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Pilot Test of In Situ Smoldering Combustion for Remediation of Navy Special Fuel Oil LNAPL at Defense Fuel Supply Point in Yorktown, Virginia

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Background/Objectives. At the Yorktown Defense Fuel Supply Point in Yorktown, Virginia (Site), various remediation activities have been performed since 2001 to address a large light nonaqueous phase liquid (LNAPL) plume of Navy Special Fuel Oil (NSFO). An estimated 750,000 to 2.5 million gallons of LNAPL are present in a 13-acre plume. NSFO is very viscous (about 500 centistokes at 59^0F) and relatively dense (specific gravity of 0.94 to 0.99), making it very difficult to recover from the subsurface. The annual operation and maintenance costs for the existing steam- and heated groundwater-enhanced LNAPL recovery system are high, and the estimated timeframe for achieving remedial action objectives (RAOs) exceeds 30 years. STAR (Self-sustaining Treatment for Active Remediation) employs smoldering combustion to thermally destroy (i.e., combust) certain types of NAPL in the subsurface, both above and below the water table. STAR is designed to achieve in situ smoldering, which is an exothermic reaction that, under controlled conditions, can self-sustain following the initial ignition. Bench- and pilot-scale treatability tests were performed to evaluate the performance of STAR for treating NSFO in situ at the Yorktown site.

Approach/Activities. Soil cores (generally from 17 to 24 feet below ground surface [bgs]) from the Site were used in a STAR treatability test conducted in a soil column using a convective ignition method. Ignition temperature and air flow rate required for a self-sustaining smoldering combustion were measured in the test sample. Thermocouples with data loggers allowed continuous monitoring of temperatures at various locations along the column. Gaseous emissions were collected and analyzed for CO, CO_2 and principal volatile organic compounds (VOCs). For the field pilot test, an ignition well and a network of multi-level thermocouples as well as soil vapor extraction points were installed within a target treatment area of approximately 2,500 ft^2. The target treatment depth interval was generally between 16 to 21 ft bgs, which was near and below the groundwater table. Other system components included a power supply for the heating element, a vapor extraction and air compressor system, and a control and data logging system. Pre- and post-test soil samples were also collected to assess the treatment efficiency.

Results/Lessons Learned. The treatability test successfully demonstrated self-sustaining combustion of NFSO LNAPL with a heat front propagation observed along the tested soil column where temperatures continued to increase to above 600^0C even after the heating element was terminated. The total petroleum hydrocarbon (TPH) concentration in soil was reduced from 13,100 mg/kg (pre-test) to non-detect (post-test). During the pilot test installation, a clay layer of approximately 1-foot thickness was identified within the target treatment depth interval (approximately 16 to 21 ft bgs). Based on the subsurface temperature data (aerial and vertical), emissions monitoring data, and post-test soil samples, it was concluded that self-sustained combustion occurred both above and below the clay, resulting in the destruction of approximately 630 kg of NSFO during the 10-day pilot test. The combustion front propagated from the ignition point to a distance up to approximately 7.5 ft in 10 days. Treatment within the

clay layer appeared to be limited potentially due to the low permeability that hindered effective air flow within that layer.