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Nitrates in Drainage Water in Minnesota

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THE SITUATION

- Nitrates identified as a health issue long ago
- USEPA set standards of 10ppm for drinking water long ago
- MN moved to address nitrates in drinking water in the late 1980s
- Voluntary BMPs established in early 1990s
BRINGING IT FORWARD

- Non-point source pollution in surface water addressed beginning in the mid-late 1990s (nitrates not part of this)
- Hypoxia in the Gulf of Mexico makes the news in the late 1990s
- USEPA develops report on dealing with Hypoxia putting onus on states
TODAY

- 45% reduction targeted in Mississippi River watershed
- Minnesota’s plan in draft form
- Public “concern” about ag drainage
- Surface water standards currently in development
HOW DOES WATER (NITRATES) GET TO STREAMS?

- Runoff
- Shallow Ground Water Flow
- Artificial Drainage
HOW TO REPORT THE DATA

- Nitrate-N
- lb./A
- Multiple year totals
- Flow Weighted concentrations
LITERATURE REVIEW

- Loss via drainage tile
- Randall and Goss (2008) world wide
  - 0 lb/A – 124 lb/A
- Majority in the
  10 lb/A – 40 lb/A
Drainage plots established at Waseca and Lamberton in 1975

Plots kept devoid of vegetation lost an average of 20 lb nitrate-N/A

This is from soil organic matter
A FIRST LOOK

<table>
<thead>
<tr>
<th>Crop Rotation</th>
<th>N Rate</th>
<th>N Time</th>
<th>Nitrate-N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>4-Yr Avg.</td>
</tr>
<tr>
<td></td>
<td>lb/A</td>
<td>ppm</td>
<td>Conc.</td>
</tr>
<tr>
<td>C-S-Corn</td>
<td>0</td>
<td>6.1</td>
<td>37.7</td>
</tr>
<tr>
<td>60+40</td>
<td>SPL</td>
<td>7.8</td>
<td>44.8</td>
</tr>
<tr>
<td>S-C-Corn</td>
<td>120</td>
<td>PP</td>
<td>8.2</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>4.6</td>
<td>34.0</td>
</tr>
<tr>
<td>60+80</td>
<td>SPL</td>
<td>7.9</td>
<td>64.2</td>
</tr>
<tr>
<td>160</td>
<td>PP</td>
<td>8.8</td>
<td>62.8</td>
</tr>
<tr>
<td>C-C-Soybeans</td>
<td>0</td>
<td>5.5</td>
<td>30.5</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>8.4</td>
<td>40.9</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>8.7</td>
<td>38.3</td>
</tr>
</tbody>
</table>

SPL – Split Applied, PP – Pre-Plant Application

Four year nitrate-N loss from a corn-corn-soybean cropping system at Waseca from 2007 – 2010. Nitrate losses calculated for the crop last in the Crop Rotation column. (Randall and Vetsch, 2011)
TAKE HOME

- Corn receiving no N fertilizer lost 10 lb/A
- Soybeans in that rotation lost 10 lb/A
- Typical losses using recommended rates ≈ 15 lb/A
- BMP says application only after soil temp is below 50° F
- Mother nature doesn’t know this!
**BUT OTHER YEARS**

<table>
<thead>
<tr>
<th>Cropping System</th>
<th>Total Discharge</th>
<th>Nitrate-N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4-Yr. Cumulative</td>
<td>4-Yr Avg. Conc.</td>
</tr>
<tr>
<td></td>
<td>Inches</td>
<td>ppm</td>
</tr>
<tr>
<td>Continuous corn</td>
<td>30.4</td>
<td>28</td>
</tr>
<tr>
<td>Corn – soybean</td>
<td>35.5</td>
<td>23</td>
</tr>
<tr>
<td>Soybean – corn</td>
<td>35.4</td>
<td>22</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>16.4</td>
<td>1.6</td>
</tr>
<tr>
<td>CRP</td>
<td>25.2</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Effect of cropping system on cumulative drainage volume, nitrate-N concentration and N loss in subsurface tile drainage during a 4 – year period (1990 – 1993) at Lamberton. (Randall, et. al., 1997)
TAKE HOME

- Numbers following the 1987-88 drought
- Loss rates as high as ≈ 40 lb/A
- Loss rates reduced to near 0 under perennials
THE EFFECT OF RATE

Corn grain yield and residual soil nitrate-N response as affected by fertilizer N rate on a Webster clay loam soil near Waseca, MN, averaged from 2001 - 2003 (Vetsch and Randall).
The same study, but at Rochester.
TAKE HOME

- Residual (loss) curve follows similar but inverse relationship to yield and rate
- At the plateau a 4 bu./A yield increase resulted in a 40 lb/A increase in residual N at Waseca
- At Rochester a 1% yield increase resulted in 100% increase in residual N
- We don’t have drainage losses to go along with residual nitrate
APPLICATION TIMING AND INHIBITORS (BMP REVIEW)

