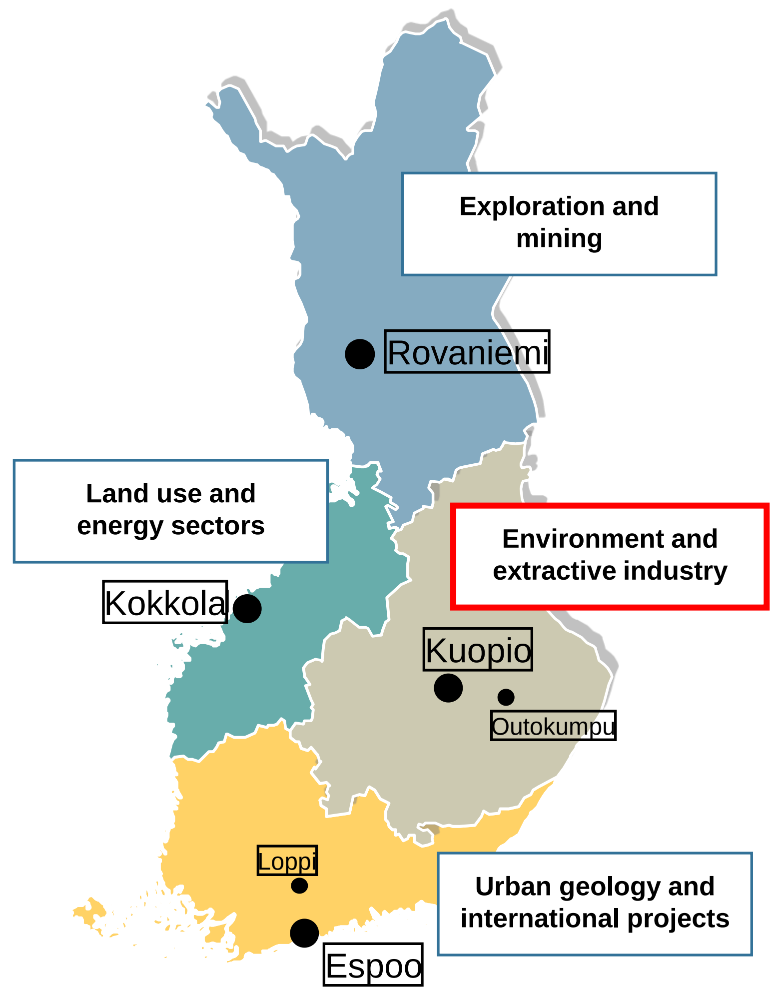
Geochemical analyses and isotopes as a fingerprinting method to distinguish geogenic and anthropogenic emissions at mine environments

– a case study at Finnish gold mine

GTK

Geological Survey of Finland (GTK)

- GTK is an internationally oriented geoscience research agency operating under the Ministry of Employment and the Economy (TEM).
- Established in 1886
- Personnel approx. 620
- Offices: Espoo, Kuopio, Rovaniemi, Kokkola and Outokumpu
- Core competencies
  - Mineral Resources and Raw Materials Supply
  - Energy Supply and Environment
  - Land use and Construction



GTK core competences and social impact

Research Programmes

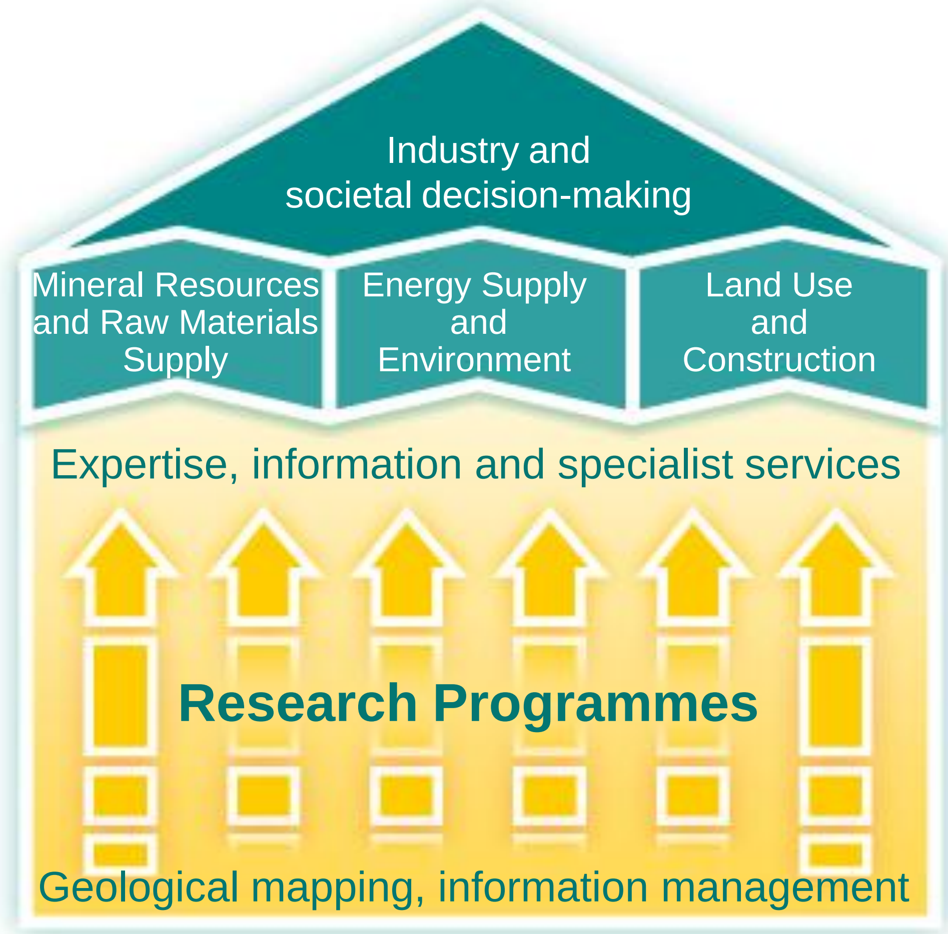
1. Mineral Potential
2. Ecoefficient Mining
3. Energy
4. Marine Geology and Global Change
5. Land Use Planning
6. Groundwater and Aggregates

Development of processes

Services

Information management and modelling

Research methods and geophysics



SUSMIN - Tools for sustainable gold mining in EU

Timetable: 1.1.2014-31.12.2016

Partners: Geological Survey of Finland, Wroclaw University of Technology (Poland), Geological Institute of Romania, University of Babes-Bolyai (Romania), Luleå University of Technology (Sweden), University of Porto (Portugal) and Trinity College Dublin (Ireland)

Stakeholders: Global mining industry and technology companies.

