Geochemical alteration of tailings in two active sulphide mine tailings areas[1]

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Abstract. The degree of geochemical alteration of tailings was studied from two different types of active sulphide mine tailings areas in a temperate climate in Finland. The Hitura tailings area contains residue from Ni ore processing, whereas the Luikonlahti site includes tailings from processing of Cu and talc ores. Drill cores were collected from both border zones and mid-impoundment areas of the facilities. Sulphide oxidation intensity and redistribution of trace metals and As were studied from the drill cores using selective extractions. Based on the results, sulphide oxidation had occurred in both tailings impoundments. The intensity of oxidation varied in different parts of the facilities depending on the impoundment structure, the depth of the water saturated zone and the delay in burial of the tailings (disposal strategy). Sulphide weathering and subsequent element redistribution were identified particularly in the shallow tailings and in the unsaturated proximal areas beside the earthen dams. Due to a higher reactivity of the Luikonlahti tailings (among others), oxidized layers were there thicker than in Hitura, despite the similar operation periods of the two sites. The high Fe sulphide content, together with the low carbonate buffering capacity, had resulted in acidic conditions and mobilization of potentially harmful metals in the Luikonlahti tailings. In contrast, in-situ retention of the released metals by secondary Fe precipitates was observed in the circumneutral Hitura tailings. Overall, continuous disposal of tailings decreased the sulphide oxidation intensity in these active tailings impoundments.

Additional Key Words: selective extractions, trace metals, Hitura, Luikonlahti, Finland

INTRODUCTION

Sulphide minerals are susceptible to oxidation in sulphide tailings areas when exposed to atmospheric conditions. Sulphide oxidation may result in generation of low quality mine drainage from the waste facilities causing deterioration of surface water and groundwater quality around the tailings impoundments. Sulphide weathering and subsequent formation of mine drainage are particularly an issue in old tailings facilities, which have been left without covering after disposal has ceased (e.g. McGregor et al., 1994; Dold and Fontboté, 2001). Oxidation of sulphide grains is suggested to be most intensive immediately after disposal, when the sulphides are reactive and the oxygen transport path is short (Elberling et al., 1994). Therefore, it is likely that sulphide weathering may initiate already during active disposal of the tailings. There are, nevertheless, only a few studies that have focused on the assessment of early-stage sulphide weathering in tailings (Smuda et al., 2006).

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This extended abstract summarises the results by Heikkinen and Räisänen (2009), who studied the intensity of sulphide oxidation in diverse parts of active sulphide tailings areas using visual observations of drill cores, pH measurements and selective extractions.

STUDY AREAS AND RESEARCH METHODS

The study areas included tailings impoundments from the Hitura Ni mine in western Finland and Luikonlahti Cu/talc mine in eastern Finland (Fig. 1). Both mines have exploited sulphide ores since the end of 1960's, and were still active at the time of the field work of this study. The ore deposits types were dissimilar between the study areas, as were the structures of the tailings impoundments.

