



**Project Title:** “Enhanced Source Removal”

**Investigators:** A. Lynn Wood (U.S. EPA, Office of Research and Development, National Risk Management Research Laboratory, GWERD, Ada, OK 74820; 580-436-8552); Carl G. Enfield (U.S. EPA, Office of Research and Development, National Risk Management Research Laboratory, Cincinnati, OK, 513-569-7489)

**Collaborators:** Strategic Environmental Research and Development Program (SERDP), U.S. Air Force, University of Arizona, Clemson University, University of Florida, Michigan Technological University, University of Oklahoma.

**Background:** Nonaqueous phase liquids, especially those which are denser than water (DNAPLs) and which tend to migrate vertically downward in the subsurface, have proven to be very recalcitrant to traditional remediation approaches. Because of the relatively small areal extent, the large contaminant mass, and the extremely long-term impact of DNAPL source zones, the potential pay-off of source removal can be very high. This has motivated the search for alternative source remediation technologies offering enhanced rates of cleanup. Several alternative methods for in-situ extraction or destruction of NAPLs have been proposed. These include the use of remedial fluids and/or thermal energy to facilitate the dissolution, mobilization, or volatilization of NAPLs, or of oxidants to degrade the organic contaminants.

**Objectives:** The objectives of the project are to: (1) assess and compare the performance of a variety of in-situ source remediation technologies in carefully monitored pilot-scale field tests, (2) develop a scientifically defensible data base which can be used to evaluate their efficacy and robustness, and (3) identify remaining technical impediments to the implementation of these technologies.

**Approach:** The project involved the side-by-side evaluation of innovative source removal techniques at two field sites representing different hydrogeological and contaminant conditions. The first study site is Operable Unit 1 at Hill Air Force Base, Utah. This is a sand and gravel aquifer contaminated with a chemically complex LNAPL present as a predominantly immobile residual phase. The demonstrations were conducted in the vicinity of two chemical disposal pits used during the 1940s and 1950s for disposal of a variety of wastes including aviation fuels and chlorinated solvents and

downgradient from a former fire-training area which may have contributed unextinguished fuels and combustion by-products. Wastes from these and other potential sources had intermingled to form the complex LNAPL mixture which was the target for these demonstrations.

The second technology demonstration site is located at the Dover National Test Site (DNTS), Dover Air Force Base, Delaware. Two physically and hydraulically isolated test cells were constructed in order to contain contaminants and remedial fluids used in the technology demonstrations and to permit accurate mass balance calculations. Each test cell was equipped with an extensive network of wells and monitoring points. Five enhanced source removal technologies are being evaluated at the DNTS. These are cosolvent solubilization, air sparging/SVE, surfactant solubilization, complex sugar flush, and cosolvent mobilization.

**Accomplishments:** All field demonstrations have been completed. Final project reports are under preparation.

**Selected Publications:**

Wood, A.L. and C.G. Enfield. 1999. Enhanced Source Removal. EPA/600/C-99/002.

Brooks M.C., M.D. Annable, P.S.C. Rao, K. Hatfield, J.W. Jawitz, W.R. Wise, A.L. Wood and C.G. Enfield. (2002). Controlled release, blind tests of DNAPL characterization using partitioning tracers. J. Contamin Hydrol. 59:187-210.

Brooks M.C., M.D. Annable, P.S.C. Rao, K. Hatfield, J.W. Jawitz, W.R. Wise, A.L. Wood and C.G. Enfield. (2003). Controlled release, blind test of DNAPL remediation by ethanol flushing. Accepted for publication in J. Contamin Hydrol.

Tick, G.R., F. Lourenso, A.L. Wood and M.L. Brusseau. (2003). Pilot-scale demonstration of cyclodextrin as a solubility-enhancement agent for remediation of a tetrachloroethene-contaminated aquifer. Environ. Sci. Technol. 37:5829-5834.