OUTCOMES AND IMPACTS OF THE RESEARCH

- Supports environmentally, socially and economically sustainable gold production in EU
- Project provides technologies and methods for sustainable mineral processing, water treatment and management of environmental and social impacts

  → To manage economical, social and environmental risks of gold mining

  → To achieve sustainability and long term development of the mining areas

MORE INFO

- http://projects.gtk.fi/susmin/

SUSMIN - Tools for sustainable gold mining in EU

APPROACH and WORK PACKAGES

1. Gold exploration

→ New geophysical techniques for gold exploration

2. Mineral processing

→ Eco-efficient ore beneficiation methods and alternatives to cyanide leaching

3. Mine water treatment technologies

→ Novel water treatment solutions by advanced adsorbents

4. Mine waste management

→ Long-term stability of mine wastes and waste facilities and prevention of contaminated drainage

5. Environmental monitoring, modelling and risk assessment

→ Solutions for monitoring, predicting and preventing environmental effects of mining

6. Sosio-economics of gold mining

→ Tools for enhancing the corporate social responsibility, community engagement and management of the stakeholder relations

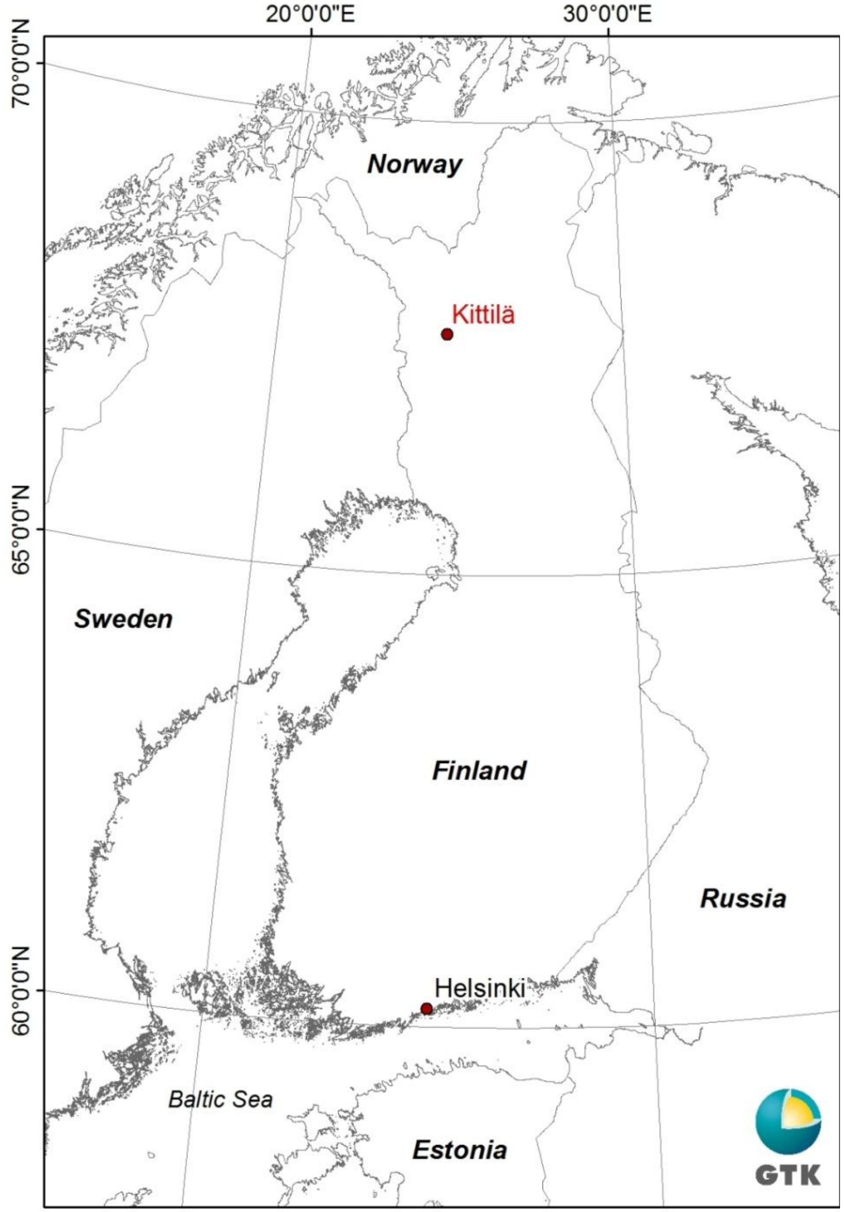
A case study at Finnish gold mine – aims of the study

- To test and evaluate geochemical analysis and isotopes as fingerprinting method and natural tracer of contaminant migration from the mine site
- To identify the anthropogenic contaminant emissions from the geogenic background
- To evaluate the removal efficiency of treatment peatlands
- To model the behaviour of contaminant emissions
  - the environmental effect of natural concentrations when exposed to mining waters
  - the solubility of contaminant compounds and contaminant bearing minerals when exposed to changing water quality
  - the dilution of the contaminant concentrations in downstream surface waters

- The research is linked to earlier studies on arsenic at the site
  - "Solutions to control and remove arsenic in beneficiation processes and operations"