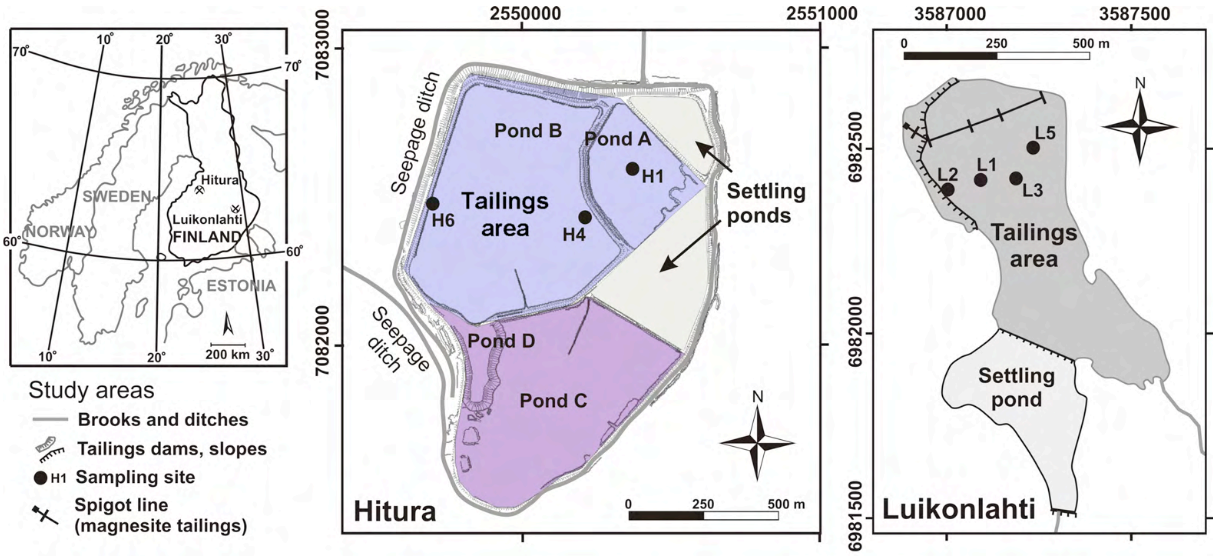

Figure 1. Location of the Hitura and Luikonlahti mines and sampling points at the tailings impoundments.

The Hitura mine and processing plant produce Ni and Cu concentrates from an ultramafic ore complex that is mainly composed of serpentinites (Papunen, 1970). Tailings are disposed into a 110 ha facility that has been dammed above the ground level and forms a regional groundwater recharge area with a major flow path from the middle of the area towards the dams. The tailings consists primary of serpentine and contain only minor sulphide minerals (e.g. pyrrhotite; S content ca.1 %; Heikkinen and Räisänen, 2008).

At Luikonlahti, a massive Outokumpu type Cu-Zn-Co-Ni ore deposit was exploited during 1968-1983, and the production continued in 1979 for talc, which was extracted from the Outokumpu type soapstone deposits until 2006 (Eskelinen et al., 1983). Luikonlahti tailings area has been dammed in a drained lake surrounded by bedrock outcrops and till-covered bedrock hills. The water flow in the impoundment is from the east towards the dammed margins in west. The facility contains currently 6 Mt of sulphide tailings overlain by 2.5 Mt of magnesite-rich tailings. Sulphide tailings are mainly composed of quartz and Fe sulphides (S content ca. 7%; low amount of carbonates), whereas the magnesite tailings contain mainly magnesite and talc with minor sulphide minerals (S content ca. 1%; Räisänen and Juntunen, 2004; Heikkinen and Räisänen, 2009).

To assess the spatial extent of the sulphide oxidation in the impoundments, tailings solids were sampled with a drilling rig at the border zone and in the middle of the impoundments

(3 cores from Hitura and 4 cores from Luikonlahti; Fig. 1). During drilling, groundwater table observations and visual description of the tailings were made. At the laboratory, tailings were analysed for pH and their element solid-phase species distributions were measured using 5-step selective extraction procedures. Details for sampling and analytical methods are presented in Heikkinen and Räisänen (2009).

RESULTS AND DISCUSSION

Element redistribution and visual observations of the tailings showed that sulphide oxidation had occurred in both tailings areas. In Hitura, the most extensive oxidation was observed in the unsaturated shallow tailings of the old, uncovered tailings pond (pond A in Fig. 1). There, a shift from sulphide bound trace metals (Ni, Co, Cu, Zn) and S (the sulphide fraction) to more mobile fractions indicated metal and S release from sulphide minerals as a result of sulphide weathering (core H1, Fig. 2). The presence of trace metals in the Fe oxyhydroxide fractions (adsorbed and coprecipitated fractions) deeper in the circumneutral, reddish brown tailings suggested subsequent retention of the metals to the secondary Fe precipitates (core H1, Fig. 2). In the shallow, dark grey tailings of the active Hitura pond (pond B in Fig. 1), trace metal and S redistributions were only minor (trace metals and S mainly in sulphide fraction; cores H4 and H6, Fig. 2), showing how continuous disposal decreases sulphide oxidation. In the unsaturated border zone core (H6), element redistribution occurred throughout the core, but was most evident in the reddish brown bottom layers, where a notable part of Ni and S occurred in a soluble form (Fig. 2) and carbonate bound Ca was negligible. This feature was interpreted to be related to a presence of a paleosurface, since there have been several temporary cessations in the ore processing during the 30 years of operation in Hitura.

