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SUPERFUND

EPA Needs to Better Focus Cleanup Technology Development

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Mr. Chairman and Members of the Subcommittee:

We are pleased to be here today to discuss the Environmental Protection Agency's (EPA) efforts to encourage the development of innovative treatment technologies to clean up Superfund and other hazardous waste sites. Thousands of sites across the United States will require some form of waste treatment to meet cleanup goals. Cleaning up these sites may cost over $750 billion over the next 30 years, according to a recent study.[1] Currently available technologies are often expensive, ineffective, or unacceptable to the public. EPA has therefore joined with industry and other government agencies to find innovative ways to treat hazardous waste that are less expensive, more effective, and safer. EPA considers treatment technologies for which adequate cost and efficacy data are not yet available to be innovative technologies. (App. II provides a glossary of the innovative treatment technologies mentioned in this testimony.)

Mr. Chairman, our testimony today responds to your request that we review the progress EPA has made in fostering the development of innovative technologies to clean up hazardous waste sites. In particular, we will focus on (1) the extent to which innovative technologies have been demonstrated and either selected or actually used for Superfund site cleanups and (2) some of the

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[1]Hazardous Waste Remediation: The Task Ahead, the University of Tennessee Waste Management Research and Education Institute (Knoxville, Tenn.: Dec. 1991).

existing barriers to the development and use of innovative technologies and EPA's efforts to reduce these barriers.

In summary, according to EPA data, the number of innovative technology field demonstrations and innovative technologies selected for use in cleaning up Superfund sites has increased. To date, EPA's Superfund Innovative Technology Evaluation (SITE) Program has initiated 62 of 119 field demonstrations to evaluate technologies accepted since the program was authorized in 1986. The number of SITE field demonstrations initiated has increased from 3 in 1987 to 23 so far this year. Innovative technologies have been selected for use in 228 cleanup actions, an increase from 3 in fiscal year 1984 to 69 in fiscal year 1991. Only eight such remedial cleanup actions have been completed, however.

Additionally, our review and discussions with EPA and industry officials identified three major barriers to the development and use of innovative technologies that we would like to address today. First, EPA has not systematically assessed Superfund site cleanup needs and has trouble matching new technologies with the requirements of specific sites. Second, the lack of reliable cost and efficacy data on innovative technologies leads government officials, private parties responsible for site cleanup, investors, and cleanup contractors to avoid possible risks associated with innovative technologies. Also, requirements for issuing permits, as well as regulations and agency policies, serve as barriers to the development and use of innovative technologies.

EPA has initiated a variety of activities to address existing barriers to the use of innovative technologies both inside and outside of EPA. Efforts by EPA's Technology Innovation Office (TIO) target the assessment of cleanup needs, the development and dissemination of cost and efficacy data, and the reduction or removal of barriers resulting from requirements for permits and regulatory procedures. However, these efforts are piecemeal and lack a systematic plan and strategy for identifying and prioritizing cleanup technology needs. Accordingly, we are recommending that EPA take a more systematic approach to determine site problems, prioritize cleanup technology and research needs, and solicit innovative technologies to meet these needs.

Before we begin a more detailed discussion of our findings, let us provide you with some background information on EPA's mandate to encourage the development of innovative technologies.

BACKGROUND

The number of hazardous waste sites and their estimated cleanup costs have grown dramatically since the Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). CERCLA required that EPA identify at least

400 sites in the nation warranting the highest priority for remedial action--referred to as Superfund sites. EPA now estimates that hazardous waste site cleanup technologies will be needed at up to about 2,000 Superfund sites, 3,500 Resource Conservation and Recovery Act (RCRA) facilities, 28,000 state non-Superfund sites, 660,000 sites with 1.8 million underground storage tanks, 638 Department of Defense installations including 7,400 sites, and 76 Department of Energy facilities with up to 1,500 contaminated areas per facility. Furthermore, total cleanup costs for these sites could rise to $752 billion--$151 billion for Superfund sites, $234 billion for RCRA facilities, $30 billion for state and private programs, $67 billion for underground storage tanks, $30 billion for Defense sites, and $240 billion for Energy sites, according to a University of Tennessee study.