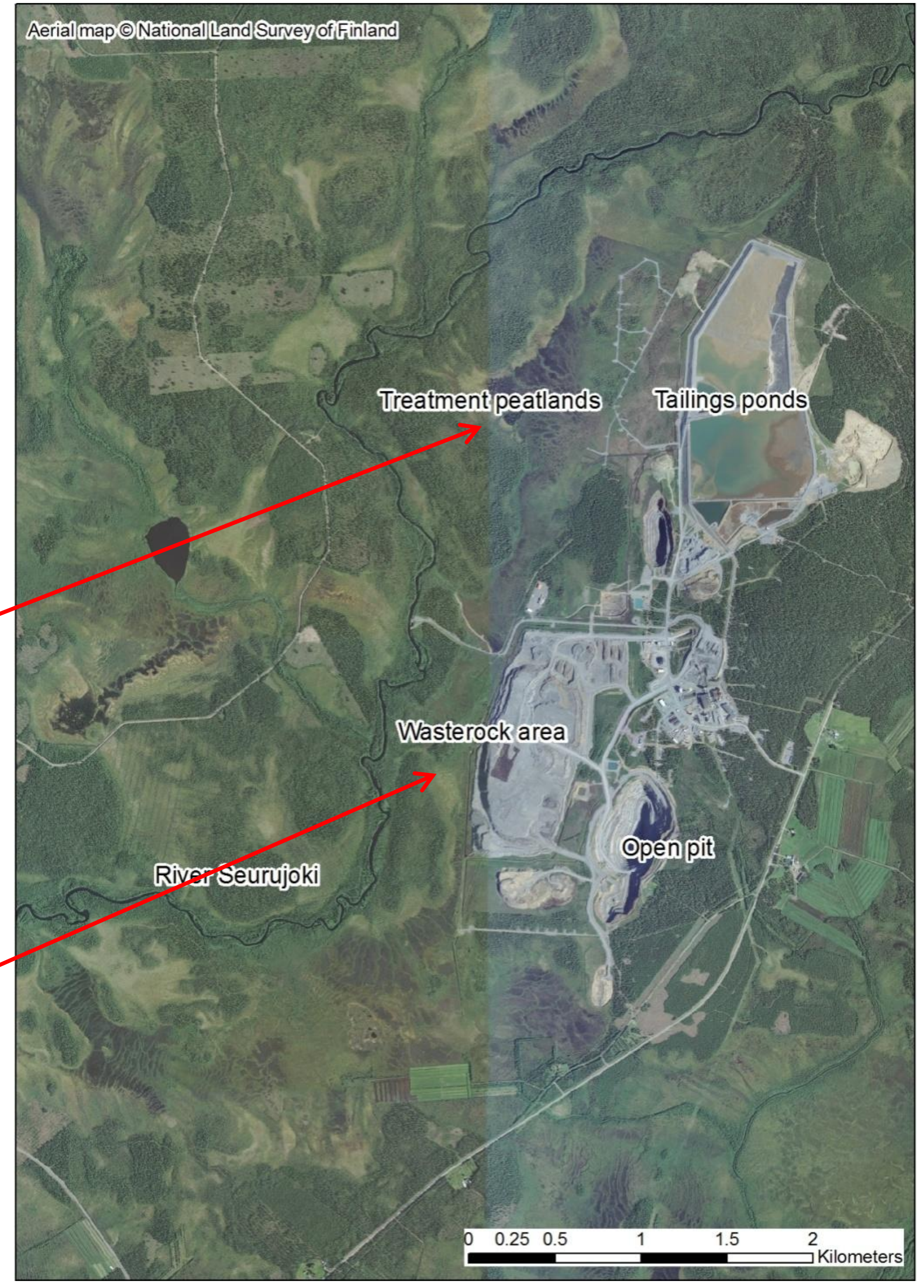
Suurikuusikko gold mine, Kittilä

- Main product: gold
  - Operation since 2009, estimated mine life through 2034
  - One of the largest known gold deposits in Europe
    - Reserves of 4.7 million ounces
  - The largest gold mine in Europe
  - Nowadays underground-only operation
  - Extraction by cyanide leaching
- Part of the Central Lapland greenstone belt
  - e.g. mafic tuffs and lavas, Fe-rich tholeiites
  - Bedrock close to surface, soil thickness 2 to 6 m (peat and glacial till)
  - Naturally rich in arsenic and antimony



Water treatment at the site

- Attenuation by naturally formed peatlands
  - mine dewatering waters and process effluent waters are directed to treatment peatlands before discharging to nearby river Seurujoki
    - to delay the flow
    - to improve the water quality by biochemical treatment (sorption and precipitation)
- Wetland 4 receive pretreated process effluent waters
  - Chemical precipitation prior to directing to the tailings ponds
  - Overflow waters from the tailings ponds are directed to the wetlands
- Wetlands 1 and 3 receive pretreated dewatering waters
  - Chemical precipitation and settling



Execution

- Sampling (since 2012)
  - Groundwater, tailings seepage water, mine dewatering water, process water, surface waters
- Geochemical analysis
  - pH, Eh, EC, DO, T, alkalinity
  - Total and soluble metals and metalloids
  - Anions, DOC and TOC
- Field measurements of physico-chemical characteristics in pursuance of sampling
- Continuous water quality monitoring of surface waters
  - YSI EXO 2 monitoring equipment
  - e.g T, DO, pH, Redox, EC, NO3, turbidity, water level

Execution

- Assessing the environmental risk caused by mining activities
  - Stable and radiogenic isotope composition of waters as fingerprinting method and natural tracer
    - O, H, S, Li, Mg, U, Sr
    - Emission sources, flow paths, interaction between mine waters, soil and bedrock, groundwater and surface waters
    - Reactions, mixing and dilution of potentially harmful substances in ground and surface waters
- Hydrochemical modelling (PHREEQC)
  - Prediction of chemical transformation and long-term impacts of mining
  - Metal speciation and precipitation/dissolution behavior

Results, Purification efficiency in treatment peatlands

- Based on loads calculated from inflow and outflow water concentrations and flow rates

Contaminant	Treatment peatland 4	Treatment peatland 1
	Purification efficiency (%)	Purification efficiency (%)
As	85-95	71-93
Sb	74-88	28
Ni	87-93	74-78
Total N	63	22
P	61	39
Fe	39-41	-73
Mn	5.2	63

→ Purification efficiencies of As, Sb and Ni are high in treatment peatland 4, As and Ni also in tp1

