

TMF safety and management following the TMF accident at the Talvivaara Mine (2012) – Lessons learned and Good Practices

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Inception Workshop of the Project to strengthen the safety of mining operations, in particular tailings management facilities (TMFs) in Kazakhstan and beyond in Central Asia

Programme for Sustainable Growth and Jobs

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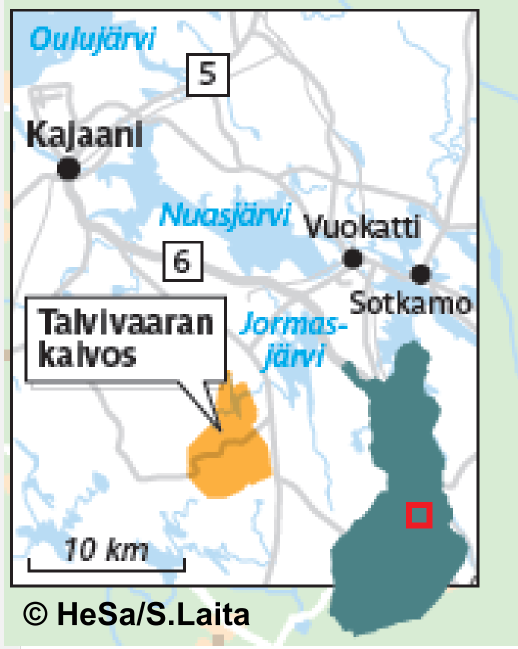
Content

- Background of Talvivaara mining activities and waste/mine water loading/problems
- Worst environmental accident in Finland? - Gypsum pond leakage 2012
- What we have learned and way forward

History of mining and environmental problems

- Largest black schist metal sulphide ore deposit in Europe
  - Found 1977, metal content too low for traditional technics
- Talvivaara ltd. Started mining 2008 with bioleaching method
  - Ore crushed, agglomerated, stacked to heaps, treated by sulphuric acid and metal leaching is based on microbial activities (bioleaching)
- Early time environmental problems related to releases of
  - **Sulphate** originated from sulphide ore & sulphuric acid used in bioleaching process
  - **Manganese** (Mn) did not precipitate in the after treatment
  - Excess **sodium** (Na) from lye (NaOH), used to prevent hydrogen sulphide (H_2S) odour problems

