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Transport of Fe and humic substances in boreal humic rivers in northern Finland

Kaisa Heikkinen

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SYKE, Helsinki

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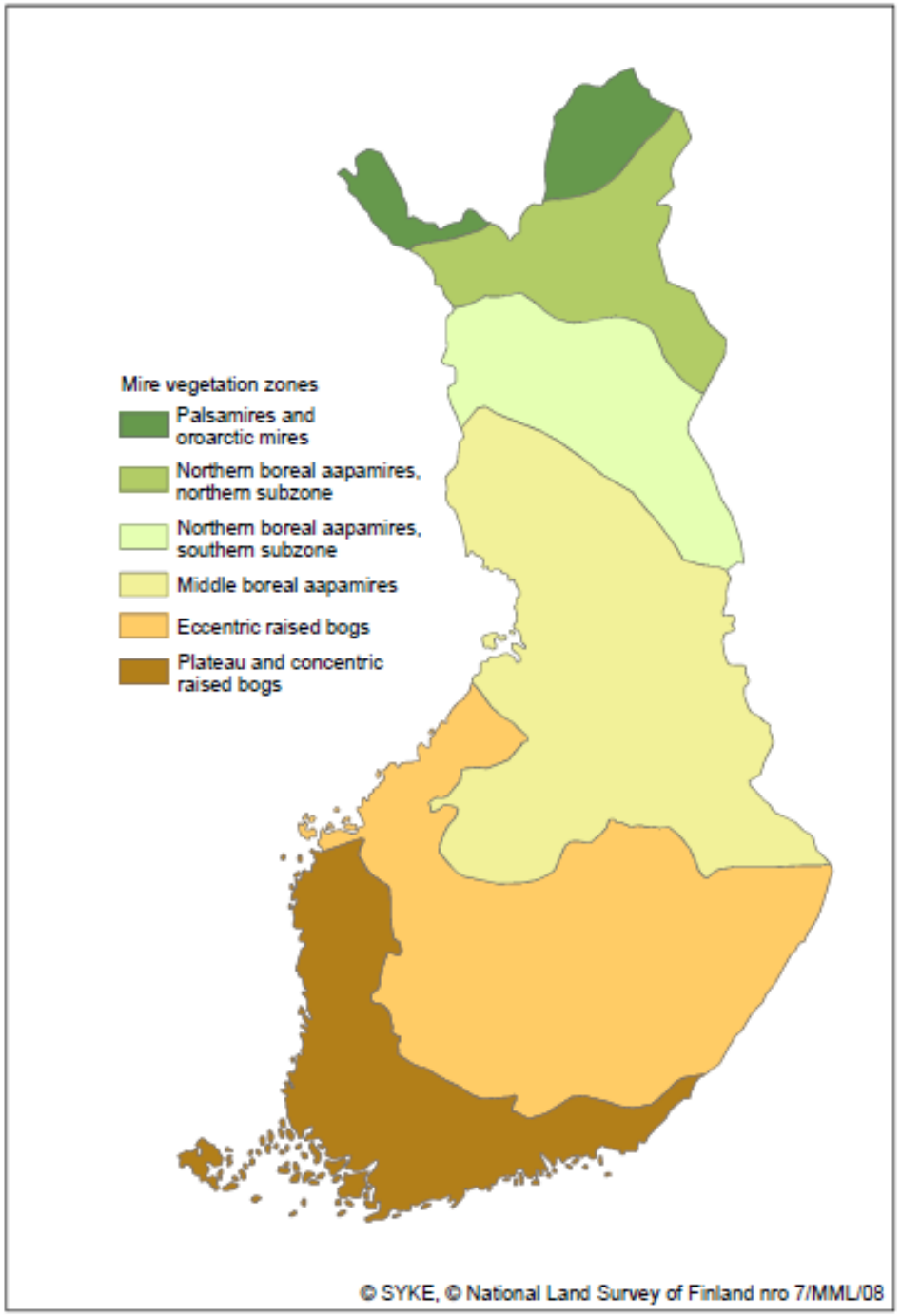


