8. Biological availability of nutrients

?

__Municipal wastewater treatment plant in Viikinmäki__

TP in outlet: 0.23 mg l^{-1}

Biological availability: 0–100%

Available P = 0–0.23 mg l^{-1}

Photos: S. Knuuttila, J. Lehtoranta, S. Mitikka, SYKE

Biologically available P

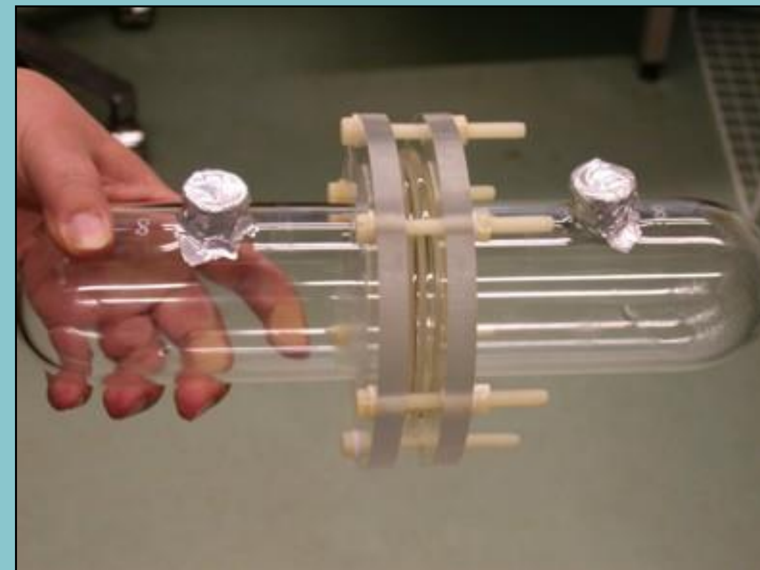
- **Available to what?**
- **Algae can grow with more than 17 pure compounds**
- **Time frame**
  - **Hydraulic retention of Pin water phase**
  - **P active in sediments**
- **Directly available P**
  - **$H_2PO_4^{-}$, HPO_4^{2-}, PO_4^{3-}**
- **Potentially available P (BAP)**
  - **P that can become directly available through naturally occurring physical, chemical and biological processes**
  - **PO_4^{3-} < BAP < TP**
- **Geochemically active P**
  - **$PO_4^{3-} < P_{geo} <$ TP**

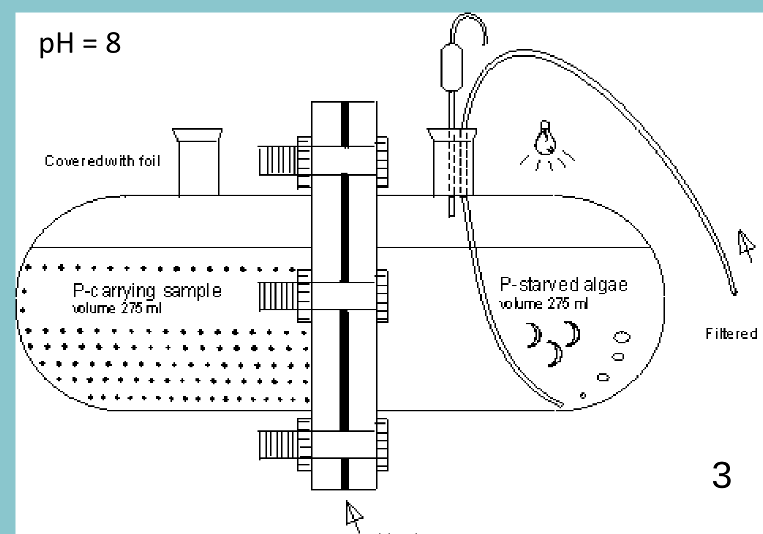
Compton ym. (2000)	**10^9 kg y^{-1}**
Total P	18.7–31.4
Geochemically active P	3.4–10.1

