Section 2: Treatment Technologies for Source Control

This section discusses the number and kinds of treatment technologies selected and used for source control in the Superfund remedial program. Source control treatment technologies are designed to treat soil, sediment, sludge, or solid-matrix wastes (in other words, the source of contamination) versus those technologies designed to treat groundwater. Groundwater technologies are discussed in Section 4. In this section, source control RODs are discussed first; however, most of the information in this section focuses on technologies, rather than RODs. It is important to note that each ROD that specified treatment may have selected more than one technology.

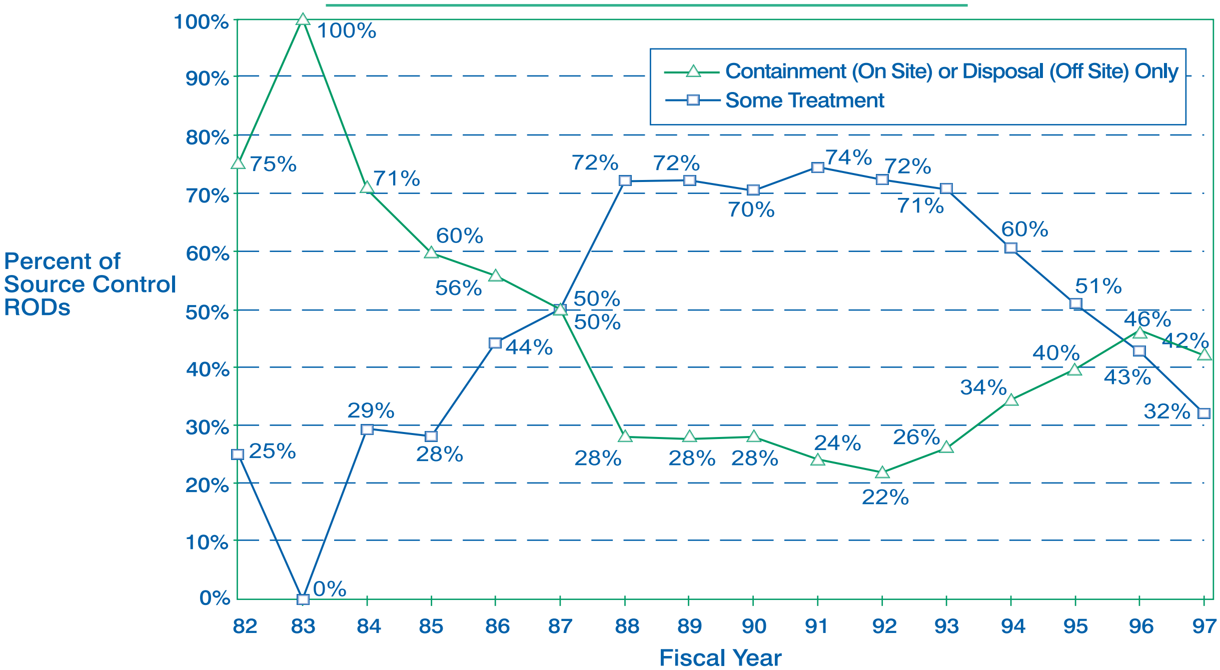
Source Control RODs

The Superfund Amendments and Reauthorization Act of 1986 (SARA) expressed a preference for permanent remedies (that is, treatment) over containment or disposal to remediate Superfund sites. From FY 1988 through FY 1993, at least 70 percent of source control RODs provided provisions for treatment of wastes (Figure 4). The increase was most dramatic in FY 1988. In 50 percent of RODs signed in FY 1987, some treatment for source control was selected, while some treatment was selected in 72 percent of those signed in FY 1988. However, the percentage of RODs selecting treatment has decreased each year since FY 1993. Correspondingly, there has been an increase in the number of source control RODs that specify on-site containment or off-site disposal only. In fact, in FY 1996 the percentage of source control RODs specifying on-site containment or off-site disposal (46 percent) was greater than the percentage of RODs specifying treatment (43 percent). The gap grew larger by 7 percent in FY 1997.

On-site containment includes capping or disposal of waste on site, and off-site disposal involves transportation of waste to an off-site disposal facility, usually a permitted landfill. For the past five years (FY 93-97), on-site containment accounted for an average of 74 percent of the containment/disposal number, and off-site disposal averaged 26 percent. For these five years, the number of both remedies have increased at approximately the same rate.

Figures 5 and 6 graphically depict, by fiscal year, the frequency of selection for the most often selected treatment technologies for source control: SVE, solidification/stabilization, and incineration (Figure 5), bioremediation, thermal desorption, and flushing

Figure 4. Superfund Remedial Actions: Treatment Versus On Site Containment/Off Site Disposal Decisions For Source Control Through Fiscal Year 1997



Source: U.S. EPA Office of Emergency and Remedial Response and U.S. EPA Technology Innovation Office, 1998. FY 1996 and 1997 data are preliminary.

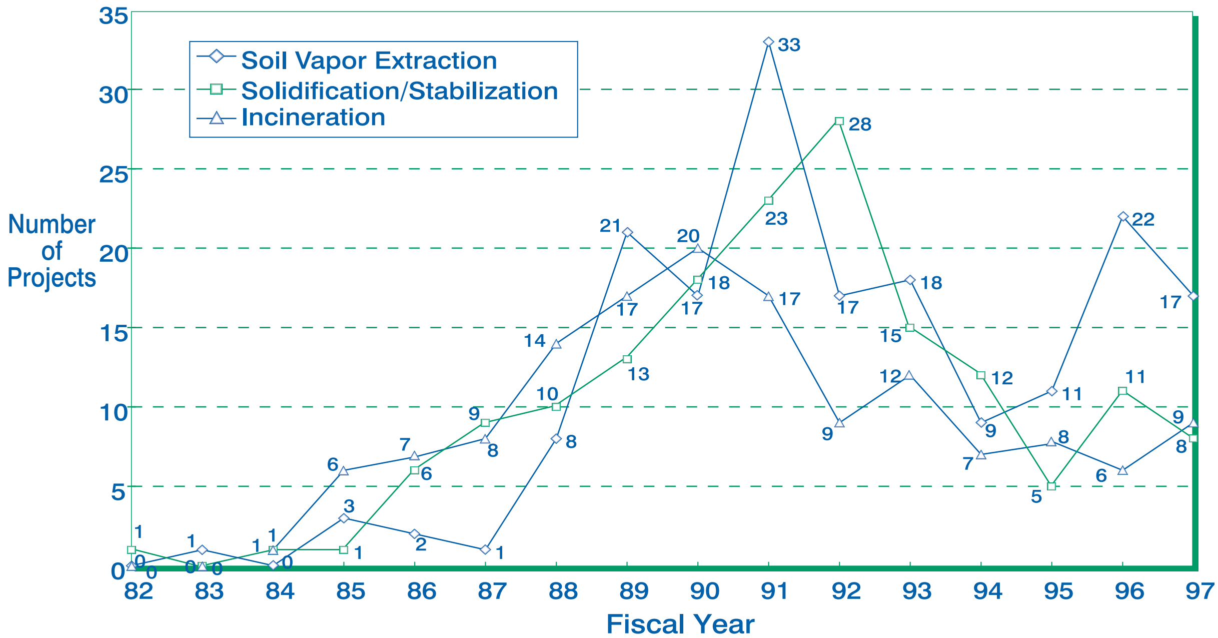
Note: The percentages for each year may not add to 100 percent because some source control RODs specified other source control remedies.

(in situ) (Figure 6). These technologies are discussed in more detail in later sections.

As shown in Figure 5, the number of SVE, solidification/stabilization, and incineration projects peaked during FY 1990 through FY 1992 and generally have since decreased from those peak levels. There have been greater than 15 projects implemented each year for SVE since FY 1989 with the exception of FY 1994 and FY 1995, in which the number of projects were 9 and 11, respectively.

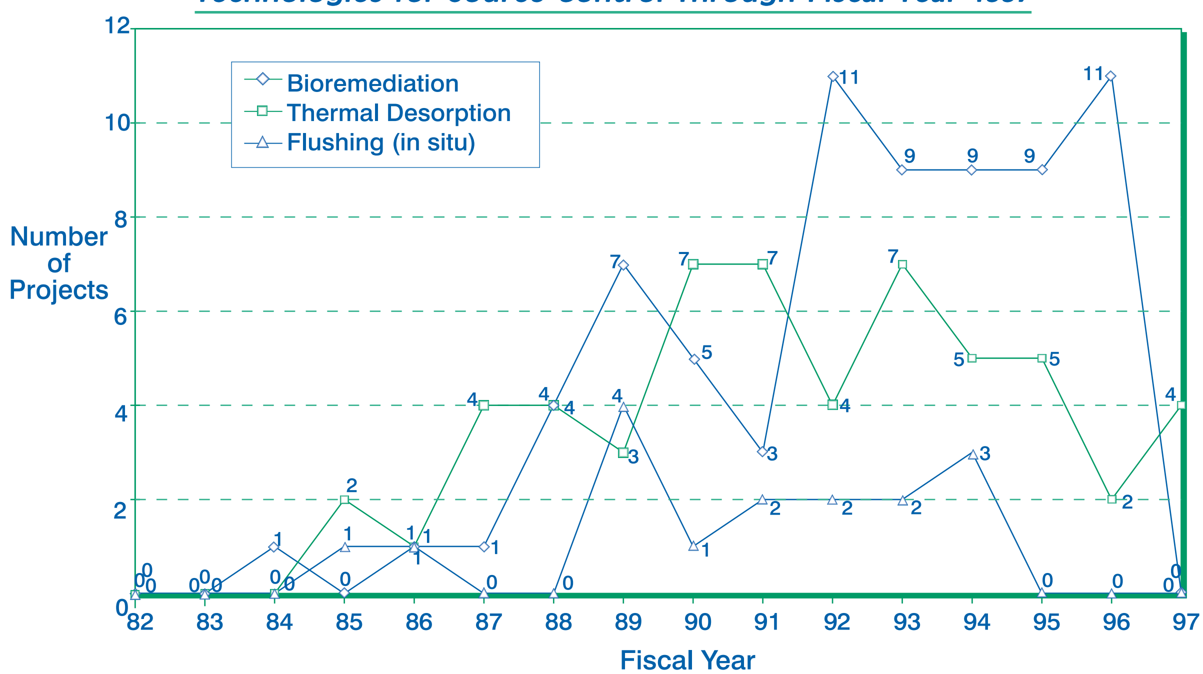
Figure 6 shows that the number of bioremediation projects has generally increased from FY 1986 through FY 1996. Only one ROD selected

Figure 5. Superfund Remedial Actions: Trends for Most Frequently Selected Technologies for Source Control Through Fiscal Year 1997



Note: Data are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998.

Figure 6. Superfund Remedial Actions: Trends for Most Frequently Selected Technologies for Source Control Through Fiscal Year 1997



Note: Data are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998.

bioremediation for source control in FY 1997. However, that remedy was changed because a treatability study indicated that bioremediation was not able to meet the cleanup goals. Hence, there were no new starts of bioremediation projects for source control in FY 1997. Thermal desorption reached a peak of seven projects in FY 1990, FY 1991, and FY 1993 and has decreased slightly since FY 1993. The number of flushing (in situ) projects has never been greater than four in any one year, and since FY 1995, there have been no flushing (in situ) projects.

Figure 7 shows the cumulative number of applications currently being implemented for source control by technology and by year. As shown in this figure, the number of applications of several technologies relative to the total number of applications (as indicated by the thickness of the wedge for a technology relative to the total thickness for any given year) has generally remained the same in recent years. The most common applications for each fiscal year are SVE, solidification/stabilization and incineration.

In Situ Versus Ex Situ Technologies

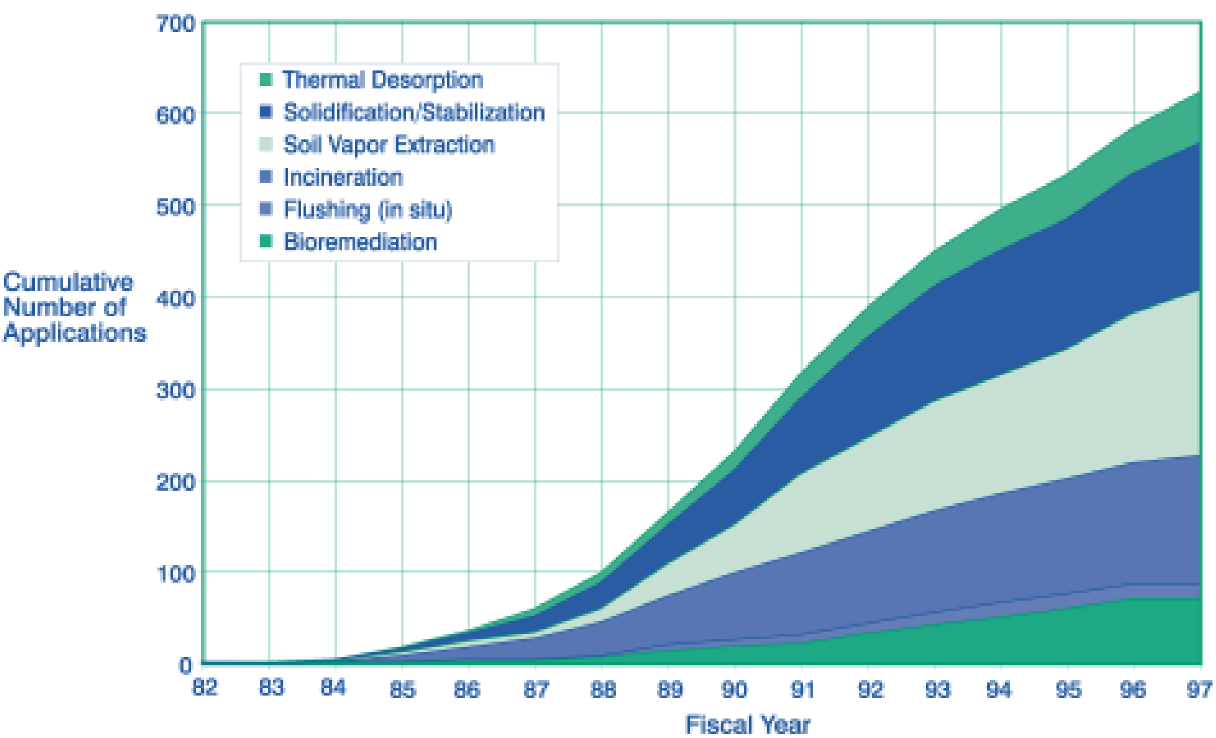
As indicated in the overview, SVE and thermal desorption are now documented in this report as established technologies. Another major change in the report is a focus on in situ versus ex situ technologies. Previous reports have focused solely on innovative technologies, discussed in more detail in Section 3.