Study areas in the middle boreal aapamires zone

- The River Kiiminkijoki basin
- The River Siuruanjoki in the River Iijoki basin

Fe in stream and river water containing oxygen

Particulate Fe

- transported with suspended solids

Dissolved organic Fe

- transported with humic substances

Very small concentrations of Fe^{2+} and Fe^{3+}

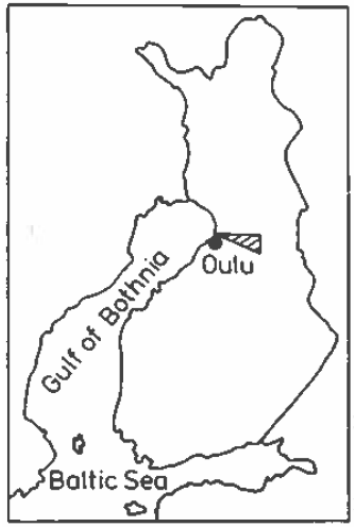
Dissolved organic matter and organic Fe-P-colloids have an important role in these waters

Table 2. Average DOC (<0,7 µm) and Fe and organic P in filtered (<1,2µm) samples from the drainage basin of the Kiiminkijoki River. Data are presented as percentages of the total amounts.

Site	DOC	Fe	Organic P
River channel	89-91	65-76	32-56
Keihäsoja brook	91	67	26
Jauhosuo peat mining area	80	72	47
Vittasuo peat mining area	83	60	62

Average organic carbon and Fe concentrations and colour in the drainage basin of the River Kiiminkijoki

	River mouth			natural Brook Keihäsoja upstream		
	X	min	max	X	min	max
DOC (mg/l)	13,7	8,2	19,9	17,4	11,5	28,4
POC (mg/l)	1,6	0,6	5,4	1,6	1,1	3,5
TOC (mg/l)	15,3	9,2	22,6	19,1	13,4	29,5
CODMn (mg/l)	17,4	11,5	26,3	27,2	15,3	45,3
Colour (Pt mg/l)	278	204	419	380	280	490
Colour in filtrates (Pt mg/l)	242	181	343	350	250	480
Tot. Fe (mg/l)	2,2	0,8	3,9	2,7	1,4	4,5
Fe in filtrates (< 1,2 µm) (mg/l)	1,7	0,4	2,7	2,1	1,3	3,3

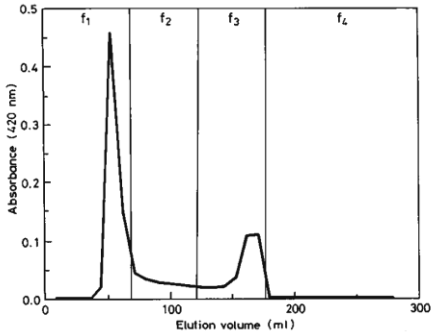


Methods used in the studies

Material transport in the river basin (Tot. Fe, Fe in filtrates, DOC, POC, SS)

Annual changes in water quality (Fe/DOC, colour/DOC, fluorescence/DOC) and discharge in a river

Changes in the nature of DOM by gel filtration



Riffle sediment quality downstream from peat extraction areas

- Sampling from 0,3 x 0,3 m areas by hand operated bilge pump to a container
- Fractionating the samples through a set of sieves of differing mesh sizes
- Analysing dry weights and ash-free dry weights of the sediment fractions
- Analysing Fe-content of the smallest (<0,075 mm) sediment fraction

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Results on the environmental impacts of peat extraction in the rivers

Needs for further research

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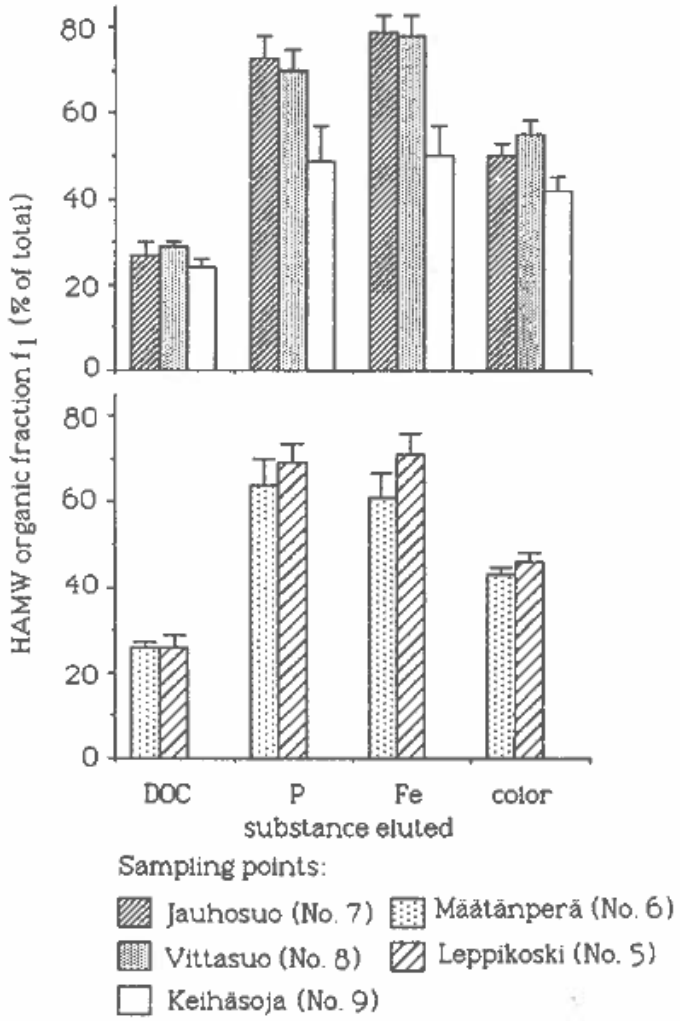

