UNDERSTANDING SOIL PHOSPHORUS

Larry G. Bundy
Dept. of Soil Science
University of Wisconsin
Why is Understanding Soil P Important?

- Determine agronomic need for P
- Water quality issues related to phosphorus (P)
- Restructuring of nutrient management standard/rules to include control of P loss
Environmental Concerns

- Phosphorus is the major nutrient promoting algae and aquatic weed growth in freshwater lakes and streams.
  - Oxygen depletion and fish kills
  - Odor
  - Limits recreation and tourism
  - Quality of drinking water drawn from surface waters.
Phosphorus and Water Quality

- Phosphorus additions to natural waters can stimulate weed and algae growth.
- Phosphorus losses from agriculture can be a major source of P entering lakes and streams.
Sources of Phosphorus to Tainter Lake, WI

- Natural: 20%
- Urban: 13%
- Agricultural: 67%

Nutrient and Pest Management Program 2002
## Forms & Concentrations of Phosphorus (P) in Soils

<table>
<thead>
<tr>
<th>Form</th>
<th>Concentration (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>1000</td>
</tr>
<tr>
<td>Soil test P (available)</td>
<td>20-50</td>
</tr>
<tr>
<td>Soil solution</td>
<td>0.01-0.30</td>
</tr>
</tbody>
</table>
Phosphorus (P) Reactions in Soils

- Soluble P additions (fertilizers) react quickly to form slowly soluble compounds:
  - Sorbed P
    - Clays
    - Al and Fe oxides
  - Secondary P minerals (precipitation/dissolution)
    - Ca, Fe, Al phosphates
Adsorption and Desorption of Phosphorus

- **Adsorption**: removal of ionic P ($\text{H}_2\text{PO}_4^-$, $\text{HPO}_4^{2-}$) from solution by reaction with solid phase of soil.
- **Solid phase**: clays, oxides or hydroxides of Fe and Al, calcium carbonates, organic matter.
- **Desorption (labile P)**: Portion of adsorbed P available for plant uptake, extraction, or measured by soil test.
Phosphorus (P) Loss Processes

- **In surface runoff:**
  - Soluble (dissolved) P
  - Particulate P (soil particles)

- **By leaching**
  - Does phosphorus leach?
PHOSPHORUS (P) IN RUNOFF

- Dissolved (soluble P) (DP)
- Particulate P (PP)
- Total P (TP) – Includes DP and PP
- Bioavailable P (BAP)

✓ DP + part of PP
## Critical Phosphorus Concentrations for Surface Waters

<table>
<thead>
<tr>
<th>Type of water</th>
<th>Form of P</th>
<th>P conc. (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lakes</td>
<td>Soluble P</td>
<td>0.01</td>
</tr>
<tr>
<td>Streams</td>
<td>Total P</td>
<td>0.10</td>
</tr>
<tr>
<td>Lakes</td>
<td>Total P</td>
<td>0.05</td>
</tr>
</tbody>
</table>
Relationship between Bray P-1 (0-2 cm) and DRP in runoff.

\[ y = -0.0025 + 0.0017x + 0.0000068x^2 \]

\[ R^2 = 0.95 \quad n = 42 \]
Influence of tillage and manure
Spring manure and tillage effects on total P load in runoff at three locations.

<table>
<thead>
<tr>
<th>Location</th>
<th>CP, 0 t/a</th>
<th>CP, 32 t/a</th>
<th>NT, 0 t/a</th>
<th>NT, 32 t/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arlington</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lancaster</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fond du Lac</td>
<td></td>
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</tr>
</tbody>
</table>

Total P (g ha⁻¹)
Soil-specific effects on soluble P
Relationship between STP and DP concentration in runoff without spring applied manure.

Fond du Lac
$r^2 = 0.66$  $n = 28$

Arlington/Lancaster/Madison
$r^2 = 0.65$  $n = 119$
Effect of soil extraction time on water extractable soil P concentration for two soils.

Respective soil test P (at 60-min) = 40 and 42 mg kg\(^{-1}\) at Lancaster and Fond du Lac.
Respective DP in runoff = 0.33 and 0.93 mg L\(^{-1}\) at Lancaster and Fond du Lac.
## Interpreting Soil P Tests

<table>
<thead>
<tr>
<th>Crop</th>
<th>Optimum</th>
<th>No response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>18-25</td>
<td>&gt;35</td>
</tr>
<tr>
<td>Corn</td>
<td>15-20</td>
<td>&gt;30</td>
</tr>
<tr>
<td>Soybean</td>
<td>10-15</td>
<td>&gt;20</td>
</tr>
</tbody>
</table>

Medium and fine-textured soils, Bray P-1 test
SOIL PHOSPHORUS BUFFERING CAPACITY

• Soil test P changes slowly with P additions or removals.

• Ave. 18 lb. $P_2O_5$/acre needed to change P test by 1 ppm
Soil Test P Changes Slowly

• Example:
  – Soil P test = 100 ppm = EH
  – Optimum soil test = 20 ppm
  – Removal needed for EH to Opt. = 18 lb $P_2O_5$/acre x 80 ppm = 1440 lb $P_2O_5$
  – Corn grain removes 60 lb $P_2O_5$/acre/year
  – 1440/60 = 24 yrs with no added P for EH change to optimum.
Decrease in soil test P in a corn-soybean rotation for 26 years. (McCollum, 1991)
<table>
<thead>
<tr>
<th>Soil Test</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low, very low</td>
<td>Crop removal +</td>
</tr>
<tr>
<td>Optimum</td>
<td>Crop removal</td>
</tr>
<tr>
<td>High</td>
<td>$\frac{1}{2}$ Crop removal</td>
</tr>
<tr>
<td>Excessively High</td>
<td>None</td>
</tr>
</tbody>
</table>
Summary

- Phosphorus (P) behavior in soil and management effects on P losses are complex
Summary

• Small amounts of P can cause surface water problems
• P losses can occur as dissolved P and particulate P
Summary

• Soils differ in effects of tillage, manure, and soil test P on P in runoff
• Excess P has accumulated in many soils
• Drawdown of soil test P is a slow process