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Electrochemical Processes for In-Situ Treatment of Contaminated Soils

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Research Objective

This research project is to develop electrochemical processes for in-situ treatment of contaminated soils. Specifically, it is to study electrokinetic (EK) and electro-Fento (EF) processes and to integrate these processes for the treatment of soils containing mixed contaminants. Our objectives are:

- To study important parameters controlling the mobilization and the transport of selected organics and metals in soils by the electrokinetic (EK) process. Factors to be studied include field strength, pH, ionic strength, soil washing agents, types of organic and metal contaminants, and soil surface properties such as cation exchange capacity(CEC), soil organic content, soil moisture content, soil composition, and surface charge.
- To study the important factors governing the oxidation of selected organic contaminants by the electro-Fenton (EF) process. Parameters such as pH, surface area and the configuration of working electrode, oxygen concentration, ferrous ion, and temperature that may affect the performance of the EF process will be investigated.
- To understand the mechanism of the oxidation of selected organic contaminants by the electro-Fenton oxidation process.

Research Progress and Implications

As of June 1998, this research project was in the midterm of the second year of a three-year project. During the last 18 months, we have completed the following laboratory studies:

- Physical Chemical Characterization of Soil Samples

  The characterization of the physical chemical properties of six soil samples. These soil samples were obtained from the Argonne National Laboratory and were collected from an undisclosed DOE site. These soil samples were characterized thoroughly for composition, soil pH, soil organic content, soil moisture content, soil cation exchange capacity, specific surface area, pH_{zpc}, hydraulic conductivity, organic contaminants, and heavy metals.

- Adsorption of Selected Organic Compounds onto Soils

  In order to understand the nature of the association of organic chemicals with soil, laboratory experimenrs were conducted to evaluate the adsorption characteristics of the selected organic chemicals onto soil samples. The following organic chemicals were evaluated: chlorophenols (4-chorophenol, 2,4-dichlorophenol, and 2,4,5,-trichlorophenol) trichloroethylene (TCE), tetrachloroethylene (PCE) and naphthalene. The major factor studied was the soil-solution ratio and the effect of a co-solvent. Results indicate that the uptake of organic compounds by soils is affected by the soil solution ratio. Generally, the amount of organic adsorbed per unit mass of the soil sample increases with decreasing soil concentration. Results also indicate that the presence of a co-solvent such as methanol will decrease the uptake of organic chemicals by soils.

- Removal of Selected Organic Compounds from Soils by Electrokinetic Process

  Both enhanced and unenhanced electrokinetic experiments were conducted. In the unenhanced mode, no pH control was attempted; pore water was electrolyzed to produce proton and

hydroxide ions. The pH profile of the soil column changes. In the enhanced mode, the pH of the cathodic chamber and the anodic chamber were controlled. Results indicate that controlled or enhanced electrokinetic processes are advantageous compared to the unenhanced mode. A neutral pH condition can achieve high energy efficiency and organic removal. This is accomplished by the use of sodium acetate and acetic acid, instead of a strong acid and a strong base, as pH modifiers. Results indicate that electrokinetic process can effectively remove organic contaminants such as chlorophenols (phenol, 2-chloro phenol, 3-chloro phenol, 4-chloro phenol and 2,3,5 tri-chlorophenol). As high as 90% organic removal can be achieved in 15 days.

- Electrochemical Generation of Hydrogen Peroxide

  Laboratory experiments were conducted to generate hydrogen peroxide using the electrochemical method. The generation of hydrogen peroxide as affected by current density, temperature, oxygen supply, pH and cathode configuration were evaluated. Results indicate that under a current density of 1 mA/cm^2, a pH of 3, and a temperature of 25 ^oC, the amount of hydrogen peroxide generation will be optimal. Pure oxygen and small oxygen bubbles are also crucial to the generation of hydrogen peroxide. Increasing surface area will increase the output of hydrogen peroxide. As high as 200 ppm hydrogen peroxide can be generated under the following conditions: 100% oxygen at a flow rate of 2000 cm^3/min, 25 ^oC, 0.05 M ionic strength, 1 Amp, 754 cm^2 cathode.

- Oxidation of Selected Organic Compounds by Fenton's Reagent

  Laboratory experiments were conducted to evaluate the efficiency of the mineralization of selected organic compounds, TCE, PCE, Naphthalene, and chloroform. Results indicate that Fenton oxidation process is very effective in mineralizing these organic compounds (except chloroform due to the degree of saturation in C-H bounding) Oxidation reactions proceed rapidly to completion. For example, in 2 minutes for the oxidation of TCE with 10^{-2} M hydrogen peroxide and $1x10^{-3}$ M ferrous ion is completed. In one minute, the oxidation of naphthalene is completed in the presence of $2x10^{-2}$ M hydrogen peroxide, $1x10^{-3}$ M ferrous ion, pH 3 and an organic concentration of 50 ppm.

- Implications

  Results obtained so far clearly indicate that an integrated electrokinetic electro-Fenton process is highly promising as an in-situ soil decontamination technique. This technology can be easily implemented.

Planned Activities

During the next half term of this research project, research activities will concentrate on the following experiments:

- *Modification of the hydrogen peroxide generation reactor*. An attempt will be made to increase the current efficiency of the electro-Fenton reactor. This is done by re-configuring the cathode. Specifically, the use of a fluidized dipolar cathode will be attempted.
- *Removal of heavy metals from soils by electrokinetic process*. Experiments will be conducted to remove heavy meals such as Cu(II), Pb(II), As(V), Hg(II), Cr(VI), and Zn(II) from soils by electrokinetic process.
- *Identify the reaction pathways of the Fenton oxidation of selected organic compounds*. Reaction pathways for the oxidation of PAHs and chlorinated organic compounds will be identified.
- *Integrate the electrokinetic and electro-Fenton oxidation processes.* Laboratory bench top EKEF reactors will be constructed to evaluate the total soil decontamination process.

Other Access To Information

"Sorption of some Organic Chemicals Exemplified by PCE, TCE and Naphthalene onto Soils," C. P. Huang, J. H. Chang and Z. Qiang, Forth International Symposium on Environmental Geotechnology and Sustainable Development, Boston, MA, August 9-13, 1998.

"Fenton Oxidation for the Treatment of Some Specific Organic Compounds Exemplified by PCE, TCE and Naphthalene in Soils," C. P. Huang, Z. Qiang and J. H. Chang, , Forth International Symposium on Environmental Geotechnology and Sustainable Development, Boston, MA, August 9-13, 1998.

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Electrochemical Processes for Insitu Treatment of Contaminated Soils, Semiannual Report, October 1997 –May 1998. **http://www.ce.udel.edu/~huang/semi97-98.html**