Fig. 4. Average percentages of total amounts of the substances eluted in the HAMW humic fraction f_1 in the Jauhosuo and Vittasuo peat mining water and the Keihäsoja brook, and in the Nuorittajoki River in the area of loading from the peat mining areas (Määtänperä and Leppikoski).

Peat extraction
→ Increase in Fe leaching
→ Increase in Fe/DOC ratio of organic colloids

Impacts of this increase can be seen also in the river water below peat extraction areas

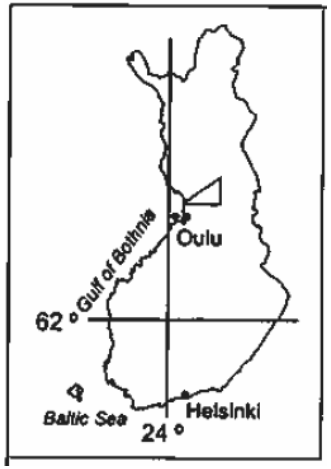

Table 4. Average molar ratio of Fe to DOC in the gel filtration fractions f_1, f_2, and f_3.

Site	Gel filtration fraction f_1	f_2	f_3
Jauhosuo peat mining area (Site no. 7)	0.068	0.008	0.005
Vittasuo peat mining area (Site no. 8)	0.060	0.008	0.006
Keihäsoja brook (Site no. 9)	0.032	0.012	0.013
River sampling points			
Määtänperä (Site no. 6)	0.042	0.021	0.005
Leppikoski (Site no. 5)	0.053	0.008	0.008
Jokikokko (Site no. 3)	0.045	0.008	0.008

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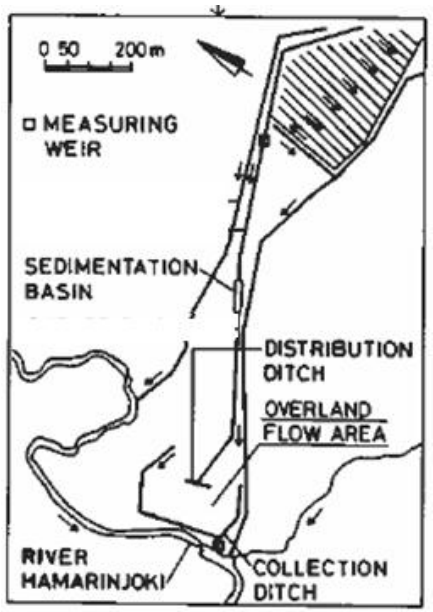
It is possible to decrease the Fe concentration of high apparent molecular weight (HAMW) DOM fraction during the dry summer periods by overland flow wetland treatment system.

