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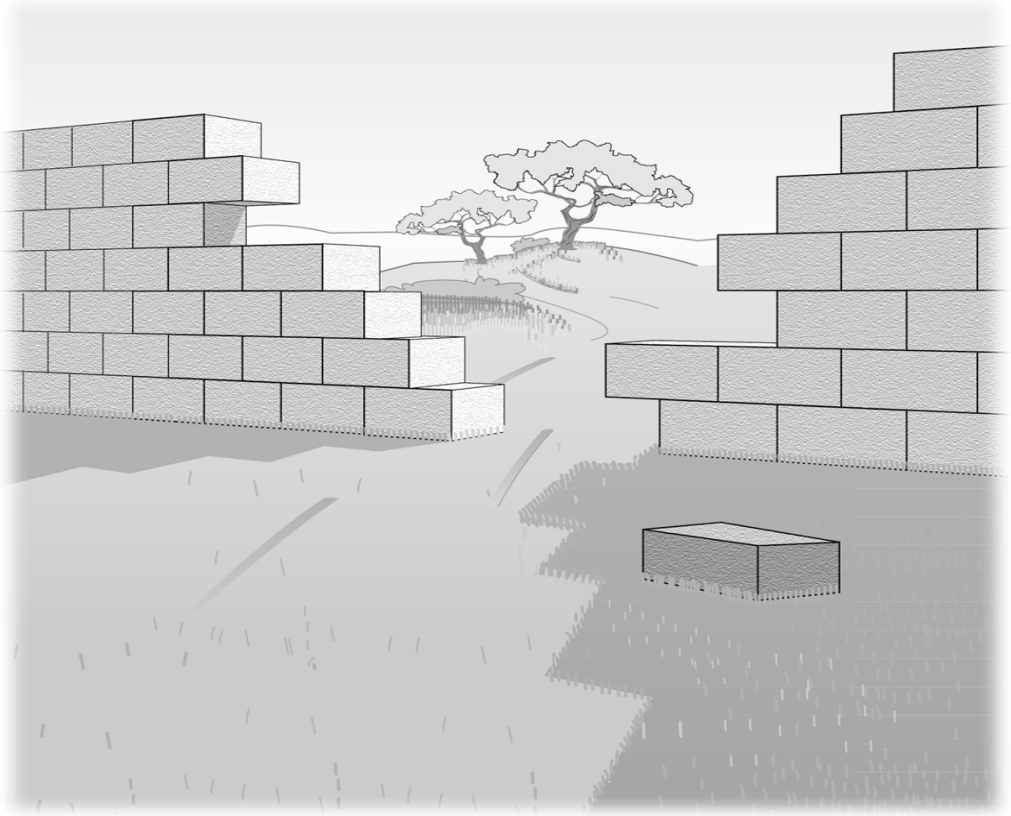
An Analysis of Barriers to Innovative Treatment Technologies: Summary of Existing Studies and Current Initiatives



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Over the last 15 years several studies have been performed to identify barriers to innovative treatment technologies (ITT). The purpose of this study is to examine the reports of those studies to identify categories of barriers, to identify barriers that are identified consistently over time and by different authors, and to determine whether there are trends in the number or types of barriers cited over time. The study also examines those barriers that may have been addressed by the various federal, state, nonprofit, and private-sector initiatives being implemented to address such barriers. This type of analysis assists in understanding how barriers affect the development and use of ITTs and can help focus the efforts of stakeholders on coordinated initiatives to remove or reduce barriers.

EXECUTIVE SUMMARY

From 1985 through 1998, a number of studies and reports were prepared about barriers to the development and use of innovative treatment technologies (ITT) to remediate hazardous waste sites. The U.S. Environmental Protection Agency's (EPA) Technology Innovation Office (TIO) commissioned a study to analyze the barriers presented in those reports and to develop findings about the barriers related to ITTs. For the analysis, 10 source documents were selected from more than 30 documents. The 10 documents contained information specifically dealing with barriers to ITTs. The remaining documents contained only general information or very little information directly related to development and use of ITTs. The 10 source document evaluated for the analysis identified 42 barriers.

The 42 barriers identified in the source documents were grouped into the following four general categories:

- Institutional (16 barriers)
- Regulatory and legislative (7 barriers)
- Technical (6 barriers)
- Economic and financial (13 barriers)

Three distinct author groups were identified: (1) technology advocates, (2) technology users and developers, and (3) government and nongovernment third-party evaluators.

The types of analyses performed on the barriers included: (1) identification of key barriers, defined as those barriers identified consistently by the individual authors; (2) evaluation of the barriers by author group to determine whether an individual author group emphasized a particular category of barrier over others; (3) evaluation of trends over time, including examination of any changes in the types and number of barriers faced by ITTs over three time periods: 1985 through 1990 (early); 1993 through 1995 (middle); and 1997 through 1998 (recent); and (4) identification of the barriers affecting the stages of the technology development process from bench-scale through full-scale application.

Key findings from these analyses indicate:

There was consistent agreement in identifying two barriers among all authors. Those barriers are: "Permitting processes for ITTs are inconsistent, involve numerous levels, and are time- and resource-intensive," and "Government and private-sector funding for the development and demonstration of ITTs is insufficient" Two additional barriers, "Economic incentives are lacking for those who might wish to develop or use ITTs," and "Cost and performance data for specific ITTs are limited," were consistently mentioned by four of five authors.

Almost 75 percent of the barriers have been cited consistently over time. Over half of the barriers have been consistently cited in all three time frames. Seventy-three percent of barriers were identified in at least two time periods (early, 1985 to 1990; middle, 1993 to 1995; and recent, 1997 to 1998), each barrier being identified in the most recent time period. Approximately 57 percent of the total number of barriers have been identified in at least one report in all three time periods.

There is no evidence that the total number of barriers to ITTs is changing over time. However, there is a shift in the types of barriers that ITT providers face today. Although there is no significant change in the total number of barriers cited over time, the average number of institutional barriers identified by the source documents over each time period has decreased, while the average number of economic and financial barriers identified has increased over time.

Only seven percent of the barriers (three barriers) — all economic and financial — were identified in the past three years alone and are potentially considered new. The barriers are financial incentives to delay remediation, the reluctance of firms to develop ITTs because of limited applicability, and the effects on employment security when using an ITT.

Nineteen percent of the barriers identified (eight barriers) have not been cited in the two documents published since 1995. Seven of those barriers (17 percent overall) may have been addressed or are no longer perceived as relevant by the author groups. Of the eight barriers that have not been cited since 1995, four are institutional, three are economic and financial, and one is technical. Seven of those barriers may have been addressed or no longer are perceived as relevant by virtue of the fact that they were cited at one time by one author but were not cited again in subsequent reports published by that same author.

All three author groups identified a majority of the technical barriers, indicating that there is agreement among the author groups about technical barriers to development and use of ITTs. Both the technology advocate and technology user and developer author groups identified 100 percent of the technical barriers, and the third-party evaluators author group identified 83 percent of the technical barriers. In the other three categories, there was more variation among the three author groups in the barriers identified.

Most barriers affect technologies at the full-scale stage of development. Of the 23 barriers analyzed, 19 (or 83 percent) affect the full-scale stage of development. Only nine barriers (or 39 percent) affect the bench- and pilot-scale stages. That trend is common to barriers in all categories.

Barriers most often affecting technologies in the bench- and pilot-scale stages of development were primarily institutional and economic and financial. Specifically, institutional barriers that are related to the coordination of research and development efforts affect the bench- and pilot-scale technologies. Economic and financial barriers, such as insufficient incentives for developers and lack of funding from government and private-sector venture capitalists, also affect most technologies in the bench- and pilot-scale stages.

1.0 INTRODUCTION

The Technology Innovation Office (TIO) of the U.S. Environmental Protection Agency (EPA) was established in 1990 to promote the use of innovative technologies for the assessment and cleanup of contaminated sites. As part of its mission, TIO seeks to identify and address barriers that may inhibit the development and use of innovative treatment technologies (ITT). ITTs are newly developed technologies that lack sufficient full-scale application data to ensure their routine consideration for site remediation. To further its ITT efforts, TIO sponsored this study to examine barriers to the development and use of ITTs through a review of existing documents. The objective of this analysis was to determine whether there were notable trends and to identify any initiatives undertaken to overcome the barriers from both the source documents and other resources.

In total, 10 documents were selected from among 33 original studies performed and reports prepared between 1985 and 1998 about the institutional, regulatory and legislative, technical, and economic and financial barriers to the development and commercialization of ITTs. Table 1-1 identifies the 10 documents used for this analysis. Only barriers identified in the source documents are included in this study.

Barriers identified and discussed in the source documents were grouped by the following:

- Barriers identified over three periods: 1985 through 1990 (early); 1993 through 1995 (middle); 1997 through 1998 (recent) to identify trends
- Barriers identified by authors (or report sponsors) grouped as technology advocates (the EPA and the National Environmental Technology Applications Center [NETAC]); technology developers and users (the U.S. Department of Energy [DOE] and the Hazardous Waste Action Coalition [HWAC]); and government and nongovernment third-party evaluators (the U.S. Office of Technology Assessment [OTA], the U.S. General Accounting Office [GAO], and the National Research Council [NRC])
- Barriers that affect various stages of technology development, including: bench- and pilot-scale testing and demonstration, full-scale testing and demonstration, and full-scale implementation

The barriers were examined further to conduct a more detailed trend analysis. The trend analysis shows how the barriers are distributed over time and by author to determine which barriers are persistent, addressed, or newly identified. Also, barriers that were mentioned consistently by different authors over

the study period were identified. Consistent mention of particular barriers also provides an indication of their persistence and the importance of those barriers as hindrances to the development and use of ITTs.

TABLE 1-1. DOCUMENTS USED FOR THE STUDY

No.	Title	Primary Author/ Sponsoring Entity	Types of Sites Discussed	Date Published
1	Superfund Strategy	OTA	Public and private sites	April 1985
2	Coming Clean - Superfund Problems Can Be Solved	OTA	Public and private sites	October 1989
3	Workshop on Developing an Action Agenda for the Use of Innovative Remediation Technologies by Consulting Engineers	EPA (OSWER/TIO)	Public and private sites	October 1990
4	Superfund: EPA Needs to Better Focus Cleanup Technology Development	GAO	Public and private sites	April 1993
5	NETAC, the EPA Model for Encouraging Private Investment in the DOE Environmental Market	EPA ORD/ University of Pittsburgh Applied Research Center	DOE sites	September 1993
6	Management Changes Needed to Expand Use of Innovative Cleanup Technologies (concerning DOE)	GAO	DOE sites	August 1994
7	Progress in Reducing Impediments to the Use of Innovative Remediation Technology	EPA (OSWER/TIO)	Public and private sites	June 1995
8	Forum on Eliminating Barriers to Innovative Technology Implementation	DOE and HWAC	DOE sites	June 1995
9	Innovations in Groundwater and Soil Cleanup: From Concept to Commercialization	NRC	Public and private sites	1997
10	Impediments to Deploying Technologies at DOE Sites and Their Solutions	DOE (Office of Environmental Restoration)	DOE sites	1998

Key:

DOE	U.S. Department of Energy	NRC	National Research Council
EPA	U.S. Environmental Protection Agency	OSWER	Office of Solid Waste and Emergency Response
GAO	U.S. General Accounting Office	ORD	Office of Research and Development
HWAC	Hazardous Waste Action Coalition	OTA	U.S. Office of Technology Assessment
NETAC	National Environmental Technology Technology Applications Center	TIO	Technology Innovation Office

Information about initiatives or programs that reduce or remove barriers is also presented. The initiatives were identified from the 10 source documents used for the analysis and are not considered to be comprehensive. In addition, a summary of the recently completed document, *Innovative Treatment Technology Developer's Guide to Support Services (Fourth Edition)*, is included to show the broad array of resources that have been developed to overcome barriers to ITTs.

Section 2.0 of this study identifies the barriers and presents the analysis. Section 3.0 presents initiatives and programs to reduce or remove barriers.

2.0 IDENTIFICATION AND ANALYSIS OF BARRIERS

Analysis of barriers assists in understanding how barriers affect development and use of ITTs and can help focus the efforts of stakeholders to coordinate initiatives to remove or reduce barriers. The following sections present the analyses of barriers by category, author, over time, and technology scale. The sections also discuss findings regarding trends.

2.1 ANALYSIS OF BARRIERS BY CATEGORY

A total of 42 barriers were identified in the 10 reports listed in Table 1-1 and were grouped into four categories for this study — institutional, regulatory and legislative, technical, and economic and financial. Table 2-1 lists the individual barriers within each category. The categories exemplify the range of hurdles ITT developers must overcome and the breadth of expertise they must be able to tap into to successfully commercialize a technology.

TABLE 2-1. BARRIERS TO ITTs BY CATEGORY

INSTITUTIONAL BARRIERS	
I-1	Actions undertaken by federal and state agencies to promote and regulate the development and use of ITTs are not well coordinated.
I-2	Rigid management hierarchies and government bureaucracy tend to perpetuate the use of 'status quo' technologies.
I-3	Schedules imposed by regulatory agencies often do not allow sufficient time to investigate the feasibility of using ITTs.
I-4	Regulators often adopt rigid approaches to applications of ITTs.
I-5	Level of communication that takes place among the various developers of environmental technologies is not adequate to promote the development of ITTs.
I-6	In general, a lack of communication exists between the developers of ITTs and the potential users of those ITTs.
I-7	EPA has not assessed Superfund site cleanup needs systematically and has had difficulty in matching ITTs with the requirements of specific sites.
I-8	Parties involved with cleanups have conflicting priorities.
I-9	Regulators may lack knowledge about ITTs.
I-10	Technology experts are not included in the formal decision-making process during which technologies are selected.

TABLE 2-1. BARRIERS TO ITTs BY CATEGORY (continued)

INSTITUTIONAL BARRIERS (continued)	
I-11	Government agencies rely too heavily on the support of contractors, some of whom have financial interests in conventional technologies, to assist in selecting cleanup remedies.
I-12	Appropriations and procurement processes create uncertainty about the levels and timing of funding that will be available to manage environmental problems at individual DOE sites.
I-13	Enforcement of regulations that govern cleanup activities is inconsistent and too strict.
I-14	Cycles of government appropriations are not coordinated with the cycles of research and development for ITTs, causing gaps in funding.
I-15	Regulators are reluctant to appear lenient in dealing with responsible parties.
I-16	Communities often are not supportive of the use of ITTs because they are unwilling to assume risks associated with the testing and use of ITTs in their neighborhoods.
REGULATORY AND PERMITTING BARRIERS	
R-1	Permitting processes for ITTs are inconsistent, involve numerous levels, and are time- and resource-intensive.
R-2	Permitting and manifesting requirements under the Resource Conservation and Recovery Act (RCRA) often inhibit the development of ITTs.
R-3	Users of environmental technologies are concerned about liabilities they might incur through the use of ITTs.
R-4	Entities that develop and use ITTs are concerned about liabilities they might incur through the licensing and transfer of ITTs.
R-5	Regulatory structures do not consider market forces and therefore do not provide incentives for cleanup contractors and site managers to use ITTs.
R-6	Tendency of regulations to evolve over time discourages the development and use of certain ITTs.
R-7	Obtaining authentic waste materials or site access needed to test ITTs can be difficult and costly and can expose the developer of the technology to uncertain liabilities.
TECHNICAL BARRIERS	
T-1	Cost and performance data for specific ITTs are limited.
T-2	Performance criteria and cleanup standards often are ill-defined and inconsistent.
T-3	No coordinated program for formally verifying the performance of ITTs.
T-4	Often difficult to apply ITTs at numerous sites because the characteristics of the sites differ.
T-5	Difficult to extrapolate information gained from testing an ITT at one site to other sites.
T-6	ITTs often are not considered until after the data collection phase of the remedial investigation, thereby leaving critical gaps in data required to evaluate the effectiveness of potentially applicable ITTs.

TABLE 2-1. BARRIERS TO ITTs BY CATEGORY (continued)

ECONOMIC AND FINANCIAL BARRIERS	
E-1	Economic incentives are lacking for those who might wish to develop or use ITTs.
E-2	Government and private-sector funding for the development and demonstration of ITTs is insufficient.
E-3	Information available to characterize potential markets for ITTs is limited.
E-4	Venture capitalists perceive the environmental management market as a high financial risk.
E-5	Technology selection decision-makers are concerned with protection of their agencies' budgets, so there is a reluctance to use technologies developed by other agencies.
E-6	Only a small portion of the entire life cycle of a project may be taken into consideration when the costs of remediation alternatives are compared.
E-7	Numerous financial incentives to delay remediation and few incentives to carry out remediation in a timely manner.
E-8	Market for environmental remediation technologies is fragmented.
E-9	Use of fixed-price contracts to procure remediation services discourages the use of ITTs.
E-10	Under the Federal Acquisition Regulation (FAR), contractors that test ITTs during cleanup design would be precluded from bidding on construction work at the site.
E-11	Lack of adequate mix of entrepreneurial, technical, and business management skills in small environmental technology companies to facilitate development of a market-driven technology.
E-12	Firms are reluctant to develop ITTs with limited applications.
E-13	Concern that use of an ITT may have adverse effects on employment in the agency that uses that technology.

Table 2-2 defines each category and shows the number and percentage of barriers identified in each category.

TABLE 2-2. CATEGORIES OF BARRIERS IDENTIFIED

Barrier Category	Definition	Number of Barriers	Percentage of Total
Institutional	Barriers that stem from the internal workings or functions of entities that seek to regulate, develop, or select ITTs for use in cleaning up hazardous waste sites or from the interaction of such entities	**16**	**38%**
Regulatory and Legislative	Barriers that are imposed by legislatures and government agencies through specific statutes, regulations, policies, and programs	**7**	**17%**
Technical	Barriers associated with the ITTs themselves, including lack of information about cost and performance	**6**	**14%**
Economic and Financial	Barriers that tend to reduce or eliminate financial incentives to entities that develop, use, or market ITTs	**13**	**31%**
	TOTAL	**42**	**100%**

Finding No. 1: **Institutional and economic and financial barriers represented almost 70 percent of the barriers cited. Technical barriers were the least often cited category of barriers at 14 percent.**

Table 2-2 shows, institutional and economic and financial categories account for 38 and 31 percent of the distribution, respectively. The two barrier categories represent almost 70 percent of all the barriers identified. This finding indicates that institutional and economic and financial barriers were cited approximately twice as often as either technical or regulatory and legislative barriers. Conversely, technical barriers represented only 14 percent of all barriers cited. Therefore, ITTs appear to face a greater number and variety of institutional and economic and financial barriers than either technical or regulatory and legislative barriers. However, no one category of barriers dominated or represented more than 50 percent of all the barriers cited.

