Nutrient Attenuation under Natural Conditions in Agricultural Drainage Ditches

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Background and Motivation

(A) Total nitrogen

(B) Total phosphorus

(Adapted from Alexander et al., 2008)

- Over 51 million acres are subject to surface and subsurface drainage systems in the Midwest (Sharpley et al., 2007. JSWC 62(4)).
Tile-fed drainage ditches in the Midwest have been reportedly associated with the pollution of downstream waters.

However, the ability of sediments to retain nutrients upstream and downstream from tile outlets, is not clear.

Effects of tile inputs on the magnitude and transport of nutrients in drainage ditches are still not well understood.
Objectives and Study Sites

- Evaluate effects of tile effluents on nutrient uptake in drainage ditches.
- Examine sediment-water interactions in drainage ditches.

<table>
<thead>
<tr>
<th></th>
<th>Box and Marshall Ditches</th>
<th>J.B. Foltz Ditch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watershed area</td>
<td>53.0 km²</td>
<td>182 km²</td>
</tr>
<tr>
<td>Location</td>
<td>W. Lfytt, IN</td>
<td>Reynolds, IN</td>
</tr>
<tr>
<td>Area drained by ditch</td>
<td>8 km²</td>
<td>8 km²</td>
</tr>
<tr>
<td>Land use</td>
<td>agriculture (90%)</td>
<td>agriculture (9%)</td>
</tr>
<tr>
<td></td>
<td>low residential (10%)</td>
<td>low residential (7%)</td>
</tr>
</tbody>
</table>
Selected Tile Outlets

J.B. Foltz Ditch study reach = 1 km

Box Ditch and Marshall Ditch study reach = 1/2 km each
Uptake Length

- Net uptake length for P and NO₃-N:
  \[ S_{net} = \sum \frac{S_{net(i)} \times x_i}{x_{total}} \]

- Mass transfer coefficient:
  \[ V_f = \frac{v \times h}{S_{net}} \]

Source: Modified from Dr. Chaubey lecture notes, Spring 2008
Sediment-Water Interactions

- EPCo is the concentration at which the net exchange rate of P between sediments and the water column is negligible (Klotz, 1988).
  - If P > sediment EPCo => sediments act as a sink of P.
  - If P < sediment EPCo => sediments act as a source of P.

- PSI is a measurement of the ability of sediments to absorb P and was determined with 2 mg/L of additional P (Bache and Williams, 1971).

- Ex-P/ Ex-N is the amount of easily available P/N for release into the water column and was determined with 1M of MgCl2 /2M of KCl.
Methodology

- Two types of ditch water samples were collected (3x each) in low, mid-range and high flow regimes from Feb to Jul 2008.
  - Soluble P (SP)
  - Ammonia (NH$_3$-N)
  - Nitrate + nitrite (NO$_3$-N)
  - Total phosphorus (TP)
  - Total nitrogen (TN)

- Quarterly sediments were collected 5m upstream and downstream from selected tile outlet from Jul 2007 to Jul 2008.

Water sampling

Sediment sampling
Uptake Length in Box Ditch

Sampling event
- Feb 09
- Mar 20
- Mar 29
- Apr 11
- May 09
- May 16
- Jun 02
- Jul 14
- Jul 21

Uptake length (m)

- SP
- NH$_3$-N
- NO$_3$-N

Velocity factors:
- $V_f = 6.80 \times 10^{-7}$ (m/s) for NO$_3$-N
- $V_f = 6.81 \times 10^{-5}$ (m/s) for NH$_3$-N
- $V_f = 3.87 \times 10^{-7}$ (m/s) for SP

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Uptake Length in JB Foltz Ditch

**Sampling event:**
- Feb 09
- Mar 20
- Mar 29
- May 09
- May 16
- Jun 02
- Jun 23
- Jul 14
- Jul 21

**V_f** values:
- **February 09:** $V_f = 2.34 \times 10^{-5}$ (m/s)
- **March 20:** $V_f = 2.25 \times 10^{-6}$ (m/s)
- **March 29:** $V_f = 1.98 \times 10^{-6}$ (m/s)
- **May 09:** $V_f = 1.65 \times 10^{-7}$ (m/s)
- **May 16:** $V_f = 8.52 \times 10^{-6}$ (m/s)
- **June 02:** $V_f = 6.06 \times 10^{-8}$ (m/s)
- **June 23:** $V_f = 2.25 \times 10^{-6}$ (m/s)
Uptake Length in Marshall Ditch

Sampling event

- Feb 09
- Mar 20
- Mar 29
- Apr 11
- May 09
- May 16
- Jun 02

Uptake length (m)

- SP
- NH₃-N
- NO₃-N

V_f = 4.99 \times 10^{-6} \text{ (m s}^{-1})
V_f = 2.73 \times 10^{-5} \text{ (m s}^{-1})
V_f = 4.71 \times 10^{-6} \text{ (m s}^{-1})
V_f = 9.31 \times 10^{-2} \text{ (m s}^{-1})
Sediment-Water Interactions

Sediments Act as P Sinks

Sediments Act as P Sources

1: Jul-Sept
2: Oct-Dec
3: Jan-Mar
4: Apr-Jun

Box Ditch
J.B. Foltz Ditch
Marshall Ditch
### Sediment-Water Interactions

<table>
<thead>
<tr>
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<th>Marshall Ditch</th>
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</thead>
<tbody>
<tr>
<td></td>
<td><strong>Ex-P</strong></td>
<td><strong>Ex-N</strong></td>
<td><strong>Ex-P</strong></td>
</tr>
<tr>
<td><strong>Jul-Sep</strong></td>
<td>1.51</td>
<td>231.0*</td>
<td>2.34</td>
</tr>
<tr>
<td><strong>Oct-Dec</strong></td>
<td>5.98*</td>
<td>20.24</td>
<td>3.16</td>
</tr>
<tr>
<td><strong>Jan-Mar</strong></td>
<td>5.38*</td>
<td>88.6*</td>
<td>1.98</td>
</tr>
<tr>
<td><strong>Apr-Jun</strong></td>
<td>1.81</td>
<td>33.7</td>
<td>2.09</td>
</tr>
<tr>
<td><strong>p-value</strong></td>
<td>&lt; 0.05</td>
<td>&lt; 0.04</td>
<td>----</td>
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</tbody>
</table>

- * Higher values
- PSI: No significant variation between upstream and downstream sediments.
Concluding Remarks

- No particular trend in nutrient concentrations along the study reaches or based on various flow regimes.
- Retention of NH$_3$-N > P > NO$_3$-N.
- Tile drains acted as a point source for nutrients, especially for NO$_3$-N.
- Sediments in the three ditches acted as a sink or a source of P, or were in equilibrium with the ditch water column P concentration.
- Mean EPC$_0$, Ex-P, PSI, and Ex-N varied spatially and seasonally.
- Sediments were not sensitive to inputs from tile drains.
- Uptake lengths were long indicating that these ditches were rich in nutrients and may influence downstream waters.