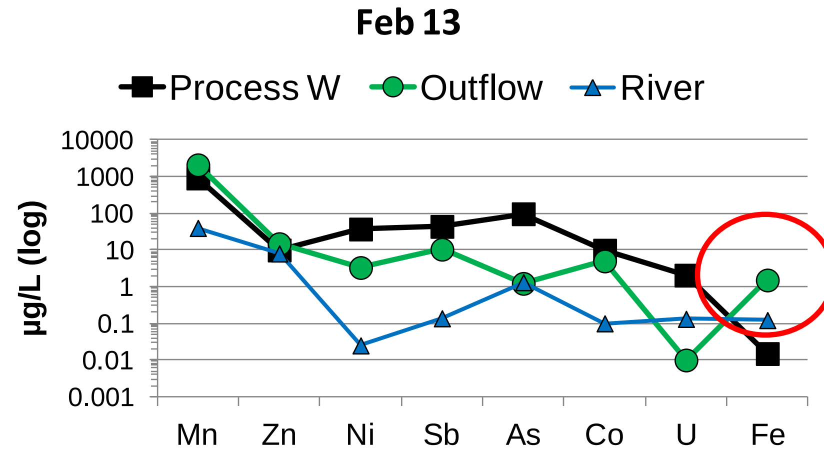
→ Purification efficiencies of Sb, N, P, Fe and Mn poor in tp 1

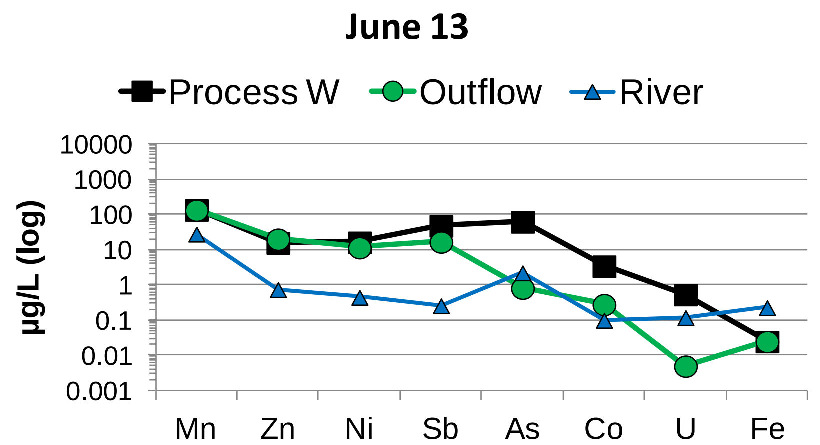
Results, Seasonal changes in removal efficiency of treatment peatlands

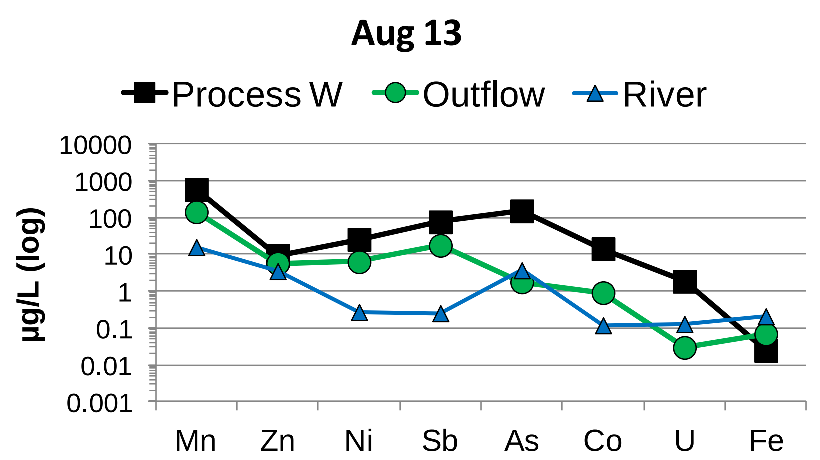
- Metals and metalloids, such as Ni, Sb, As, Co and U were removed throughout the year
  → Sorption to metal(oxy)hydroxides

- Removal of Mn, Co and Zn were more efficient in summer than winter

- Mn, Fe and Zn seem to be leaching from the peatland during winter
  → decreased rate of microbial processes and formation of metal(oxy)hydroxides





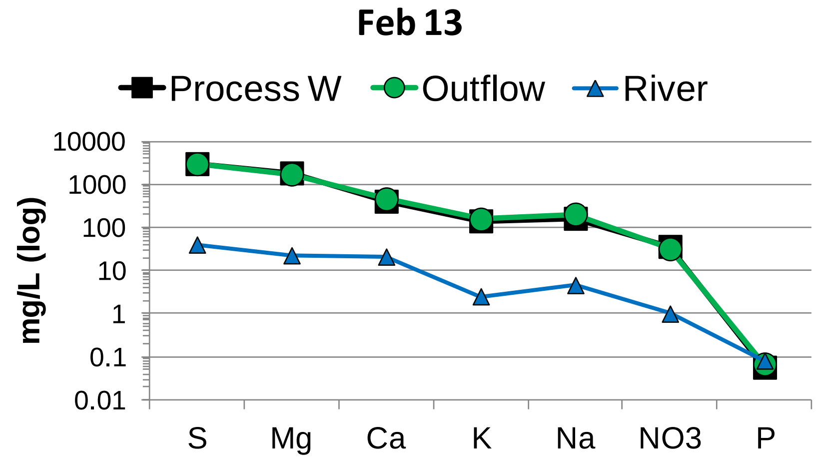


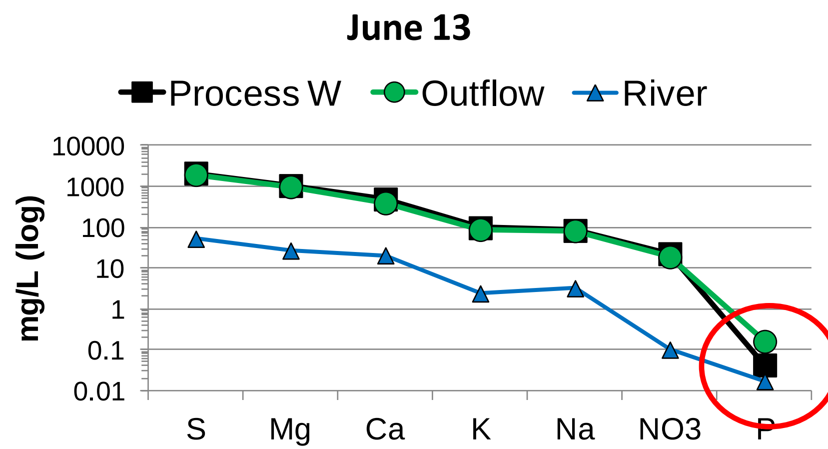
Results, Seasonal changes in removal efficiency of treatment peatlands