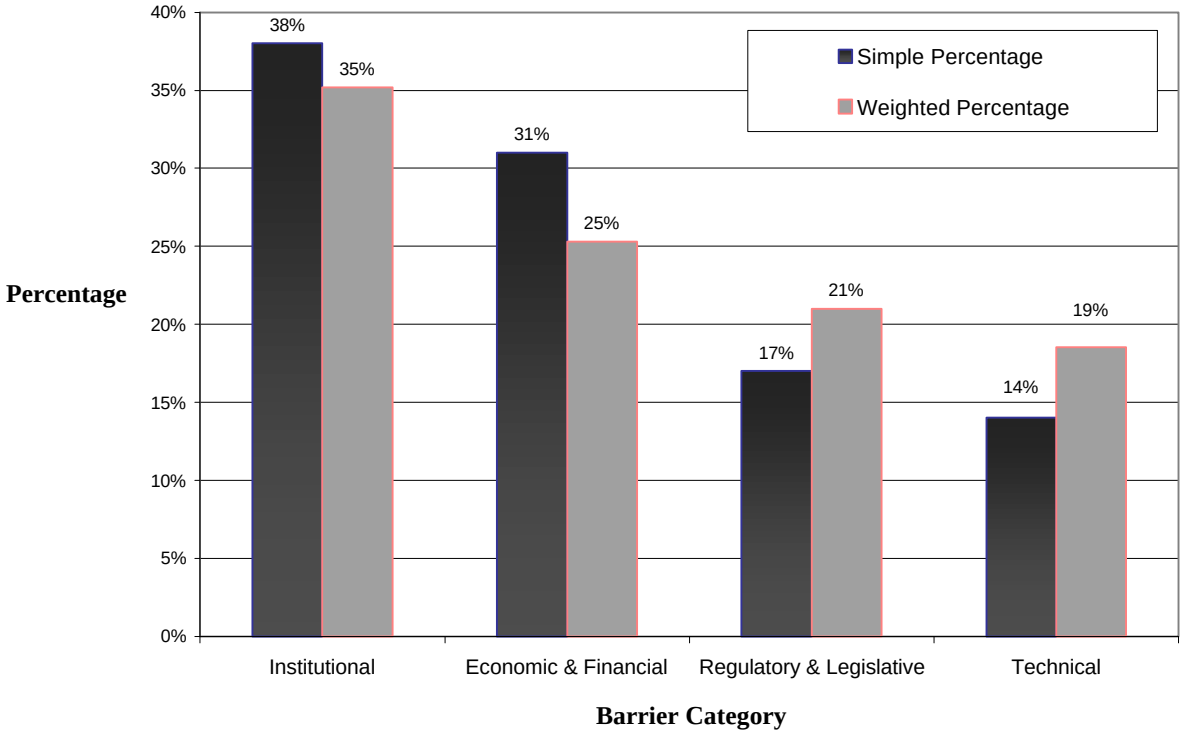
Although technical barriers were cited least frequently (14 percent), there may be more consensus among the individual authors about the specific barriers within that category versus specific barriers in other categories, such as institutional barriers. For example, 50 percent of the technical barriers (three of six) identified were cited in six or more documents (at least 60 percent of the documents). In contrast, only two institutional barriers of a total of 16 (less than 13 percent) were cited in six or more documents.

Because some barriers were cited more frequently than others, a weighted percentage for each barrier category was calculated. The weighted percentage for each barrier category can be viewed as a measure of the relative level of agreement regarding barriers within that category, compared with other categories. The weighted percentage was based on the number of times a specific barrier was cited. For example, the methodology assigns a higher weight to a barrier that was cited in 8 of 10 source documents versus a barrier that was cited in 3 of the 10 source documents.[1] Figure 2-1 compares the simple percentage with the weighted percentage. As Figure 2-1 shows, the weighted percentages for institutional and economic and financial barrier categories decreased slightly, while the percentages for technical and regulatory and legislative barrier categories increased. Although institutional and economic and financial barrier categories still represent the majority of barriers identified (approximately 60 percent), the technical and regulatory and legislative barrier categories now represent 40 percent of the barriers identified.

This weighted frequency analysis provides an indication of those barriers for which there is greater consensus. For example, if a majority of reports mention the same technical barriers, while at the same time presenting a variety of institutional barriers (some of which are identified in only one or two reports), that may indicate that the technical barriers are better understood or merit more attention than some of the institutional barriers that are identified less often. Finding No. 3 in Section 2.2 of this study presents a more thorough examination of this point.

[1] Weighted percentages for each category were calculated as follows: if two reports listed the same barrier, it was counted twice or as two "hits." The number of hits for each of the 42 barriers was counted and divided by the total number of hits (164) to derive a weighted percentage. The barriers then were grouped into the four categories, and the percentages were recalculated by category.

FIGURE 2-1. COMPARISON OF SIMPLE AND WEIGHTED PERCENTAGE OF BARRIERS BY CATEGORY



2.2 ANALYSIS OF BARRIERS BY AUTHOR

The 10 source documents reviewed for this study were written by five authors: (1) OTA, (2) GAO, (3) EPA or EPA jointly with another entity, (4) DOE or DOE jointly with another entity, and (5) NRC.

Barriers were analyzed by author to determine whether various authors recognize similar barriers or whether some barriers reflect the perspectives of specific groups. As Table 2-3 shows, the authors were grouped to represent the following three perspectives on technology development and use.

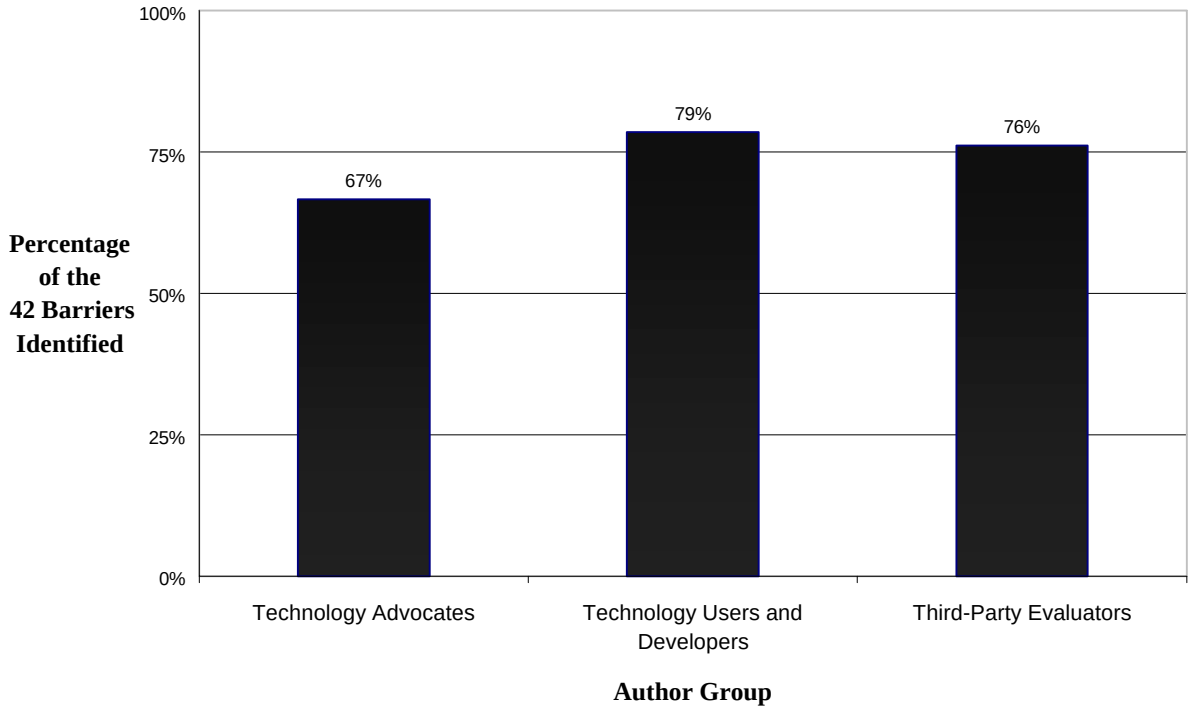
TABLE 2-3. AUTHOR GROUPS

Author	Group
EPA/NETAC	Technology advocates
EPA, DOE/ HWAC	Technology users and developers
OTA, GAO, NRC	Government and nongovernment third-party evaluators

Finding No. 2 **Each author group has a comprehensive view of barriers, identifying at least two-thirds or more of the barriers. However, the specific barriers cited within each category differ from author group to author group.**

Of the 42 barriers, the technology advocate author group identified 67 percent (28 barriers), the technology user and developers identified 79 percent (33 barriers), and the third-party evaluators identified 76 percent (32 barriers). Figure 2-2 shows the percentage of barriers identified by each author group. No author group identified 100 percent of the 42 barriers. However, different authors identified different barriers within each category. For example, the technology advocate group identified 9 of the 16 institutional barriers identified by all authors. The third-party author group identified 12 of the 16 institutional barriers. The two groups agreed only on six barriers.

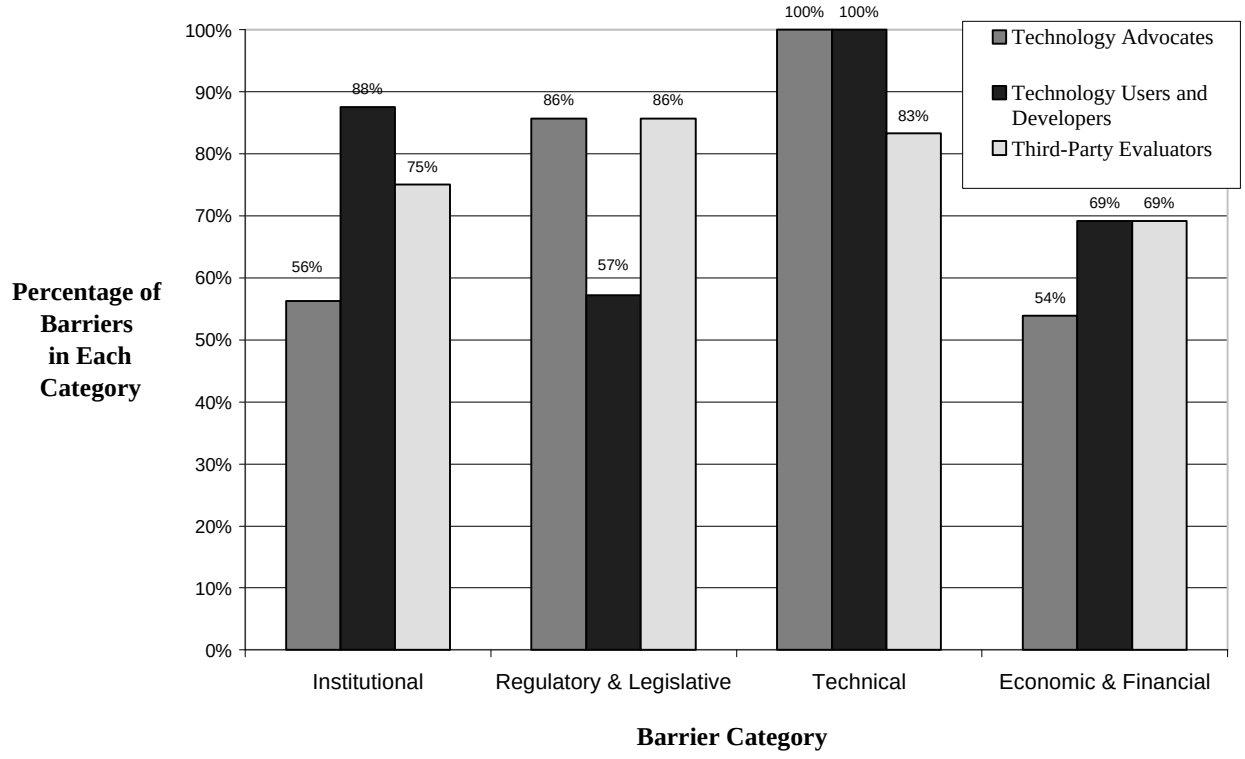
FIGURE 2-2. PERCENTAGE OF ALL 42 BARRIERS IDENTIFIED BY AUTHOR GROUP



Finding No. 3 **All three author groups identified a majority of the technical barriers, indicating that there is agreement among the author groups about the technical barriers to development and use of ITTs.**

Figure 2-3 shows the percentage of barriers identified in each barrier category by author group. Within each barrier category, all three author groups identified 50 percent or more of the barriers. Within the technical barrier category, the technology advocate and technology user and developer author groups identified 100 percent of the technical barriers, and the third-party author group identified 83 percent of the technical barriers, indicating general agreement among the three author groups regarding specific technical barriers. There was greater variation among author groups in the other three categories of barriers. For example, within the regulatory and legislative barrier category, the technology advocate and third-party author groups identified approximately 86 percent of the barriers, while the technology user and developer author group identified 57 percent. Result indicates that there is a higher degree of consensus among the various authors groups about the technical barriers and relatively less agreement about the institutional barriers.

FIGURE 2-3. PERCENTAGE OF BARRIERS IN EACH CATEGORY IDENTIFIED BY VARIOUS TYPES OF AUTHOR GROUP

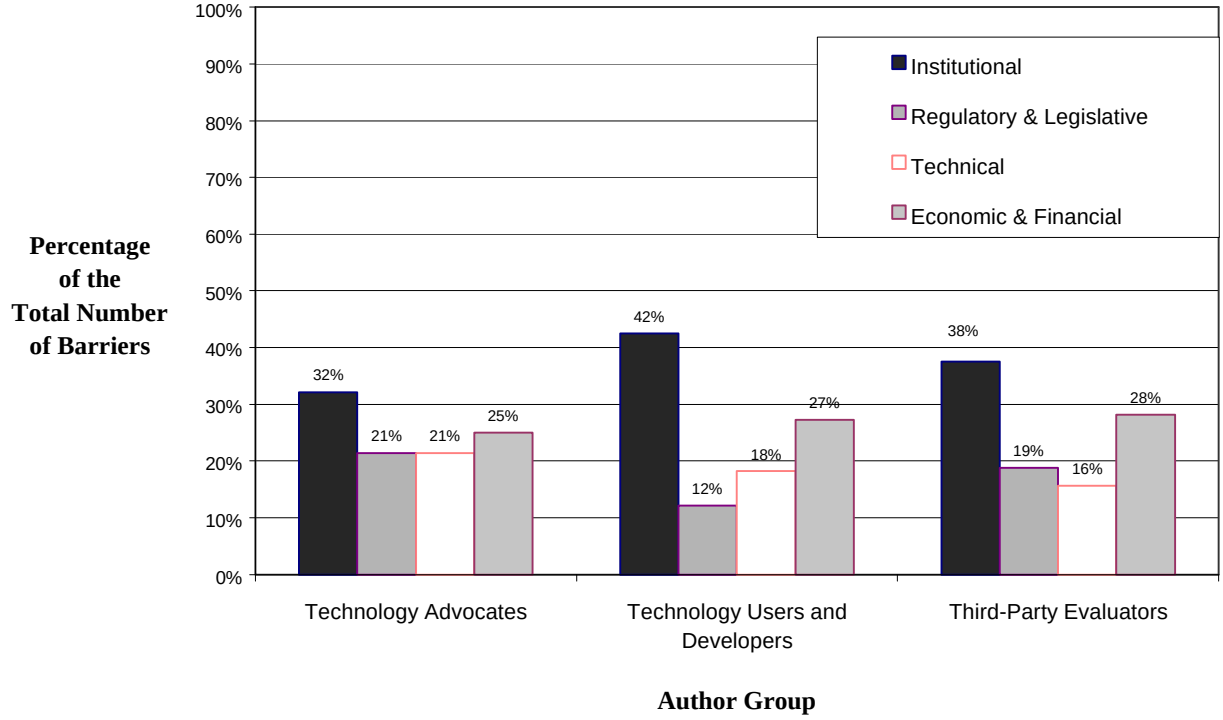


Note: The numbers above represent the percentages of the total number of barriers listed in all reports (42) that were identified by each author group in each barrier category. For example, of the 16 institutional barriers identified in all reports, technology advocates identified nine, or 56 percent.

Finding No. 4 **The most common category of barrier identified by each author group was institutional barriers, followed by economic and financial barriers. However, the authors do not concur regarding specific barriers in the barrier categories.**

Figure 2-4 shows the percentage of barriers by category identified by author group. Although there were some differences among the three author groups about specific institutional barriers (as illustrated in Figure 2-3), institutional barriers were the most commonly identified barrier category. The prevalence of institutional barriers indicates the relative importance of institutional barriers among the author groups. However, the individual institutional barriers identified by each author group varied. This finding indicates a lack of agreement among author groups about specific institutional barriers and illustrates how the perspectives of the various stakeholders differ. The differences in perspectives among stakeholders in turn may lead to problems in addressing institutional barriers.

FIGURE 2-4. CATEGORY OF BARRIER AS A PERCENTAGE OF THE TOTAL NUMBER OF BARRIERS IDENTIFIED BY AUTHOR GROUP



Note: The numbers above represent the percentages of the total number of barriers identified by specific author type in each category. For example, technology advocates identified a total of 28 barriers, nine of which were institutional. Therefore, 32 percent of the barriers identified by technology advocates were institutional. The percentages may not add to 100 percent as a result of rounding.

Finding No. 5 Only two barriers appeared in reports by all authors.

Of the 42 barriers, only two were discussed by all authors. Those barriers were the regulatory and legislative barrier, "Permitting processes for ITTs are inconsistent, involve numerous levels, and are time- and resource-intensive" and the economic and financial barrier, "Government and private-sector funding for the development and demonstration of ITTs is insufficient." The economic and financial barrier, "Economic incentives are lacking for those who might wish to develop or use ITTs" and the technical barrier, "Cost and performance data for specific ITTs are limited" were cited by four of five authors.

2.3 TREND ANALYSIS OF BARRIERS OVER TIME

The 10 reports reviewed for this study were published in 1985, 1989, 1990, 1993, 1994, 1995, 1997, and 1998. To review trends over time, the reports were grouped by publication date into three time periods: 1985 through 1990 (early), 1993 through 1995 (middle), and 1997 through 1998 (recent).

The analysis of barriers over time assumes that discussion of a barrier in a report indicates that the barrier existed at the time the report was published. For example, barriers discussed in the DOE report published in 1995 are assumed to have been relevant in the middle time period (1994 through 1995). Since none of the studies had purposely set out to identify barriers that had been eliminated or addressed, the analysis relies on the publication time periods (early, middle, recent) in which a barrier was cited to determine whether a barrier has persisted over time and whether it still is considered a barrier. A review of trends over time provides insight into how barriers may have evolved and determines whether (1) certain barriers have been mitigated to the extent that they no longer impede the development and use of ITTs, (2) certain barriers persist over time and require continued mitigation efforts, or (3) new barriers have been identified. The review of trends over time also may indicate the authors' perspectives of the importance of the barrier at a given time.