PO_4^{3-} Detergent-P $Na_5P_3O_{10}$ Org.-P Fe~P Apatite

Time

Determining algal-availability of phosphorus





Chemical extractions

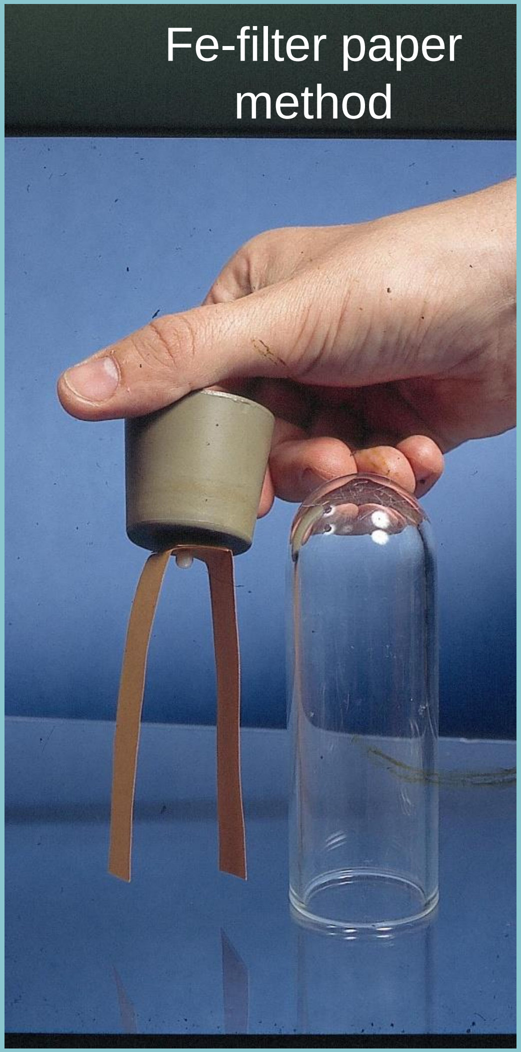
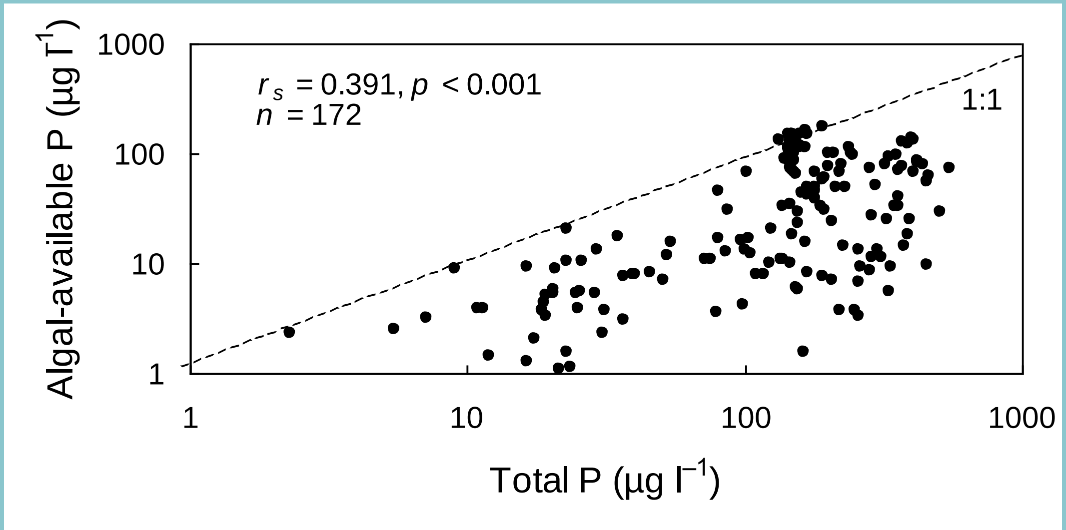


