Combining Remediation Technologies for Complex Hydrogeological Sites Impacted by Chlorinated Solvents (Brazil)

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Background/Objectives. Groundwater in a complex hydrogeological site at an inactive appliances manufacturing plant located in Sao Paulo City, Sao Paulo State (Brazil site), is impacted with dissolved chlorinated volatile organic compounds (CVOCs) including perchloroethylene (PCE), trichloroethylene (TCE), cis-1,2-dichloroethylene (1,2-DCE), vinyl chloride (VC) and 1,1,2,2-tetrachloroethane (1,1,2,2-TCA). PCE was present at the highest concentration in groundwater (>200,000 µg/L) and in soil (4,000 µg/kg). Investigations showed CVOC plumes covering approximately 10,474 m^2 with 13 m thickness (from 4 to 17 mbgs). Additionally, DNAPL was found in some portions of the area. The hydrogeological model showed highly complex lithology with highly contaminated clayey layers crossed by permeable sand lenses, with considerable horizontal continuity, ranging from 0.5 to 3.0 meters thick. The sandy layers were responsible for most of groundwater flow and contaminant transport.

Approach/Activities. After understanding the complex hydrogeological model of the area. The aquifer was divided into hydraulic levels, confined by the clayey layers. The shallow aquifer was most important considering the potential of vapor intrusion inside the area. The remediation approach considered a synergetic combination of multiple techniques that included soil excavation and in situ chemical reduction (ISCR) aiming to remediate the site within 24 months enabling a future residential occupation. Additionally, multi-phase extraction (MPE) was employed for DNAPL recovery and soil vapor extraction (SVE) was implemented to control vapor intrusion at occupied areas. The ISCR approach was the subject of field-scale pilot testing for site-specific process optimization, gathering data for future full-scale remediation. Following a successful pilot-test, the full-scale remediation included excavation and off-site disposal of approximately 11,700 metric tons of contaminated soil (mainly clay), and in situ groundwater treatment by reactive Provect-IR® Antimethanogenic ISCR amendment (containing ca. 40% weight basis mixed-grade ZVI + multiple organic carbon sources + other reagents). The ISCR amendment was applied via 453 multilayered, direct-push injection points, resulting in 270 metric tons of product injected. Monthly measurements of physical-chemical parameters were performed to evaluate the reactive zone during injections.

Results/Lessons Learned. Remediation efficiency was quantified by contaminant mass and concentration reduction targeting remediation goals at multiple monitoring well locations. After 24 months following remedial activities, groundwater analytical data confirmed remediation efficiency with all compounds of concern (COC) below target levels calculated by human health risk assessment. Specifically, CVOCs total contamination mass was reduced from 221.35 kg to 67.07 kg (>70% reduction), with no groundwater samples above target levels. For most of the monitoring wells inside the area, ORP values remained between -50 and -100 mV (AgCl electrode), indicating the maintaining of reactive environment conditions created by amendment injected that should support continued, long-term removal of residual mass. Cost and performance monitoring of the remedial program will be reviewed that confirm the efficacy of the implemented approaches.