Estimating Natural Source Zone Depletion Rates from Subsurface Temperature Data

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Natural Source Zone Depletion (NSZD) is increasingly used as a component of LNAPL site assessment and remedial strategy. NSZD evaluations can be used to quantify the rate of LNAPL depletion via natural processes for comparison to recovery or degradation rates achievable by active remediation. At sites where the effects of active remediation are/or would be less than natural depletion rates, a compelling case can be made against continuing or implementing active remediation on grounds of efficacy and sustainability. Common methods for quantifying NSZD rates are based on measurements of vertical biogenic soil gas profiles (e.g., oxygen, methane, and/or carbon dioxide) and soil gas diffusivity (Johnson et al., 2006; ITRC,2009), and/or measurements of carbon dioxide flux at grade (Sihota et al.,2011; McCoy et al., 2014). These methods rely on stoichiometric relationships for biological hydrocarbon degradation and to estimate petroleum depletion rates from oxygen consumption or carbon dioxide production rates. These test methods are viable, but are often not reliable at sites where soil gas transport conditions are complex. This includes sites where impervious surface caps are present, low permeability subsurface strata in the subsurface impede vertical gas transport, or where petroleum hydrocarbon impacts are at great depth. The biologically-mediated NSZD processes that destroy hydrocarbons and alter the composition of soil gas (e.g., consume oxygen and produce carbon dioxide) also release heat and create subsurface temperature anomalies above the natural soil temperature profile. Recent research has focused on measuring temperature in and around LNAPL-affected areas and characterizing thermal anomalies (areas of warmer temperature) associated with exothermic NSZD processes. A case study is presented for an active rail yard where NSZD is being used to establish performance-based remedial endpoints for an existing LNAPL recovery system. LNAPL is present at depths exceeding 300feet below ground surface, and subsurface stratigraphy is complex, containing caliche in the unsaturated zone. Given the technical and economic challenges associated with conventional methods for determining NSZD rates, a temperature-based NSZD evaluation was implemented. The equipment, methodology, and results of the assessment, along with a description of the model used to calculate heat flux and, correspondingly, the rate of hydrocarbon degradation responsible for generating excess heat in the subsurface are discussed.