The Congress included language in the 1986 Superfund Amendments and Reauthorization Act (SARA) requiring EPA to foster the development of new, cost-effective methods for cleaning up hazardous waste sites. SARA directed EPA's Administrator to carry out a program of research, evaluation, testing, development, and demonstration of innovative treatment technologies that would clean up hazardous waste sites more permanently than waste containment techniques. SARA defined the technologies as those that permanently alter the composition of hazardous waste to significantly reduce toxicity, mobility, or volume, or those that assess the extent, chemical and physical characteristics, and environmental impact of site contamination. SARA also directed EPA's Administrator to initiate at least 10 field demonstrations of innovative technologies in each of fiscal years 1987 through 1990.

In response to SARA, EPA established the SITE Program to accelerate the development of innovative technologies. SITE has four components: the Demonstration Program, the Emerging Technologies Program, the Monitoring and Measurement Technologies Program, and Technology Transfer activities. The Demonstration Program publishes data on the cost, performance, reliability, and applicability of selected innovative technologies after field demonstrations are conducted. The Emerging Technologies Program provides financial assistance to developers of new technologies undergoing laboratory tests. The Monitoring and Measurement Technologies Program tests new technologies to assess the nature and extent of site contamination. Technology Transfer activities include disseminating information derived from the other three SITE components to the EPA regions, the states, responsible parties, and Superfund contractors. SITE solicits technologies for inclusion in the first two components of the program through annual requests for proposals.

EPA established the Technology Innovation Office in response to a recommendation in the EPA Administrator's 1989 report entitled <u>A Management Review of the Superfund Program</u>. TIO's mission is to increase government's and industry's use of innovative treatment technologies at contaminated sites. TIO's main activities include searching for ways to increase the flexibility of policies, permit requirements, state grants, and contracting procedures; helping to generate data that vendors are required to provide on the cost and performance of their technologies; providing inventors and developers with Superfund site profiles; and disseminating information on the technologies.

Before discussing the barriers to the use of innovative technologies and EPA's efforts to reduce them, we would first like to describe the extent to which these technologies have been demonstrated and selected.

NUMBER OF INNOVATIVE TECHNOLOGIES DEMONSTRATED AND SELECTED HAS INCREASED

The number of innovative technologies demonstrated and selected has increased significantly over the last few years. However, we believe that the difficulties experienced in the SITE Program and the broader barriers to the development of innovative technologies that we will discuss later in this testimony have probably prevented these numbers from increasing more rapidly. Although EPA initially had trouble meeting SARA's mandate to conduct 10 SITE field demonstrations per year, the number of demonstrations has increased to 23 so far this year. The number of innovative technologies selected for use in full-scale remedial actions or removals each year has increased steadily from 3 in fiscal year 1984 to 69 in fiscal year 1991.

SITE Has Increased the Number of Field Demonstrations

SITE has accepted 111 innovative technologies to date, for which it has planned 119 field demonstrations. Of these 119 field demonstrations, 95 are for cleanup remedies in the Demonstration Program and 24 are for devices in the Monitoring and Measurement Technologies Program. SITE has initiated 62 of the planned field demonstrations, all but 3 of which have been completed. Following each completed demonstration, SITE's Demonstration Program typically publishes data in a technology evaluation report and an applications analysis report.

Innovative Technologies Are Now Selected or Used for Many More Remedial Actions, But Few Actions Have Been Completed

TIO lists 228 cleanup actions to treat sources of contamination for which innovative technologies have been selected since 1980, when the Superfund legislation was passed. The 228 cleanup actions include both remedial and removal actions at 181 Superfund sites, but exclude other technologies that EPA does not track.[2] Sharp increases in the selection of innovative technologies began to occur between fiscal years 1986 and 1987, which suggests that SARA's mandate to use treatment and innovative technologies had a positive impact. The number of sites for which at least one innovative technology has been selected each year has also increased from 2 in fiscal year 1984 to 56 in fiscal year 1991. (App. I provides information by fiscal year on the technologies selected.) At least one innovative treatment technology has been selected for cleanup actions at 181 sites in all since fiscal year 1984. Of the technologies selected, 166 were for remedial actions and 15 were for removal actions. As of July 23, 1992, only 8 remedial cleanup actions and 14 removals, or 10 percent, of the 228 cleanup actions listed by TIO had been completed. Final cost and efficacy data on these technologies can only be compiled once the cleanup actions have been completed.

