Development of an Adaptive Framework for Optimizing Bioremediation Implementation at a Fractured Bedrock Chlorinated Solvent DNAPL Site

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Background/Objectives. Enhanced in situ bioremediation (EISB) has been implemented at a former manufacturing site in Australia where historical releases of chlorinated solvent dense, non-aqueous phase liquids (DNAPLs) resulted in DNAPL trapped within the basalt bedrock and persistent groundwater contamination in the fractured basalt aquifer. Over time, the source areas have resulted in a plume that has a mixture of chlorinated ethenes, ethanes and methanes, including chloroform (CF) at concentration ranges that may be inhibitory for bioactivity in some areas. As part of the ongoing efforts to optimize the EISB program, performance data from up to 10 years of EISB implementation was evaluated to better understand the overall impact of the historical remedial activities on the DNAPL sources and plumes and identify potential optimization opportunities. Specific objectives included identifying residual DNAPL sources remaining based on contaminant response to the EISB program, quantifying changes in concentrations of constituents of interest (COIs) in response to various remedial programs, assess the overall effectiveness of the EISB program in reducing mass remaining on site, and develop an adaptive framework for EISB implementation moving forward to meet cleanup goals.

Approach/Activities. Since 2011, full-scale EISB has been implemented through injection of an amendment solution containing propylene glycol (PG) as the electron donor. Over this timeframe, a total of approximately 350 tonnes of PG was injected across two DNAPL source areas on site. Following PG injections, recirculation was initiated to enhance donor distribution, partially contain the impacted groundwater on site, and to enhance dissolution of DNAPL. Annual groundwater monitoring events (GMEs) have been undertaken since the initiation of the EISB program to monitor the effectiveness of the remedial programs. This historical dataset of annual GME groundwater data from initiation of EISB in 2011 through 2021 was compiled and evaluated for completeness and accuracy as part of a data mining exercise. Once the dataset was confirmed, spatial and temporal trends were evaluated to understand historical EISB performance and identify areas of COI mass persistence, donor limited conditions, and potentially inhibitory concentrations of CF.

Results/Lessons Learned. During the 10-year period of operation of the EISB program to date, the average concentrations for individual COIs have reduced between 75% to 99.9% compared to pre-EISB baseline levels. Within the active EISB treatment areas, optimal conditions for active biodegradation were observed, as well as trends consistent with active biodegradation, including the classical stepwise reduction of parent products concurrent with increasing daughter products, then reductions of daughter products, including vinyl chloride. Methane generation became more prominent with reduction of CVOC concentrations in some areas, with some wells recently experiencing significant degassing of methane during sampling. The historical data analysis provided insight into areas of the site that had been effectively cleaned up over time and no longer warranted active treatment and also helped to identify areas where rebound was recently being observed due to electron donor depletion and/or elevated CF concentrations that may be inhibiting bioactivity. The adaptive framework will focus injections

into areas of mass persistence only and minimize donor injections into cleaner areas to mitigate methane generation. A bioaugmentation trial is proposed to mitigate potential CF inhibition.