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Characterization of selected conservative and non-conservative isotopes in mine effluent and impacted surface waters: Implications for tracer applications at the mine-site scale

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Characterization of selected conservative and non-conservative isotopes in mine effluent and impacted surface waters: implications for tracer applications at the mine-site scale

Effluent from Europe's largest active gold mine is discharged to the adjacent River Seurujoki via natural treatment wetlands in Lapland Finland. Site waters, including two sources of mine effluent, treatment wetland surface water and Seurujoki river water were chemically and isotopically characterized. The results of isotopic characterization were evaluated to determine the effectiveness of selected environmental conservative isotopes (**δ^{18}O, δD, ^{87}Sr/^{86}Sr**) as tracers of water/solute source. Non-conservative isotopes (**δ^{7}Li, δ^{26}Mg, δ^{25}Mg, $\delta^{34}S_{SO4}$**) were evaluated as tracers of fractionation inducing processes that provide insight to contaminant attenuation and mobility mechanisms**.** The two sources of mine effluent were chemically distinct, and the impacts of mine effluent were persistent in downstream river water to at least 12.8 km. Sr isotope-based estimates of mine effluent discharge to the river were in good agreement with Cl concentration-based estimates, and suggest effluent comprised approximately 4% of river discharge in both June 2013 and June 2015. These instantaneous mixing results were applied in a multi-isotope approach to characterize non-conservative solute and isotopic behavior for Li and SO_4. In 2015 ^{7}Li was enriched in downstream river water by approximately 3‰ with no discernible concentration change, suggesting ongoing in-stream ion exchange reactions with oxy-hydroxide precipitates. While SO_4 was attenuated by over 50% in the downstream direction, the observed $^{34}S_{SO4}$ depletion indicates that bacterial sulfate reduction was not a driver of in-stream attenuation. Further, depletion of ^{18}O and deuterium in treatment wetland 4 indicated that fresh meteoric water comprised approximately 25% of the treatment wetland discharge in March 2015. The contemporaneous flushing of numerous contaminants (Na, Ca, Mg, SO_4, Mn, and Li) from the wetland supports the conceptual model in which disruption of contaminant concentration gradients will lead to contaminant leaching from the wetlands.

Keywords: Environmental isotopes; tracers; mine water; mine effluent; gold mine; sequential mixing; natural treatment wetlands; non-conservative isotope tracers; solute mobility

1. Introduction

To meet modern demands for mineral resources, mining as a global industry has expanded dramatically over the last century. Industry expansion has been accompanied by increased need to manage the impacts of mining on human health and the environment. The greatest pathway of mining related contamination posing risk to human health and the environment is via water. Some of the most persistent and harmful impacts of mining on water resources are chemical and ecological deterioration resulting from the discharge of saline and metalliferous waters either produced directly during mineral processing, or as drainage from exposed rock surfaces within the mine (e.g. Younger et al. 2002). Accordingly, mine water management technologies are continually evolving, as are monitoring techniques to