BARRIERS TO INNOVATIVE TECHNOLOGY DEVELOPMENT AND USE AND EPA'S EFFORTS TO REMOVE THESE BARRIERS

We would like to focus now on the three major barriers to the use of innovative technologies in Superfund cleanups and EPA's efforts to reduce or remove these barriers. As mentioned earlier,

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[2]EPA excludes certain innovative technologies because it finds them too difficult to track, for example, in situ solidification, solidification/stabilization when used for organics and selected inorganics (e.g., arsenic, hydrogen cyanide, and chromium VI), surface water treatments, and above-ground treatments for groundwater.

EPA has not systematically assessed Superfund site cleanup needs and has trouble matching new technologies with the requirements of specific sites. Furthermore, the lack of reliable cost and efficacy data on these technologies leads key parties to avoid possible risks associated with their use. Finally, permit requirements, regulations, and agency policies serve as additional barriers to the use of innovative technologies.

EPA Has Not Assessed Its Cleanup Needs and Has Trouble Matching Technologies With Sites

As we pointed out in a recent report and in testimony before this Subcommittee in June of this year,[3] EPA has not yet developed an automated cleanup remedy data base to provide comprehensive information on Superfund site contamination and remedies selected for various media, cost estimates, and cost and efficacy data on completed cleanups. Without systematic information on contaminants and problems at Superfund sites, let alone at other hazardous waste sites, EPA cannot fully inform potential developers of its cleanup needs or target its solicitations for innovative technologies to meet the needs that pose the greatest risk to human health and the environment or that occur most frequently. The effects of this problem can be seen in difficulties experienced in the SITE Program.

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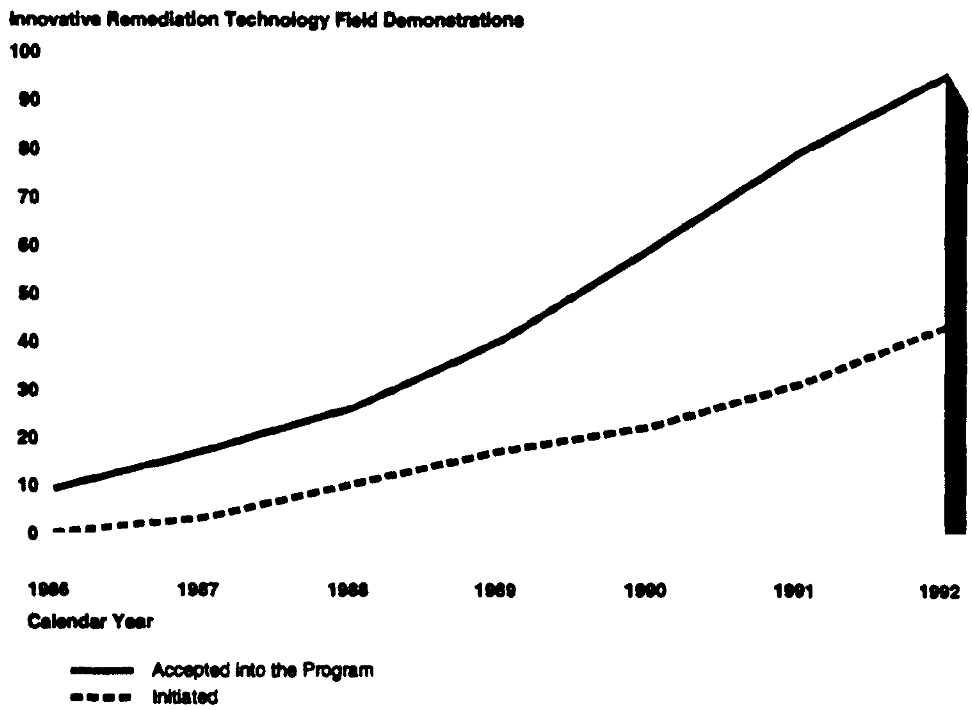
[3]Superfund: Problems With the Completeness and Consistency of Site Cleanup Plans (GAO/RCED-92-138, May 18, 1992) and (GAO/T-RCED-92-70, June 30, 1992).

