Phosphorus and Sediment Runoff Losses from High-Moisture Soils

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Phosphorus Impacts Freshwater Ecosystems

Experimental Lakes Area, University of Manitoba

+ C + N no P

Picture taken in 1974

+ C + N + P

Picture taken in 2001
What do we know about P losses from soils?

• Very complicated!

• Function of:
  • Soil Test P
  • Soil erosion and runoff potential
  • Landscape position, slope, and distance to water body
  • Rainfall intensity and duration
  • Time of year (temperature, soil moisture)
  • Nutrient or manure application rate, timing and method
When do P losses occur?

- Late winter - Spring
  - Soils are wet / saturated for extended periods
  - Crops are not growing

- Many field runoff studies are conducted when soils are dry
How does soil moisture impact runoff P losses?

- **Particulate-bound P**
  - Affects structure / aggregation
  - Limits infiltration

- **Soluble P**
  - P diffusion
  - Redox effects on P sorption / release
Objectives

- Investigate the effects of two near-surface moisture gradients, P source, and time on:
  1) redox status
  2) runoff sediment and P losses
  3) changes in soluble P and amorphous iron after incubation and reoxidation
Experimental Conditions

- Chalmers Silty Clay Loam
  - 2 Treatments
    - Swine Slurry (42 kg P ha\(^{-1}\))
    - Control
  - 2 Moisture Conditions
    - WET – water table 18 cm from surface
    - SAT – water table 2 cm from surface
  - Three replicates (12 boxes total)
# Chalmers Soil Properties

<table>
<thead>
<tr>
<th>Sand</th>
<th>Clay</th>
<th>OM</th>
<th>pH</th>
<th>CEC</th>
<th>Bray-P1</th>
<th>TKN</th>
<th>TKP</th>
<th>WET</th>
<th>SAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>27</td>
<td>2.9</td>
<td>7.3</td>
<td>13.8</td>
<td>40</td>
<td>1460</td>
<td>585</td>
<td>36</td>
<td>38</td>
</tr>
</tbody>
</table>

The table shows the properties of Chalmers Soil, including percentages, cmol/kg, and mg/kg of various components.
Runoff Box Design

- 45 cm top layer
- 31 cm middle layer
- 20 cm soil layer
- 15 cm sand layer
- Water supply nozzles
Soil Redox Measurement

Agar/KCl Salt Bridge
Platinum Redox Electrodes
Rainfall / Runoff / Soil Collection

- Rainfall simulations conducted at 1, 7, 14, and 28 days.
- Rainfall intensity = 73 mm h\(^{-1}\).
- 30 min of runoff collected, weighed, and subsampled.
- Soil samples collected after draining.
Runoff and Soil Analyses

- **Runoff**
  - Sediment concentration
  - pH
  - Dissolved Reactive P (DRP)
  - Total Kjeldahl P (TKP)

- **Soil (before and after)**
  - Dilute Salt Extractable P (DSP)
  - Acid-ammonium oxalate (Al_{ox}, Fe_{ox}, P_{ox})
Soil Redox Potential - 2 cm Depth

![Graph showing soil redox potential over time for different treatments: Control - SAT, Control - WET, Slurry - SAT, Slurry - WET.](image-url)
Soil Redox Potential – 10 cm Depth

- Control - SAT
- Control - WET
- Slurry - SAT
- Slurry - WET
# Effect of Swine Slurry on Runoff

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Slurry</th>
<th>Control</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runoff:Rainfall</td>
<td>0.85</td>
<td>0.94</td>
<td>0.044</td>
</tr>
<tr>
<td>pH</td>
<td>7.7</td>
<td>7.9</td>
<td>0.164</td>
</tr>
<tr>
<td>Sediment (g)</td>
<td>10.25</td>
<td>8.1</td>
<td>0.369</td>
</tr>
<tr>
<td>DRP (mg)</td>
<td>0.16</td>
<td>0.11</td>
<td>0.008</td>
</tr>
<tr>
<td>TKP (mg)</td>
<td>4.13</td>
<td>4.47</td>
<td>0.66</td>
</tr>
</tbody>
</table>

mass / cm runoff
## Effect of Moisture on Runoff

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SAT</th>
<th>WET</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runoff:Rainfall</td>
<td>0.96</td>
<td>0.83</td>
<td>0.010</td>
</tr>
<tr>
<td>pH</td>
<td>8.06</td>
<td>7.62</td>
<td>0.019</td>
</tr>
<tr>
<td>Sediment (g)</td>
<td>11.30</td>
<td>7.08</td>
<td>0.108</td>
</tr>
<tr>
<td>DRP (mg)</td>
<td>0.15</td>
<td>0.11</td>
<td>0.037</td>
</tr>
<tr>
<td>TKP (mg)</td>
<td>5.56</td>
<td>3.05</td>
<td>0.013</td>
</tr>
</tbody>
</table>

**mass / cm runoff**
Runoff Sediment Concentration

Effect of Moisture and Time

![Bar chart showing the effect of moisture and time on runoff sediment concentration. The x-axis represents runoff event (day) with values 1, 7, 14, and 28. The y-axis represents g/cm runoff with values 0 to 18. The chart compares WET and SAT conditions.](chart.png)
Effect of Reoxidation on Soil DSP

- SAT significantly lower than Initial and WET
- Averaged over treatment, WET and SAT sig. lower than Initial
### Effect of Reoxidation on $\text{Fe}_{\text{ox}}$

<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
<th>WET</th>
<th>SAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Al}_{\text{ox}}$</td>
<td>879</td>
<td>933</td>
<td>929</td>
</tr>
<tr>
<td>$\text{Fe}_{\text{ox}}$</td>
<td>2200</td>
<td>2530</td>
<td>2660*</td>
</tr>
<tr>
<td>$\text{P}_{\text{ox}}$</td>
<td>271</td>
<td>291</td>
<td>300</td>
</tr>
</tbody>
</table>

* Indicates significant difference between Initial and SAT according to LSD ($a=0.05$)
SAT condition produced lower redox potentials
- swine slurry decreased Eh in WET condition

Swine slurry decreased runoff volume, and increased DRP in runoff

SAT condition increased runoff, pH, DRP and Total P in runoff

Sediment concentration decreased with time in WET soil
- surface sealing

Dilute salt extractable P lower, $\text{Fe}_{\text{ox}}$ greater in incubated soils following reoxidation
Conclusions

- A relatively small increase in soil moisture can greatly impact sediment and P losses in runoff.
- Moisture has a greater impact on total P runoff losses than a recently incorporated manure application.
- High moisture conditions followed by oxidation decreases soluble P and increase the amorphous Fe-oxide content of surface soils.
Questions to be answered

- Are same trends observed with higher or lower testing soils?
- How does fertilizer/manure application method impact P losses under high moisture conditions?
- Does soil reduction impact P leaching losses?
- How do seasonal fluctuations in soil redox impact long-term runoff P losses?