow (Diversion) Structure

Outflow (Capacity Control) Structure

Nitrate in Tile Drainage >>>

Wood Chips

Nitrogen Gas

Bacteria

Denitrification Bioreactor with By-Pass Flow >>>

Reduced Nitrate Loading to Surface Waters

Water with dissolved nitrates flows into a wood chip pit. The wood chips serve as a home and food for bacteria in the low-oxygen environment. Bacteria convert nitrates into dinitrogen gas, and water flows from the output minus nitrates.

Farm Journal Magazine

Deltaires
Stimulated denitrification as a solution

Wood chip bioreactors: The principle

Use of natural soil microorganisms
Wood chips: carbon and electron donor
Denitrifying woodchip bioreactors: challenges

Sufficient organic matter leaching for denitrification

Woodchip lifespan

The right redox potential:

- too high: oxygen, no denitrification, woodchip degradation
- too low: nitrous oxide, sulfide, methane, (methylmercury)

Flow optimization

Seasonal variation in flow and temperature

Permeability

Gao et al., 2003
Other carbons sources

Concentrated carbon source dosing is well known in (waste)water treatment (ethanol, methanol, etc)
How to dose cost-efficiently and robustly in the field?

Astrasand reactor (Paques)
This research: optimizing carbon source dosing

We tested:
- Carbon sources
- Dosing strategies

Our approach:
1. Laboratory tests
2. Field pilots
3. Outlook to the future
1. Laboratory tests
Materials tested:

1. Reference (groundwater)
2. Methanol
3. Ethanol
4. Beet pulp
5. Rabbit food pellets
6. Wood chips
Materials tested:

1. Reference (groundwater)
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### Results lab tests

<table>
<thead>
<tr>
<th>Material</th>
<th>Nitrate removal</th>
<th>Remarks</th>
<th>Suitable?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methanol</td>
<td>+</td>
<td>Suitable for controlled dosing without pump</td>
<td>+</td>
</tr>
<tr>
<td>Ethanol</td>
<td>+</td>
<td>Suitable for controlled dosing without pump</td>
<td>+</td>
</tr>
<tr>
<td>Beet pulp</td>
<td>++</td>
<td>Suitable for high denitrification at low dosing</td>
<td>+</td>
</tr>
<tr>
<td>Rabbit food pellets</td>
<td>?</td>
<td>Clogging</td>
<td>-</td>
</tr>
<tr>
<td>Wood chips</td>
<td>+</td>
<td>No side-effects, long lifetime</td>
<td>+</td>
</tr>
</tbody>
</table>
2. Field pilots

a) Wood chips
Drains enveloped with woodchips

Envelope with sand and woodchips (30 cm width)

Surface

Drain outlet

Three options tested:
1. Wood chips
2. Wood chips + deeper
3. Beet pulp + wood chips
Installation
## Experimental setup

<table>
<thead>
<tr>
<th>Drain nr.</th>
<th>Wood chips (m³)</th>
<th>Sand (m³)</th>
<th>Beet pulp (m³)</th>
<th>Depth (m)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11</td>
<td>5</td>
<td>0,5</td>
<td>1,0</td>
<td>Beet pulp + wood chips</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>5</td>
<td>0</td>
<td>1,2</td>
<td>Wood chips + deeper</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>5</td>
<td>0</td>
<td>1,0</td>
<td>Wood chips</td>
</tr>
</tbody>
</table>

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Nitrate removal using drains surrounded with wood chips

Date

28/dec 17/jan 6/feb 26/feb 18/mrt

NO3 (mg N/l)

Wood chips
Wood chips, deep
Wood chips + beet pulp
Reference

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Longer term N removal efficiency

- Efficiency decreases
- Deeper drains remain most efficient
Redox potential plays a key role
2. Field pilots

a) Wood chips
b) Ethanol
Ethanol dosing

Approach: ethanol dosing with a tube (no pumping needed) (no energy, no maintenance, no pumps breaking down)
Ethanol reactor: schematic top view

Water in

Water flow: 1 - 5 m3 / day
Volume tank: ± 0.5 - 1 m3

Water uit

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Ethanol reactor in practice

[Image of an ethanol reactor setup in a field with various components demonstrated.]
Ethanol reactor: redox potential

![Graph showing redox potential over time for reactor in, reactor out, and slootwater.](https://example.com/graph.png)
Ethanol reactor: summary

- Effective nitrate removal possible (effluent concentrations below water quality goals)
- Compact method for efficient nitrate removal with small size, high degree of control
- Costs mainly from operation and maintenance, not ethanol

- More information needed on:
  - Longer term robustness
  - Effects of temperature
  - Practice
3. Outlook

- Optimization of dosing:
  - Not too much, not too little
  - Flow proportional
  - Alternative e-donors
    (organic waste?)
Overall conclusions & outlook

- Additional carbon source dosing boosts denitrification
- Dosing has to be done with care to prevent negative side effects
- Passive dosing of concentrated carbon source can be an efficient option
- Further optimisation is needed

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Thank you!

All farmers, water authorities and contractors for practical assistance

Thank you for listening!

Questions?