Characterizing groundwater flow paths in high-altitude fractured rock settings impacted by mining activities

MICHAEL WIREMAN[1], GARETH J. DAVIES[2] & BRUCE STOVER[3]

[1]United States Environmental Protection Agency, 999 18th Street, Suite 500, Denver Colorado 80202-2405, USA, e-mail: wireman.mike@epa.gov
[2]Cambrian Ground Water Co., 109 Dixie Lane, Oak Ridge Tennessee 37830, USA, e-mail: daviesgj@bellsouth.net
[3]Denver Grouting, A Division of Hayward Baker, 11575 Wadsworth Blvd., Broomfield, CO, USA, 80020, e-mail: bkstover@haywardbaker.com

ABSTRACT

The Rocky Mountains of the western USA have tens of thousands of abandoned, inactive and active sites related to precious- metal (gold, silver, copper) mining. Mining activities often resulted in mobilization and transport of associated heavy metals (zinc, cadmium, lead) which can pose a significant threat to aquatic communities in mountain streams. Transport of heavy metals from sources associated with mining (waste rock piles, tailings impoundments, underground workings, mine pits) can occur along numerous hydrological pathways. A number of techniques that utilize geological, hydrological and hydrochemical data can be used to identify and characterize hydrologic flowpaths within these predominantly fractured-rock settings. Interpretation of data obtained from these techniques will aid in developing solid conceptual understandings related to transport of dissolved metals to streams.

Fractured- rock ground-water systems behave like triple porosity aquifers with, at mine sites, added porosity elements such as adits, stopes and shafts. Characterization techniques that have proved to be useful in these settings include surface and ground-water tracing, isotopic analyses, hydrogeologic mapping, analyses of hydrochemical data, geochemical modelling and selected surface and borehole geophysical techniques. Groundwater tracing techniques make fewer assumptions about pathways than do hypothetical (e.g. Darcy) or numerical simulations and are therefore more reliable. Fluorescent dyes constitute some of the most analytically sensitive, versatile, non-toxic and inexpensive artificial water tracers available. Surface water tracing allows for very accurate stream flow measurements and the identification of ground-water inflow zones to streams. Radiogenic isotopes, including tritium and sulphur 35 can be used to help characterize residence time along ground-water flow paths. Stable isotopes are useful for characterizing ground-water recharge conditions and for separating surface and subsurface pathways. Oxygen 18 data can be used to complete end-member mixing analysis that can be used to determine which sources and pathways are most important. The use of inverse geochemical modelling can also be useful for evaluating the potential for groundwater flow between two or more known points.

These tools used in combination can provide multiple lines of evidence regarding the location and nature of the hydrological flowpaths that transport total and dissolved metals from mining-related sources to mountain streams. An understanding of the nature of the hydrological pathways is very important for appropriate geochemical modelling of metals transport. This paper presents the results of the application of these techniques at the Mary Murphy Mine, an abandoned precious metals mine in Southern Colorado. The results of these types of studies are very useful for helping to determine appropriate remedial actions.