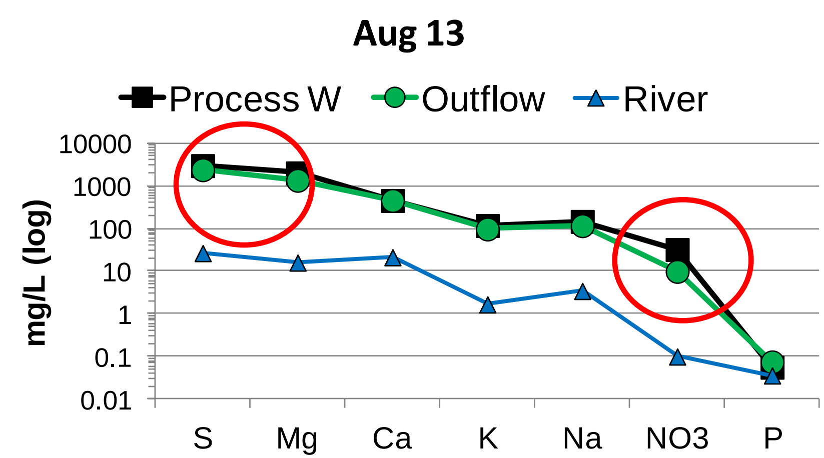
- During winter and summer, sulfur, alkali and earth alkali metals were not removed from the process effluent waters

- At late summer, some removal of sulphur, Mg, NO_3 and P were detected
  → plant uptake and microbial processes

- Also nutrient concentrations in River Seurujoki close to treatment peatland discharge point were lower in summer than winter

