

Arsenic Remediation in Simulated Groundwater Using Zerovalent Iron: Laboratory Column Tests

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ABSTRACT

We performed three column tests to study the behavior of permeable reactive barrier (PRB) materials under dynamic flow conditions in the absence, as well as in the presence, of added phosphate and silicate. The column consisted of a 10.3-cm depth of 50 : 50 (w : w, Peerless iron : Oil Creek sand) in the middle and a 10.3-cm depth of a sediment from Elizabeth City, SC in both upper and lower portions of the 31-cm long glass column. The flow rate was maintained at 28 mL h⁻¹ during the three- to four-month experiments. Consistent with previous batch study findings, dissolved phosphate (0.5 or 1 mg P L⁻¹) and silicate (10 or 20 mg Si L⁻¹) showed strong inhibition for arsenate and arsenite (1 mg As(V) L⁻¹ + 1 mg As(III) L⁻¹ in 7 mM NaCl + 0.86 mM CaSO₄) removal by Peerless iron in the column tests. The presence of added phosphate and silicate resulted in earlier breakthrough ($\approx 0.5 C_0$) and earlier complete breakthrough of total dissolved arsenic relative to absence of added phosphate and silicate in the bottom port effluent. Phosphate and silicate were also removed by the PRB materials, especially by the Peerless iron. Competition between arsenate and phosphate (also silicate) for the sorption sites on the Peerless iron seems to be the cause of the observations. This effect is especially important in the case of silicate for designing a PRB of zerovalent iron for field use because silicate is a common chemical species in terrestrial waters and silicate is abundant in fly-ash. As expected, total dissolved As concentrations in different positions of the column followed the order: column influent > bottom port effluent > middle port effluent > top port effluent > column effluent. The steady state As removal in the middle Peerless iron and sand mixture zone may result from the continuous supply of corroded iron that serves as the sorbents for both arsenate and arsenite. Infrared spectroscopic examination of iron corrosion products revealed formation of carbonate form of green rust in each of the columns, which also was confirmed by X-ray diffraction. Sorption capacities for both arsenate and arsenite were determined for the Elizabeth City sediment, and the Oil Creek sand, local to Oklahoma. Arsenic sorption isotherms were fitted satisfactorily with Langmuir isotherms with the sediment showing greater maximum sorption capacity for As(V) than for As(III) at a pH range from 6 to 9; whereas, no detectable sorption of As was observed for the Oil Creek sand.