Phosphorus mobilisation and risk assessments in a small agricultural catchment with heavy clay soil

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Sources + risk of mobilisation

Transport

Drainage system

Visible
Catchment E23 with heavy clay soil

Mineral P fertilisation close to zero

Mean soil P balance close to zero

Tile drainage system on average since 1937
Culvert opening

Wooden structures to prevent stream bank erosion
Transport
Ditches and drainage systems need improvements
Concentrations in the stream

On-line measurement of turbidity and NO$_3$N

Flow-proportional water sampling at the endpoint

Manual synoptic water sampling of the entire catchment
Concentrations in the stream

Turbidity - suspended solids (SS)  
Turbidity - particulate-bound phosphorus (PP)
Concentrations in the stream - related to flow (hysteresis curve) in a flow event
Concentrations in the stream

Particle peak arrives earlier than nitrate peak in stream water

- First particles (and particulate bound P)
Concentrations in the stream

- First particles
- Then peak water flow
Concentrations in stream

- First particles
- Then peak water flow
- After 4-8 hours the nitrate peak
Concentrations in the stream

<table>
<thead>
<tr>
<th></th>
<th>SS (mg/l)</th>
<th>PP (mg/l)</th>
<th>DRP (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High flow pulses autumn</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>End of culvert</td>
<td>280</td>
<td>0.13</td>
<td>0.07</td>
</tr>
<tr>
<td>End of catchment</td>
<td>450</td>
<td>0.76</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Concentrations of PP and SS increase in high flow pulses in the open stream especially in autumn. Concentrations of dissolved reactive phosphorus (DRP) increase to a lesser extent.

Agreement with flow-proportional sampling.
Transport in stream/soil

Stream-end of catchment    Stream - culvert opening

Electric conductivity (mS m\(^{-1}\))

Water rich in salts slowly passing through the soil
Water poor in salts – channelized flows in the soil
Sources
+ risk of mobilisation
Sources + risk of mobilisation

Not-inversed topsoil – most of the P from 0-5 cm

Higher risk for P leaching with higher P-AL topsoil content
**Sources**

P-AL measured in an extract with ammonium lactate (weak organic acid)

Root exudates with organic acids – the crop can take P bound to iron (Fe) - and aluminium (Al) in the soil.
"degree of phosphorus saturation" (DPS) in the lactate extract (mole basis)

DPS = \( \frac{P-\text{AL}}{\text{Fe-AL} + \text{Al-AL}} \times 100 \)

Numbers higher than 25 also in the subsoil means enhanced risk for high P leaching
Sources + risk of mobilisation

How much P can the very soil material sorb or release?

Correlation between PSI and maximum amount of P that can be sorbed (Börling, et al., 2003)
PSI and concentrations of Fe + AL and P in Al extract - two fields exceptions -

Sources + risk of mobilisation

PSI and much manure??
Sources + risk of mobilisation

Pw/PSI and DPS in AL-extract

Round-up treated broad bean

All other sites in the catchment

**P_w** - leaching from crop residues
Sources + risk of mobilisation

DRP in tile drains and water-soluble P (Pw) in soil

Water-soluble P (Pw) approx 2% of P-AL
Transport

Topographical wetness index (TWI) for a small drained agricultural catchment?

Significantly different TWI for 4 of the largest fields
## Transport

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Clay (%)</th>
<th>Porosity (vol %)</th>
<th>Sat. hydraulic conductivity (m day(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-15</td>
<td>60</td>
<td>45</td>
<td>0.007</td>
</tr>
<tr>
<td>35-40</td>
<td>80</td>
<td>50</td>
<td>0.003</td>
</tr>
<tr>
<td>75-80</td>
<td>80</td>
<td>56</td>
<td>0.020</td>
</tr>
</tbody>
</table>
Saturated hydraulic conductivity: 0.007-0.06 m day\(^{-1}\)

Theoretically, tile drain spacing should be reduced 11 m drain spacing between instead of current 14-16 m
**Risk assessment**
Areas in catchment  E23

<table>
<thead>
<tr>
<th>Sources</th>
<th>Transport (rills, ponded water)</th>
<th>Transport (re-drainage needed)</th>
<th>Source <em>and</em> transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 %</td>
<td>3 %</td>
<td>12 %</td>
<td>7 %</td>
</tr>
</tbody>
</table>

Conclusions

Important factors to be considered:

• Small P soil pools ($P_w$)
• Short- and long-term effects of manure addition (PSI)
• Open stream management and bank erosion
• Soil hydrology in drained agriculture landscape
• Efficiency of artificial drainage system
Measures will start – structure liming, open stream management, manure with better precision

Thank you!

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