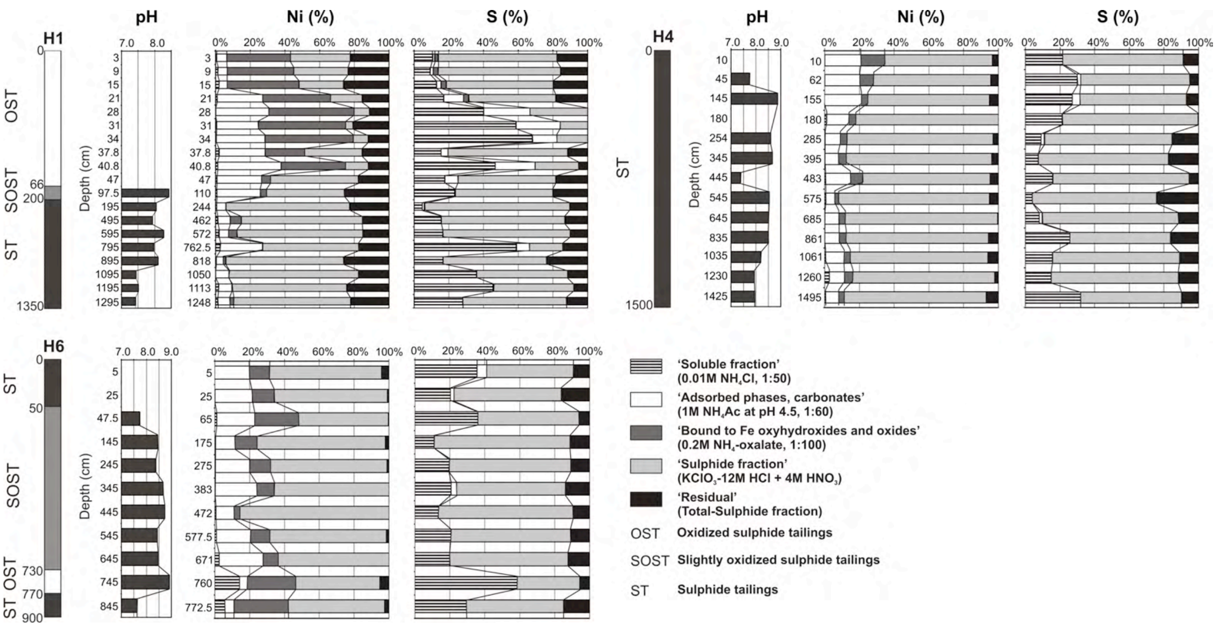

Figure 2. Ni and S solid-phase speciation (in fraction percentages) and pH values of the Hitura tailings cores.

In the Luikonlahti tailings area, oxidized tailings (trace metals and S in a more mobile form than in sulphide fraction; strong reddish brown colouring from secondary Fe precipitates) were observed mainly in the sulphide tailings in the western part of the impoundment, close to the earthen dam, where the tailings were unsaturated (cores L1, L2, Figs 1 and 3). There, the oxidized and slightly oxidized zone was several meters thick even though the sulphide tailings were currently covered with a 1-2 m thick layer of magnesite tailings (Fig. 3). In the eastern part of the impoundment (cores L3, L5), the element redistribution was less intense in the sulphide tailings than in the west, except for the bottom layers of core L5 (Fig. 3). In the east, the sulphide tailings were water saturated and covered with a thicker magnesite cover (3.9-5.9 m) than in the west. The magnesite tailings on top of the sulphide tailings showed only minor metal redistribution (Fig. 3), indicating that sulphide weathering has not been significant in these low sulphide tailings.

