

Using Stable Isotope and Groundwater Geochemistry to Trace Sulfur Cycling at an Abandoned High-Sulfide Tailings Impoundment

M.C. Moncur^{1,2}, C.J. Ptacek¹, B. Mayer³, D.W. Blowes¹, S.J. Birks^{2,1}

¹University of Waterloo, Waterloo, ON, Canada, ²Alberta Innovates Technology Futures, Calgary, AB, Canada, ³University of Calgary, Calgary, AB, Canada

When exposed to the atmosphere, sulfide-rich mine tailings oxidize and release acid and metals to tailings pore waters. Discharge of this metal-rich water can lead to severe degradation of water quality in receiving lakes and streams. The former Sherritt-Gordon Zn-Cu Mine, located in Sherridon, Manitoba, Canada, deposited high-sulfide tailings into the Woods Lake Tailings Impoundment between 1937 to 1951. The tailings cover an area of 40 ha, completely filling nearby Trap Lake and partially filling Woods Lake. Over the past half century, microbially mediated sulfide oxidation reactions have led to the depletion of sulfides ($\delta^{34}\text{S-SO}_4$: 0.2 to 1.2 ‰) in the upper 40 cm of the tailings. Consequently, concentrations of sulfide oxidation products are very high in the unsaturated tailings pore water (Fe: 107 g/L, SO_4 : 244 g/L, Zn: 4.8 g/L, Cu: 1.1 g/L, and pH: 0.67), with highest concentrations of metals and lowest pH conditions present in the zone of active oxidation. Concentrations of dissolved metals and sulfate decrease below the water table, but remain elevated in deeper groundwater (33 g/L Fe and 55 g/L SO_4). At the border between the tailings and Woods Lake concentrations of metals and SO_4 decrease. This decrease coincides with significant sulfur isotope fractionation with depth ($\delta^{34}\text{S-SO}_4$ 29.4‰), suggesting that the decrease in concentrations is due to bacterially mediated (dissimilatory) sulfate reduction, not dilution. Additional indicators of bacterial sulfate reduction include: increased pH, alkalinity, dissolved H_2S , production of methane and decreased Eh with depth. Saturation indices calculated using the equilibrium/mass transfer model MINTQA2 suggest that secondary sulfide minerals are potentially precipitating in the zone of bacterial sulfate reduction. Presently bacterial sulfate reduction occurring at the tailings edge appears to lead to a substantial decrease in loading of dissolved metals, sulfate and low pH groundwater to Woods Lake. However, metal loadings may increase if the underlying organic-rich lake sediment, which is utilized as a carbon source for bacterial sulfate reduction, is exhausted.