SITE does not identify specific site needs and then accept only those innovative technologies that meet these needs; therefore, it provides little direction in its annual innovative technology solicitation. To be accepted into the SITE Program, developers need not prove that their technologies can potentially address problems at specific sites. As a result, EPA may be accepting technologies in search of an application, rather than solutions to specific site problems. SITE's difficulties in matching technologies with sites for field demonstrations support this concern. Of the 95 field demonstrations of innovative remediation technologies in the SITE Program, more than half have not yet been matched with a suitable field demonstration site, and 4 of these have been waiting since 1987. As the number of field demonstrations accepted has continued to outpace the number of demonstrations initiated, SITE has fallen further behind in matching technologies to sites (see fig. 1).

Figure 1: Cumulative Number of Innovative Remediation Technology Field Demonstrations Accepted and Initiated, by Calendar Year



Values for calendar year 1992 are totals through August 1992.

To its credit, SITE has offered some guidance to direct developers in its solicitations for innovative technologies. For example, in the 1992 solicitation, SITE's guidance lists five types of technologies sought, including "in situ and on-site treatment processes for large volumes of soil and sediment with relatively low contaminant levels." This description is vague, however, and does not provide specific guidance on what soil volumes EPA considers large, what compositions of soil and sediment need to be addressed, what contaminants need to be addressed, what contaminant levels EPA considers relatively low, and what target efficacy levels, cost, and completion times the technologies should be able to achieve. The solicitation also describes three sites with different contamination conditions as examples. Although the examples give information on, among other things, contaminant types, contaminated media, and contamination levels at various sites, it is unclear how many similar sites could benefit from the same technology. Furthermore, the solicitation does not discuss why these conditions require innovative technologies.

EPA has several efforts underway to begin to assess its cleanup needs. For example, TIO has completed a survey to help identify areas that would benefit from innovative groundwater technologies. EPA officials also have met with selected private parties responsible for site cleanups to discuss technology needs. In addition, TIO plans to collect available information on the numbers and types of contaminated Superfund, non-Superfund, federal facility, RCRA, and underground storage tank sites. TIO's effort is part of a study designed to assist vendors and investors in making financing, development, and marketing decisions by providing data on the innovative technologies market.

We believe these and other EPA efforts to assess site cleanup needs are a step in the right direction. However, these efforts are piecemeal and lack a systematic plan and strategy for identifying and prioritizing cleanup technology needs. Without such a plan, EPA will have difficulty targeting technology development to meet its most urgent cleanup needs and focusing its technology solicitations in areas that present the greatest risk to human health and the environment. EPA generally agrees that such a plan and strategy would be useful, but until recently, it has not had sufficient information about sites and technologies to develop one.

Lack of Cost and Efficacy Data Contributes to Risk Aversion

As EPA has pointed out, a second major barrier to the use of innovative technologies is that EPA officials, potentially responsible parties, and potential investors all tend to avoid investing resources in technologies that appear to be too risky. EPA officials involved in remedy selection are concerned that innovative technologies will not perform at least as effectively as currently available technologies and may not achieve cleanup goals within the desired times. Potentially responsible parties fear that innovative technologies may fail, forcing them to pay for another technology.

Even when responsible parties have held successful tests of innovative technologies for treating site wastes, contractors may be unwilling to bid on carrying out the innovative technology. For example, at the Brio site in Texas, bioremediation of polycyclic aromatic hydrocarbons had been successfully demonstrated. But of the three contractors who bid on the remediation, one dropped out, one bid on a combination of incineration and bioremediation, and one bid on incineration only. According to responsible parties for the Brio site, contractors would also not guarantee the results of bioremediation at the site.

Investors also face uncertainty about innovative technologies as potential investments because of a lack of information about whether they will work and the extent of the market for a given technology. A key factor contributing to risk aversion, common to all parties involved with innovative technology development and use, is the lack of cost and efficacy data to be used to guide remedy selection and investment decisions for these technologies.

Under the SITE Program and TIO, EPA has undertaken concrete activities to assist in the development and dissemination of cost and efficacy data, but the amount of substantive data available is still limited. The SITE Program helps match developers with demonstration sites where their technologies may offer more cost-effective remedies, collects and analyzes demonstration data, and reports cost and efficacy data. These reports provide extensive data that, if they were more timely, would be of more assistance to government officials, responsible parties, and investors in selecting remedies, deciding on investments, and reducing perceived risk. The average time from completion of the demonstration until report publication is currently about 19.3 months for evaluation reports and 19.4 months for application reports. In March 1990, EPA's Office of the Inspector General identified and made recommendations concerning these publication delays and SITE's problems with matching technologies with sites for field demonstrations.[4] The recommendations urged EPA to initiate demonstrations using more than one technology and to develop incentives for project managers to allow their sites to be used for demonstrations. Despite these recommendations, both problems persist.

