Laboratory and field evaluation of limestone dissolution in passive systems for neutralization of acidic mine drainage

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Extended Abstract

Short-term closed-container (cubitainer) tests can be used to indicate limestone dissolution rates and the corresponding alkalinity of effluent as a function of detention time in a limestone bed for passive neutralization of acidic mine drainage (AMD). Various test configurations can simulate conditions closed to the atmosphere (underground system) or open to the atmosphere (above-ground system) and the effects of limestone purity, secondary coatings, and particle size on dissolution rate. Coupled with data on the flow rate and acidity concentration of the tested AMD, the cubitainer rate data can be used to estimate the long-term performance and minimum effective size of a limestone bed in an anoxic limestone drain (ALD) or comparable system.

Construction characteristics and data on influent and effluent composition were collected for 5 to 11 years at five limestone drains in Pennsylvania. Influent at the Morrison and Howe Bridge discharges in the Bituminous Coalfield had average pH of 5.3 and 5.8 and net acidity (= computed acidity – alkalinity) of 434 and 495 mg/L as $CaCO_3$, respectively. Influents at the Orchard, Buck Mtn., and Hegins discharges in the Southern Anthracite Coalfield were characterized by lower pH and acidity, with average pH of 3.5, 4.6, and 3.5 and net acidity of 30, 28, and 47 mg/L as $CaCO_3$, respectively. Effluent from each drain had higher pH, alkalinity, and Ca, and lower acidity, Fe, and Al concentrations than the influent. Although estimated detention time averaged 56 hours at Morrison, 22 hours at Howe Bridge, and less than 5 hours at the Orchard, Buck Mtn., and Hegins ALDs, net-alkaline effluent was produced from only the Orchard and Buck Mtn. ALDs. The long-term average flow multiplied by the difference between average concentrations of Ca for influent and effluent indicated average annual limestone dissolution rates of 1.0, 9.0, 1.5, 22.9, and 5.0 tonne/yr at the Morrison, Howe Bridge, Orchard, Buck Mtn., and Hegins drains, respectively. These annual dissolution rates have progressively declined with age of the systems as the limestone has been consumed.

For the five limestone drains in Pennsylvania, cubitainer tests with AMD influent from each of the sites indicated limestone dissolution rates were larger for high-purity limestone than for dolomite and for conditions closed to the atmosphere than open conditions, but the rates for fresh, uncoated versus environmentally exposed, metal-hydroxide-coated limestone were comparable for a given condition. The dissolution rates as measured by cubitainer tests, after corrections for surface area and fluid volume, were in agreement with field data for alkalinity and dissolved Ca production rate. Models developed on the basis of the cubitainer tests accurately revealed decadal-scale declines in limestone mass and corresponding alkalinity concentrations with increased age of a limestone treatment bed. Thus, cubitainer tests can be a useful tool for designing ALDs or similar systems and predicting their performance. Because a limestone bed could become plugged long before the limestone substrate has been consumed, engineering designs that are larger than the minimum size indicated by cubitainer tests and/or that incorporate provisions for flushing or replacement of the limestone bed could be warranted.

Suggested References

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