



## **Geochemistry and migration of anthropogenic arsenic emissions in Yara Siilinjärvi industrial site, Finland**

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Arsenic is a problematic element due to its relatively high mobility over a wide range of redox-conditions and its toxicity to humans, animals and plants. In extractive and industrial minerals arsenic is a common element and cannot be eluded in mining and quarrying activities. Therefore, mining and industrial activities are one of the most serious arsenic polluters at local scale. In assessing environmental effects, it is important to compare anthropogenic arsenic load to geological background. The aim of this study was to characterize environmental effects and risks of the arsenic bearing calcinate tailings to the surrounding environment.

Yara Finland industrial site in Siilinjärvi, Eastern Finland produces mainly fertilizers and phosphoric acid, but also 250 000 t/a iron calcinate is recovered as by-product at the sulphuric acid plant. The tailings area is located about 200 m from Lake Kuuslahti and surrounded by double ditches collecting runoff and seepage waters to seepage ponds. Some seepage water migrates to a bedrock fracture zone under the tailings area and contaminant transport from the fracture zone is controlled by pumping the water back to seepage ponds. The arsenic content (500 mg/kg) of the calcinate tailings is very high considering that the natural arsenic concentrations of the local bedrock and soil are low (<2 mg/kg). A total of 55 soil and sediment samples were analyzed for hot aqua regia, ammonium oxalate and acetate extractable arsenic representing total, chemically adsorbed and bioavailable fractions. In addition 14 water samples were analyzed for total and soluble metal and metalloid concentrations, anions, DOC, TOC, pH, redox and alkalinity. The metal speciation in surface and ground waters was modeled by PhreeqC.

According to the results main arsenic pathways from the tailings to environment and into the Lake Kuuslahti are by dust and surface runoff. Close to the tailings arsenic concentrations are high and exceed the Finnish threshold values of contamination for soil (50 mg/kg) and water (10  $\mu\text{g/l}$ ). However, the arsenic concentrations further away from the tailings are fairly low and close to natural background values. Remarkable part (up to 45 %) of total arsenic in soils and sediments was ammonium oxalate extractable i.e. chemically adsorbed on soil particles. About 10 % of arsenic fraction was ammonium acetate extractable and thus easily mobilized and bioavailable. According to the geochemical modelling, arsenic occurred in groundwater as trivalent arsenic acid ( $\text{H}_3\text{AsO}_3$ ) at pH <6 and mainly as pentavalent arsenate-compounds ( $\text{H}_2\text{AsO}_4^-$  and  $\text{HAsO}_4^{2-}$ ) at pH >6. In surface waters arsenic occurred mainly as arsenate-compounds regardless of the pH.

Since the arsenic is mainly in form of less toxic arsenate and the concentrations in ditch waters and Lake Kuuslahti are low, it appears that arsenic concentration levels do not pose a risk to aquatic organisms. However, it is essential to control the environmental effects by minimizing the dust emissions from the tailings area and pumping the seepage water from the bedrock fracture zone.