Performance of a Deep Iron Permeable Reactive Barrier for Groundwater Remediation of VOCs

by

Grant Hocking, Samuel L. Wells and Rafael I. Ospina
Golder Sierra LLC
Atlanta, GA

(submitted to 2001 International Containment & Remediation Technology Conference, to be held June 10-13 at Orlando, FL)

ABSTRACT: Azimuth controlled vertical hydraulic fracturing technology constructed a full scale in situ iron permeable reactive barrier (PRB) at moderate depth at a Superfund site in south eastern Iowa for remediation of groundwater contaminated with chlorinated solvents, primarily trichlorooethene (TCE). The iron permeable reactive barrier was completed in late 1999 and was two hundred and forty (240) feet in length, three (3) inches in average thickness and constructed down to a total depth of seventy five (75) feet. The permeable barrier was constructed across the contaminated plume, perpendicular to the groundwater flow direction, and is a source control reactive barrier with the remnant plume downgradient of the PRB being naturally attenuated. Groundwater monitoring wells were installed prior to the PRB construction both upgradient and downgradient of the proposed PRB alignment. The groundwater monitoring wells have been sampled pre and post PRB construction for volatile organic compounds (VOCs) and other parameters to assess the performance of the PRB. Twelve (12) months of post-PRB groundwater monitoring data confirm the PRB is abiotically degrading the halogenated volatile organic compounds into harmless daughter products, ethene and ethane. The groundwater concentrations of VOCs downgradient of the PRB have declined at rates and are at levels close to or below those predicted during the PRB design stage.

SITE BACKGROUND

A former manufacturing facility in South-Central Iowa was contaminated with trichloroethene (TCE) in both the soils in the vadose zone and in the groundwater. Groundwater concentrations of TCE were detected up to levels of 14,000 ppb. The site consists of medium to fine channel sands underlain and overlain by over consolidated stiff to very stiff till. The sands are generally classified as medium to fine sand and characterized as loose flowing sands with a permeability of approximately 1 Darcy. The record of decision (ROD) was modified to incorporate an enhanced dual phase soil vapor extraction system in the vadose zone and an iron permeable reactive barrier (PRB) for groundwater remediation.

PROBABILISTIC DESIGN METHODOLOGY

The design methodology for the groundwater remedy involved a probabilistic design approach as outlined in Hocking et. al. (1998a) and further refined to incorporate both the degradation of VOCs within the PRB and by natural attenuation mechanisms active downgradient of the PRB. The methodology incorporates a probabilistic multi-specie VOC degradation model for degradation within the PRB and a probabilistic fate and transport model for VOC natural attenuation downgradient of the PRB, see Hocking et. al. (2001). At this Site, a PRB system of

3” in average thickness (the minimum thickness considered practical for placement) was deemed sufficient to reduce upgradient VOCs concentrations to below MCLs immediately downgradient of the PRB. Probabilistic distributions were assigned to all of the system’s parameters based on their expected variability. Degradation rates of the remnant groundwater plume downgradient from the PRB were quantified by the fate and transport model. A VOC soil column desorption test was conducted to quantify the desorption phenomena of VOC from the native soils. The desorption test data enabled predictions to be made of downgradient monitoring well performance and the time necessary to remediate the remnant downgradient groundwater plume to below MCL levels by natural attenuation.

PRB CONSTRUCTION

The Azimuth controlled vertical hydrofracturing technology, (Hocking, 1996, Hocking and Wells, 1997 and Hocking et. al. 1998b and c) was used for the installation of the PRB. The iron permeable reactive barrier system was constructed perpendicular to the groundwater flow direction and extended in depth to intercept the channel and horizontal sand units. The completed PRB required the injection of 115 tons of granular iron into the subsurface. The final geometry of the constructed PRB extended approximately 240 feet in overall length from a depth of approximately 25 feet down to a maximum depth of 75 feet. The as-built PRB had a cross sectional area of 7,040 sft, as determined from a composite of resistivity images/injections recorded during construction, and of an average iron thickness of 3”.