In situ technologies for source control are those applications in which the contaminated medium is treated in place without excavation. Ex situ technologies require excavation of the contaminated medium and treatment either on-site or off-site, as may be the case with incineration.

Figure 8 provides a cumulative overview of in situ and ex situ treatment technologies currently in use for source control. Through FY 1997, a total of 672 treatment technologies selected in approximately 614 source control RODs specifying some treatment were being implemented. There are more technologies than RODs because some sites are implementing more than one technology.

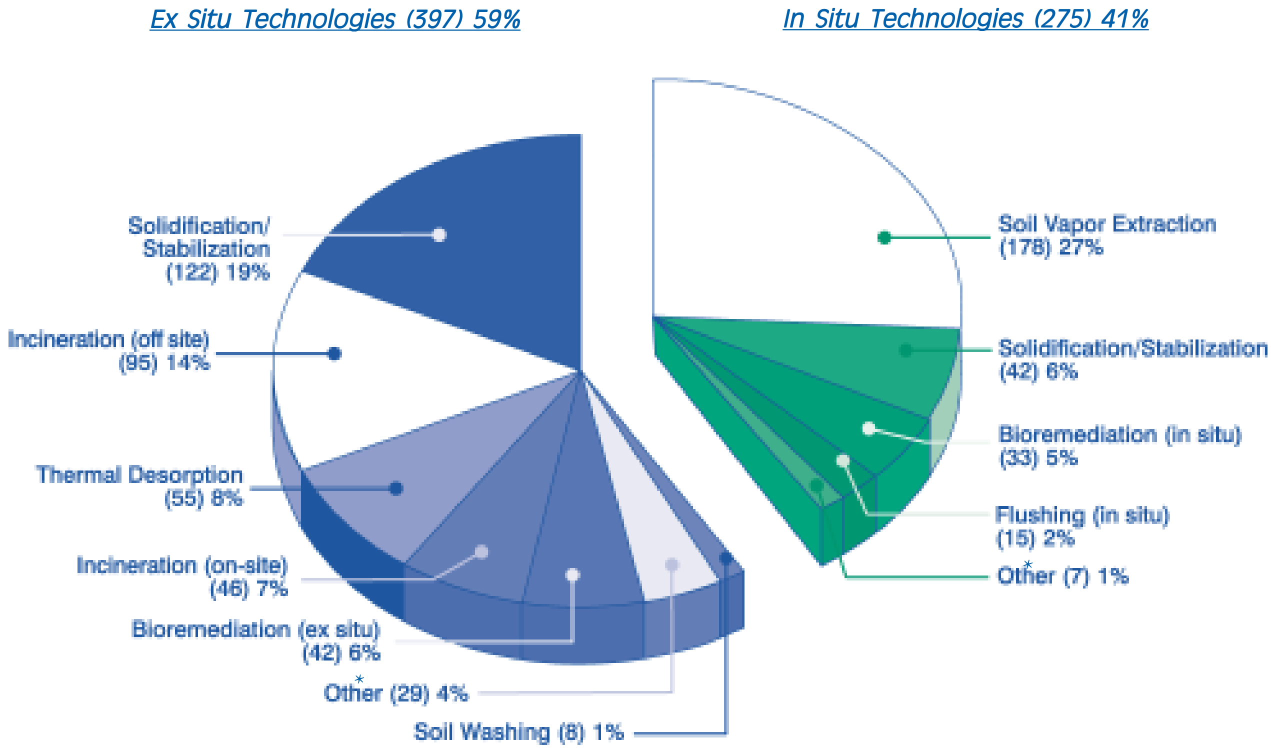
As indicated in Figure 8, SVE (27 percent), solidification/stabilization (6 percent), and bioremediation (in situ) (5 percent) are the most common in situ technologies. The most common ex situ technologies are incineration (21 percent), which includes both off-site (14 percent) and on-site (7 percent), solidification/stabilization (19 percent), thermal desorption (8 percent), and bioremediation (ex situ) (6 percent).

Figure 7. Superfund Remedial Actions: Cumulative Trends for Most Common Technologies for Source Control



Note: *Data are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998.*

Figure 8. Superfund Remedial Actions: Summary of Source Control Treatment Technologies Through Fiscal Year 1997



Note: Data are derived from Records of Decision (RODs) for FY 1982-1997 and anticipated design and construction activities as of August 1998. A site may use more than one technology. See Figure 29 for in situ groundwater treatment technologies.

( ) Number of times this technology was selected or used.

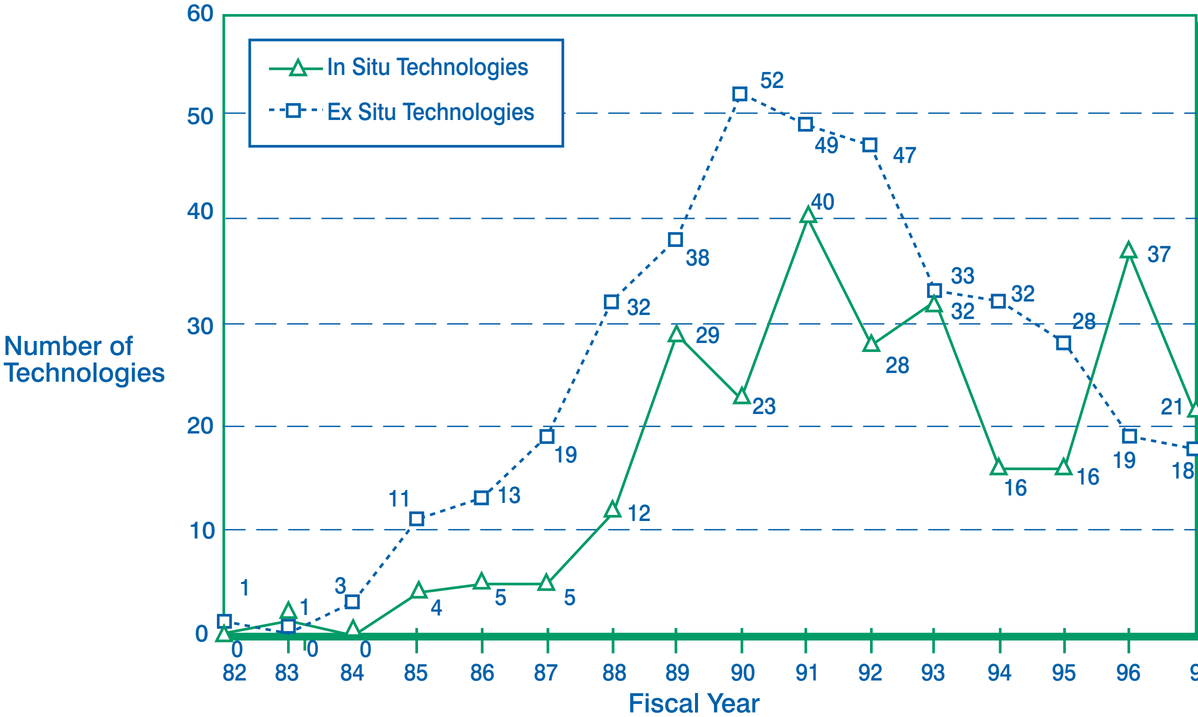
** "Other" ex situ technologies are: chemical treatment, cyanide oxidation, dechlorination, flushing, mechanical soil aeration, neutralization, open burn/open detonation, physical separation, SVE (two projects), solvent extraction, and vitrification. "Other" in situ technologies are: chemical treatment, hot air injection, phytoremediation, surfactant flushing, thermal desorption (one project), thermally enhanced recovery, and vitrification.*

As of August 1998, 41 percent of all treatment technologies for source control at Superfund remedial sites were in situ.

Figure 9 compares the selection of in situ technologies versus ex situ technologies for source control since FY 1982. As shown in the figure, FY 1996 marked the first year that there were more in situ technologies than ex situ technologies being implemented. In fact, in FY 1996 there were twice as many in situ technologies as ex situ technologies. In FY 1997, the trend toward in situ technologies continued with 21 in situ applications versus 18 ex situ applications. Appendix A provides the number of in situ and ex situ technologies, by technology type, for both source control and groundwater treatment by fiscal year.

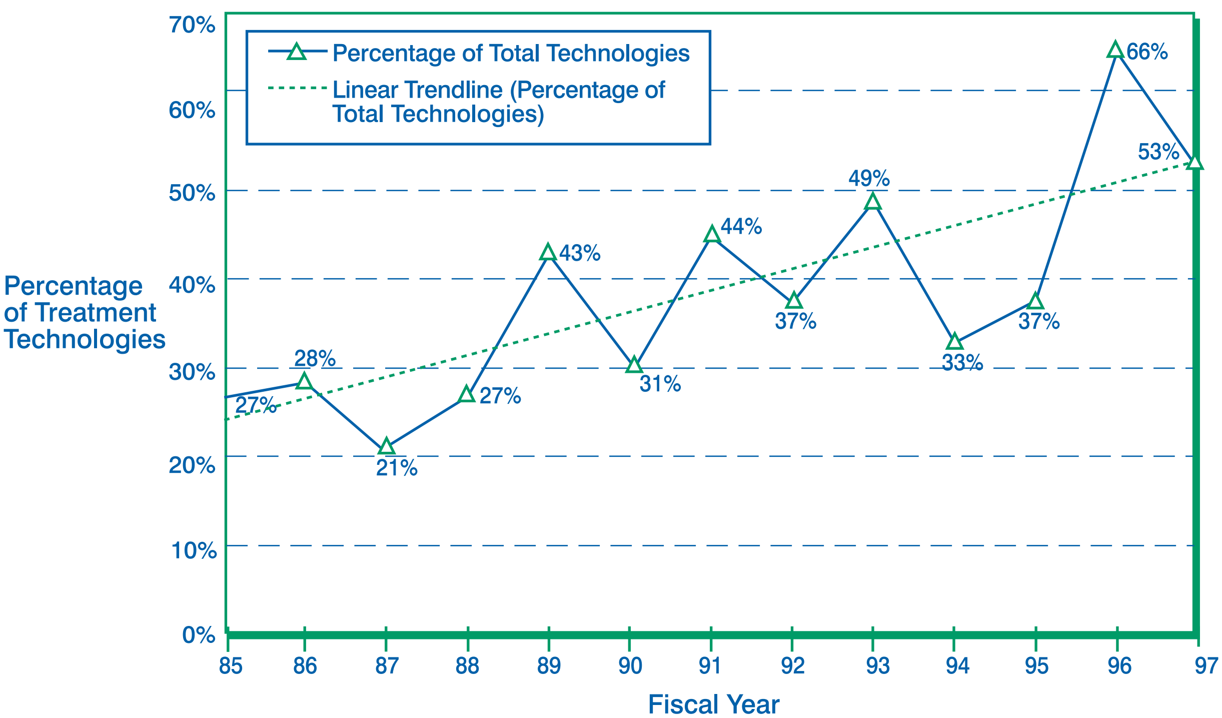
Figure 10 shows the number of in situ technologies as a percentage of all treatment technologies for source control by year. As a percent of all treatment technology applications, in situ technologies have been steadily increasing since FY 1985 as shown by the trendline. Trendlines are used in problems of prediction, also known as regression analysis. Using a regression analysis, the trendline can be extended in a chart forward or backward beyond the actual data to show a trend. In FY 1996, in situ technologies reached a high point, representing 66 percent of all source control treatment technologies implemented that year. Several factors may play a role in this upward trend. Because there is no excavation with in situ technologies, there is reduced risk from exposure to contaminated media. Also, for large sites where excavation costs for ex situ technologies run into millions of dollars, in situ technologies may be more cost effective. Also in recent years, site characterization technologies have become more sophisticated, leading to more accurate delineation of the contaminated media. With better

Figure 9. Superfund Remedial Actions: In Situ Technologies Versus Ex Situ Technologies by Fiscal Year



Note: Data are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998.

Figure 10. Superfund Remedial Actions: In Situ Technologies for Source Control by Fiscal Year



Note: Data are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998.

information about the nature and extent of contamination present, site managers and responsible parties can be more confident in choosing an in situ technology.

Appendix B, Source Control Technology Summary Matrix, lists each of the treatment technology projects for source control at remedial sites by EPA region. (The summary matrix also includes in situ groundwater projects, removal actions, and non-Superfund projects that will be discussed in later sections.) The EPA REACH IT on-line searchable database (see Notice on page v) contains detailed information on treatment technologies being implemented at all Superfund sites.

Implementation Status of Treatment Technology Projects

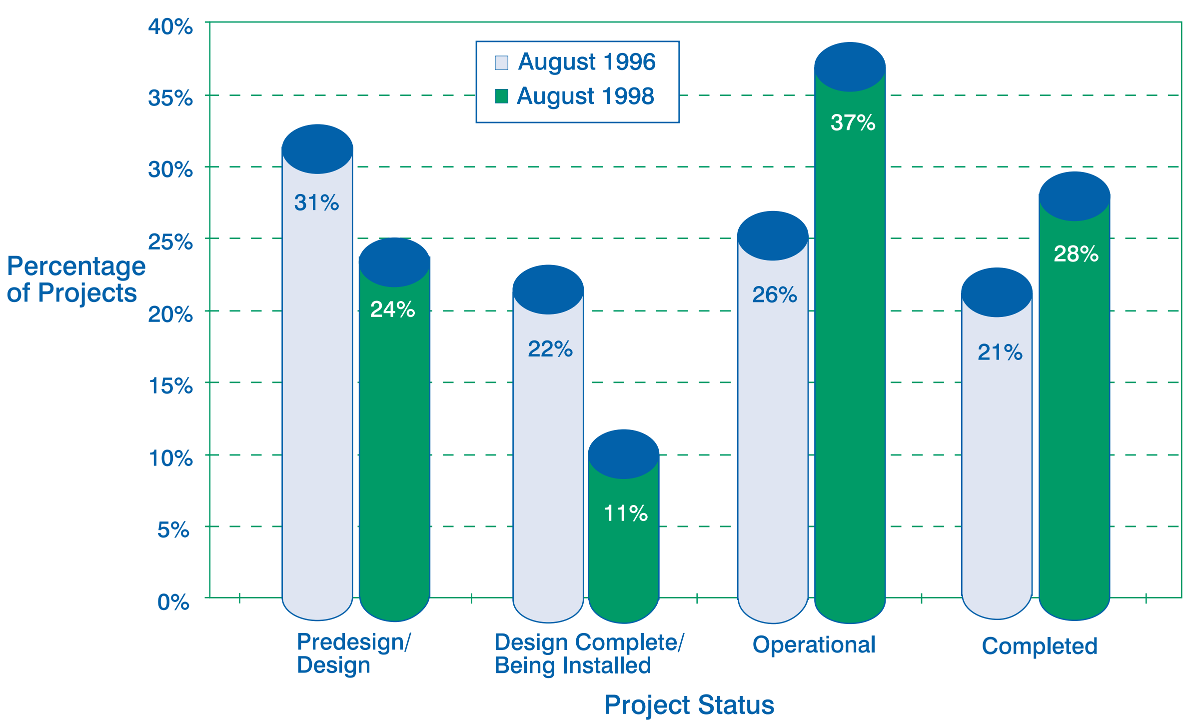
In the past two years, 105 additional treatment technology projects for source control and 29 innovative technology projects for in situ groundwater treatment have been implemented. Of these projects, 14 have already been completed.