Fe is eluted mainly in this HAMW fraction



Kompsasuo overland flow wetland in northern Finland

Fe

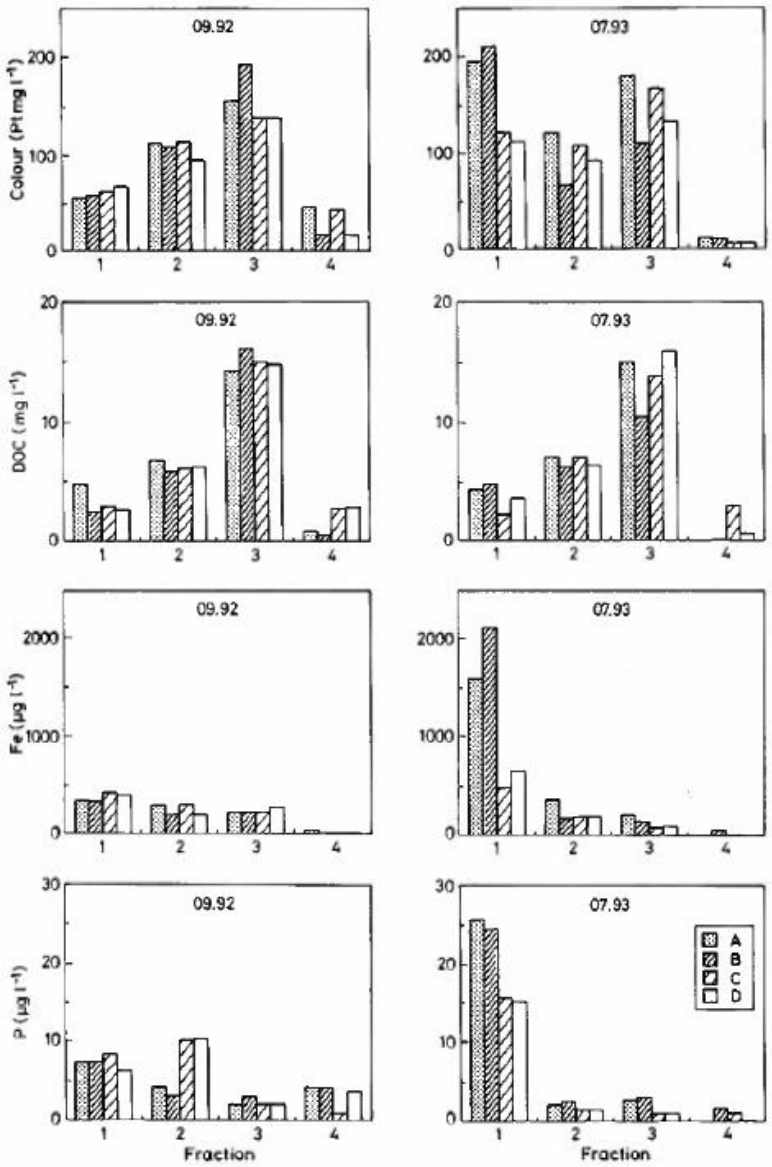


Fig. 4. Colour, DOC, Fe and P in gel filtration fractions f_1, f_2, f_3 and f_4 from the northern peat mining area of Kompsasuo. A = measuring weir above the sedimentation basin and the OFA, B = distribution ditch above the OFA, C = surface water below the OFA, D = measuring weir below the OFA.

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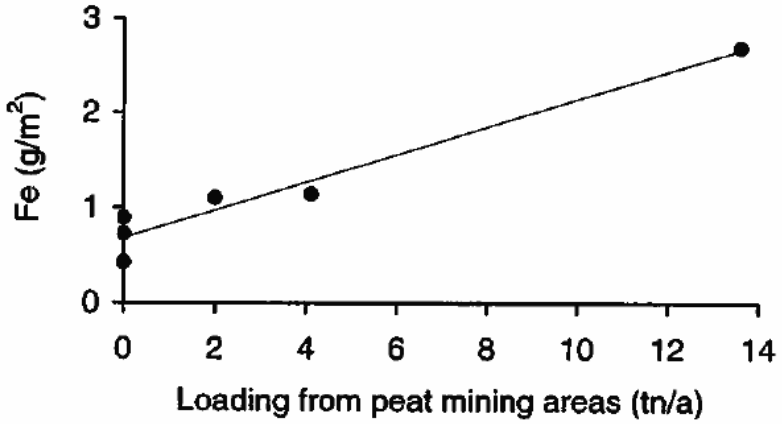

