Long-term Impacts of Poultry Manure Application on Soil Nutrients, Crop Yields, and Water Quality in Subsurface Drainage

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A 20-year project funded by the Iowa Egg Council: Project Timeline

1998 – 2008
Corn – Soybean Rotation
- 150 lbs N/acre (PM)
- 300 lbs N/acre (PM2)
- UAN at 150 lbs N/acre

2008

2008 - 2011
The Role of Poultry Manure on Pathogen Losses to Soil and Water

2008 - 2018
Continuous Corn
- 100 lbs N/acre (0.5PM)
- 200 lbs N/acre PM
- UAN at 200 lbs N/acre
Goal: Provide a summary of our 18 year soil and water quality study

1. Describe the impact of long-term manure application on soil nitrogen and phosphorous levels;
2. Assess the impact of poultry manure application on crop yield;
3. Assess long term water quality trends.
Iowa leads the United States in egg production.

Iowa is the #1 egg producing state in the nation
- 15 billion eggs per year

Per capita consumption in the U.S. was estimated at 251 eggs in 2013

Egg production = manure production (roughly 10 billion lbs annually in Iowa)

N:P ratio is unbalanced resulting in challenges for proper land application of manure
When properly managed, poultry manure is a great source of fertilizer to enhance crop production.

- Poultry manure is generated annually in Iowa to land apply to 7% of all row crop acres, or 40% of Iowa’s continuous corn acres at an agronomical recommended rate.
- This is a great resource for farmers in Iowa
- Iowa has very hydric soils and approximately half of Iowa’s cropland is artificially drained
Tile drainage artificially lowers the water table to enable or enhance crop production.

Subsurface drainage has the potential to increase transport of contaminants to surface waters.
Methods:
Experimental Design (1998-2009)

- Urea Ammonium Nitrogen at 168 kg per hectare
- Poultry manure at 168 and 336 kg per hectare
Methods:
Experimental Design (2010-2017)

- Continuous corn
- UAN at 224 kg per hectare
- Poultry manure at 112 and 224 kg per hectare
- Monitoring no-till plots for pathogens
Manure Application and Tillage Practices
Drain Tile Sampling

Sample Collection Location
Increased soil P was measured with poultry manure application.

### Average Soil PO₄-P (Bray-P, ppm)

<table>
<thead>
<tr>
<th>Years</th>
<th>PM 112 kg N ha⁻¹</th>
<th>PM 168 kg N ha⁻¹</th>
<th>PM2 224 kg N ha⁻¹</th>
<th>PM2 336 kg N ha⁻¹</th>
<th>UAN 168 kg N ha⁻¹</th>
<th>UAN 224 kg N ha⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998-2002</td>
<td>---</td>
<td>60.42b</td>
<td>---</td>
<td>80.48a</td>
<td>34.09b</td>
<td>---</td>
</tr>
<tr>
<td>1998-2007</td>
<td>---</td>
<td>44.8a</td>
<td>---</td>
<td>58.5b</td>
<td>17.0c</td>
<td>---</td>
</tr>
<tr>
<td>2010-2014</td>
<td>113a</td>
<td>---</td>
<td>252b</td>
<td>---</td>
<td>---</td>
<td>15c</td>
</tr>
</tbody>
</table>

1998-2002 (0-15cm, fall)
- UAN resulted in the lowest soil P concentrations.

1998-2007 (0-30cm, fall)
- Soil P increased with time for poultry manure applied at the single and double application rates.
- Soil P decreased with time with UAN application (not significantly)

2010-2014 (0-15cm, spring)
- Soil P was lowest with UAN treatment
- Poultry manure at the single application rate had higher soil P than the half application rate, which was much higher than UAN.
Subsurface drainage N-losses were lowest with poultry manure applied at equal or lower rates than UAN.

### Average Annual NO$_3$-N Loss to Subsurface Drainage (kg ha$^{-1}$)

<table>
<thead>
<tr>
<th>Years</th>
<th>PM</th>
<th>PM2</th>
<th>UAN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>112 kg N ha$^{-1}$</td>
<td>168 kg N ha$^{-1}$</td>
<td>224 kg N ha$^{-1}$</td>
</tr>
<tr>
<td>1998-2003</td>
<td>---</td>
<td>15.43a</td>
<td>---</td>
</tr>
<tr>
<td>1998-2009</td>
<td>---</td>
<td>14.70</td>
<td>---</td>
</tr>
<tr>
<td>2010-2014</td>
<td>13.6a</td>
<td>---</td>
<td>43.4b</td>
</tr>
</tbody>
</table>

**1998-2003**
- Poultry manure applied at the double application rate resulted in the highest loss to subsurface drainage.

**1998-2009**
- The single poultry manure application rate had considerably lower N losses than both UAN (at the single application rate) and the double application rate poultry manure.

