INFILTRATION THROUGH A MINE-WASTE DUMP AND TRANSPORT OF METALS TO A NEARBY STREAM, CLEAR CREEK COUNTY, COLORADO[1]

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Abstract. Results of geophysical surveys, tracer studies, and synoptic sampling of the Waldorf mine site in Clear Creek County, Colorado, were used to evaluate the infiltration of adit water through a mine-waste dump to nearby Leavenworth Creek both before and after remediation in 2002. The common objective of these integrated studies was to evaluate metal transport from several mining-affected areas: notably the mine adit, mine-waste dump and adjacent wetland, and mill-tailings sediment. Trout are unable to survive in Leavenworth Creek downstream from the mine site because concentrations of copper and zinc exceed hardness-corrected acute and chronic standards for aquatic wildlife. Trout do survive in beaver ponds off of the main channel of the creek, which suggests that remediation to reduce metal loads might promote trout recovery in an 8-km reach downstream from the mine. Remediation in 2002 by rerouting of the adit around the waste dump was intended to improve water quality, but no discernable difference could be detected 1 year later. This study illustrates the need to develop a broad-based understanding of metal transport for an entire mine site in order to effectively improve stream quality.

Before the remediation in 2002, a NaCl tracer was used to measure the infiltration rate of adit water moving through the dump. The tracer was detected in seepage at the base of the dump in less than 24 hours, providing a maximum flow rate of 90 m/day. Flume measurements of braided surface channels flowing over the dump indicated that 43 percent of the adit discharge infiltrated the dump. Constituents that behaved conservatively in this system (Ca, Mg and Sr) helped to characterize different sources of water and the degree of mixing. Ground-water ages, determined by chlorofluorocarbon (CFCs) analysis, were 25 years for the adit and 15 years for the adjacent wetland area. Electromagnetic (EM) and direct current (DC) resistivity surveys conducted before and after remediation between 2002 and 2004 were used to map physical properties of the mine-waste dump, including preferential flowpaths of water moving through the mine-waste dump and contaminated wetland.

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Metal loading from several mining-affected inflows to Leavenworth Creek was determined from a LiBr tracer-injection study in 2002 and synoptic water-quality sampling of the stream and tributary inflows in 2003. Water chemistry of selected constituents such as Ca and Sr that behave conservatively in this system were used to (a) distinguish among different sources of mining-affected water, including the adit, mine-waste dump, and mill tailings; and (b) to quantify the relative contribution from each of these sources to a 930-m stream reach. Water-chemistry sampling and discharge measurements were repeated at selected sites in 2003 to compare zinc and copper loads before and after remediation.

Rerouting of adit water in 2002 was intended to improve water quality; however, the pre-remediation sampling results indicate that the dump was actually a net sink for most metals, including copper and zinc. This was not known until after remediation. Zinc and copper concentrations in adit water decreased after traveling across the dump and, in some cases, after traveling through the dump. The metals are thought to have sorbed onto manganese-oxide precipitates. The wetland area did not appear to have a significant effect on zinc concentrations, although the pH generally decreased between the waste dump and the wetland area.

Lastly, these studies indicate that the adit/waste-dump/wetland area is not necessarily the largest source of metal loading to the stream. Repeated sampling in different years indicates that metal loading from the adit/waste-dump/wetland area and from the leaching of the dispersed mill tailings are approximately equal. In the first year (before remediation) the tailings were the largest source, and in the second year (after remediation) the adit/waste-dump/wetland area was the larger source of zinc and copper in the creek. Contact of adit water with the dump material before remediation did not significantly affect the load(s) of either copper or zinc in adit water flowing to Leavenworth Creek. One year later, any changes that may have resulted from rerouting the adit flow were masked by higher adit discharge resulting from a larger snowpack.