Finding No. 6 **There is no evidence that the total number of barriers to ITTs is changing over time. However, there is a shift in the types of barriers that ITTs face today.**

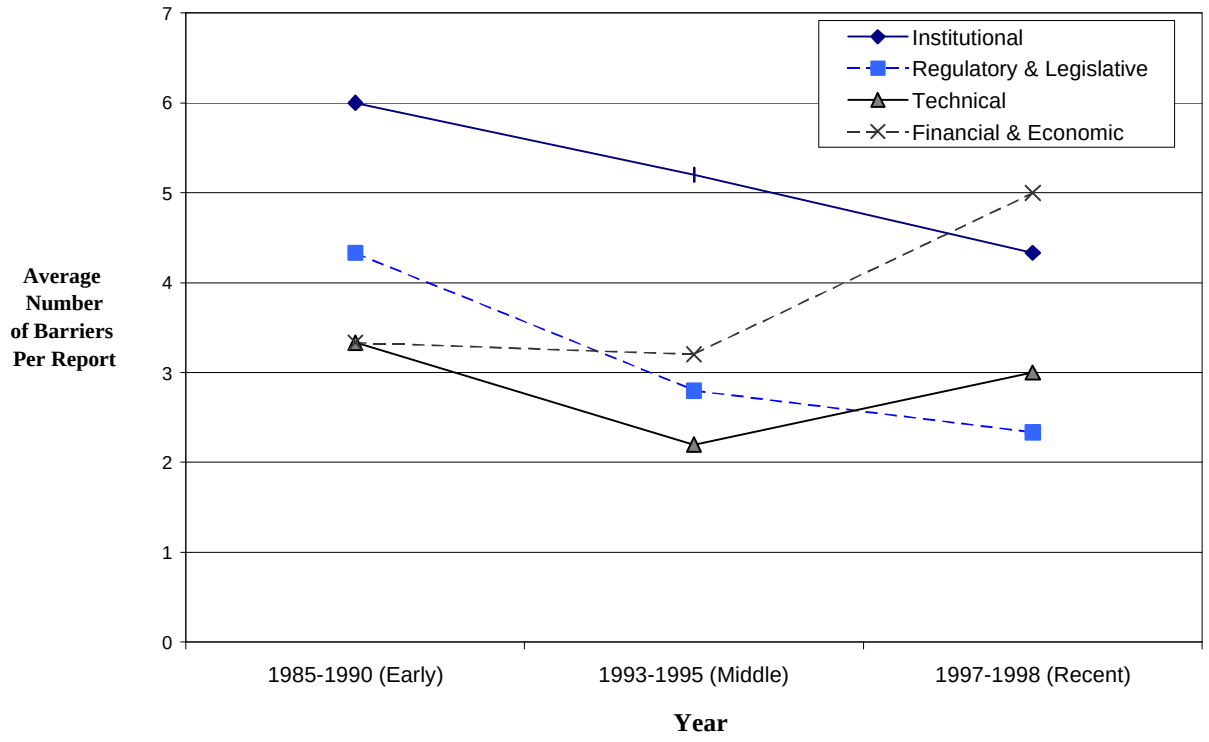
In the early years from 1985 through 1990, the number of barriers cited in two OTA reports and one EPA report were 14, 18, and 19, respectively. More recently, in 1997 and 1998, the number of barriers cited by NRC and DOE were 17 and 27, respectively. Although the most recent DOE report cited 27 barriers, a number significantly higher than that in any report published during the early years, three of those barriers cited by DOE appear to be specific to DOE only. Further, since the recent NRC report cited fewer barriers (17) than the 1990 report (19), it does not appear that the total number of barriers is decreasing or increasing. A closer examination by barrier category over time reveals some interesting results.

Because more reports were published during the middle time frame than during the early or recent time frames (five compared with three and two) a count of the total number of barriers identified in each category for each time frame would give unequal weight to the middle time frame. Therefore, the numbers of barriers in each category were averaged on a per report basis within each time frame. Figure 2-5 shows the results.

As shown in Figure 2-5, there has been a shift in the type of barriers identified from the early to the recent time periods. The average number of institutional barriers identified from the early time frame to the recent time frame has decreased steadily. However, the average number of economic and financial barriers cited over the same time frame has increased. In addition, the average number of regulatory and legislative barriers has decreased slightly, and the average number of technical barriers has increased slightly. However, those changes are not as great as those in the numbers of institutional and economic and financial barriers.

The increase in the number of economic and financial barriers may indicate a greater awareness on the part on the authors of the financial incentives and wherewithal needed to successfully commercialize ITTs. The decrease in the number of institutional barriers may indicate the success of policies, programs, and initiatives on the part of EPA, DOE, other federal agencies, and state governments to address or remove those barriers.

FIGURE 2-5. AVERAGE NUMBER OF BARRIERS IDENTIFIED BY CATEGORY PER REPORT FROM 1985 - 1998



Note: The numbers shown represent the average number of barriers on a per report basis identified in each barrier category for the time frames shown. For example, in the 1985-1990 time frame, three reports were published. The average number of institutional barriers identified in those reports was six.

Finding No. 7 **Almost 75 percent of the barriers have been cited consistently over time. Over half of the barriers have been consistently cited in all three time frames.**

Data indicate that 73 percent of the barriers (31 of 42) have persisted over time and continue to affect the development and use of ITTs. Barriers were defined as persistent if they appeared in documents from at least two time periods, including the most recent time period. Nearly three-quarters of the barriers identified in either the early or the middle time frame continue to exist today. That finding indicates that ITTs still face a significant number of barriers that have been known to exist for some time. Approximately 24 of those 31 barriers (57 percent of the total number of barriers) have been identified in at least one report in all three time periods, indicating that more than half the barriers that were identified in the early years are perceived to continue to exist in the middle and recent time frames. Although initiatives, programs, and policies developed to address those barriers have achieved some success, the persistence of some barriers over time is evidence that more efforts may be required.

Finding No. 8 **Only three potential new barriers have been identified since 1997 – all economic and financial barriers. However, at least two of those barriers may be unique to DOE sites.**

The three potential new barriers are:

- "Numerous financial incentives to delay remediation and few incentives to carry out remediation in a timely manner."
- "Concern that use of an ITT may have adverse effects on employment in the agency that uses that technology."
- "Firms are reluctant to develop ITTs with limited applications."

Only one barrier, "Numerous financial incentives to delay remediation and few incentives to carry out remediation in a timely manner," was identified in both reports from the recent time frame (1997 to 1998). Although it is possible that the barrier existed before 1997, the fact that it was identified only recently illustrates a change in focus on the part of the authors from what may be considered more obvious institutional, regulatory and legislative, or technical barriers to a more subtle in-depth examination of the incentives for the technology user or site owner to use ITTs. Such an approach represents a new perspective, by which barriers are examined not only from a "technology push" viewpoint, but also from a demand-side "pull," or market-based, viewpoint.

It is possible that two barriers, "Numerous financial incentives to delay remediation and few incentives to carry out remediation in a timely manner," and "Concern that use of an ITT may have adverse effects on employment in the agency that uses that technology," which were identified only by DOE, are unique to DOE. There is a lack of financial incentives within DOE to conduct timely cleanups because the appropriations process creates significant uncertainty about the timing and level of funding available for the management of environmental problems at DOE sites. Further, because DOE is the owner of a large number of sites, it is likely that there is concern about the use of ITTs that might reduce the number of personnel of the DOE facilities needed to install, operate, and maintain the ITTs.

The third barrier identified above, "Firms are reluctant to develop ITTs with limited applications," also may be unique to DOE. Wastes at DOE sites are unique (radioactive waste), and the market for treating such wastes may be limited to DOE (on the other hand, DOE itself might be considered a large market

because DOE's problems are extensive). In addition, the limited application barrier may be a reference to "niche" markets for ITTs that continue to lack good solutions.

Finding No. 9 **Eight barriers are not identified in the two documents published since 1995. Four of those barriers are institutional, three are economic and financial, and one is technical.**

The four institutional barriers that have not been cited since 1995 are: "Government agencies rely too heavily on the support of contractors, some of whom have financial interests in conventional technologies, to assist in selecting cleanup remedies;" "Technology experts are not included in the formal decision-making process during which technologies are selected;" "Communities often are not supportive of the use of ITTs because they are unwilling to assume risks associated with the testing and use of ITTs in their neighborhoods;" and "EPA has not assessed Superfund site cleanup needs systematically and has had difficulty matching ITTs with the requirements of specific sites."

The three economic and financial barriers that have not been cited since 1995 are: "Use of fixed-price contracts to procure remediation services discourages the use of ITTs;" "Under the Federal Acquisition Regulation (FAR), contractors that test ITTs during cleanup design would be precluded from bidding on construction work at the site;" and "Lack of adequate mix of entrepreneurial, technical, and business management skills in small environmental technology companies to facilitate development of a market-driven technology."

The one technical barrier that has not been cited since 1995 is: "ITTs often are not considered until after the data collection phase of the remedial investigation, thereby leaving critical gaps in data required to evaluate the effectiveness of potentially applicable ITTs."

Finding No. 10 **Of the eight barriers that are not identified in the two documents published since 1995, seven may have been addressed or no longer are perceived as relevant.**

Seven barriers may have been addressed or no longer are perceived as relevant as by virtue of the fact that they were cited at one time by one author but were not cited again in subsequent reports published by that same author. The eighth barrier was cited by two authors in their first reports as well as in their subsequent reports.

The four institutional barriers that do not appear after 1995 are:

- "Government agencies rely too heavily on the support of contractors, some of whom have financial interests in conventional technologies, to assist in selecting cleanup remedies."
- "Technology experts are not included in the formal decision-making process during which technologies are selected."
- "Communities often are not supportive of the use of ITTs because they are unwilling to assume risks associated with the testing and use of ITTs in their neighborhoods."
- "EPA has not assessed Superfund site cleanup needs systematically and has had difficulty in matching ITTs with the requirements of specific sites."

The first institutional barrier listed above was identified by EPA in 1990 and by DOE in 1995, but was not identified again in the more recent reports published by either author. Therefore, from the perspective of EPA and DOE, this barrier may have been addressed or is less relevant than previously thought. The second institutional barrier listed above was identified by OTA in 1989, GAO in 1994, and DOE in 1995. DOE did not identify the barrier again in its 1998 study, and neither OTA nor GAO has published a subsequent study. Therefore, from the perspective of DOE, it may have been addressed or is no longer relevant, but, from the perspective of OTA and GAO it is difficult to determine whether the issue remains a barrier. The third institutional barrier listed above was identified by EPA in 1990 and DOE in 1995, but was not identified again in more recent reports by either author. It is possible that the barrier has been addressed. Under the Superfund reforms, community stakeholders have been included in the decision-making process and extensive efforts have been made to educate citizen groups and the general public about ITTs. Communities may be more comfortable with the use of ITTs and better understand the risks associated with them. The fourth institutional barrier listed above was identified by OTA and GAO. Both authors identified it as a barrier in their first reports and their subsequent reports. Consequently, when their second reports were published, the authors still considered it a barrier. Therefore, a conclusion that it has been addressed can not be made. However, because no other author group identified it as a barrier, it may not be as relevant as previously thought, or it may be an artifact of the unique perspective of the authors. Reports published by OTA and GAO focused more closely on program evaluation than those prepared by DOE or EPA. Lack of mention by other authors also may indicate that efforts undertaken by EPA have been successful in decreasing the impact of this barrier.

The one technical barrier that was mentioned before 1995 was "ITTs often are not considered until after the data collection phase of the remedial investigation, thereby leaving critical gaps in data required to evaluate the effectiveness of potentially applicable ITTs." EPA cited that barrier in 1990, and DOE cited it in 1995, but it was not cited in the more recent reports published by either EPA or DOE or by other authors. It is likely that the barrier has been addressed or is of less concern than in the past.

Three economic and financial barriers, "Use of fixed-price contracts to procure remediation services discourages the use of ITTs;" "Under the Federal Acquisition Regulation (FAR), contractors that test ITTs during cleanup design would be precluded from bidding on construction work at the site;" and "Lack of adequate mix of entrepreneurial, technical, and business management skills in small environmental technology companies to facilitate development of a market-driven technology," were mentioned in only one report each and may not have been considered relevant or important by other authors. The fact that they were not mentioned again in later reports by the same authors, in conjunction with the fact that no other authors mentioned them, may indicate that they were less important or less relevant than other barriers.

Finding No. 11 **Five barriers related to government business operations and developers' market position were identified by one individual author at a single point in time after 1990 and were not identified in any other source document.**

The five barriers, all economic and financial, that were mentioned by only one author, at one point in time, and were not identified in any other documents included in this study are:

- "Use of fixed-price contracts to procure remediation services discourages the use of ITTs," mentioned in 1990 by EPA TIO
- "Under the Federal Acquisition Regulation (FAR), contractors that test ITTs during cleanup design would be precluded from bidding on construction work at the site," mentioned in 1993 by GAO
- "Lack of adequate mix of entrepreneurial, technical, and business management skills in small environmental technology companies to facilitate development of a market-driven technology," mentioned in 1993 by EPA and NETAC
- "Firms are reluctant to develop ITTs with limited applications," mentioned in 1998 by DOE
- "Concern that use of an ITT may have adverse effects on employment in the agency that uses that technology," mentioned in 1998 by DOE

The fact that the first three barriers (above) were not identified in subsequent reports by the same authors indicates that they may have been addressed or they may no longer be considered relevant. The last two barriers were identified only in the most recent DOE report and therefore may be considered new or unique to DOE sites. See Finding No. 8 in Section 2.3 of this report for further discussion of those two barriers.

2.4 ANALYSIS OF BARRIERS BY STAGE OF ITT DEVELOPMENT

An analysis was performed to determine the degree to which barriers identified inhibit the development or use of ITTs at various stages of development. The analysis was based on the information obtained from the source documents, as well as the professional judgment of the analysts in determining the relative effect of a given barrier on the various stages of development, as defined in Table 2-4.

TABLE 2-4. STAGES OF ITT DEVELOPMENT

Stage of Development	Definition
Bench-scale	The bench-scale is that stage of development at which an ITT has been shown to be feasible using laboratory equipment but for which insufficient data are available to attempt to test or implement the technology at full-scale.
Pilot-scale	The pilot-scale is that stage of development at which sufficient data have been obtained about an ITT to demonstrate that the technology may be feasible at full-scale and for which sufficient data are available to establish the design and operating conditions needed to test the ITT at full-scale.
Full-scale testing and demonstration	The full-scale testing stage is that stage of development at which an ITT is tested outside the laboratory and in a manner that demonstrates the technology's potential usefulness in the implementation of large-scale cleanups at hazardous waste sites.
Full-scale implementation	The full-scale implementation stage is that stage of development at which an ITT has been tested and proven feasible for use at hazardous waste sites, but still lacks cost and performance data adequate to facilitate the use of the technology on a large-scale, commercial basis.

Bench- and pilot-scale stages of development are grouped together for this analysis because they constitute the 'formative' period of the process of developing ITTs. Further, to eliminate any bias resulting from 'outlier' barriers and to help focus the analysis, only those barriers mentioned in four or more of the 10 source documents were included in the analysis. The resulting data set includes only 23 of the 42 barriers. Findings from this analysis are presented below.

Finding No. 12 **Six barriers related to the lack of coordination and consistency among various programs and procedures, limited availability of market information, and inadequate economic incentives to develop and use ITTs affect all stages of development.**

The six barriers that affect all stages of development are related to the lack of coordination and consistency among various programs and procedures, limited availability of market information, and inadequate economic incentives to develop and use ITTs. The six barriers — two institutional, one regulatory and legislative, one technical, and two economic and financial are:

- "Actions undertaken by federal and state agencies to promote and regulate the development and use of ITTs are not well coordinated"
- "The level of communication that takes place among the various developers of environmental technologies is not adequate to promote the development of ITTs"
- "Permitting processes for ITTs are inconsistent, involve numerous levels, and are time- and resource-intensive"
- "Performance criteria and cleanup standards often are ill-defined and inconsistent"
- "Economic incentives are lacking for those who might wish to develop or use ITTs"
- "Information available to characterize potential markets for ITTs is limited"

Finding No. 13 **Nearly 80 percent of barriers mentioned in four or more documents primarily affect ITTs at the full-scale testing and full-scale implementation stages. Barriers that affect the development and use of ITTs at the bench- and pilot-scale stages were primarily institutional and economic and financial.**

Of the 23 barriers analyzed, 19 (or 83 percent) affect the full-scale implementation stage, and 18 (or 78 percent) affect the full-scale testing stage. Only nine barriers (or 39 percent) affect the bench- and pilot-scale stages of development. That trend is common to barriers in all categories.

Bench- and pilot-scale technologies appear to be affected primarily by institutional and economic and financial barriers. Institutional barriers arise from a lack of communication and coordination among the parties involved in developing and using ITTs. Economic considerations, such as financial incentives for developers and information about future market opportunities for their technologies also play a significant role in bench- and pilot-scale development and testing. The barriers at the bench- and pilot-

scale stages are crucial because such barriers can affect the potential number of ITTs available at the full-scale stage.

This finding is consistent with the prevailing belief that technology developers encounter more barriers at the full-scale testing and implementation stages because of the numerous parties involved and the complexities of full-scale cleanup.

2.5 AUTHORS' AGREEMENT ON SPECIFIC BARRIERS BY CATEGORY

For this analysis, agreement by the authors on a specific barrier was determined to exist if the barrier was consistently mentioned. A barrier was defined as consistently mentioned if it was cited in more than six documents over the three periods (early, 1985 to 1990; middle, 1990 to 1995; and recent, 1997 to 1998), and by at least one member of each group of authors. This section presents the most consistently mentioned barriers in each of the four categories.

2.5.1 Institutional Barriers

Finding No. 14 **Of the 16 institutional barriers, two that are related to agency coordination and government hierarchies were mentioned consistently in the 10 source documents.**

Of the 16 institutional barriers, two were mentioned consistently:

- "Actions undertaken by federal and state agencies to promote and regulate the development and use of ITTs are not well coordinated"
- "Rigid management hierarchies and government bureaucracy tend to perpetuate the use of 'status quo' technologies"

2.5.2 Regulatory and Legislative Barriers

Finding No. 15 **Of the seven regulatory and legislative barriers, three barriers that are related to the permitting process, manifesting requirements, and liabilities of users, were mentioned consistently.**

The three consistently mentioned barriers in this category are:

- "Permitting processes for ITTs are inconsistent, involve numerous levels, and are time- and resource-intensive"
- "Permitting and manifesting requirements under the Resource Conservation and Recovery Act (RCRA) often inhibit the development of ITTs"
- "Users of environmental technologies are concerned about liabilities they might incur through the use of ITTs"

2.5.3 Technical Barriers

Finding No. 16 **Of the six technical barriers, three that are related to limited cost and performance data, inconsistent cleanup standards, and lack of formal, coordinated verification programs were mentioned consistently.**

Of the six technical barriers, three were consistently mentioned are:

- "Cost and performance data for specific ITTs are limited"
- "Performance criteria and cleanup standards often are ill-defined and inconsistent"
- "No coordinated program for formally verifying the performance of ITTs"

2.5.4 Economic and Financial Barriers

Finding No. 17 **Of the 13 economic and financial barriers, three barriers that are related to lack of economic incentives, insufficient funding for development and demonstration, and limited market information, were mentioned consistently.**

Of the 13 economic and financial barriers, the three mentioned consistently are:

- "Economic incentives are lacking for those who might wish to develop or use ITTs"
- "Government and private-sector funding for the development and demonstration of ITTs is insufficient"
- "Information available to characterize potential markets for ITTs is limited"

3.0 INITIATIVES CITED IN SOURCE DOCUMENT'S TO MITIGATE BARRIERS

Information presented in the 10 source documents indicates that a number of initiatives have been undertaken to help mitigate the effects of barriers. The list of initiatives presented below is not comprehensive, but includes only efforts the authors identified in their source documents.

3.1 INITIATIVES TO MITIGATE INSTITUTIONAL BARRIERS

Initiatives discussed in the 10 documents include those that focus on facilitating communication, sharing information, and coordinating in and among government agencies, technology developers, and users.