Talvivaara mine: location and scale



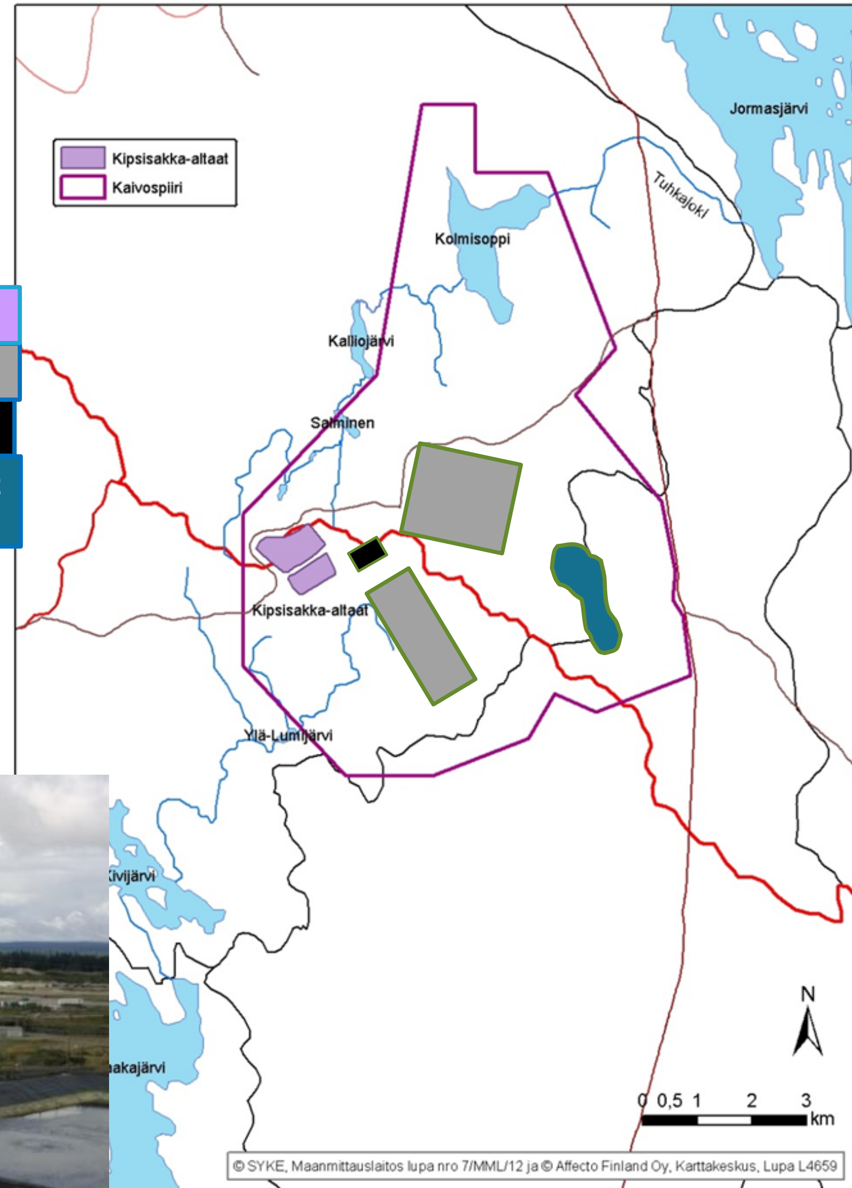
- Total area of 60 km^2

Gypsum ponds

Bioleaching fields

Factory area

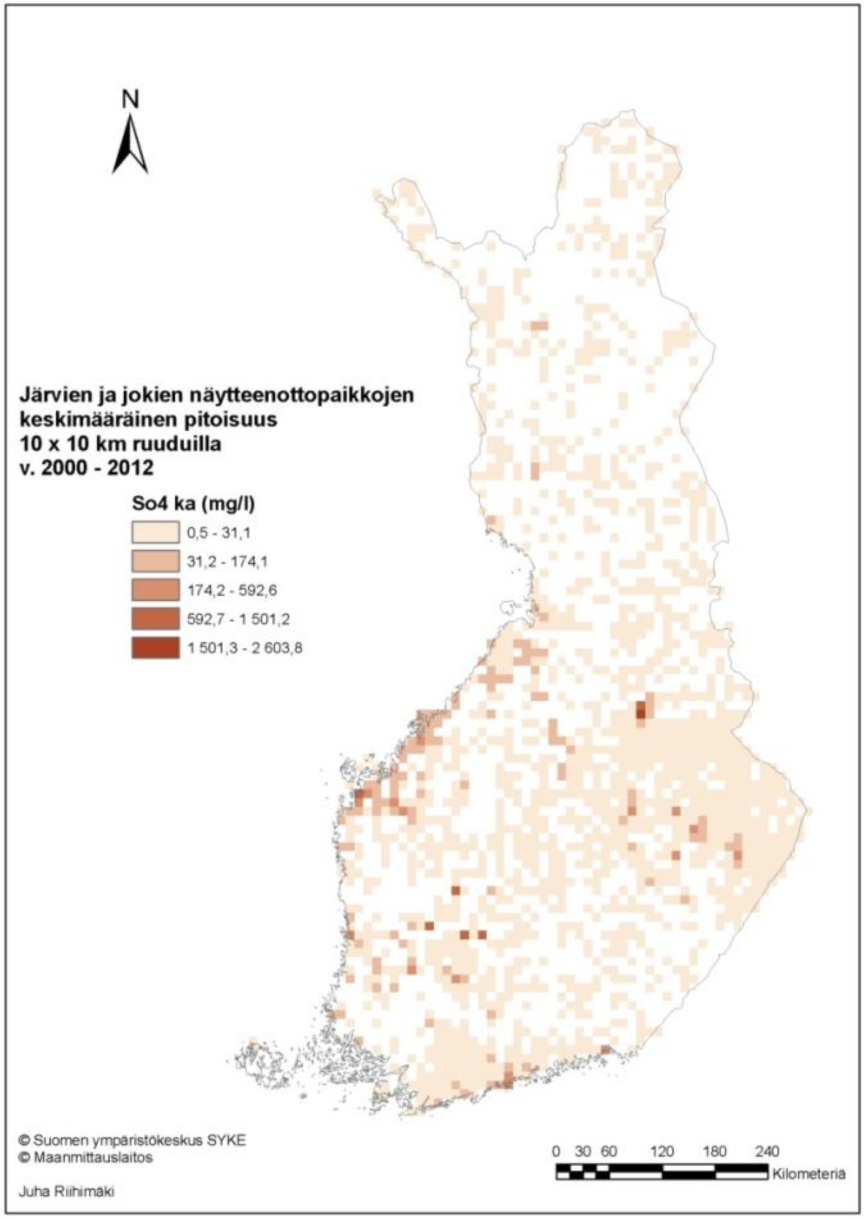
Open pit mine



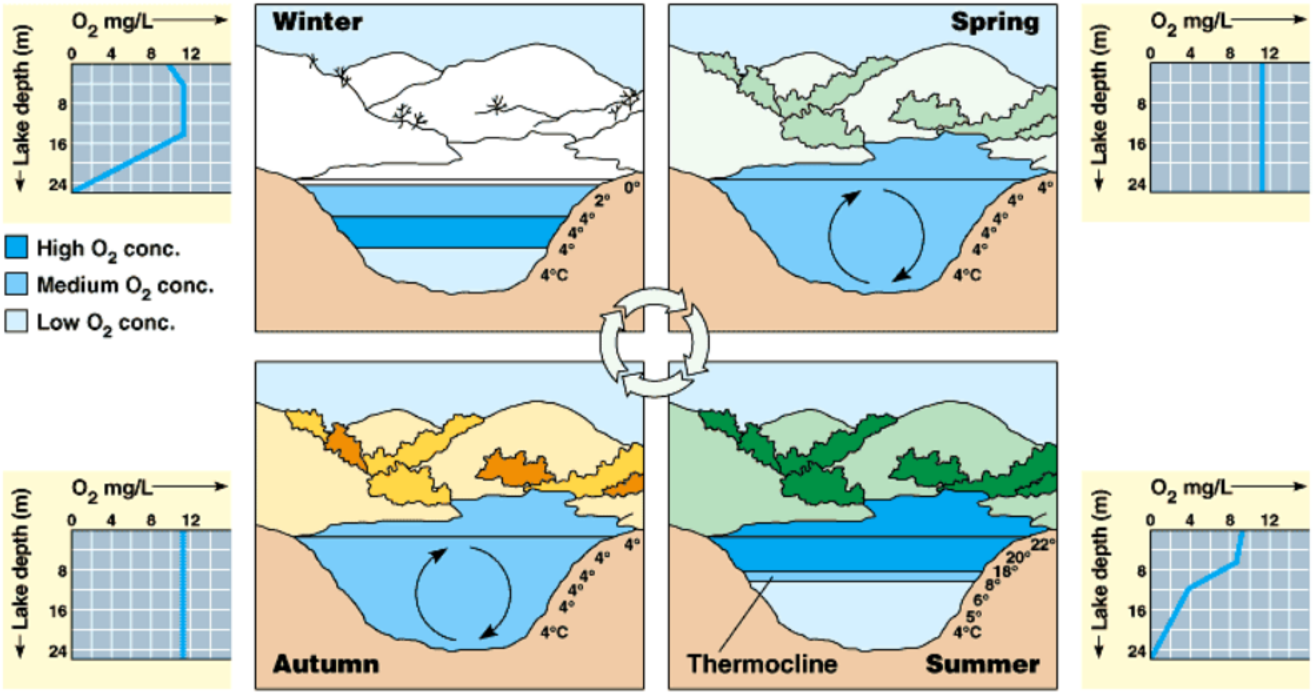
Typical for Talvivaara mining waters

Sulphate, SO_4

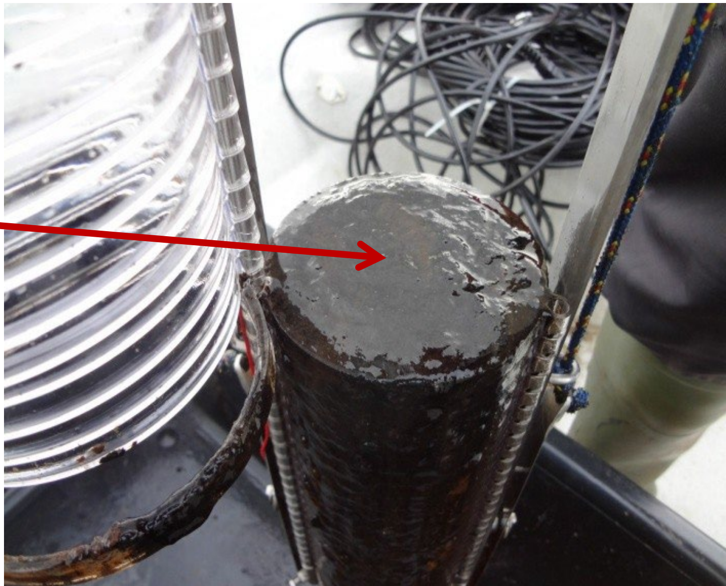
- Normal concentrations:
  - Marine 3000 mg/l
  - Sulphate soils 2000 mg/l
  - Median conc. In Finnish lakes 3.8 mg/l
- Harmful concentration for freshwater species from 500 mg/l
- Household water limit 250 mg/l



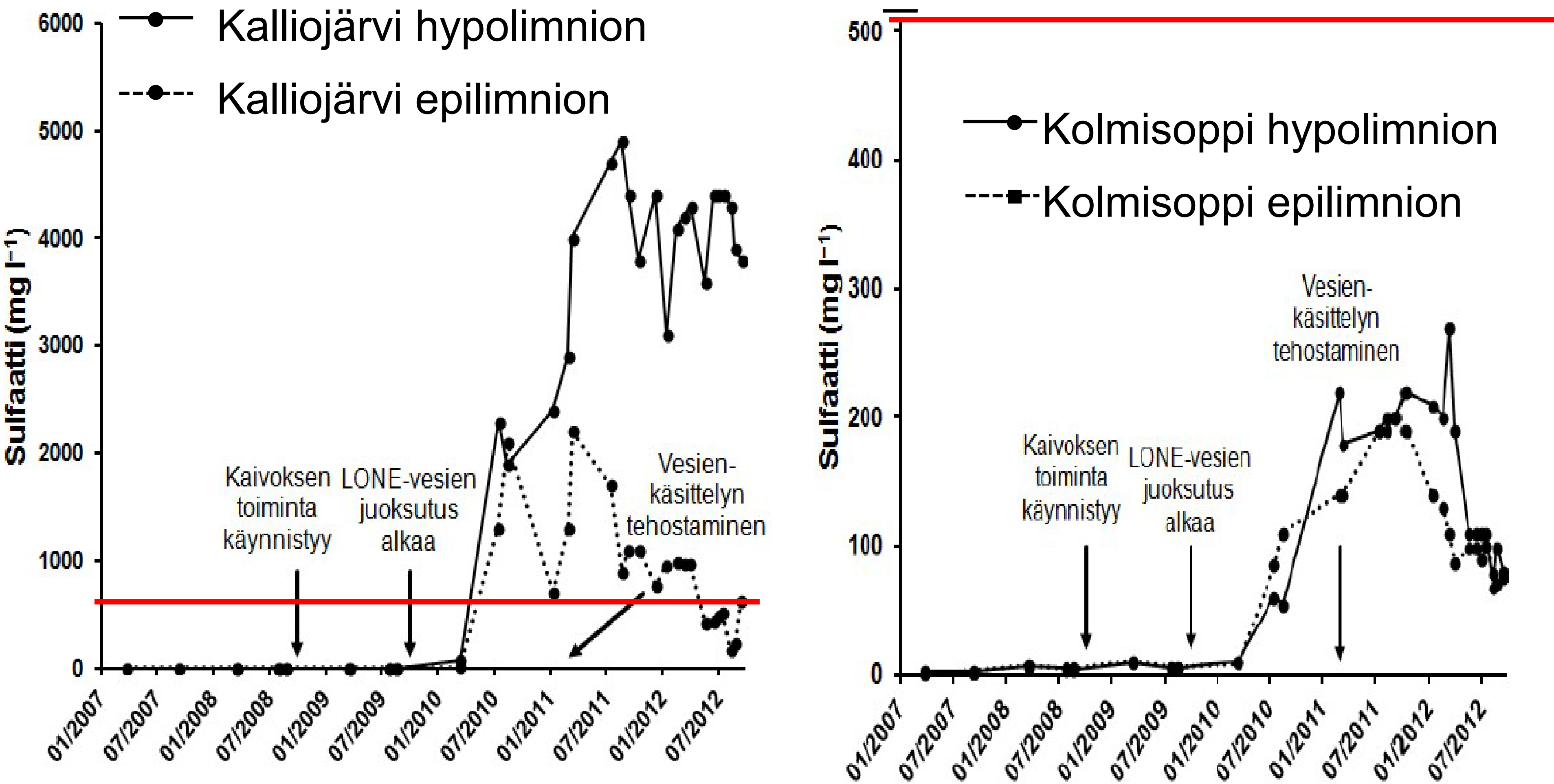
Changes in circulation of lakes!



