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TECHNOLOGIES FOR CLEAN-UP OF CONTAMINATED SOIL AND GROUND WATER IN THE UNITED STATES: CURRENT PRACTICE AND INFORMATION RESOURCES

W.W. Kovalick, Jr.

Technology Innovation Office, U.S. Environmental Protection Agency
1200 Pennsylvania Ave. (5102G), Washington, D.C. 20460
email:kovalick.walter@epa.gov

Abstract: Contaminated soil and groundwater have been the subject of legislative attention in the U.S. for about 20 years. Major strides in implementing cleanup programs have been accomplished. From complex abandoned hazardous waste sites to underground petroleum storage tanks to (more recently) Brownfields redevelopment, much assessment and clean up work have been carried out. This paper describes some of data on the kinds of contamination, media, and technologies deployed to deal with problems at these sites. In addition, it highlights technology partnerships that have evolved to demonstrate and verify site measurement and clean up technologies and to assure a more robust set of clean-up options. Finally, the advent of the Internet has increased access to a considerable body of publicly available information on the cost and performance of these technologies that might be of interest in the Asian context.

Keywords: Contaminated land; groundwater; remediation; site characterization; field analysis and sampling; technology demonstration; verification

INTRODUCTION

Beginning in 1980 with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Congress created a national program to clean up over 1400 significant abandoned hazardous waste sites in the United States. Also known as Superfund, this law spurred the development of more than forty state clean-up programs to respond to thousands of other sites; subsequently, Congress created programs to deal with releases of contaminants from currently operating industrial facilities and with leaking underground tanks, primarily from petroleum hydrocarbons. As of 1998, much progress has been made in cleaning up sites identified in the Superfund program. 441 sites have construction underway, and almost 700 are construction complete as of August 2000. Since 1992, over 70% of cleanups are paid for by the parties responsible for the contamination.

TECHNOLOGY DEPLOYMENT AND DEMONSTRATION

The U.S. EPA and others have developed considerable information on the kinds of problems being addressed at contaminated sites and the nature of the technologies used to remediate them.

Superfund Implementation

The problems of abandoned hazardous waste sites addressed under the Superfund program have posed difficult challenges. For example, 50% of the sites in the National Priority List contained trichloroethylene, and 47% presented lead contamination problems. In most cases, the contaminants are mixtures and occur in both the soil and the groundwater. These complexities have made the development of solutions more demanding.

Figure 1 portrays the almost 700 treatment technologies that have been selected in the program between 1980 and the fall of 1997. Technologies in this figure only deal with source control in the soil, excluding 473 containment remedies at sites. Overall 79% of National Priority List sites with active remedies have some form of treatment (there can be more than one remedial action at each site.)

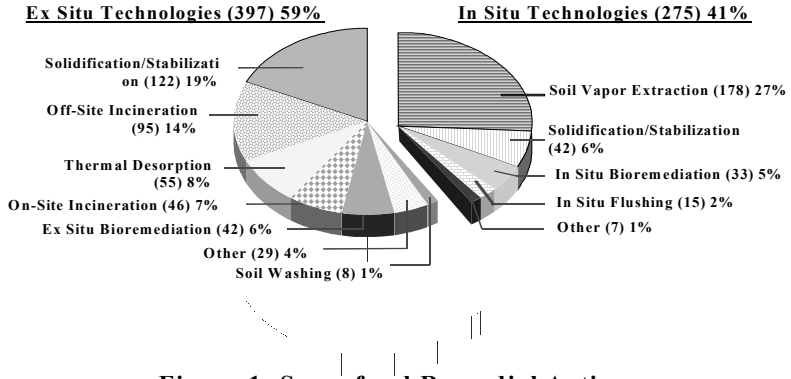

Figure 1: Superfund Remedial Actions
Summary of Selected Source Control Technologies*

*Through Fiscal Year 1997

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The yearly totals indicate that soil vapor extraction is the largest technology category; Figures 2 and 3 further show the trends for this technology and other conventional ex-situ technologies over time. The percent of decisions selecting in-situ treatment technologies for soil has grown from 27 to 53% since 1985. Clearly, the sensitivity to more cost effective, less intrusive solutions is indicated by this data. Soil vapor extraction (SVE) stands as one of the most widely practiced and effective means of removing volatile compounds from the sub-surface.