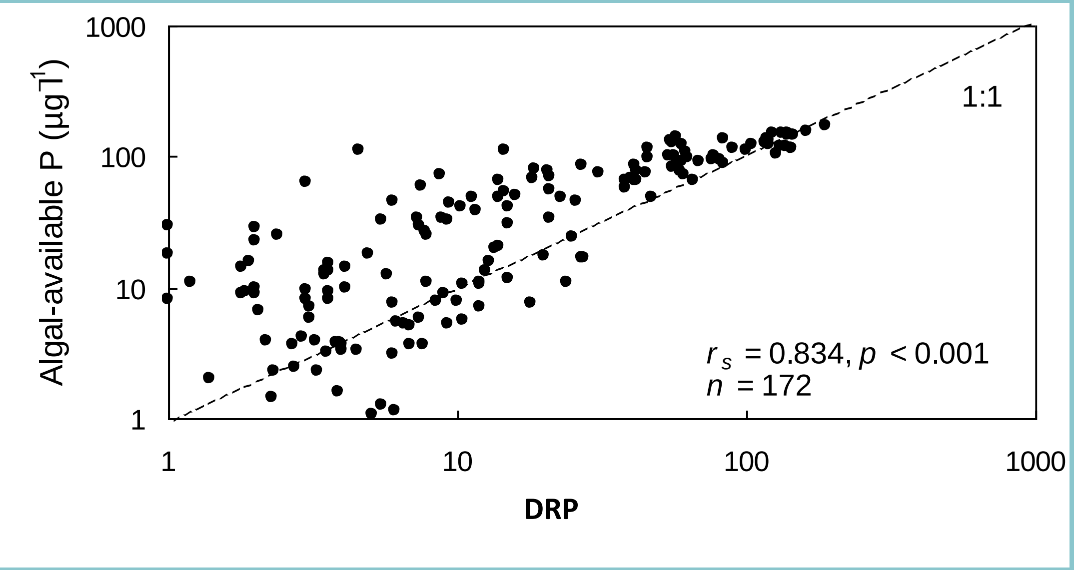
Photo: Vuokko Puranen, Kemira

$FeCl_3 + NaOH \rightarrow$
$Fe(OH)_3 + NaCl$

Photo: Risto Uusitalo, MTT

Algal availability of total P and dissolved reactive P

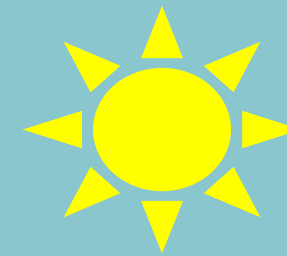




Ekholm & Krogerus (2003)