- **Dense, salty water => permanently stratified lakes**
  - consuming the oxygen near bottom
  - changes in bottom fauna
- Ecosystem changes
- Salinization changes species distribution
  - some sites have1/3 brackish water algae species (diatoms)



Sulphate and lakes (L.Kalliojärvi 30 ha, L. Kolmisoppi 200 ha)



Ratava P. 2013. JY.

______ = harmful for freshwater biota

Gypsum pond leakage accident in Nov 2012

Background

- High precipitation during summer 2012
  - Low evaporation and poor processes in ore tailings
  - Excess of process waters at area.
  - Process waters pumped to gypsum storage NOT valid for low acidity waters
- Breakage of HDPE-film and release of minewaters (pH 3, high amount of sulphate and heavy metals)

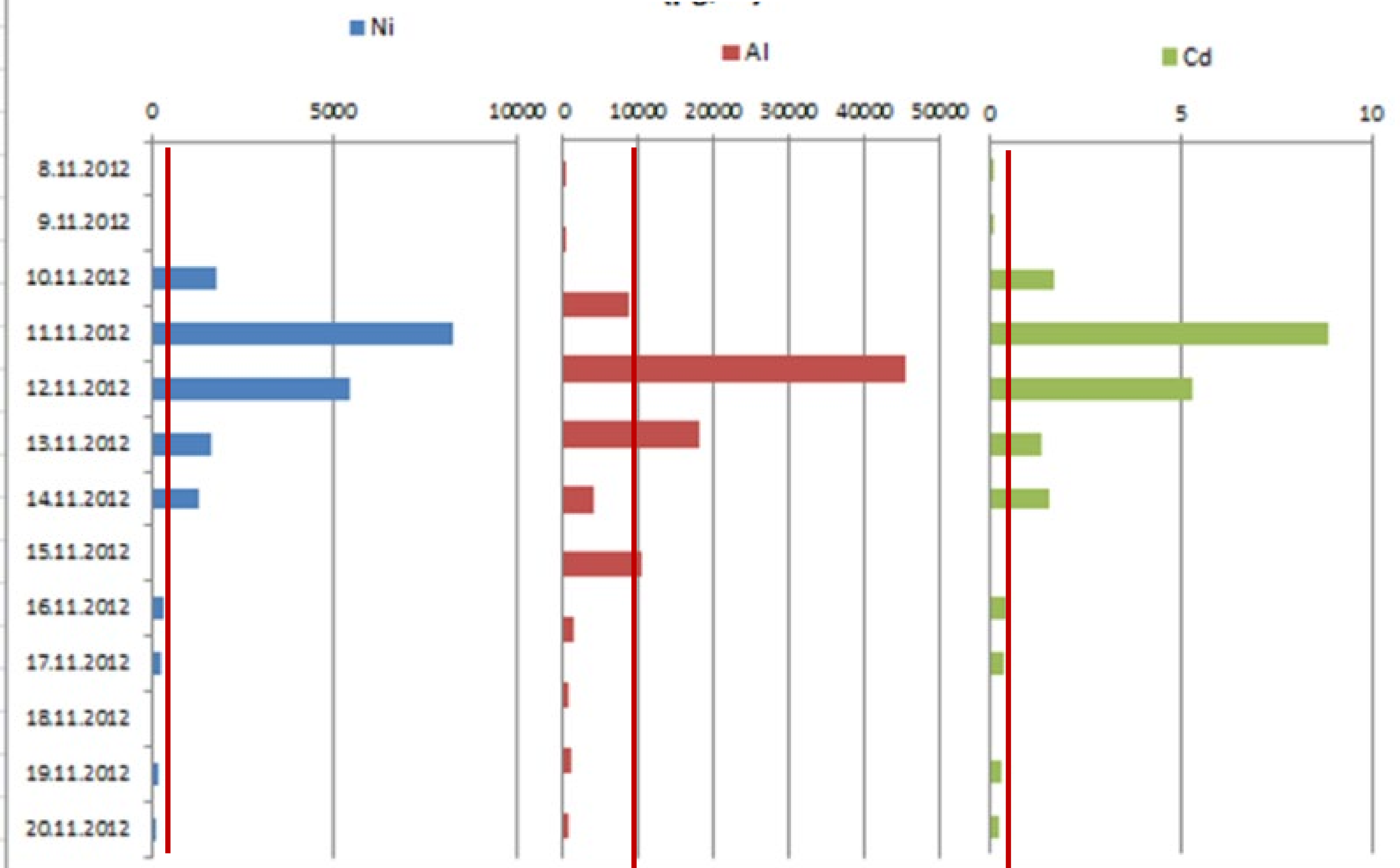
Gypsum pond leakage accident in Nov 2012

- Mine waters 1,2 milj. m^3
- Nickel 2000 kg
- Zinc 1000 kg
- Uranium 70 kg
- Cadmium 2 kg

Pulse to the South - Lumijoki 8.-20.11.2012

"Estimated effect levels" (red lines):

Ni ca. 50 µg/l **Al ca.1000 µg/l** **Cd ca. 0,5 µg/l**



Assessment of the effects (Feb 2013) of the Talvivaara emission 11/2012 in surface waters

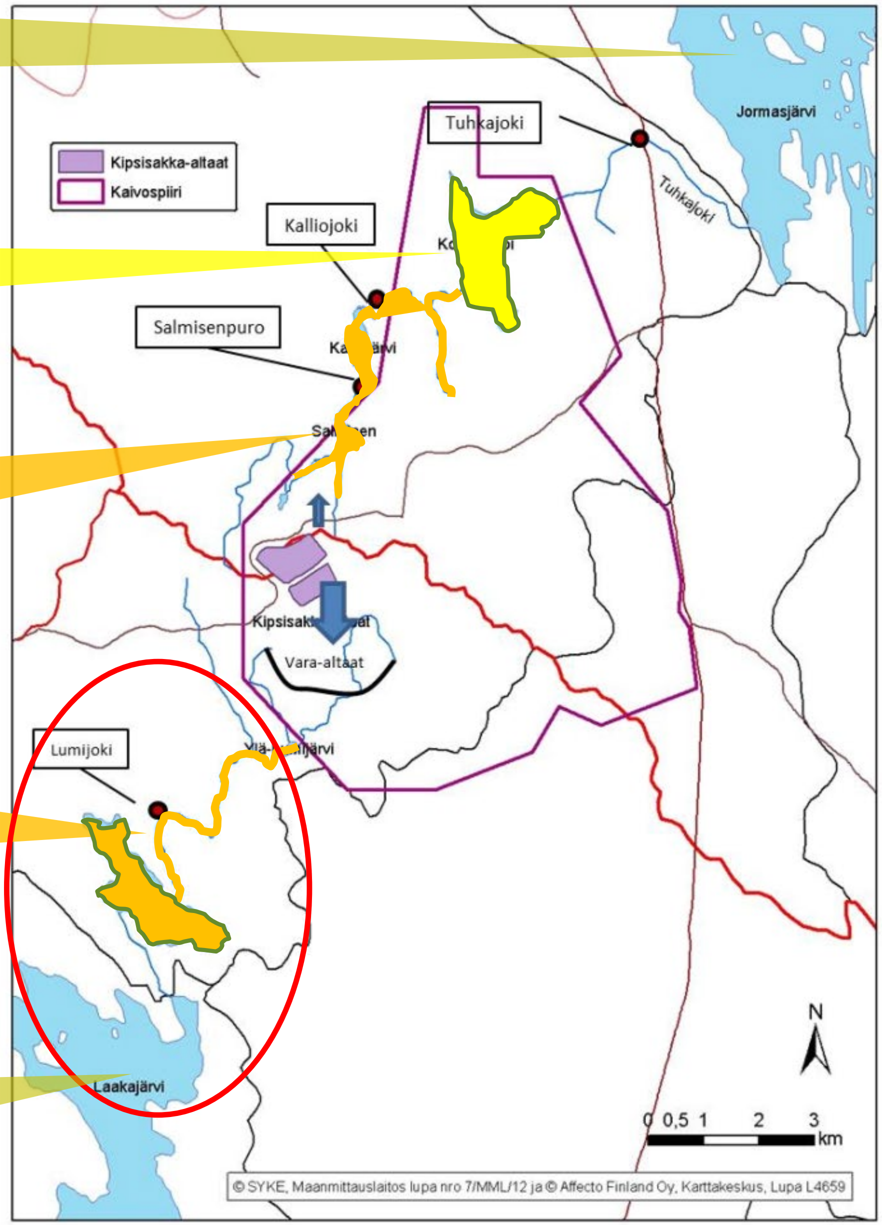
L. Jormasjärvi (2200 ha) Slightly contaminated from earlier emissions, not yet from this spill

