Heterogeneity Development and Its Influence on Long-Term PRB Performance

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Abstract: Despite significant degradation efficiencies of zero-valent iron (Fe^0) towards a wide range of contaminants, the operating life of a Fe^0-based permeable reactive barrier (PRB) is limited because of accumulation of mineral precipitates associated with Fe^0 reactions in groundwater. It is uncertain how mineral precipitation, gas production, and microbial activity cause the development of flow heterogeneity. In this controlled field study, we pumped site groundwater through large-volume columns filled with Fe^0 to monitor the changes of chemical parameters over time. Additionally, we conducted tracer tests to identify hydraulic changes and related these changes to chemical changes. Over a 14-month period, a significant change occurred in the chemical parameter profiles in the columns. The ionic profiles suggest that mineral precipitation and accumulation are the causes of pore clogging around the inlet of the column. The detailed tracer test showed the close relationship of hydrologic residence time to pH measurements. We concluded that during the early operation of a PRB, pH is a key indicator for monitoring the change in hydrologic residence time resulting from heterogeneity development.

Gas production and microbial activity were also investigated. Results show that the extraction of gases could liberate pore spaces for water flow and reaction. Microbial activity played a minor role in the early treatment of the Fe^0-PRB system. Overall heterogeneity in flow was caused mainly by mineral precipitation. According to this study, the development of flow heterogeneity (in addition to natural variation) should be detected near one-year operation of a PRB with a similar groundwater input. Such a development is important in estimating the long-term performance of the barrier.