Challenges in Developing Background Temperature Profiles for NSZD Using the Biogenic Heat Method

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Background/Objectives. Evaluations concluded the remaining LNAPL at an active refinery was in a lesser state of mobile saturation and no longer effectively recoverable by active means. As a result, the active LNAPL recovery program was terminated with agency approval pending results of an evaluation to demonstrate and quantify ongoing LNAPL mass reduction via natural source zone depletion (NSZD). An NSZD study was conducted using the biogenic heat method. However, challenges were encountered in obtaining representative temperature data from background wells at the active refinery and an analytical solution was required to estimate more representative NSZD rates.

Approach/Activities. Temperature data were collected from 16 wells in four different LNAPL release areas and 12 background wells across the refinery. Test wells were selected to account for varying conditions such as surface cover (paved and unpaved), vadose zone thickness, LNAPL thickness, and LNAPL type. Background locations were selected based on lack of LNAPL in the well, distance from source areas / LNAPL bodies and operational areas, and previously collected groundwater quality data. Subsurface temperature data were collected per methods described by Sweeny and Ririe (2017). Strings of Thermochron iButton® DS1922L temperature data loggers (iButtons) were deployed in the test wells. Temperature data from background locations were subtracted from the source area well temperature data to calculate background corrected temperature values. NSZD rates were calculated based on heat flux using the change in background corrected temperature in the hydrocarbon oxidation zone and corresponding depths, an assumed thermal conductivity constant (K_T), and the heat release (ΔH_o) for decane (assumed to be representative).

Results/Lessons Learned. Maximum background corrected temperatures using measured subsurface temperature data ranged from 4.5 to 9.4 °F and resulted in estimated NSZD rates that ranged from 100 to 700 gallons/acre/year. Measured background temperatures were generally very similar to the source area temperatures and suggested interference due to subsurface anthropogenic heat sources, heat generation due to biodegradation of natural organic matter in wetland sediments or residual contaminants, and/or surface effects from solar radiation. Based on the data, it became evident that identifying true background locations without interferences would be unlikely due to historical impacts and ongoing operations at the active refinery. Therefore, the sinusoidal Van Wijk & de Vries (1963) function was used as an analytical solution to estimate background subsurface temperature profiles based on ambient temperature data, key soil properties, and curve fitting constants. The Van Wijk & de Vries analytical approach resulted in subsurface temperatures that were more representative of a typical background profile. Maximum background corrected temperatures ranged from 8.9 to 10.4 °F and NSZD rates ranged from 400 to 2,100 gallons/acre/year. The temperature profiles correlated well with the sitewide background groundwater temperature data which supported the accuracy of the analytical approach. Overall, the empirical method and analytical solution provided a conservative range of NSZD rates for use in site remedial decision making and agency justification.