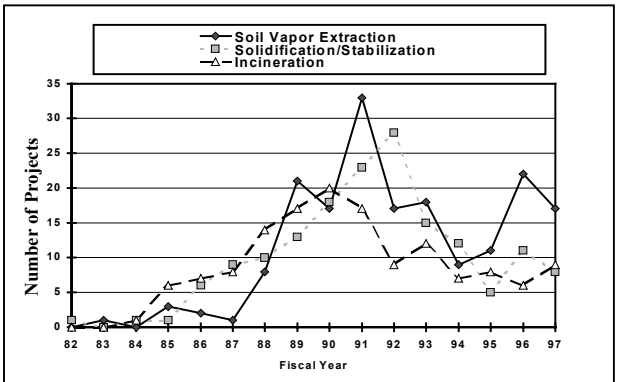

Figure 2: Superfund Remedial Actions:
Trends for Most Frequently Selected Technologies*

*Source control, through 1997

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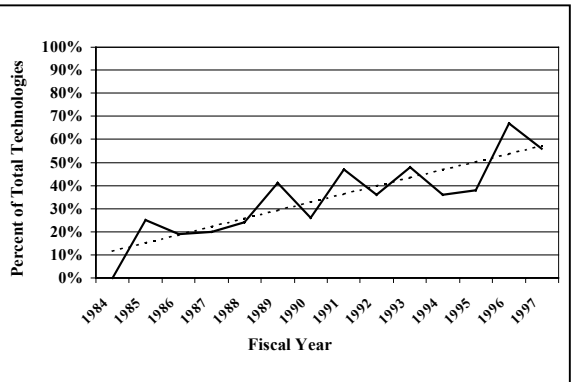

Figure 3: Superfund Remedial Actions:
In Situ Technologies for Source Control

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Another view of the deployment of these technologies is through the lens of contaminants addressed. Overall, more than three-quarters of the Superfund projects address organics alone. Halogenated volatiles are being most often treated by SVE. BTEX and PAH components are being treated most often by bioremediation, while PCBs and other semi-volatile organic compounds are most often treated by incineration. Metals are being treated almost exclusively by solidification - stabilization with a few soil washing and flushing projects.

For groundwater contamination, there is a much less robust set of remediation approaches available at this time. Figure 4 shows that 90% of the remedy choices are to pump and treat contaminated water at the surface. Figure 5 lists the 75 projects that have been deployed as alternatives to pump and treat or to be used in association with pump and treat. The discussion following on new technology demonstration and development will highlight some of the technologies currently with the highest developmental interest.

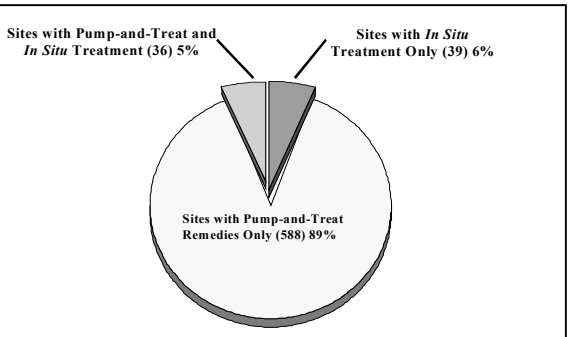

Figure 4: Superfund Remedial Actions: Groundwater Remedies* Total Sites = 663

*Through FY97

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Technology	Number of Projects Selected
Air Sparging	38
Bioremediation (in situ) - Bioslurping	1
Bioremediation (in situ) - Groundwater	16
Bioremediation (in situ) - Biosparging	2
Chemical treatment	3
Dual-Phase Extraction	9
Oxidation (in situ)	1
Permeable Reactive Barrier	4
Well Aeration (in situ)	1
Total	75

Figure 5: Superfund Remedial Actions: Project Status of Treatment Technologies*

*Through August 1998

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Demonstration Programs and Cost and Performance Data

Given the need for cost and performance data on newer and innovative technologies, several government-sponsored programs have been developed to gather such data. A recently released publication from my office, Innovative Remediation Technologies: Field Scale Demonstration Projects in North America, 2nd Ed., summarizes over 600 planned and complete, full-scale demonstrations that were conducted by various branches and departments of the U.S. government, the State of California, and the government of Canada. This report consolidates key reference information in a matrix that allows project managers to quickly identify new technologies that may answer their cleanup needs and provides contacts for obtaining technology demonstration results and other information. Figure 6 provides an overview of the various technologies covered by the report, while Figure 7, with 383 projects, shows the recent emphasis on demonstration of in-situ approaches. (This report is available and searchable on-line at www.clu-in.org/products/nairt/search.cfm.)