Figure 11 shows how projects have progressed through the remedial pipeline. In August 1996, when the eighth edition of the ASR was published, more than half – approximately 53 percent – of all projects were in the earlier stages of the remedial process (predesign, design, or being installed). As of August 1998, approximately 65 percent of all projects are now either operational or completed.

Figure 12 shows a breakdown of project status by the following technology types: ex situ source control technologies, in situ source control technologies, and groundwater technologies. As shown in Figure 12, there has been an increase in the percentage of completed projects for all three technology types. The increase is most dramatic for ex situ technologies, where the percentage of projects completed increased by 15 percent. For groundwater projects, only 24 percent of the projects were operational and none were completed in August 1996. As of August 1998, however, 51 percent of groundwater projects are operational, and four percent have been completed.

Appendix B provides a matrix that indicates the status of all projects. Figure 13 provides a summary of project status as of August 1998 by technology type. [Note: This table does include new

Figure 11. Superfund Remedial Actions: Status of Treatment Technologies in 1996 Versus 1998



Note: Source of August 1996 data was the Innovative Treatment Technologies: Annual Status Report (ASR) Eighth Edition (EPA-542-R-96-010). Data for August 1998 are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998. Does not include data for the following technologies: incineration (off site), mechanical soil aeration, neutralization, open burn/open detonation and solidification/ stabilization (S/S)(Data for these technologies was not collected for ASR 8th edition). Includes 10 projects selected in RODs or ROD amendments for FY 1998. FY 1998 data are not comprehensive.

information on incineration (off site), solidification/stabilization, mechanical soil aeration (MSA), open burn/open detonation (OB/OD), and neutralization.] For ex situ projects, the majority (60 percent) have been completed. This percentage is primarily due to the incorporation of status data for solidification/stabilization, incineration (off site), MSA, OB/OD, and neutralization projects selected in RODs dating back to FY 1982. The eighth edition of the ASR did not contain status information for any of these projects.

EPA analyzed approximately 206 completed projects to calculate the average time to complete cleanup. The time to complete cleanup was defined as the time from start of operation to completion of a project. For ex situ technologies the average time to complete cleanup was 13 months, and for in situ technologies, 19 months.

In terms of individual technologies, the majority of projects for the most common ex situ technologies [solidification/stabilization, incineration (off site), thermal desorption, and incineration(on site)] have been completed. For these four technologies, the percent of projects completed has ranged from 55 percent to 79 percent. Bioremediation (ex situ) represents the largest number of projects (33 percent) that are operational even though it is only the fifth most common ex situ technology. This high percentage is most likely due to the length of treatment time required for bioremediation as compared with other ex situ technologies. Although bioremediation enhances the ability of microorganisms to degrade or detoxify contaminants, the time required to reach cleanup goals is often limited by the natural degradation process. Other factors such as temperature and moisture – which are influenced by the weather – play a large role in determining the degradation rate for bioremediation. Because of these considerations, bioremediation typically requires a longer period of time for treatment compared to other ex situ technologies such as incineration, thermal desorption, or solidification/stabilization where treatment time is primarily limited by the capacity and throughput of the equipment used.

For a few technologies representing less than 10 applications each, there is little change in status. For example, in August 1996, there were 12 projects in the predesign or design phase for soil washing, solvent extraction, vitrification, cyanide oxidation, and hot air injection. As of August 1998, 10 of those projects are still in the predesign or design phase, except for two soil washing projects that have been cancelled.

The EPA REACH IT on-line searchable database presents information on project status and projected schedule as well as some brief performance and operating data on remedial, removal, and non-Superfund projects that have been completed. Data provided include periods of operation, typical pre- and post-treatment concentrations of key

Figure 12. Superfund Remedial Actions: Treatment Technologies in the Remedial Pipeline by Technology Type

	Predesign/ Design	Design Complete/ Being Installed	Operational	Completed	Total
Ex Situ Source Control Technologies					
August 1996	32%	18%	14%	36%	159
August 1998	25%	9%	15%	51%	170
In Situ Technologies					
August 1996	29%	22%	37%	13%	184
August 1998	22%	11%	48%	19%	233
Groundwater Technologies					
August 1996	40%	36%	24%	0%	45
August 1998	31%	14%	51%	4%	75

Note: Source of August 1996 data was the Innovative Treatment Technologies: Annual Status Report (ASR) Eighth Edition (EPA-542-R-96-010). Data for August 1998 are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998. Does not include data for the following technologies: incineration (off site), mechanical soil aeration, neutralization, open burn/open detonation and solidification/stabilization (S/S)(Data for these technologies was not collected for ASR 8th edition). Includes 10 projects selected in RODs or ROD amendments for FY 1998. FY 1998 data are not comprehensive.

Figure 13. Superfund Remedial Actions: Project Status of Treatment Technologies as of August 1998

Technology	Predesign/ Design	Design Completed/ Being Installed	Operational	Completed	Total
Ex Situ Source Control Technologies					
Solidification/Stabilization	28	14	11	69	122
Incineration (off site)	6	8	6	75	95
Thermal Desorption	14	4	3	34	55
Incineration (on site)	4	2	4	36	46
Bioremediation (ex situ)	11	6	15	10	42
Soil Washing	6	1	0	1	8
Neutralization	0	0	2	3	5
Solvent Extraction	2	1	1	1	5
Dechlorination	1	1	0	2	4
Chemical Treatment	1	0	2	0	3
Mechanical Soil Aeration	0	0	0	3	3
Vitrification	2	0	0	0	2
Open Burn/Open Detonation	0	0	0	2	2
SVE	1	0	0	1	2
Physical Separation	0	0	0	1	1
Flushing (in situ)	0	0	1	0	1
Cyanide Oxidation	1	0	0	0	1
Total	77	37	45	238	397
Percentage of Ex Situ Technologies	19%	9%	12%	60%	
Percentage of All Source Control Technologies	11%	6%	7%	35%	59%
In Situ Source Control Technologies					
SVE	35	20	87	36	178
Solidification/Stabilization	15	3	4	20	42
Bioremediation (in situ)	9	5	15	4	33
Flushing (in situ)	5	0	9	1	15
Thermally Enhanced Recovery	0	0	1	1	2
Hot Air Injection	1	0	0	0	1
Phytoremediation	0	0	1	0	1
Surfactant Flushing	1	0	0	0	1
Thermal Desorption	0	0	1	0	1
Vitrification	0	0	0	1	1
Total	66	28	118	63	275
Percentage of In Situ Technologies	24%	10%	43%	23%	
Percentage of All Source Control Technologies	10%	4%	18%	9%	41%
In Situ Groundwater Technologies					
Air Sparging	9	6	23	0	38
Bioremediation (in situ)	5	1	12	1	19
Dual-Phase Extraction	4	2	2	1	9
Permeable Reactive Barrier	3	1	0	0	4
Chemical Treatment	1	1	0	1	3
Oxidation (in situ)	0	0	1	0	1
Well Aeration (in situ)	1	0	0	0	1
Total	23	11	38	3	75
Percentage of Groundwater Technologies	31%	14%	51%	4%	
Percentage of All Technologies	3%	1%	5%	<1%	10%
GRAND TOTAL	**166**	**76**	**201**	**304**	**747**
PERCENTAGE OF GRAND TOTAL	**22%**	**10%**	**27%**	**41%**	

Note: Data are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998. Includes 13 projects selected in RODs or ROD amendments for FY 1998. FY 1998 data are not comprehensive.

contaminants treated, cleanup goals, operating parameters (such as retention time and additives), materials handling required, and management of residuals.

Contaminants Addressed

The data collected for this report form the basis for an analysis of the classes of contaminants treated by each technology type at remedial action sites. Figure 14 provides that information, by technology, for seven major groups of contaminants: halogenated volatile organic compounds (VOC), benzene, toluene, ethylbenzene, and xylene (BTEX), other VOCs, polychlorinated biphenyls (PCB), polynuclear aromatic hydrocarbons (PAH), other semivolatile organic compounds (SVOC), and metals. For this report, compounds are categorized as halogenated VOCs, SVOCs, or PAHs according to the lists provided in EPA's SW-846 test methods 8010, 8270, and 8310. Overall, more than three-quarters of the Superfund remedial projects address organics alone. Alternatives to treat metals are limited; only one-fifth of all projects address metals alone or in combination with organics. The EPA REACH IT on-line searchable database contains information about specific contaminants treated at each site where a treatment technology is being used.

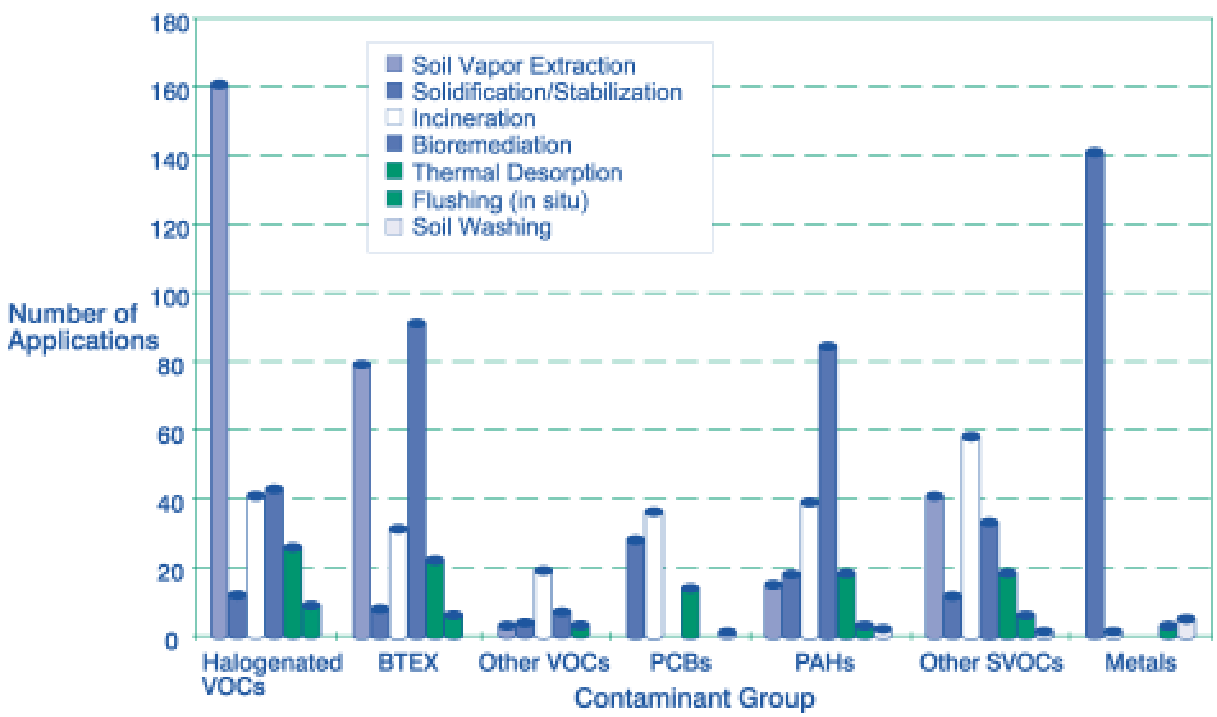
Selecting a treatment technology for a contaminant often depends on its physical and chemical properties. For example, VOCs are amenable to treatment by certain technologies such as SVE because of their volatility. In other cases, metals, which are not volatile and do not degrade, are not amenable for treatment by SVE, thermal desorption, or bioremediation. However, because metals readily form insoluble compounds when combined with appropriate additives, such as Portland cement, solidification/stabilization is most often used for treatment of these contaminants.

As shown in Figure 14, halogenated volatiles are being treated most often by SVE. BTEX or PAH components are being treated most often by bioremediation. PCBs and other SVOCs are being treated most often by incineration. Metals are being treated almost exclusively by solidification/stabilization, with a few soil washing and flushing (in situ) projects.

Quantity of Soil Addressed

EPA analyzed the quantity of soil addressed by the various treatment technologies. Data on the quantity of media treated are available for 447 sites

Figure 14. Superfund Remedial Actions: Contaminants Treated by Technology Type



Note: Data are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998. Includes 13 projects selected in RODs or ROD amendments for FY 1998. FY 1998 data are not comprehensive.