L. Kolmisoppi (200 ha) Contaminated, effects to be expected

L Salminen (10,5 ha) L. Kalliojärvi (30 ha) Heavily contaminated area, severe effects

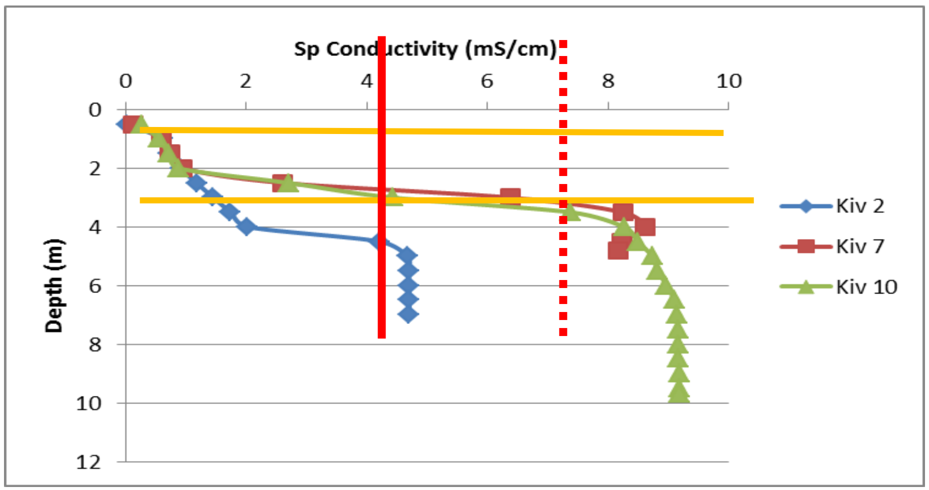
L. Kivijärvi (125 ha): the ”gatekeeper” towards South

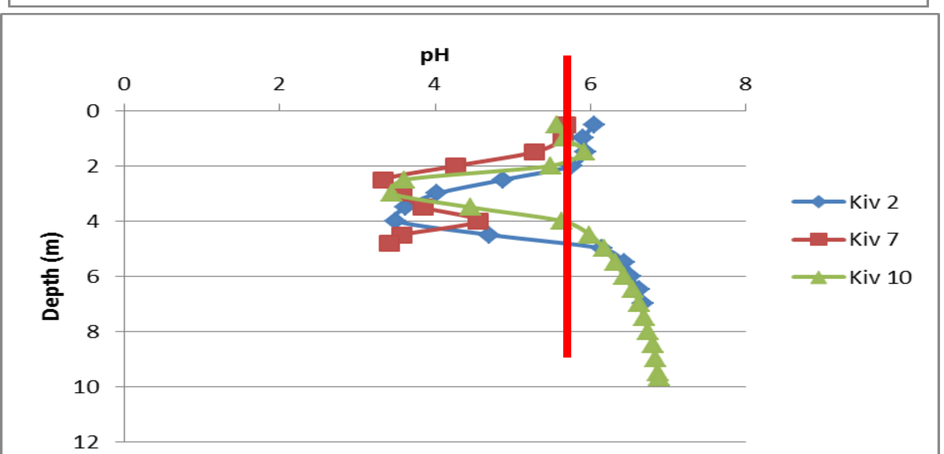
L. Laakajärvi (3400 ha) Slightly contaminated from earlier emissions, not yet from this spill

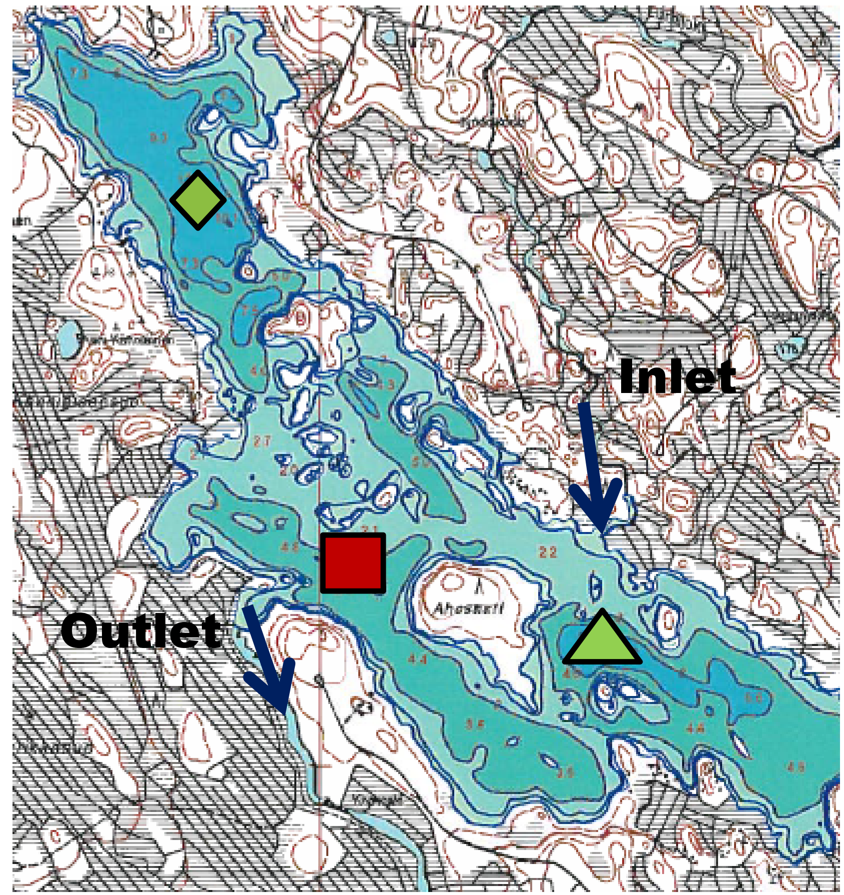


Environmental status of Lake Kivijärvi (Febr. 2013)

