Downgradient Thermal Front Migration and Enhancement of Plume Area In-Situ Bioremediation after Thermal Source Area Remedy

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Background/Objectives: We present modeling and field data for downgradient migration of elevated groundwater temperatures associated with a source area thermal remedy, and the influence of the thermal front on a combined anaerobic bioremediation / chemical reduction remedy implemented in the proximal portion of the downgradient plume. An in situ thermal remedy was implemented for a chlorinated volatile organic compound (CVOC) source area at a site in Elizabeth, New Jersey. Two permeable reactive barrier zones (PRBZs) were constructed in the proximal portion of the plume area to reduce downgradient CVOC mass flux. An additional objective was to take advantage of enhanced CVOC desorption and increased microbial activity associated with elevated groundwater temperatures downgradient of the thermal treatment area. The PRBZs utilized a combined reagent to enhance in-situ chemical reduction (with zero valent iron) and an organic carbon substrate to enhance anaerobic bioremediation. Groundwater modeling was utilized to assess downgradient migration of the thermal front associated with the source remedy, groundwater temperatures in the PRBZs, and the potential effects of elevated groundwater temperature on the biotic and abiotic reaction mechanisms.

Approach/Activities: A MODFLOW model originally developed for contaminant fate and transport for the site and proximal portion of the downgradient plume area was converted into a heat transport model to evaluate the evolution of groundwater temperature over time and distance from the thermal treatment area. The heat transport equations are analogous to the contaminant transport equations used in MT3DMS. The resulting maximum groundwater temperatures and their evolution over time were evaluated at the PRBZ locations.

Results/Lessons Learned: One of the primary questions associated with coupling the plume area PRBZ remedy with the source-area thermal remedy was if groundwater temperatures at the PRBZs would exceed ranges conducive to microbiological activity (approximately 35°C). Model results indicate that a temperature increase of approximately 15°C at the center (to maximum groundwater temperatures of approximately 30 to 35°C) can be expected. The heat front covers nearly three quarters of the plume’s width and all its length through both PRBZ zones. Groundwater temperatures in the PRBZs peak shortly after the thermal system reaches its maximum run time, and are anticipated to dissipate slowly over a period on the order of approximately 300 days. Based upon Arrhenius equation considerations, warmer groundwater temperatures in the PRBZs are anticipated to increase biological activity and ZVI reaction rates by approximately one to two orders of magnitude. The thermal remedy will be in operation in September 2017 and construction of the PRBZs is anticipated by early spring 2018. Monitoring will include groundwater temperature to calibrate and check the model, groundwater geochemical characteristics to evaluate the evolution of redox conditions and microbiological activity in the PRBZs, and the ultimate effectiveness of combining a source-area thermal remedy with a plume-area combined biotic and abiotic remedy, to optimize use of the downgradient heat transport to increase desorption and biotic/abiotic reaction rates.