

Quantifying the potential seepage from the Quillayes porphyry Cu tailing dam using stable isotopes (Chile)

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INTRODUCTION

Chile is extraordinarily enriched in porphyry-style copper deposits and is the largest Cu producer worldwide. Mining activities of these ores, which are characterized by low Cu grades and high tonnages, produce several environmental footprints, as large amounts of tailing production and disposal in dams, and seepage of tailing dam waters towards the neighboring aquifers. The tailing dam managements usually includes different strategies to minimize seepage towards groundwater, such as drainage ditches and pumping wells installed as hydraulic barriers. Nevertheless, these strategies are not always sufficient to avoid seepage waters, and there is a growing interest to develop tools to trace and quantify the impact of tailings in groundwater. Mine tailings are characterized by high contents of dissolved sulfate, and isotopic studies have been used to trace the sources and processes of SO_4^{2-} in tailing waters (e.g., Dold and Spangenberg, 2005; Spangenberg et al., 2007), due to their potential environmental impact. However, less studies are focused to the use of isotope geochemistry as a monitoring tool to determine the tailings seepage towards the aquifers.

In the present study, isotope data ($\delta^2\text{H}$ - $\delta^{18}\text{O}$ - H_2O and $\delta^{34}\text{S}$ - $\delta^{18}\text{O}$ - SO_4^{2-}) from the hydric systems related to the Quillayes tailing dam (from the Pelambres porphyry Cu deposit, Chile) have been studied to illustrate their potential as tool for quantifying tailings seepage contribution to groundwater.

MINE TAILINGS DAM

Figure 1 shows the location of the Quillayes mine tailings from the Los Pelambres porphyry copper mine, as well as the situation and types of studied water samples. It is worth mentioning that the water used in the mine flotation plant (~1,600 masl) is from the Quillayes dam surrounding waters (~1,300 masl).

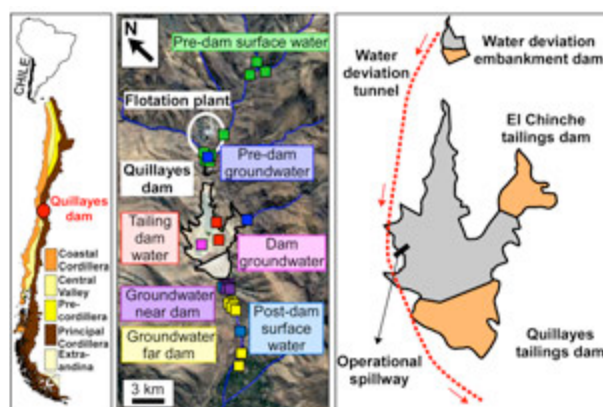


Fig 1. Location of the Quillayes tailing dam and studied water samples.

$\delta^2\text{H}$ - $\delta^{18}\text{O}$ OF WATER

The isotope signature of the Quillayes tailing dam waters projects far from the local meteoric waters, suggesting that waters are affected by evaporation (Fig. 2). The isotopic composition of groundwater samples collected downstream from the Quillayes dam plotted in the

calculated evaporated trend, suggesting a mixing at different proportions of highly evaporated water from the tailings dam and local meteoric waters (Fig. 2). Those groundwater samples located closer to the dam showed a mine tailing water contribution ranging from 40 to 80 %, whereas groundwater samples located farther and downstream from the dam had a tailing water proportion lower than ~20 % (Fig. 2).