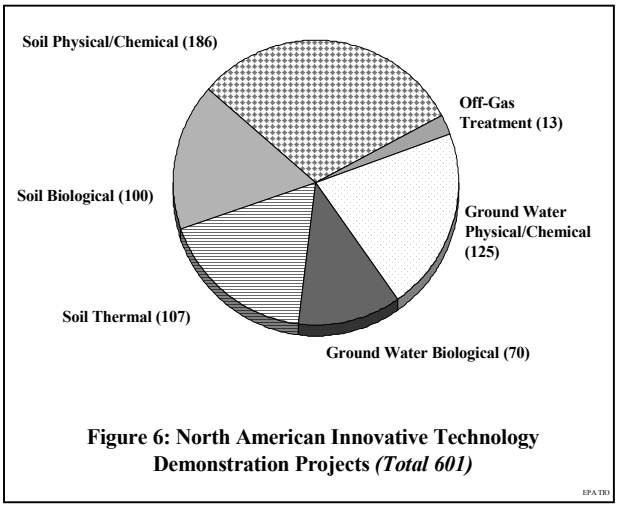

Figure 6: North American Innovative Technology Demonstration Projects *(Total 601)*

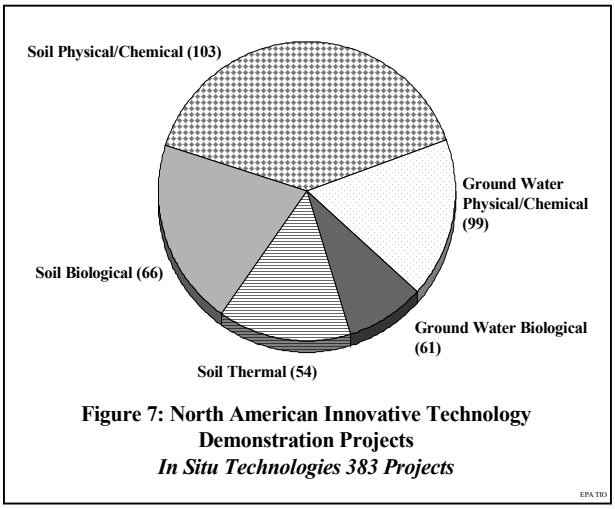

Figure 7: North American Innovative Technology Demonstration Projects
In Situ Technologies 383 Projects

Notable among these demonstration programs are those conducted under the Superfund Innovative Technology Evaluation (SITE) program (www.epa.gov/ORD/SITE). Authorized by the 1986 amendments to the Superfund law, the SITE program represents a major agency effort to aid commercialization. SITE primarily conducts full-scale field evaluations of innovative technologies developed by private vendors. The program develops credible cost effectiveness information so that decision makers can choose the technology with confidence in its performance. Over 130 technologies developers have participated in the demonstration program, with 100 field efforts already completed. Sixty-six technologies at earlier stages of development participated in the emerging (laboratory- and pilot-scale) part of the program, which is no longer operating.

Beyond this demonstration level information, Federal agencies in the U.S. which both develop new technologies and clean up contaminated sites joined together in 1990 to form the Federal Remediation Technologies Roundtable (www.frtr.gov) chaired by U.S. EPA. Beginning in 1995, the agencies realized the value of the information that would be developed as the cleanup of contaminated sites progressed. They jointly developed a guide to gathering cost and performance data for almost 30 technology categories for both soil and groundwater. Detailed case studies of cost and performance data on projects have since been gathered using these guides. A searchable database of 218 case studies (up to 30 pages each) is now available on the Roundtable web site with direct access to the reports.

TECHNOLOGY PARTNERSHIPS

Beginning in the early 1990's, U.S. EPA, other Federal agencies, and industry all realized that the current solutions for certain contaminated site problems were too costly or ineffective. In particular, the realization that groundwater contamination in the form of non-aqueous phase liquids both lighter than water (LNAPLs) and denser (DNAPLs) form pools of immiscible liquid and serve as major sources of contamination. Unless all sources of contamination are removed, traditional pump and treat systems may only contain the problem. Interest in newer techniques to address these problems (including various biological processes, permeable reactive barriers, in situ flushing with surfactants and cosolvents, and in situ oxidation) has grown in the last five years. In addition, for

soil contaminated with metals the suite of approaches is severely limited; of recent special interest has been the use of plants – phytoremediation - to remediate such soils.

