INNOVATIVE REMEDIATION STRATEGIES AT REDEVELOPMENT SITES

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Brownfield sites with complex physical settings, such as weathered or fractured bedrock and deep contaminants, complicated chemical and physical composition of contaminants, and operating or redevelopment complications, can pose problems for the effective use of traditional remedies. The conditions at these sites make it difficult to reach end-point remedial goals. In addition, unique source distribution of multiple contaminants often leads to ineffective or inefficient use of traditional remedies. These challenging sites require innovative remedial technologies and creative thinking to reach remediation goals and allow redevelopment to occur on schedule and on budget. Of course, proper characterization and delineation of contamination are essential for the successful use of innovative remedies, just as they are for traditional cleanup approaches.

Traditional remediation strategies for treating volatile organic compounds (VOCs) have greatly evolved over the last 20 years. Newer treatments focus on contaminant destruction, rather than reduction by such traditional remedies as pump and treat or soil vapor extraction. Innovative contaminant destruction, along with chemical and biological manipulation techniques, are creatively designed to successfully achieve best-value outcomes (regulatory closure) for responsible parties. Treatability and design pilot testing is performed in order to help develop, screen, and provide detailed feasibility evaluations of innovative remedial solutions for impacted sites. Full-scale remedial strategies often incorporate multiple technologies for achieving source reduction and plume migration control objectives and are combined with appropriate risk and engineering controls to prevent potential contaminant exposure under the intended redeveloped or future use scenario for a site. This article examines three Brownfield projects and how treatment of VOCs required creative remedial approaches to conquer the challenges posed at each of the sites and allow redevelopment to proceed.[1]

Demonstration Projects

CVOC Combined Remedy in a Fractured Bedrock Setting—Missouri

This 330-acre site was used for telecommunications manufacturing since the 1950s and had numerous areas of solvent and cutting oils storage, handling and disposal across the one-million-square-foot building interior. The scale and size of the multiple source areas and their proximity to off-site receptors posed significant challenges to the cleanup design. In addition, the site was in the process of being redeveloped into a corporate/university office center and was occupied and being converted during the cleanup. Thus, the remedial actions had to be coordinated with redevelopment actions and use of the building. The geology of the site consists of weathered bedrock near the surface that becomes less weathered (i.e., more competent) at depth added complexity, but also was integral to the success of the final remedial design.

Both traditional remedial strategies (soil vapor extraction, soil excavation and disposal, groundwater use restrictions and institutional controls) and an innovative engineered funnel and gate (F&G) permeable reactive barrier (PRB) were implemented to control or eliminate exposure to chlorinated volatile organic compounds (CVOCs). Use of institutional controls, an engineered barrier, focused soil excavation and disposal, and the F&G PRB (engineering control) was selected based on its ability to prevent and/or eliminate exposure to CVOCs via soil leaching to groundwater, groundwater ingestion, dermal contact and inhalation exposure pathways, and the groundwater ingestion exposure pathway at multiple source areas.

An F&G is essentially the installation of impermeable “wings”—slurry wall funnels that direct groundwater to the treatment “gate” located at the leading edge of a groundwater plume. The gate is where a chemical reducing agent (in this case, zero valent iron) is applied that reductively dechlorinates the CVOCs to innocuous by-products. A key to this design is a hard, geologic bottom “key-in” layer for F&G construction preventing the contaminants from flowing across and not migrating vertically. In this case, an F&G PRB trench, consisting of a 950-foot-long main funnel and gate system, and 50-foot-long upgradient pilot performance trench, were installed in a fractured bedrock aquifer. Trench construction involved installation of an 8-foot-deep excavation bench cut in the soil overburden to facilitate a stable work platform for trenching the underlying bedrock. An 18-inch-wide trench cut was installed in the remaining shale/limestone bedrock in order to key the PRB into the underlying crystalline limestone. PRB construction and site restoration were completed over a six-month period, followed by a three-year PRB performance groundwater monitoring period with monitoring wells installed in the pretreatment area, the treatment area (the gate) and the downgradient, post-treatment area. Performance monitoring results indicated greater than 99 percent (%) reduction of CVOC within the PRB and prevention of off-property plume migration. Following the performance monitoring period, the site received a Certificate of Completion from the Missouri Department of Natural Resources.

In-Situ Chemical Reduction via Soil Blending and Direct Injection - Kansas

CVOC contamination was identified at a rail car cleaning facility in Kansas based on historical process water management activities. Spent chlorinated solvents (mainly 1,1,2-trichloroethane (TCA)) from rail car cleaning operations were historically stored in surface impoundments, resulting in soil and groundwater contamination beneath a former “Dirty Pond” source area. Free-phase dense non-aqueous phase liquid (DNAPL) was indicative based on 1,1,2-TCA groundwater concentrations greater than 1 million parts per billion (ppb). This extremely high concentration of contamination is very hard to address with conventional remedial systems, which have limited capacity to achieve regulatory objectives. The high levels of TCA and DNAPL combined with complex geology, consisting of 20 feet of unconsolidated soil and a weathered bedrock barrier sitting on top of competent bedrock, were the significant variables leading to an innovative remedial design.