Figure 15. Superfund Remedial Actions: Estimated Quantities of Soil to Be Treated by Source Control Technologies

Technology	Total Number of Sites	Number of Sites with Data	Quantity (cubic yards) Minimum	Maximum	Average	Total Quantity
In Situ						
Bioremediation (in situ)	29	17	5,000	281,000	79,000	1,345,000
Flushing (in situ)*	15	6	19,360	1,000,000	62,000	314,000
Hot Air Injection	1	1	—	—	—	700
Solidification/Stabilization	41	30	180	207,000	43,000	1,288,000
SVE	178	123	75	6,135,000	237,000	29,107,000
Thermally Enhanced Recovery	2	1	—	—	—	200
Vitrification	1	1	—	—	—	5,000
AVERAGE			6,100	1,906,000	105,250	
TOTAL	267	179				32,057,000
Ex Situ						
Bioremediation (ex situ)	42	37	21	1,936,000	80,000	2,966,000
Chemical Treatment	3	1	—	—	—	50,000
Dechlorination	4	4	700	30,000	19,000	78,000
Flushing (in situ)	1	1	—	—	—	14,000
Incineration (off site)	94	49	5	23,000	4,000	194,000
Incineration (on site)	46	36	12	330,000	48,000	1,736,000
Mechanical Soil Aeration	3	2	3,200	12,000	8,000	15,000
Neutralization	5	2	42,000	43,000	43,000	85,000
Open Burn/Open Detonation	2	0	—	—	—	—
Physical Separation	1	1	—	—	—	8,000
Soil Washing	7	6	6,400	177,000	40,000	242,000
Solidification/Stabilization	119	76	18	1,033,000	48,000	3,655,000
Solvent Extraction	5	4	7,000	13,000	9,000	38,000
SVE	2	2	535	3,000	6,000	3,000
Thermal Desorption	55	47	250	180,000	25,000	1,153,000
AVERAGE			5,500	3,780,000	38,000	
TOTAL	389	268				10,237,000

Note: Data are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998. Includes 13 projects selected in RODs or ROD amendments for FY 1998. FY 1998 data are not comprehensive.

* *Average soil volume per project and total volume does not include data for Lipari Landfill (flushing system treating an estimated volume of 1 million cy)*

of a total of 656 remedial action sites where source control treatment technologies are being used to treat soil. Typically, in situ technologies are used to address larger quantities of soil, while ex situ technologies are used to treat smaller quantities. Because quantities for in situ projects often cannot be accurately determined and many projects are not completed, the quantities in Figure 15 should be considered estimates.

For ex situ technologies, the average volume of soil treated per project ranged from approximately 4,000 cubic yards (cy) to 80,000 cy. Bioremediation (ex situ) represented the highest average volume per project followed by chemical treatment (50,000 cy). For in situ technologies, the average volume of soil treated per project ranged from 43,000 to 237,000 cy. Bioremediation and SVE were the two in situ technologies being used to treat large sites. For example, there are four SVE projects treating sites with more than two million cy of contaminated soil. There also are three bioremediation (in situ) projects treating sites with more than 250,000 cy of contaminated soil. Also, at Lipari Landfill in New Jersey, an in situ flushing project is treating a 16-acre site with an estimated volume of one million cubic yards of soil.

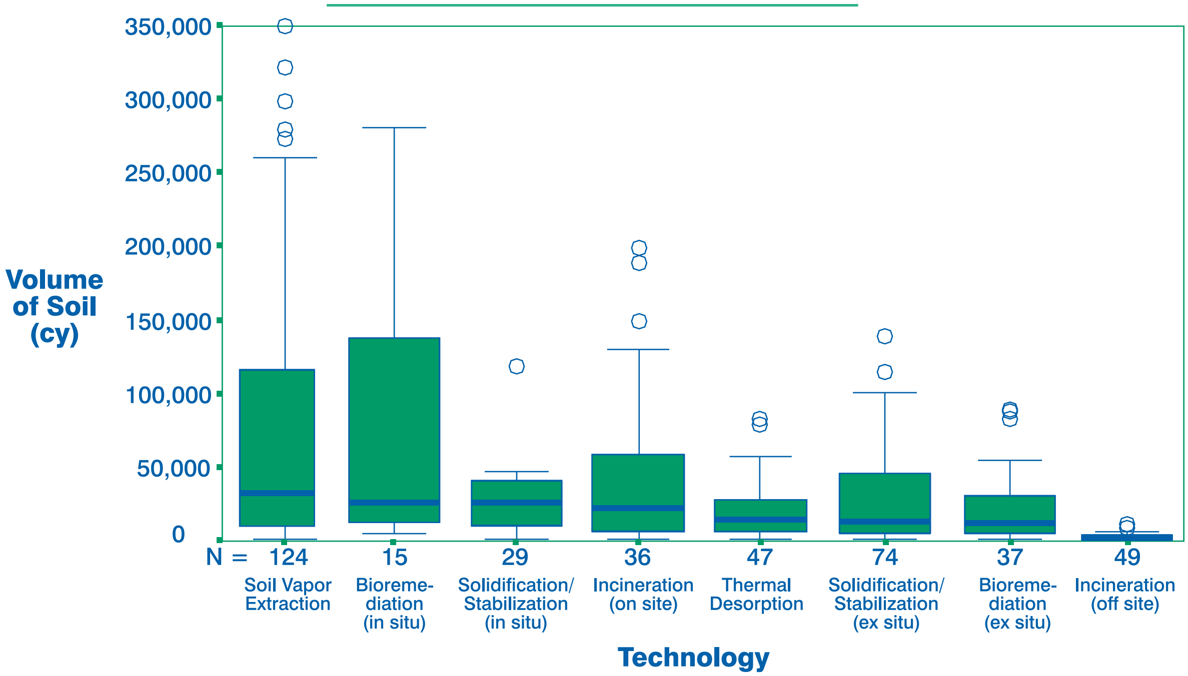
EPA's calculation of the average volume per project, shown in Figure 15, did not include the data for the Lipari Landfill in situ flushing project because that data skewed the average for that technology by more than 400 percent.

Figure 16 is a box plot of the volume of soil treated by individual technologies. Presentation of data in the box plot format is useful because it shows how the data are distributed by displaying the median (average value for all projects), 25th, and 75th percentiles as well as the largest and smallest nonoutlier values. Outliers and extreme values can also be displayed. The 25th percentiles represents the value at which 25 percent of the cases have smaller values and 75 percent have larger values. The 75th percentile represents the value at which 25 percent of the cases have larger values and 75 percent have smaller values. With a box plot, the 25th and 75th percentiles, are shown as the ends of the box. The largest and smallest nonoutlier values are shown by lines that extend from the ends of the box. Outliers represent values that are between one-and-a-half and three box lengths from the top or bottom of the box. Extreme values, which are values greater than three box lengths from the top or bottom of the box, are not shown on Figure 16.

As shown in Figure 16, the median value for the volume of soil per project for all technologies was below 50,000 cy. This value indicates that for at least 50 percent of the sites being addressed by treatment technologies, the volume of soil treated is 50,000 cy or less. However, the range of values as shown by the length of the box and whiskers for SVE and bioremediation (in situ) was much greater than those for all other technologies. The 75th percentile value for SVE and bioremediation (in situ) is above 100,000 cy, indicating that the volume being treated by these technologies exceeded 100,000 cy for 25 percent of the projects for which data were available. In contrast the median and range for the volumes of soil treated by other technologies, such as solidification/stabilization (both in situ and ex situ), incineration (both on site and off site), thermal desorption, and bioremediation (ex situ), are much smaller than for either SVE or bioremediation (in situ). The box plot reaffirms the assertion that in situ technologies are typically used to treat larger sites.

As shown in Figure 16, the median value for volume of soil per project for solidification/stabilization (both in situ and ex situ), incineration (both on site and off site), thermal desorption, and bioremediation (ex situ) was below 30,000 cy. The largest range in soil volumes for these technologies was for projects

Figure 16. Superfund Remedial Actions: Average Soil Volumes by Technology



Note: Extreme values (three box lengths from the top or bottom of box) are not included. Outliers are shown as circles. N equals the number of data points. Data are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998.

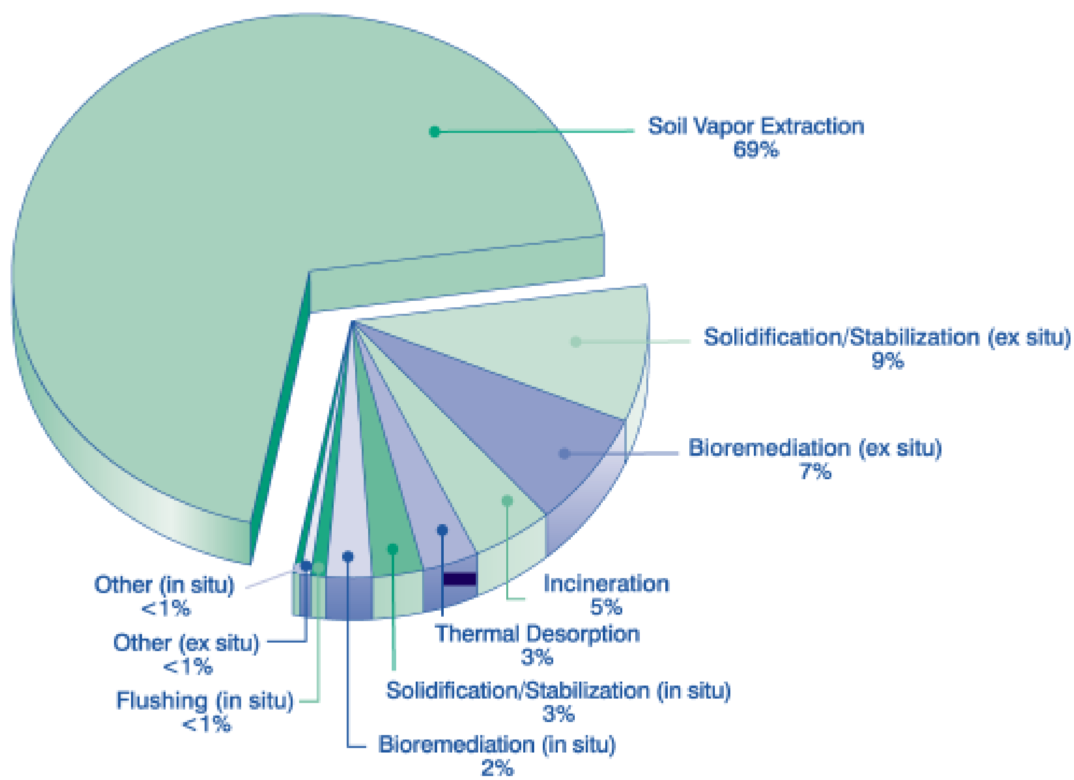
implementing incineration (on site). It is interesting to note that there were a number of incineration (on site) projects in which the soil volume exceeded 120,000 cy. This high volume indicates that in some cases for very large volumes of soil it may be less costly to use incineration (on site). On the other hand, for projects implementing thermal desorption, the range of volumes was much smaller, with the larger projects approaching 80,000 cy. For projects in which waste was incinerated off-site, the volume of soil treated and the range of volumes treated was very small relative to the other technologies displayed in Figure 16, indicating that incineration (off site) is typically used for relatively small volumes (less than 5,000 cy). In fact, nearly 82 percent of the sites implementing incineration (off site) for which data are available reported treating volumes of less than 5,000 cy.

Figure 17 shows the total volume being treated by each technology type. As shown in Figure 17, a majority of the soil volume is treated by SVE.

EPA also analyzed the average quantity of soil treated by year for each technology to identify any trends or changes in the average volume of soil treated. For some of the most common technologies, bioremediation (ex situ and in situ), flushing (in situ), SVE , thermal desorption, and solidification/stabilization (in situ), the average volume of soil treated per project has tended to increase over the years. However, there has been some fluctuation. For example, the average volume per project in FY 1988 was approximately 20,000 cy for thermal desorption. However, in FY 1994 the average volume was about half of that, at approximately 11,000 cy. In FY 1995, the average volume increased to approximately 46,000 cy.

For incineration and solidification/stabilization (ex situ), the average volume of soil treated per project has tended to decrease over the years.

Figure 17. Superfund Remedial Actions: Total Volume of Soil Treated by Technology Type



Note: Data are derived from Records of Decision (RODs) for FY 1982-1997 and anticipated design and construction activities as of August 1998. Includes 13 projects selected in RODs and ROD amendments for FY 1998. FY 1998 data are not comprehensive. "Other (in situ)" technologies include: hot air injection, thermally enhanced recovery and vitrification. "Other (ex situ)" technologies include: chemical treatment, dechlorination, ex situ flushing, physical separation, soil washing, and ex situ SVE.

New Information on Established Technologies

As mentioned earlier, this year's report includes updated data on incineration (off site), solidification/stabilization, MSA, OB/OD, and neutralization projects. Information on these established technologies for ASR versions prior to this ninth edition was based on a review of RODs rather than on interviews with regional or state staff. Therefore, the only information for sites using these established technologies was the name of the site and the year the ROD was signed. Previous versions of the ASR did not reflect any changes in the remedy that may have occurred during the design phase of the cleanup and did not report on the implementation status of these established technology projects. The eighth edition of the ASR did update the data for incineration (on site) projects. This ninth edition of the report updates the data for incineration (off site), solidification/stabilization, MSA, OB/OD, and neutralization to make the report comprehensive in terms of all treatment (both established and innovative) technologies as well as any remedy changes that have occurred throughout the remedial process during the previous years.

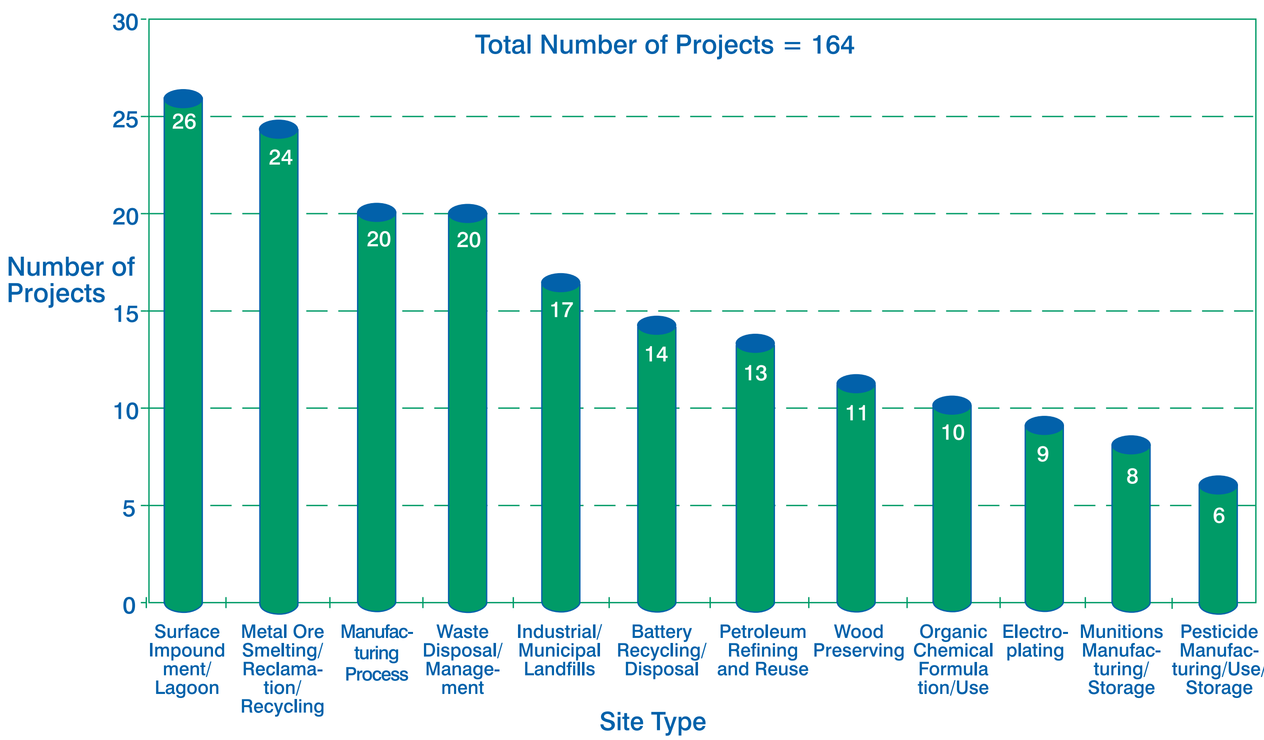
Figure 18 shows the site types treated by solidification/stabilization projects. Surface impoundments/lagoons, metal ore smelting/recycling, manufacturing process, and waste disposal/management sites are most frequently addressed by solidification/stabilization.

