Thermal Heterogeneity Induced By Smouldering Combustion In Homogeneous Porous Medium

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Abstract

Smouldering is flameless combustion which depends on an exothermic surface reaction occurring within a porous medium. It is harnessed by engineers to destroy organic liquid wastes in soil as the technology Self-sustaining Treatment for Active Remediation (STAR). During this remediation process, air is injected into the contaminated soil matrix to provide oxygen for the oxidation reaction that creates hot and clean soil. To maximize STAR's remedial performance, understanding the factors that affect the airflow distribution is important. Airflow distribution is affected by heterogeneity, the non-uniform distribution of properties. The influence of physical heterogeneity is well known, but the influence of thermal heterogeneity is unknown. The latter results from radial heat loss during smouldering, which induces a heterogeneous temperature field, in turn affecting air viscosity and density, resulting in heterogeneous pneumatic conductivity and heterogeneous smouldering in the heated porous media. This research explores the effect of thermal heterogeneity in applied smouldering by integrating laboratory experiments and numerical simulations.

A 2D axisymmetric Darcy scale model of smouldering combustion in an inert porous medium was developed in COMSOL Multiphysics® considering the effect of chemistry, heat and mass transfer using the PDE Interface. The Time-Dependent solver was considered while Quadratic Lagrangian was performed for spatial discretization and implicit Backward Differentiation Formula (BDF) used for time-stepping. The model was validated with experimental results. Simulations were conducted to enable understanding of the impact of air flow heterogeneity on the smouldering front temperature, velocity field, oxygen consumption pattern, and energy balance in the system.

This research improves the understanding of smouldering science and also reveals the role of thermal heterogeneity on smouldering applications in engineering. This understanding is applicable to optimize STAR's remedial performance as well as other remediation and thermal energy storage technologies associated with heated airflow in an inert porous medium such as soil vapour extraction and packed bed thermal energy storage systems.

Figures used in the abstract

Figure 1 : Temperature of Solid

Figure 2 : Pneumatic Conductivity of Air

Figure 3 : Mass Fraction of Granular Activated Carbone (GAC)

Figure 4 : Mass Fraction of Oxygen