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Scaling-up Experiments of Smouldering Combustion as a Remediation Technology for Contaminated Soil

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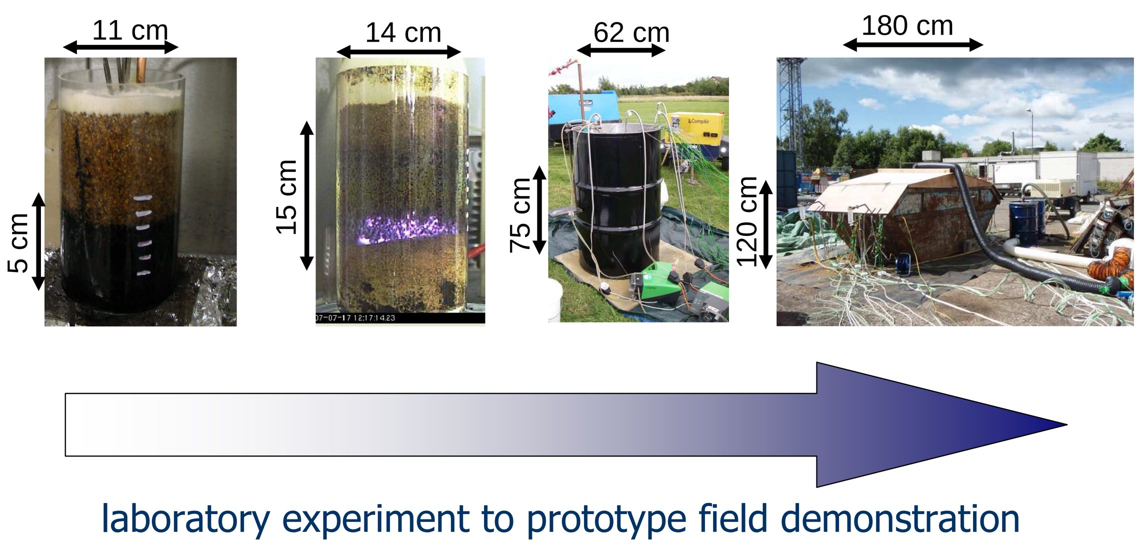
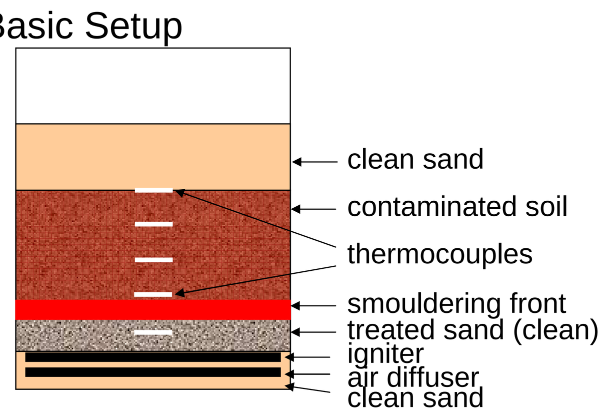
Introduction

Self-sustaining Treatment for Active Remediation (STAR) is a novel, patent-pending process that uses smouldering combustion as a remediation technology for land contaminated with hazardous organic liquids. Compounds such as chlorinated solvents, coal tar and petroleum products, called Non-Aqueous Phase Liquids (NAPLs) for their low miscibility with water, have a long history of use in the industrialised world and are among the most ubiquitous of contaminants worldwide. In high, acute doses, these contaminants are toxic to humans and the environment. Many of these contaminants are toxic and suspected or known carcinogens. Thousands of NAPL-contaminated sites require remediation. Existing remediation technologies are expensive and ineffective at reducing NAPL source zones sufficiently to restore affected water resources to appropriate quality levels. STAR introduces a self-sustaining smouldering reaction within the NAPL pool in the subsurface and allows that reaction to provide all of the post-ignition energy required by the reaction to completely remediate the NAPL source zone in the soil.

