Soil, Sediment, Bedrock and Sludge

Electrokinetic Separation

Introduction

The process of electrokinetic remediation eliminates metals and organic contaminants from low permeability soil, sludge, and sediments. Electrokinetic separation utilises electrochemical and electrokinetic methods to desorb and remove, metals and organics.

Description:

Electrokinetic remediation relies on a low-intensity direct current through the soil between electrodes that are divided into a cathode and anode array, mobilising charged species, and causing the ions and water to move toward the electrodes. Metal ions, ammonium ions, and positively charged organic compounds move toward the cathode. Anions such as chloride, cyanide, fluoride, nitrate, and negatively charged organic compounds move toward the anode. The current generates an acid front at the anode and base front at the cathode. This acidic environment may assist in mobilising sorbed metal contaminants for transport to a collection system located at the cathode. The two main mechanisms of contaminant transport through the soil are electromigration and electroosmosis. Electromigration, involves charged particles being transported through the substrate. In contrast, electroosmosis is the movement of liquid containing ions relative to a statically charged surface. Electromigration is the primary mechanism for the process of elctrokinetic remediation. The direction and rate an ionic species moves is dependant on its charge in magnitude and polarity, in addition to the magnitude of electro osmosis-induced flow velocity. Non-ionic species, both inorganic and organic, are transported along with the electroosmosis induced water flow. Two options are undertaken during electrokinetic remediation - enhanced removal and treatment without removal.

Enhanced removal is accomplished through the electrokinetic transport of contaminants toward the polarised electrodes in order to concentrate the contaminants for removal and *ex-situ* treatment. Removal of contaminants at the electrode is done by either electroplating at the electrode; precipitation or co-precipitation at the electrode or complexing with ion exchange resins.

Treatment without removal is when electro-osmotic transport of contaminants through treatment zones placed between electrodes takes place. The polarity of the electrodes is reversed intermittently, causing a reverse in the direction of the contaminants back and forth through treatment zones. The rate at which the electrode polarity is reversed is driven by the transport rate of contaminants through the soil. The process may be utilised on *in-situ* remediation of soils impacted with organic species.

Applicability:

Contaminants suitable for electrokinetic separation include heavy metals, anions, and polar organics in soil, sludge, and sediments. Treatable concentrations vary from a few mg/l to tens of thousands of mg/l.

Limitations:

- Efficiency is greatly reduced for wastes with a moisture content of less than 10 percent. Maximum effectiveness is between 14 and 18 percent.
- The existence of buried metallic or insulating material can result in variability in the electrical conductivity of a soil, and consequently the geological spatial variability should be delineated. In addition, deposits that show high electrical conductivity, for example ore deposits, can cause the technique to be inefficient.
- Inert electrodes, such as carbon, graphite, or platinum, should be exploited so no residue will be introduced into the treated soil. Metallic electrodes have the potential

to dissolve due to the electrolysis process and introduce corrosive products into the soil.

- Electro kinetic's is most effective in clays because of the negative surface charge of clay particles. However, the surface charge of the clay is changed by the charges in the pH of the pore fluid and the adsorption of contaminants. Extreme pH at the electrodes and reduction-oxidation changes brought about by the electrode reactions may inhibit the processes effectiveness, even though acidic conditions may assist in metals removal.
- Undesirable products such as chlorine can form as a result of oxidation/reduction reactions.

Performance Data:

There have been few commercial applications of electrokinetic remediation, particularly in the United States. The technology has been tested at both pilot and full scale including at the Battelle Memorial Institute. The EPA undertaking independent assessments of the results, found pilot-scale studies have demonstrated that concentrations of lead decreased to less than 300 mg/kg during 30 weeks of electrokinetic processing, where the initial concentration of lead was approximately 4,500 mg/kg.

Cost:

Costs will ultimately vary depending on the quantity of soil that requires treating. In addition the conductivity of the soil, the type of contaminant, spacing of electrodes will also impact costs. Direct cost estimates of about £ 12 per cubic meter for a suggested energy expenditure of £ 0.05 per kilowatt-hours, together with enhancement, could cost in the region of £ 35/m^3 or more.