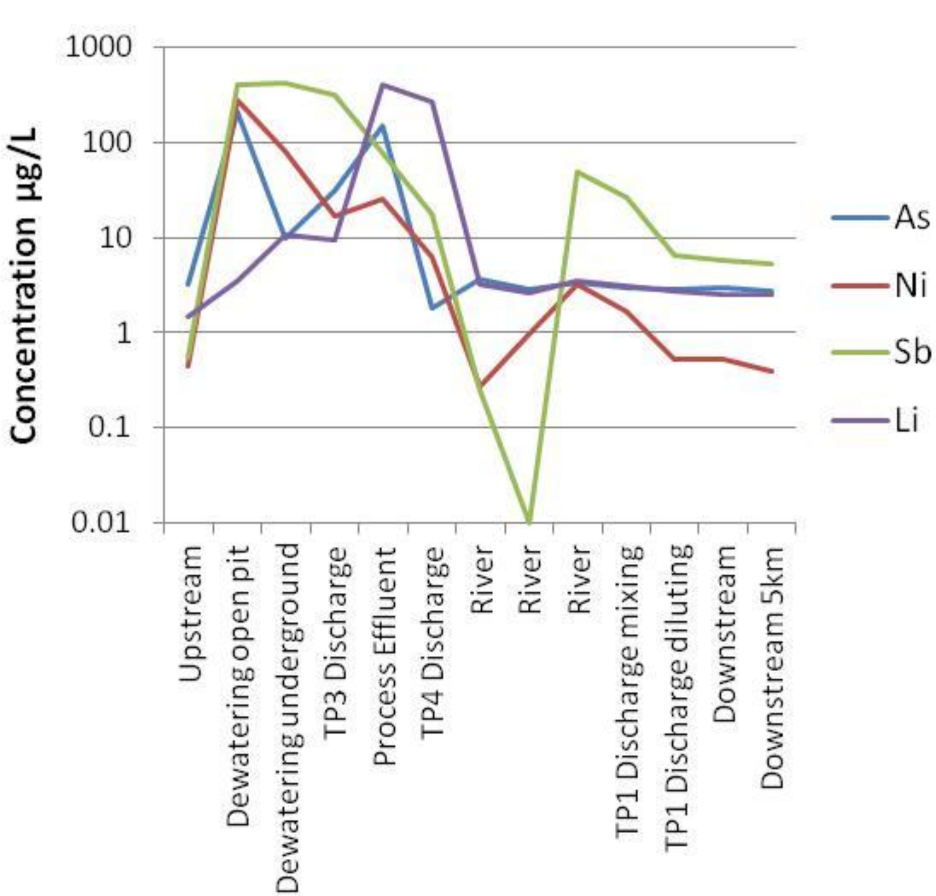


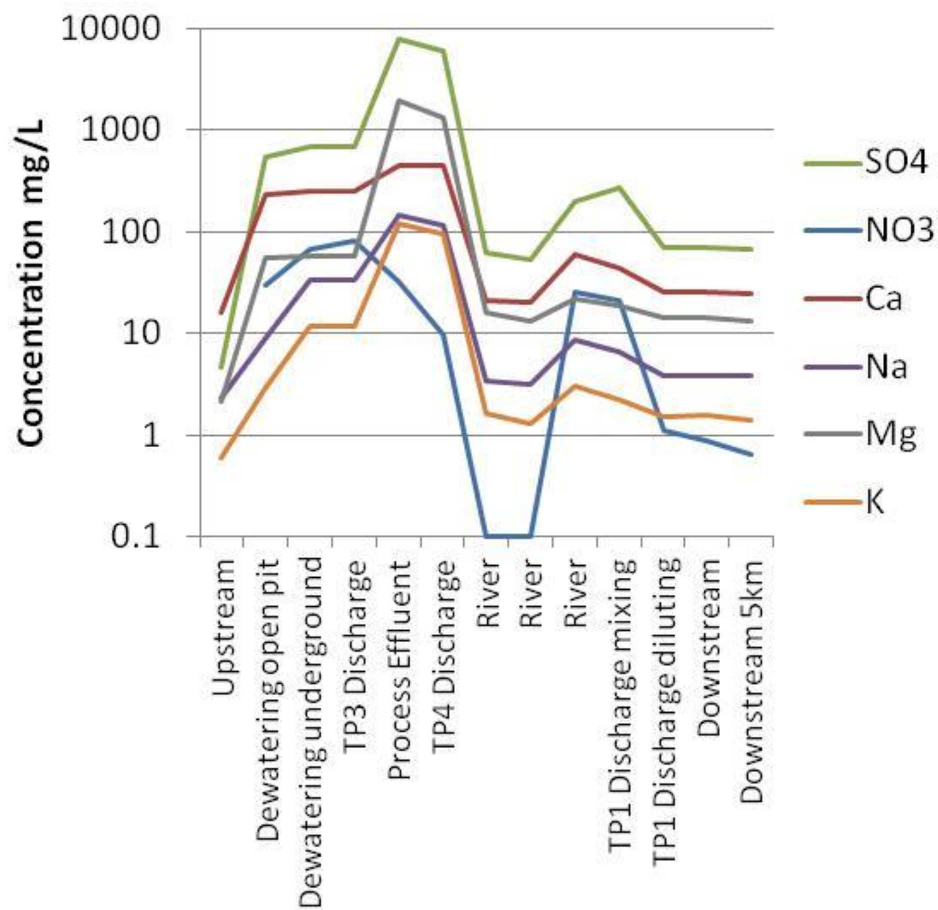




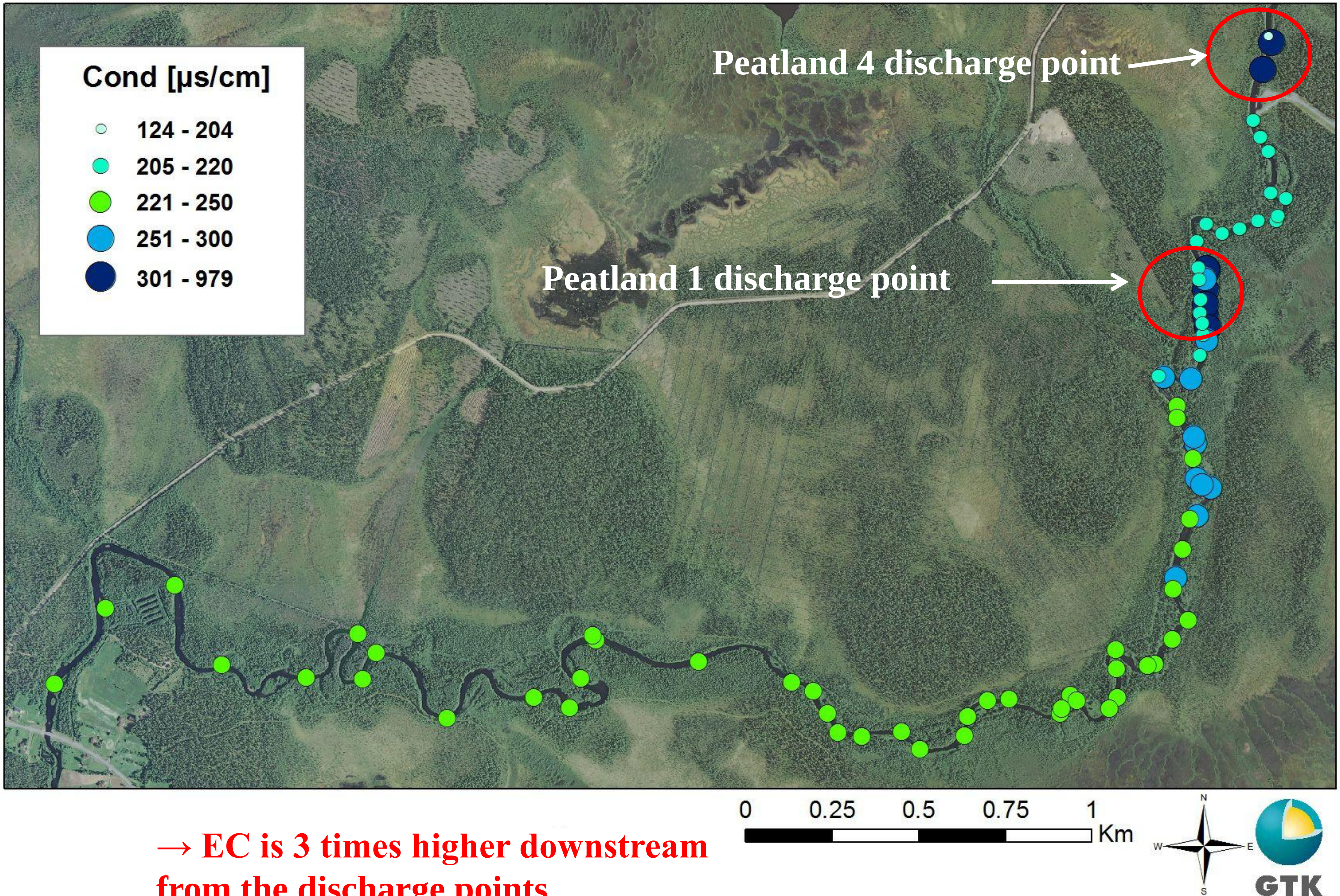
Results, concentrations in River Seurujoki

- Peat adsorbs arsenic, but especially sulfate, earth alkali and alkali metals are released to River Seurujoki
- Sb, SO_4, Mg concentrations increase downstream