- The Federal Remediation Technologies Roundtable (FRTR) was established in 1991 as an interagency committee. The purpose of the FRTR is to facilitate the exchange of information and provide a forum for joint action in the area of development and demonstration of ITTs for the remediation of hazardous waste. Member agencies include the U.S. Department of Defense (DoD), the U.S. Army, the U.S. Army Corps of Engineers (USACE), the U.S. Navy, the U.S. Air Force, DOE, the U.S. Department of the Interior (DoI), and EPA.

The FRTR addresses the consistently mentioned barrier "Actions undertaken by federal and state agencies to promote and regulate the development and use of ITTs are not well coordinated."

- The Remediation Technology Development Forum (RTDF) was organized by EPA's TIO and ORD in 1992 to enhance cooperation and information-sharing among EPA, DOE, DoD, state governments, private-sector technology companies, and public interest groups. The RTDF encourage collaboration among those entities in defining, setting priorities among, and funding innovative concepts for cleanup technologies. The RTDF seeks to combine the financial and intellectual resources of members of the forum to promote coordination of research and reduce duplication in research and development efforts.

The RTDF addresses two barriers "In general, a lack of communication exists between the developers of ITTs and the potential users of those ITTs" and "Parties involved with cleanups have conflicting priorities."

- The Office of Technology Development (OTD) program was restructured in January 1994 by DOE to address difficulties in coordination among DOE offices. The technology development program combined activities of the DOE Office of Waste Management and the Office of Environmental Restoration for increased coordination.

The DOE initiative addresses the consistently mentioned barrier, "Rigid management hierarchies and government bureaucracy tend to perpetuate the use of 'status quo' technologies."

- The Six-State Partnership for Environmental Technology is developing a process for facilitating the reciprocal evaluation, acceptance, and approval of environmental technologies. Development of the process began in 1995 as a cooperative effort of EPA and the states of California, Illinois, Massachusetts, New Jersey, New York, and Pennsylvania to promote verification of the performance of ITTs. Further, in an attempt to help interested parties overcome certain bureaucratic burdens that hinder the development and use of ITTs, DOE initiated the Environmental Restoration and Waste Management Program. That program supports measures taken to comply with federal, state, and local requirements governing cleanups at DOE sites.

These initiatives address two consistently mentioned barriers, "Actions undertaken by federal and state agencies to promote and regulate the development and use of ITTs are not well coordinated" and "Rigid management hierarchies and government bureaucracy tend to perpetuate the use of 'status quo' technologies." The Six-State Partnership and the DOE initiative also address two other barriers, "Regulators often adopt rigid approaches to applications of ITTs" and "Enforcement of regulations that govern cleanup activities is inconsistent and too strict."

3.2 INITIATIVES TO MITIGATE REGULATORY AND LEGISLATIVE BARRIERS

Information presented in the 10 source documents indicates that a number of initiatives have been undertaken to help overcome regulatory and legislative barriers. A number of initiatives have been undertaken within EPA, DOE, and several states to reduce the regulatory burdens that affect the development and use of ITTs. Examples include:

- Since 1992, EPA has been granting states the authority to implement the Treatability Exclusion Rule; the Research, Development, and Demonstration Permit Program; and the Subpart X Permit Program. Those authorities are granted to states to simplify the approval process for technologies and to allow more flexibility in testing and demonstrating ITTs.

The initiative addresses the consistently mentioned barriers, "Permitting processes for ITTs are inconsistent, involve numerous levels, and are time-and resource-intensive" and "Permitting and manifesting requirements under the Resource Conservation and Recovery Act (RCRA) often inhibit the development of ITTs."

- In 1993, EPA issued the Superfund Response Action Contractor Indemnification Rule (58 Federal Register [F.R.] 5972). The rule was designed to help contractors that use ITTs obtain lower deductibles under their liability insurance.

The initiative addresses the consistently mentioned barriers, "Users of environmental technologies are concerned about liabilities they might incur through the use of ITTs," and "Entities that develop and use ITTs are concerned about liabilities they might incur through the licensing and transfer of ITTs."

- In 1994, EPA revised the Treatability Study Sample Exclusion Rule (59 F.R. 8362). The rule was revised to exclude contaminated media used in testing ITTs from certain permitting and manifesting requirements under RCRA.

The initiative addresses the barrier, "Obtaining authentic waste materials or site access needed to test ITTs can be difficult and costly and can expose the developer of the technology to uncertain liabilities."

3.3 INITIATIVES TO MITIGATE TECHNICAL BARRIERS

Information presented in the source documents indicates that a number of initiatives have been undertaken to help mitigate the effects of the technical barriers identified in this report. Examples of those initiatives, which focus on the development and verification of cost and performance data, are described below:

- EPA's Superfund Innovative Technology Evaluation (SITE) program was established in 1986 to help accelerate the development of ITTs. To address the lack of cost and performance data, field demonstrations of certain ITTs are conducted under the program. The program then publishes data on the cost, performance, reliability, and applicability of those ITTs. In addition to remediation technologies, new site characterization technologies also are tested under the SITE program.

The program addresses the consistently mentioned barriers, "Cost and performance data for specific ITTs are limited" and "No coordinated program for formally verifying the performance of ITTs."

- DoD, in partnership with EPA, launched the DoD National Environmental Technology Demonstration Program (NETDP) in 1993. The program conducts pilot-scale demonstrations of technologies at a large number of sites throughout the nation. The program focuses on the testing and demonstration of technologies that are used to remediate media contaminated with fuel hydrocarbons, heavy metals, and solvents and on those technologies that integrate biological and physiochemical remediation processes.

The program addresses the consistently mentioned barriers, "cost and performance data for specific ITTs are limited" and "No coordinated program for formally verifying the performance of ITTs."

- The FRTR, which was established in 1991 as an interagency committee to exchange information and to provide a forum for joint action on the development and demonstration of ITTs, produced a guide that specifies how cost and performance data should be documented at federal sites, along with more than 150 case studies of completed projects.

The initiative addresses the consistently mentioned barriers, "Cost and performance data for specific ITTs are limited" and "Often difficult to apply ITTs at numerous sites because the characteristics of the sites differ."

- TIO developed the EPA REmediation And CHaracterization Innovative Technologies (EPA REACH IT) system in 1998 to provide accessible information on innovative treatment and characterization technologies to environmental professionals through the Internet. The system contains searchable data on approximately 1,300 innovative remediation and 150 characterization technologies and 750 service providers that offer those technologies. The system provides information submitted by technology firms about the performance and capabilities of specific ITTs and information submitted by EPA, DoD, DOE, and state project managers about sites at which ITTs are deployed.

The initiative was designed to address the consistently mentioned barriers, "Cost and performance data for specific ITTs are limited" and "Difficult to extrapolate information gained from testing an ITT at one site to other sites."

3.4 INITIATIVES TO MITIGATE ECONOMIC AND FINANCIAL BARRIERS

The source documents present a number of recommendations to help mitigate the effects of certain economic and financial barriers. The source documents did not list initiatives or programs that had been established to address economic and financial barriers. The recommendations focus primarily on (1) reducing uncertainties in the ITT market that tend to make the market less attractive than other markets to venture capitalists and (2) providing more financial incentives to those entities that might wish to invest in the development of ITTs. The recommendations include:

- DOE should guarantee payment to technology firms on specified schedules. Implementing the recommendation could help improve the reliability of streams of revenues for those technology firms that market ITTs to DOE.

The recommendation addresses the consistently mentioned barrier, "Economic incentives are lacking for those who might wish to develop or use ITTs."

- The government should require accounting procedures that would require publicly held firms to report on their balance sheets with greater accuracy the full costs of environmental liabilities. Implementing the recommendation also could encourage publicly held firms to conduct cleanups in a timely manner.

The recommendation addresses the barrier, "Only a small portion of the entire life cycle of a project may be taken into consideration when the costs of remediation alternatives are compared."

4.0 INITIATIVES CITED IN EPA DEVELOPER'S GUIDE TO MITIGATE BARRIERS

In addition to initiatives found in the 10 source documents used for this study, many other initiatives to reduce or remove barriers to ITT commercialization have begun. Table 4-1 summarizes the initiatives described in detail in *The Innovative Treatment Technology Developer's Guide to Support Services, Fourth Edition*, which is available online at <*http://clu-in.org*>. The table cross references the initiative with a barrier category or categories and identifies the commercialization stage of technology development to which the initiative is directed. Table 4-2 cross referenced each barrier category and specific barrier against the programs or initiatives that might address that barrier. It also identifies the source document for each barrier. In Table 4-2, the barriers listed above the double lines are consistently mentioned barriers.

Table 4-1. Initiatives from EPA's Developer's Guide Cross Referenced with Barrier Categories

INITIATIVES	BARRIERS TO DEVELOPMENT AND USE				COMMERCIALIZATION STAGES FROM EPA'S DEVELOPER'S GUIDE																		
					Proof of Concept				Demonstrating Your Technology								Getting the Work					Getting Paid	
					Financial and Market Research Assistance				Technology Testing, Demonstration, Evaluation and Transfer Assistance								Business Development Assistance					Administrative and Financial Management Assistance	
	Institutional	Regulatory and Legislative	Technical	Economic and Financial	Grants and Loans	Investors and Venture Capital	Business Planning	Market Research and Analysis	Full-Scale and Field Demonstrations	Bench-Scale and Pilot Demonstrations	Laboratory Treatability Study Facilities	Research and Development Centers	Independent Testing and Certification Programs	Technical Assistance	Information Dissemination Assistance	Permitting and Regulatory Assistance	Networking and Business Facilitation	Direct Sales and Marketing	Commercialization Assistance	Export Assistance	Procurement and Proposal Development Assistance	Business Management and Administration	Financial Management
1 Advanced Technology Program, U.S. Department of Commerce *Web: www.atp.nist.gov*			●	●	◆									◆									
2 Air Force Center for Environmental Excellence (AFCEE) Innovative Technology Program *Web: www.afcee.brooks.af.mil/er/orgert.htm*	●		●	●					◆	◆					◆								
3 Air Force Center for Environmental Excellence (AFCEE) Business Opportunities *Web: www.afcee.brooks.af.mil/business.htm*				●													◆	◆					
4 Air Force Small Business Environmental Database (AFSBED) *Web: www.brooks-smallbusiness.com*	●			●				◆							◆		◆	◆					
5 America's Business Funding Directory *Web: www.businessfunding.net*				●	◆	◆	◆															◆	◆
6 Angel Capital Electronic Network (ACE-Net) *Web: www.ace-net.sr.unh.edu/home.html*				●		◆	◆																
7 Argonne National Laboratory, Argonne, IL *E-mail: gborland@anl.gov*			●						◆	◆	◆												
8 Business Assistance Center, U.S. EPA Region 3 *Web: www.epa.gov/region3/sbac*	●	●		●												◆		◆	◆	◆			
9 Business Communications Center, U.S. Department of Energy *Web: www.pr.doe.gov/prbus.html*	●			●			◆											◆			◆		

Table 4-1. Initiatives from EPA's Developer's Guide Cross Referenced with Barrier Categories

INITIATIVES	BARRIERS TO DEVELOPMENT AND USE				COMMERCIALIZATION STAGES FROM EPA'S DEVELOPER'S GUIDE																		
					Proof of Concept				Demonstrating Your Technology								Getting the Work					Getting Paid	
					Financial and Market Research Assistance				Technology Testing, Demonstration, Evaluation and Transfer Assistance								Business Development Assistance					Administrative and Financial Management Assistance	
	Institutional	Regulatory and Legislative	Technical	Economic and Financial	Grants and Loans	Investors and Venture Capital	Business Planning	Market Research and Analysis	Full-Scale and Field Demonstrations	Bench-Scale and Pilot Demonstrations	Laboratory Treatability Study Facilities	Research and Development Centers	Independent Testing and Certification Programs	Technical Assistance	Information Dissemination Assistance	Permitting and Regulatory Assistance	Networking and Business Facilitation	Direct Sales and Marketing	Commercialization Assistance	Export Assistance	Procurement and Proposal Development Assistance	Business Management and Administration	Financial Management
10 California Environmental Technology Certification Program, California EPA *Web: www.calepa.ca.gov/programs/envirotech/encertpg.htm*			●										◆										
11 California Environmental Technology Export Program *E-mail: togburn@commerce.ca.gov*	●			●				◆							◆					◆			
12 California Remedial Technology Assessment Program *Phone: (916) 322-3294*	●	●	●	●	◆		◆		◆							◆							
13 Capital Network *Web: www.thecapitalnetwork.com/overview.html*				●		◆																	
14 Carnegie Mellon University, Pittsburgh, PA *E-mail: minkley@andrew.cmu.edu*	●		●								◆	◆			◆								
15 Center for Environmental Industry and Technology *E-mail: kilbride.carol@epa.gov*	●	●	●	●		◆			◆	◆			◆			◆		◆		◆			
16 Commerce Business Daily (CBD), U.S. Department of Commerce *Web: http://cbdnet.access.gpo.gov/*				●														◆			◆		
17 DataMerge Venture Capital Database *Web: www.datamerge.com/indexcentral.html*				●	◆	◆																	
18 Doing Business with EPA, EPA Office of Acquisition Management *Web: www.epa.gov/oam*				●														◆			◆		
19 Envirobiz Market Research *Web: www.envirobiz.com/buttons/remhome.htm*				●				◆										◆					

Table 4-1. Initiatives from EPA's Developer's Guide Cross Referenced with Barrier Categories

INITIATIVES	BARRIERS TO DEVELOPMENT AND USE				COMMERCIALIZATION STAGES FROM EPA'S DEVELOPER'S GUIDE																		
					Proof of Concept				Demonstrating Your Technology								Getting the Work					Getting Paid	
					Financial and Market Research Assistance				Technology Testing, Demonstration, Evaluation and Transfer Assistance								Business Development Assistance					Administrative and Financial Management Assistance	
	Institutional	Regulatory and Legislative	Technical	Economic and Financial	Grants and Loans	Investors and Venture Capital	Business Planning	Market Research and Analysis	Full-Scale and Field Demonstrations	Bench-Scale and Pilot Demonstrations	Laboratory Treatability Study Facilities	Research and Development Centers	Independent Testing and Certification Programs	Technical Assistance	Information Dissemination Assistance	Permitting and Regulatory Assistance	Networking and Business Facilitation	Direct Sales and Marketing	Commercialization Assistance	Export Assistance	Procurement and Proposal Development Assistance	Business Management and Administration	Financial Management
20 Environment in Asia, Asia Environmental Trading, Ltd. *Web: www.asianenviro.com*	●			●				◆								◆	◆		◆	◆			
21 Environmental Business Council Resources *Web: http://clu-in.org*	●		●	●											◆		◆		◆			◆	
22 Environmental Capital Network *Web: http://bizserve.com/Environmental.Capital.Network/*				●		◆	◆																
23 Environmental Export Council *Web: www.eec.org*	●			●														◆		◆			
24 Environmental Security Technology Certification Program (ESTCP), U.S. Department of Defense *Web: www.estcp.org*	●		●						◆				◆		◆								
25 Enviro-Tech Center *Web: www.envirotechcenter.org*	●		●	●					◆		◆	◆							◆			◆	
26 Environmental Technology Networks, U.S. Agency for International Development Global Technology Network *Web: www.usgtn.org/pages/energy.html*	●			●				◆									◆			◆			
27 Environmental Technology Verification (ETV) Program, Site Characterization and Monitoring Technologies Pilot *Web: www.epa.gov/etv/02/02_main.htm*	●		●						◆				◆		◆								
28 EPA Hazardous Waste Clean-up Information (CLU-IN) Web Site *Web: http://clu-in.org*	●	●	●	●			◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆				

Table 4-1. Initiatives from EPA's Developer's Guide Cross Referenced with Barrier Categories

INITIATIVES	BARRIERS TO DEVELOPMENT AND USE				COMMERCIALIZATION STAGES FROM EPA'S DEVELOPER'S GUIDE																		
					Proof of Concept				Demonstrating Your Technology								Getting the Work					Getting Paid	
					Financial and Market Research Assistance				Technology Testing, Demonstration, Evaluation and Transfer Assistance								Business Development Assistance					Administrative and Financial Management Assistance	
	Institutional	Regulatory and Legislative	Technical	Economic and Financial	Grants and Loans	Investors and Venture Capital	Business Planning	Market Research and Analysis	Full-Scale and Field Demonstrations	Bench-Scale and Pilot Demonstrations	Laboratory Treatability Study Facilities	Research and Development Centers	Independent Testing and Certification Programs	Technical Assistance	Information Dissemination Assistance	Permitting and Regulatory Assistance	Networking and Business Facilitation	Direct Sales and Marketing	Commercialization Assistance	Export Assistance	Procurement and Proposal Development Assistance	Business Management and Administration	Financial Management
29 EPA REmediation And CHaracterization Innovative Technologies (EPA REACH IT) *Web: www.epareachit.org*	●		●	●											◆				◆				
30 EPA-WASTE Listserve: All Hazardous and Solid Waste and Comprehensive Environmental Response, Compensation, and Liability Act Federal Registers *Web: www.epa.gov/epaoswer/hotline/listsrv.htm*		●														◆							
31 eWeb *Web: www.slu-edu/eweb*				●		◆	◆															◆	
32 Export-Import Bank of the United States *Web: www.exim.gov*				●	◆															◆			
33 Federal Remediation Technologies Roundtable (FRTR) *Web: www.FRTR.gov*			●	●											◆								
34 Federal Technology Transfer Act Program, U.S. EPA *Web: www.nalusda.gov/ttic/guide.htm* and *www.etc2.org*	●		●	●				◆				◆		◆	◆		◆		◆				
35 Foresight Science and Technology, Inc. *Web: www.seeport.com*	●			●	◆		◆	◆									◆	◆	◆				
36 Globaltechs *Web: www.globaltechs.com*	●		●	●				◆							◆								
37 Global Network of Environment & Technology (GNET) Contracting Opportunities *Web: www.gnet.org/filecomponent/2501.html*	●		●	●				◆							◆			◆	◆				

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38 Great Lakes and Mid-Atlantic Hazardous Substances Research Center *Web: www.engin.umich.edu/dept/cee/research/HSRC/index.html*	●		●									◆		◆	◆								
39 Great Plains-Rocky Mountain Hazardous Substance Research Center *Web: www.ensg.ksu.edu/HSRC*	●		●									◆		◆	◆								
40 Ground Water Remediation Field Laboratory, Dover Air Force Base, DE *Phone: (302) 678-8284*	●		●						◆		◆												
41 Ground-Water Remediation Technologies Analysis Center (GWRTAC) *Web: www.gwrtac.org*	●		●	●											◆			◆					
42 Gulf Coast Hazardous Substance Research Center *E-mail: curlessjh@hal.lamar.edu*	●		●									◆		◆	◆								
43 Hazen Research, Inc. *Web: www.Hazenusa.com*	●		●							◆	◆	◆											
44 Idaho National Engineering Laboratory, Idaho Falls, ID *E-mail: hainke@inel.gov*	●		●						◆		◆												
45 IIT Research Institute (IITRI), Chicago, IL *Web: www.iitri.org*			●	●			◆						◆						◆				
46 Illinois Pollution Prevention and Technical Assistance Program *Web: www.wmrc.uiuc.edu*	●		●	●									◆		◆		◆		◆				