**2010-2014**
- With the entire plots now receiving manure or chemical fertilizer, more N loss (in proportion to fertilizer rate) was measured.
NO₃-N concentrations increased during summer with greatest losses from UAN plots
Poultry manure application did not significantly increase risk of P loss to subsurface drainage.

1998-2003
- Poultry manure applied at the double application rate resulted in the highest loss to subsurface drainage. The differences were however, not significant.

1998-2009
- There was no apparent increased risk of P transport to subsurface drainage with poultry manure application.

2010-2014
- Although there were no significant differences between P loads, UAN did have the lowest overall P load.

### Average Annual PO₄-P Loss to Subsurface Drainage (kg ha⁻¹)

<table>
<thead>
<tr>
<th>Years</th>
<th>PM</th>
<th>PM2</th>
<th>UAN</th>
</tr>
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<tr>
<td></td>
<td>112 kg N ha⁻¹</td>
<td>168 kg N ha⁻¹</td>
<td>224 kg N ha⁻¹</td>
</tr>
<tr>
<td>1998-2003</td>
<td>---</td>
<td>0.008a</td>
<td>---</td>
</tr>
<tr>
<td>1998-2009</td>
<td>---</td>
<td>0.007a</td>
<td>---</td>
</tr>
<tr>
<td>2010-2014</td>
<td>0.027a</td>
<td>---</td>
<td>0.029a</td>
</tr>
</tbody>
</table>
Corn yields were highest with poultry manure application.

<table>
<thead>
<tr>
<th>Corn Yields (kg ha⁻¹)</th>
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</thead>
<tbody>
<tr>
<td><strong>Years</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>1998-2003</td>
</tr>
<tr>
<td>1998-2009</td>
</tr>
<tr>
<td>2010-2017</td>
</tr>
</tbody>
</table>

1998-2002
- Poultry manure at the single and double application rates resulted in similar yields – 2X PM did not increase corn yield
- UAN yields were statistically lower than PM2 yields

1998-2009
- Poultry manure at the double application rate resulted in higher yield than both UAN and poultry manure at the single application rate

2010-2017
- Poultry manure at the single application rate yields were greater than poultry manure at the half application rate, which was greater than UAN
Soybean yields were higher with poultry manure application.

<table>
<thead>
<tr>
<th>Soybean Yields (kg ha⁻¹)</th>
<th>Years</th>
<th>PM 112 kg N ha⁻¹</th>
<th>PM2 224 kg N ha⁻¹</th>
<th>UAN 168 kg N ha⁻¹</th>
<th>UAN 224 kg N ha⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998-2002</td>
<td>---</td>
<td>3333a</td>
<td>---</td>
<td>3391a</td>
<td>2961a</td>
</tr>
<tr>
<td>1998-2009</td>
<td>---</td>
<td>3300a</td>
<td>---</td>
<td>3500b</td>
<td>2800c</td>
</tr>
</tbody>
</table>

- **1998-2002**
  - Similar yields were achieved with all treatments

- **1998-2009**
  - UAN yields were significantly lower than both poultry manure treatments
Microbial Water Quality Results: 2010-2012

- Tillage and treatment significantly impacted EC, ENT, and SALM.
- Differences were found between the wet year (2010) and the dry years (2011 and 2012) for individual bacteria measurements.
- GM concentration from chisel plow treatments were always below U.S. water quality standards for EC.

Bacteria concentrations follow flow patterns during rainfall events, concentrations from manured plots were greater than UAN plots.
Summary

Soil Quality
- Soil P was higher for all poultry manure treatments

Crop Yields
- Poultry manure yields were higher than UAN yields for most years.

Water Quality
- Lower NO$_3$-N losses to drainage were observed with poultry manure applied at rates equal to or less than UAN.
- Risk of P loss was not significantly greater with poultry manure application throughout this study.
- Tillage, treatment, and precipitation patterns all impacted EC, ENT, and SALM concentrations in drainage
Major Findings

1998 – 2008
Poultry manure yields were higher than UAN yields
Lower NO$_3$-N losses to drainage were from poultry manure treatment.
Phosphorus concentrations in drainage not different among treatments

2008 – 2016
Poultry manure yields were higher than UAN yields
Lower NO$_3$-N losses to drainage were from poultry manure treatment
Phosphorus concentrations (not loads) higher in soils and drainage from poultry manure treatments

2008 - 2011
Tillage, treatment, and precipitation impacted EC, ENT, and SALM concentrations in drainage
EC levels in drainage always below water quality standards
Acknowledgements

▪ ABE-Water Quality Research Lab- Loren Shiers, Leigh Ann Long
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    ▪ Iowa Agriculture and Home Economics Experiment Station
  ▪ ABE - Carl Pederson
Peer Reviewed Journal Articles


