

Molybdenum stable isotope variations associated with redox gradients in drainage from Mo-rich mine tailings

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Molybdenum stable isotope variations can provide insights into the fate and transport of Mo in the environment (e.g. Nägler et al., Chem Geol 2011,289:1-11). In this study, Mo isotope fractionation was examined in a Mo-rich tailings impoundment at a mine site in the western Rocky Mountains. Historical water quality monitoring data show that Mo is attenuated between the upstream and downstream zones of the impoundment. Molybdenum stable isotope compositions ($\delta^{98}\text{Mo}$) were measured along the flow path.

Tailings pond waters, representing the upstream portion of the flow path, are alkaline (pH ~7.5) and oxygenated. Mo concentrations historically range from 1,000 to 3,000 $\mu\text{g/L}$ and $\delta^{98}\text{Mo}$ was 0.7 ‰ (relative to NIST-SRM-3134=+0.25 ‰).

Downstream from the tailings dam, drainage emanates from an anoxic, basal drain. Basal drainage is circumneutral (pH ~6.7), has elevated Fe and Mn concentrations, and contains dissolved sulfide. Relative to the pond waters, Mo concentrations are lower (~800 $\mu\text{g/L}$) and $\delta^{98}\text{Mo}$ increased to 0.9-1.1 ‰. Processes which may have driven this shift in Mo concentrations and $\delta^{98}\text{Mo}$ include precipitation of powellite (CaMoO_4) and/or secondary Fe-Mo sulfide minerals in the saturated tailings impoundment.

Oxygenation of basal drainage occurs below the impoundment in a sedimentation and collection pond resulting in Fe- and Mn-oxyhydroxide precipitation. Mo concentrations decreased to ~50 to 190 $\mu\text{g/L}$, accompanied by a further shift to heavy $\delta^{98}\text{Mo}$ (1.3-2.6 ‰). Fe oxyhydroxides were highly enriched in Mo (760-4,500 ppm) which was isotopically light (-0.3 to +0.2 ‰), consistent with the isotopic shift observed in the aqueous phase.

This study highlights the potential of Mo stable isotopes to track Mo attenuation processes and provides an indication of fractionation processes resulting from mineral precipitation and oxyhydroxide adsorption.