Effect of pulse current on energy consumption and removal of heavy metals during electrodialytic soil remediation

Contamination of soils and groundwater keep attracting attention of worldwide. The contaminants of concern include a wide range of toxic pollutants such as heavy metals, radionuclides, and organic compounds. The environment and humans are exposed to these pollutants through different exposure pathways to unacceptable dosages, leading to intolerable adverse effects on both public health and the environment. In the last decades, soil and water remediation have gained growing awareness, as the necessity becomes clearer for development of such techniques for elimination of the negative impact from the contamination on human health and land use.

Electrochemical remediation has been recognized as a promising group of technologies for remediation of contaminated sites, leading to several research programs worldwide for the development. Electrochemical remediation is also synonymously referred to as electrokinetics, electrokinetic remediation, electoremediation or electroreclamation. Electrochemical remediation technologies are part of a broader class of technologies known as direct current technologies. The techniques utilize the transport processes obtained by application of the electric DC field: transport of water (electroosmosis) and ions (electromigration), with electromigration being the most important transport process when treating heavy metal contaminated soils.

Electrodialytic remediation (EDR), one of the enhanced electrochemical remediation techniques, is developed at the Technical University of Denmark in the early 1990s and aims at removal of heavy metals from contaminated soils. The electrodialytic remediation method differs from the electrokinetic remediation methods in the use of ion exchange membranes for separation of the soil and the processing solutions in the electrode compartments. Therefore no current is wasted for carrying ions from one electrode compartment to the other.

The EDR technique has been tested for decontamination of a variety of different heavy metal polluted particulate materials: mine tailings, soil, different types of fly ashes, sewage sludge, freshwater sediments and harbor sediments. In previous works including both lab and pilot scale experiments, this technique has demonstrated effective removal of heavy metals from all the contaminated materials. In the PhD project, the focus turns to energy saving aspect of EDR which influencing costs and thus the applicability for remediation beyond bench and pilot scale.

The overall aim of the present PhD study is to clarify and understand the underlying mechanisms of the effect of pulse current on energy consumption and removal of heavy metals during electrodialytic soil remediation. Series of experiments with constant and pulse current in twodifferent industrially polluted soils were conducted.

Results showed that the pulse current gave positive effect in relation to energy saving and improvement of removal of heavy metals during EDR. The positive effect was related to enahncement of the acidification process, increasing the electric conductivity in soil pore fluid, and diminishing the polarization process of membranes and soil particles. The efficacy of pulse current was found dependent on applied current density, soil buffering capacity, and applied pulse frequency. In stationary EDR, the efficacy of pulse current was more significant at higher current densities, higher buffering capacities, and lower pulse frequencies (i.e. adequate relaxation time with respect to the current “ON” time). On the contrary in suspended EDR, higher pulse frequency was preferred, and the difference was due to the different transport process of ions between stationary and suspended EDR. The major energy was consumed by the fouling of cation exchange membrane in stationary EDR, whereas major energy consumption was found in soil suspension in suspended EDR. Compared with stationary EDR (maximum 70% energy saving), less energy was saved (maximum 33%) in suspended EDR, even with higher applied current densities.

Although it was demonstrated that the pulse current is a possible way to decrease the energy consumption and increase the removal efficiency of heavy metals during EDR, long-term tests are still needed in future research to evaluate the possible decay of the enhancing effect induced by pulse current as a function of remediation time. Although the influences of applied current density and soil buffering capacity on pulse current were investigated, the test range of current density and buffering capacity was relatively narrow; therefore more experiments are needed to make the conclusions more general. Moreover, clarification on the redistribution of ionic species in the soil pore fluid and interaction between ions and soil particles at the relaxation period are also needed for fundamental understanding the mechanisms related to pulse current.