EPA has initiated additional efforts to provide descriptive, operating, and cost and efficacy data on innovative technologies. TIO publishes and disseminates bibliographies, technical guides, citizen fact sheets, and newsletters. It sponsors an annual innovative technology forum and has joined with professional organizations to develop several training courses. TIO also leads projects to exchange information with other federal agencies, such as the Federal Remediation Technologies Roundtable, an interagency work group established to exchange information on cleanup technologies. EPA also has two data bases with information on innovative technologies--the Alternative Treatment Technology Information Center (ATTIC) and the Vendor Information System for Innovative Treatment Technologies (VISITT). ATTIC highlights the characteristics of new technologies, including data on their cost and effectiveness for treating specific contaminants and media. The VISITT data base contains information on innovative

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[4]The Site Demonstration Program: Much Promise But Delayed Results, U.S. Environmental Protection Agency, Office of the Inspector General (Washington, D.C.: Mar. 1990).

technologies, including the names of vendors, technology descriptions and limitations, and lists of contaminants and media treated.

TIO has developed a variety of channels for disseminating information on innovative technologies that will become even more important as cost and efficacy data and other key information become available for an increasing number of technologies. Other information exists or is under development that TIO could disseminate. For example, major corporations have also tested innovative technologies and gathered information from other companies and academia in the search for remedies for sites for which they are responsible, according to industry officials we interviewed. Additionally, cost and efficacy data will eventually become available for innovative technologies as remedial actions using these technologies are completed.

Requirements, Regulations, and Agency Policies Serve as Barriers to Innovative Technology Development and Use

Permit requirements, as well as regulations and agency policies, currently function as the third key barrier we would like to discuss today to the development and use of innovative technologies. Resource Conservation and Recovery Act procedures for issuing permits restrict research and development activity and key RCRA regulations aimed at protecting the public health and the environment can preclude the use of promising new technologies for site cleanups. In addition, the Federal Acquisition Regulations (FAR) and agency acquisition policies can discourage contractors from testing innovative technologies by preventing the contractors' subsequent involvement in cleanups at the same sites. Furthermore, the inconsistencies among federal, state, and local cleanup standards hinder efforts to develop engineering design standards.

Developers are required to obtain a RCRA permit before conducting research using certain hazardous wastes--for example, to test the efficacy of an innovative technology for treating a hazardous waste. However, to obtain the permit, the applicant must submit data on the innovative technology--data that cannot be developed until the technology is tested on hazardous waste. Currently, small amounts of waste may be tested without a permit, but these amounts are not large enough to test many technologies. Because of the time and cost involved in applying for permits, delays resulting from the need to redo administrative paperwork, and the lack of assurance that a permit will ultimately be granted, RCRA permits function as barriers to the development of innovative technologies.

TIO has a number of efforts under way to reform the process for issuing RCRA permits and to make sites available for testing innovative technologies. TIO and RCRA officials are planning to increase the amount of waste that developers can use without a permit. EPA will then encourage states to increase their research limits accordingly. Also, TIO is working on ways to decrease processing time for issuing permits and to provide more detailed guidance on the information required to apply for a permit. EPA and other federal agencies are also working to increase the number of facilities available for testing full-scale innovative technologies. The Congress appropriated funds to set up a full-scale Army demonstration laboratory, and the U.S. Army Corps of Engineers is developing another laboratory at Vicksburg, Mississippi. In addition, TIO has developed a test and evaluation facility in Pittsburgh. Developers will be able to bring equipment and contaminated soil to these laboratories to run tests and generate performance data without needing RCRA permits.

EPA, other federal agencies, and industry are also using federal facilities for joint projects to evaluate treatment "trains" (the use of multiple technologies to achieve desired cleanup levels) and material-handling equipment without obtaining a RCRA permit. The federal agencies benefit because industry will cover the cost of evaluating innovative technologies used at the sites. Industry benefits because it will obtain cost and efficacy data, and the federal parties will be responsible for purchasing the equipment and assuming the risk should the equipment fail. Partnerships such as these have already been planned for McClellan Air Force Base in California and three other federal sites.

