Pushing the Edge of Practicable: Engineered Methods for Non-Ideal Aquifer Conditions for Enhanced In Situ Bioremediation Remedy

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Background/Objectives. An approximate 2.3-acre area of elevated TCE concentrations, upwards of 180,000 µg/L, were identified within overburden groundwater at an active manufacturing facility that necessitated remediation to achieve the remediation objectives of the maximum concentration limit (MCL) of 5 µg/L. The TCE surface release migrated into the degraded shale overburden and spread due to lithological structure mimicking the strike and dip of the underlying bedrock. The overburden aquifer groundwater was of low pH in the range of 3.5 to 5.9 pH units, aerobic with dissolved oxygen above 7 mg/L and positive oxidation-reduction potential (ORP) upwards of ~700 mV, and predominately of low permeability with hydraulic conductivities of ~$5x10^{-8}$ cm/s. The requirement and objectives consisted of reducing the concentrations of TCE to or below the MCL and application of a remedial technology that could address both matrix diffused TCE within the lower permeability clay and the non-ideal aquifer conditions for in situ remedies.

Approach/Activities. The remediation applied was enhanced in situ bioremediation (EISB) consisting of the application of emulsified vegetable oil (EVO) and dehalococcoides (Dhe). Given the non-ideal aquifer conditions, a pilot scale 100-foot trench application was employed above the bedrock, filled with clean sub-rounded gravel and four 4-inch application wells with 5-foot screens within the saturated depth interval of the overburden aquifer. This allowed for gravity drainage of ~ 30 feet of head pressure necessitating gradients for lateral spread of the applied EISB components within the higher transmissive sand lenses intermixed between the lower permeability zones, and then matrix diffusion into the clay due to the longer life of the EVO within the subsurface. A sodium bicarbonate buffered EVO (RNAS Newman Zone Buffered Non-ionic formulation) was used that was supplemented with additional sodium bicarbonate (both powered and later RNAS Neutral Zone) to address the lower pH conditions and KB-1® Primer to anaerobically condition the application water. The bioaugemention consisted of using Dhe culture (SiREM KB-1® Plus), and was applied within the feed to the trench under a nitrogen blanket in a “layer-cake”-like application of buffered EVO with KB-1® Primer, sodium lactate (JRW WilClear Plus™), KB-1® Plus Dhe, sodium lactate, and then buffered EVO with KB-1® Primer.

Results/Lessons Learned. TCE concentrations were reduced to the MCL in a few wells but many are substantially above. Lateral spread was observed >50 feet and also into the fractured bedrock based on visual of EVO in wells and total organic carbon (TOC) laboratory analysis. Constant application of pH buffer raised the strongly acidic conditions of the overburden aquifer above 5.5 pH units was a struggle for some of the wells but once achieved reductive dichlorination occurred. Similarly, the application of strongly reduced anaerobic water with each EVO batch aided in changing the aerobic aquifer to slightly anaerobic with ORP and DO of ~-50 mV, and ~0.5 mg/L, respectively. Dhe populations were prevalent throughout the study area with populations greater than 50 feet laterally of 10^5 enumeration/liter ~6-months after inoculation. Maintaining these conditions had to be continuous or dichlorination was hampered if not stopped. EISB can be engineered to overcome non-ideal conditions, but is excessive effort considered a success or failure.