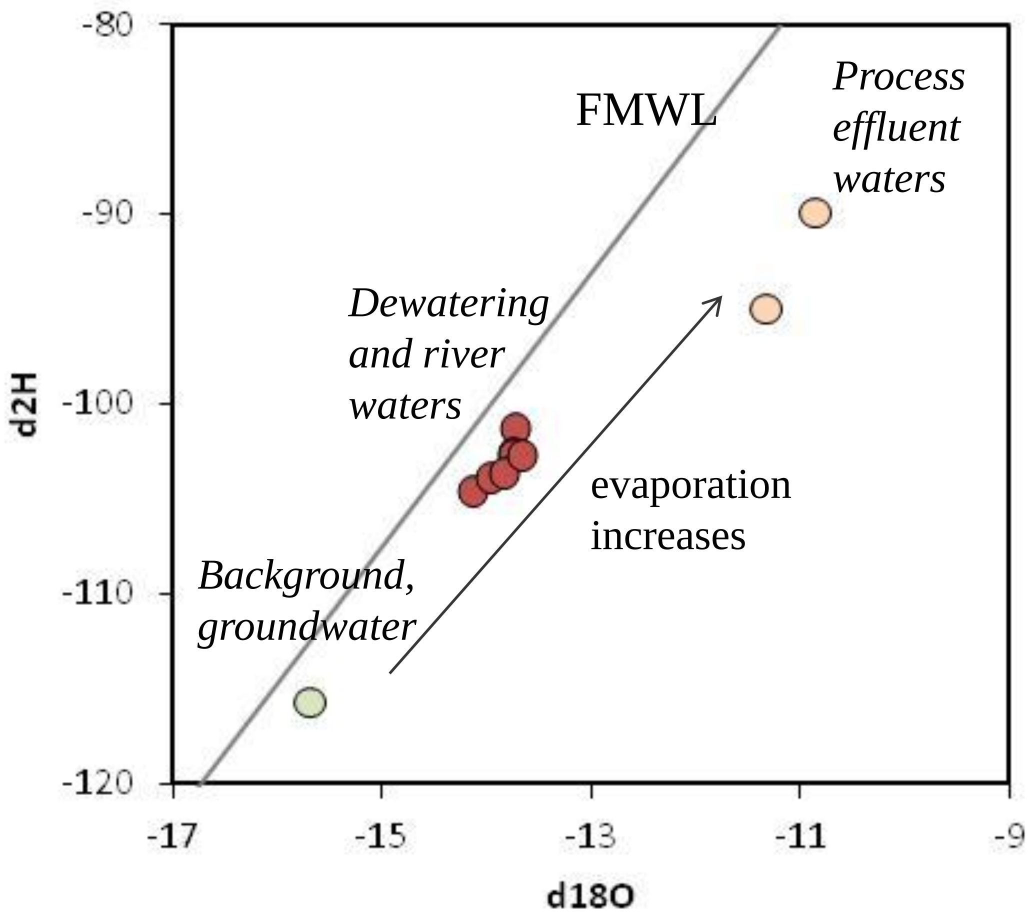
Results. Electrical conductivity & effects to downstream waters



→ EC is 3 times higher downstream from the discharge points
→ Salinization of River Seurujoki?

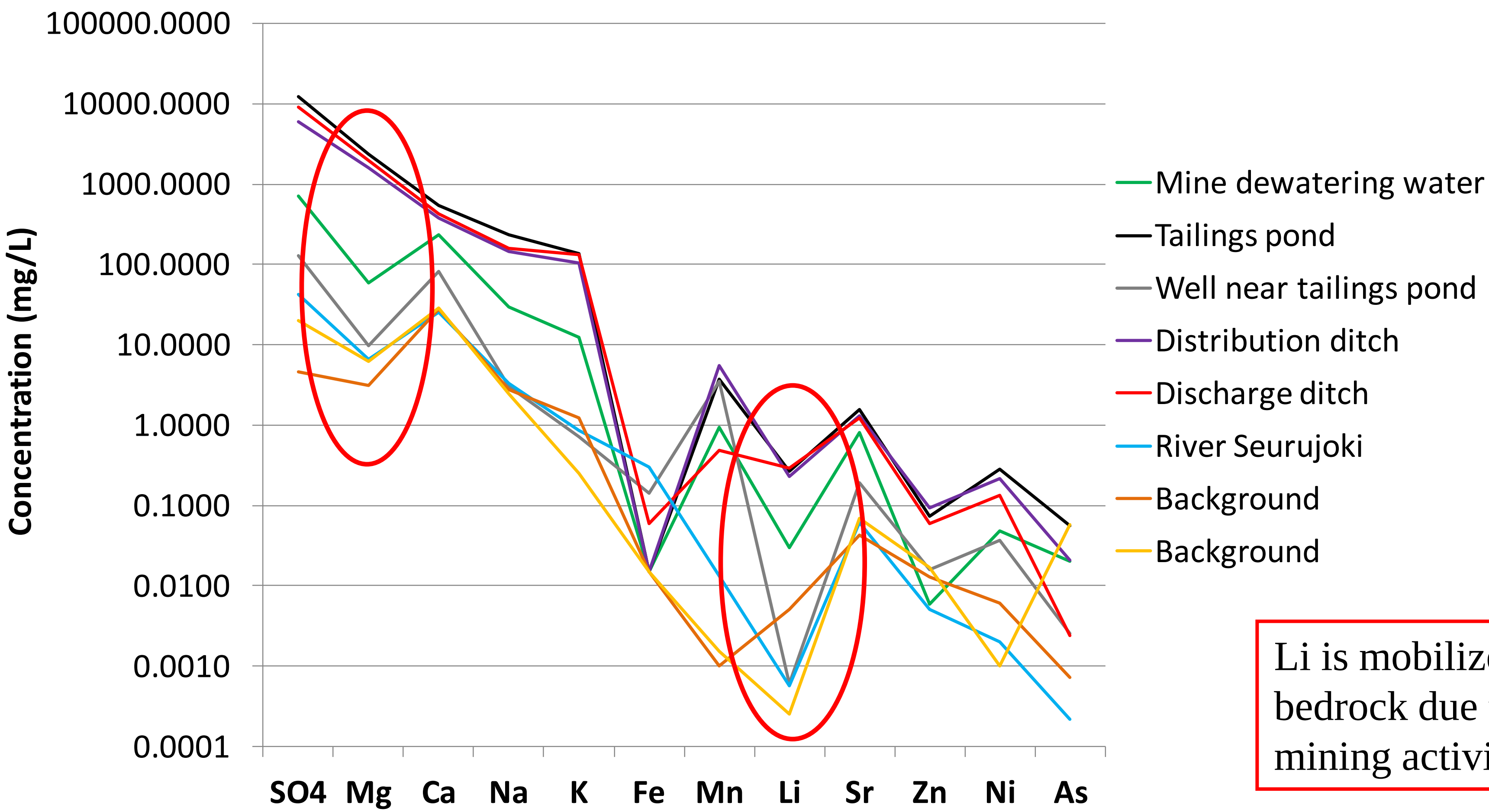
Stable isotopic composition of waters

- Clear difference between process effluent waters and natural waters
  - Can be used as natural tracer to distinguish process waters from natural waters
- No difference between surface waters and dewatering waters
- The migration of mine waters to groundwaters?
  - Groundwater wells to be installed in July 2014, sampling in August



