



IMPACT OF THE CONSTRUCTION OF A WETLAND ON ELEMENT MOBILITY IN THE MARINE SHORE PORPHYRY COPPER TAILINGS DEPOSIT, BAHÍA DE ITE, PERU

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INTRODUCTION

The Bahía de Ite located in the Atacama desert, about 50 km south of Ilo, Moquegua, Southern Peru (Fig. 1) received from 1960 to 1997 about 785 million metric tons of tailings from two porphyry copper deposits, Cuajone and Toquepala, Moquegua, operated by the Southern Peru Copper Corporation (SPCC).

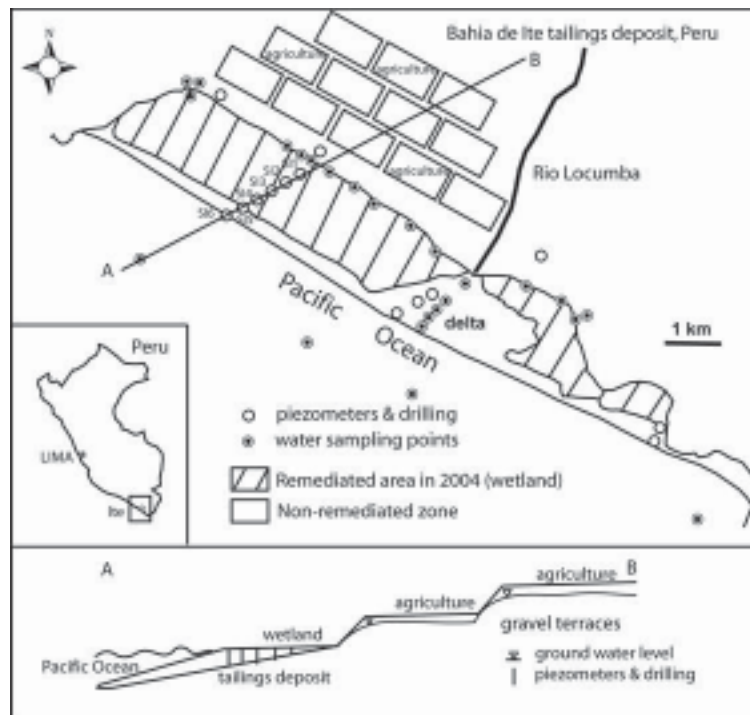


Figure 1: Overview of the Bahía de Ite marine shore tailings deposit, Peru with the location of the sampling point from the 2004 campaign. The vertical scale in the lower profile is strongly exaggerated for better visibility.

The Bahía de Ite area is characterized by gravel terraces, on which extensive agriculture was practiced since the early 1940's (Fig. 1). The water for irrigation was taken from the Locumba River, which contains high natural arsenic concentrations (400 – 700 µg/L As). After deposition ceased in 1997, the remediation was initiated by SPCC with the installation of a wetland cover on the oxidizing tailings, using the alkaline water from the Locumba River and transplantation of the flora, which developed locally, where the alkaline water infiltrated on the oxidizing tailings. Since then, nearly the complete surface (about 80%) of the tailings deposit was covered with this wetland, except the central delta area and some areas close to the shoreline (Fig. 1). The goal of this study is to investigate the biogeochemical processes induced by the installation of the wetland cover and the effects on element liberation and retention processes in the tailings.

METHODOLOGY

In October 2004, nine piezometer nests were installed in three profiles (North, Delta, South) to a maximal depth of 10 m (Fig. 1). 220 water samples were taken from piezometers and surrounding water flows and seeps and analyzed for 20 elements by ICP-AES. As was measured by atomic absorption spectroscopy (AAS) with hydride system. SO₄ and Cl were measured by ion chromatography (IC). Solid samples were obtained by flush drilling at each piezometer nest down to maximum 16 m depth. 315 solid samples were taken and 60 selected samples were subjected to sequential extractions after DOLD (2003). Mineralogy was determined by polished thin sections and by X-ray diffraction (XRD).