Greater than 135,000 pounds of *in situ* chemical reducing (ISCR) “cocktail” were applied to the source area to dechlorinate the TCA parent compound. Unlike the treatment application in the gate described in the F&G remedy above, the ISCR agent was blended with contaminated media because the source area was an open area without operational or building constraints. ISCR remediation success is predicated on being a “contact sport.” Blending of the impacted aquifer materials aggressively increases the contact of the ISCR agent with the contaminants. In this case, the contractor used specially-built, proprietary soil blending equipment attached to a track backhoe excavator. The ISCR agent selected for this application consisted of lactates, fatty acids, alcohols, a phosphate buffer, and zero valent iron (i.e., Redox Tech’s ABC®+ product) and was designed to enhance reductive dechlorination of TCA and its breakdown products. *In situ* blending ensured even agent distribution and contact with the impacted aquifer media down to underlying bedrock. An additional 24,280 pounds of ISCR agent were applied through 147 Geoprobe® injection points immediately downgradient of the soil blending (former Dirty Pond) source area to help control migration of the dissolved plume area. Approximately 18 months after remedy implementation, concentrations of key CVOCs had been reduced by greater than 99.9% in the source area monitoring wells. The reuse transaction for the site closed and the new tenant’s operations were able to proceed during the remediation and performance monitoring process.

Combining Multi-Source Area Removal and ISCR at a Former Chemical Distribution Facility - Indiana

This site was a former chemical manufacturing facility that was the anchor parcel for an industrial park redevelopment project. A series of subsurface (soil and groundwater) investigations at the site indicated that the shallow soil and groundwater contained VOCs at six (6) source area releases. The VOCs at the site consisted primarily of chlorinated solvents, including trichloroethylene (TCE), TCA, tetrachloroethylene (PCE), and the associated daughter breakdown compounds, such as cis-1,2-dichloroethylene (cis-1,2-DCE) and vinyl chloride. However, given the various historic operations at the site, chemical distribution was difficult to clearly delineate and generally assumed to be spread across the site. Given the clay geology, making extraction of fluids and vapors with traditional methods difficult, excavation was determined to be the most effective remedy. The use of a site-wide grid for soil sampling combined with innovative ex-situ treatment to reduce concentrations to non-hazardous disposal criteria led to a very cost-effective and timely remediation.[2]

A 10-foot-square site sampling grid and an on-site mobile analytical laboratory were utilized to collect and analyze over 900 soil and groundwater samples in real time in order to delineate six CVOC source areas and facilitate *in situ* waste characterization of soils. Based upon the remedial pilot test results, feasibility analysis, and remedial objectives for the site, a combined strategy of source removal via soil excavation, limited *ex situ* ISCO treatment of characteristically hazardous soils, ISCR treatment of groundwater and institutional controls was selected and implemented to achieve approved regulatory closure in a practical and cost-effective manner. Excavation of over 15,900 tons of CVOC-impacted soils was completed in six remediation areas of concern. The risk-based soil Remedial Objectives (RO) for TCE for subsurface and surface soils were 36 mg/kg and 24 mg/kg, respectively. Greater than 1100 tons of soil were determined to be characteristically hazardous, and were therefore treated *ex situ*, utilizing chemical oxidation for disposal as a nonhazardous, special waste. This allowed for a disposal cost savings of approximately $300,000. Over 12,300 gallons of ISCR amendment (Anaerobic BioChem® with zero valent iron) were injected at 42 locations within the former excavation areas and along downgradient property boundaries. Greater than 85 percent of the contaminant mass was estimated to be removed based on the RO and remediation implementation. The site has been remediated and sold as the anchor parcel in a 62-acre industrial park redevelopment.

Conclusion

The above-described projects illustrate the importance of integrating available technologies with creative design and redevelopment goals, so that innovative solutions achieve best results for the project. Cost and time savings can be achieved with creative thinking and holistic planning by consultants, lawyers and clients for successful project completion.

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Endnotes

[1] USEPA's *Innovative Remediation Technologies: Field-Scale Demonstration Projects in North America, 2nd Edition*, 542-B-00-004, 2000, provides a cumulative collection of projects where best practices of innovative technologies were used and a holistic look at the evolution of remediation technologies in real world settings.

[2] Other remedial approaches, such as thermal/steam extraction, were determined to be 2.5 times more expensive than the gridding, excavation and *ex situ* treatment option chosen for the site.