Tracing water and dissolved sulfate sources in active mine tailings using S, H and O isotopes

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A multiple stable isotope study ($\delta^{34}S_{sulfide}$, $\delta^{34}S_{sulfate}$, $\delta^{18}O_{sulfate}$, $\delta^{2}H_{water}$, $\delta^{18}O_{water}$) from the active tailings impoundment Carén, originating from the exploitation of the giant porphyry copper deposit El Teniente, Chile, is used to get insight into the water pathways, mixing processes and mineralogical transformations of recently discharged tailings (~200,000 t/day). The $\delta^{2}H_{water}$ and $\delta^{18}O_{water}$ values from fresh tailings (–85.1‰ to –89.0‰ $\delta^{2}H$, –11.5‰ to –11.8‰ $\delta^{34}O$) indicate the high altitude origin (>1,900 m) of the water used in the flotation processes. The $\delta^{2}H_{water}$ and $\delta^{18}O_{water}$ covariations from tailings profiles and decantation-lake record the relative importance of the processes of evaporation and mixing of meteoric, ground- and tailings waters. The enrichment in heavy isotopes of surface waters is due to: (1) evaporation mainly during the dry summer season (up to –65.2‰ $\delta^{2}H$ and –4.7‰ $\delta^{34}O$), and (2) mixing with the isotopically heavier (lower altitude) meteoric water during the wet winter season (up to –39.1‰ $\delta^{2}H$, –2.6‰ $\delta^{34}O$). Infiltration of isotopically heavy groundwater into the tailings sediments is suggested by the ^{2}H- and ^{18}O-enrichment in deeper zones (up to –59.2‰ $\delta^{2}H$ and –6.9‰ $\delta^{34}O$). The results indicate that surface waters have only limited interaction with deep tailings sediments and a short residence time in the tailings impoundment.

The main processes controlling the variability of the $\delta^{34}S$ and $\delta^{18}O$ values of the water-soluble sulfate are dissolution of primary gypsum/anhydrite (12.0 ± 0.6‰ $\delta^{34}S$) and oxidation of primary sulfides (pyrite, chalcopyrite; –3.7 ± 1.5‰ $\delta^{34}S$), as observed in other porphyry copper tailings in Chile [1]. During the transport of tailings from the flotation plant to the tailings impoundment and during the dry summer, the oxidation rate of primary sulfides increased, resulting in lower $\delta^{34}S_{sulfate}$ values near the surface and in freshly deposited tailings (down to 5.6‰ $\delta^{34}S$). The changes of the $\delta^{18}O_{sulfate}$ and $\delta^{18}O_{water}$ variations in tailings and lake show the relative importance of water and atmospheric oxygen in oxidation of sulfides.

References

[1] Dold, B. and Spangenberg, J.E., 2005. Sulphur speciation and stable isotope trends of water-soluble sulfates in mine tailings profiles. Environ. Sci. and Technol., 39: 5650-5656.