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Electrokinetically-Based Remediation of Chlorinated Ethenes in Low Permeable Soils

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Background/Objectives. Remediation of contaminated soils with low hydraulic conductivity is often challenging, especially when the pollutants are chlorinated ethenes. The limited possibility for transport of reactants in a hydraulic gradient or by diffusion in such soils hampers the use of remediation techniques, which are working well in coarser soils. However, transport of ions (electromigration), charged particles (electrophoresis) and water (electroosmosis) can be obtained when applying an electric DC field to the fine-grained soils. Different electrokinetic soil (EK) remediation methods utilize these transport processes. In recent years, research, development and implementations have combined EK with already practiced remediation techniques, because of the inadequate performance of these in fine-grained soils. The Capital Region of Denmark has hosted bench-scale and in situ remediation tests which combined EK with practiced techniques at sites contaminated with chlorinated ethenes. The methods are EK-BIO (Electrokinetic-Enhanced Bioremediation), EK-saturate (electrokinetically-enhanced saturation of soil prior to EK), EK-ISCO (electrochemically-enhanced in situ chemical oxidation) and EK-TAP™ (electrokinetically delivered thermally activated persulfate). The objective of the present work is to point out the major findings from these tests as well as to define major current knowledge gaps towards an optimal implementation of these techniques.

Approach/Activities. A comprehensive literature survey combined with in-depth knowledge about the in situ experiments in the Capital Region of Denmark and the subsurface, in which they were conducted, forms the basis of this work. Many papers have been published on EK soil remediation (alone and combined with other techniques). Many of the papers focus on 1-D model systems, where the soil is simulated with glass beads or kaolinite to gain fundamental knowledge. A further step towards development of remediation methods is work dealing with lab experiments and soils sampled at contaminated sites. This research includes the influence of soil type and in few papers also the heterogeneity, but still often in 1-D or 2-D. In situ experiments or full-scale actions have been reported on a few EK techniques. Even though the contaminants may be others than targeted here, these offer important knowledge on the up-scaling process, together with the tests focusing on chlorinated ethenes in the Capital Region of Denmark.

Results/Lessons Learned. There is no direct and easy transformation of results from 1-D and 2-D lab scale experiments to 3-D in situ remediation of heterogeneous soils with aged contamination, regardless of combination of EK and already practiced remediation methods. A major overall knowledge gap is how to foresee and control the electrokinetic transport processes in highly heterogeneous and changing soil/contamination systems (changing due to the applied current). Important knowledge is systemized to highlight the major parameters and effects, which are, or are not, sufficiently understood. This because the different combined methods showed interesting potentials, but also challenges, which need to be met to support successful implementation.