United States
Environmental Protection
Agency

Solid Waste and
Emergency Response
(5102W)

EPA542-S-95-001
April 1995

EPA

Emerging Abiotic In Situ Remediation Technologies for Ground Water and Soil

Summary Report

Purpose

This document summarizes the status and trends in the development of abiotic technologies to treat contaminated ground water in-place or increase contaminant solubility and mobility to improve their removal by pumping. It is an overview of six status reports that document demonstrations and research on specific emerging abiotic technologies. This information will allow stakeholders to understand the current investments in emerging abiotic technologies and make more informed decisions concerning their use for remediation.

This document and the underlying status reports do not cover trends in the use of bioremediation. EPA has other resources summarizing the progress of bioremediation technologies. See the section of "Related Information Sources" for information about the *Bioremediation in the Field* newsletter and the Bioremediation in the Field Search System database. The database contains information on the status of over 400 sites where bioremediation is being applied, and the newsletter provides updates on performance evaluations of new technologies, resources, and regulations affecting the use of bioremediation. At these sites, a broad range of in situ and ex situ biotreatments are being applied, including land treatment, bioventing, bioreactor treatment, nutrient addition, and many other techniques.

Method

EPA has identified six abiotic technologies that are emerging as possible clean-up remedies. For each technology, EPA has produced a separate report identifying research projects, demonstrations, and field applications of the technology. The technologies are:

- surfactant enhancements
- treatment walls
- hydraulic fracturing/pneumatic fracturing
- cosolvents
- electrokinetics
- thermal enhancements

Information in each report was found in computerized databases such as EPA's Vendor Information System for Innovative Treatment Technologies (VISITT) and Alternative Treatment Technologies Information Center (ATTIC) and databases available from Knight-Ridder Information Services; and in publications such as the Hazardous Substance Research Center Annual Reports, the Superfund Innovative Technology Evaluation Technology Profiles and the Department of Energy Office of Technology Development Program Summary. The review also included conference summaries, proceedings, and compendia. It was supplemented with personal interviews and discussions with representatives of other federal agencies, academic research centers, and hazardous waste remediation consulting firms.

Technology Needs

The predominance of ground-water contamination at hazardous waste sites and the lack of methods to treat the contamination is a problem of great concern to EPA. According to a recent report released by the National Research Council, there are approximately 300,000-400,000 contaminated waste sites[1]. The contaminated ground water found at Superfund sites is often the limiting factor for complete site remediation. Until recently, many believed that contaminants in surface soils were the only significant source of ground-water contamination. Consequently, development of remediation technologies focused mainly on this source. Ground-water treatment was limited to pump-and-treat technology while in situ ground-water treatment was ignored. Technologies to remediate contaminated ground water in situ are not yet well developed, primarily because contaminated ground water plumes are difficult to define, contaminants can migrate in different directions simultaneously, and, in most cases, the subsurface is unreachable for in situ characterization.

Researchers and regulators studying data from pump-and-treat remediation systems have become convinced that the source of much ground-water contamination is dense non-aqueous phase liquids (DNAPLs) and other compounds that migrate downward into aquifers and often form pools of subsurface contaminants. In these cases, the efficiency of contaminant removal is contingent on solubility of the contaminant, efficacy of the pumping system, and hydraulic characteristics of the aquifer. Unless they directly remove the contaminant source, pump-and-treat systems only treat the symptom (solubilized contaminants), and not the cause. Because of this, there is a need for technologies that improve the efficiency of pumping systems as well as in situ treatment of contaminated ground water and subsurface contaminant sources.

Technology Descriptions and Analyses

Thermal Enhancements. Thermal enhancement technologies include the injection of hot water or steam or the use of radio frequency or electrical resistance heating to increase the mobility, solubility, or volatility of organic contaminants, particularly immiscible compounds.

There are approximately 16 completed, ongoing or future demonstrations. Two demonstrations will be using the "Contained Recovery of Oily Wastes (CROW™)," a patented technology by Western Research Institute. Almost all the other demonstrations were or will be conducted at federal facilities. There are 11 completed demonstrations which provide some cost and performance information. Most of the demonstrations treated VOCs, SVOCs, and BTEX; however, two demonstrations were designed to treat PAHs from wood treating sites and one treated pesticides.

There were only two research projects being conducted. The dearth of research may be explained by the fact that the physical site conditions, not chemical reactions, are the major controlling factors on the use of the technology. Therefore, laboratory studies, although important, are not critical.

Surfactant Enhancement. Surfactants increase the solubility of the contaminant in water and also increase mobility by reducing interfacial tension between the contaminant and the soil matrix, resulting in direct mobilization.