Technology Development

Beginning in 1992, EPA invited industry to jointly share the agenda of choosing promising developmental approaches and co-directing efforts to conduct field evaluations of new approaches to solving these problems. The Remediation Technologies Development Forum (www.rtdf.org) has become an umbrella for seven different Action Teams to address new approaches to DNAPL and metal problems. The RTDF is premised on joint agenda setting between industry, government, and academe and pooling in-kind and cash resources to evaluate technologies in the field. Figure 8 shows the seven Action Teams that have developed over time and the associated problem sets of interest. Successful outcomes from these partnerships have included a patented process (Lasagna™) for removing chlorinated solvents from clay-like soils; this process won an R&D 100 Award from R&D Magazine in 1999. Nationwide training has been provided on permeable reactive walls and in-situ bioremediation of groundwater, and this year we will see a joint evaluation by industry and government of the efficacy of phytoremediation of petroleum hydrocarbons at 11 locations.

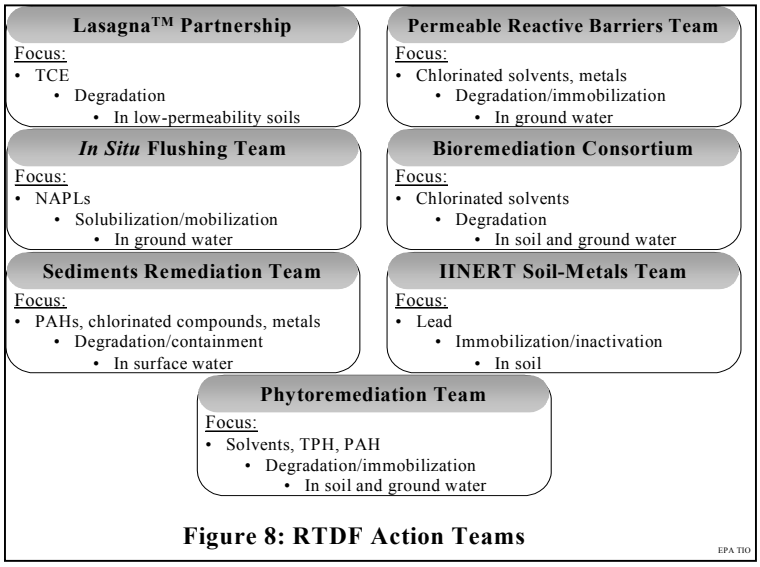

Figure 8: RTDF Action Teams

In addition, U.S. EPA is partnered with the U.S. Departments of Defense and Energy to fund development and evaluation of jointly selected remediation and site characterization technologies. Under the Strategic Research and Development Program(SERDP) and Environmental Security Test and Certification Program(ESTCP), more fundamental research and technology development as well as verification is conducted among projects proposed independently as well as jointly by the Departments and EPA. For further information, see www.serdp.org and www.estcp.org.

Technology Verification

One of the important barriers to the adoption of new environmental technologies is the confidence of the user in the data about cost and performance of the technology. Responding to this need, EPA has established the Environmental Technology Verification Program (ETV). The goal of ETV is to verify the environmental performance characteristics of commercial technology through the evaluation of objective and quality assured data, so that potential purchasers and permitters are

provided with an independent and credible assessment of what they are buying and permitting. The ETV (www.epa.gov/etv) program is operated in twelve technology areas with considerable stakeholder involvement. One of the crucial issues for remediation technologies is performance measurement before, during, and after completion of a cleanup. As such, one of the twelve technology areas is the Site Characterization and Monitoring Technologies Pilot. Begun in the spring of 1995, it has verified 40 innovative technologies.

INFORMATION RESOURCES

Other internet sites (not already cited in this paper) that should be highlighted include:

- www.epa.gov/tio or www.cluin.org Clean Up Information web site operated by the Technology Innovation Office contains over 300 documents related to the remediation and characterization of soil and groundwater, and provides frequent updates on developments in the field. It has an extensive links to other remediation sites both in the U.S. and internationally.
- www.epareachit.org Sponsored by the Technology Innovation Office, this voluntary data base, Remediation and Characterization Innovative Technologies contains information on over 350 remediation and 150 site characterization technologies. While the technology data is principally vendor claims, it provides a comprehensive listing of vendors who are free to note demonstration, verification, and case studies to increase the confidence in their information.
- www.gwrtac.org The Groundwater Remediation Technologies Analysis Center (GWRTAC) is partnered with EPA and the Departments of Energy and Defense to provide up-to-date information on groundwater clean up technologies, vendors, and case studies and produces both analyses and peer-reviewed reports on the state of practice for these technologies.

ACKNOWLEDGEMENT

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