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SITE DEMONSTRATION OF THE DYNAPHORE/FORAGER SPONGE TECHNOLOGY TO REMOVE DISSOLVED METALS FROM CONTAMINATED GROUNDWATER

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INTRODUCTION

A Superfund Innovative Technology Evaluation (SITE) demonstration was conducted of the Dynaphore/Forager Sponge technology during the week of April 3, 1994 at the N.L. Industries Superfund Site in Pedricktown, New Jersey. The Forager Sponge is an open-celled cellulose sponge incorporating an amine-containing chelating polymer that selectively absorbs dissolved heavy metals in both cationic and anionic states. This technology is a volume reduction technology in which heavy metal contaminants from an aqueous medium are concentrated into a smaller volume for facilitated disposal.

The developer states that the technology can be used to remove heavy metals from a wide variety of aqueous media, such as groundwater, surface waters and process waters. The sponge matrix can be directly disposed, or regenerated with chemical solutions. For this demonstration the sponge was set up as a mobile pump-and-treat system which treated groundwater contaminated with heavy metals. The demonstration focused on the system's ability to remove lead, cadmium, chromium and copper from the contaminated groundwater over a continuous 72-hour test. The removal of heavy metals proceeded in the presence of significantly higher concentrations of innocuous cations such as calcium, magnesium, sodium, potassium and aluminum.

METHODOLOGY

The Forager Sponge is an open-celled cellulose sponge which contains a water-insoluble polyamide chelating polymer for the selective removal of heavy metals. The polymer is intimately bonded to the cellulose so as to minimize physical separation from the supporting matrix. The functional groups in the polymer (i.e., amine groups in the polymer backbone and pendent carboxyl groups) provide selective affinity for heavy metals in both cationic and anionic states, preferentially forming coordination complexes with transition-group heavy metals (groups IB through VIIIB of the Periodic Table). The order of affinity of the polymer for metals is influenced by solution parameters such as Ph, temperature, and total ionic content. The following affinity sequence is generally expected by Dynaphore:

$Cd^{++} > Cu^{++} > Fe^{+++} > Au^{+++} > Mn^{+++} > Zn^{++} > Ni^{++} > Co^{++} > Pb^{++} > Au(CN)_2^- > SeO_4^{-2} > AsO_4^{-3} > Hg^{++} > CrO_4^{-2} > UO_4^{-2} > Ag^+ > Al^{+++} > K^+ > Ca^{++} > Mg^{++} >> Na^+$

The high selectivity for heavy metals and the low selectivity for alkali and alkaline earth metals (Na^+, K^+, Mg^{++}, and Ca^{++}) is especially useful for the treatment of contaminated natural waters which may contain high concentrations of these innocuous chemical species. These monovalent and divalent cations do not interfere with or compete with absorption of heavy metals from contaminated waters.

The sponge is highly porous and thus promotes high rates of absorption of ions. Absorbed ions can be eluted from the sponge by techniques typically employed for regeneration of ion exchange resins. Following elution, the sponge is ready for the next absorption cycle. The useful life of the media depends on the operating environment and the elution techniques used. Where regeneration is not desirable or economical, the sponge can be compacted to an extremely small volume to facilitate disposal. The metal-saturated sponge can also be incinerated with careful attention given to the handling of resultant vapors.

The sponge can be used in columns, fishnet-type enclosures, or rotating drums. For this demonstration, the sponge was utilized in a series of four 1.7 cubic foot columns situated on a mobile, open trailer-mounted unit measuring approximately 50 square feet. Each column was 5 feet in height with an 8 inch inside diameter. The columns were connected for upward flow series and each column contained a removable fishnet bag filled with about 24,000 half inch sponge cubes. The trailer was equipped with a wastewater pump, water heater, and both a rotameter and positive displacement type flow totalizer.

This technology was evaluated over a continuous 72-hour operational period, resulting in a total treatment volume of approximately 4,300 gallons. Groundwater was pumped from an existing monitoring well into a 6500 gallon influent storage tank. Although concentrations of some of the critical metals exceeded cleanup goals for the site, the groundwater in the influent storage tank was then spiked with nitrate solutions of lead, copper, and cadmium to assure effective evaluation (quantification) of the developer's claim. The spiked solutions were added to the influent storage tank approximately 24 hours prior to the start of the demonstration and the tank was kept well mixed via recirculation throughout the demonstration.