P release from sediments

1. Prevalence of microbial Fe reduction and a coupled Fe and P cycling



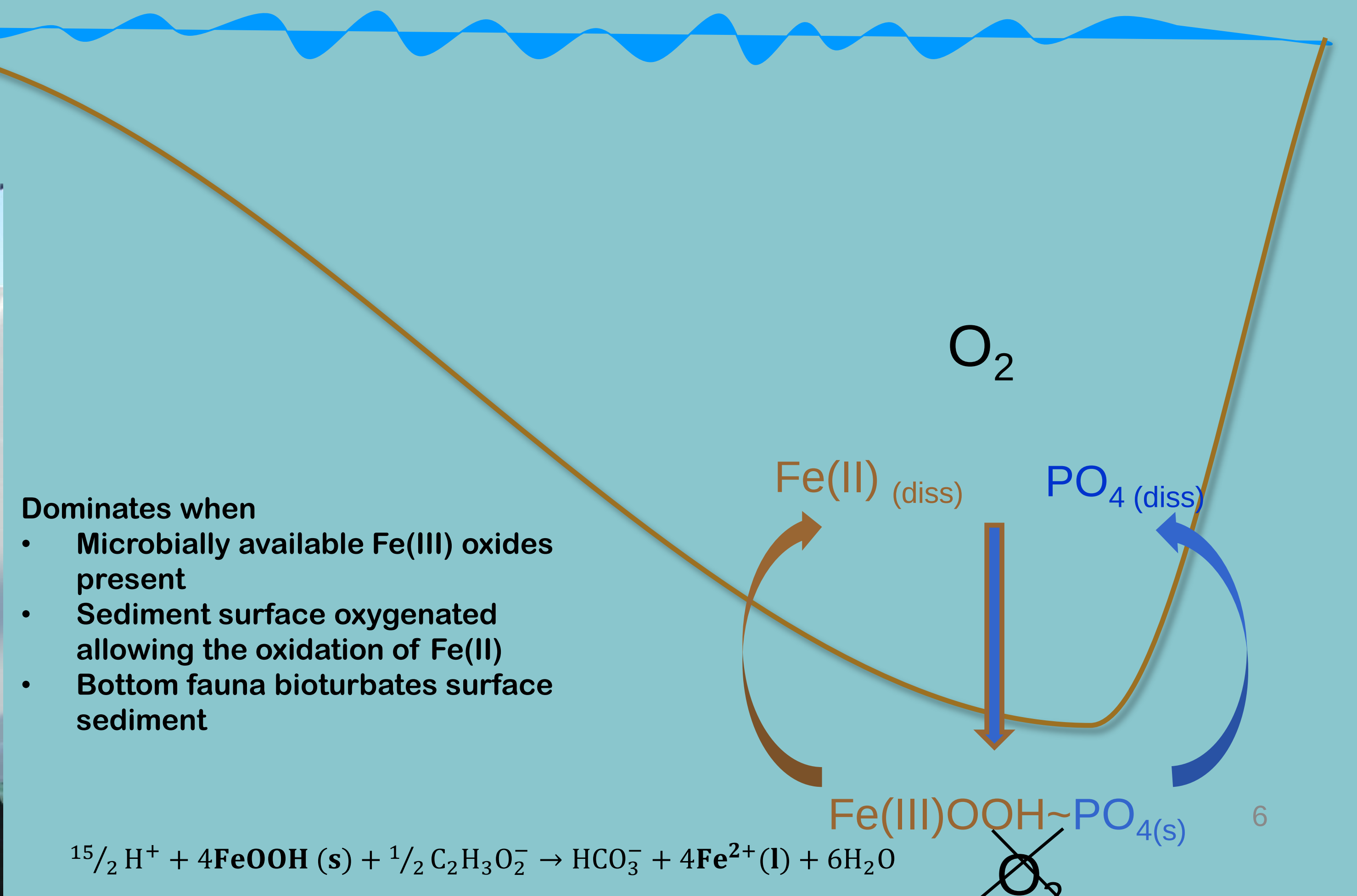


Photo: Seppo Knuuttila

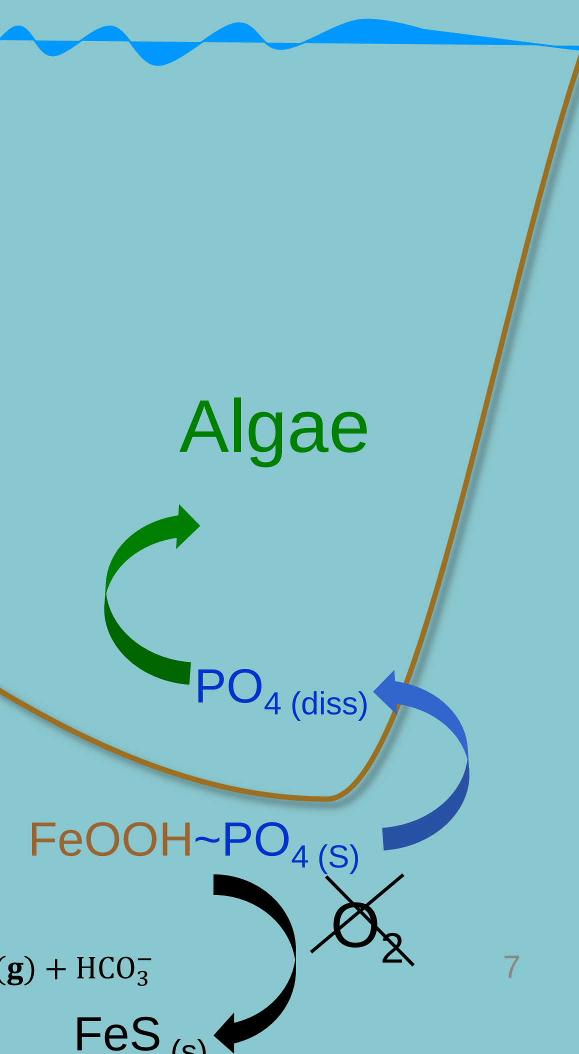
Dominates when

- **Microbially available Fe(III) oxides present**
- **Sediment surface oxygenated allowing the oxidation of Fe(II)**
- **Bottom fauna bioturbates surface sediment**

$$^{15}/_2\,H^+ + 4\mathbf{FeOOH\ (s)} + {}^{1}/_2\,C_2H_3O_2^- \rightarrow HCO_3^- + 4\mathbf{Fe^{2+}(l)} + 6H_2O$$

P release from marine sediments

2. Prevalence of microbial SO_4 reduction and an uncoupled Fe and P cycling



Dominates when

- **Fe(III) oxides consumed**
- **Plenty of labile organic C**
- **Sediment surface is anoxic**

$$\frac{1}{2}H^+ + \frac{1}{2}\mathbf{SO_4^{2-}}(\mathbf{l}) + \frac{1}{2}C_2H_3O_2^- \rightarrow \frac{1}{2}\mathbf{H_2S}(\mathbf{g}) + HCO_3^-$$