Additional new information in this report includes data on the volume of contaminated media treated by incineration (off site) and solidification/stabilization. As mentioned earlier, Figure 15 indicates that the average volume of soil treated per project was significantly lower for incineration (off site)(approximately 4,000 cy) versus incineration (on site)(approximately 48,000 cy).

The difference in average volume treated is most likely related to cost. Incineration (off site) is cost-effective only for small volumes of contaminated soil because of the cost of transporting waste off-site.

For solidification/stabilization projects, the volume of soil treated was roughly the same regardless of whether the technology was applied in situ or ex situ. The data collected for solidification/stabilization projects also indicate that most projects

Figure 18. Superfund Remedial Actions: Site Types for Solidification/Stabilization



Note: Data are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998. Includes three projects selected in RODs or ROD Amendments for FY 1998. FY 1998 data are not comprehensive. Does not include instances in which the number of projects with the same type was less than six. Projects can have more than one site type.

used inorganic binders, primarily Portland cement to solidify and stabilize the waste.

Remedy Changes

As indicated in Section 1, remedies selected for Superfund remedial actions are documented through a ROD. When a remedy is changed, the change can be documented through a second ROD, a ROD amendment, or an ESD. A ROD amendment can also be used to add a new remedy. In some cases, a decision document is not necessary to document a change if the new remedy was included in the original ROD as a contingency. Remedy changes often occur during the predesign or design phase of a project when new information about site characteristics are discovered or treatability studies for the selected technologies are completed.

Appendix D provides a list of sites tracked by this series of annual reports where remedy changes have occurred. For each remedy change, Appendix D documents the original remedy, the new or alternative remedy selected, the primary reasons for the change, and the decision document, if any, used to document the change. The appendix only lists a change in treatment technologies tracked by the nine editions of this report. It is not a comprehensive list of changes in Superfund RODs.

This report documents approximately 248 (235 source control and 13 groundwater) projects where remedy changes or deletions involving treatment technologies have occurred. In other words, those responsible for the site determined that the treatment technology selected originally was no longer the appropriate remedy for that site. For some projects the new remedy or alternative selected was an innovative or established technology, or containment, including capping, or excavation and off-site disposal. For some projects, the alternative had not been determined.

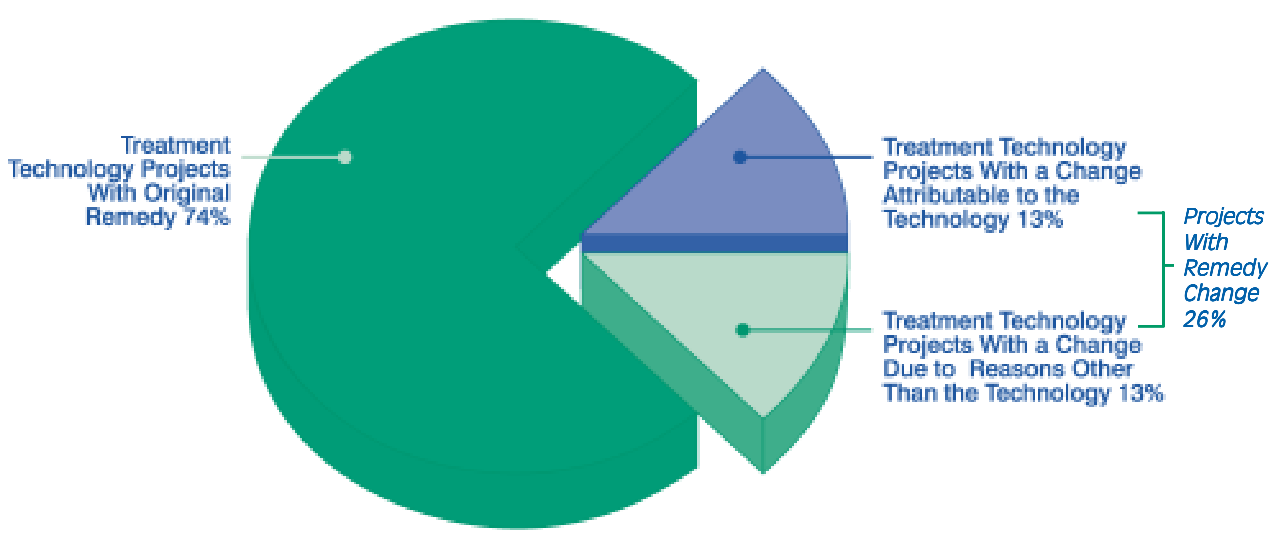
Those 248 projects do not include 24 projects under which another treatment technology was added at a site. In a number of cases, another technology was added to an existing technology, either to enhance the original technology or to treat another area of the site.

Figure 19 shows the percent of projects tracked by this report that are continuing with the original remedy versus the percentage of projects that have experienced a remedy change. Overall, the 248 projects where the remedy has changed represent approximately 26 percent of all treatment technologies tracked by this report. Consequently, for the majority of projects (74 percent), the remedy has remained unchanged.

As indicated, Appendix D provides the primary reasons cited for a remedy change. In some cases, reasons related to the technology such as the cost or performance were cited. In other cases, the change was made for other reasons that were not attributable to the technology such as revised cleanup goals or changes in conditions at the site such as contaminants at the site that were naturally attenuating.

Figure 19 shows the percentage of projects in which the reason cited was attributable to the technology versus the percentage of projects experiencing a change for reasons other than the technology. As

Figure 19. Superfund Remedial Actions: Projects With a Remedy Change



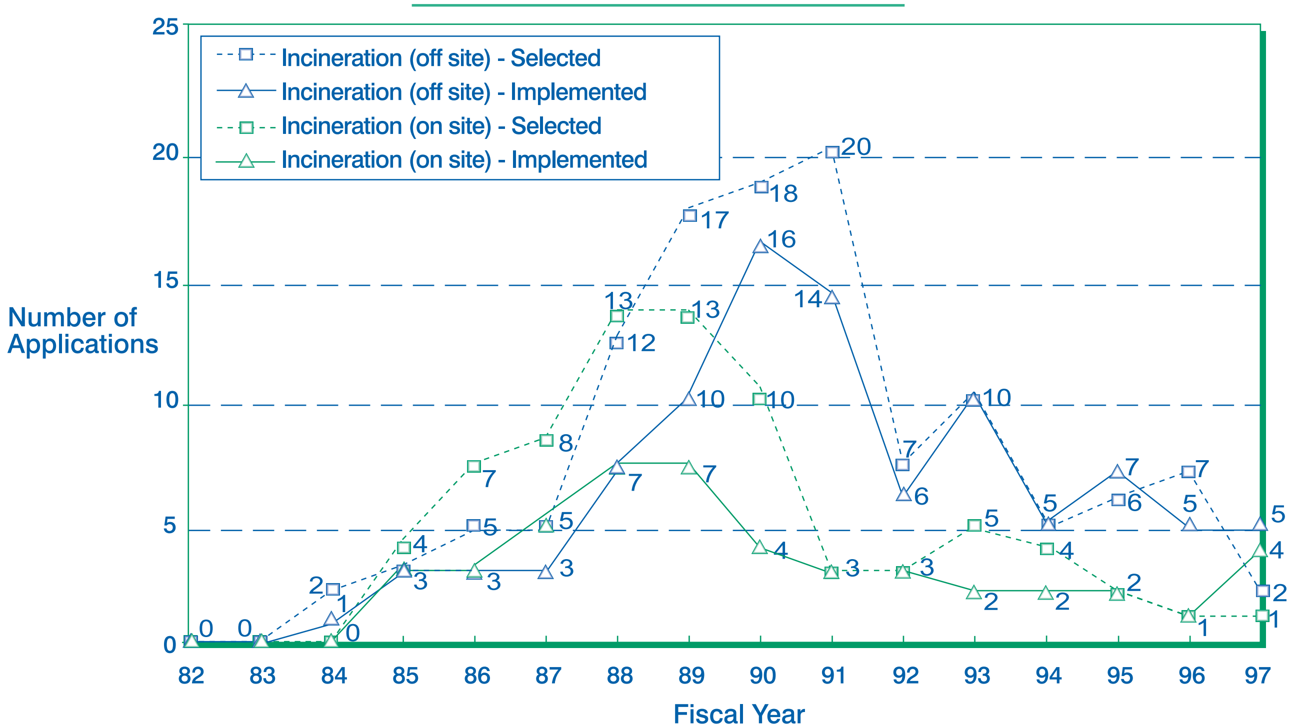
Note: Data are derived from Records of Decision (RODs) for FY 1982–1997 that selected treatment technologies for source control and innovative technologies for groundwater and anticipated design and construction activities as of August 1998. Includes 13 projects selected in RODs or ROD amendments for FY 1998. FY 1998 data are not comprehensive. Does not include RODs selecting pump-and-treat or other aboveground treatment for groundwater.

shown in Figure 19 for approximately half of the projects experiencing a remedy change, the change was due to problems with the original treatment technology such as an inability to meet treatment goals.

During the effort to update information on incineration (off site) and solidification/stabilization projects that were selected in RODs dating back to FY 1982, a large number of remedy changes involving these projects were discovered and are documented in this report.

Figures 20 through 22 compare the number of RODs in which incineration, solidification/stabilization, or bioremediation was selected and the actual number of such projects implemented respectively from FY 1982 through FY 1997. The differences between the number selected and the number implemented is the result of changes in the remedy that occurred during the remedial process. For most years, as the figures show, the number of incineration, solidification/stabilization, and bioremediation technologies implemented is slightly less than the number selected in RODs for most years. The gap between incineration projects selected and those implemented (Figure 20) is greatest for FY 1989 through FY 1991. For solidification/stabilization technologies (Figure 21) the widest gap occurred over a longer time frame, from FY 1988 through FY 1993. In both cases, the years showing the largest gaps are years in which incineration and solidification/stabilization were selected in RODs most often. However, the gaps between the number of times the technologies were selected and the number of times they were implemented generally decreased after 1994, coinciding with an overall decrease in the number of projects for which these technologies were selected. The decreased gaps may have a number of causes. For example, in the years in which the greatest differences were observed (FY 1988 through FY 1993), many innovative treatment technologies were relatively untried or unavailable. Therefore, incineration and solidification/stabilization were the two primary conventional treatment options available to site managers. As knowledge of the capabilities of other remedial options became more widespread, project managers re-evaluated initial remedy selections, adjusting them on the basis of new information. Containment or off-site disposal were the most frequent substitutes for the technologies originally selected, although thermal desorption, SVE, and other treatment technologies also were selected. (Appendix D of this report provides a table that lists the projects for which technologies were changed).

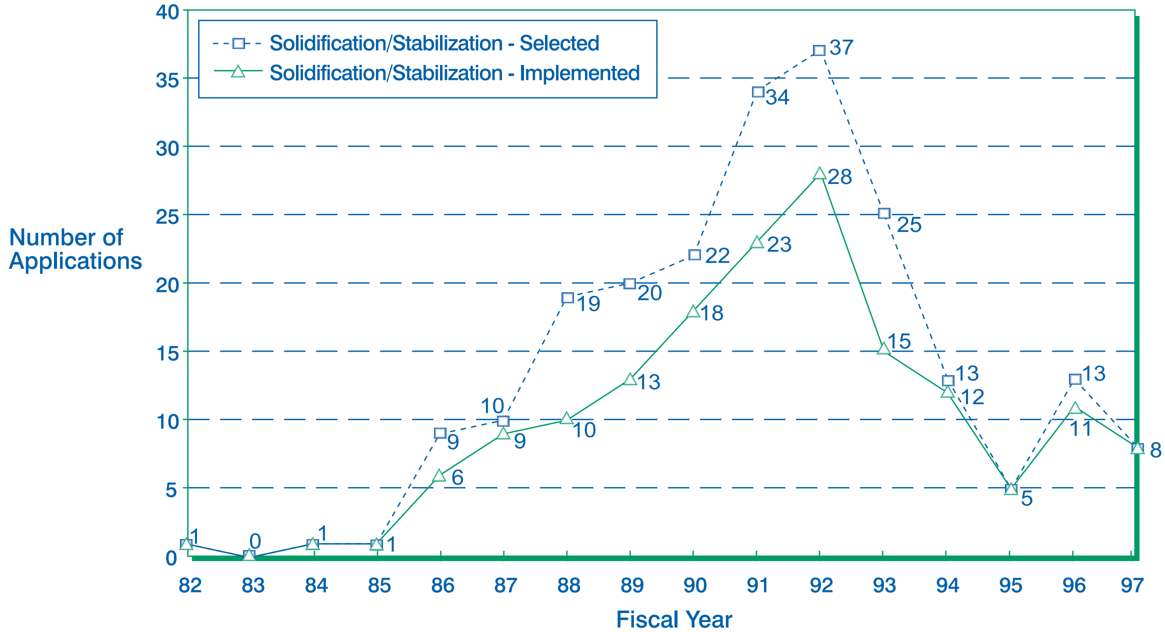
Figure 20. Superfund Remedial Actions: Changes in Incineration Remedies



Note: Data are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998. The differences between the number selected and the number implemented is the result of changes in the remedy that occurred during the remedial process. Includes remedies that have been added or dropped.

