Simulating the release of soil phosphorus in sulphidic sediments

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Theoretical background: Coupled biogeochemical cycling*

*See: Frontiers in Ecology and the Environment 2011;9
Agriculture is a major contributor to Fe losses

Agricultural rivers: 6.1–6.5% Fe in total suspended solids (Mäkiaho 2007)

Mäkiaho A. 2007. Transport of iron and suspended sediments by Finnish rivers into the Baltic Sea, University of Helsinki.
Phosphorus release from Fe oxides
1. Microbial Fe reduction

Fe(III) oxides reduced by microbes to dissolved Fe(II)
- \( \text{CH}_3\text{COO}^- + 8 \text{Fe(III)} + 4 \text{H}_2\text{O} \rightarrow 2 \text{HCO}_3^- + 8 \text{Fe(II)} + 9 \text{H}^+ \)

Dominates when there are
- Microbially available Fe(III) oxides
- Sediment surface oxic enabling re-oxidation of Fe(II)
Phosphorus release from Fe oxides

2. Chemical Fe reduction

“Sulphate-mediated eutrophication”

SO₄ is reduced by microbes to HS⁻ or H₂S
- CH₃COO⁻ + SO₄²⁻ → 2 HCO₃⁻ + HS⁻

Dominates when:
- Fe(III) oxides consumed
- Plenty of labile organic C
- Sediment surface is anoxic
What is a sulphidic system?

<table>
<thead>
<tr>
<th>Site</th>
<th>SO$_4$ (mg l$^{-1}$)</th>
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</thead>
<tbody>
<tr>
<td>Sea water</td>
<td>2400</td>
</tr>
<tr>
<td>The Baltic Sea (off Helsinki)</td>
<td>500</td>
</tr>
<tr>
<td>Lake Pyhäjärvi</td>
<td>9.6</td>
</tr>
<tr>
<td>Lake Pielinen</td>
<td>2.5</td>
</tr>
</tbody>
</table>

- SO$_4$ concentration in runoff increases with field percentage (Mattsson et al. 2007)
The experiment

Sandy clay soil (60–1000 mg)
(a) 80 ml brackish water medium (−P) + SO$_4$
(b) 80 ml filtered Baltic Sea water
+ acetate (0.375–24 mg C)
+ 10 µl sediment

Incubation on a shaking table
• At dark
• (a) +10 C, (b) +8 C
• (a) 308 d, (b) 745 d

Determinations
• Fe(II), Total Fe, DRP, TOC, SO$_4$, NH$_4$, pH
Mineralization processes in the experiment

Fe reduction

SO₄ reduction
Phosphorus release as a function of carbon added

\[
P = 0.41 \cdot (1 - e^{-0.89 \text{Carbon}})
\]

\[
\frac{0.41}{1.47} = 0.28
\]
Conclusions

- Release of P from soil can be enhanced by organic C and simulating a highly reducing environment
- The approach may serve as an alternative method for estimating the potentially mobile P
- Eroded soil is a major potential P source in sulphidic and eutrophic systems, such as the Baltic Sea or SO$_4$-rich lakes
  - The load of P, N (and in freshwaters SO$_4$) should be reduced
  - BUT: to what extent does Fe in soil inhibit SO$_4$ reduction and P release?
  - What P form (PP/DRP) should be reduced?
How to manage that field plot?

Thank you!