In Situ Smoldering Combustion (STAR): Challenges, Limitations, and Methods Developed to Maximize Remedial Performance

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Background/Objectives. STAR is an innovative remediation technology based on the principles of smoldering combustion where the contaminants are the source of fuel. Like all in situ technologies, STAR faces many challenges for successful implementation. This presentation highlights the interplay between key controlling variables and design to achieve optimal application of STAR. This interaction will be demonstrated through case studies illustrating STAR performance under challenging conditions.

Approach/Activities. Rigorous laboratory studies and field pilot tests of the STAR technology will be presented. The laboratory studies used both one-dimensional (column) and two-dimensional combustion tests to elucidate key features of smoldering combustion critical to the successful implementation of STAR in the field. The field tests illustrate the factors influencing key remedial design parameters such as propagation rate and radius of influence (ROI) as well as remediation performance (i.e., soil concentration reductions) under a variety of subsurface conditions.

Results/Lessons Learned. STAR requires sufficient fuel (i.e., contaminant concentrations) and permeability (to deliver air) to maintain a self-sustaining smoldering combustion reaction. Silty sand or coarser geologic units are well suited while minimum required total petroleum hydrocarbon (TPH) concentrations are a function of scale. Lab column tests, where heat losses through the experimental apparatus are large, suggest that the minimum concentration is on the order of 5,000 to 10,000 mg/kg TPH, however implementation in the field (where heat losses are reduced due to increased scale) demonstrate that this minimum is on the order of 3,000 to 5,000 mg/kg TPH. Soil concentrations below this level will be combusted and the process can tolerate “gaps” in contaminant distribution on the order of a few feet, as data from a rigorous 1D and 2D combustion study will illustrate.

STAR is best suited to low volatility compounds such as coal tar, creosote, and petroleum hydrocarbons, as high volatility compounds (e.g., gasoline) are typically volatilized faster than they can be combusted. A new method to overcome this limitation is to add a surrogate fuel such as vegetable oil to the target treatment zone to act as the primary fuel for combustion, and to use the heat of the combusting surrogate to volatilize the contaminants for subsequent capture and treatment at ground surface. The effectiveness of this method will be illustrated through pilot test data comparing “standard” STAR versus “vegetable oil-enhanced” STAR for the treatment of gasoline and diesel at a former refinery site.

Not all challenges in developing a new technology are technical. Logistical challenges can also have a significant impact on success. A case study will be presented describing the full-scale implementation of STAR at a coal tar site involving two complete process trains (air delivery, heaters, vapor extraction/treatment, and controls) targeting approximately 2000 sequentially grouped ignition points covering 14 acres of impacts at depths ranging from 10 to 35 feet bgs. This case study will discuss key findings and the progress of, and evolutionary improvements to, the technology since the remediation program was initiated.