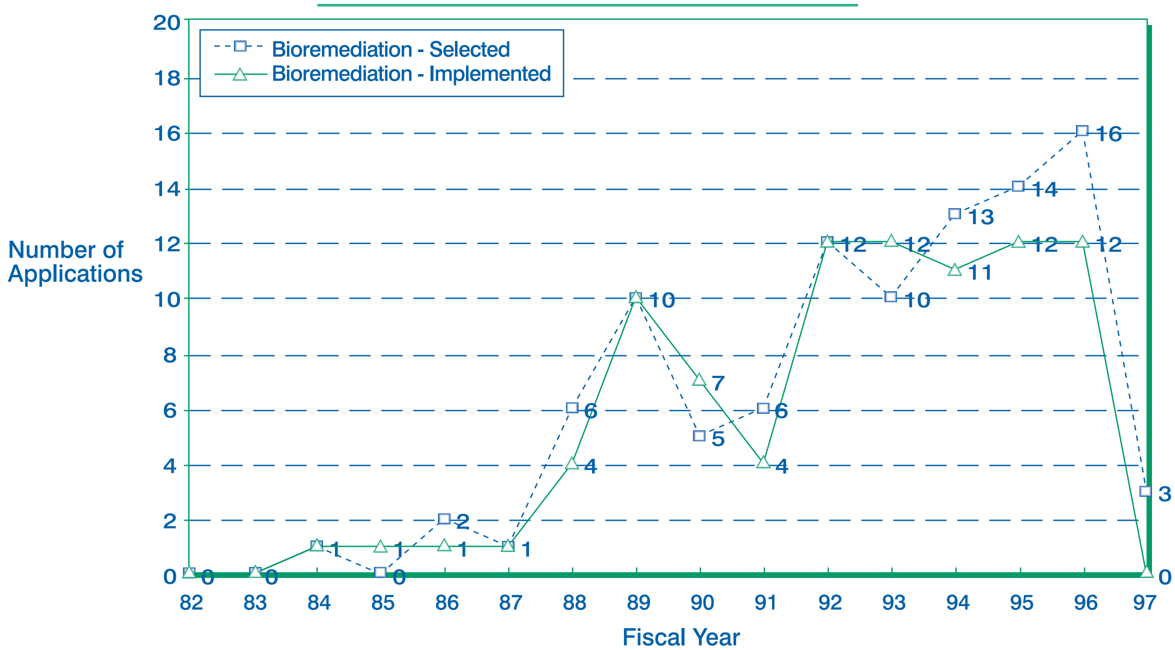
For most years, the difference between the number of bioremediation projects selected and the number actually implemented is relatively small (Figure 22), even though the number of bioremediation projects selected increased steadily from FY 1988 through FY 1996. Half of the time, the number of bioremediation projects implemented was equal to or greater than the number selected. The gap between the number of times the technology was selected and the number of times it was implemented widened after 1994, but the gap remained fewer than two to four projects.

Figure 21. Superfund Remedial Actions: Changes in Solidification/Stabilization Remedies



Note: Data are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998. The differences between the number selected and the number implemented is the result of changes in the remedy that occurred during the remedial process. Includes remedies that have been added or dropped.

Figure 22. Superfund Remedial Actions: Changes in Bioremediation Remedies



Note: Data are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998. The differences between the number selected and the number implemented is the result of changes in the remedy that occurred during the remedial process. Includes remedies that have been added or dropped.

Section 3: Innovative Applications

This section discusses innovative treatment technologies. In the Foreword, innovative technologies were defined as treatment technologies whose use is inhibited by lack of data on cost or performance. For the first time, SVE and thermal desorption, formerly defined as innovative, are now categorized as established in this report. The eighth edition of the ASR, published in 1996, considered SVE and thermal desorption as transitional because of the large number of applications of those technologies. They have been reclassified in this report as established because several reports and case studies have been published documenting the cost and performance of both SVE and thermal desorption. Figure 23 lists the technologies that were categorized as innovative and established in the eighth edition ASR (1996) versus those in this report. The Federal Remediation Technologies Roundtable (FRTR) has published 140 case studies on a wide range of treatment technologies which are now available for viewing on-line or downloading from the FRTR web site at http://www.frtr.gov. Of these, 27 pertain to SVE and 12 pertain to

Figure 23. Superfund Remedial Actions: Technologies Listed as Innovative and Established in 1996 Versus 1998

ASR 8th Edition 1996	ASR 9th Edition 1998
Innovative Source Control Technologies	
	Bioremediation (ex situ) - Biopile
Bioremediation (ex situ) - Composting	Bioremediation (ex situ) - Composting
Bioremediation (ex situ) - Land Treatment	Bioremediation (ex situ) - Land Treatment
Bioremediation (ex situ) - Other	Bioremediation (ex situ) - Other
Bioremediation (ex situ) - Slurry-Phase	Bioremediation (ex situ) - Slurry-Phase
Bioremediation (ex situ) - Solid-Phase	Bioremediation (ex situ) - Solid-Phase
Bioremediation (in situ) - Bioventing	Bioremediation (in situ) - Bioventing
Bioremediation (in situ) - Lagoon	Bioremediation (in situ) - Lagoon
Bioremediation (in situ) - Other	Bioremediation (in situ) - Other
Chemical Treatment	Chemical Treatment
Contained Recovery of Oily Wastes (CROW)	Changed to: Thermally Enhanced Recovery
Cyanide Oxidation	Cyanide Oxidation
Dechlorination	Dechlorination
Flushing (in situ)	Flushing (in situ)
Hot Air Injection	Hot Air Injection
Physical Separation	Physical Separation
	Phytoremediation
Plasma High Temperature Recovery	Remedy no longer being implemented
SVE	Now Classified as Established
Soil Washing	Soil Washing
Solvent Extraction	Solvent Extraction
	Surfactant Flushing
Thermal Desorption	Now Classified as Established
Vitrification	Vitrification
Established Source Control Technologies	
Incineration (off site)	Incineration (off site)
Incineration (on site)	Incineration (on site)
Mechanical Soil Aeration	Mechanical Soil Aeration
Neutralization	Neutralization
Open Burn/Open Detonation	Open Burn/Open Detonation
	SVE
Solidification/Stabilization	Solidification/Stabilization
	Thermal Desorption
In Situ Groundwater Technologies	
Air Sparging	In Situ Air Stripping (Air Sparging)
	Bioremediation (in situ) - Bioslurping
	Bioremediation (in situ) - Biosparging
Bioremediation (in situ) - Groundwater	Bioremediation (in situ) - Groundwater
Dual-Phase Extraction	Dual-Phase Extraction
Oxidation (in situ)	Oxidation (in situ)
Passive Treatment Wall	Changed to: Permeable Reactive Barrier
Well Aeration (in situ)	Well Aeration (in situ)

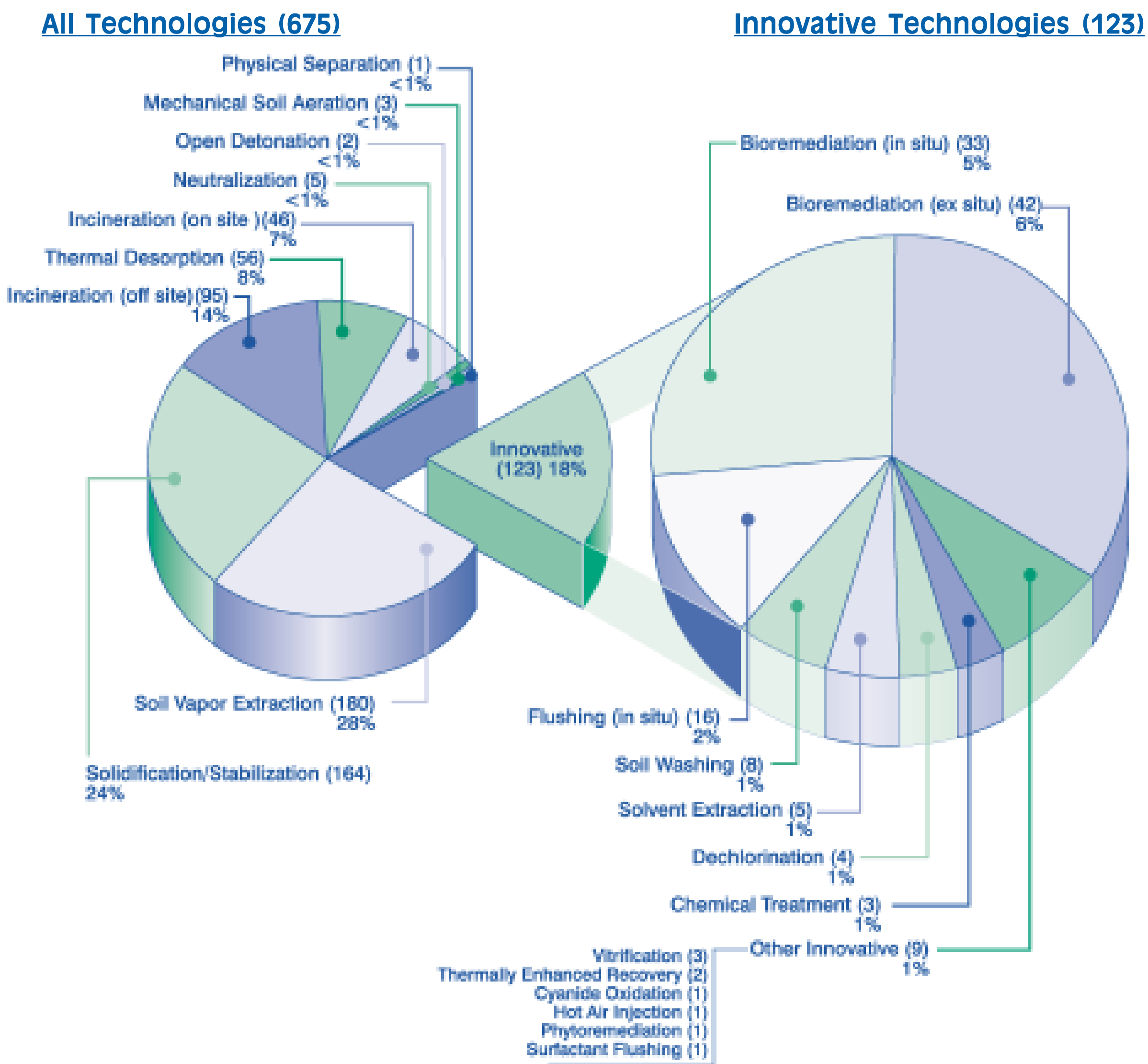
thermal desorption. The case studies were developed by EPA, DoD, and DOE. The case studies and abstracts present available cost and performance information for full-scale remediation efforts and several large-scale demonstration projects. The case studies contain information on site background and setting, contaminants and media treated, technology, cost and performance, and points of contact for the technology application. The studies contain varying levels of detail, reflecting the differences in the availability of data and information.

Although SVE and thermal desorption are no longer included in the innovative category, there are several innovative enhancements or adaptations of these technologies. For example, SVE can be enhanced using pneumatic fracturing or a variety of thermal methods. Additional information on enhancements for SVE systems is contained in EPA's Soil Vapor Extraction (SVE) Enhancement Technology Resource Guide (EPA-542-B-95-003) and EPA's Analysis of Selected Enhancement for Soil Vapor Extraction (EPA-542-R-97-007).

Figure 23 also shows the use of three innovative technologies that were not included in the eighth edition ASR because they had not been selected in RODs; biosparging, phytoremediation, and surfactant flushing.

Figure 24 provides an overall picture of the number and type of innovative and established technologies used for source control.

Figure 24. Superfund Remedial Actions
Summary of Innovative Source Control Treatment Technologies
Selected Through Fiscal Year 1997



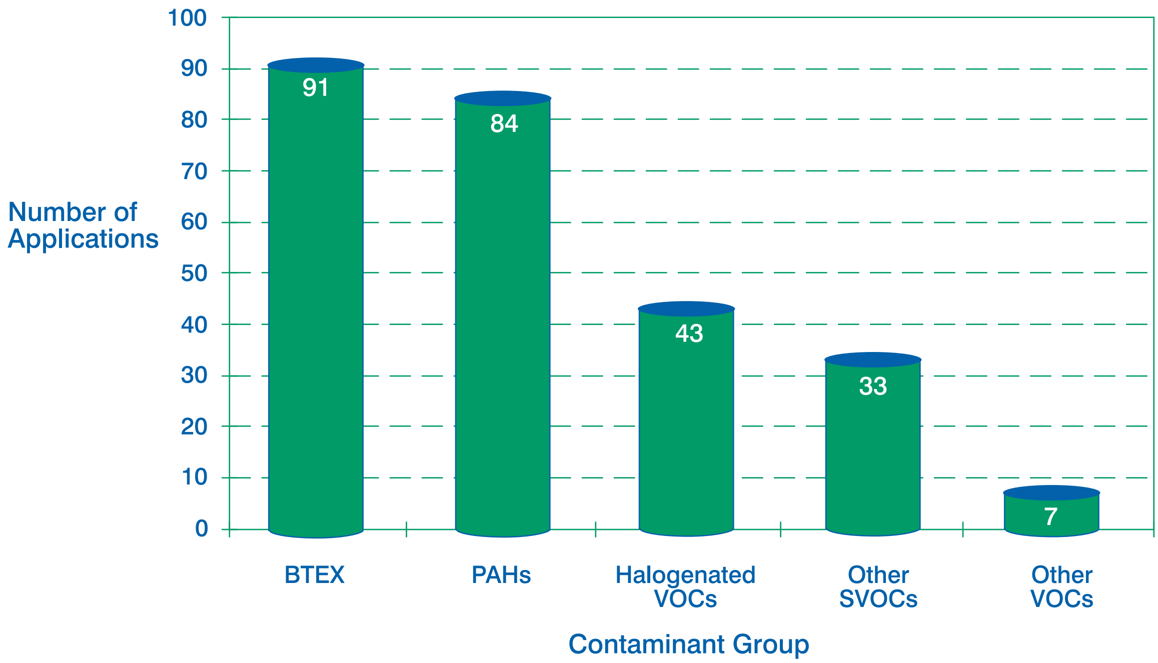
Note: Data are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998. Includes 13 projects selected in RODs or ROD amendments for FY 1998. FY 1998 data are not comprehensive.