Photo: Seppo Knuuttila

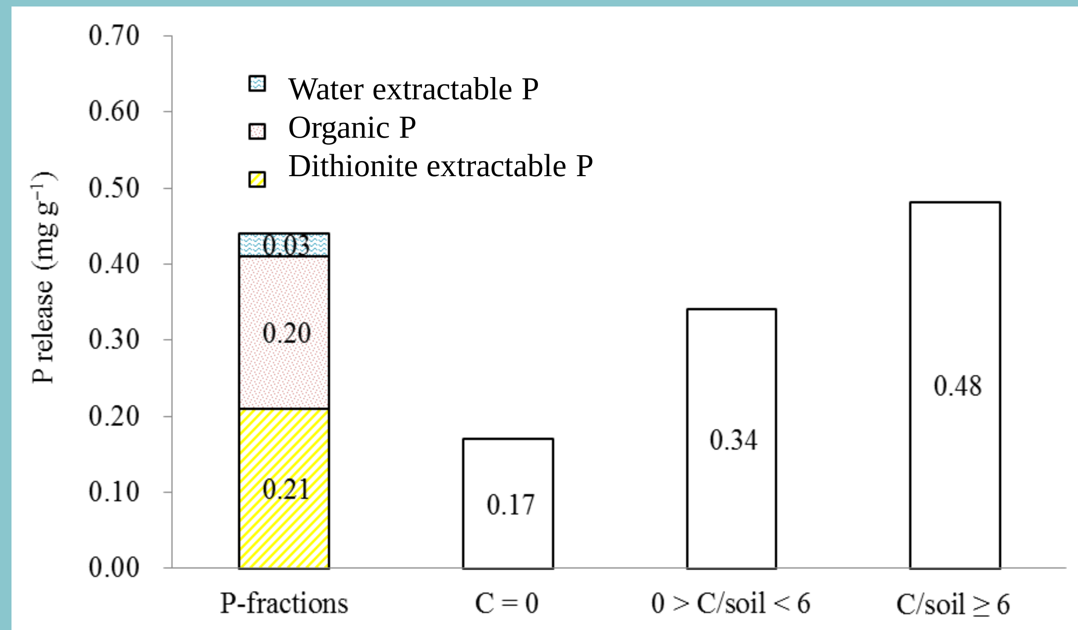
P forms from experimental fields

Field	Runoff (mm)	Dissolved reactive P (kg ha^{-1})	Particulate P (kg ha^{-1})			Erosion (kg ha^{-1})
			Total	Algal-available	Redox-sensitive	
Aurajoki						
1997-1998	136	0.425	2.65	0.51	1.34	1500
1998-1999	235	0.497	2.41	0.47	1.30	1170
1999-2000	238	0.411	1.68	0.32	0.95	1030
2000-2001	221	0.511	1.39	0.26	0.81	920
Jokioinen						
1997-1998	64	0.035	0.353	0.047	0.118	400
1998-1999	125	0.073	0.232	0.024	0.097	250
1999-2000	60	0.029	0.281	0.038	0.099	300
2000-2001	68	0.034	0.261	0.034	0.094	290
Lintupaju						
1997-1998	121	0.183	1.022	0.160	0.430	1330
1998-1999	209	0.197	0.802	0.110	0.360	920
1999-2000	174	0.139	0.847	0.120	0.370	1040
2000-2001	163	0.125	1.974	0.330	0.780	2270

Uusitalo & Ekholm (2004)

Release of soil P in anoxic brackish water

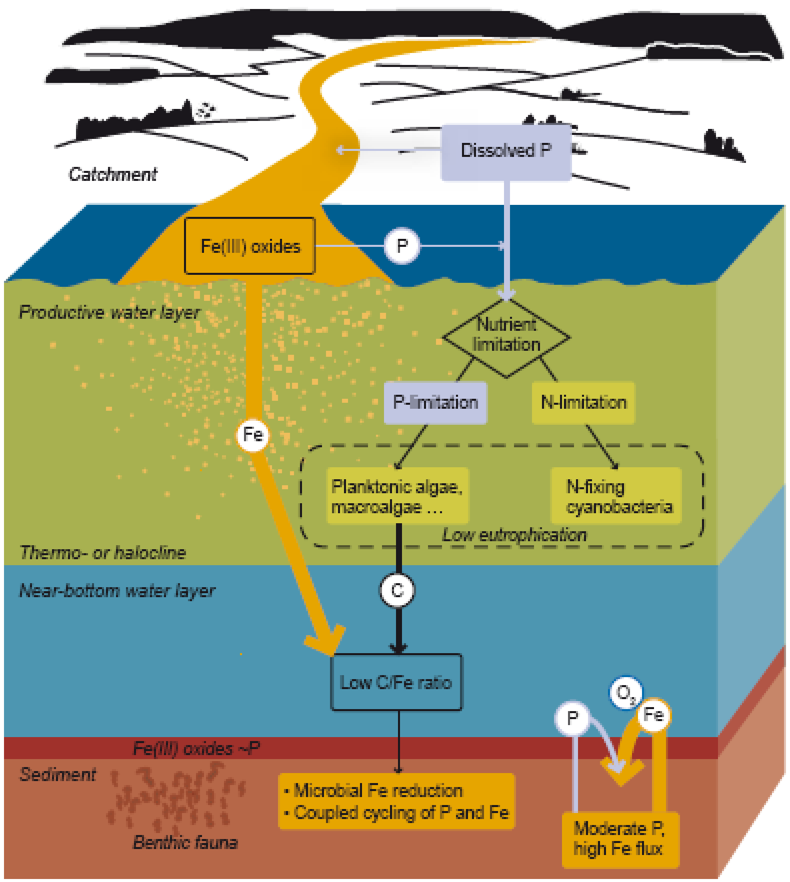
Photos: Seppo Knuuttila, Jouni Lehtoranta