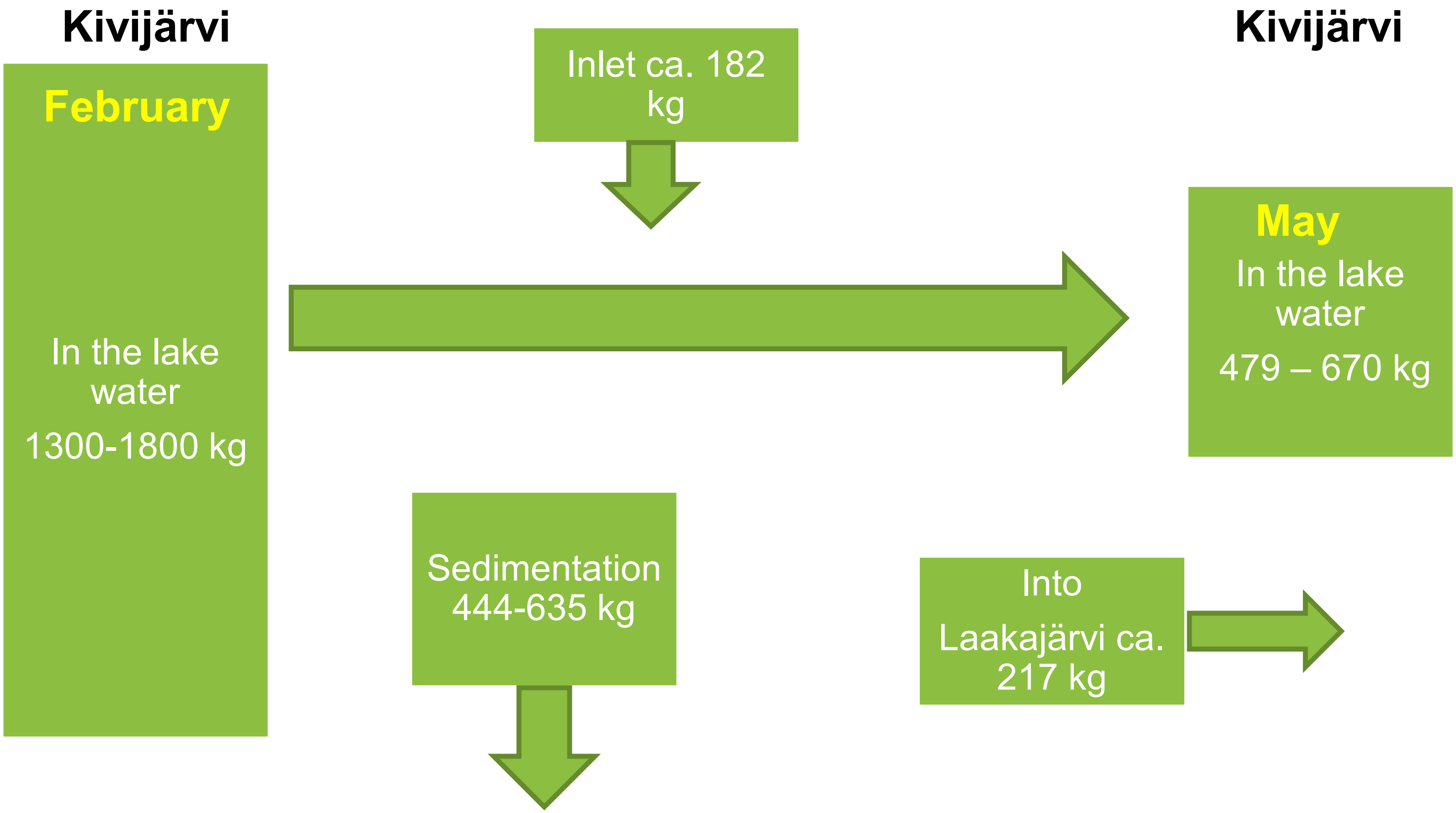
- In normal spring conditions, melting waters have crossed the lake (the deep has earlier strongly salinized)
- Cocktail of metals and acidity in 2-4 m depth
- Largest amount near the outlet Kiv7 (NOT in deepest Kiv 10)
- Metals may be pushed further because the extra release from mine is salty, 4-7 mS/cm





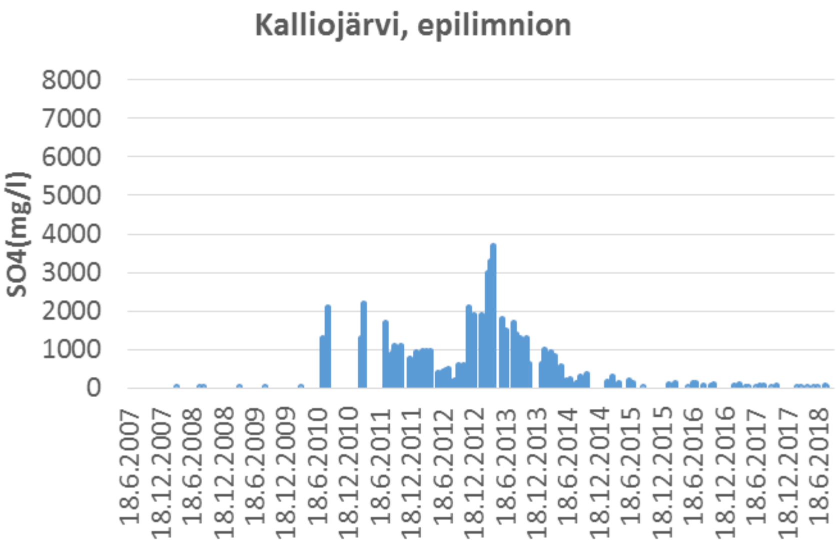


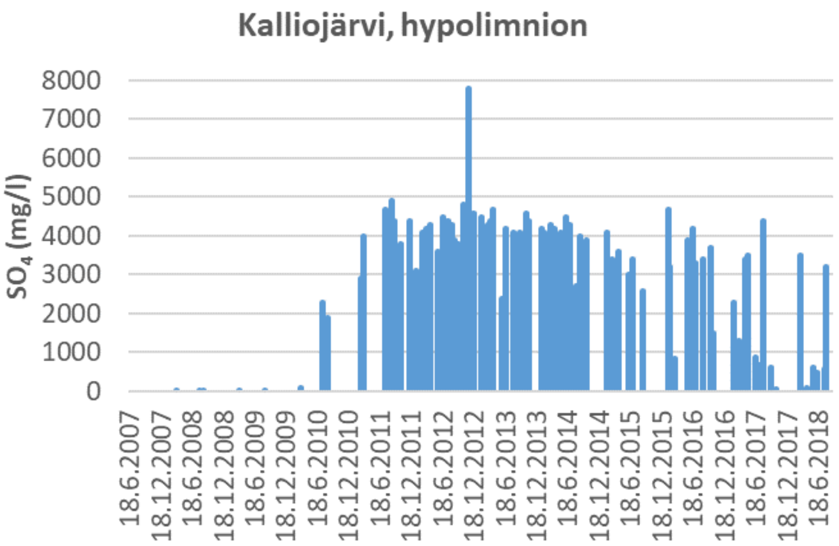
But what actually happened with the Ni masses in L. Kivijärvi….



Current status

- Lakes Salminen and Kalliojärvi still stratified
  - L. Kalliojärvi below 3,5 metres (15-20 % of total area)
- Lake Kivijärvi two deepest basin stratified (10-15 % of total area)





Mine water discharges and resistance of impacted lakes

How to measure the effects in lakes?

Possibilities to restore mine water impacted lakes

Management and restoration of surface water bodies receiving mine waters - (KaiHali) 2015-2018

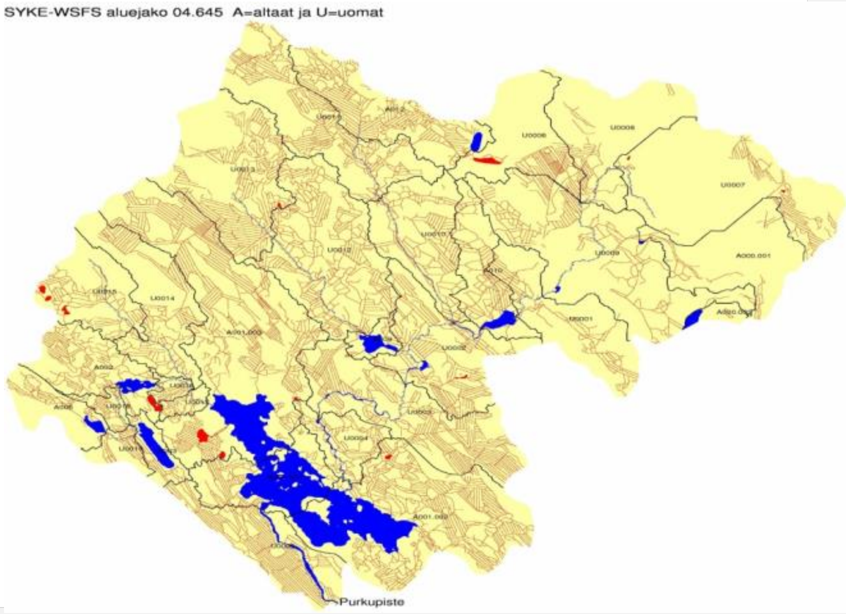
Mine water discharges and resistance of impacted lakes

How to measure the effects in lakes?