RESULTS AND DISCUSSION

Stratigraphy and Mineralogy: Un-remediated oxidizing tailings: The stratigraphy of the oxidizing tailings was generally characterized by a 10 – 20 cm thick cover of efflorescent salts on the surface containing mainly water-soluble sulfates and chlorites ranging from white, blue, yellow-greenish, and reddish colours. This enrichment of the mobile elements from the oxidation zone towards the surface was controlled by the high evaporation in the Atacama desert, which induced a strong capillary transport to the tailings surface and was frequently observed in arid climates (DOLD, 2005; DOLD and FONTBOTÉ, 2001). The underlying low-pH oxidation zone (pH 1 – 4) showed straw-yellowish colour (jarosite), with orange-ochre-brown Fe(III) hydroxides, which were mainly related to dehydration

cracks and grain size limits, where the Fe(III)-rich solutions percolated. The gangue mineralogy of the oxidation zone was dominated by quartz, muscovite, biotite, plagioclase, anhydrite, gypsum, a vermiculite-type mixed layer mineral resulting from the alteration of biotite (DOLD and FONTBOTÉ, 2001), and relicts of pyrite. The underlying neutral primary zone was characterized by the primary mineral assemblage from the ore (quartz, muscovite, biotite, plagioclase, anhydrite, gypsum), with about 4 wt% pyrite and traces of chalcopyrite, molybdenite, chalcocite-covellite. It is important to mention that in the northern profile the primary zone showed in the drill cores close to the shore line (SI4 and SI5) in the whole depth of the stratigraphy a orange-reddish colour, resulting from fine Fe(III) hydroxides coatings on the silicates. *Remediated tailings:* The stratigraphy of the remediated area showed similar patterns as the oxidized tailings (yellow oxidation zone with underlying gray primary zone). On the top of the oxidation zone, up to 30 cm thick horizon of black organic matter with a water cover of some cm up to 1.5 m was present.

Aquatic chemistry: Un-remediated oxidizing tailings: At SI5 the pH ranged from 1 to 2.5 in the oxidation zone (Eh = 620 mV) with high metal concentrations in solution (220 mg/L Fe, 74 mg/L Al, 8.19 mg/L Mn, 19.6 mg/L Cu, 2.4 mg/L Ni, 2.08 mg/L Zn). Arsenic was below detection limit in the oxidation zone, as this element is frequently associated with the secondary Fe(III) hydroxides in the low-pH oxidation zone. Below the oxidation front, the pH increases to values of 4.5 to 5.5 and the Eh decreases to 170 mV at 3 m depth. At 3 m depth a plume of Fe²⁺ (650 mg/L Fe) was present. Arsenic reached maximum concentrations of 100 µg/L at 100 cm depth, but was generally very low (close or below detection limit of 2 µg/L in SI5 and SI4), as at SI5 and SI4 the Fe(III) hydroxide coating scavenged arsenic (confirmed by sequential extraction data). *Remediated tailings:* Below the wetland, in SI2 – SI4, the pH was close to neutral values and the Eh showed more reducing conditions (100 – 150 mV). Due to this strong geochemical change of the system the heavy metal concentrations in solution were generally low (7.4 – 236 mg/L Fe, up to 4.3 mg/L Zn; Al, Cu, and Ni were generally close or below detection limit). However, arsenic maintains high concentrations under these conditions (up to 1.4 mg/L), especially close to the infiltration of the fresh water with its natural arsenic concentrations of around 500 µg/L of As.

PRELIMINARY CONCLUSIONS

The data of the mineralogical and geochemical study of the marine shore tailings deposit at the Bahía de Ite, Peru suggest that the hydrology of the tailings deposit is controlled by the influx of fresh water from the Locumba River and the infiltrations of the irrigation water (natural background of around 500 $\mu\text{g/L As}$) occurring on the gravel terraces, with very low infiltrations of marine water into the tailings deposit. The construction of the wetland on the oxidizing low-pH tailings resulted in the increase of the pH to neutral values and the decrease of the redox state to more reducing conditions. This geochemical change reduced the mobility and further liberation of the bivalent cations Cu, Ni, and to a lesser extent Zn. The installation of the wetland also promoted the reduction of Fe(III)-rich water of the oxidation zone, forming a plume of Fe(II), which was pushed towards the sea by the increasing hydraulic pressure of the wetland. In contact with the more oxidizing seawater ($E_h = 400$ mV), the Fe(II) oxidized to Fe(III) and hydrolyzed, forming a thin coating of Fe(III) hydroxides of the sandy material in the area of the shore line. This Fe(III)hydroxide coating seems to act currently as filter for the arsenic, which infiltrates from the seeps along the former shore line into the tailings deposit.

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