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47 Illinois Waste Management and Research Center *E-mail: Gvvelde@wmrc.hazard.uiuc.edu*	●		●	●	◆					◆	◆	◆		◆									
48 Innovative Treatment Remediation Demonstration (ITRD) Program *E-mail: mmhight@sandia.gov*	●	●	●						◆			◆	◆		◆	◆							
49 International Buyer Program, U.S. Department of Commerce *Web: www.ita.doc.gov/uscs/uscsibp.html*	●		●	●													◆	◆	◆	◆			
50 International Trade Administration (ITA), U.S. Department of Commerce *Web: www.ita.doc.gov*				●				◆												◆			
51 International Venture Capital Institute *Phone: (203) 323-3143*	●		●	●		◆									◆		◆						
52 Interstate Technology and Regulatory Cooperation (ITRC) Working Group *Web: www.itrcweb.org*	●	●	●												◆	◆							
53 Market Access and Compliance (MAC) On-Line, U.S. Department of Commerce *Web: www.mac.doc.gov*				●				◆												◆			
54 MBI International's Center for Biotechnology Entrepreneurship *E-mail: windish@mbi.org*	●		●	●		◆	◆	◆	◆	◆	◆	◆	◆	◆				◆	◆				
55 McClellan Air Force Base, Sacramento, CA *E-mail: lu.jim@mcclellan.af.mil*	●		●						◆														

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56 Michael D. Dingman Center for Entrepreneurship, University of Maryland *Web: www.bmgt.umd.edu/Dingman*	●		●	●		◆	◆	◆									◆	◆					
57 National Business Incubation Association *Web: www.nbia.org*			●	●		◆	◆					◆							◆	◆	◆	◆	
58 National Center for Ground Water Research *E-mail: wardch@rice.edu*	●		●									◆			◆								
59 National Center for Integrated Bioremediation Research and Development *Web: http://ncibrd.engin.umich.edu*	●		●						◆	◆	◆												
60 National Defense Center for Environmental Excellence *Web: www.ndcee.ctc.com/index.htm*	●		●	●						◆	◆		◆	◆	◆		◆						
61 National Environmental Technology Demonstration Program, U.S. Department of Defense	●		●							◆			◆		◆								
62 National Environmental Technology Test Sites (NETTS) Program *Web: www.hgl.com/serdp/netts/default.html*	●	●	●	●					◆							◆			◆				
63 National Environmental Waste Technology Testing and Evaluation Center *E-mail: maryanhb@mse-ta.com*	●		●						◆	◆	◆	◆	◆										
64 National Technology Transfer Center (NTTC) *Web: www.nttc.edu*	●		●	●								◆		◆	◆				◆				
65 Naval Construction Battalion Center, Port Hueneme, CA *E-mail: elory@nsesc.navy.mil*	●		●						◆														

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66 Naval Environmental Leadership Program (NELP) *Web: www.nelp.navy.mil*	●		●						◆						◆								
67 New Jersey Commission on Science and Technology *E-mail: scitech@scitech.state.nj.us*			●	●	◆									◆									
68 New Jersey Institute of Technology - Otto H. York Center for Environmental Engineering and Science *Phone: (973) 802-1946*	●		●									◆		◆	◆								
69 New Mexico State University *E-mail: werc@nmsu.edu*	●		●						◆	◆		◆											
70 Northeast Hazardous Substance Research Center *Web: www.cees.njit.edu/nhsrc*	●		●	●	◆				◆		◆	◆											
71 Oak Ridge Subsurface Weirs, Oak Ridge, TN *E-mail: jardinepm@ornl.gov*	●		●						◆		◆												
72 Office of Environmental Restoration and Waste Management, U.S. Department of Energy *Web: www.em.doe.gov/er*	●		●	●	◆							◆	◆	◆									
73 Office of Environmental Technologies Exports, U.S. Department of Commerce *Web: www.ita.doc.gov/*	●			●				◆												◆	◆		
74 Office of International Trade, U.S. Small Business Administration *Web: www.sba.gov/OIT*	●			●	◆			◆									◆			◆			
75 Office of Science and Technology, U.S. Department of Energy *Web: http://em-50.em.doe.gov*	●		●						◆					◆	◆								

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76 Olympic Venture Partners *E-mail: info@ovp.com*				●		◆																◆	
77 Ontario Centre for Environmental Technology Advancement *Web: www.oceta.on.ca*				●		◆		◆											◆				
78 Overseas Private Investment Corporation *Web: www.opic.gov*				●	◆															◆			
79 Program Research and Development Announcements (PRDA) and Research Opportunity Announcements (ROA), U.S. Department of Energy *Web: cbdnet.access.gpo.gov*	●		●	●	◆				◆	◆	◆												
80 Remediation Information Management System (RIMS) *Web: www.remedial.com*	●		●	●				◆							◆								
81 Remediation Technologies Development Forum *Web: www.rtdf.org*	●		●						◆	◆	◆	◆			◆				◆				
82 Research Triangle Institute *Web: www.rti.org/gen_info.html*	●		●	●								◆			◆			◆					
83 Resource Conservation and Recovery Act (RCRA), Superfund, and Emergency Planning and Community Right-to-Know Act (EPCRA) Hotline *Web: www.epa.gov/epaoswer/hotline/index.htm*		●														◆							
84 Sandia National Laboratories *Web: www.sandia.gov*	●		●	●							◆	◆		◆					◆				
85 Savannah River Research Campus *Phone: (803) 652-7772*	●		●	●								◆					◆					◆	

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86 Service Corps of Retired Executives (SCORE) *Web: www.score.org*	●		●	●			◆	◆									◆	◆				◆	◆
87 Small Business and Contracting Opportunities, U.S. Department of Defense *Web: www.acq.osd.mil/sadbu*	●		●	●											◆			◆			◆		
88 Small Business Development Center Program, U.S. Small Business Administration *Web: www.sba.gov*	●		●	●			◆	◆						◆			◆	◆	◆		◆	◆	◆
89 Small Business Guide to Federal R&D Funding Opportunities *Web: www.seeport.com/manuals/r&dbook/rdguide.htm*				●	◆			◆										◆	◆				
90 Small Business Innovative Research Program, U.S. Small Business Administration *Web: www.sba.gov/SBIR/sbir.html*				●	◆													◆	◆				
91 Small Business Technology Transfer Program, U.S. Department of Energy *Web: http://sttr.er.doe.gov/sttr*				●	◆	◆															◆		
92 Smithville Phase IV Bedrock Remediation Program *Phone: (905) 957-4077*	●		●						◆		◆												
93 Solution Quest *Web: www.solquest.com*				●			◆														◆	◆	
94 South and Southwest Hazardous Substance Research Center *Web: www.hsrc.org/hsrc/html/south.html*	●		●									◆			◆								

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95 Southern Technology Applications Center (STAC) *Web: www.state.fl.us/stac*	●	●	●	●			◆	◆				◆		◆		◆	◆	◆	◆				
96 State Science and Technology Institute (SSTI) *Web: www.ssti.org*	●		●	●											◆				◆				
97 State Sources of Commercialization Assistance *Web: http://clu-in.org/products/ebc/ebcrpt.htm*				●				◆										◆					
98 State University of New York at Buffalo *Web: http://wings.buffalo.edu/hazwaste*	●		●	●	◆					◆													
99 Superfund Innovative Technology Evaluation (SITE) Program, U.S. EPA *Web: www.epa.gov/ORD/SITE/index.html*	●	●	●						◆	◆	◆	◆	◆	◆	◆	◆							
100 Superfund Technical Liaison Program, U.S. EPA *Phone: (202) 260-7667*	●	●	●											◆	◆	◆							
101 Sustainable Business Network *Web: http://sbn.envirolink.org/busopps/index.html*				●		◆																	
102 TechCon *Web: http://web.ead.anl.gov/techcon/*	●	●	●	●				◆							◆	◆	◆		◆				
103 TechKnow *Web: www.techknow.org*	●		●												◆								
104 Technology Transfer Society *Web: www.t2s.org*	●		●	●			◆								◆		◆						
105 Tennessee Technology Foundation *Phone: (423) 220-8832* or *(615) 253-1946*	●		●	●		◆		◆						◆			◆		◆		◆		

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106 Toxic Substances Control Act (TSCA) Assistance Information Service, U.S. EPA *E-mail: tsca-hotline@epa.gov*		●	●											◆		◆							
107 Trade Information Center, U.S. Department of Commerce *Web: www.ita.doc.gov/tic*		●		●		◆		◆								◆			◆	◆			
108 UNISPHERE *Web: www.unisphere.com*	●		●	●		◆		◆					◆				◆		◆	◆			◆
109 U.S. Army Corps of Engineers (USACE) Environmental Programs Contracting Opportunities *Web: www.environmental.usace.army.mil/hq/tools/opportunity/opportunity.html*				●														◆			◆		
110 U.S. Business Advisor: Laws and Regulations *Web: www.business.gov*	●	●													◆	◆							
111 U.S. EPA Laws and Regulations *Web: www.epa.gov/epahome/rules.html*		●														◆							
112 U.S. EPA National Exposure Research Laboratory - Environmental Sciences Division (NERL-ESD) *Web: www.epa.gov/crdlvweb*	●		●								◆	◆		◆	◆								
113 U.S. EPA National Risk Management Research Laboratory (NRMRL) *Web: www.epa.gov/ORD/NRMRL*	●		●							◆	◆	◆	◆	◆	◆								
114 U.S. EPA Test and Evaluation Facility *Phone: (513) 569-7051*	●		●								◆	◆	◆										
115 U.S. Small Business Administration *Web: www.sba.gov*	●		●	●	◆	◆	◆	◆		◆								◆		◆		◆	

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116 University of California, Los Angeles *Web: http://cct.seas.ucla.edu/cct.home.html*	●		●									◆		◆	◆								
117 University of Cincinnati *Phone: (513) 556-3738*			●									◆											
118 University of Florida *Web: www.floridacenter.org*	●		●									◆		◆	◆								
119 University of Tennessee *Phone: (423) 974-8080*			●									◆											
120 University of Waterloo *Phone: (519) 885-1211, ext. 2189*	●		●							◆	◆	◆											
121 University of Wyoming Center for Environmental Simulation Studies *E-mail: qskinner@uwyl.edu*	●		●								◆	◆	◆										
122 Virginia's Center for Innovative Technology *Web: http://cit.org*	●		●	●		◆						◆	◆	◆					◆				
123 Volunteer Army Ammunition Plant, Chattanooga, TN *Web: www.volunteersite.com/volsite.htm*	●		●						◆		◆												
124 Waterways Experiment Station Hazardous Waste Research Center *Web: www.wes.army.mil/el/hwrc*	●		●								◆	◆	◆	◆	◆								
125 Western New York Technology Development Center *Web: wings.buffalo.edu/wnytdc*			●	●		◆					◆	◆											

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126 Western Region Hazardous Substance Research Center *Web: www-seep-server.stanford.edu/SEEPWeb/wrhsrc*	●		●									◆			◆								
127 SR-Superfund Reforms, Round 1, Round 2, and Round 3 *Web: www.epa.gov/superfund/programs/reforms/byround.htm*	◆	◆	◆	◆	◆									◆		◆							

Table 4-2. Barriers to ITTs Cross Referenced by Initiatives

		INITIATIVES UNDERWAY	SOURCE DOCUMENTS										
			EPA			DOE		THIRD PARTY					
		Cross Reference to Table 4-1	EPA/TIO 1990	EPA/NETAC 1993	EPA/TIO 1995	DOE/HWAC 1995	DOE 1998	OTA 1985	OTA 1989	GAO 1993	GAO 1994	NRC 1997
INSTITUTIONAL BARRIERS												
I-1	Actions undertaken by federal and state agencies to promote and regulate the development and use of ITTs are not well coordinated.	27, 33, 48, 52, 61, 81			◆	◆	◆	◆	◆	◆	◆	
I-2	Rigid management hierarchies and government bureaucracy tend to perpetuate the use of status quo technologies.	2, 10, 12, 15, 24, 27, 34, 48, 52, 61, 72, 75, 79, 81, 99		◆		◆	◆	◆	◆		◆	
I-3	Schedules imposed by regulatory agencies often do not allow sufficient time to investigate the feasibility of using ITTs.	27, 29, 33, 43, 52, 100, 114	◆	◆			◆		◆		◆	
I-4	Regulators often adopt rigid approaches to applications of ITTs.	10, 27, 52	◆		◆		◆	◆				
I-5	The level of communication that takes place among the various developers of environmental technologies is not adequate to promote the development of ITTs.	20, 21, 26, 28, 49, 51, 56, 74, 81, 86, 88, 95, 104, 105, 108, 122	◆		◆		◆					◆
I-6	In general, a lack of communication exists between the developers of ITTs and the potential users of those ITTs.	12, 19, 24, 26, 28, 29, 37, 49, 54, 64, 73, 80, 87, 103, 105, 107, 108	◆		◆	◆	◆					
I-7	EPA has not assessed Superfund site cleanup needs systematically and has had difficulty in matching ITTs with the requirements of specific sites.	12, 99, 100, 102						◆	◆	◆	◆	
I-8	Parties involved with cleanups have conflicting priorities.	*				◆	◆		◆		◆	

* No specific initiative addressing this barrier was identified in the source documents or EPA s *The Innovative Treatment Technologies Developer s Guide to Support Services, Fourth Edition* reviewed in preparing this table. It is important to note that this list is not comprehensive and initiatives or policies may exist that address these barriers.

Table 4-2. Barriers to ITTs Cross Referenced by Initiatives

		INITIATIVES UNDERWAY	SOURCE DOCUMENTS									
			EPA			DOE		THIRD PARTY				
		Cross Reference to Table 4-1	EPA/TIO 1990	EPA/NETAC 1993	EPA/TIO 1995	DOE/HWAC 1995	DOE 1998	OTA 1985	OTA 1989	GAO 1993	GAO 1994	NRC 1997
INSTITUTIONAL BARRIERS (continued)												
I-9	Regulators may lack knowledge about ITTs.	10, 12, 24, 27, 28, 29, 36, 41, 42, 52, 58, 59, 61, 64, 66, 68, 75, 80, 81, 94, 99, 103, 113, 116, 118, 120, 124					◆		◆		◆	
I-10	Technology experts are not included in the formal decision-making process during which technologies are selected.	66, 100				◆			◆		◆	
I-11	Government agencies rely too heavily on the support of contractors, some of whom have financial interests in conventional technologies, to assist in selecting cleanup remedies.	24, 27, 28, 29	◆			◆					◆	
I-12	Appropriations and procurement processes create uncertainty about the levels and timing of funding that will be available to manage environmental problems at individual DOE sites.	9, 37, 102				◆	◆					
I-13	Enforcement of regulations that govern cleanup activities is inconsistent and too strict.	8, 10, 52, 110							◆			◆
I-14	Cycles of government appropriations are not coordinated with the cycles of research and development for ITTs, causing gaps in funding.	110		◆			◆					
I-15	Regulators are reluctant to appear lenient in dealing with responsible parties.	10, 27					◆				◆	
I-16	Communities often are not supportive of the use of ITTs because they are unwilling to assume risks associated with the testing and use of ITTs in their neighborhoods.	2, 24, 27, 28, 29, 36, 38, 41, 42, 52, 61, 64, 66, 68, 80, 81, 92, 99, 103, 113	◆			◆						
	TOTALS		**6**	**3**	**4**	**8**	**11**	**4**	**8**	**2**	**9**	**2**

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REGULATORY AND PERMITTING BARRIERS												
R-1	Permitting processes for ITTs are inconsistent, involve numerous levels, and are time- and resource-intensive.	10, 27, 52		◆	◆	◆	◆	◆	◆	◆	◆	◆
R-2	Permitting and manifesting requirements under the Resource Conservation and Recovery Act (RCRA) often inhibit the development of ITTs.	*	◆		◆			◆	◆	◆	◆	◆
R-3	Users of environmental technologies are concerned about liabilities they might incur through the use of ITTs.	*	◆	◆		◆	◆	◆	◆	◆		
R-4	Entities that develop and use ITTs are concerned about liabilities they might incur through the licensing and transfer of ITTs.	34, 54	◆	◆		◆	◆		◆			
R-5	Regulatory structures do not consider market forces and therefore do not provide incentives for cleanup contractors and site managers to use ITTs.	*			◆				◆			◆
R-6	Tendency of regulations to evolve over time discourages the development and use of certain ITTs.	*	◆									
R-7	Obtaining authentic waste materials or site access needed to test ITTs can be difficult and costly and can expose the developer of the technology to uncertain liabilities.	2, 7, 12, 15, 24, 25, 40, 44, 48, 55, 59, 62, 63, 65, 66, 69, 70, 71, 81, 92, 99, 123					◆	◆				
	TOTALS		**4**	**3**	**3**	**3**	**4**	**4**	**5**	**3**	**2**	**3**
TECHNICAL BARRIERS												
T-1	Cost and performance data for specific ITTs are limited.	2, 24, 27, 28, 29, 33, 41, 48, 50, 60, 66, 68, 80, 81, 99, 103	◆	◆	◆	◆	◆			◆	◆	◆
T-2	Performance criteria and cleanup standards often are ill-defined and inconsistent.	*	◆	◆	◆	◆	◆	◆	◆			◆

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TECHNICAL BARRIERS (continued)												
T-3	No coordinated program for formally verifying the performance of ITTs.	10, 27, 48, 55, 75, 81, 99	◆			◆	◆	◆	◆			◆
T-4	Often difficult to apply ITTs at numerous sites because the characteristics of the sites differ.	38, 40, 59, 60, 62, 121, 123	◆			◆						◆
T-5	Difficult to extrapolate information gained from testing an ITT at one site to other sites.	2, 24, 27, 28, 29, 33, 41, 48, 50, 60, 66, 68, 80, 81, 99, 103	◆				◆					◆
T-6	ITTs often are not considered until after the data collection phase of the remedial investigation, thereby leaving critical gaps in data required to evaluate the effectiveness of potentially applicable ITTs.	10, 12, 27, 28, 29, 33	◆			◆						
	TOTALS		**6**	**2**	**2**	**5**	**4**	**2**	**2**	**1**	**1**	**5**
ECONOMIC AND FINANCIAL BARRIERS												
E-1	Economic incentives are lacking for those who might wish to develop or use ITTs.	*	◆	◆	◆	◆	◆	◆				◆
E-2	Government and private-sector funding for the development and demonstration of ITTs is insufficient.	1, 5, 6, 12, 13, 15, 17, 22, 32, 35, 47, 51, 54, 56, 57, 67, 70, 72, 74, 78, 79, 89, 90, 91, 101, 105, 107, 115	◆	◆		◆		◆		◆		◆
E-3	Information available to characterize potential markets for ITTs is limited.	19, 20, 26, 53, 73, 93, 107		◆	◆	◆	◆		◆			◆
E-4	Venture capitalists perceive the environmental management market as a high financial risk.	5, 6, 13, 15, 17, 22, 31, 51, 54, 56, 57, 76, 77, 101, 108		◆		◆	◆	◆				◆

* No specific initiative addressing this barrier was identified in the source documents or EPA s *The Innovative Treatment Technologies Developer s Guide to Support Services, Fourth Edition* reviewed in preparing this table. It is important to note that this list is not comprehensive and initiatives or policies may exist that address these barriers.