Experimental Scales



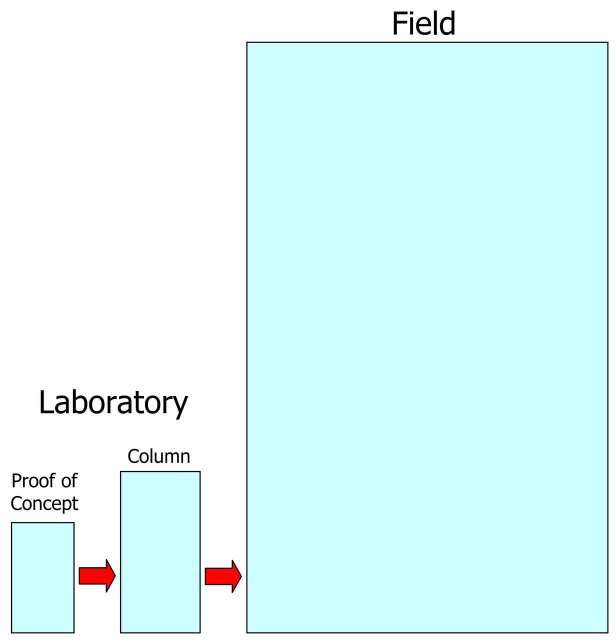
Basic Setup

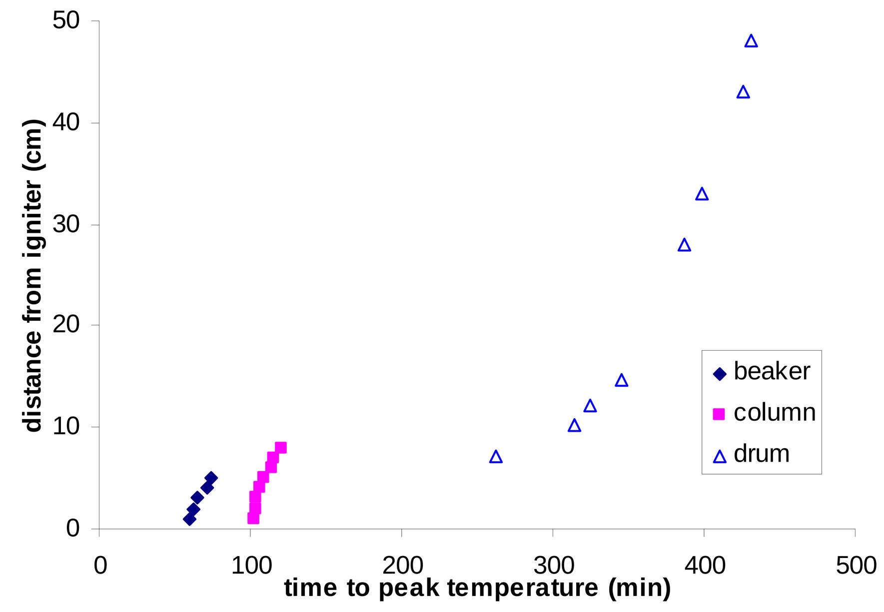


Contaminated soil

Mechanically mixed coal tar in sand or field-obtained contaminated soil

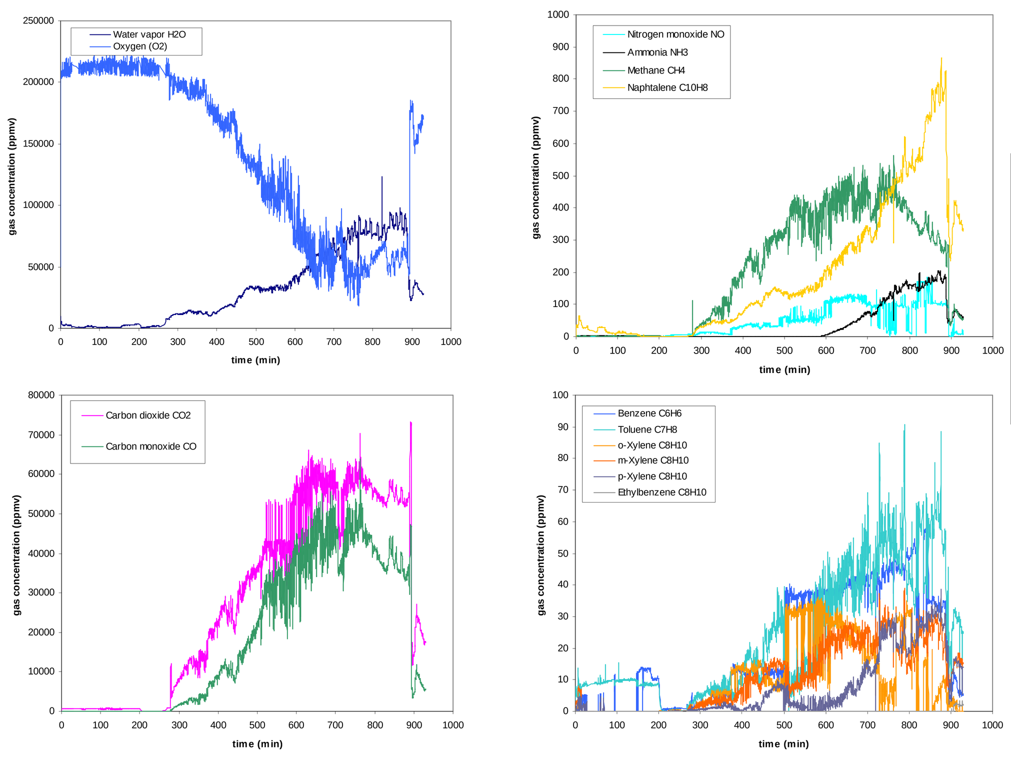
Effects of Scale





Propagation velocity of the smouldering front, represented as the distance from the igniter versus time to peak temperature, seemed influenced by experimental scale. It seemed constant in the laboratory experiments but accelerating with distance in the field experiment. The latter is an observation consistent with forward smouldering.

Emissions Analysis



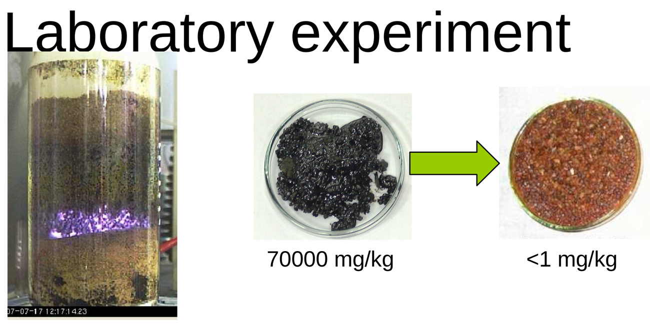
	Total mass released (kg)*
Water vapor H2O	72
Carbon dioxide CO2	161
Carbon monoxide CO	69
Nitrogen monoxide NO	0.2
Methane CH4	0.4
Benzene C6H6	0.2
Toluene C7H8	0.2
Naphtalene C10H8	3.1
Xylenes C8H10	0.4

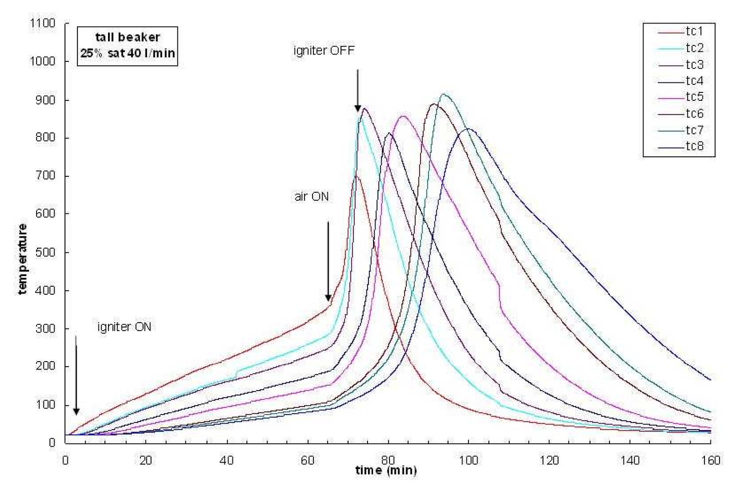