As shown in Figure 24, innovative technologies represent approximately 18 percent of all technologies for source control. Bioremediation comprises most of the innovative technology applications (75). Other innovative technologies include flushing (in situ), phytoremediation, soil washing, solvent extraction, and vitrification.

Bioremediation

Contaminants treated by bioremediation are shown in Figure 25. The contaminants treated most often are BTEX compounds; PAHs are the SVOCs addressed most frequently; and halogenated VOCs are being treated at 43 sites. Currently, 75 projects are implementing various forms of bioremediation for source control. Figure 26 illustrates the types of bioremediation for source control. Land treatment is the most common form of ex situ bioremediation with 29 projects, followed by composting (six projects). Based on available data, bioventing has been specified for 19 of the 33 in situ soil bioremediation remedies.

Figure 25. Superfund Remedial Actions: Contaminants Treated by Bioremediation*

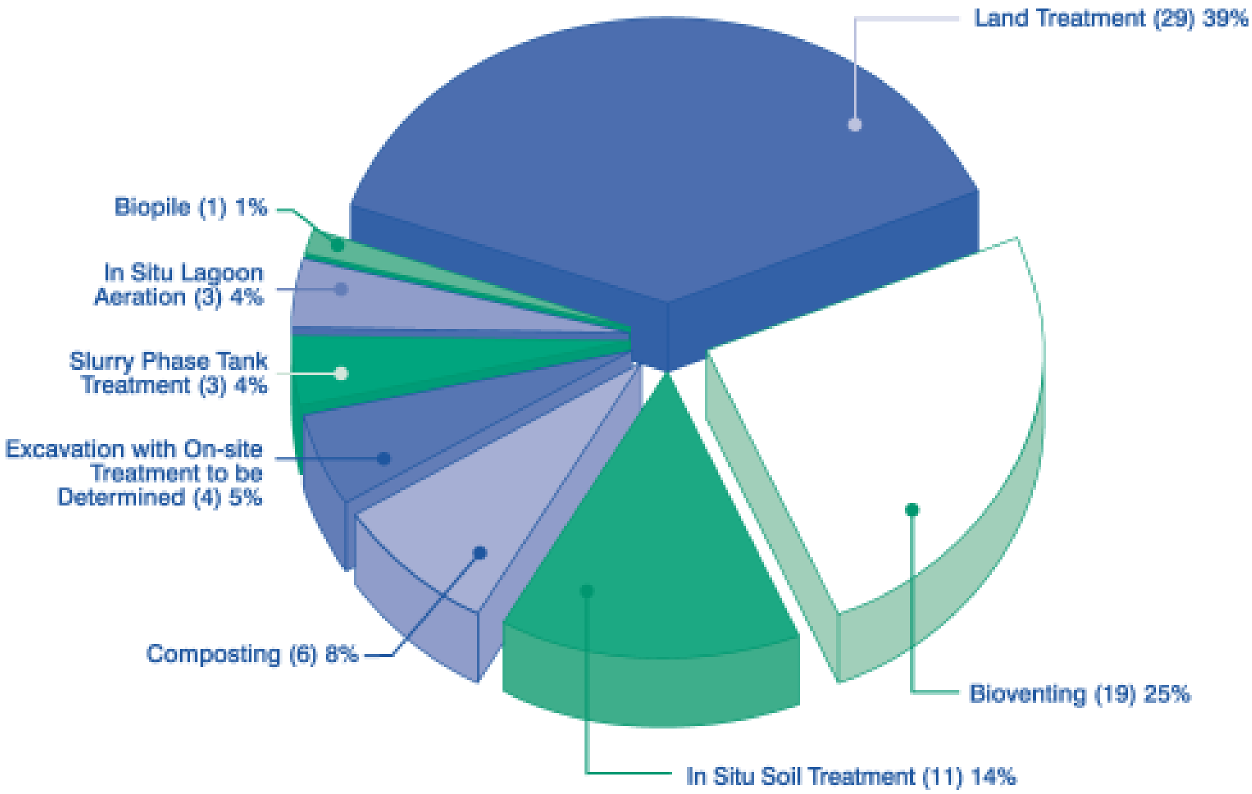


* *Includes in situ groundwater technologies*

Note: *At some sites, treatment is for more than one contaminant. Treatment may be planned, ongoing, or completed.*

Data are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998. Includes six projects selected in RODs or ROD amendments for FY 1998. FY 1998 data are not comprehensive.

Figure 26. Superfund Remedial Actions: Bioremediation Methods for Source Control



Note: *Data are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998. Includes four projects selected in RODs or ROD amendments for FY 1998. FY 1998 data are not comprehensive.*

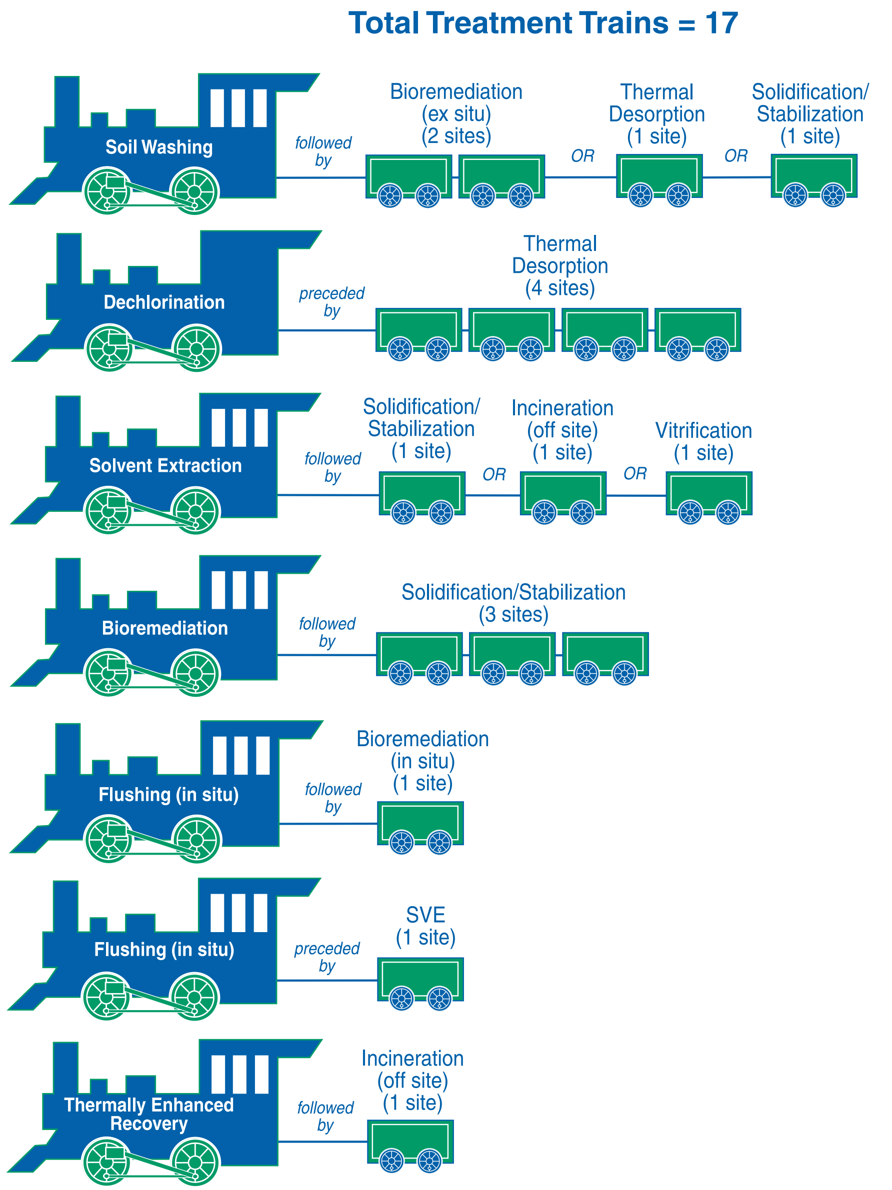
Treatment Trains

In some cases, several innovative and established technologies may be used together in treatment trains, which are either integrated processes or a series of treatments that are combined in sequence to provide the necessary treatment. Seventeen remedial sites use treatment trains for source control.

Figure 27 identifies specific treatment trains used in remedial actions. Appendix C provides the names of sites that use treatment trains. Innovative treatment technologies may be used with established technologies or with other innovative technologies. The most common treatment trains are dechlorination preceded by thermal desorption, soil washing followed by aboveground bioremediation (usually slurry-phase treatment) and bioremediation followed by solidification/stabilization. Technologies may be combined to reduce the volume of material that requires further treatment; to prevent the emission of volatile contaminants during excavation and mixing; or to treat multiple contaminants in a single medium.

This year's report documents 17 treatment trains involving innovative technologies. This number is down from 32 treatment trains documented in the ASR eighth edition. The decrease was the result of classifying SVE and thermal desorption as established technologies, as well as some technologies that have been changed or cancelled.

Figure 27. Superfund Remedial Actions: Treatment Trains with Innovative Treatment Technologies



Note: Data are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998. Includes one project selected in a ROD amendment for FY 1998. FY 1998 data are not comprehensive.

Section 4: Groundwater Technologies

Groundwater treatment remedies include conventional pump-and-treat and in situ treatment, or a combination of both. Figure 28 shows the overall types of groundwater treatment remedies selected. Groundwater treatment remedies have been selected for 663 sites. Of these, 588 sites are implementing pump-and-treat systems alone, and 39 sites are using pump-and-treat systems and in situ treatment, either for the same area of the site or for different areas. In situ treatment alone has been selected as a single remedy at 36 sites to treat groundwater contamination. For some of these sites, it is possible that pump-and-treat is being conducted at another part of the site.

Figure 29 lists the specific types of in situ treatments selected. More detail on their implementation status is in Figure 13 (see p. 16).

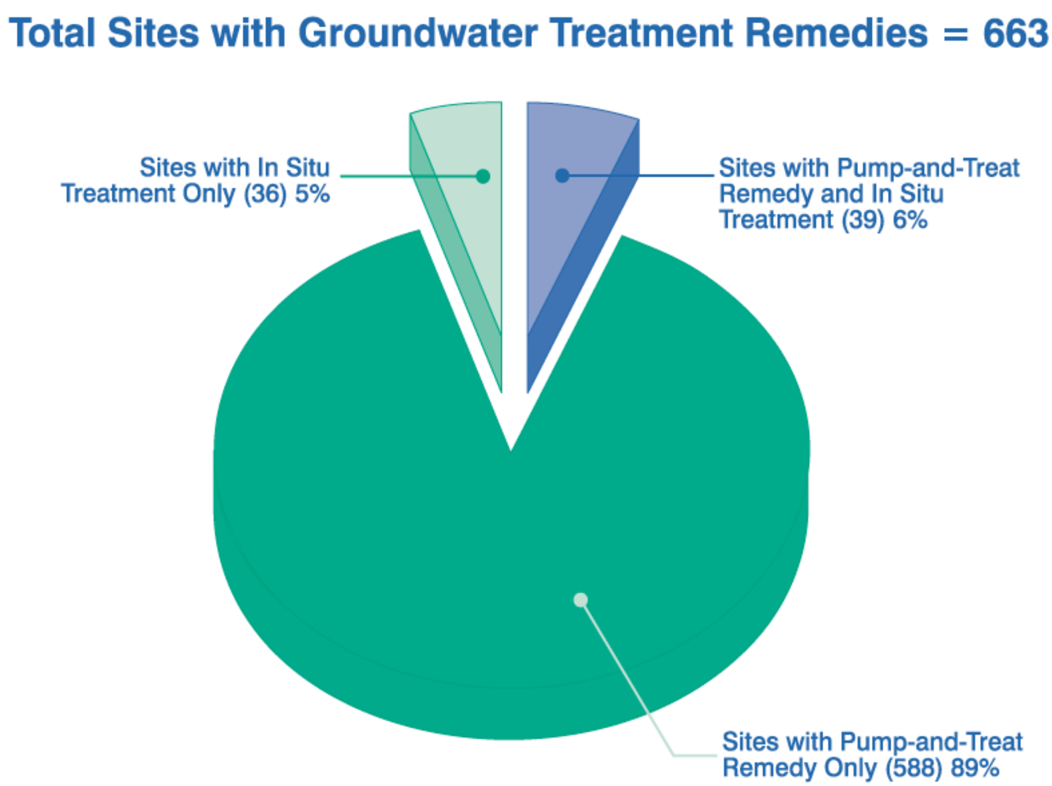
EPA has selected in situ treatment of groundwater 75 times at 65 remedial sites. EPA selected in situ treatment of groundwater for more than 26 remedial sites in FY 1996 and FY 1997. More than half of these projects are in the operational phase. Completion of these projects is expected to require 5 to 20 years. The EPA REACH IT on-line searchable database provides more detailed information for each in situ groundwater application at Superfund remedial action sites. Appendix A lists the number of in situ groundwater treatment technologies selected each year. The summary matrix in Appendix B provides site names, technologies, and project status.

Figure 30 indicates the types of sites addressed by air sparging. Vehicle maintenance/fuel lines/storage/spills and manufacturing process sites are most frequently addressed by this technology. Contaminants treated by air sparging are shown in Figure 31. Halogenated VOCs are the contaminants treated most frequently.

In recent years, an increasing number of RODs have specified natural attenuation as a remedy for groundwater contamination.

Figure 32 shows the number of RODs that selected natural attenuation for groundwater at Superfund

Figure 28. Superfund Remedial Actions: Groundwater Remedies Through Fiscal Year 1997



Note: Pump-and-treat remedy data based on Records of Decision (RODs) for FY 1982–1997; in situ treatment data based on anticipated design and construction activities as of August 1998. Includes four projects selected in RODs or ROD amendments for FY 1998. FY 1998 data are not comprehensive.

Source: U.S. EPA Office of Emergency and Remedial Response, 1998. FY 1996 and 1997 data are preliminary.

remedial action sites. As shown in the figure, the selection of natural attenuation has steadily increased since FY 1985. EPA's Office of Emergency and Remedial Response (OERR) analyzed FY 1982 through FY 1994 RODs selecting natural attenuation. The analysis revealed that the most common reason cited for selecting natural attenuation was low or decreasing contaminant concentrations at the site. The analysis also indicated that the most prevalent contaminant found at these sites was VOCs.