Possibilities to restore mine water impacted lakes

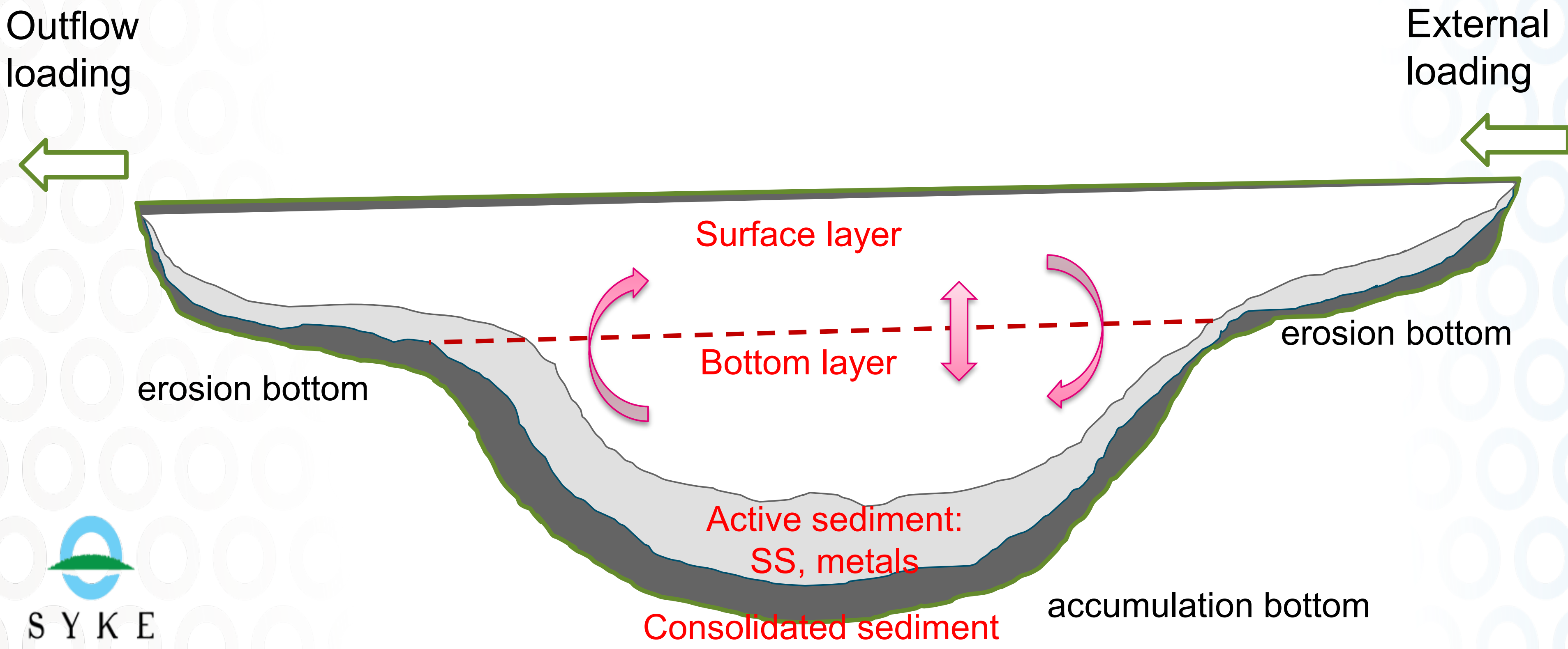
Improve mine water dilution and mixing model in VEMALA-system

- Modelling of loading and dilution depends on amount of water and residence time of lake-river chain
- VEMALA model uses water body network with water bodies wider than 2 metres.
- Covers whole Finland:
  - More than 110 000 rivers/brooks and 30 000 lakes



2-layer lake model

- Development of the 2-layer lake model for retention:
  - 0-2m: surface layer
  - 3-max depth: deep layer with sedimentation and mixing taken into account.
  - Thermocline at 2m depth: Mixing ( )in Spring and Autumn depending on water temperature and diffusion ( )taken into account



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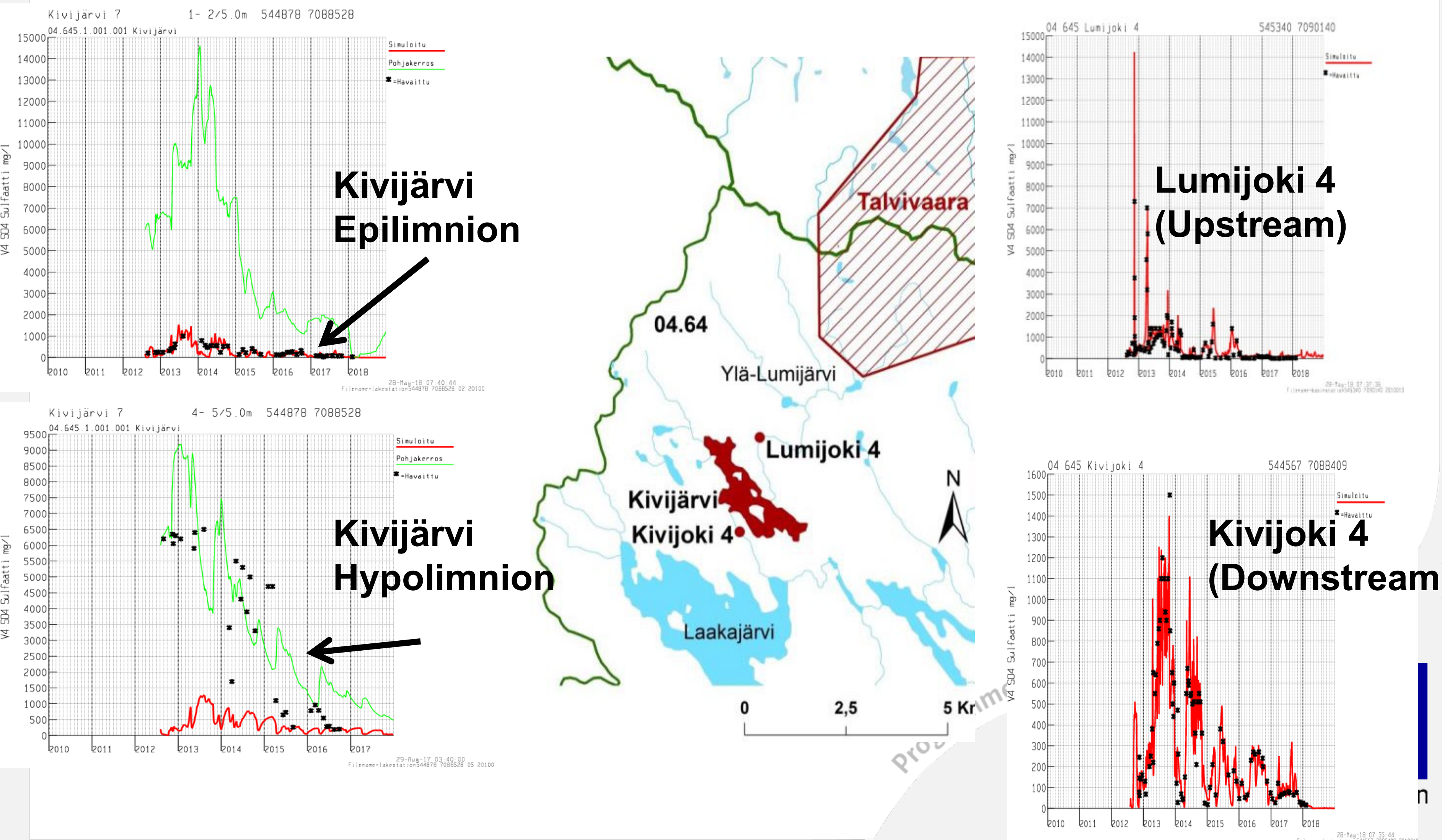
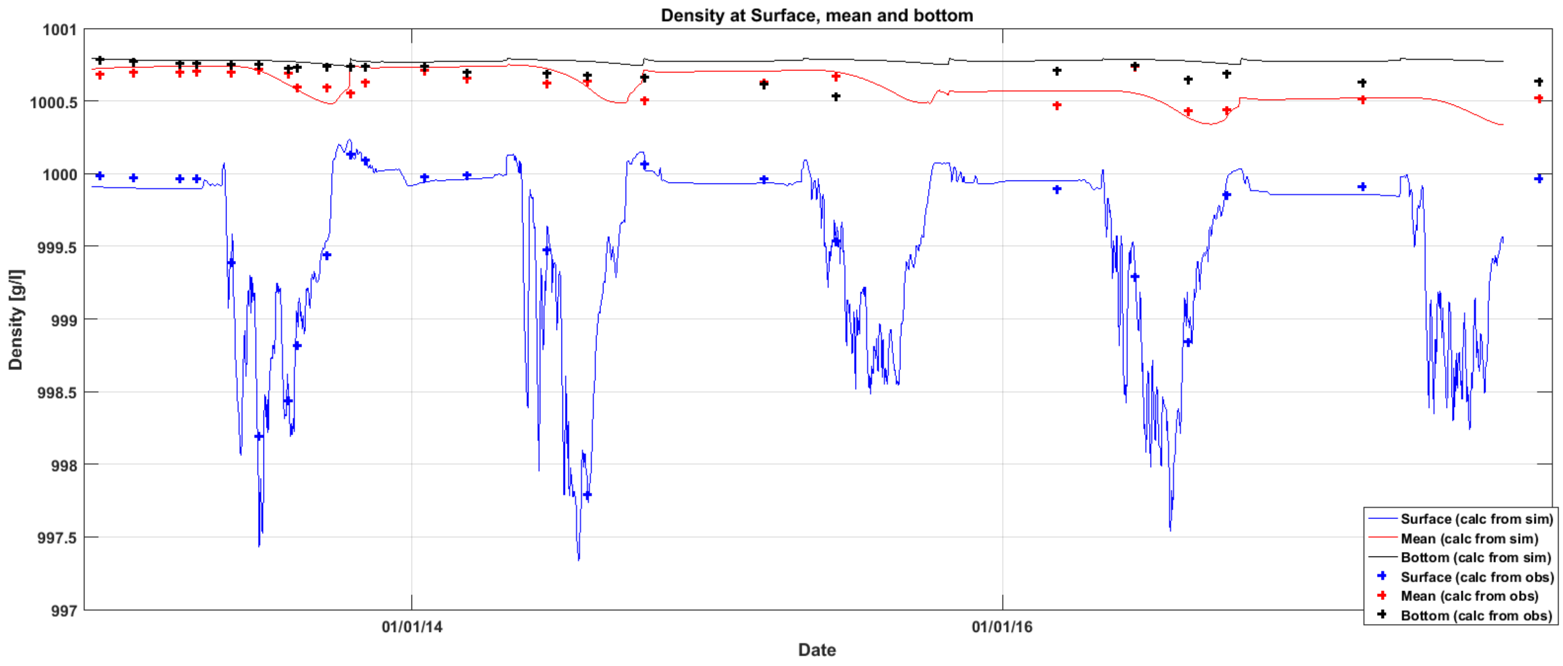
Sulphate simulations

