ELECTROKINETIC REMEDIATION OF MERCURY-CONTAMINATED SOILS[1]

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ABSTRACT

A series of batch tests were conducted to investigate the relative desorption potential of mercury from kaolin and glacial till soils under the effect of three extractant agents, namely, KI, Na-EDTA and NaCl (all of them with a concentration of 0.1 M). These tests were conducted under different pH conditions (within a pH range between 2 and 12). Also batch tests using deionized water were performed for comparison purposes. The extractant agents were selected from the solutions that form strong soluble complexes with mercury. The results of the batch tests revealed that the extractant agent KI was the most effective agent for removing mercury from both soils. Na-EDTA also, but in lesser extend, exhibited mercury removal. Electrokinetic tests were conducted to evaluate the effect of the extractant agents Na-EDTA and KI. For comparison purposes, electrokinetic baseline tests using deionized water were also carried out. All of these electrokinetic tests were conducted under the same conditions of voltage gradient (1 V/cm) and extractant ion concentration (0.1 M). The results of these electrokinetic tests revealed that KI was efficient in removing mercury from soils, while Na-EDTA did not show any significant removal of mercury. Overall, 95% removal was achieved from kaolin; however, only 77 % removal was achieved from glacial till mainly as a result of existence of insoluble mercury complexes in this soil.

INTRODUCTION

Throughout the country there are numerous contaminated sites that have been polluted with mercury as a result of accidental spills and improper disposal practice. These mercury-contaminated soils have adverse effects on the ecology and human health. According to the United Stated Environment Protection Agency (USEPA), mercury-contaminated soils must now be treated with the Best Demonstrated Available Technology (BDAT), which is retorting or roasting (i.e., thermal treatment technology). The high cost of this technology and the insufficient national capacity to treat mercury-contaminated soils by the BDTA, as pointed out by the gas industry, make it necessary to study other technologies in order to treat the numerous already polluted soils.

Research performed to date shows that electrokinetic remediation is a viable method to remove different heavy metals from various soil types (Reddy and Shirani, 1997; Reddy et al., 1997; Reddy and Parupudi, 1997; Reddy et al., 1999; Reddy and Chinthamreddy, 199; Chinthamreddy and Reddy, 1999). In this research the enhancement of the electrokinetic remediation of mercury-contaminated clayey soils was investigated under laboratory conditions. The

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[1] Proceedings of the International Containment & Remediation Technology Conference, Orlando, Florida, USA, June 2001.

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electrokinetic remediation process is a technology for in-situ or ex-situ decontamination. In clayey soils electrokinetics refers to the transportation of liquid solution, and ions towards an electrode location in the soil, under the action of an applied direct current electric field or a gradient voltage. These products are subsequently removed from the ground via collection systems.

The objective of this study is to investigate the feasibility of using the electrokinetic process as a new cost-effective extraction method to clean up mercury (II) polluted soil. There are three motives for undertaking this research:

- The natural gas industry has been subjected to many mercury releases to the soil environment from mercury manometers. This industry points out that there is an insufficient national capacity to treat mercury contaminated soils by the Best Demonstrated Technology (BDTA), and therefore other technologies must be studied.
- The previous studies that investigated the use of electrokinetics to remediate mercury-contaminated soils suffer several limitations. The present research aims to perform a systematic investigation with the goal of developing enhanced electrokinetic remediation of mercury-contaminated soils.
- Also this research is aimed at obtaining a better understanding of the transient chemical and physical processes during application of the voltage gradient in different soil compositional conditions so that the geochemical effects can be accurately incorporated into the electrokinetic performance predictive models.

EXPERIMENTAL

Two types of soils, kaolin and glacial till, were used for this investigation. Kaolin is a commercially available soil and was obtained from the Thiele Kaolin Company in Georgia. Glacial till is a field-derived soil and was obtained from a project site within the Chicago metropolitan area. Physical and chemical tests were conducted to characterize these soils. These two soils are significantly different in their properties and encompass properties of a wide range of clayey soils encountered in the field. Initially these soils were spiked with mercury (II).

Batch tests were conducted to investigate the mercury desorption from the soils under the effect of different extractant solutions and different pH environments (pH range 2-12). The extractants used were disodium ethylenediaminetetraacetate (Na-EDTA), potassium iodine (KI), and sodium chloride (NaCl). All of the extracting agents were used at a concentration of 0.1 M. Deionized water was also used for comparison purposes. From the batch tests, Na-EDTA and KI were identified as the most effective extractants for desorption of mercury from both soils. A detailed procedure of batch tests is given in Chaparro (1999).

Initially, the electrokinetic removal efficiency of Na-EDTA and KI was investigated by conducting experiments under the same characteristics of gradient voltage (1.0 V/cm) and solution concentration (0.1 M) of both extractants. A description of the electrokinetic test setup and testing procedure is given in Chaparro (1999). These tests indicated that KI was more effective extractant than Na-EDTA. Finally, knowing that KI was the most effective extractant solution, electrokinetic remediation technology, using this extractant solution, was investigated under two conditions. The first condition consisted of evaluating the effect of different voltage gradients (1.0 and 1.5 V/cm) under 0.1 M KI concentration. The second condition consisted of evaluating the effect of different extractant concentrations (0.1M KI and 0.5M KI) under voltage gradient of 1.5 V/cm.

RESULTS

The batch test results shows that the efficiency of mercury removal from the soils is closely related to the complexes that the extractants ions and mercury ions form. The most effective extractant found was KI, with its iodide ion forming a high soluble complex with mercury (HgI_4^{2-}), which has a stability constant of 29.8. The next most effective extractant was Na-EDTA, which also forms a soluble complex with mercury. The stability constant of the Hg-NaEDTA complex changes depending on the pH. For a pH of 12, the approximately stability constant of the Hg-NaEDTA complex is 23.3, while for pH of 2, the approximate stability constant is 8.1. Finally, the NaCl extractant solution showed that it was not an effective extractant for mercury removal, although its chlorine ions form a soluble complex with mercury ($HgCl_4^{2-}$), with a stability constant of 15.4.

The electrokinetic tests conducted on kaolin soil showed that the electrokinetic treatment under 0.1 M KI and 1.0 V/cm conditions is enough to remove approximately 95% of the initial contaminant present (500 ppm of Hg(II)), leaving a residual concentration of 11 ppm of Hg in the soil after the electrokinetic treatment. The tests conducted on glacial till indicated that increasing potassium iodide (KI) concentration and the increasing of voltage gradient increases mercury removal. Under the effect of 0.5 M KI and 1.5 V/cm, 77% of the initial contaminant present (500 ppm of Hg(II)) was removed, leaving a residual concentration of 116 ppm of Hg in the soil after the electrokinetic treatment. The low Hg(II) removal in glacial till soils may be due to the more complicated soil composition of this soil, such as the presence of carbonates and organic matter.

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