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ECONOMIC AND FINANCIAL BARRIERS (continued)												
E-5	Technology selection decision-makers are concerned with protection of their agencies' budgets, so there is a reluctance to use technologies developed by other agencies.	*				◆	◆	◆	◆			
E-6	Only a small portion of the entire life cycle of a project may be taken into consideration when the costs of remediation alternatives are compared.	*				◆	◆		◆			◆
E-7	Numerous financial incentives to delay remediation and few incentives to carry out remediation in a timely manner.	*					◆					◆
E-8	Market for environmental remediation technologies is fragmented.	3, 19, 28, 37		◆								◆
E-9	Use of fixed-price contracts to procure remediation services discourages the use of ITTs.	*	◆									
E-10	Under the Federal Acquisition Regulation (FAR), contractors that test ITTs during cleanup design would be precluded from bidding on construction work at the site.	*								◆		
E-11	Lack of adequate mix of entrepreneurial, technical, and business management skills in small environmental technology companies to facilitate development of a market-driven technology.	5, 21, 25, 31, 57, 76, 85, 86, 88, 93, 115		◆								
E-12	Firms are reluctant to develop ITTs with limited applications.	44, 72, 75, 79					◆					
E-13	Concern that use of an ITT may have adverse effects on employment in the agency that uses that technology.	*					◆					
	TOTALS		**3**	**6**	**2**	**6**	**8**	**4**	**3**	**2**	**0**	**7**

* No specific initiative addressing this barrier was identified in the source documents or EPA s *The Innovative Treatment Technologies Developer s Guide to Support Services, Fourth Edition* reviewed in preparing this table. It is important to note that this list is not comprehensive and initiatives or policies may exist that address these barriers.

APPENDICES

APPENDIX A

SUMMARY OF TEN DOCUMENTS USED FOR THIS STUDY

A comprehensive literature review of documents related to barriers of innovative treatment technologies (ITT) identified an initial list of 33 documents. A preliminary review of the 33 documents was performed to select documents that provide the most useful information in which to articulate the barriers to acceptance of ITTs. A review of those documents was performed, and the documents were classified as follows:

- Nine of the documents provided little or no information about barriers to the development and use of ITTs and therefore were determined not to be useful to this study.
- Twelve of the documents discussed barriers to the use of innovative environmental technologies in general, including pollution prevention technologies, but did not provide information about barriers that specifically affected the development, selection, and use of ITTs. Therefore, these documents were determined not to be useful to this study.
- Twelve of the documents were determined to contain relevant information about barriers to the development and use of ITTs. However, two of these documents were reviews of other studies and therefore were eliminated from the study.

Based on this review, and at the direction of the U.S. Environmental Protection Agency (EPA) work assignment manager (WAM), 10 documents that held the most value for further detailed analysis were selected for use in this study. These documents contain information that is sufficient to develop a general understanding of the barriers to ITTs; however, they do not necessarily contain as comprehensive a discussion, or explore as many facets of barriers as that found in the documents related to "innovative environmental technologies." These documents served as the basis for the analysis of barriers to ITTs. This appendix presents a summary of each of these 10 documents. The remaining 23 documents are listed in Appendix B.

Document No.: 1

Title: *Superfund Strategy*

Author/Sponsor: Congress of the United States, Office of Technology Assessment (OTA)

Publication Date: 1985

Overview:

EPA estimates of the number of Superfund sites is very low, and existing resources are not sufficient to permanently cleanup even that very low number of sites (one-fifth of OTA's estimate). Although, at many sites responses have been limited, they usually consist of moving the waste to land disposal sites or leaving the waste in the ground. The public has begun to demand permanently effective cleanups, that is, cleanups that minimize the likelihood that further action will be necessary in the future to address the same sites or wastes for the same sites. To achieve such permanent cleanups, waste and contaminated materials must be treated, rather than merely moved. But little progress has been made in accomplishing permanent cleanups, particularly in the case of the expensive, difficult, and uncertain task of cleaning up contaminated groundwater. Moreover, detailed goals for permanent cleanups remain unclear; without such goals, it is difficult to select cost-effective cleanup technologies and evaluate their performance.

Statement of Problem:

Cleanup has focused on containment strategies adopted by the construction industry. Minimal thought has been given to the development and application of ITTs specifically designed to deal with the unique problems encountered at hazardous waste sites. With increasing evidence that containment strategies are ineffective in the long term and that it might be necessary to take further remediation action at a site or on a waste, and as the dimensions of groundwater problems at sites become increasingly clear, technologies designed to destroy the toxic component of hazardous wastes are being developed by the private sector. However, institutional, regulatory and legislative, and economic and financial barriers hamper the adoption of ITTs by the Superfund program.

Barriers Identified in the Report:

The document identifies the following barriers to the adoption of ITTs:

- *Policy uncertainties create market uncertainties:* Because Superfund is viewed as a short-term program, market support for long-term development of ITTs is weak. Uncertainties about the ultimate size of the Superfund program and the type of cleanup effort it will encompass create market uncertainties. Uncertainties also arise because technology is at an advanced stage than

the regulatory process. There is no clear-cut way to objectively judge the effectiveness of ITTs or to compare them with traditional technologies.

- *Access to financing for research and development (R&D)*: Without adequate funding for R&D and demonstration, no technology will reach the stage at which it can demonstrate an acceptable level of reliability and effectiveness under field conditions. The crucial and expensive demonstration period is preceded by bench and pilot-test stages that often must be funded without guarantees that a commercial product will result.
- *Institutional practices and regulatory effects*: Cleanup standards are not consistent and valid waste materials for testing are difficult to acquire. That circumstance raises the cost of, or even prevents, demonstrations and creates inconsistencies in the information available about ITTs. There is no established procedure for collecting and disseminating the information that is generated. Institutional and regulatory and legislative barriers include:

  - *Permitting requirements are expensive and time-consuming:* There is duplication of procedures between the states and the federal government and even among EPA regions.

  - *Testing that will result in applicable and valid data requires the use of real material rather than synthetically produced wastes. Valid waste for testing is difficult to obtain.*

  - *Policy uncertainties, the lack of regulations, or uncertainties about new regulations can have negative effects on technology development:* Existing regulations also affect adoption of technologies because of: (1) duplication in the permitting requirements of federal, state, and local agencies; (2) differences between various states and EPA regions; and (3) the preemption of other applicable or relevant environmental regulations.

- *There is a regulatory bias toward the 'status quo' or existing technology*: Regulations (including the National Contingency Plan [NCP]) and guidance including, EPA's "*Guidance on the Preparation of Feasibility Studies*" encourage a bias toward containment and, to a lesser extent, traditional incineration technologies. A predilection for short-term costing and a reluctance to reach beyond comfortable, traditional technology favor the 'status quo.'

Document No.: 2

Title: *Coming Clean - Superfund Problems Can Be Solved*

Author/Sponsor: Congress of the United States, OTA

Publication Date: 1989

Overview:

Superfund began in 1980 as a short-term emergency clean up effort. By 1985, when Congress debated reauthorizing Superfund for a second five year period, the program had become controversial and confrontational. Among other things, Superfund at the time lacked a unified national infrastructure of education, training, databases, research, and development. In addition, OTA found that as many as 75

percent of cleanups were unlikely to be effective over the long term. The report responds to a request from the House Committee on Public Works and Transportation and the House Committee on Energy and Commerce for an examination of the implementation of the Superfund Amendments and Reauthorization Act of 1986 (SARA).

Statement of Problem:

OTA recognized several problems involving "...our technological capabilities to manage hazardous waste and cleanups...". Three types of problems plagued the Superfund program; they were related to workers and technology. Long-term support on the part of the government for basic research and R&D on critical problems was deemed necessary. The potentially enormous size of the cleanup business initiated R&D, and hundreds of new companies offered advanced cleanup technologies. Use of better, and often more expensive, technologies was limited by decision makers who were overly cautious, had available only inadequate information, or were interested primarily in minimizing front-end costs. Although almost everyone working in the Superfund system understood the congressional intent to shift to permanently effective cleanup technologies and to acknowledge the public's support for that policy, a number of factors resulted in slow and uneven implementation.

Barriers Identified in the Report:

The document identifies the following barriers to the adoption of ITTs:

- *Because data on cost and operational history are limited, ITTs historically have been screened out early in the evaluation process:* Certain elements of the evaluation process create a bias against the use of ITTs. For example, because of liability for damages resulting from failure of a technology, contractors, potentially responsible parties, and government alike are reluctant to recommend the use of ITTs that have not been demonstrated fully.

- *There are significant delays between R&D and demonstration and between demonstration and full-scale application*: The delays in adopting new ITTs, in turn, create a delay between market expectations and market returns on R&D investments. The existence of such delays tends to influence the expanding national cleanup effort to depend on older technologies, rather than assume the risk and uncertainty, but the chance for bigger gains, offered by newer technologies. Further, the public may have little patience with delays in Superfund cleanups. Insecurities about the Superfund system and pressures from outside delay the adoption of ITTs, even as the need for them increases.

- *Few incentives to select improved cleanup technologies have been built into the Superfund program:* There are far more penalties than rewards for choosing new solutions over older ones, even though the older approaches may not offer reliable, permanent, long-term protection. Those who bear the responsibility for paying for cleanups see ITTs as more expensive in the near term than conventional containment or land disposal and monitoring. Engineering companies have

strong concerns about liability for ineffective work or work that is judged later by standards that differ from those that governed the conduct of the work. There is less risk in using 'standard' off-the-shelf technologies than in adopting new and innovative ones. Engineers who use unproven technologies in their designs are gambling with their clients' money. If the gamble backfires, the engineering firm might be held liable. Engineers, therefore, are not likely to use unproven technologies in remedial designs because of potential liability; the result is an impasse: engineers do not want to use ITTs, but technologies cannot reach commercial status unless they are used.

- *There is pressure on those in government to complete reports and records of decision (ROD):* Such pressure impedes the use of ITTs because the selection process for such technologies is likely to be more lengthy and costly than that for conventional approaches. There are a few exceptions, mostly on the part of responsible parties that are aware that the use of a new technology will reduce costs, compared with the cost of older technologies. Such parties also tend to consider the use of ITTs as a means of reducing future liability. As a rule, parties that give weight to such considerations tend to select permanent remedies, including ITTs.

- *Another disincentive to the use of ITTs is the need to obtain a regulatory delisting of the residue of a treatment operation if the material is to be sent off site after treatment:* The Resource Conservation and Recovery Act (RCRA) regulatory program is plagued with considerable inefficiencies. If delisting cannot be obtained quickly, the cost of using a treatment technology escalates, because a residue automatically is considered hazardous unless found to be otherwise through the delisting process. Uncertainty about delisting and the potentially high cost of managing residue can block the adoption of an effective treatment technology.

- *The technology development pipeline is clogged*: R&D efforts are moving forward, buoyed by continued optimism about the number of cleanups, the availability of cleanup funds from government entities, and the availability of venture capital. But the cleanup market rarely meets the expectations of technology developers. The rapid growth of Superfund and public pressures on the government to produce more cleanups faster do not necessarily promote adoption of ITTs. One company that had developed a new form of thermal destruction, which had garnered much attention and been applied successfully in several site demonstrations, went bankrupt. Competition increases constantly so that available business and opportunities for site demonstrations are distributed among a growing number of technology companies. Small market share can limit both the success of a company and its ability to continue its technology development efforts. The Superfund Innovative Technology Evaluation (SITE) program has had mixed results. Analytical contractors have provided inadequate services. The SITE program tends to overemphasize positive results and to discount negative results. Of crucial concern as well, the SITE program never has focused on true ITTs that would represent breakthroughs in particulary difficult cleanup applications and technologies for which prior R&D has justified field demonstration. Some of the technologies in EPA's SITE program are variations of well-known, commercial technologies that have been demonstrated several times or even have been applied in an actual cleanup. Because the SITE program information is widely distributed, it appears to become a public relations opportunity for companies. Months or even years pass before results from SITE demonstrations are made available to the public. Such long delays in obtaining proof from a SITE demonstration might serve only to prolong the stigma attached to a technology that continues to be considered innovative and unproven through such a delay.
- *No clear rules establish what constitutes proof of effectiveness of cleanup for ITTs:* There is no clear understanding of the amount and type of information that is considered reasonable proof of effectiveness and reliability. The engineering aspect of technology selection can obscure

fundamental goals for environmental protection, resulting in the rejection of ITTs that are environmentally more effective than the approaches selected. The key problem is how to bridge the gap among technology selection decisions and laboratory results.

- *Information about newer technologies is disseminated poorly:* The latest technical information about generic and specific cleanup technologies, their costs, and their performance and implementation at sites is not well distributed. Therefore, the considerable experience gained through private, state, and RCRA corrective action cleanups, as well as cleanups performed by federal agencies other than the EPA may go untapped. The expanding reservoir of cleanup-related R&D, including university work, is not shared effectively, as well. Transfer of information and communication are key problems. For both the general public and individuals in the Superfund workforce, it is difficult to cope with the flood of scientific and technological data and details, which are increasing at a rapid rate as more vendors enter the market. But technology development and the selection of technologies are crucial in making Superfund work more effectively and efficiently.

- *Loyalty to existing technologies and inexperience in the workforce reduce the number of ITTs selected for use in cleanups:* Superfund contractors, their parent companies, or their subsidiaries, often own cleanup equipment and technologies. Such a contractor may have a stake in the adoption of a particular technology. EPA's remedial division, which should be performing cleanups as dictated by the principles of the SARA, appears so wedded to architecture and engineering (A&E) firms in developing RODs that it appears virtually impossible to get an ITT accepted within any reasonable length of time.

Document No.: 3

Title: *Workshop on Developing an Action Agenda for the Use of Innovative Remedial Technologies by Consulting Engineers*

Author/Sponsor: EPA

Publication Date: October 1990

Overview:

In October 1990, EPA's Technology Innovation Office (TIO), in conjunction with the National Advisory Council on Environmental Policy and Technology (NACEPT), sponsored a workshop to develop an action plan for addressing barriers that impede the use of ITTs to remediate soils and groundwater that have been contaminated with hazardous waste. Participants in the workshop suggested actions that the public and the private sectors can undertake to overcome barriers associated with availability of information, training, professional development, regulatory uncertainty, and liability.

Statement of Problem:

The lack of descriptive information and of data on the performance and cost of ITTs impedes the use of those technologies. The R&D costs of bringing a technology from bench-scale to pilot-scale can be prohibitive. The inconsistent and inconstant nature of regulations that govern the use of ITTs is a disincentive to development. In the absence of cleanup standards, consulting engineers are reluctant to use unproven ITTs because of liability considerations.

Barriers Identified in this Report:

The document identifies the following barriers to the adoption of ITTs:

- *It is difficult to extrapolate the applicability of the technology:* Information obtained by testing a technology at one site cannot be used easily at other sites because the combinations of wastes and characteristics of sites vary significantly. There is a need to collect standardized data on technologies and sites.

- *Data on technologies are unreliable:* Consulting engineers are unwilling to assume the liability associated with reliance on bench-scale data. Vendor data typically are based on tests conducted under synthetic, and therefore unrealistic, conditions.

- *ITTs often are not considered until after the data collection phase of the remedial investigation, leaving crucial gaps in the data necessary to evaluate the potential effectiveness of the technology.*

- *Schedules imposed by regulatory agencies do not allow the time necessary to investigate ITTs; further, the preselection of remedial alternatives by agencies is a disincentive to such investigation.*

- *Communication among technology developers is not adequate to promote the development of ITTs.*

- *There is a shortage of available and accessible information about the full-scale implementation of remediation projects:* Data associated with the full-scale implementation of remediation technologies often are not published because such information often cannot successfully pass through the peer review process and because proprietary cost and performance data often are considered confidential.

- *The number of personnel qualified to develop and implement ITTs is inadequate:* Universities find it difficult to locate specific sites for conducting hazardous waste research projects, without raising concern about liability.

- *The financial burden of conducting R&D necessary to bring an ITT to the pilot-scale stage can be prohibitive:* Under the SITE program, the entrepreneur waits too long to realize a return on the investment in a technology.

- *It can be prohibitively time-consuming to meet regulatory requirements, and changes in regulations discourage investment in specific technologies:* The RCRA and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) programs take different approaches to solving the same hazardous waste remediation problem. The new land disposal

restrictions (LDR) are hampering cleanup activities. Current laws and regulations are inflexible and impractical and do not promote the most effective remediation solutions.

- *In the absence of cleanup standards, consulting engineers are reluctant to use unproven ITTs because of liability considerations:* ITTs are by definition unproven, so there is a built-in bias to prefer established technologies. Because there are no standard practices that guide risk assessment and site remediation, engineers find it difficult to defend themselves against lawsuits and prove to the public that they have met cleanup standards.

- *The fixed-price procurement process is inappropriate for the development of ITTs because the technologies often require redesign:* Costs associated with the uncertainty of technology are magnified by the liability issue.

Activities to Address Existing Barriers:

The document identifies the following activities that are being or should be undertaken to address barriers to the adoption of ITTs:

- Develop a site classification program based on industrial activities, contaminants, and remedial technologies, so that data on the performance of ITTs can be extrapolated more easily. Identify a panel of experts for each type of technology to define the specific parameters to be used in evaluating ITTs.

- To alleviate the risk of depending on bench-scale data, evaluate tax incentives that reward the client for taking risks by adopting innovative approaches. Establish independent organizations responsible for setting criteria for judging the validity of data. Provide a facility at which vendors of ITTs can perform pilot-scale tests to obtain data under any numerous but standard conditions at a nominal cost.

- Consider ITTs early in the remedial investigation stage when the data collection plan is developed.

- Provide incentives to make the release of information profitable to its owner. Start the peer review process earlier in the remediation process.

- Increase collaboration between universities and research institutes and consulting engineering firms.

- Take a more flexible approach to regulation by allowing the selection of a technology at different stages of the remediation process and in the absence of a ROD.

- The government should share in the exposure to liability arising from use of new and improved technologies.

Document No.: 4

Title: *Superfund: EPA Needs to Better Focus Cleanup Technology Development*

Author/Sponsor: U.S. General Accounting Office (GAO)

Publication Date: April 1993

Overview:

EPA established the SITE program in response to SARA, which required that the agency accelerate the development of ITTs. ITTs are defined in SARA as treatment technologies for which adequate cost and efficacy data are not yet available. The four components of the SITE program are:

- The Demonstration Program, which publishes data on the cost, performance, reliability, and applicability of selected ITTs after field demonstrations have been conducted
- The Emerging Technologies Program, which provides financial assistance to developers of new technologies that are undergoing laboratory tests
- The Monitoring and Measurement Program, which tests new technologies to assess the nature and extent of contamination at a site
- The Technology Transfer Effort, which disseminates information gathered through the three SITE programs to EPA regions, states, PRP, and Superfund contractors

Implementation figures indicate that there are 109 ITTs in the SITE program for which the program has planned 117 field demonstrations. To date, SITE has initiated 74 field demonstrations. The number of field demonstrations conducted each year has increased from three in 1987 to 32 in 1992.

EPA established TIO to increase the use of ITTs at contaminated sites by both government and industry. TIO promotes increased flexibility in policies, permit requirements, state grants, and contracting procedures. TIO also helps vendors of ITTs prepare cost and performance data for their technologies, as well as disseminate information about those technologies.

TIO reports that ITTs have been selected for use in 228 remedial or removal cleanup actions, with the annual number increasing from three in fiscal year (FY) 1984 to 68 in FY 1991. As of 1993, only 11 such remedial cleanup actions and 14 removal actions or 11 percent of the cleanup actions identified had been completed.

This GAO study evaluates the effectiveness of the SITE and TIO initiatives.

