Successful Bioremediation of Carbon Tetrachloride

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Background/Objectives. Carbon tetrachloride (CT) is a toxic, carcinogenic compound widely used as a general solvent in industrial degreasing operations and a common groundwater contaminant. CT can be degraded under anaerobic conditions to chloroform (CF), dichoromethane (DCM) and non-chlorinated end products. While metabolic (i.e., energy yielding) degradation pathways for CT are not widely reported, CT is degraded both cometabolically and abiotically to CF and DCM with breakdown products often representing more significant remediation challenges than CT itself. CF, for example, is highly toxic and inhibits microbial metabolism. Fortunately, anaerobic metabolic reduction of CF to DCM and DCM fermentation to non-chlorinated end products has been reported. Furthermore, a Dehalobacter dominated culture that actively degrades CF and DCM via similar pathways has been developed. These well documented pathways, and available amendments, makes remediation of CT contaminated sites increasingly approachable and feasible.

Approach/Activities. Our knowledge of CT remediation has been expanded by a series of bench scale studies, field application and the development of bioaugmentation cultures capable of degrading chlorinated methanes. These cultures have been evaluated in several bench-scale studies that have proven invaluable in identifying the conditions compatible with bioremediation success for chlorinated methanes. In a karst aquifer site in the United States CT was detected at up to 25,000 µg/L, far exceeding its aqueous solubility indicating the presence of dense non-aqueous phase liquid (DNAPL). At another site (mixed CT/TCE site in the mid-west) a treatability study was performed to assess the feasibility of overcoming inhibition of TCE degradation by chlorinated methanes and the effectiveness of different donors as well as zero-valent iron (ZVI) and ferrous fumerate combined with bioaugmentation.

Results/Lessons Learned. The mid-west CT/TCE site study results indicated conversion of CT to CF was enhanced by ZVI addition. ZVI mediated degradation was followed by slower removal of CF and DCM to non-chlorinated end products via enhanced bioremediation. Notably, the complete dechlorination of the chlorinated ethenes to ethene was delayed until declines in chlorinated methanes were observed; presumably due to inhibition by CF. Based on promising treatability data a site pilot test was implemented.

At the karst aquifer site, the bench-scale treatability study indicated that CT could be degraded to innocuous end products using emulsified vegetable oil and bioaugmentation. In the subsequent field demonstration, dechlorination of high CT concentrations was observed and bioremediation was evident from increases in key dechlorinators (Dehalobacter) combined with reductions in daughter products (CF and DCM). Repeated bioaugmentation/biostimulation amendment additions were required, in part due to the hydraulics of the karst aquifer and CT from upgradient entering the bioactive zone. Even with the challenges of high CT concentrations and fractured rock matrix the concentration of CT reached non-detect or near non-detect levels in the two main monitoring wells within four years of active remediation.