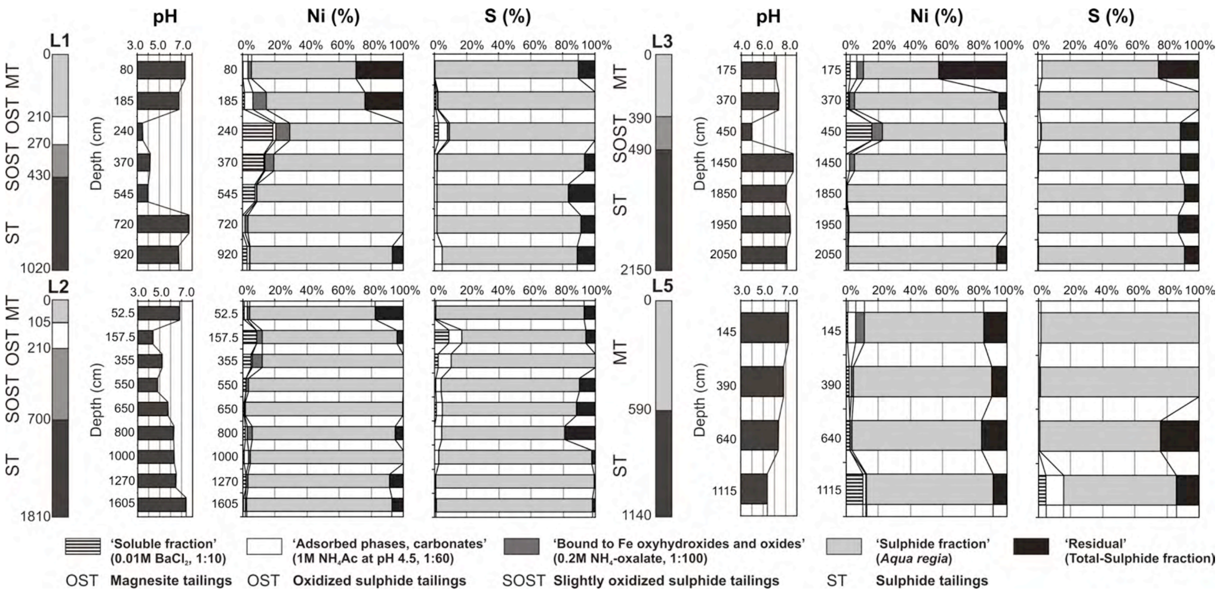

Figure 3. Ni and S solid-phase speciation (in fraction percentages) and pH values of the Luikonlahti tailings cores.

Based on the results, the impoundment structure and depth of water table as well as the disposal strategy have been the major controls for the spatial distribution and the intensity of sulphide oxidation in Luikonlahti. The sulphide weathering has most likely initiated already during the disposal phase in the unsaturated part of the impoundment. Delayed burial of the sulphide tailings by magnesite tailings could be an additional explanation for the observed oxidation, since the deposition of the magnesite tailings has focused on the eastern side of the facility. The element solid-phase redistribution in the bottom layers of the saturated tailings, implying initial sulphide weathering, most likely results from infiltration of oxygen-rich waters from the adjacent bedrock hill. In contrast to Hitura, sulphide weathering has resulted in low pH conditions in the oxidized Luikonlahti tailings with subsequent mobility of trace metals (metals in soluble fraction instead of adsorbed fraction) (Fig. 3).

CONCLUSIONS

Based on the study, continuous disposal of tailings reduces sulphide oxidation during the operational phase of a mine, particularly in low sulphide tailings. Intensive sulphide weathering may, however, occur during active tailings disposal if the tailings are Fe sulphide-rich and are unsaturated after disposal, as in Luikonlahti. Other factors that influenced the occurrence and intensity of sulphide oxidation included impoundment structure and disposal strategy. Sulphide oxidation was observed to result in acidic conditions and subsequent migration of trace metals even in an active tailings area. Nevertheless, in low sulphide tailings with sufficient buffering capacity circumneutral conditions favoured in-situ retention of the metals released during sulphide weathering.

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