There were 10 demonstrations or commercial applications. Many of these were supported by the State University of New York (SUNY) at Buffalo, which conducted much of the early research for the technology. The target contaminants at the demonstrations were VOCs, SVOCs, BTEX and one demonstration for PCBs. There were nine research projects identified, a relatively large number which reflects the need of laboratory and bench-scale support. There are a variety of surfactants available and the effectiveness of each of these to treat a specific contaminant in a specific geochemical environment is usually unknown until laboratory and bench scale treatability tests are conducted. Consequently, research support for this technology is necessary and important. Research is being supported by a variety of stakeholders, including the federal government, private industry and research facilities. All the current research is being conducted on organic contamination.

Treatment Walls. These are vertical treatment zones installed across the flow path of a contaminant plume to treat the contaminants as the plume passes through the zone. These mechanically simple barriers may contain metal-based catalysts for degrading volatile organics, chelators for immobilizing metals, or nutrients and oxygen to enhance bioremediation.

Four of the 11 ongoing or completed demonstrations are using or have used in situ metal-enhanced dehalogenation. The patent for this technology is held by the University of Waterloo. The remaining demonstrations are testing the use of O^2, nutrients for bioremediation, and chemical reactants to reduce Cr^{+6}. Preliminary results from four demonstrations are expected in 1995.

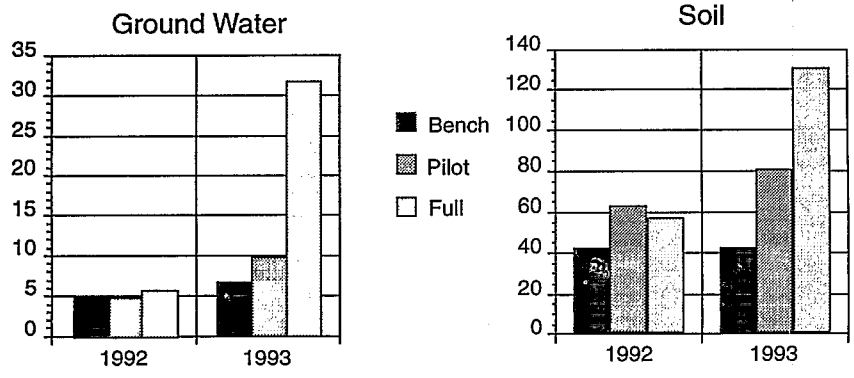
There are 10 research projects identified, sponsored primarily by DOE and EPA. This research is divided between the treatment of metals and organics.

Hydraulic Fracturing/Pneumatic Fracturing. Fracturing consists of the injection of pressurized water or air to increase the size and number of fractures in a consolidated material or relatively impermeable unconsolidated material. The enlarged fractures provide more treatment area for an in situ technology or more pathways to remove solubilized or mobilized contaminants.

Demonstrations of pneumatic fracturing are being conducted by two vendors, with the New Jersey Institute of Technology providing a supporting role with research. The demonstrations were included in the EPA Superfund Innovative Technology Evaluation (SITE) program. One demonstration of hydraulic fracturing was included in SITE. There were no current direct research efforts identified.

Cosolvents. Cosolvents are a form of in situ flushing that involves the injection of a solvent mixture (e.g., water plus a miscible organic solvent such as alcohol) that enhances the solubility of organic contaminants.

Figure 1: Development Status of VISITT and SITE Program Technologies



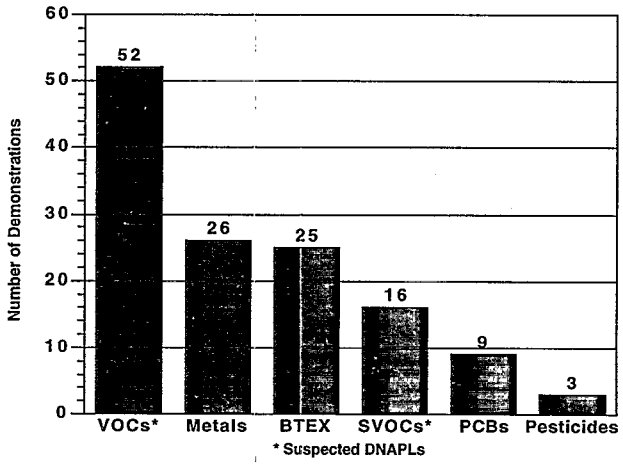
Developers of 31 technologies claim to treat ground water and soils. Soils in this context also include solids, debris, and sludge. There were a total of 177 technologies in 1992 and 289 technologies in 1993.

The use of cosolvents is in the very early stage of development. No vendors were identified who are marketing the technology and three planned demonstrations will be conducted by a partnership between a federal laboratory, a military base, and a university. One research project was completed in 1991.