- ➢Kivijärvi has been divided into 3 basins and 2 layers.



Further modelling of stratification by MyLake-model

- Modelling of stratification by MyLake-model
- MyLake – model can be merged to VEMALA



Mine water discharges and resistance of impacted lakes

How to measure the effects in lakes?

Possibilities to restore mine water impacted lakes

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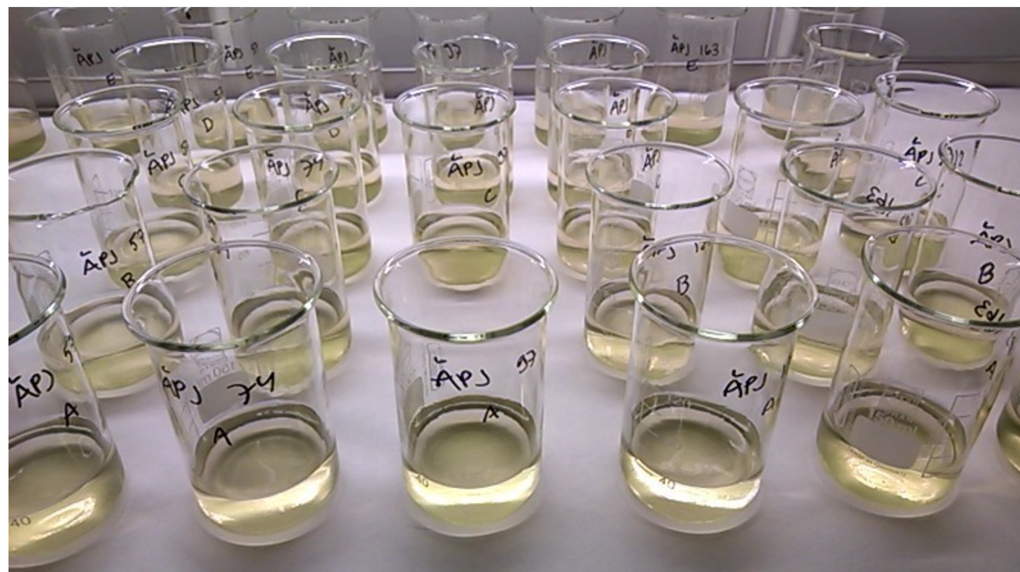
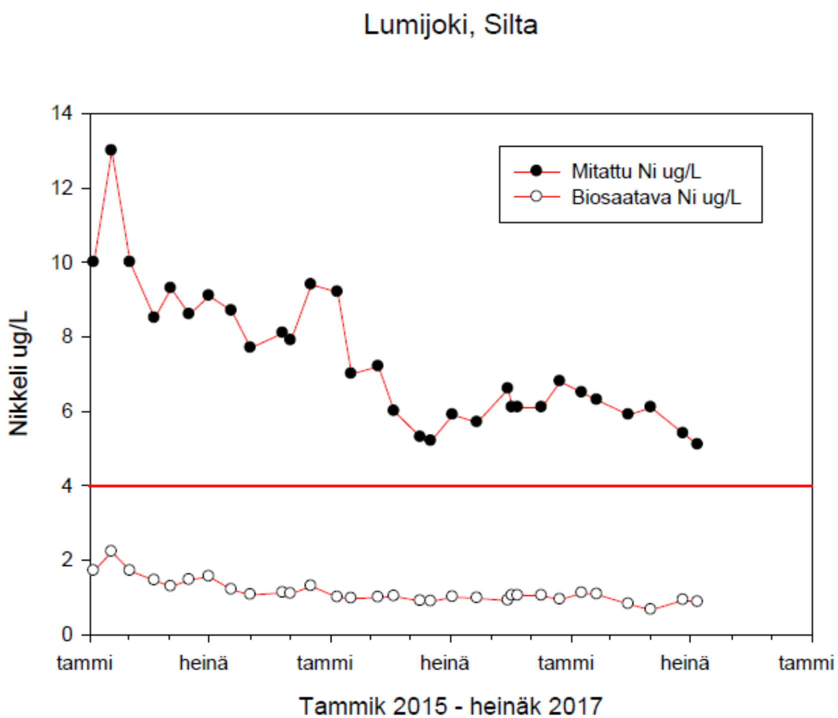
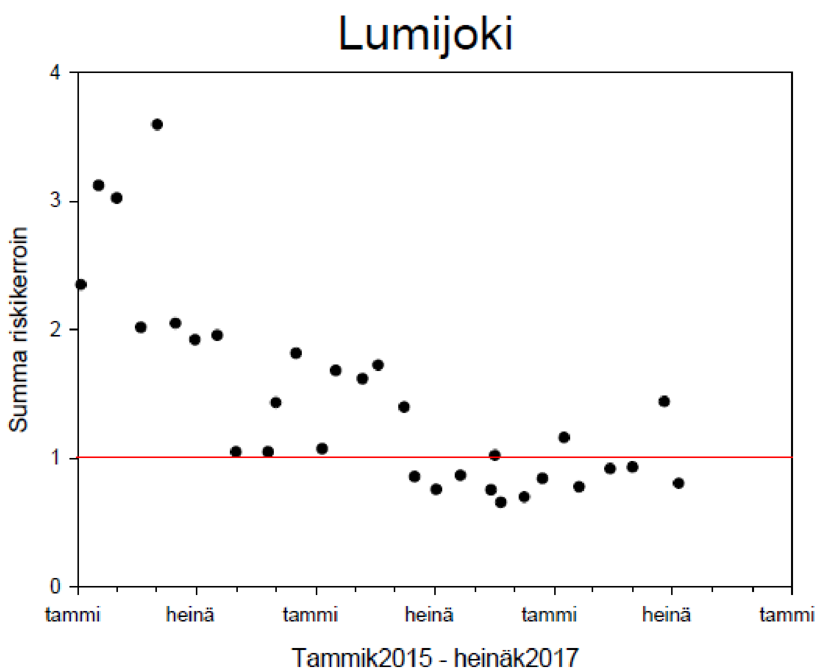
Development of bioligand models (BLM)

- Demonstration of simple EU risk assessment models for metals
  - Local Environmental Quality Standards (EQS) of Ni, Cu, Zn
  - Minimum water quality parameters; pH, DOC, Ca
  - Demonstration of additive metal models







Summa: Ni, Zn, Cu, Cd

Mine water discharges and resistance of impacted lakes

How to measure the effects in lakes?

