Self-Sustaining Treatment for Active Remediation (STAR): Smoldering Combustion for the Treatment of Recalcitrant Compounds

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Resumo

Esta apresentação irá proporcionar uma visão geral dos princípios científicos por trás auto-sustentáveis de tratamento para despoluição Active (STAR), e resumir os seis anos da prova de uma investigação de conceito que tem sido realizado com êxito até à data. Além disso, esta apresentação irá fornecer o projeto e os resultados de um estudo in situ STAR-piloto em uma facilidade de manufacturing anterior cresol em Nova Jersey, que foi desenhado para testar STAR em grande escala e em condições de saturação (ou seja, abaixo da superfície do solo e abaixo da água de mesa).

Abstract

This presentation will provide an overview of the scientific principles behind Self-Sustaining Treatment for Active Remediation (STAR), and summarize the six years of proof-of-concept research that has been successfully conducted to date. In addition, this presentation will provide the design and results of an *in situ* STAR pilot study at a former cresol manufacturing facility in New Jersey that was designed to test STAR at a large scale and under saturated conditions (i.e., below ground surface and below the water table).

Keywords: NAPL, Remediation, Smoldering, in situ

1 - INTRODUCTION

Coal tar contamination at manufactured gas plant (MGP) sites and hydrocarbon-impacted soils associated with the oil and gas industry are complex problems that only a handful remedies are capable of addressing in a cost effective and timely manner. STAR – based upon the principles of *in situ* smoldering combustion – is an innovative approach that has significant potential for the remediation of sites impacted by such non aqueous phase liquids (NAPLs).

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NAPL smoldering is different from existing thermal remediation techniques. *In situ* thermal remediation requires the continuous input of energy in order to primarily volatilize and, in some cases, thermally degrade (pyrolize) and mobilize (via viscosity reductions) the organic phase. All of these processes are endothermic and require continuous external fuel input. In contrast, NAPL smoldering has the potential to create a combustion front that (i) initiates at a single location with the NAPL-occupied porous medium, (ii) initiates with a one-time, short-duration energy input, (iii) propagates through the NAPL-occupied medium in a self-sustained manner, and (iv) destroys the NAPL wherever the front passes.

This work presents an overview of the scientific principles behind STAR, and summarizes the six years of proof-of-concept research that has been successfully conducted to date. Furthermore, the design and results of a STAR pilot study, focusing on an *in situ* application of the technology at a former cresol manufacturing facility in New Jersey, will be presented.

2 - PROOF-OF-CONCEPT (POC) EXPERIMENTS

Proof-of-concept (POC) laboratory experiments have been conducted at the University of Edinburgh and the University of Western Ontario over the course of the past six years to demonstrate the viability of STAR as a NAPL remediation technology. Summaries of these earlier studies are presented in Pironi *et al.* (2008) and Switzer *et al.* (2009).

These experimental studies successfully demonstrated a number of key properties of the STAR process: (1) STAR requires only a short duration energy input (i.e., ignition) at a single location to initiate the reaction; (2) STAR is then self-sustaining, such that the reaction propagates itself through the NAPL without additional energy input, (3) STAR is self-terminating, such that the reaction naturally ceases when no NAPL remains, and (4) STAR avoids injecting costly fluids or conveying NAPL or contaminated groundwater to the surface for treatment.

Figure 1 presents photographs of a coal tar contaminated sand before and after STAR at the ‘bin’ scale (treatment volume = 2.5 cubic meters). The visual appearance of STAR-treated soils and the level of contaminant destruction (>99.9%) resulting from STAR as observed in this experiment is typical of most of the studies performed to date.

a) b)

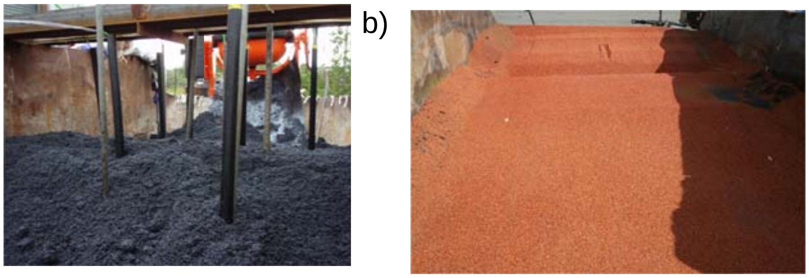

Figure 1: ‘Before’ (a) and ‘after’ (b) photographs of coal-tar impacted soil treated with STAR