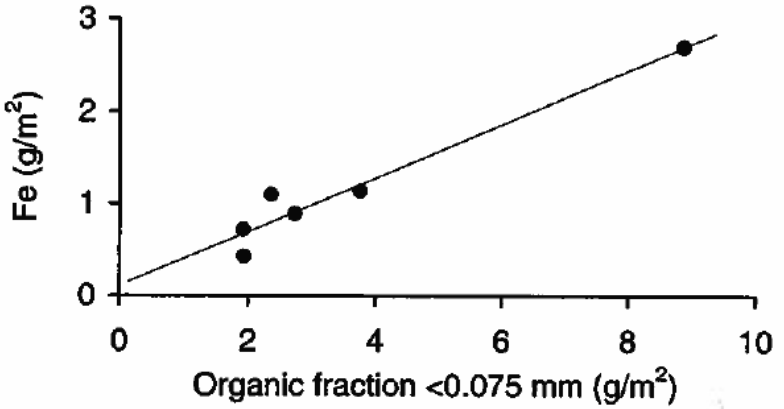

Fig. 5. Amounts of Fe (g/m^2) attached to <0.075 mm PM on the riffle beds, plotted against mean PM loading from peat mining areas (tn/a), zero values representing the three reference sites, and mean Fe content of the <0.075 mm PM, plotted against the total mean dry weight of the respective organic fraction, in August 1993.

Impacts of Fe loading can be seen even on the river riffle beds of the rivers affected

What is the role of increasing Fe/DOC content of the DOM in this river bed deterioration?

Is the same happening also in Central Finland?

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Results on the annual change in the nature of dissolved organic matter in the rivers

Needs for further research

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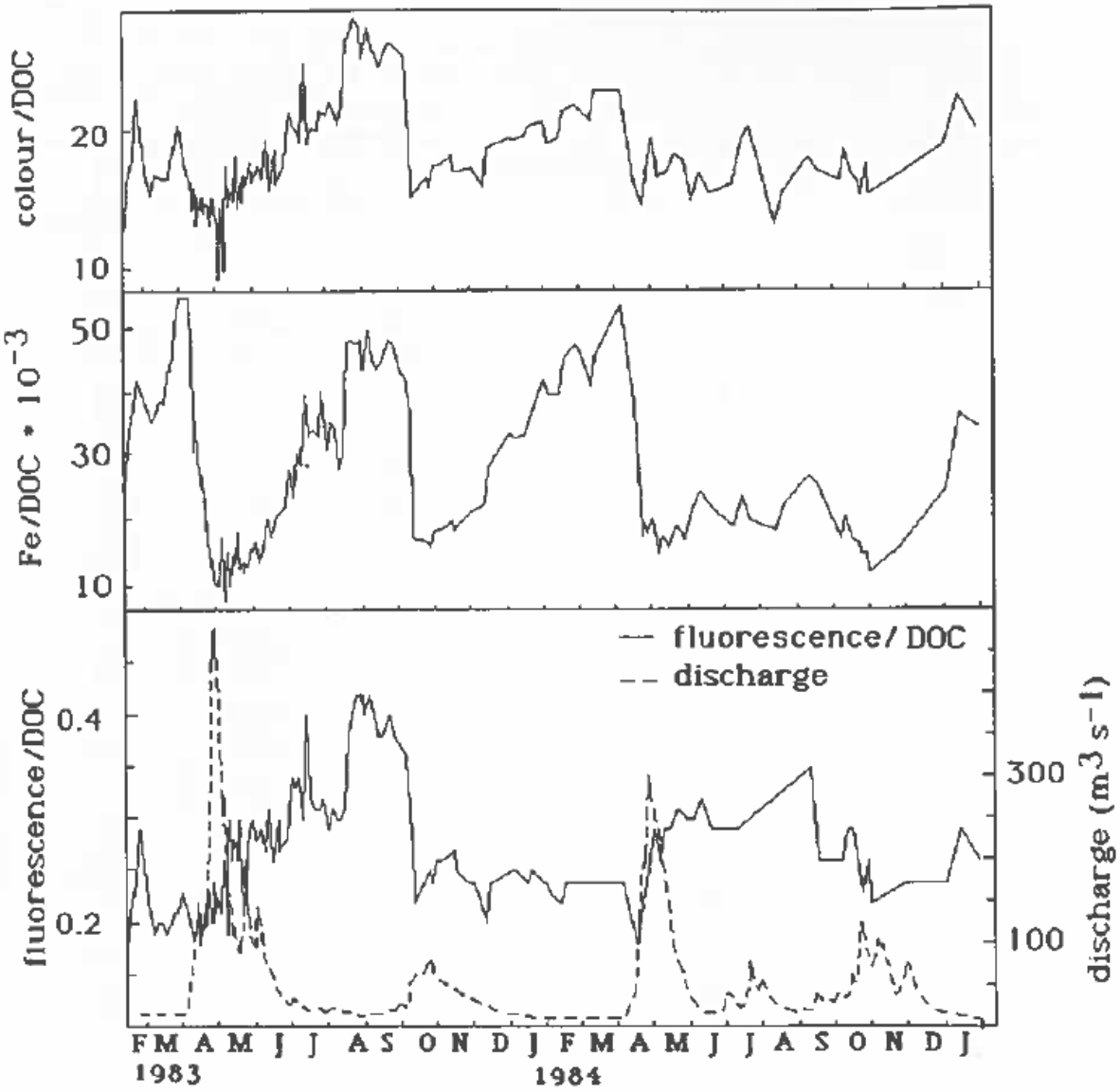

