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NATIONAL RISK MANAGEMENT RESEARCH LABORATORY
GROUND WATER AND ECOSYSTEMS RESTORATION RESEARCH

Steam Injection Into Fractured Bedrock at Loring Air Force Base

Introduction to the Problem

Hundreds of contaminated sites exist where most or all of the subsurface contamination resides in fractured bedrock. Due to the complexity of the hydrogeologic systems in fractured bedrock, few types of remediation have been attempted.

Background

Over 450 drums that contained spent solvents were disposed of in the Loring Air Force Base quarry. Ground water sampling below the buried drums revealed ground water contamination from leaking drums. The contamination consisted of mostly tetrachloroethene (PCE). A research project was undertaken on steam injection remediation in fractured rock.

Objectives

- Determine whether steam injection can be used to heat fractured bedrock
- Determine whether steam injection can enhance the recovery of volatile contaminants from fractured limestone
- Evaluate changes in rock and ground water concentrations due to the steam injection
- Evaluate horizontal and vertical migration of contaminants from the treatment zone during steam injection
- Evaluate the use of electrical resistance tomography and borehole radar tomography to track steam/heat fronts in fractured limestone

Approach

Site characterization activities, including sampling of rock to determine contaminant concentrations, discrete interval transmissivity testing, and discrete interval groundwater sampling, was carried out and interconnectivity testing was performed. Based on all of the characterization data, a steam injection, extraction, and monitoring system was designed and constructed. Steam injection was initiated in September 2002 and continued for approximately 80 days. Concurrently, vapors and ground water were extracted and analyzed. After steam injection was complete, three rounds of post-treatment ground water samples and post-treatment rock chip samples were taken.

Accomplishments

Steam injection rates were lower than initially anticipated due to low permeability of the fracture network. However, effluent sampling during the steam injection showed that aqueous and vapor-phase concentrations increased, starting about three weeks after steam injection was initiated. Although effluent concentrations continued to increase throughout the 80 days of the steam injection, steam injection had to be stopped due to lack of sufficient funding. If remediation had been completed, it appears that significant additional recoveries would have been possible. Ground water concentrations in the area that received the most steam were reduced in the post treatment

samples. However, in other areas concentrations increased. The post-treatment rock chip samples seem to show an overall decline in contaminant concentrations in the rock. Ground water sampling indicates vertical and hydraulic migration did not occur. The characterization and steam injection data were evaluated to determine the usefulness of different types of characterization data for remediation in fractured rock.

Final Report

Steam-Enhanced Remediation Research for DNAPL in Fractured Rock, Loring Air Force Base, Limestone, Maine (PDF) (211 pp, 16.5 MB) (EPA/540/R-05/010) August 2005 - Abstract

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