General Statement of Problem:

EPA has yet to develop a plan that sets priorities among cleanup needs. The agency's efforts fail to target solicitation of technology development to meet needs in specific areas.

This GAO study evaluates the effectiveness of the SITE and TIO initiatives.

Barriers Identified in this Report:

The document identifies the following barriers to the adoption of ITTs:

- *EPA has not assessed systematically Superfund site cleanup needs and has had difficulty in matching new technologies to the requirements of specific sites:* EPA does not have an automated cleanup remedy database that provides information about remedies by medium, cost, and efficacy. Because systematic information about technologies used at Superfund sites is lacking, EPA cannot inform potential developers or users fully, nor can the agency assess effectively which technology needs should be addressed to reduce risks to human health or the environment. When the SITE program attempts to solicit new technologies from developers and vendors, its guidance is vague and does not identify specific needs. Therefore, solicitations are not targeted to specific cleanup needs, thereby creating potential problems in selecting technologies with a defined need. For example, EPA accepts technologies in search of an application, rather than seeking solutions to site-specific problems (applications seeking technologies). Under the SITE program, therefore, it is difficult to match technologies with sites for field demonstration.

- *Lack of reliable data on the cost and efficacy of ITTs has led parties involved in cleanup to avoid the use of such technologies to avoid the possible risks associated with those technologies:* EPA officials, PRPs, and potential investors all tend to be risk-averse in situations in which complete information is not available. There are not always guarantees that ITTs will work effectively, within the required schedule for meeting milestones, and be cost-competitive with currently proven technologies. Although EPA has undertaken efforts to improve data on cost and efficacy under the SITE program, the availability of substantive data remains limited. After a demonstration has been completed, an average of 19 months passes before cost and performance reports are published. It has been recommended that, to accelerate the process, EPA initiate demonstrations that test more than one technology at a time and develop incentives that will lead project managers to allow the use of their sites for such demonstrations.

- *Requirements for issuing permits, as well as regulations and agency policies, are barriers to the development and use of ITTs:* Regulations that are intended to protect human health and the environment can preclude the use of promising new technologies for site cleanup by requiring a permit application that includes data on performance and risk that have not yet been developed. The time and cost associated with obtaining a testing permit (under RCRA) also is identified as a barrier. Inconsistencies among guidance and regulations of federal, state, and local authorities often increase the number of hurdles a developer of ITTs must overcome. Approval by one state may not translate into acceptance by another state. The Federal Acquisition Regulation (FAR) can discourage contractors from testing ITTs by prohibiting the contractors' subsequent involvement in cleanup activities at the site at which the test was conducted. A contractor that has tested a technology for EPA usually is prohibited for three years from working for the

responsible parties. EPA is working to amend requirements under the FAR to allow exemptions for the demonstration of ITTs. EPA has made, and will continue to make, reforms in regulations and policies that will encourage parties to increase their research and development activities. Further, a number of multiple federal facility sites and government research facilities will be made available for the testing and evaluation of ITTs. Therefore, developers will be able to conduct tests without obtaining the permits that would be necessary for activities conducted at private property.

Activities EPA is Undertaking to Address Existing Barriers:

Efforts by TIO target the assessment of cleanup needs, the development and dissemination of data on cost and efficacy, and the reduction or removal of barriers that arise from permit requirements and regulatory procedures. But the report found that to date, efforts have been piecemeal, and a systematic plan and strategy have been lacking.

Recommendations made in the report include the suggestion that TIO take a more systemic approach to identify problems at sites, set priorities among cleanup technologies and research needs, and solicit the development of specific technologies.

Conclusions:

The efforts of both TIO and the SITE program have contributed to increased development and selection of ITTs. However, ITTs still cannot fulfill cleanup expectations reliably and cost-effectively. EPA could take more steps to stimulate R&D, as well as the acceptance of new cleanup technologies on the part of site managers and parties responsible for site cleanup.

Document No.: 5

Title: *National Environmental Technology Applications Center, The EPA Model for Encouraging Private Investment in the DOE Environmental Market: A Summary Report to the U.S. Department of Energy*

Author/Sponsor: U.S. Environmental Protection Agency (EPA) and National Environmental Technology Applications Center (NETAC)

Publication Date: September 1993

Overview:

Through an interagency agreement, DOE and EPA conducted a project under which they defined a model for determining how private sector funds can be invested in cost-sharing agreements with DOE to accelerate the development of technologies that have strong commercial potential in the DOE environmental market. The primary impetus for the project was the need for safe, efficient, and cost-effective technologies to clean up DOE's nuclear weapons complex. EPA's participation was motivated by its interest in working cooperatively with DOE to facilitate site cleanups in a timely and environmentally acceptable manner. DOE is endeavoring to establish even closer ties with other federal agencies, Congress, state and local governments, universities, and other organizations, such as the venture capital and financial community, that can help DOE achieve its cleanup objectives.

Interviews were conducted with more than 90 private investors, and discussions were held with investors who participated in the Project Steering Committee that served the effort. The top five barriers to the development and implementation of ITTs from the investors' perspective are identified.

Statement of Problem:

Private investors have shied away from the environmental technology market.

Barriers Identified in the Report:

The document identifies the following barriers to the adoption of ITTs:

- *The pathway to commercialization of environmental technologies is unpredictable:* Investors cannot predict project revenues for an environmental technology company because of uncertainty in the marketplace. In the DOE marketplace, that uncertainty is increased further by a lack of adequate and meaningful information from DOE (for example, information about planned procurement outlays for environmental efforts at sites and timing of such efforts). Investors rely

on such information to make informed investment decisions. In addition, there is a procurement bias in favor of "tried and true" methods (rather than new methods). Technology users and regulators prefer proven technologies — even if they cost more than new technologies — to address environmental needs.

- *There is a pronounced lack of entrepreneurial management in small environmental technology companies:* Such companies generally have strong technical expertise but few business or marketing skills that can facilitate development of a market-driven technology.

- *Inconsistent, multilevel permitting contributes to the unpredictability of the commercialization pathway for environmental technologies:* Requirements for multilevel approvals not only create time-consuming and costly delays for technology companies and their investors, they also fragment the market, creating numerous local markets — another factor that has negative effects on the ability of investors to project a company's revenue flow and capital needs. The regulatory and permitting requirements, customer bases, and technology needs of the various local markets may differ.

- *Potential liability (that is, strict liability) in the environmental industry, especially in the area of site restoration and remediation, is of concern for the private sector:* Strict liability, as defined under CERCLA, is of concern. Another such concern is related to licensing and technology transfer of internally developed technologies by large companies. As investors pointed out, Fortune 100 corporations have developed numerous pollution control technologies primarily for internal use. Those technologies may be useful solutions that can be marketed externally. However, large corporations hesitate to license such technologies. Corporations fear potential liability if harm or damage results from the use of a developed technology, since the corporation may be perceived as a "deep pocket" source of funds to support the remediation of such problems.

- *Performance data are incomplete and the criteria used to determine the success of a technology are ill-defined:* Technology developers usually have difficulty in obtaining access to demonstration sites. If demonstrations are not conducted, developers, investors, regulators, and potential users lack adequate data to evaluate a technology's real performance and economics. In addition, to properly evaluate a technology, the criteria that define success must be established and agreed upon up front.

Activities to Address Existing Barriers:

DOE developed a model, a six-step, market-driven process based on incentives, to encourage private investment in the development, demonstration, testing, and commercialization of solutions that meet DOE's environmental needs. The model is a mechanism for creating a predictable commercialization pathway (that is, prediction of revenue flow) for private investment in environmental technology companies. The six steps are:

Step 1: Identification of performance requirements

Step 2: Preparation of a request for proposal (RFP) for team technology demonstrations

Step 3: Formation of market-driven teams

Step 4: Selection of teams

Step 5: Phased development, demonstration, and testing of teams' systems

Step 6: Award of DOE performance contracts to successful teams

Conclusions:

The document makes the following conclusions with respect to the barriers to the adoption of ITTs:

- A pilot program must be implemented to validate and refine the model. The model complements initiatives currently underway that could serve as opportunities to validate the model:
  - DOE's integrated demonstrations (ID)
  - DOE's environmental restoration management contracts (ERMC)
  - Memorandum of agreement (MOU) with the Western Governors' Association
- The model recommends that DOE continue to streamline and accelerate its procurement processes.
- The model recommends that an independent study be conducted to identify private-sector market opportunities in the DOE environmental market.
- The model recommends industry-driven conferences and publications to communicate DOE's environmental needs and EPA's participation in cooperatively working with DOE to clean up its sites.
- The time frame for Step 5 under the model -- three to three and one-half years -- appears to favor technologies in the later stages of development.
- The model encourages the market-driven identification of commercially viable technologies for the DOE environmental market. The model motivates the private sector to identify those technologies and technology companies that offer safe, efficient, and cost-effective solutions. Those benefits extend to all environmental technology companies that participate in implementation of the model.

Document No.: 6

Title: *Management Changes Needed to Expand Use of Innovative Cleanup Technologies* (for DOE)

Author/Sponsor: GAO

Publication Date: August 1994

Overview:

Over the past 40 years, DOE and its predecessor agency disposed of more than one billion cubic feet of hazardous or radioactive material at facilities around the country. Contamination of soil and groundwater is now widespread, and more than 5,700 individual contaminated plumes have been identified on DOE lands. In 1989, DOE established the Office of Technology Development (OTD), with the goal of ensuring that cleanup technology is developed to the stage at which it can be commercialized and, therefore be made available in the private sector. OTD's mission is to fund a variety of projects that demonstrate the potential of new and improved approaches to cleanup problems. OTD supports work in the Office of Environmental Management, which in turn works with EPA to identify and select the most appropriate technologies and to set milestones for completing cleanup work.

Statement of Problem:

Although OTD has conducted several demonstration projects to show the effectiveness of innovative approaches to cleanup, new technologies are not being considered seriously for use in cleaning up DOE sites. DOE has received $23 billion for environmental management since 1989; yet, little cleanup has been completed. Only about six percent of DOE's contaminated sites have been cleaned up or closed.

Barriers Identified in this Report:

The document identifies the following barriers to the adoption of ITTs:

- *Local officials fear that the use of new technologies may cause projects to miss milestones, should the technology fail:* DOE is under pressure to meet its scheduled milestones and the expected cleanup pace is set to accelerate over the next few years. Public frustration often results when regulators allow DOE to miss cleanup milestones. However, regulators also note that their hesitancy to appear too lenient with DOE may not be as widespread as perceived. They point to several regulatory options that would allow the agency to use ITTs in combination with conventional techniques to meet milestones effectively. For example, in January 1994, EPA published the guidance *Technology Innovation Strategy* (EPA 543-K-93-002), which was designed to stimulate the adoption of new technologies by streamlining incentives for innovation and reducing barriers in the regulatory framework.

- *Conflicting priorities among stakeholders tend to prevent the approval of innovative approaches to site cleanup:* For example, local governments may place a high priority on economic development and job creation and view faster cleanup as a threat to local economies. The public is primarily concerned about risks associated with the cleanup process. Therefore, the various stakeholders tend to view innovative approaches differently. Accordingly, DOE must balance the interests of those diverse stakeholder groups.

- *Field officials, as well as local stakeholders, may not be familiar with newer technologies that might be appropriate for their sites:* If there is no incentive to innovate, field officials believe that there is no need to increase the uncertainty related to the performance and cost of a remedy by adopting an innovative technology. Stakeholders might associate the newer technologies with an unacceptable level of risk; they might be said to be risk-averse. (The report refers to the GAO report *Superfund: EPA Needs to Better Focus Cleanup Technology Development*.)

- *Field officials often rely on the recommendations of on-site contractors at the site who may favor particular technologies because of their own experience with them and investments in them:* DOE long has been criticized for its extensive reliance on contractors for technical decision-making. Contractors also tend to favor established technologies, in part because of the additional capital costs associated with the use of a new technology.

- *Program officers do not always work together effectively:* Lack of internal coordination has prevented the agency from maximizing investments in ITTs. Individual DOE offices have not worked together as a well-coordinated and integrated unit to overcome resistance to the use of new technology, nor have offices worked together to develop a comprehensive assessment of technology needs. DOE explained that OTD develops technologies for problems that are common within the DOE complex, while program offices develop technologies that address problems at specific sites. The analysis revealed no clear distinctions among projects and little coordination among offices regarding the scope and objectives of projects.

- *DOE does not have a comprehensive needs assessment through which technology development projects can be ranked and funded in the most effective way:* An initial description of needs completed in 1991 did not indicate specific needs for technology development. In many locations, DOE field officials are studying specific cleanup needs for their particular site. Therefore, field offices may not be developing technologies that can be considered most appropriate from an agency-wide perspective.

- *OTD's technical experts do not play a role in the formal decision-making process through which technology choices are made*: For example, OTD does not have a role in negotiating agreements for cleanup milestones. In the absence of OTD's involvement at such key points, the full range of technology choices is not likely to be evaluated throughly.

Activities DOE is Undertaking to Address Existing Barriers:

The document identifies the following activities that are being or should be undertaken to address the barriers to the adoption of ITTs:

- In January 1994, DOE began restructuring its technology development program. The activities related to the technology development program conducted by the Offices of Waste Management,

Environmental Restoration, and Technology Development were to be managed centrally and directed by OTD.

- Five priorities for technology development have been established: remediation of tanks containing high-level waste; characterization, treatment, and disposal of mixed waste; cleanup of contaminated plumes; stabilization of landfills; and decommissioning and final disposition of DOE facilities. Implementation teams are being established for the five priorities to facilitate the use of ITTs. The teams will be made up of representatives of headquarters, selected regulators, and field users.

- The DOE peer review process and performance measurement criteria are being modified to reflect the five priority areas.

- In a July 1993 policy statement, DOE's Office of Environmental Restoration directed its field staff to consider new and ITTs early in the process of selecting cleanup procedures.

- DOE also is expanding research outreach to help ensure that the technology development efforts of agencies are coordinated closely to maximize benefits and reduce costs.

Conclusions:

Although DOE's new strategy should help correct coordination problems, insufficient emphasis is placed on ensuring that parties at all levels are aware of innovations in remediation technology. The roles of stakeholders must be clarified, so that more new technologies can be selected. The strategy also fails to link technology experts with field decision makers. DOE's new approach does not overcome contractors' resistance to recommending technologies with which they are unfamiliar.

Document No.: 7

Title: *Progress in Reducing Impediments to the Use of Innovative Remediation Technology*

Author/Sponsor: EPA

Publication Date: June 1995

Overview:

TIO was created in April 1990 to act as an advocate for new treatment technologies. Because of its small size, TIO has relied on cooperative ventures with partners both within and outside EPA, to maximize the impact of available resources to enhance the state of remediation technology.

The report identifies changes EPA and TIO have made to advance or promote information sharing about and the demonstration and actual use of ITTs. The report identifies four categories of efforts and lists 54

actions that EPA has taken to change its approach to the development of ITTs. The four major categories, as well as examples of the steps taken, are listed below:

- *Policy and regulatory improvements*: For example, the Revision to the Treatability Study Sample Exclusion Rule (59 Federal Register [F.R.] 8362), promulgated in February 1994, is intended to increase the limits on the quantities of contaminated media used in treatability studies that may be conditionally exempt from permitting and manifest requirements under RCRA so that large-scale demonstration testing may be conducted. Another example of policy and regulatory improvements is OSWER Directive 9380.017FS, issued in August 1991, which encourages reasonable risk-taking in selecting treatment technologies, requires that ITTs be considered routinely as treatment options, and establishes incentives for more frequent use of ITTs.

- *Improvements in research, development, and demonstration:* For example, TIO worked with EPA's Office of Research and Development (ORD) to organize the Remedial Technologies Development Forum (RTDF), which encourages collaboration among companies, public interest groups, states, universities, DOE, and the U.S. Department of Defense (DoD) in defining, setting priorities among, and funding new, untried concepts for cleanup technologies to promote coordination and eliminate duplicative research and development. Another EPA effort to promote improvements in research, development, and demonstration was the establishment of a Groundwater Remediation Technologies Analysis Center (GWRTAC), which tracks ongoing groundwater research and development, promotes coordination of the activities of public and private research groups, and encourages the demonstration of promising remediation technologies.

- *Improvements in information-sharing:* For example, OSWER published 37 case study reports of cleanups. These reports were prepared by the Federal Remediation Technologies Roundtable (FRTR) in a four-volume publication. In another example, OSWER developed and maintained the Vendor Information System for Innovative Treatment Technologies (VISITT), which provides current information about vendors of ITTs, their products, and their capabilities. As of 1994, the VISITT database included information about 277 technologies offered by 171 developers and vendors, and the system had been accessed by more than 10,000 users in more than 60 countries. OSWER also developed and enhanced EPA's Clean-Up Information (CLU-IN) electronic bulletin board to provide up-to-date information on ITTs to hazardous waste professionals.

- *Improvements in training:* For example, TIO developed and continues to operate the CERCLA Education Center (CEC), a unique training forum that provides basic and advanced training on the laws, regulations, and processes that make up the Superfund program to on-scene coordinators, remedial project managers, site assessment managers, and other Superfund staff.

Conclusions:

TIO recognizes that there are significant barriers that impede the proliferation of ITTs. TIO continues to strive to overcome those barriers to promote the supply of technologies and information to the market to expedite the cleanup of the nation's waste sites.

Document No.: 8

Title: *Forum on Eliminating Barriers to Innovative Technology Implementation*

Author/Sponsor: DOE and the Hazardous Waste Action Coalition (HWAC)

Publication Date: June 1995

Overview:

The Joint Forum on Eliminating Barriers to Technical Innovation in Remediation first convened on June 14, 1995. The forum was sponsored jointly by DOE and the HWAC, an association that represents the community of engineering and science firms that have expertise in the cleanup of hazardous and nuclear waste. The primary purpose of the forum was to convene key stakeholders to identify specific barriers to technical innovation and develop approaches to address those barriers.

The forum focused on efforts to:

- Assess and set priorities among barriers to innovation previously identified in earlier forums and pre-workshop activities
- Identify short-term action plans to address specific barriers to innovation

Barriers Identified in the Report:

The document identifies the following barriers to the adoption of ITTs:

- *Absence of verified and validated information for ITTs*: There is no overall system for addressing the absence of validated cost and performance data for technical issues relevant to a specific remediation project. There is a need for validated cost and performance data for specific technologies. Experiences of entities other than DOE are relevant to the effort to overcome the general lack of technology verification and validation. Data obtained by the effort would prove valuable in technology verification and validation.
- *Environmental restoration, relative to other construction activities, is perceived to be risky from a financial and liability perspective, and results are considered unpredictable.* Technologies that involve less risk to environmental restoration projects are inherently more attractive than ITTs. ITTs for which there are no established and documented performance histories therefore are not widely utilized.

- *Developers of ITTs and potential users of such technologies do not communicate well.* The respective needs of technology developers and users differ significantly. Developers need opportunities and funding to apply their solutions without incurring unacceptable risks to themselves, yet maintain their proprietary rights. Users must achieve tangible results with predictable cost and performance in a very risky environment.

Activities to Address Existing Barriers:

DOE has made a commitment to innovative remediation and has recognized the need for cooperation and the development of partnerships between DOE and its stakeholders to promote technical innovation in remediation.

