



1.0



1.1



1.25



1.4



1.6



2.0



2.2



2.5



2.8



3.2



3.6



4.0



4.5



5.0



5.6



6.3



7.1



8.0



9.0



10.0

1 of 1

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Laboratory Evaluation of the In Situ Chemical Treatment Approach to Soil and Groundwater Remediation

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LABORATORY EVALUATION OF THE IN SITU CHEMICAL TREATMENT APPROACH TO SOIL AND GROUNDWATER REMEDIATION

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ABSTRACT

Results of initial proof of principle laboratory testing activities successfully demonstrated the viability of the in situ chemical treatment approach for remediation of soil and groundwater contaminated by hexavalent chromium. Testing activities currently in progress further indicate that soils contaminated with hexavalent chromium and uranium at concentrations of several hundred parts per million can be successfully treated with 100 ppm hydrogen sulfide gas mixtures. Greater than 90% immobilization of hexavalent chromium and 50% immobilization of uranium have been achieved in these tests after a treatment period of one day. Activities associated with further development and implementation of the in situ chemical treatment approach include conducting additional bench scale tests with contaminated geomeedia, and undertaking scale-up laboratory tests and a field demonstration.

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INTRODUCTION

Radionuclide and metal contamination of groundwater and soils is an important environmental issue at federal facilities. The initial approach to remediation often involves removal of the most highly contaminated soils by excavation and the bulk of groundwater contaminants through the conventional pump and treat approaches. These methods have economic limitations, however, and in many instances may not be able to satisfy regulatory performance goals (1). Recognition of these limitations has generated interest in the application of in situ technologies for remediation (2,3).

One potentially viable approach to in situ remediation involves the introduction of chemical treatment agents that will immobilize contaminants by inducing precipitation, either through changes in pH or redox conditions or by supplying a constituent that will combine with the contaminant to form an insoluble product. The chemical agent could be introduced to a contaminated zone either as a gas or as a solution.

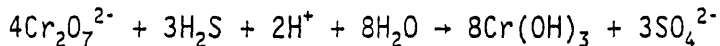
As illustrated in Figure 1, contamination is often associated with a source situated in vadose zone unsaturated soils. Leaching of the contaminant from the vadose zone by infiltration processes subsequently results in contamination of an associated aquifer. The initial approach to remediation frequently involves mass removal of contaminated soils by excavation and contaminated groundwater by pumping. Following initial removal actions, the in situ chemical treatment approach could be undertaken to complete site and aquifer restoration. Thus, injection of treatment solutions upgradient of the groundwater contaminant plume could be undertaken during pumping. Transport of the treatment agent through the contaminated aquifer would serve to

immobilize residual contamination and thus accelerate remediation of the aquifer (3, 4). Treatment of the unsaturated zone could also be conducted simultaneously with groundwater treatment by injection and withdrawal of treatment gases, as shown in Figure 1.

PLACE FIG. 1 HERE

LABORATORY TESTING ACTIVITIES

Initial proof of principle testing activities confirmed that chemical treatment of soils containing hexavalent chromium with reducing gas mixtures (e.g., hydrogen sulfide or sulfur dioxide) results in significant reduction and immobilization of the contaminant (5). In these tests, clean soils were collected near the Hanford Site and spiked with hexavalent chromium to a level of 5 ppm. Portions of the contaminated soil were then treated by gas mixtures consisting of 0.27% and 1% hydrogen sulfide in nitrogen at mole ratios of S:Cr equal to 20 and 100. The reduction of hexavalent chromium by hydrogen sulfide during treatment may be represented by the reaction



where hexavalent chromium is represented by the dichromate anion. This reaction results in the reduction of chromium to the trivalent oxidation state, with the resultant precipitation of chromium hydroxide.

Subsequent to treatment, the soils were leached with water and the leachates analyzed to assess the degree to which chromium was immobilized. Results of these tests indicated as much as 97% immobilization of chromium, with the degree of immobilization being largely independent of hydrogen sulfide concentrations and mole ratios over the range indicated above. Sulfur dioxide/nitrogen mixtures were also evaluated in associated tests, but found to be somewhat less effective, resulting in about 50% immobilization under the treatment conditions chosen.