PRB PERFORMANCE

The measured groundwater contaminant concentrations in the two immediate downgradient monitoring wells GW-1 and GW-2 are shown on Figure 1 for one (1) year of monitoring data

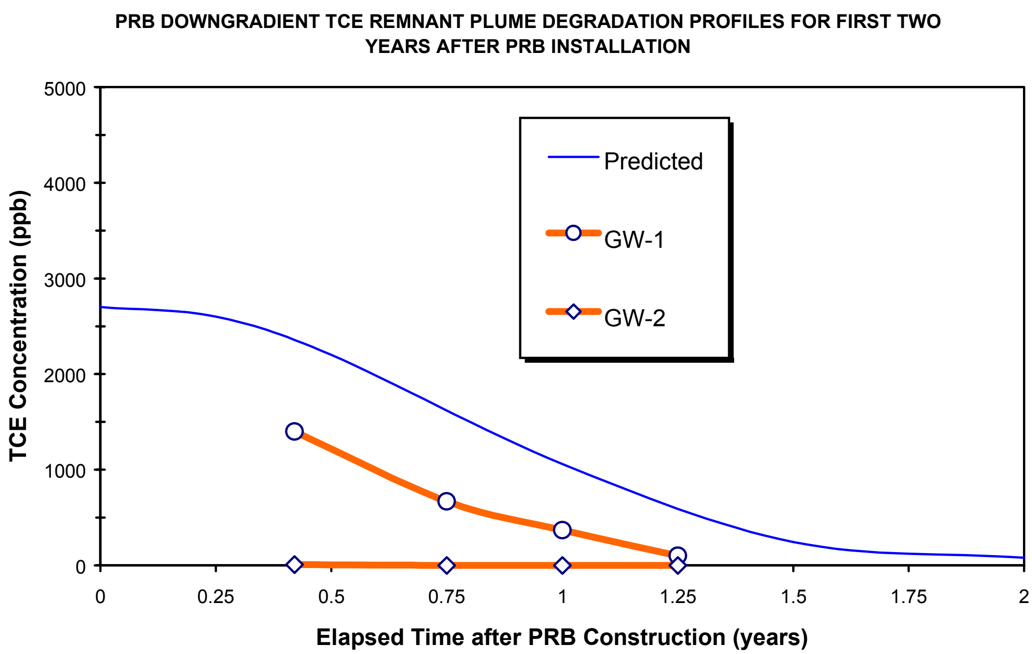

FIGURE 1. PRB Downgradient Groundwater Monitoring Data.

following PRB construction. The TCE concentrations in GW-1 are decreasing at the same rate as predicted but are at a lower concentration than the conservatively predicted trend line. All other VOCs in both of the groundwater monitoring wells were below their detection limits. The similarity in the trend rate of reduction of TCE as predicted and as measured provides confidence in the laboratory column reactivity and soil desorption test data. The PRB appears to be functioning as predicted and given the elapsed time of one (1) year since completion of the PRB construction and the close correlation between downgradient groundwater data compared to that predicted, the performance of the PRB is expected to continue functioning in the near term as designed.

CONCLUSIONS

The design methodology for the PRB incorporated a probabilistic multi-specie VOC degradation model for degradation within the PRB and a probabilistic fate and transport model for VOC natural attenuation downgradient of the PRB. Downgradient groundwater monitoring data one (1) year following PRB construction demonstrate that the PRB is functioning as expected. The prime benefits of the azimuth controlled vertical hydraulic fracturing installation method are cost savings over alternate installation techniques, flexibility to accommodate depth and thickness requirements, minimal site disturbance to overlying confining units and groundwater flow regimes, ability to be retrofitted if necessary, minimal waste volumes generated and deep application of the technology.

REFERENCES

Hocking, G. (1996). Azimuth Control of Hydraulic Fractures in Weakly Cemented Sediments. 2nd North American Rock Mechanics Symp, Montreal, A.A. Balkema, Rotterdam, pp 1043-1048.

Hocking, G. and S. L. Wells (1997). Oriented Vertical Hydraulic Fracture Iron Reactive Walls. ASCE Environmental Group Meeting, Atlanta, GA, March.

Hocking, G., S. L. Wells, and R. I. Ospina (1998a). Design and Construction of Vertical Hydraulic Fracture Placed Iron Reactive Walls. 1st Int. Conf. On Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA, May.

Hocking, G., S. L. Wells, and R. I. Ospina (1998b). Field Performance of Vertical Hydraulic Fracture Placed Iron Reactive Permeable Barriers. Emerging Remediation Technologies for Soil and Groundwater Cleanup, Florida Remediation Conf., Orlando, FL, November 10-11.

Hocking, G., S. L. Wells, and R. I. Ospina (1998c). Performance of the Iron Reactive Permeable Barrier at Caldwell Superfund Site. RTDF Meeting, Oak Ridge, TN, November 17-18.

Hocking, G., S. L. Wells, and R. I. Ospina (2000). Deep Reactive Barriers for Remediation of VOCs and Heavy Metals, 2nd Int. Conf. On Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA, May 22-25.

Hocking, G., S. L. Wells, and R. I. Ospina (2001). Probabilistic Design of Permeable Reactive Barriers, submitted to the 2001 Int. Containment & Remediation Conf, Orlando, FL, June 10-13.