*projected values based on total running time because gas capture failed during the trial.

Gas analysis was conducted by real-time analysis of the exhaust gas with Fourier Transform Infrared (FTIR) spectroscopy. When STAR was initiated, carbon dioxide and carbon monoxide concentrations increased and oxygen concentrations decreased. Toxic species detected in the exhaust gas included naphthalene, benzene, toluene and xylenes (coal tar constituents and potential degradation products) as well as nitrogen monoxide and methane. No sulphur compounds (e.g., sulphur dioxide) were detected though their presence is possible in field scenarios.

Experimental Results

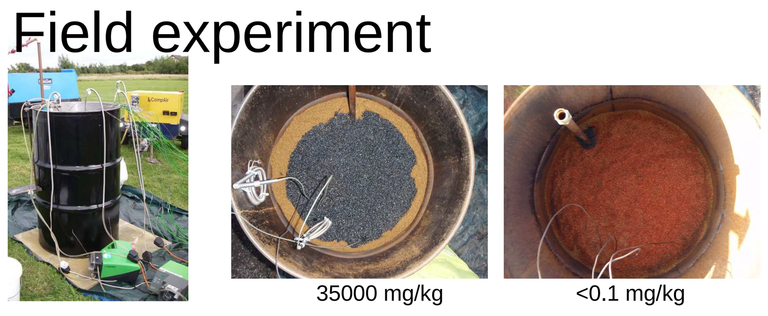
Laboratory experiment





Temperature profiles, as measured by thermocouples embedded in the contaminated soil and the clean sand above, are typical of smouldering but the observed temperatures are significantly higher.