PLACE FIG. 2 HERE

Solution tests were also undertaken during the initial stages of this work to provide information regarding treatment of Cr(VI) solutions by selected reducing agents, including ferrous sulfate, sodium sulfite, sulfurous acid, sodium sulfide, sodium thiosulfate, sulfur dioxide, and hydrogen sulfide (5). Reduction and immobilization of chromium was most readily achieved with ferrous sulfate, sodium sulfide, and hydrogen sulfide, and resulted in lowering solution concentrations to <50 ppb Cr(VI).

Additional tests with hydrogen sulfide gas mixtures have been recently conducted with several soil types to better evaluate the effect of varying the major treatment parameters for soils contaminated at moderately high levels. Three soils from the Hanford Site, Sandia (Mixed Waste Landfill Integrated Demonstration), and Fernald (Uranium Soils Integrated Demonstration) have been included in these tests and were spiked to the 200 ppm concentration level with both Cr(VI) and U(VI). Treatment was performed in these tests with gas mixtures containing hydrogen sulfide concentrations of 2000 ppm and 100 ppm and at a mole ratio of S:(Cr+U) equal to only 10. Results recently obtained from these tests verify that gas mixtures as dilute as 100 ppm hydrogen

sulfide can achieve 90% or more immobilization of hexavalent chromium and illustrate that adequate treatment can be obtained using a mole ratio only moderately larger than the minimum required stoichiometric ratio. The tests also suggest that a portion of the uranium was immobilized (approximately 50%).

TECHNOLOGY DEVELOPMENT AND DEMONSTRATION ACTIVITIES

Future activities necessary for developing and applying the in situ chemical treatment approach to contaminated soils are currently in the planning stages. Candidate waste sites are being identified, and one will be selected as a test site. Once a selection has been made, samples of contaminated soil will be collected for further testing activities. These tests will be similar to those described above, and will have the primary objective of verifying that treatment with 100 ppm hydrogen sulfide mixtures will be effective for immobilizing the metals or radionuclides of concern at the test waste site.

Transfer of the technology to the field will be initiated through larger scale laboratory tests. These tests will be designed to evaluate the treatment of a significant volume of soil, and will involve injection of the treatment gas into the soil through a central injection point and extraction through an array of points situated in a radial configuration about the injection point. This system will be configured so that the treatment gas mixture is recirculated through the soil until the treatment process is completed. Subsequent to treatment, the soil will be sampled at various points to verify that the site was treated in a homogeneous manner and that a required degree of contaminant immobilization has been attained.

System design and development activities will take place in parallel with the laboratory scale-up tests. Important aspects of system design include development of instrumentation and equipment that will control gas mixing and flow operations, monitor gas composition, and record important system parameters. Evaluation of system requirements associated with full-scale operations will also be undertaken, and the necessary components will be obtained.

Preliminary safety and regulatory review results suggest that the in situ chemical treatment approach is viable provided adequate control of the chemical agents is maintained during application. Identification and resolution of potential regulatory or safety issues associated with implementation of the approach will continue in parallel with laboratory testing and system design activities. Final selection of appropriate treatment parameters and performance goals for the designated test waste site will, in addition, be performed during this period.

The final stage of development will involve conducting a full-scale field demonstration. This demonstration will involve drilling vadose zone boreholes for gas injection and withdrawal. After completion of the boreholes, it is anticipated that a cover will be placed over the test site to minimize escape of treatment gases. The gas will be then be circulated through the contaminated site soils for a suitable period of time. At the end of the treatment period, excess hydrogen sulfide will be purged from the system with air and the cover will be removed. Additional boreholes will then be drilled and soil samples obtained to evaluate the effectiveness of treatment.

CONCLUSIONS

Results of testing activities to date suggest that the in situ chemical treatment approach may be a useful remediation technology, especially for wide-spread inorganic contamination at low concentrations. Future development will focus on site-specific testing of contaminated geomedia and definition of treatment parameters and performance goals, leading to a field demonstration of soil treatment with diluted hydrogen sulfide mixtures. Efforts associated with this demo will include scale-up of the soil treatment system through larger scale lab tests and engineering design activities. A full-scale field demonstration will then be conducted and the site subsequently characterized to determine if performance goals were achieved.

