Geochemical Controls on Limestone Utilization in Abandoned Mine Land Reclamation

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Abstract: The effectiveness of limestone in acid mine drainage (AMD) treatment is often underrated due to its tendency to lose efficiency over time. Acidic waters promote dissolution of limestone, thereby generating alkalinity. However, native metals also tend to precipitate. Precipitation of oxides, sulfates, and salts can form coatings on the limestone which act as chemical barriers, reducing the buffering capacity and inhibiting alkalinity generation. These interactions are highly dependent on the site-specific influent pH and mineral acidity, which fluctuate with the seasonal discharge. A fundamental approach to perceiving the long-term behavior of complex conditions within limestone-based treatments is to employ physio-chemical models which simulate the progression of rates over time and space. We present the first approximation to a fully coupled model for simulating chemical reactions between limestone and AMD in passive limestone treatment systems. A coupled model is developed in PHREEQC simulating conditions in either oxic or anoxic drains, over long time frames. Particularly, emphasis is placed on the modeling of reactive limestone surface area and drain porosity. Mineral reactions and iron redox reactions are modeled kinetically, and the loss of reactive limestone surface area and drain porosity are directly coupled to the formation of iron and aluminum precipitates. Decadal simulations are conducted and compared with historical chemistry data from an operating anoxic limestone drain in Indiana. The model successfully reproduced many characteristics observed in the field including reductions in acidity and aqueous metals and increased alkalinity over a time-span of 15 years, despite formation of oxides. Application of the model can be a valuable strategy in assessing feasibility, and forecasting long-term performance at other sites slated for reclamation. As modeling such as ours allows consideration and comparison of various design characteristics including length, cross-sectional area, velocity, and grain size, it may be useful in optimizing drain performance.

Additional Key Words: reactive transport modeling, armoring, kinetics, passive AMD treatment, limestone drains

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