Stable isotope composition of waters from porphyry copper mine tailings in different climatic environments, Chile

J.E. SPANGENBERG, B. DOLD, M.-L. VOGT AND H.R. PFEIFER

Institute of Mineralogy and Geochemistry, University of Lausanne, BFSH2, CH-1015 Lausanne, Switzerland; Jorge.Spangenberg@unil.ch, Bernhard.Dold@unil.ch, Marie-Louise.Vogt@unil.ch, Hans-Rudolf.Pfeifer@unil.ch

The stable isotope composition of water (δ^2H and $\delta^{18}O$) is a powerful tracer of fluid sources, pathways, mixing processes and dissolved constituents. We explore its application in four mine tailings impoundments formed from the exploitation of Chilean porphyry copper deposits: Talabre (2350 m altitude, hyperarid climate) from Chuquicamata mine, Cauquenes (725 m, Mediterranean) and Carén (flotation plant at 1900 m altitude, impoundment at 230 m, Mediterranean) from El Teniente mine, and Piuquenes (2150 m, Alpine) from La Andina mine. The main factors determining the O and H isotope composition of tailings waters are the isotopic composition of meteoric water and evaporative fractionation. At Piuquenes the $\delta^{18}O$ values range from –14.9 to –12.3‰ and δ^2H values from –111.8 to –100.8‰. The heaviest isotopic waters are from the open-to-evaporation decantation lake (–6.3‰ $\delta^{18}O$, –66.2‰ δ^2H). At Cauquenes the $\delta^{18}O$ values range from –11.7 to –6.5‰ and the δ^2H from –84.6 to –55.0‰, with –4.9‰ $\delta^{18}O$ and –42.3‰ δ^2H. Carén waters have $\delta^{18}O$ values ranging from –10.8 to –4.4‰ and δ^2H values ranging from –79.7 to –45.7‰. The groundwaters from the hyperarid climate at Talabre are the isotopically heaviest (–7.6 to –3.8‰ $\delta^{18}O$, –64.6 to –43.0‰ δ^2H). These δ^2H and $\delta^{18}O$ data indicate the hydrological inputs and outputs to the tailings impoundments. The displacement from the meteoric water line towards higher $\delta^{18}O$ values is partly due to exchange with O-bearing minerals (e.g., Fe oxy-hydroxides, bacterial sulfate reduction). In depth profiles the isotopic values from the saturated zone represent steady state conditions with constant evaporation and flux from the water table. From the saturated zone towards the surface, two zones can be distinguished. In a capillary zone, a mix of vapour and liquid water follows an evaporative isotopic trend with enrichment in heavy isotopes. In temperate climate, water between the capillary zone and the surface is a mix of evaporated moisture, rainfall and recently discharged tailings water. In hyperarid climate the dry uppermost zone contains isotopically light diffused and atmospheric water vapour.