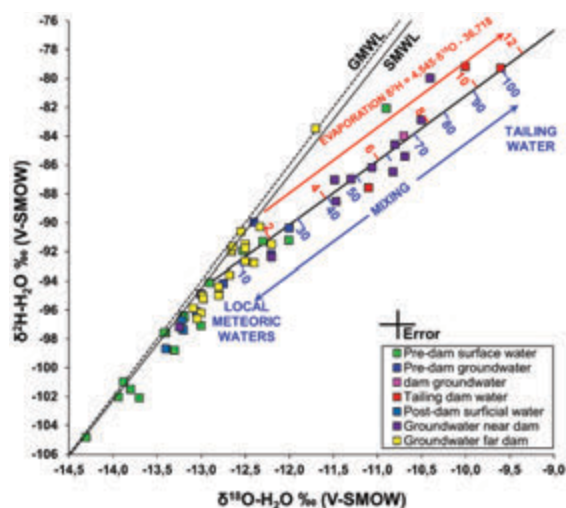


Fig 2. Plot of $\delta^2\text{H}$ versus $\delta^{18}\text{O}$ for waters from the Quillayes tailing impoundment and surrounding areas. Global Meteoric Water Line (GMWL) after Craig (1961). Santiago de Chile Meteoric Water Line (SMWL) from 1993 to 1994 LAEA/WMO data.

□ ^{34}S -□ ^{18}O OF DISSOLVED SULFATE

The dissolved sulfate may originate from: i) oxidation of ore sulfides (e.g., pyrite); ii) dissolution of primary ore sulfates (mainly anhydrite); and iii) fertilizers used in farmlands (Fig. 3). These sulfate sources have a distinct isotopic signature; therefore the isotopic composition can be used to identify the origin of dissolved sulfate.

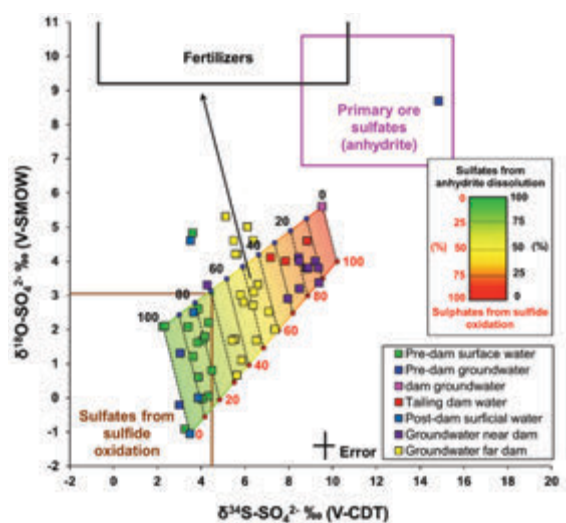


Fig 3. Plot of $\delta^{34}\text{S}$ versus $\delta^{18}\text{O}$ for dissolved sulphate from the Quillayes tailing dam and surrounding waters. Isotopic data of primary ore sulphates (anhydrite) are from Kusakabe et al. (1984) and Cannell (2004), fertilizers from Vitória et al. (2004) and sulphate from sulphide oxidation are calculated according to Van Stempvoort and Krouse (1994) and using $\delta^{34}\text{S}$ values of ore sulphides from Cannell (2004).

A mixing model using the $\delta^{34}\text{S}$ - $\delta^{18}\text{O}$ of SO_4^{2-} showed that tailing dam water (concentration up to 2 g/l) had higher contribution of SO_4^{2-} from the dissolution of primary ore sulfates than sulfide oxidation (Fig. 3). Furthermore, the $\delta^{34}\text{S}$ and $\delta^{18}\text{O}$ signatures of dissolved sulfate in the surface water (concentration between 13 and 191 mg/l) are consistent with a high influence of sulfate from sulfide oxidation (Fig. 3). On the other hand, the $\delta^{34}\text{S}$ and $\delta^{18}\text{O}$ of SO_4^{2-} in groundwater downstream from the Quillayes dam suggests a mixing at different proportions of dissolved sulfate from the tailings dam and natural waters. The groundwater closer to the dam (concentration between 1.0 and 1.5 g/l) showed a sulfate contribution from the tailing dam between 70 and 90 %, whereas farther to the dam groundwater (200-700 mg/l) had a tailing sulfate contribution lower than 60% (Fig. 3).

CONCLUSIONS

This multi-isotopic study has permitted to quantify the contributions from dam tailings and natural waters in the aquifer downstream from the Quillayes dam, showing a higher contribution of dam tailings waters in groundwater closer to the dam than those located downstream.

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