Electrokinetics. The basis of this technology is that positively-charged organic or inorganic contaminants can be made to migrate in an electric field to a collection point for removal by pumping. Most of the six demonstrations are being sponsored or cosponsored by the federal government (Department of Energy or Army Corps of Engineers). Of these demonstrations, approximately half were designed to treat metals and half were for treating BTEX and TCE. There is a relatively large number of universities conducting research in electrokinetics, many being supported by DOE. Louisiana State University (LSU) is heavily involved in this research and has published over 30 papers. They are also in partnership with a private company that is deploying and commercializing the technology. Besides LSU, there are seven other research facilities conducting studies on the technology.

The following table (Figure 2) summarizes the number of activities being conducted to test and demonstrate the six technologies analyzed in the status reports. The number of research projects represents the number of research centers actively conducting research to develop and fine-tune technologies. The research projects involve technologies that are not necessarily ready to be demonstrated. Each project consists of one group, generally a university or laboratory, but in some cases a technology vendor. The number of ongoing or future demonstrations represents the number of locations where the technology is being demonstrated or will be demonstrated in the near future. The number of completed demonstrations represents the number of demonstrations that have already taken place. Commercial applications represent individual sites where the technology is being used commercially to remediate a site. A single organization may be involved in more than one demonstration or commercial application.

Figure 3: Contaminants Treated or Studied During Demonstrations or Research Projects of In Situ Technologies



The amount of activity taking place and the capabilities of the technologies being studied are good news for the outlook for cleaning up contaminated ground water at hazardous waste sites. Further, the contaminants that are being treated in the technology demonstrations and applications are among the most commonly occurring chemicals at hazardous waste sites.

Footnotes

[1]National Research Council. *Alternatives for Ground Water Cleanup*. Washington, DC: National Academy Press, 1994.

[2]U.S. Environmental Protection Agency. *Profile of Innovative Technologies and Vendors for Waste Site Remediation*. EPA 542-R-94-002, December 1993.

Figure 2: Development Status of Selected In Situ Technologies

Technology	Research Projects	Ongoing or Future Demos	Completed Demos	Commercial Applications
Thermal Enhancements	2	5	11	—
Surfactants	9	6	3	1
Treatment Walls	11	9	2	1
Fracturing	—	2	10	—
Cosolvents	1	3	—	—
Electrokinetics	10	5	1	—
Total	33	30	27	2

Ordering Information for the Status Reports

The full status reports can be ordered from EPA's Center for Environmental Information and Publications (NCEPI). To order, send or fax your name, address, phone and fax numbers, and the order number(s) of the publication(s) to:

NCEPI
11305 Reed Hartman Highway, Suite 219
Cincinnati, OH 45241
513-489-8695 (fax), 513-489-8190 (voice number for confirmation of fax)

The report numbers for the individual reports are as follows:

Surfactant Enhancements: EPA542-K-94-003
Treatment Walls: EPA542-K-94-004
Hydraulic Fracturing/Pneumatic Fracturing: EPA542-K-94-005
Cosolvents: EPA542-K-94-006
Electrokinetics: EPA542-K-94-007
Thermal Enhancements: EPA542-K-94-009

Related Information Sources

The following publications and databases (with the exception of those with an * after the title) are available from NCEPI:

*Alternatives for Ground Water Cleanup.** National Research Council Committee on Ground Water Cleanup Alternatives. Washington, DC: National Academy Press, 1994.

Bioremediation in the Field (BIF) newsletter and Bioremediation in the Field Search System (BFSS) Database Version 1.0, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response and Office of Research and Development.

*Cleaning Up the Nation's Waste Sites: Markets and Technology Trends.** U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. EPA 542-R-92-012, NTIS order number PB93-140762, April 1993.

Innovative Treatment Technologies: Annual Status Report (Sixth Edition). U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. EPA 542-R-94-005, September 1994.

Profile of Innovative Technologies and Vendors for Waste Site Remediation. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. EPA 542-R-94-002, December 1993.

Selected Alternative and Innovative Treatment Technologies for Corrective Action and Site Remediation (A Bibliography of EPA Information Resources): Fall Update. U.S. Environmental Protection Agency. EPA/542/B-93/010, November 1993.

Superfund Innovative Technology Evaluation Program Technology Profiles (Seventh Edition). U.S. Environmental Protection Agency, Office of Research and Development. EPA/540/R-94/526, November 1994.

Vendor Information System for Innovative Treatment Technologies. U.S. Environmental Protection Agency, Technology Innovation Office. VISITT Database Version 3.0, Fall 1994.

This material has been funded by the United States Environmental Protection Agency under contract number 68-W2-0004.
Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

EPA
United States
Environmental Protection
Agency
(5102W)
Washington, DC 20460

Official Business
Penalty for Private Use
$300

EPA542-S-95-001