Conclusions:

The document makes the following conclusions or recommendations with respect to the barriers to the adoption of ITTs:

- Develop a strategic approach to technology validation and verification that is based upon an existing state model (California).
- Adopt a systematic, program-wide strategic approach to innovative remediation that specifies development of local plans to clearly identify issues related to risk in operation effectiveness, stakeholder concerns, logistics, and economics.
- Modify contracting practices to permit multi-site and other contracting mechanisms to apply successful ITTs to numerous DOE sites under the same contract.
- Modify the 'risk' provisions of contracts to provide incentives to apply ITTs, and remove or reduce contractual disincentives to innovation.
- Increase awareness within the DOE community of the regulatory flexibility currently exhibited by EPA.
- Increase the use of performance-based RODs and interim response actions to reduce the uncertainty associated with cleanups before adopting an ITT.

Document No.: 9

Title: *Innovations in Groundwater and Soil Cleanup*: *From Concept to Commercialization*

Author/Sponsor: National Research Council (NRC)

Publication Date: 1997

Overview:

During the 1990s, as the limitations of conventional subsurface remediation technologies have become increasingly clear, the use of ITTs has become increasingly common in the cleanup of contaminated soil and of leaking underground storage tanks that contain petroleum products. However, ITTs are used only rarely for cleaning up groundwater at major contaminated sites regulated by the Superfund and RCRA programs.

Statement of Problem:

Since the late 1980s, reports prepared by a number of organizations have indicated that there are significant barriers to the development of remediation technologies for commercial markets. Barriers to the use of ITTs are complex and range from the inherent variability of the subsurface environment to regulatory obstacles, conservatism on the part of owners of hazardous waste sites and their consultants, and lack of reliable data on technology performance.

Much of this report focuses on developing credible data sets that can be used to compare ITTs with conventional ones and to transfer technology used at one site to another site without repeating all elements of testing performed for the site at which the technology was applied.

Barriers Identified in the Report:

The document identifies the following barriers to the adoption of ITTs:

- *The remediation technology market is fragmented by client type and by site type:* Clients can be grouped into two categories: (1) the private sector, including companies representing a broad range of types and sizes, and (2) the public sector, including federal agencies. Within the private sector market, there is wide variation by type of client and size of site. Similarly, the characteristics of the public-sector market vary because of the significant differences among the agencies responsible for contaminated sites. Further complicating matters, clients usually are represented by consultants that may have their own concerns about the performance of ITTs. A much more difficult problem for remediation technology vendors is the fragmentation of the remediation market according to type of site. A technology that works well for cleaning up a particular contaminant in a particular geologic setting may not work at all when applied to the same contaminant in a different geologic setting. When a new technology is offered to the client, it must be accompanied by technical expertise on applying the system in the setting of the particular client's site of concern.

- *The regulatory structure for implementing hazardous waste cleanups, especially at Superfund and RCRA sites, has added to the inherent difficulties that vendors of ITTs face in bringing new products to the market:* The two programs rely on regulatory push rather than market pull to create demand. The process of technology selection is regulated strictly and the penalties for failing to initiate remediation promptly are insufficient.

- *In many cases, it is less costly to a company to delay remediation through litigation than to select a technology and begin cleanup:* The incentive to delay, rather than begin, cleanup reduces market demand for remediation technologies, including ITTs. Economic incentives for carrying out remediation are lacking under current policies. Companies perceive remediation as a tax on earnings and a bottom line deduction, rather than as an activity undertaken in the company's economic self interest. Companies frequently do not report liabilities related to environmental cleanup on their corporate balance sheets; therefore, there is no economic incentive to improve remediation. If a company were to assess voluntarily all its future remediation costs and post the total on its balance sheet, the value of the company would be reduced, creating a disadvantage relative to companies that do not report such liability.

- *The time line for selecting and installing a remediation technology can be very long and can vary unpredictably from site to site:* This circumstance is caused by the incentives to delay remediation and in part by the long series of regulatory steps involved in selecting a cleanup remedy for a site. Because of unpredictable time delays technology developers and investors find it difficult to forecast cash flow, resulting in serious financial difficulties for technology providers that are of great concern to investors.

- *Private-sector companies can be hesitant to share information about their contaminated sites:* Because of this lack of information-sharing, technology vendors find it difficult to predict the potential size of the market for their product and to establish sites to which they can refer future clients for evidence of the technology's performance.

Conclusions:

The document makes the following conclusions with respect to the barriers to the adoption of ITTs:

- Economic incentives for remediation must be created. If customers derived financial value and economic differentiation from improved remediation and accelerated cleanup, they would perceive remediation as an activity worth pursuing in part based on their own self-interest.

- Enforcement of regulations must be more consistent. It is imperative to have a predictable, known, and consistent enforcement mechanisms, accompanied by severe penalties. Lacking sufficient enforcement and penalties for noncompliance, the system rewards those who delay.

- The regulatory process for selecting cleanup goals and remediation technologies should be more predictable. For example, the detailed steps in selecting remedies for two different sites that have similar geophysical characteristics and contaminants should be similar, regardless of the regulatory program under which the sites are being cleaned up or the EPA office responsible for overseeing the cleanup. EPA should conduct a detailed review of remedy selection procedures at Superfund and RCRA sites in its 10 regions. Using the results of that review, EPA should identify the degree to which the procedures vary and should recommend steps for making the process more consistent. EPA also should consider whether the establishment of national cleanup standards for groundwater and soil would enhance the cleanup process by providing greater consistency. In addition, EPA should develop guidelines that would establish tentative time lines for reaching the various regulatory milestones at sites of various degrees of complexity. Such guidelines would assist technology developers in anticipating with greater certainty how long they might have to wait before they receive a job contract.

- Customers must have the freedom to choose any remediation technology or group of technologies they desire to meet the required cleanup standards. Regulators should be indifferent about how a company or federal agency cleans up a site, as long as the regulatory requirements for risk reduction are met. Current regulatory preapproval of remediation technologies should be curtailed. GAO should examine the program of the state of Massachusetts under which licensed site professionals select remediation technologies on behalf of environmental regulators and should recommend whether such a program should be implemented nationwide.

- Complete information about the size and nature of all sectors of the remediation market must be made available. Companies, as well as government agencies, should be required to disclose fully information about all contaminated sites that exceed a given size or pose a risk greater than an established level. EPA could use such information to develop a national registry of contaminated sites.

- More opportunities should be created to test ITTs and verify their performance. Programs that encourage the testing of ITTs should be given high priority. Further, a coordinated program is needed for formally verifying remediation technology performance. Official, federally-sanctioned verification of the performance of technologies provides customers with assurance that performance data on new technologies are valid and representative of the expected performance of the technology. Verification of performance also could reduce regulatory barriers, expedite the entry of technologies into the market, and facilitate the raising of capital needed to commercialize new technologies.

Document No.: 10

Title: *Impediments to Deploying Technologies at DOE Sites and Their Solutions, Getting the "Right Technology at the Right Site at the Right Time"*

Author/Sponsor: DOE

Publication Date: 1998

Overview:

This report examines problems and commonly proposed solutions related to barriers to implementing improved technologies in the DOE Environmental Management program. The problems discussed in the report were identified over the four years preceding its publication. Many of the barriers are being addressed by recently instituted initiatives in the Office of Environmental Restoration and the Office of Science and Technology.

Statement of Problem:

DOE's technology problems related to remediation technologies arose because the agency lacked a well-coordinated and fully integrated technology development and deployment program. The agency's

technology needs have not been comprehensively identified to support prudent decisions about research, nor have the various environmental management program offices in headquarters and in the field worked together effectively to identify and evaluate all the possible technology solutions available. Further, internal decision-making processes have prevented a full discussion of opportunities for the application of new and promising technologies in environmental cleanup and waste management activities.

Barriers Identified in the Report:

The document identifies the following categories of barriers to the adoption of ITTs:

- *Attitudinal barriers*: The federal budget process discourages rapid cleanup efforts because funding allocated to sites decreases as cleanup progresses. There is little incentive to complete projects as quickly and cost-effectively as might be possible. Adverse effects of new technologies on employment are perceived by many as a disincentive to their use. A significant disincentive is the "not invented here" attitude toward outside technologies, which is evident within DOE and reflected in resource allocations.

- *Management barriers*: Rigid management hierarchy and bureaucracy tend to encourage continuation of the 'status quo.' Flexibility of senior management and acceptance of responsibility on the part of lower management and staff are crucial to the implementation of new ideas and procedures and to the reduction of impediments to the deployment of innovative and improved technologies at DOE sites.

- *Technical barriers*: The lack of a third-party process for the verification and validation of data on performance and cost of specific applications is a perceived limit on DOE's ability to implement new technologies.

- *Lack of teamwork and coordination*: Two significant disincentives to the development and implementation of ITTs are the lack of cooperation by regulatory agencies and the lack of acceptance on the part of stakeholders:

  - The lack of uniform interstate regulatory acceptance results in increased costs and delays during the process of developing and implementing ITTs. In the absence of a national process, technologies must be demonstrated repeatedly, and requirements vary from demonstration to demonstration. Further, regulators in each state must scrutinize the details of performance claims carefully before they approve each proposed implementation.
  - Lack of acceptance on the part of stakeholders slows both the development and the implementation of ITTs.

- *Lack of communication*: Knowledge is not shared within the DOE complex, among DOE organizations, among DOE and industry, or among DOE and regulators.

- *Perception of the environmental market as a high risk market*: A leading disincentive is the perception of high risk associated with uncertainties in the environmental management market. The perception of high risk is found throughout the environmental market and has brought about the widely discussed lower-than-expected investment in the development and commercialization

of new technologies. Factors that contribute to the perception include: (1) the lack of definition of the environmental management market and its submarkets, (2) the lack of specific performance requirements, and (3) the lack of award incentives based on early competition in production design.

- *Procurement barriers*: Two significant obstacles prevent procurement and large-scale use of the services of technology providers by DOE: (1) lack of such service providers and (2) lack of economic incentives. There are other barriers, as well, including:

  - It is difficult to entice vendors to develop technologies that have limited applicability outside DOE
  - Contracts do not provide incentives or reward risk-taking
  - States and other stakeholders are reluctant to turn over some efforts to private industry
  - The DOE procurement process is time- and resource-intensive
  - It is difficult to identify contract opportunities with DOE, particularly for smaller companies

- *Budget process barriers:* Only a very small portion of the entire life cycle of a project is taken into consideration when remediation alternatives are compared. The R&D cycle, which may take 5 to 10 years, is not aligned with the appropriations cycle for DOE R&D programs. The appropriations process creates significant uncertainty about the timing and level of funding available for the management of environmental problems at individual DOE sites. Therefore, even though the technology base may have been developed on schedule to enable cleanup on time and within projected limits, adequate funds may not be appropriated. This disincentive combines with inefficiencies in procurement to create significant additional uncertainties that increase investors perception of risk in the DOE market.

- *Regulatory Barriers*: While it may be the policy of regulators to promote the use of ITTs, the practice is perceived by the regulated community to be quite different. The requirements that technology providers and DOE perform a full demonstration in each state in which a technology is under consideration is a financial disincentive to the use of the technology. In addition, the inconsistent, multi-level permitting and regulatory process, from state to state and from regulator to regulator, and inconsistent regulatory enforcement preclude large-scale implementation of ITTs. Inability or reluctance to use the full flexibility of environmental statutes limits the ability to use performance-based contracting to identify the best remediation strategy. Because of strict liability under CERCLA, responsible parties are very selective about cleanup technologies, often opting for more proven methods even if those methods are more costly. Other barriers include regulators' lack of knowledge about new technologies, conflicting perceptions on the part of regulators, lack of urgent regulatory requirements or drivers, excessive cost of compliance with DOE orders, issues related to allocation of liability and indemnification, and the reluctance of regulators to appear too lenient with DOE.

Conclusions:

Although over the past few years, ITTs have been incorporated into the remedy selection process, very few such technologies have been selected as cleanup options. To promote the evaluation and selection of

ITTs, incentives must be provided. DOE's Office of Environmental Restoration has initiated an effort to work with industry to identify incentives, as well as candidate sites for application of ITTs.

Regulators and stakeholders often do not accept an innovative technology as the chosen remedy because detailed documentation is not available to certify and validate its cost and performance. Therefore, it is important that cost and performance information about ITTs be collected and published.

APPENDIX B

LIST OF OTHER DOCUMENTS REVIEWED FOR THIS STUDY

Documents that discuss innovative environmental technologies -- Of the 33 documents subjected to preliminary reviews for this study, 12 discuss the barriers to innovative environmental technologies. For the most part, these documents address issues related to a wide variety of environmental technologies. Some mention of the innovative treatment technologies (ITT) market can be found, but ITTs are not necessarily the main focus of the documents. The 12 documents are listed below:

Barriers to Environmental Technology Innovation and Use; Research Report; Funded by the Joyce Foundation and the U.S. Environmental Protection Agency (Cooperative Agreement); Prepared by the Environmental Law Institute; January 1998.

Bridge to a Sustainable Future: National Environmental Technology Strategy; National Science and Technology Council; April 1995.

Bridging the Valley of Death: Financing Technology for a Sustainable Future; Funded by and Prepared for the U.S. Environmental Protection Agency (Interagency Agreement); Prepared by the U.S. Small Business Administration; December 1994.

Environmental Technology Initiative: FY 1994 - FY 1995 Projects, *Removing Barriers to Innovations That Protect Public Health and the Environment* (EPA 238-R-96-001); U.S. Environmental Protection Agency and Innovative Technology Council; July 1997.

Improving Technology Diffusion for Environmental Protection, Report and Recommendations of the Technology Innovation and Economics Committee; Prepared for the U.S. Environmental Protection Agency; Prepared by the National Advisory Council for Environmental Policy and Technology (NACEPT); October 1992.

Incentives and Barriers to Commercializing Environmental Technologies, Results of an Environmental Technology Market Needs Assessment; Prepared for the U.S. Environmental Protection Agency, Office of Research and Development; Prepared by the National Environmental Technology Applications Corporation, University of Pittsburgh Trust, Pittsburgh, Pennsylvania; March 1990.

National Environmental Technology Strategy: Status & Action; 3rd Annual Private Enterprise Government Interaction (PEGI) Roundtable Conference; PEGI Task Group Committee on Environment and Natural Resources; Rosslyn, Virginia; November 7, 1995.

Report on Barriers to Pollution Prevention; Minnesota Office of Waste Management; March 1991.

Stakeholder Attitudes on the Barriers to Innovative Environmental Technologies; Funded by the U.S. Environmental Protection Agency (Cooperative Agreement); Prepared by Abt Associates, Inc. with the collaboration of the Environmental Law Institute; January 1998.

Technology for a Sustainable Future: A Framework for Action; National Science and Technology Council.

Transforming Environmental Permitting and Compliance Policies to Promote Pollution Prevention, Removing Barriers and Providing Incentives to Foster Technology Innovation, Economic Productivity, and Environmental Protection; Prepared for the U.S. Environmental Protection Agency; Prepared by NACEPT's Technology Innovation and Economics Committee; April 1993.

White House Conference on Environmental Technology (working papers); Washington, D.C.; December 11-13, 1994.

Documents or information sources that contained little or no information about barriers to innovative environmental technologies or ITTs -- Nine of the 33 documents contained general information on barriers to innovative environmental technologies and ITTs, but minimal information directly related to barriers to their development and use. The nine documents and web sites are listed below:

Cleaning Up the Nation's Waste Sites: Markets and Technology Trends, 1996 Edition (EPA 542-R-96-005); U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response; April 1997.

Environmental Technology Verification Program Verification Strategy (EPA/600/K-96/003); U.S. Environmental Protection Agency, Office of Research and Development; February 1997.

Regulatory Barriers to Pollution Prevention: A Position Paper of the Implementation Council of the American Institute for Pollution Prevention; Prepared for the U.S. Environmental Protection Agency, Risk Reduction Engineering Laboratory, Cincinnati, Ohio; Prepared by the Aluminum Company of America; 1991.

Summary of Treatment Technology Effectiveness for Contaminated Soil (9355.4-06); U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response; June 1990.

Environmental Technology Initiative; http://www.gnet.org/eti/abouteti.htm

National Environmental Technology Test Sites (NETTS) Program;
http://www.serdp.gov/netts/default.html

Reinvention for ITTs (RefIT); http://www.wpi.org/epa/refit/

Resolving Barriers to Soil Treatment: Session Output and Analysis; Concurrent Session, 7th National TIE Workshop; April 1995; http://www.em.doe.gov/tie/sum955a.html

White House Conference on Environmental Technology; http://es.epa.gov/program/exec/techconf.html

Document that summarized "barrier studies" -- Two documents presented a review of other studies on barriers to ITTs, but provided little new information on the subject. These documents were:

Summary of Barrier Studies and Examples of Technology Programs for Development of Innovative Remedial Technologies; Miljostyrelsen (National Environmental Protection Agency, Denmark); May 1997.

Hard Times for Innovative Cleanup Technology; Environmental Science and Technology (ES&T); December 1997.

APPENDIX C

LIMITATIONS OF THE STUDY AND ANALYSIS

While each of the documents used for this report describes specific barriers to the development and use of innovative treatment technologies (ITT), the documents do not establish priorities among those barriers in terms of the significance of their effects on the development and use of ITTs. Most of the documents reviewed for this report do not provide insight into which of the barriers might be easiest to resolve. Some of the documents, however, do identify or recommend potential approaches to the removal or reduction of the barriers identified. Such recommendations are provided throughout this report, but are not subjected to detailed analysis.

Of the 10 documents reviewed for this report, four pertain specifically to the use of ITTs in the U.S. Department of Energy (DOE) environmental remediation market segment. However, the types of barriers encountered in using ITTs in the DOE environmental market largely are relevant to the use of ITTs in other market segments. In fact, in its report for DOE, *Management Changes Needed to Expand Use of Innovative Cleanup Technologies*, the U.S. General Accounting Office (GAO) states that those barriers identified that pertain to DOE are similar to those that inhibit the use of ITTs by other government agencies, and particularly by EPA.

The analyses presented in this report are subject to the following limitations:

1) Of the 10 documents reviewed for the study, five pertain specifically to the use of ITTs in the U.S. Department of Energy (DOE) environmental remediation market. The types of barriers encountered in using ITTs in the DOE environmental market also may be relevant to the use of ITTs in other markets. Nevertheless, because of the number of the documents reviewed that address the DOE market, the findings presented in this study might be biased toward the identification of barriers that pertain to that market.

2) No analysis at the state level could be performed for the study because none of the documents used for the study address barriers that are unique to individual states. Because state agencies frequently determine whether ITTs meet performance and cleanup standards, the absence of a comparative analysis of barriers introduced by the various regulations and standards imposed by state agencies is a limitation to this study.

3) The barriers identified in the study are grouped in four categories: institutional; regulatory and legislative; technical; and economic and financial. Each barrier was assigned to only one category. However, because the categories are broad and at times may overlap, it is likely that certain barriers easily could fit into more than one category.

4) Because this report was written based on information obtained from other sources, access to the original data was not possible. Therefore, it is assumed that publication dates (ranging from 1985 to 1998) of the sources used indicate that the barriers which the publications discuss were in fact barriers to developing and using ITTs at the time of publication.

5) For some barriers, no specific initiative addressing them was identified in the source documents or developers' guide reviewed for this analysis. It is important to note that the list of initiatives and programs provided in Table 4-1 is not comprehensive and initiatives or policies may exist that address these barriers.