Chemical Tracers at a Closed Milling Site with Natural and Anthropogenic Contaminants

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Ore milling sites are often located in areas with natural sources of contaminants. Stakeholders concerned with the long-term impacts of such sites may be interested in distiguishing these natural sources from anthropogenic sources. This objective can be challenging to meet when the multiple sources are geochemically similar. In a case study that presents this challenge, we applied a computational code named M3 [1]. The M3 code combines multivariate statistics with mixing and mass balance analysis to determine the proportion of endmembers in samples downgradient of sources, as well as possible reactions that impact contaminants during transport. This type of analysis is well suited for simple datasets that lack more sophisticated tracers (e.g., noble gases, isotopes, etc.).

In the case study presented here, three endmembers were identified as the following: (1) upgradient background Ca-HCO_3 type groundwater with near-neutral pH; (2) natural acid rock drainage (ARD) Mg-SO_4 type groundwater with pH between 3.5 to 4; and (3) milling-impacted Na-SO_4 type groundwater with pH near 7.7. Considering the concentrations of major ions (Ca, Na, HCO_3, and SO_4) and constituents of concern (COCs; including As, Mo, Se, U) in 25 wells at the site, multiple runs of the M3 code showed that four wells contain a significant proportion of all three endmembers. Another two wells are likely a mixture of background and milling-impacted groundwater only. Four more wells are likely a mixture of background and natural ARD-type groundwater only. The remaining wells are similar to background groundwater. Compared with expected COC concentrations based solely on mixing, mass balance calcuations for the six wells with some component of milling-impacted groundwater show that additional attenuating processes may account for the observed COC concentrations. Current characterization of the aquifer solids will provide insight into the attenuating processes (sorption and precipitation) that may impact COC concentrations. The results of this analysis have been instrumental in designing the solute transport model for this site.

[1] Laaksoharju M., Skårman C., Skårman E. (1999), *Applied Geochemistry* 14(7), 861–871.