# Aquifer Plume Persistence Following Full-Scale Source Zone Remediation Due to Aquitard Back Diffusion with Insights on Degradation Effects

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**Background/Objectives.** It is well-known that contaminant diffusion into low permeability silt and clay-rich zones, commonly present within or at the base of sandy aquifers, can result in significant dissolved and sorbed mass accumulation over decades, often with the sorbed fraction dominating due to high organic carbon common in finer-grained sediments. This is generally accentuated given that dense non aqueous phase liquids (DNAPLs) preferentially accumulate along low permeability zones typically control the distributions in the aquifer, placing high concentrations from DNAPL dissolution at the interfaces with these low permeability zones where the mass storage capacity is large. Subsequently if source concentrations decline, either due to natural source zone depletion or engineered source zone reduction or isolation efforts, declining concentrations at the interfaces initiates back-diffusion releasing mass stored in the low permeability zones that can cause long term plume persistence in the aquifer. However, the occurrence of abiotic and/or biological degradation within these low permeability strata often with strongly reducing conditions can strongly reduce the longevity of back diffusion effects.

**Approach/Activities.** A detailed study is ongoing at a field site in South Carolina involving a heterogeneous sandy aquifer overlying a thin clay-rich aquitard, where small releases of mixed chlorinated solvent DNAPL from lab quality control testing occurred into a gravel-filled drain in the surficial aquifer decades ago. Dissolution of the DNAPL resulted in formation of a plume in the aquifer down-gradient of the source zone with diffusion into the underlying aquitard. In 2007 source zone remediation was implemented using in situ soil mixing with zero-valent iron and bentonite (ZVI-bentonite) to lower the hydraulic conductivity (source zone encapsulation) and enhance degradation. A 'rate of plume response' study was initiated in 2008 involving detailed high resolution multi-level monitoring along transects perpendicular to groundwater flow at two down-gradient positions and additional multi-levels along the plume center-line (i.e., longsect) with 3-D groundwater sampling performed six times over the next decade. Characterization of aquifer conditions and contaminant mass distribution was conducted in 2008-2009 using the membrane interface probe (MIP) and collection and detailed subsampling of continuous cores across the aquifer and into the aquitard. In 2018, a comprehensive field episode was conducted a decade after the source remediation to assess conditions within the treated source zone and downgradient plume, including subsampling of continuous cores near previous locations, magnetic susceptibility for ZVI distribution, combined MIP-HPT (Hydraulic Profiling Tool) characterization, microbial assessment and compound specific isotope analyses (CSIA) on groundwater and core samples.

**Results/Lessons Learned.** The various high-resolution datasets provide exceptional insights into contaminant mass distribution in the aquifer and underlying aquitard, showing that, while reduction in downgradient plume concentrations is occurring, back-diffusion is a strong contributor to plume persistence, as well as incomplete treatment in the source area. Strong degradation is occurring within the aquitard, which is expected to reduce the magnitude and longevity of back diffusion and enhance aquitard integrity by reducing contaminant flux into the deeper aquifer. This presentation will discuss insights from the various high resolution measurements for a multi-process-based site conceptual model improving decision making.