RCRA land disposal regulations, which also apply to the disposal of contaminated soil and debris found at Superfund sites, can serve as barriers to the full-scale use of innovative technologies. These RCRA regulations prevent hazardous waste that does not meet specified treatment standards from being disposed of at landfills. These treatment standards are established on the basis of the cleanup efficacy of the best demonstrated available technology. Typically, however, the best treatment for many wastes, especially organic wastes, is incineration. Incineration can achieve nearly complete destruction of the wastes, but at significantly higher cost and often with lower public acceptance. Because innovative technologies, such as bioremediation, soil washing, or chemical treatment, may not be able to achieve the same standard as the RCRA-mandated technology, they may be excluded from use at many sites, even though they could meet cleanup levels set for these sites.

The Federal Acquisition Regulations allow contractors either to prepare plans and specifications or to do construction work, but prohibit the same contractor from doing both for the same project. Because a contractor that tests the efficacy of a technology during cleanup design is likely to be precluded from bidding on construction work at the site, contractors are discouraged from testing innovative technologies. EPA is working to amend the EPA Acquisition Regulations to clarify issues associated with the procurement of innovative technologies and to allow possible exceptions for contractors to work on both design and construction on a case-by-case basis.

Because EPA policy bars contractors from working for both EPA and responsible parties at the same site, the same contractor may not be used for a cooperative effort to clean up a site. A contractor that has tested a technology for EPA or an EPA contractor during site studies is usually prevented for 3 years from working for the responsible party during any phase of site activity. This restriction can impact contractors who test the efficacy of possible cleanup remedies and thus also indirectly affect the use of innovative technologies. To alleviate this problem, EPA has proposed conflict-of-interest regulations that do not preclude responsible parties from using EPA contractors to perform such work as evaluations of innovative technologies.

Inconsistencies among federal, state, and local authorities can often frustrate innovative technology developers and users and make it difficult to develop engineering design standards. In some cases, the requirements of federal statutes are overridden by more stringent state and local requirements. State and local governments can influence regulatory and permit requirements for proposed research and development projects. Also, new methods or technologies demonstrated in one state or EPA region may not be acceptable in another. Because no standard cleanup levels exist against which to judge the efficacy of innovative technologies, site-specific risk assessments result in different target cleanup levels from site to site and state to state.

CONCLUSIONS

In conclusion, Mr. Chairman, SITE and TIO efforts have clearly contributed to increased development and selection of innovative technologies for the cleanup of Superfund hazardous waste sites. However, hazardous waste cleanup technologies are still not able to fulfill Superfund cleanup expectations reliably and cost-effectively for many types of sites. Additional time will be needed to allow cleanup technology to catch up with program expectations. We believe that without a clear sense of existing site conditions and the cost and efficacy of current technologies to address these site conditions, EPA cannot effectively direct developers to help meet these needs.

RECOMMENDATION

To better focus cleanup technology development, we recommend that the Administrator, EPA:

-- systematically determine site problems and technology needs for the cleanup of Superfund, RCRA, and underground storage tank sites;

-- develop a plan that prioritizes cleanup and resulting research needs; and

-- target solicitations to specific areas in need of technology development.

INNOVATIVE TECHNOLOGIES SELECTED

The variety of innovative technologies selected for use in cleanup actions has increased along with the number of technologies selected. However, certain key technologies have driven much of the increase. Of the 228 cleanup actions for which innovative technologies were selected, 71 percent involve three types of technologies: soil vapor extraction (85 cleanup actions); bioremediation (50); and thermal desorption (28). (See table 1.)