- No fall N in SE MN or sandy soils
- No fall urea in SC/C MN
- Use Inhibitor in SC/C MN
<table>
<thead>
<tr>
<th>Rate</th>
<th>Time</th>
<th>N-Serve</th>
<th>Conc.</th>
<th>C</th>
<th>Sb</th>
<th>Total</th>
<th>Avg.</th>
<th>Corn Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>Fall</td>
<td>Yes</td>
<td>11.5</td>
<td>115</td>
<td>90</td>
<td>205</td>
<td>144</td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>Fall</td>
<td>Yes</td>
<td>13.2</td>
<td>121</td>
<td>99</td>
<td>220</td>
<td>166</td>
<td></td>
</tr>
<tr>
<td>160</td>
<td>Fall</td>
<td>Yes</td>
<td>18.1</td>
<td>142</td>
<td>139</td>
<td>281</td>
<td>172</td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>Spr.</td>
<td>No</td>
<td>13.7</td>
<td>121</td>
<td>98</td>
<td>219</td>
<td>180</td>
<td></td>
</tr>
</tbody>
</table>

Nitrate-N concentrations, losses in tile water, and corn grain yield as affected by rate and time of N application (as anhydrous ammonia) at Waseca (2000–2003). (Randall, Unpublished)
TAKE HOME

- Fall N application with inhibitor has similar loss to spring application
- Under applying has a big yield penalty with relatively little environmental benefit
- Trend toward higher yield with spring application
NITRATE-N MOVEMENT

- Requires free nitrate in the soil
- Water in excess of field capacity (saturation) to run through drain tile
THE SEASONAL CYCLE

Relationship between monthly subsurface tile drain flow from facility B in 1987 – 2001 and 30 year normal monthly precipitation and water use (ET) by corn at Waseca, MN. (Randall, 2004)
FLOW BY MONTH

<table>
<thead>
<tr>
<th>Month</th>
<th>Drain Flow</th>
<th>Nitrate Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>February</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>March</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>April</td>
<td>25</td>
<td>17</td>
</tr>
<tr>
<td>May</td>
<td>25</td>
<td>29</td>
</tr>
<tr>
<td>June</td>
<td>21</td>
<td>27</td>
</tr>
<tr>
<td>July</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>August</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>September</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>October</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>November</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>December</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

TAKE HOME

- Most flow is in April – July
- Nitrate loss mirrors drainage
- On average 50% of drainage occurs on just 7 calendar days
WHAT ABOUT MANURE?

- No different than commercial fertilizer
- Use recommended rates and an inhibitor
- Timing is key
PUTTING IT ALL TOGETHER

- Soil Organic Matter mineralizes the equivalent of 20 lb nitrate-N/A per year
- Corn and soybeans lose about 10 lb nitrate-N/A per year even though not fertilized
  - A relatively high Nitrogen Use Efficiency (NUE)
- Corn at BMP rates lose about 15 lb nitrate-N/A per year
  - 2/3 from naturally mineralized N
IN ADDITION

- The Nitrogen BMPs are accurate with their recommendations
  - Fall N, Inhibitors
- Environmental hazard goes up significantly when N is over-applied
  - This relationship needs to be explored in more detail
- Movement depends on excess water and free nitrate
REMEMBER

- Numbers vary based on climatic cycles (numbers go very high post-drought)
- You might get away with some things some years, but....
MANAGEMENT

- We can not afford “insurance N”
- Use an inhibitor when fall applying
- Logically applications closer to the time of crop use decrease the likelihood of loss
- We don’t know the rate of BMP adoption – therefore how much is to be gained
FUTURE N TECHNOLOGY

- In season N test (soil, tissue, light)
- Better inhibitors
- Application technology (in season or too wet)
- Increased NUE of corn hybrids
- Stay in touch with the science
FUTURE RESEARCH DIRECTIONS

- Loss vs. Rate curves
- Evaluate new technology
- Precision management
- Post-drought management
- Cover Crops
WHERE WE ARE TODAY

- Our crops leak N
- Perennials do not, but there is no market
- Movement **not** via drain tile is by shallow groundwater flow (just because it isn’t going through the tile doesn’t mean it won’t get to the stream anyway)
- Therefore drain tile provides the opportunity to capture the water before it reaches the rivers
THE FUTURE

- Tightening up on N management is essential (we must be honest about what is going on) – it is the cheapest and easiest thing to do
- Reducing N rates below recommendations might not produce much result
- Cover crops provide a great opportunity to capture free nitrate so it is held in the field
THE FUTURE

- All the tools are laid out in the MPCA plan
  - N management
  - Drainage Water Management
  - Wetland Treatment
  - Cover Crops
  - Perennial Vegetation
STAY TUNED

- Every farmer will need to address this issue in some way
- Incremental progress is acceptable
- Solutions can be customized to meet local conditions

- But that is a different talk for a different day
Thank You