Possibilities to restore mine water impacted lakes

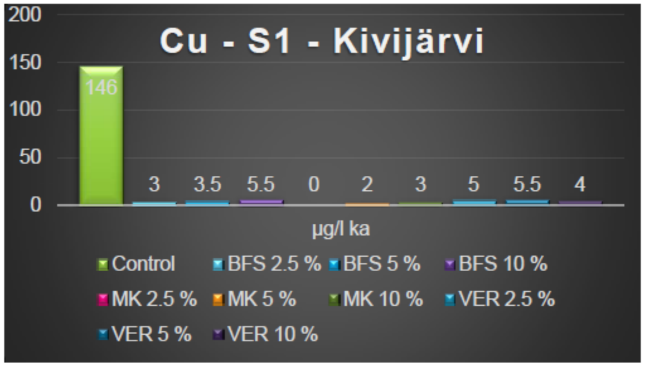
Can we remove sulphate and metals by microbes in lake sediment and peat?

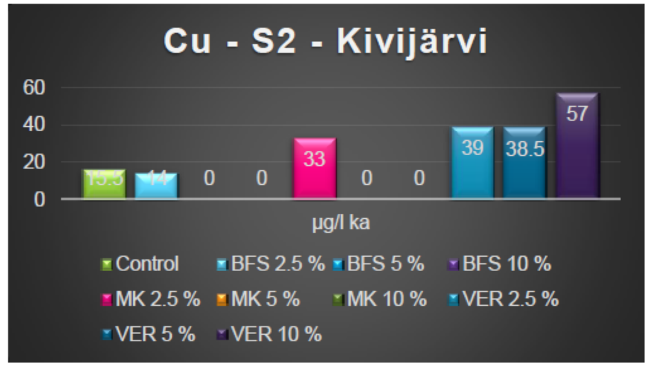
- Non-purified mine water + sediment + peat
  - Added sugars (C) and iron oxides
  - Creation of sulphides
  - Incubation of several weeks

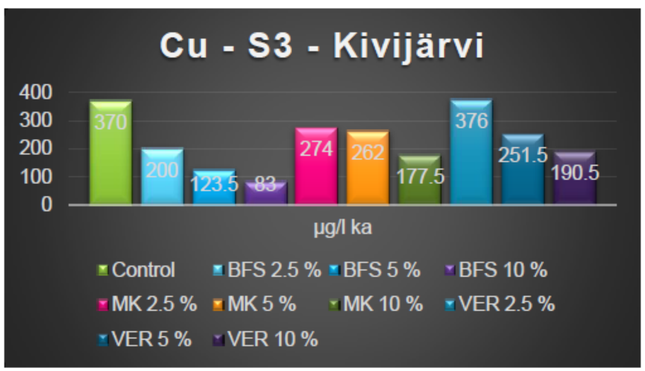
Preliminary results

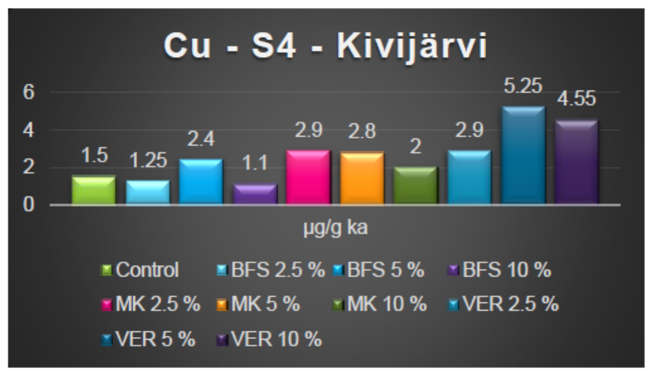
- Half of sulphate was removed in sediment incubation
  - Added C reduced sulphate
- Almost all Zn and Ni was bound during sediment incubation
- Huge release of phosphorous
- Peat incubation did not work
  - Too low pH

Can we remove metals by geopolymers?





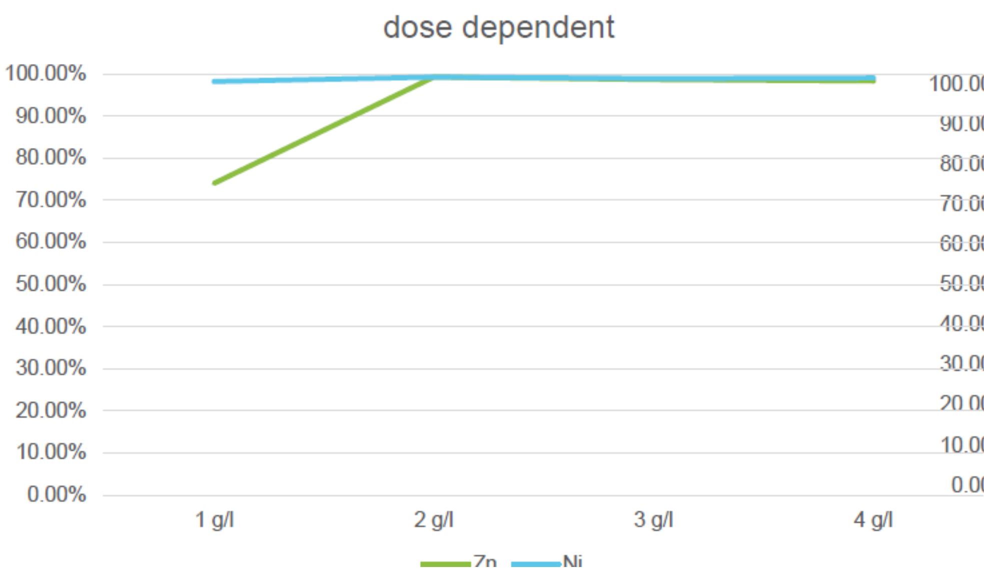


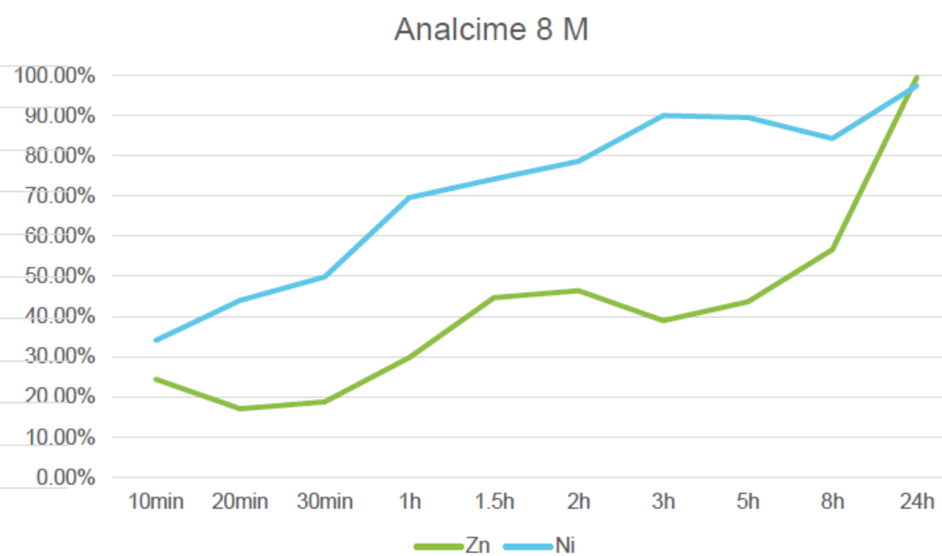


- Used method is BCR-extraction with four steps (acid soluble, reductive, oxidicing and residue)
- Examined metals Ti, Cr, Cu, Zn, As, Sr, Cd, Ba, U, Ni, Al and Fe (on slide for Cu)
- Blast-furnace slag geopolymer is found to be most efficient adsorbent for these metals

Adsorbent development

metal removal tests, analcime geopolymer 8 M NaOH





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Conclusions

- Talvivaara mine and related wastewater releases caused permanent stratification of nearby small lakes
- Gypsum pond accidents released harmful substances to nearest water courses
- Lakes are slowly recovering but active restoration measures are still partly needed to remove stratification and some contaminated sediments of nearest ponds and wetlands
- Accident stimulated development of models and estimation tools to evaluate other environmental disasters or threats

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Thank you for your attention!

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