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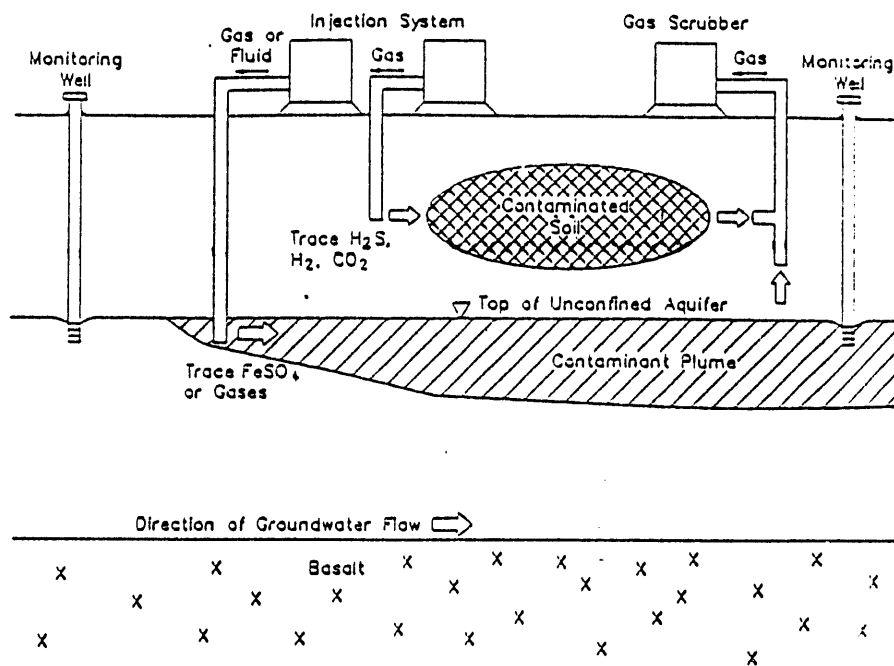


Figure 1. Chemical Treatment of the Vadose and Saturated Zones

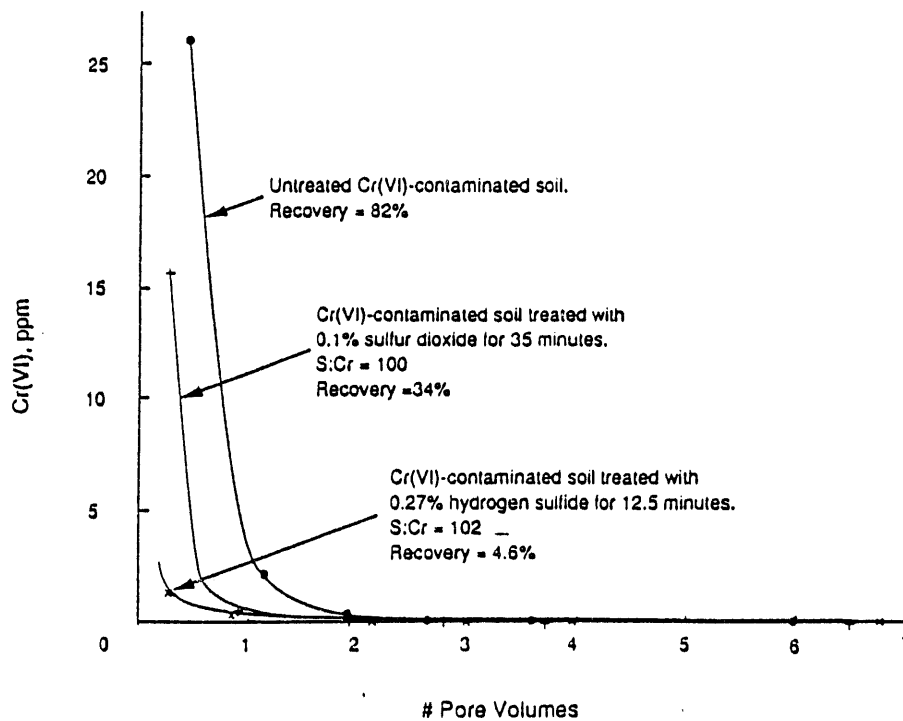


Figure 2. Cr(VI) Breakthrough Curves for Soil Leach Tests

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