Steam Injection into Fractured Limestone at Loring Air Force Base

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A research project on steam injection for the remediation of spent chlorinated solvents from fractured limestone was recently undertaken at the former Loring AFB in Limestone, ME. Participants in the project include the Maine Department of Environmental Protection, EPA Region I, the Air Force, EPA's Office of Research and Development, and SteamTech Environmental Services. In addition, expert advise on characterization of fractured rock and steam injection was provided by researchers from Queen's University and the University of California – Berkeley. The primary objective of the project was to facilitate development of promising technologies for bedrock remediation while reducing the amount of mass remaining in the subsurface at this site.

Site History and Characterization

The Quarry was located in the northwest corner of the former Loring AFB, and was used as a source of limestone gravel for the base, and at some time drums of spent chlorinated solvents from base operations were stored or disposed of there. During the 1990s, approximately 450 drums were removed from the upper tier of the Quarry. Subsequent investigation of the groundwater revealed concentrations of tetrachloroethene at levels that would indicated the presence of nonaqueous phase liquids (NAPLs). Other contaminants found in the groundwater included trichloroethene, carbon tetrachloride, and BTEX. Characterization of the fracture system indicated a very complex system with the presence of three different fracture systems as well as several faults. Fracturing within the treatment zone, however, was sparse. Groundwater flow is believed to be controlled by bedding plane fractures.

The Steam Injection Research

In Summer 2001, installation of a steam injection system aimed at the area where high levels of PCE and TCE were known to exist in groundwater in the fractured limestone was initiated. As boreholes were installed of the system, characterization of the contaminant distribution, the fracture system, and the hydrogeology was undertaken. Based on the results of the characterization activities, the injection and extraction system was redesigned, based on injecting steam into the relatively clean boreholes, and extracting contaminants from the most highly contaminated boreholes. Steam injection was initiated in September 2002 and continued for 80 days. Temperature distribution in the subsurface and the extraction rate of contaminants was monitored, and changes were made to the system to optimize the amount of steam injected into the system and the amount of contaminants recovered. After the funding for the research was exhausted and the injection terminated, extraction continued for an additional 7 days, and periodic temperature monitoring was continued for an additional 3 months. During the Summer of 2003, post-treatment groundwater and rock core samples were obtained and analyzed. Data is being compiled to describe heat flow in the fractured rock system, as well as the flow and transport of contaminants in the aqueous and vapor phase. This presentation will describe the design of the steam injection system and what was learned about steam and contaminant movement in fractured limestone during the steam injection.

This is an abstract for a proposed presentation and does not necessarily reflect EPA policy.

Dr. Eva Davis received a Ph.D in Agricultural Engineering from Colorado State University in 1990, with a specialization in groundwater contamination. Since that time, she has worked for the US Environmental Protection Agency doing research and technical support for thermal remediation of soils and aquifers. Her research has focused on temperature effects on the properties of organic contaminants, temperature effects on flow in porous media, hot water injection for remediation, and steam injection treatability studies. Her technical support activities include site specific consulting to assess sites for the applicability of thermal remediation, site characterization to support application of the technologies, and operational support for sites with a variety of contaminants and in a range of geologic settings.

Dr. Gorm Heron is the principal engineer and scientist for SteamTech Environmental Services. He has been the lead designer on the seven field projects conducted since 1998. Prior to this, Dr. Heron was a research engineer at UC Berkeley, and a post-doctoral researcher at the USEPA Kerr Research Center in Ada, Ok. He has worked on thermal remediation since 1995. He holds an Master of Science in Civil Engineering (1990) and a Ph.D in Environmental Science and Engineering from Technical University of Denmark (1994).

Dr. Steve Carrroll has been the lead geologist for seven field implementations of thermal remediation since 1999. In addition, he was the project manager for three thermal remediation projects between 2001 and the present. He is the lead geologist and geophysicist for SteamTech Environmental Services. Dr. Carroll holds a Ph.D in Geology from University of Aberdeen (1992) and a Bachelor of Science in Geology from University of Glasgow (1987).

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