Figure 3. Ratio of fluorescence to DOC, molar ratio of Fe to DOC and ratio of colour to DOC at the mouth of the River Kiiminkijoki

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Reasons for changes
Needs for further research 1/2

In the peatlands of the area

• Fe is probably enriched in the deeper, at least partly anaerobic peat horizons → Fe concentrations increase with decreasing discharge

- **Is it so? How enriched? Role on anaerobic conditions?**
- **How Fe is mobilized from these deeper peat horizons?**
  - **When ochre is formed – when only Fe-content of HS is increased?**
- **How and why peatland drainage changes natural Fe cycling and mobilization processes in peatlands? Is at least part of these processes taking place in precipient freshwater environment after drainage → Environmental deterioration?**

• Leaching of DOC is most intensive from the most intensively decomposing peatland surface layers → DOC concentrations decrease with decreasing discharge

→ Increase in Fe/DOC ratio at low flow conditions
→ Clear and rapid decrease in Fe/DOC ratio at high flow conditions

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Reasons for changes
Needs for further research 2/2

There was increase in the ratio of fluorescence to DOC in summer but not in winter

- This is probably result of precipitation and sedimentation/ trapping of weakly fluorescent iron-organic colloids
- **Is it so? What role has increasing Fe content of DOM in these processes?**
- **What are the temperature-dependent bacterial processes in these processes?**
- **What role these processes have in the boreal humic river ecosystem?**

Effects of other factors on this precipitation?

- **Water acidity**
- **Increasing stream velocity/strong currents in the rapids of the rivers**

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Other needs for further research

Natural transport of Fe in mineral soils and peatlands of the northern boreal drainage basins

- Origin
- Processes
- Amounts
- Factors effecting this transport
  - Climate change
  - Drainage of peatlands
  - Other landuse (forestry)
- Our Fe resources?

Environmental impacts of Fe in waters

- How is the biota of humic waters developed for living in high Fe concentrations?
- Is toxic Fe $^{2+}$ formed in brook/river channels and if is, what is its impact area in running water?
- What are the environmental impacts of increasing Fe content of DOM in rivers and lakes? Can also Fe in the DOM be toxic?

Articles on the subject:

Heikkinen, K. 1990. Seasonal changes in iron transport and nature of dissolved organic matter in a humic river in northern Finland. - Earth Surface Processes and Landforms 15:583-596.

Heikkinen, K. 1990. Nature of dissolved organic matter in the drainage basin of a boreal humic river in northern Finland. - J. Environ. Qual. 19(4):649-657.

Heikkinen, K. & Ihme, R. 1995. Retention of organic Fe-P-colloids from peat mining water in an overland flow wetland treatment system in northern Finland. Arch.Hydrobiol. 134: 547-560.

Heikkinen, K., Ihme, R., Osma, A-M. & Hartikainen, H. 1995. Phosphate removal by peat from peat mining drainage water during overland flow wetland treatment. J. Environ. Qual. 24: 597 - 602.

Laine, A. & Heikkinen, K. 2000. Peat mining increasing fine-grained organic matter on the riffle beds of boreal streams. Arch. Hydrobiol. 148:9-24.

Laine, A., Heikkinen, K. & Sutela, T. 2001. Incubation success of brown trout (Salmo trutta eggs in boreal humic rivers affected by peatland drainage. Arch. Hydrobiol. 150 (2): 289-305.

Postila, H., Heikkinen, K., Saukkoriipi, J., Karjalainen, S.M., Kuoppala, M., Härkönen, J., Visuri, M., Ihme, R. & Klöve, B. 2011, Turvetuotannon valumavesien ympärivuotinen käsittely. TuKos-hankkeen loppuraportti. Suomen ympäristö 30/2011. Suomen ympäristökeskus.

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