Table 1: Number of Cleanup Actions (Remedial and Removal) for Which Each Type of Innovative Technology Was Selected, by Fiscal Year

	Fiscal Year of Record of Decision (ROD)								
Technology[a]	1984	1985	1986	1987	1988	1989	1990	1991	Total
Soil vapor extraction	0	1	1	2	10	19	19	33	85
Thermal desorption	0	1	2	3	4	2	6	10	28
Ex situ bioremediation	1	0	1	1	5	9	6	4	27
In situ bioremediation	1	0	0	3	4	4	5	6	23
In situ flushing	0	1	1	1	2	3	2	7	17
Soil washing	0	0	0	0	3	4	8	2	17
Dechlorination	0	1	0	2	1	1	3	3	11
Solvent extraction	0	1	0	0	1	5	0	1	8
Chemical treatment	1	0	0	2	1	0	1	0	5
In situ vitrification	0	0	0	0	0	1	1	1	3
Other technologies	0	0	0	0	0	1	0	2	3
Total	3	5	5	14	31	49	51	69	228[b]

[a]For technology definitions, see appendix II.

[b]Because in situ vitrification was selected for the Parson's Chemical site emergency response, it is included in the total even though the cleanup action has no ROD.

GLOSSARY

Ex situ bioremediation is a technology that uses microorganisms to degrade organic contaminants on excavated soil, sludge, and solid wastes. The microorganisms use the contaminants for food, thus breaking them down; the end products are typically carbon dioxide and water. Ex situ bioremediation includes slurry-phase bioremediation, in which the soils are mixed with water to form a slurry, and solid-phase bioremediation, in which the soils are placed in a tank or building and cultivated with water and nutrients. EPA has selected bioremediation to treat volatile organic compounds (VOC), semivolatile organic compounds (SVOC), and polycyclic aromatic hydrocarbons (PAH).

In situ bioremediation involves pumping nutrients, an oxygen source, and sometimes microbes into the soil or aquifer under pressure through wells or spreading them on the surface for infiltration to the contaminated material. The microorganisms present in the soil then degrade the contaminants as in ex situ bioremediation.

Chemical treatment converts contaminants to less hazardous compounds through chemical reactions. One type of chemical treatment, neutralization, is an available technology and is not considered by EPA to be an innovative technology.

Dechlorination results in the removal or replacement of chlorine atoms bonded to hazardous compounds. EPA has selected dechlorination to treat polychlorinated biphenyls (PCB), dioxins, pesticides, and SVOCs.

In situ flushing introduces large volumes of water, at times supplemented with treatment compounds, into the soil, waste, or groundwater to flush hazardous contaminants from a site. This technology assumes that injected water can be effectively isolated within the aquifer and recovered. EPA has selected this technology to treat VOCs, metals, SVOCs, and PAHs.

Soil vapor extraction removes volatile organic constituents from the soil by using vapor extraction wells, sometimes combined with air injection wells, to strip and flush the contaminants into the air stream for further treatment. Vacuum extraction has been selected to treat halogenated and nonhalogenated VOCs, benzene, toluene, ethylbenzene, xylene, and SVOCs.

<u>Soil washing</u> physically removes contaminants from soil particles through mechanical action and washing with water (sometimes using additives). The agitation of the soil particles allows the smaller diameter, more highly contaminated fine particles to separate from the larger soil particles, thus reducing the volume of material that needs subsequent treatment. EPA has selected this remedy to treat metals, PAHs, dioxins, pesticides, and SVOCs.

<u>Solvent extraction</u> is a process that operates on the principle that organic contaminants can be separately dissolved and removed from the waste in a solvent. The solvent used varies depending on the waste to be treated. EPA has selected this remedy to treat PCBs, VOCs, PAHs, dioxins, and SVOCs.

<u>Thermal desorption</u> is a process that heats waste in a controlled environment to cause organic compounds to volatilize from the waste. The operating temperature is less than 1,000 degrees Fahrenheit. The volatilized contaminants will usually require further control or treatment. The contaminants most often treated with thermal desorption include VOCs, PCBs, SVOCs, pesticides, and metals.

APPENDIX II

In situ vitrification treats contaminated soil in place at temperatures of approximately 3,000 degrees Fahrenheit. Metals are encapsulated in a glass-like structure of melted silicate compounds. Organic wastes may be treated by combustion. EPA has selected the remedy to treat metals, pesticides, VOCs, and SVOCs.

Air sparging involves injecting gas into the aquifer so that the gas attaches to volatile contaminants as it percolates up through the groundwater. The gas is then captured with a vapor extraction system.

Contained recovery of oily wastes (CROW) is a process that displaces oily wastes with steam and hot water. The contaminated oils and groundwater seep up into a more permeable area and are pumped out of the aquifer.

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