Calculation of Biodegradation Rates above and below the Water Table

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Background/Objectives. Following 20 years of LNAPL recovery, an improved remedial approach is desired. Bioventing is being applied to an area with LNAPL impacts both above and below the water table in order to enhance biodegradation in the vadose zone and to assess the impact of bioventing in the smear zone as part of a pilot-scale system. The approach is intended to preferentially degrade contaminants that drive risk. The area where bioventing is being applied has: a surficial clay barrier extending to approximately 10 feet below ground surface that limits vertical vapor transport; a water table at approximately 30 feet bgs; and LNAPL impacts extending to 60 feet bgs due to historical groundwater pumping. Quantification of biodegradation rates is needed to assess system performance. Sparging, vapor extraction and bioventing were all considered as methods to enhance biodegradation during this phase.

Approach/Activities. A conceptual model to evaluate methods that were appropriate to measure background NSZD rates as well as enhanced degradation rates was developed. Lines of evidence included microbial RNA and DNA, dissolved gas sampling, soil gas monitoring/sampling, temperature, and respiration testing. Soil gas advection and diffusion were evaluated with helium tracer testing. Many of these approaches needed to consider the non-ideal nature of site conditions. Surface efflux, soil gas gradient and temperature measurements of NSZD were all inhibited by subsurface heterogeneity. A sandy aquifer and vadose zone is overlain by a clay layer that remains sufficiently moist throughout the year to result in a trapped methane layer where lateral diffusion/advection is the dominant process.

Results/Lessons Learned. Calculation of aerobic degradation using typical respiration testing or temperature gradient calculation methods is complicated by the continuous generation of methane in the saturated zone; oxygen consumption near the water table can be dominated by methane oxidation, especially during low water tables. The oxidation of methane also generates heat which can add uncertainty to the temperature gradient methods. As temperatures in the impacted vadose zone increased to >35 deg C due to the enhancement of aerobic biodegradation due to bioventing, temperatures also increased at depths of over 20 feet below the water table, leading to higher rates of methane generation from anaerobic biodegradation.

Biodegradation rate quantification required using both oxygen depletion and methane generation rates, quantified through respiration testing, to estimate a total hydrocarbon degradation rate. Oxygen depletion in locations where methane was present was assumed to be due to methane oxidation and was not included in aerobic respiration calculations. During aeration of vadose zone, soil vapor data combined with dissolved gas results indicated the majority of methane produced originated from the saturated zone. The nested vapor monitoring probe network, which includes vertical spacing of approximately 2 feet across the water table, was able to confirm the conceptual site model used to generate the calculation method, with methane present in probes directly above the water table and higher oxygen depletion rates. Vapor probes in the vadose zone where bioventing had created an aerobic zone did not contain methane, and oxygen depletion could be attributed to aerobic respiration.

The enhanced biodegradation rates calculated using the methods developed are consistent with increased microbial activity and changes in COC concentrations above and below the water table. Results show monoaromatic BTEX hydrocarbons degrading preferentially with system operation. Pilot-scale results are currently being assessed for design of larger scale system(s) at the site.