3 - *IN SITU* PILOT TEST

A pilot test to evaluate the efficacy of STAR to treat coal tar-impacted soils was conducted at a former cresol manufacturing plant in Newark, New Jersey. The test was conducted in a 9-foot fill unit overlying a peaty clay aquitard in a 20 foot by 60 foot pilot test area (PTA) located within the former lagoon area of the site. The PTA contains more than four feet of highly saturated and mobile coal tar located at the bottom of the fill unit. The PTA was instrumented with thermocouples to track the combustion front and the surface was sealed with concrete to allow for vapour collection and treatment.

Figure 2 presents the hourly rate of coal tar mass destruction and the total cumulative mass of coal tar destroyed during one phase of testing conducted at the Site. More than 3500 kg of coal tar was destroyed over an 11-day period, with sustained destruction rates greater than 800 kg per day. Thermocouple data showed the propagation of the combustion front more than 30 feet from the ignition point.

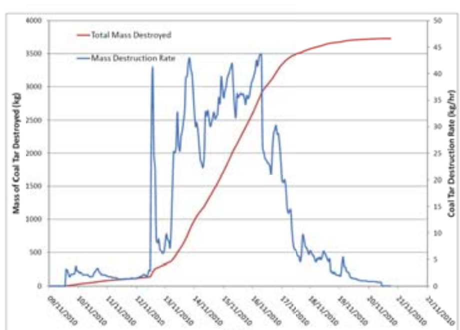

Figure 2: In Situ STAR Pilot Test mass destruction rate and cumulative coal tar destroyed

Soil cores were collected from the PTA following the completion of the test. Figure 3 shows the degree of contamination before STAR pilot testing and Figure 4 shows soil cores collected after the pilot test from STAR treated areas. Laboratory analysis of soil samples from these cores showed average concentration reduction for semi-volatile organic compounds (SVOCs) greater than >99.72%.

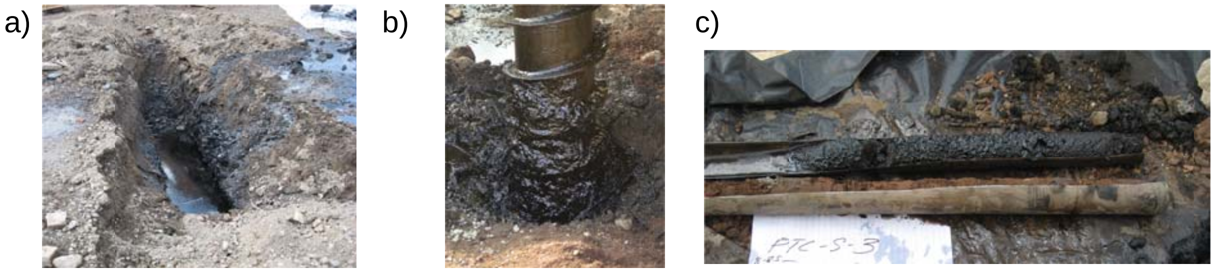

Figure 3: ‘Before’ photographs of coal-tar impacted soil a) test pit b) well installation c) soil core

Figure 4: ‘After’ photographs of STAR Treated soil cores collected from PTA

Pilot testing at the site has demonstrated both the viability and the outstanding remediation performance of the STAR technology in a real-world environment. The tests identified some of the key factors affecting the smoldering combustion process, identified key considerations for scale-up, and demonstrated the robustness and effectiveness of the technology under complex circumstances. Further testing directed towards scale-up of the process for full-scale implementation at the site begins in 2011, with site closure targeted for December 2015.

4 - CONCLUSIONS

STAR has been demonstrated to be highly effective for the treatment of soils contaminated with recalcitrant compounds such as coal tar and petroleum hydrocarbons. Field pilot studies have identified have demonstrated the robustness and effectiveness of the technology for both *In Situ* and *Ex Situ* applications.