A New Technology for In Situ Remediation of Contaminated Sites by Cryo-Enhanced Delivery of Reactants in Low Permeable Clayey Deposits

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Background/Objectives. Over the past decades, subsurface contamination with chlorinated solvents has spurred the development of many in situ remediation technologies involving injection of treatment agents in the subsurface to promote reduction of the contaminants. While many successful remediation projects have been performed in permeable aquifers, the techniques fail to meet remediation goals and appropriate timeframes in low permeable deposits such as clayey soils.

The main obstacle is obtaining an efficient distribution and contact between contaminants and treatment agents. Efforts to achieve such contact and ensure adequately long reactivity of the reagents using fracturing or EK techniques have proven difficult in many cases. Hence, in such cases, only excavation or thermal treatment can meet the needed timeframes and goals. While effective, these techniques are both expensive and have large carbon footprints, and especially in urban environments, they can be difficult to implement.

Here we present the initial development of CryoRem, a promising novel technology to evenly distribute treatment agents in clayey soil in situ using controlled and slow freezing of the subsurface. Compared to thermal heating, there is less cost, less energy consumption, and no need for subsequent treatment of waste products.

Approach/Activities. In this new technology the soil close to the freezing probe is slowly frozen. This creates cryosuction, leading to a fast migration of water and soluble compounds towards the freezing front. By adding reactants to the water, reactants are distributed fast and evenly in the contaminated soil. The technology is developed through laboratory experiments, a field experiment and development of numerical models. The results all feed into the design of a pilot-scale experiment that will demonstrate the technology at a contaminated site. At this conference we will present the results of the laboratory and field experiments.

Results/Lessons Learned. In a series of laboratory experiments, we apply directional freezing on blocks of clayey till to study the physical and chemical processes of the novel technology. The first set of laboratory experiments show that we can distribute soluble compounds in clayey soils at a speed several orders of magnitudes faster than diffusive transport or normal advective transport. The transport velocity is dependent on the temperature gradient and is initiated when the soil temperature drops below -1 °C in part of the soil. Further studies, that will be finalized before the conference, will focus on transport of treatment agents and how they respond to freezing and finally we will test the method on clayey till contaminated with chlorinated solvents. To study the technology at larger scale we will conduct a field-scale experiment with directional freezing in two boreholes in clayey till. Focus areas will be distribution of soluble compounds, maximizing the distance of cryo-enhanced transport, and how multiple freezing fronts influence transport of water and soluble compounds.