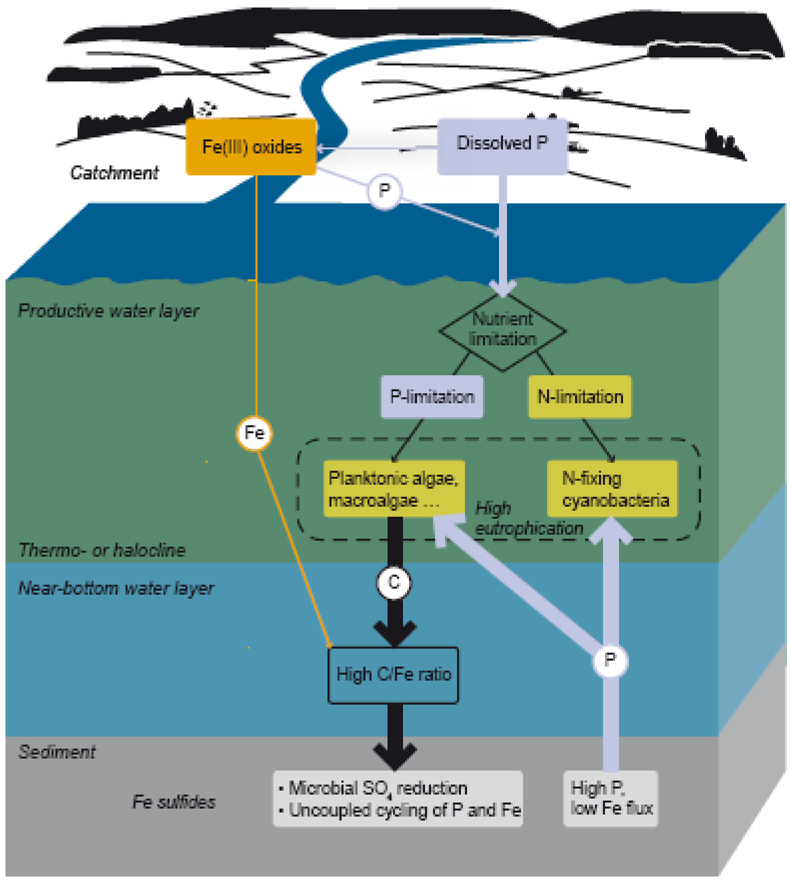
- **Increase in organic C enhanced the release of P from soil (up to 44% of total P)**
- **Does Fe in eroded soil have an effect?**
  - **Agricultural rivers: 6.1–6.5% Fe in total suspended solids**
  - **Can eroded soil maintain Fe reduction and inhibit SO_4 reduction?**

Ekholm & Lehtoranta (2012)
Lehtoranta et al. (2015)

Does control of soil erosion inhibit eutrophication?



Ekholm & Lehtoranta (2012)



Biologically available N

- In general: N availability > P availability
- Algae can use many N compounds
  - NO_x-N, NH_4-N, small molecular weight organic compounds
- NO_3-N is bound by soil particles weakly
  - N is lost from agricultural areas largely in a dissolved form
- TN – (NO_x-N + NH_4-N) = organic N
  - Humic-bound N relatively inactive, but
  - Bacteria degrade some of it, as does UV radiation

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