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Quantifying Petroleum Biodegradation Rates using Temperature

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Background/Objectives. Quantification of petroleum LNAPL biodegradation rates can play a key role in development and implementation of an appropriate LNAPL site management strategy, whether for the purpose of assessing the effectiveness of bioremediation technologies (e.g., bioventing), or for establishing rates of natural source zone depletion (NSZD). Conventional methods for quantifying biodegradation rates rely on stoichiometric relationships for aerobic biodegradation of hydrocarbons, along with measurements of oxygen utilization and/or carbon dioxide production. These methods are viable, but often provide information that is representative of only a small volume of subsurface over short periods of time. Additionally, these methods can be difficult to apply at sites where soil gas transport conditions are complex (e.g., sites with low permeability surface caps, or where hydrocarbon impacts are at great depth).

The biodegradation reactions responsible for altering the composition of soil gas (e.g., oxygen utilization and/or carbon dioxide production) also release heat. The excess heat from biodegradation creates thermal anomalies that can be resolved through subsurface temperature profiling within existing wells, or from dedicated sensors buried in soil. Given the relative simplicity and cost-effectiveness of data collection, thermal profiling in support of petroleum biodegradation studies has gained considerable attention in recent years. However, models for translating temperature data into biodegradation rates are in the developmental phase.

Approach/Activities. An energy balance model is presented and applied to quantify rates of biodegradation. Temperature signals unrelated to petroleum biodegradation processes, such as seasonal variability in radiant heating and cooling at ground surface, are filtered out of the analysis, and the model allows for input of thermal properties of soil and aquifer matrices. Example applications of the model are provided for case study sites to quantify NSZD rates, and rates of biodegradation associated with bioventing. Temperature data inputs were collected using dataloggers in monitoring wells, and thermistors buried in the ground to demonstrate the applicability of in-well temperature monitoring.

Results/Lessons Learned. The use of temperature data can serve as a cost-effective means of quantifying petroleum biodegradation rates associated with either NSZD or active bioremediation, providing an alternative approach where methods based on soil gas flux are impractical. The method can easily be adapted to collect and analyze long-term temperature datasets to filter out seasonal temperature fluctuations, and provide information on temporal variability in biodegradation rate. The presentation will discuss the development and use of the thermal model to quantify biodegradation rates along with the findings of sensitivity evaluations and estimation of background soil temperatures at a site.