Preliminary results, choosing isotopes for fingerprinting method

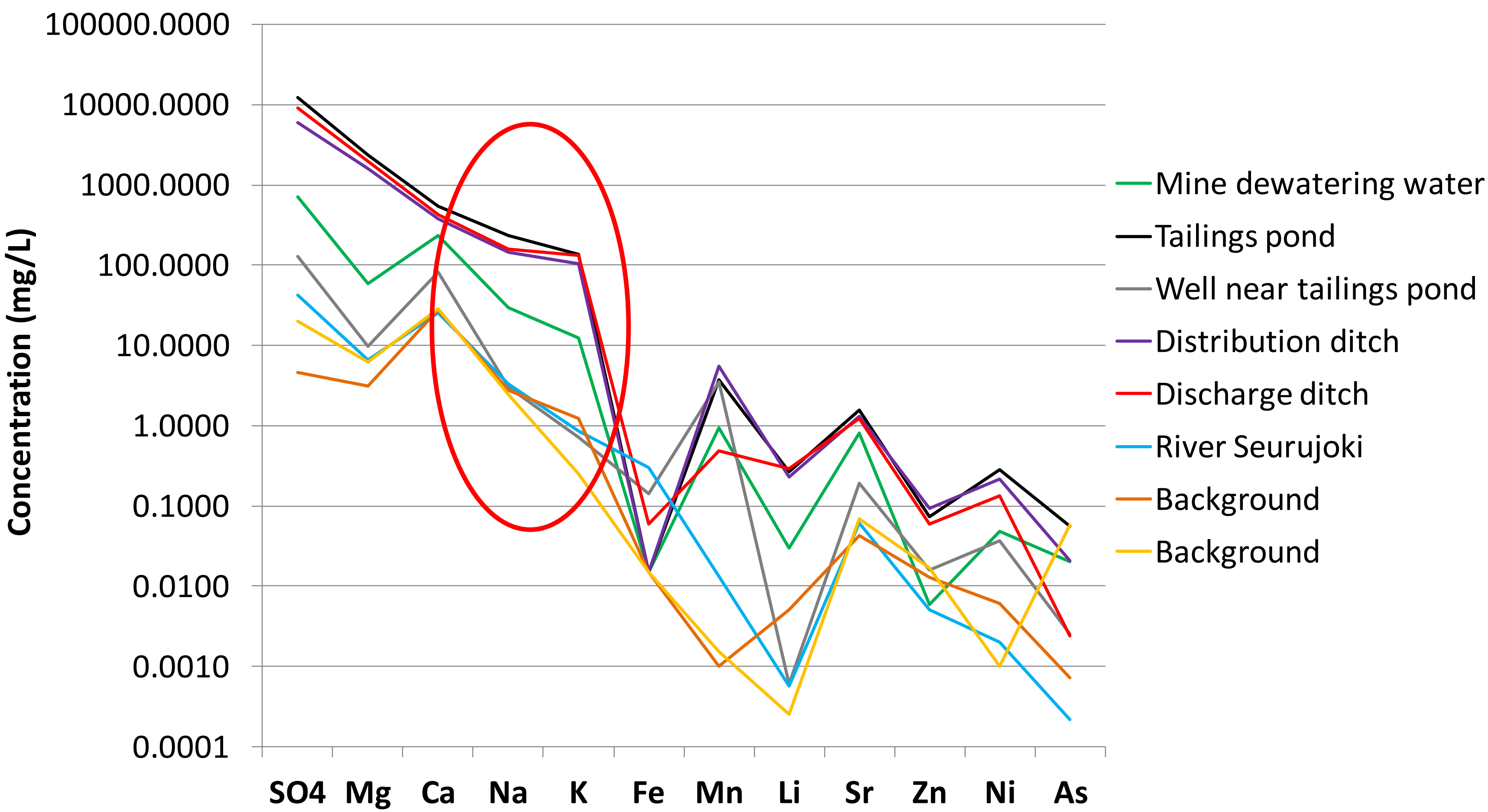
- Li and Mg concentrations vary significally between natural waters and mine waters
  → could be used as fingerprinting method to distuingish mine waters from natural waters



Li is mobilized from the bedrock due to the mining activities

Preliminary results, process chemical residues in waters

- K and Na in waters indicate process chemical residues (xanthates) in waters
  → could be used to distinguish the process water impact on natural waters



Conclusions

- Process effluent and mine dewatering waters have high concentration of alkali and earth alkali metals (e.g. Ca, Na, K, Li, Mg)
  - Clear difference seen also in O and H isotopic fractionation between process effluent waters and natural waters
  - No significant difference in O and H isotopic fractionation between dewatering waters and natural waters
    - Suitable natural tracer for process waters, but not for dewatering waters
  - Potential isotopes for investigating mine water related impact
    - Li, Mg indicating the impact of process waters
    - U, Sr indicating the impact of dewatering waters
  - Chemical residues from process effluents: K and N

Conclusions

- Treatment peatlands are efficient to remove metals and metalloids such as Ni, Sb, As, U throughout the year
  - Sulphur, earth alkali and alkali metals are not removed
    → increased EC and salt concentrations downstream

- Ecological risks are increased
  - Mine waters discharged to wetland are ecotoxic, toxicity is linked to the amount of suspended solids
  - Chemical equilibrium and the contaminant sorption behaviour in wetland should be studied to prevent leaching in long-term

Thank you!

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