The groundwater was pumped from the influent storage tank through the four-column system at a treatment flow rate of 1 gpm or 0.08 bed volumes per minute. The influent temperature was raised approximately 15°C to increase reaction rates in order to improve absorption of the critical metals. The treated effluent was initially discharged to a 250 gallon portable tank from which it was subsequently pumped to a 20,000 gallon effluent storage tank for transport off-site for treatment at a local POTW.

Grab samples for analysis of critical parameters were collected from the raw influent, final effluent and intermediate column effluent points. In addition, equal volume 24-hour composite samples were collected for total metals, chemical oxygen demand, total suspended solids, total dissolved solids, sulfate and gross alpha and beta radioactivity. Since the developer reported that replacement or regeneration of the columns should not be necessary, side tests on laboratory scale columns treating standard metal salt solutions were performed to aid in evaluating the absorption capacity and regenerative capabilities of the sponge.

In addition to the lead, cadmium and chromium which were the contaminants of concern at the NL site and therefore the critical parameters for this study, copper was also considered a critical parameter because of the high removal efficiency observed in predemonstration treatability tests.

The developer claimed that the technology would achieve at least a 90% reduction of lead and copper, an 80% reduction in cadmium and a 50% reduction of chromium (as trivalent chromium) in the groundwater.

RESULTS

Analytical results of the critical parameters for the raw influent and final effuent are presented in Table 1. These data show that the treatment claims for cadmium, copper, and lead were achieved. However the developer did not achieve treatment claims for chromium. The treatment claim was based on comparing the mean concentration of the raw influent to the mean concentration of the final effluent.

Table 1: Treatment Performance for Critical Metals

Parameter	90% Confidence Interval for Avg. Influent Conc. (ug/L)	90% Confidence Interval for Avg. Effluent Conc. (ug/L)	90% Confidence Interval for Percent Removal (%)	Developer's Treatment Claim (%)
Cadmium	537 +/- 11	56 +/- 13	90 +/- 2.7	80
Chromium	426 +/- 31	290 +/- 30	32 +/- 5.8	50
Copper	917 +/- 14	25 +/- 0	97 +/- 0.04	90
Lead	578 +/- 12	18 +/- 3	97 +/- 0.59	90

Effective removal of cadmium, copper and lead was achieved in the presence of a groundwater pH ranging from 3.1-3.8; a sulfate concentration of approximately 20,000 mg/L; a TDS concentration of approximately 23,000 mg/L and disproportionately higher concentrations of other cations such as magnesium (72 mg/L), potassium (82 mg/L), aluminum (149 mg/L), calcium, (224 mg/L) and sodium (6000 mg/L). The technology's low affinity for these cations was supported by the near zero removal rates of these ions.

Effective removal of chromium (based on the 50% claim) was achieved within the first 10 hours of operation until performance markedly decreased. The decrease in the removal efficiency could be the result of the sponge's higher affinity for the other critical metals. Based on the developer's regeneration tests on sponge cubes taken from the demonstration columns, regeneration is feasible for lead, copper and cadmium.

Following completion of the demonstration, the sponges were easily removed from the columns via an overhead pulley system installed on the trailer. They were then placed in plastic sleeve bags and hand compacted into 55-gallon drums. A waste compacting firm was able to compact 16 sleeves of sponges into one drum, using a standard industrial waste compactor.

The cost to treat heavy metal contaminated groundwater over a one year period with the Forager Sponge technology is estimated at $340/1000 gallons, assuming the sponges are not regenerated and are replaced upon saturation; or $238/1000 gallons, assuming the sponges are regenerated twice providing for three useful treatment cycles. This cost estimate assumes groundwater characteristics are similar to the demonstration groundwater and the cadmium, lead and copper are treated to demonstration performance claims utilizing a four-column, pump-and-treat unit similar to the demonstration unit. The system would operate 24 hours a day, 7 days a week at a flow rate of 1 gpm resulting in a total treatment volume of approximately 525,000 gallons.

CONCLUSIONS

The Dynaphore Inc. Forager Sponge represents a new approach for the selective removal of heavy metals from water. The developer contends that the cost can be greatly reduced by performing treatability tests on the particular water to be treated and thereby modifying the chelating polymer structure for that particular contaminated water. In addition, the sponge can be used for in-situ applications, e.g., placing a single container bag unit of sponge vertically at the neck region of convergent groundwater collecting zone downstream of the plume. The sponge can also be placed in a trench installation for groundwater remediation employing a multitude of containers of sponge horizontally placed in a sand bag type of arrangement. Containers of sponge can also be utilized tea-bag style or placed within a conduit through which water flows by gravity effect. Loose sponge is being evaluated in tumble operations in soil washing treatments and in stirred tanks for sludge remediation.

FOR MORE INFORMATION

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