Field experiment



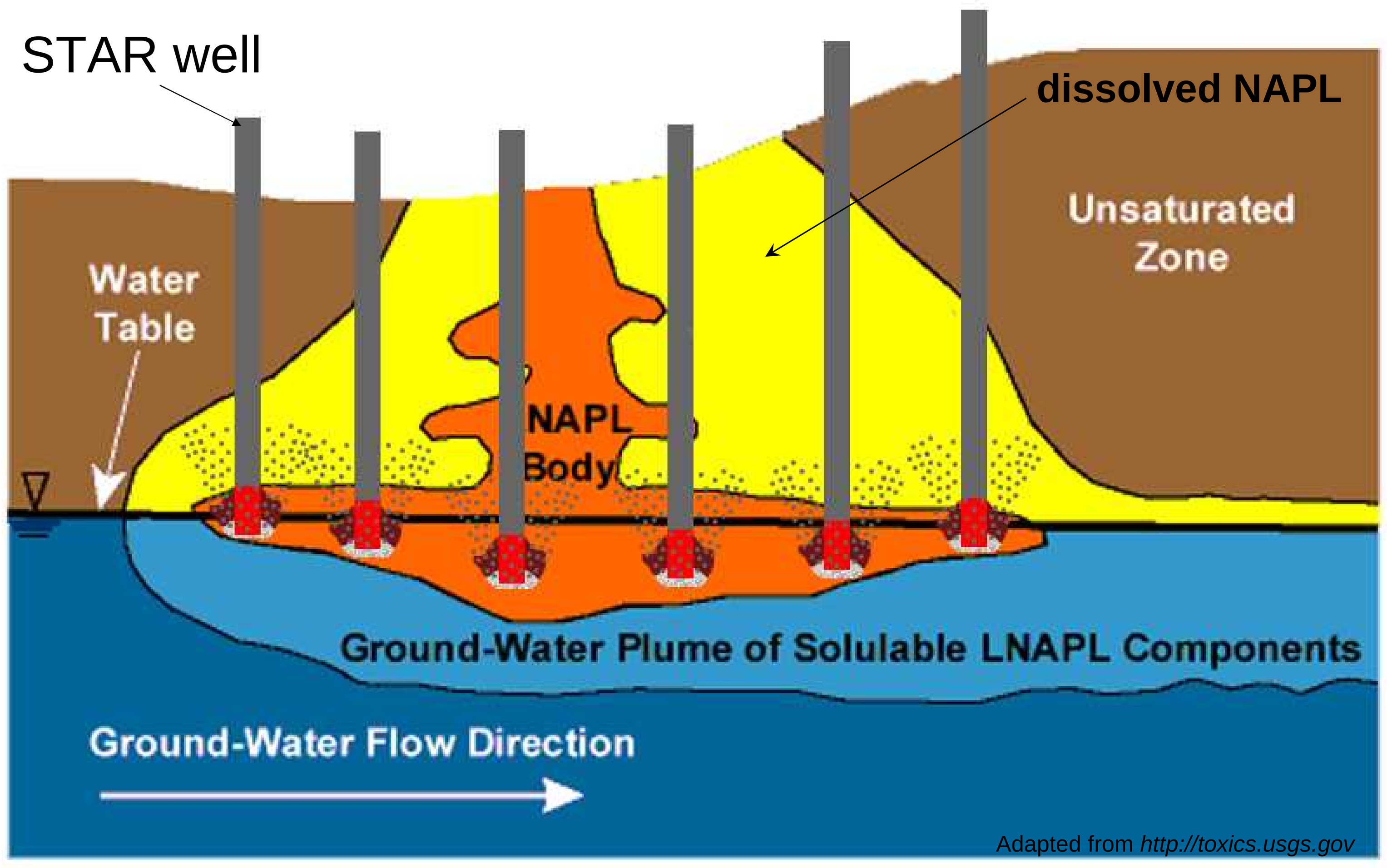
Prototype ex situ field demonstration

Remaining Questions

- What is the resulting soil structure?
- Can STAR be combined with other remediation strategies? (e.g., bioremediation)
- What is the maximum possible water content for STAR?
- How much soil organic matter can be present?
- Are there conditions that might allow a runaway reaction?
- *…and many more!*

Future Work: In Situ STAR

- Example of STAR applied to a lighter-than-water NAPL spill
- Ideal scenario is to avoid excavating the contaminated soil



Adapted from *http://toxics.usgs.gov*

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