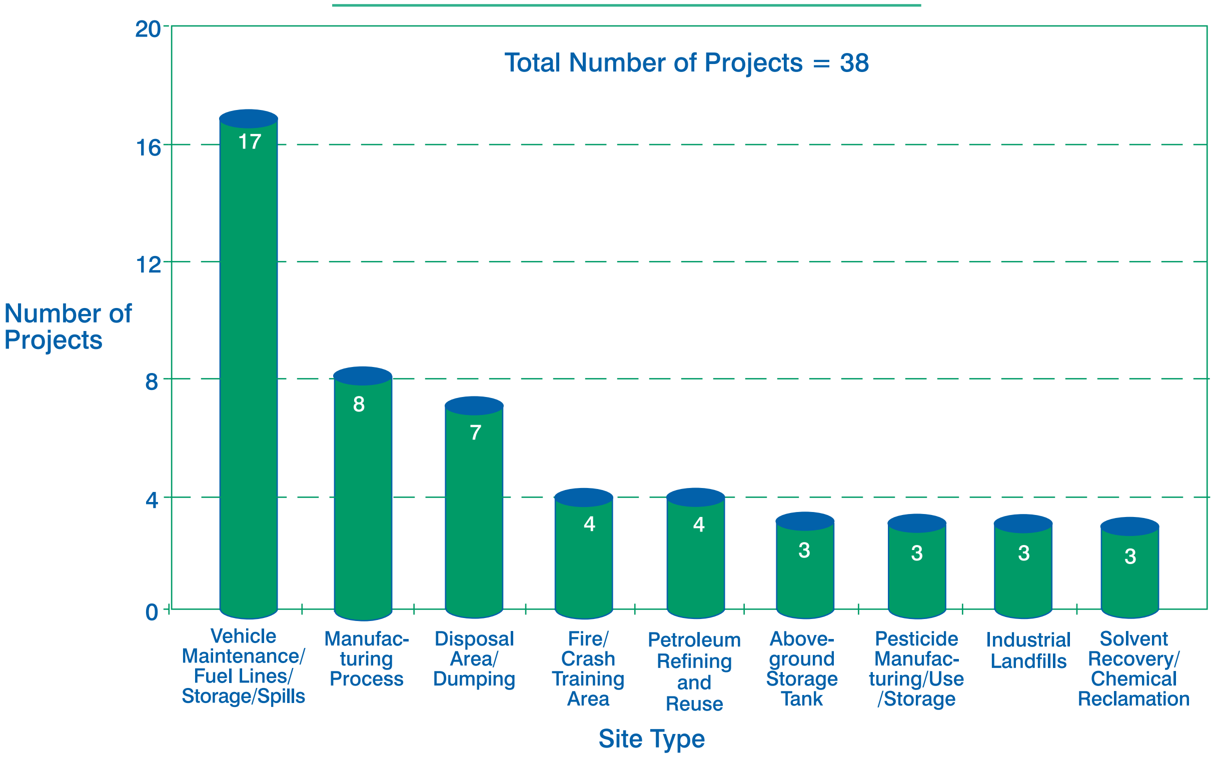
EPA recently finalized guidelines on the use of natural attenuation to remediate groundwater. Use

Figure 29. Superfund Remedial Actions: In Situ Groundwater Treatment Technologies

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

Note: Data are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998.

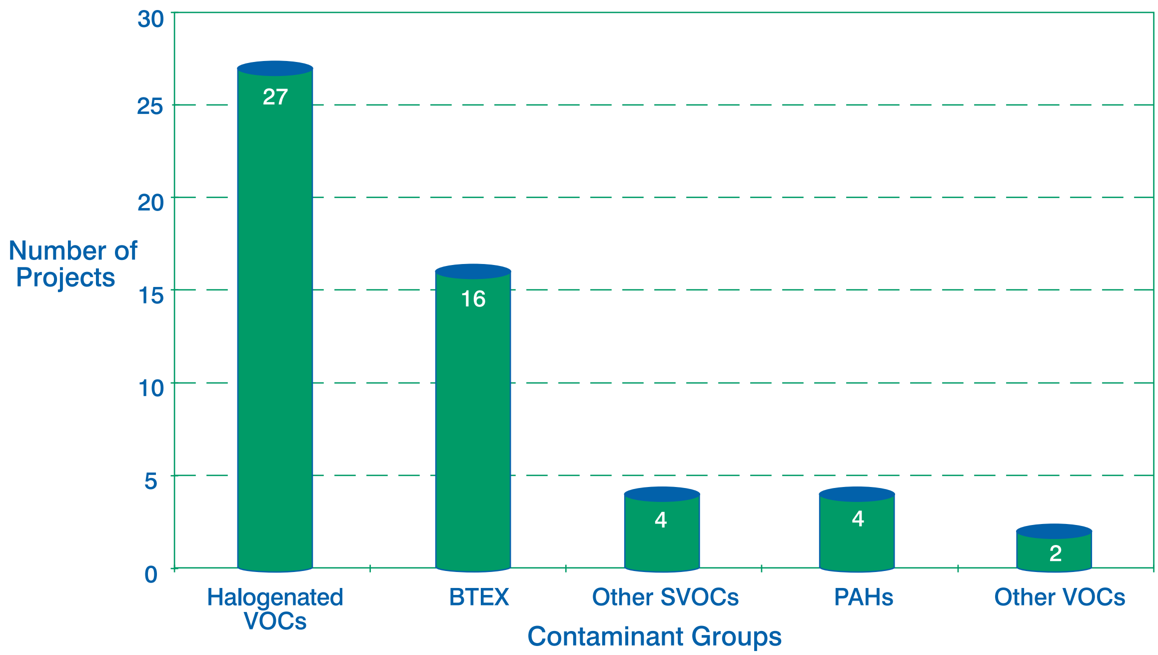
Figure 30. Superfund Remedial Actions: Types of Sites Addressed by Air Sparging



Note: Data are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998. Includes one project selected in a ROD amendment for FY 1998. FY 1998 data are not comprehensive. Projects can have more than one site type. Does not include instances in which the same site types was less than three.

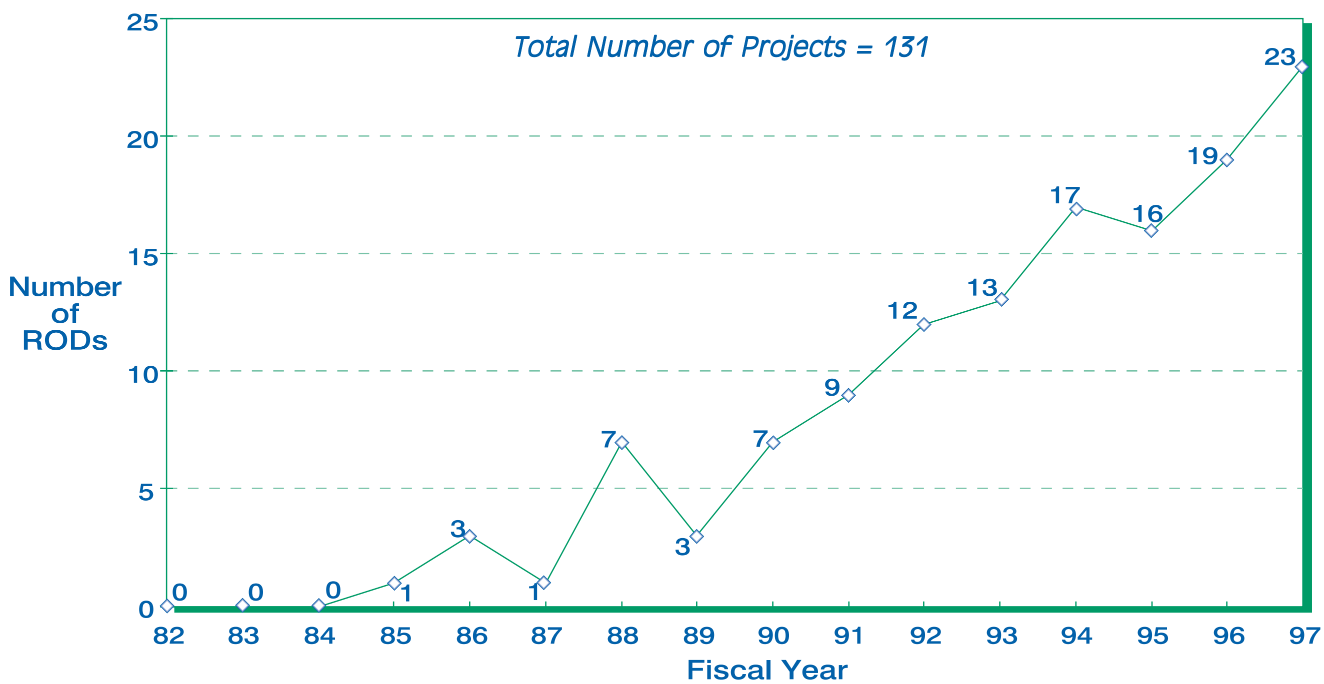
of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites, OSWER Directive Number 9200.4-17 is available by calling 800-424-9346 or 703-412-9810, or on the Internet at http://www.epa.gov/swerust1/directiv/d9200417.htm. Appendix E lists the sites selecting natural attenuation.

Figure 31. Superfund Remedial Actions: Contaminants Treated by Air Sparging



Note: Data are derived from Records of Decision (RODs) for FY 1982–1997 and anticipated design and construction activities as of August 1998. Includes one project selected in a ROD amendment for FY 1998. FY 1998 data are not comprehensive. There may be more than one contaminant group per project.

Figure 32. Superfund Remedial Actions: Natural Attenuation for Groundwater by Fiscal Year



Source: U.S. EPA Office of Emergency and Remedial Response, 1998. FY 1996 and 1997 data are preliminary.

Section 5: Superfund Removal Actions

Removal actions are usually conducted in response to a more immediate threat caused by a release of hazardous substances than threats addressed by remedial actions. Approximately 5,500 removal actions have been undertaken to address these more immediate threats. To date, innovative treatment technologies have been used in relatively few removal actions. The treatment technologies addressed in this report have been used 97 times in 54 removal actions (Figure 33). The eighth edition of the ASR documented only 33 removal actions using innovative technologies. The increase in removal actions documented in this report is primarily the result of a more comprehensive effort to collect data.

Figure 33 indicates that 54 percent of removal projects that involve treatment technologies have been completed. Since removal actions are responses to an immediate threat, and often involve smaller quantities of hazardous wastes than remedial activities, the implementation of the technology may progress faster at a removal site than at a remedial site.

As removal actions involve smaller quantities of waste or immediate threats, they require quick action to alleviate the hazard. Often, such activities do not lend themselves to on-site treatment or innovative technologies. In addition, SARA does not establish the same preference for innovative treatment for removals as it sets forth for remedial actions.

The EPA REACH IT on-line searchable database provides more detailed information for each application of an innovative technology at a removal site. The summary matrix in Appendix B lists each removal site and treatment technology.

Figure 33. Superfund Removal Actions: Project Status of Treatment Technologies as of August 1998

Technology	Predesign/ Design	Design Complete/ Not Installed/Being Installed/ Installed	Operational	Completed	Total
Source Control Technologies					
SVE	1	3	15	10	29
Bioremediation (in situ)	0	2	18	6	26
Bioremediation (ex situ)	0	0	2	13	15
Thermal Desorption	0	0	0	6	6
Chemical Treatment	0	0	0	5	5
Soil Washing	0	0	0	3	3
Dechlorination	0	0	0	2	2
Solvent Extraction	0	0	0	2	2
Vitrification	0	0	0	2	2
TOTAL	1 (1%)	5 (6%)	35 (39%)	49 (54%)	90
In Situ Groundwater Technologies					
Air Sparging	0	2	1	1	4
Bioremediation (in situ)	0	0	1	0	1
Bioremediation (in situ)-Bioslurping	0	0	1	0	1
Bioremediation (in situ)-Biosparging	0	1	0	0	1
TOTAL	0 (0%)	3 (43%)	3 (43%)	1 (14%)	7

Note: Data based on interviews conducted in FY 1988 with EPA Superfund Removal Branch Chiefs and On-Scene Coordinators for each region and anticipated design and construction activities as of August 1998.

Section 6: Actions Under Other Federal Programs

Innovative technologies also are being conducted under federal programs other than Superfund. Many of those projects are conducted at DoD and DOE facilities. These projects were identified through various sources of information, including discussions with DoD and DOE personnel, and should not be considered exhaustive. The RCRA corrective action sites using an innovative technology were identified through the review of SBs, which are decision documents prepared for some actions at corrective action sites. Because innovative technologies likely have been used at other RCRA sites, but not documented in statements of basis (SBs), the list in this report should not be considered complete. Figure 34 summarizes the types of innovative treatment technologies and the number of projects, and indicates the status of each. The summary matrix in Appendix B lists the name of each site, the technology selected, and the status of the project. The EPA REACH IT on-line searchable database provides more detailed information for each application.

Figure 34. Sample Projects Under Other Federal and RCRA Corrective Action Programs: Status of Treatment Technologies as of August 1998

Technology	Predesign/ Design	Design Complete/ Not Installed/Being Installed/Installed	Operational	Completed	Total
Other Federal Programs					
Bioremediation (in situ)*	1	2	11	5	19
SVE	1	3	8	6	18
Bioremediation (ex situ)	1	1	3	9	14
Thermal Desorption	0	0	1	4	5
Air Sparging	0	1	1	2	4
Vitrification	0	0	2	2	4
Incineration (off site)	1	0	0	1	2
Soil Washing	0	0	0	2	2
Dual-Phase Extraction	0	0	1	0	1
Flushing (in situ)	0	0	0	1	1
Well Aeration	1	0	0	0	1
Dechlorination	0	0	0	1	1
TOTAL	5 (7%)	7 (10%)	27 (37%)	33 (46%)	72
RCRA Corrective Action					
SVE	1	1	7	0	9
Bioremediation (in situ)*	0	2	0	0	2
Bioremediation (ex situ)	1	0	0	0	1
Air Sparging	0	0	1	0	1
Thermal Desorption	0	1	0	0	1
Well aeration (in situ)	0	0	1	0	1
TOTAL	2 (13%)	4 (27%)	9 (60%)	0 (0%)	15

Note: *Data based on interviews conducted in FY 1988 with EPA RCRA Corrective Action, DoD, and DOE points of contact for each site, and anticipated design and construction activities as of August 1998.*

* *Includes in situ groundwater treatment.*