Mass Transport Controls on Aluminum Removal in Limestone-Based Treatment Systems

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Abstract: Limestone dissolution is an essential process in a wide variety of acid mine drainage (AMD) treatment technologies. Although calcite dissolution rates have been well characterized under laboratory conditions, application of lab-based rate laws to field-scale treatment systems appear to systematically over-predict treatment effectiveness. This difference parallels the widely documented discrepancy between lab and field rates ―even after accounting for temperature and solution chemistry―for alumino-silicate minerals where explanatory factors include mineralogical impurities, complex surface geometries, surface armoring by secondary mineral formation, and biological influences. While all of these factors may play a role in AMD treatment effectiveness, it is also possible for limestone dissolution to be rate limited by mass transport. To assess the possible influence of mass transport on rates of limestone-based AMD treatment we have measured rates of limestone dissolution and metals removal for two systems―one in the field and one in the lab―both treating aluminum-dominated AMD. Focusing on aluminum-dominated AMD allows mass transport effects to be isolated from other complicating factors. The field system consisted of an open limestone channel treating an AMD discharge with an average acidity of 61.4 mg/L as $CaCO_3$ equivalent, pH 3.46, Al 7.3 mg/L, Fe 0.49 mg/L, and Mn 0.71 mg/L. The lab system consisted of a limestone column reactor with an influent solution of pH 3.3 and Al 20 mg/L. Both systems removed Al and increased pH even though effluent pH never exceeded 4.8. Both Al removal and Ca addition rates varied with volumetric flow rate in a manner consistent with mass transport limited dissolution. Moreover, removal of Al at low pH suggests a mass transport mechanism for precipitation of aluminum hydroxide. A geochemical model will be presented to synthesize the lab and field results as well as to draw out lessons for limestone-based AMD treatment system design.

Additional Key words:

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