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Insights from Continuous Monitoring of LNAPL Natural Source Zone Depletion Rates

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Background/Objectives. LNAPL natural source zone depletion (NSZD) rates are being monitored at a large fuel release site (15-acre LNAPL zone). Initial characterization of NSZD rates through multiple carbon dioxide flux measurement events was characterized by significant spatial and temporal variability. An alternative approach involves measuring the heat generated by NSZD processes, and converting the temperature data to an NSZD rate. A thermal monitoring system was installed at the site in April 2014, and subsurface temperatures have been continuously monitored at multiple locations and depths since that time. The objective is track both short-term and long-term variability in the NSZD rate, using a method that offers the advantages of fewer biases due to climatic factors, reduced time spent at sites, and lower costs.

Approach/Activities. The NSZD thermal monitoring system installed at this site is believed to be the nation's first for continuous tracking of NSZD rates. Strings of multi-depth thermocouples were installed vertically through the LNAPL zone at multiple locations. The thermocouples were connected to a data logger. Data are downloaded remotely on a daily basis. An energy balance approach is used to determine the heat released through LNAPL biodegradation in units of watts/m^2 of surface area. Generated heat values are divided by the heat of reaction for the NSZD processes to produce continuous estimates of NSZD rates in terms of LNAPL mass/m^2/year. Volumetric loss rates are developed using an assumed LNAPL density.

Results/Lessoned Learned. Continuous thermal monitoring of NSZD rates has proven to be effective. Field equipment has proven to be reliable, data analysis has been automated, costs are favorable, and observed NSZD rates are consistent with other methods. Key findings include the following:

- Methanogenesis is a dominant intrinsic bioremediation process, and appropriate vertical placement of thermocouples above the LNAPL zone is key to capturing the thermal fingerprint generated from methane oxidation.
- NSZD rates derived from temperature monitoring show significant temporal variability. The variability does not appear to be a function of the significant water table fluctuations that occur at the site. Variability in soil moisture (and resulting gas diffusivity) appears to be a primary cause of NSZD rate variability.
- NSZD rate measurements were incorporated into an LNAPL mass balance that explained depletion of recoverable LNAPL.
- LNAPL mass loss rates through NSZD were much higher than mass removal rates being achieved through operation of an LNAPL recovery system.
- Based on the NSZD rates documented at the site, the state regulatory agency approved the decommissioning of the LNAPL recovery system and recognized the combination of NSZD of the LNAPL zone and MNA of the associated aqueous phase plume as the approved remedial strategy for the site.