Slower Than Expected Aquifer Cleanup: Back Diffusion or Something Else?

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Background/Objectives. Slower remediation is often expected from the site where the lower permeability (*K*) zone is significant. Remediation professionals have become aware that back diffusion of contaminants from lower *K* zones can increase the time required to meet cleanup goals. Mathematical models are available to describe the back-diffusion process and used to estimate the time to achieve cleanup goals. Semi-analytical/analytical models are popular methods for easy to use and quick estimation of cleanup time. However, we observed much slower cleanup compared to the estimated time from semi-analytical/analytical back diffusion models. Which field conditions other than back diffusion can make slower remediation?

Approach/Activities. Detailed site characterizations were conducted at a mild heterogeneous site including soil and groundwater sampling, tracer tests, and direct push logging with hydraulic profiling tool (HPT) and cone penetrometer testing (CPT). These results were used to develop flow and transport models for simulation of contaminant diffusion into lower *K* zones and back diffusion following source removal. Semi-analytical and numerical models were developed and tested by comparing measured and observed changes in downgradient concentrations following PRB installation. Contaminant source loading duration, travel time to receptor, mobile/immobile volume fraction, interfacial area, average thickness of low *K* zone, and sorption to high and low *K* material are the parameters considered for the model simulations. It is noteworthy that site characterizations imply the discontinued flow channel exists in the middle of the site due to the lower *K* materials, and semi-analytical model assumed continuous flow zone due to model restriction and numerical model implemented disconnected flow channel by geostatistical method.

Results/Lessons Learned: While back diffusion of contaminants from low *K* zones is a consideration at most sites, the disconnected flow channel intensifies the longer cleanup times. A semi-analytical model, that cannot realize disconnected flow zone, estimates faster cleanup times than field observation at a given site. In general, a semi-analytical model estimates over 3 order-of-magnitude (OoM) reductions in 4 years, but field observation shows 0.4~3 OoM reductions in 4 years depending on the monitoring location. Once disconnected flow channels are considered in numerical models, slower reduction observed in the field can be reproduced. We suggest that the disconnected flow channel should be considered and the measurement methods and implementation into the model are the future work to provide better estimate of cleanup time.