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Opposites Attract

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Contaminated site cleanup has commonly been accomplished by deployment of just one remediation technology. This one technology was expected to be effective and applicable over the entire life of the remediation. As our collective experience and knowledge base has expanded, this paradigm has shifted and coupling of multiple technologies in time or space has become the norm. This is because contaminated sites typically include a variety of contaminants with different treatability characteristics, distributions, and mass fluxes, which change over time and with remediation progress; and hydrological and geological regimes may vary significantly across a site. The Interstate Technology & Regulatory Council recently issued a document entitled, *Integrated DNAPL Site Strategy* (November 2011) that addressed those complexities and how to couple remediation technologies to provide a more effective and less costly cleanup of contaminated sites. A key point was that technologies that were commonly considered incompatible can be successfully coupled with careful consideration of the design. Two examples are outlined below: in-situ chemical oxidation (ISCO) followed by anaerobic bioremediation (ABIO) (sequential coupling of technologies), and ISCO treatment of a source area with in-situ chemical reduction (ISCR) treatment of a downgradient plume area (simultaneous coupling of technologies).

Oxidants and other reagents utilized in ISCO generally have antimicrobial properties. There is little doubt that the use of oxidants results in a significant initial reduction in microbial activity. However numerous lab and field studies have shown that the geochemical shifts associated with ISCO are transient; microbial activity resumes and often exceeds pre-ISCO levels once the geochemical shifts are ameliorated by the natural capacity of the aquifer. One well-studied example is Site 11 at the Kings Bay Naval Submarine Base (Chapelle et al., 2005). The aquifer was anaerobic and natural degradation of chlorinated solvents was occurring, but source reduction was desired to speed the remediation and prevent contaminants from migrating offsite. After ISCO treatment of the source area with catalyzed hydrogen peroxide, the aquifer was left in a very oxic state. Samples collected one week after treatment indicated little microbial activity. However, samples collected six months after the ISCO showed that anaerobic conditions had returned and microbial activity recovered to a level exceeding pre-treatment conditions. The oxic conditions did not persist and natural attenuation returned. Subsequently, emulsified vegetable oil was injected in the ISCO treatment area to further enhance ABIO. The site has reached maximum contaminant levels at the downgradient property boundary, and full regulatory closure is expected soon (EPA, 2009).

The second case is a site at which ISCO is being utilized in a concentrated source area and ISCR is being simultaneously utilized in the downgradient plume area (Bryant et al., 2013). A persistent source remained after previous remediation efforts, and a groundwater plume approximately 900 feet long extended from the source area and affected offsite property and surface water. Rapid source area treatment was conducted by hydraulically emplacing potassium permanganate solid slurry for ISCO. For the plume, construction is in progress for three zero valent iron (ZVI) barriers for ISCR, also injected as solid slurry. The primary design concern for coupling ISCO and ISCR was that groundwater containing dissolved permanganate would reach the first ZVI barrier, destroying the permanganate and prematurely oxidizing the ZVI. Laboratory analyses were conducted to assess the natural oxidant demand from the formation. Those results were coupled with permanganate fate and transport models to assess permanganate degradation before reaching the first ZVI barrier. A field pilot test was conducted and monitored for almost two years and confirmed that the permanganate was attenuating as desired. The source area ISCO treatment was completed and the plume-area ZVI treatment is under construction.

Many other, similar combinations can be envisioned. The key requirement for successful deployment of coupled technologies is careful consideration of the transient nature of the geochemical and hydrological conditions associated with each technology. Soils and aquifers have a large capacity to absorb and attenuate geochemical shifts associated with remediation. Aquifers are very dynamic systems, and ground water migrates into and out of treated areas. Microbial populations will re-equilibrate once treatment has ended and the geochemical shifts are attenuated. The complexity of contaminated site remediation calls for thinking outside the box and developing new and innovative remediation approaches.

References for this article are available upon request.

For additional information regarding this article, please contact Dr. Dan Bryant.

You can also find this article in the February 2014 Edition of the magazine Pollution Engineering.

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