



Demonstration Bulletin

In Situ Electrokinetic Extraction System

Sandia National Laboratories

Technology Description

Sandia National Laboratories (SNL) has developed an *in situ* soil remediation system that uses electrokinetic principles to remediate hexavalent chromium-contaminated unsaturated or partially saturated soils. The technology involves the *in situ* application of direct current to the soil, which results in dissolved chromate ions migrating through water in soil pores to the oppositely charged electrode, a phenomenon known as electromigration. In addition to electromigration, a bulk flow of pore water moves toward the cathode in a phenomenon known as electroosmosis. Chromate ions are extracted in the anode effluent. The In Situ Electrokinetic Extraction (ISEE) technology was demonstrated at SNL's Unlined Chromic Acid Pit (UCAP) from May 15 to November 24, 1996. The target contaminant was hexavalent chromium in the form of chromate ions. This demonstration was funded by the U.S. Department of Energy's Office of Science and Technology through the Subsurface Contamination Focus Area. The ISEE technology was independently evaluated under the U.S. Environmental Protection Agency's (EPA) Superfund Innovative Technology Evaluation (SITE) Program.

The SNL ISEE system consists of the following: an electrode system, a vacuum control system, a water control system, a power application system, a monitoring system, and ancillary equipment. Figure 1 shows the ISEE system's main components.

The electrode system consists of anodes and cathodes. The layout of the system used for performance testing at the UCAP site consisted of a central row of four anodes and two rows of four cold finger cathodes each placed 3 feet from either side of the anode row.

The innovative feature of the ISEE system is that lysimeter technology is used to create a continuum between the anode effluent (anolyte) and the pore water both hydraulically and electrically. The electrode fluid is held under tension inside the electrode by an applied vacuum to keep the fluid from saturating the adjacent soil. This feature allowed the removal of chromate from unsaturated soil during the demonstration without significantly altering soil moisture. The vacuum control system maintains a vacuum in the anode electrode. This vacuum creates the pressure gradient between the anode porous ceramic casing and the surrounding soil necessary to hydraulically control water movement between the anode casing and the soil. Hydrogen gas, produced by electrolysis reactions of applying direct current, is purged from the electrode casing to eliminate the danger of explosion.

The water control system consists of a water circulation and pH control systems. The anode water circulation system mixes the anolyte in the electrode, removes and samples anolyte, monitors the chemical condition of the anolyte, and maintains the anolyte temperature at about 12°C. Circulation is maintained in a recycle flow loop by a bladder pump. Because the bladder pump works under vacuum conditions, an additional vacuum source is necessary for its operation. The pH control system maintains the pH of the anolyte at about 6 using a 10 percent sodium hydroxide solution. The cathode water control system consists of chiller water to cool the cathodes with no electrode fluid recirculation systems.

The power application system energizes the electrodes. The demonstration system consisted of four 10-kilowatt power supply units. Each unit was operated independently under constant voltage conditions. The current applied to each electrode was monitored and limited to 15 amperes.

The monitoring system records water control system information such as anode casing water level, recycle flow rate, influent and effluent rates, recycle flow temperature, conductivity, and pH. The monitoring system also records air purge rates, vacuum in the anodes, and ancillary equipment information such as soil temperature and voltage profiles of subsurface soil. The monitoring system can shut down the entire ISEE system if operational parameters are not within established ranges.

Waste Applicability

The ISEE technology developed by SNL is applicable for treating unsaturated soil contaminated with chromate ions. According to SNL, this technology can be modified to treat saturated contaminated soils and to remove contaminants besides chromate dissolved in the pore water. Because other ions will compete with contaminant ions to be removed, it is necessary to determine the electrical conductivity of the soil pore water and the contaminant ion concentration to determine the applicability of the technology.

Demonstration Approach

During the SITE demonstration, 13 tests were performed during six phases. The test areas ranged from 36 to 72 square feet over a zone of contaminated soil from 8 to 14 feet below ground surface. The first 12 tests were conducted so that SNL could determine the ISEE system's preferred operating conditions for test 13 and to facilitate the migration of hexavalent chromium toward the central portion of the test area. Test 13 consisted of system performance testing.

Test 13 targeted a central portion of the demonstration area measuring 12 by 6 feet. Four anodes and eight cold finger cathodes were configured based on efficiency data obtained during the previous tests. This system was operated for over 700 hours from October 21 to November 24, 1996, a period long enough to determine the system performance and treatment cost data.

In general, anolyte samples were collected daily during the system's period of operation. The samples were analyzed in-house for chromate by SNL, and confirmation was obtained by having split samples analyzed by an outside laboratory. The in-house anolyte results constitute a significant basis for EPA's evaluation of system performance.

In addition, pre- and post-demonstration soil samples were collected and analyzed for (1) total and hexavalent chromium and (2) total chromium in leachate using the toxicity characteristic leaching procedure (TCLP).

Demonstration Results

Because of the demonstration site logistics, the demonstration was terminated before chromium extraction rates declined and

the soil was completely remediated. From the SITE evaluation of the ISEE system, the following preliminary findings were made :

- At the system's preferred operating conditions determined by SNL (test 13), (1) approximately 200 grams (g) of hexavalent chromium were removed during about 700 hours of operation (0.29 g per hour), and (2) the overall removal efficiency for the system was approximately 0.13 g of hexavalent chromium per kilowatt hour.
- Within the test areas, 18 out of 43 pre-demonstration soil samples exceeded the TCLP limit of 5 milligrams per liter (mg/L) of total chromium. The samples that exceeded the TCLP limit contained chromium at concentrations of 5.6 to 103 mg/L, with a median concentration of 15.4 mg/L. Post-demonstration results indicate that 18 out of 35 soil samples exceeded the TCLP regulatory criterion for chromium. The samples that exceeded the TCLP limit contained chromium at concentrations ranging from 6 to 67 mg/L, with a median concentration of 20.4 mg/L.

Key findings of the SITE demonstration, including sample analytical results, will be discussed in detail in the innovative technology evaluation report and the technology evaluation report. The results will also be summarized in a demonstration capsule.

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