# Geochemical behavior of trace metals in acid mine drainage: a case study of the Bugu stream in the Uljin Pb-Zn mine area

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Mining activities often produce acid mine drainage (AMD) which contains a high percentage of trace metals. AMD is produced by the oxidation of sulfides in mine wastes. This study was performed to understand the process(es) regulating the fate, transport and speciation of trace metals in AMD. The Bugu stream in the Uljin Pb-Zn mine area was chosen for this study. Orebodies of the Uljin Pb-Zn mine were formed by the contact metasomatism of limestones during igneous intrusion and yielded major ore minerals such as sphalerite, galena and chalcopyrite. AMD is produced from mine wastes that were dumped in and around the Bugu stream. The Bugu stream has a total length of about 3 km and flows into the Deokgu reservoir. Trace metal pollution of the Bugu stream has not been studied.

Water sampling for this study was conducted in May 2004. A total of 20 samples were collected from the Bugu stream and tributaries. In order to fractionate the metals into particulate, colloidal, and truly dissolved fractions, we used a successive filtration technique which consists of a conventional method (using 0.45 ㎛ membrane filter) and an ultrafiltration. A tangential-flow ultrafiltration method with a 10 kD membrane filter was used to determine the truly dissolved fraction of metals. To examine the geochemical speciation of trace metals, both ASV (Anodic Stripping Voltammetry) and geochemical modeling using a computer program PHREEQC were used. To examine the role of colloidal precipitation in the fate and behavior of trace metals, laboratory neutralization experiments were also conducted by mixing of WJ-4 (mine seepage; pH = 3.15) with WJ-20 (uncontaminated side tributary; pH = 6.89). Cations were analyzed by ICP-AES with USN and ICP-MS, while anions by IC.

Along the water course in the Bugu stream, mixing of the seepage water from mine waste dumps with uncontaminated side tributaries results in dilution and associated increase of pH (to near neutral condition). Concentrations of the dissolved metals are mostly negatively correlated with water pH: $R^2$=0.7981 for aluminum, $R^2$=0.5041 for iron, $R^2$=0.8375 for manganese, $R^2$=0.8026 for zinc, $R^2$=0.5291 for lead, $R^2$=0.3377 for copper, and $R^2$=0.5783 for cadmium. As a result, the concentrations of most metals in AMD decrease abruptly. In particular, Pb, Cd and Cu were removed rapidly from water due to pH increase. However, less reactive metals such as Zn and Mn were not removed rapidly. In downstream sites with near neutral pH, dominant portions of Al and Fe occur as colloidal and particulate fractions. About >95% of Cd and Cu appears to be effectively removed during the formation of colloidal and particulate Fe and Al, probably

due to adsorption and co-precipitation, whereas manganese and zinc do not effectively removed and maintains in dissolved fraction. The results of ASV analysis indicate that about 80-100% of Zn exist as electrochemically labile species in the stream. Geochemical modeling using PHREEQC indicates that Zn exist mainly as $Zn^{2+}$ and $ZnSO_4$. The results of mixing-neutralization experiments generally agreed well with field observations. The dominant fractions of Fe in mine drainage were changed with a progressively larger degree of the mixing with uncontaminated side tributary water (WJ-20): from mainly a 'dissolved' fraction in the water (pH = 3.15-3.32) with a small amount (<40%) of WJ-20, toward dominantly a 'particulate' or 'colloidal' fraction in the water with >40% of WJ-20 (pH = 3.32 to 6.89). When the WJ-20 water mixed significantly (>93%), pH of mine drainage increased to >4.70 and then Fe-colloids characteristically formed from water.

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Key words: AMD, Metal partitioning, Tangential-flow ultrafitration, ASV, geochemical modeling