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Report to Congressional Requesters

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SUPERFUND

EPA Has Identified Limited Alternatives to Incineration for Cleaning up PCB and Dioxin Contamination

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The Honorable Jerry Lewis
Chairman
The Honorable Louis Stokes
Ranking Minority Member
Subcommittee on VA, HUD,
and Independent Agencies
Committee on Appropriations
House of Representatives

The Honorable James M. Talent
The Honorable Jim Chapman
The Honorable Barney Frank
House of Representatives

One of the most contentious environmental issues facing the Environmental Protection Agency (EPA) today is the use of incineration to clean up Superfund sites contaminated by polychlorinated biphenyls (PCB) or dioxin. Across the country, local community groups are protesting the choice of incineration as the treatment remedy. Many people believe that incinerators have the potential to emit hazardous substances that could lead to adverse health effects in their communities. Consequently, these community groups want EPA to use technologies other than incineration to clean up sites. However, EPA believes that the effectiveness and safety of many alternative technologies remain unproven.

Because of the public's concerns about the use of incineration at PCB- and dioxin-contaminated sites, you asked us to identify (1) what EPA has done to encourage the development and use of alternative or "innovative" technologies at all contaminated sites, including those with PCBs and dioxin;[1] (2) whether EPA has identified innovative technologies that can be used at PCB- and dioxin-contaminated sites; and (3) what factors have limited the use of innovative technologies at PCB- and dioxin-contaminated sites. In addition, to provide an illustration of how EPA decides what cleanup technology will be used, you asked us to conduct three case studies at PCB- and dioxin-contaminated sites where EPA has proposed incineration as the remedy. Our observations on these sites—Texarkana

[1]EPA considers a technology to be innovative if it has not been used in a full-scale application or if it is the first-time application of an existing technology to a new contaminant. More specifically, EPA defines innovative treatment technologies as those that lack the cost and performance data necessary to support their routine use.

Wood Preserving Company, Texas; Times Beach, Missouri; and New Bedford Harbor, Massachusetts—are described in appendix I.

Results in Brief

Although EPA has taken a number of steps to encourage the development and use of innovative technologies in general, it has not yet identified any technologies it believes to be as effective as incineration for most PCB- or dioxin-contaminated sites. As a result, EPA has relied on incineration for many sites with PCB and dioxin contamination. Specifically, we found the following:

- EPA has established programs and issued guidance to encourage the development and use of innovative technologies for all types of contaminants.[2] Overall, EPA has chosen innovative technologies in about 20 percent of its cleanup decisions at Superfund sites. However, EPA has used innovative treatment technologies at only about 10 percent of the PCB-contaminated sites and 3 percent of the dioxin-contaminated sites, and then mostly at small, uncomplicated sites.[3]
- EPA has not identified any innovative technologies it believes to be as effective as incineration for treating the waste at large, complex PCB- or dioxin-contaminated Superfund sites. However, several innovative technologies are being developed and tested that may someday prove as effective, either alone or in combination, in cleaning most sites with these contaminants. Accordingly, EPA has recognized that some of its previous decisions on the cleanup technologies to be used should be reevaluated to take advantage of recent technological advancements.
- EPA has identified a number of barriers that currently inhibit the further development and routine use of innovative technologies at Superfund sites. A primary barrier is the inability of current innovative technologies to meet performance standards for incineration—the remedy on which regulatory standards are based.[4] Other barriers include technical limitations, limited cost and performance data, and the lack of incentives to invest in the development of innovative technologies. Because of these

[2]EPA's innovative technology programs and guidance are focused on all types of contaminants, as opposed to being focused on individual contaminants such as PCBs or dioxin. As requested, we focused on PCBs and dioxin because they are difficult to treat and highly toxic. (See app. II for a discussion of PCB and dioxin contamination.)

[3]At other sites, large volumes of complex waste, such as those with multiple contaminants or high levels of contamination, make the use of innovative technologies more difficult. However, sites with small volumes of uniform waste, even those containing PCBs or dioxin, can more readily accommodate the use of innovative technologies.

[4]Performance standards are based on the level of effectiveness of a specific technology. Performance standards generally are not based on the level of health risk associated with that level of effectiveness.

barriers, and of the proven effectiveness of incinerators, EPA has so far relied on incineration to clean up most sites contaminated with PCBs or dioxin.

Background

With the enactment of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in 1980, the Congress created the Superfund program to clean up the nation's most severely contaminated hazardous waste sites. The program was extended in 1986 and in 1990 and is now being considered again for reauthorization. Under CERCLA, EPA investigates contaminated areas and then places the nation's most highly contaminated sites on a priority list, called the National Priorities List (NPL), for investigation and cleanup. As of September 1995, EPA had 1,238 sites on the NPL. Of these sites, approximately 190 had PCB contamination and about 80 had dioxin contamination.[5]

After EPA puts a site on the NPL, the agency goes through an extensive process to determine what remedy or remedies for cleanup would be appropriate for that site. The remedy selected depends upon the characteristics of the individual site, such as the types and levels of contamination, the complexity of the site's problem, the site's risk assessment, and the cleanup standards.

EPA weighs each potential remedy against a number of criteria set forth in federal regulations. These criteria include the long-term protection of human health and the environment; compliance with the applicable or relevant and appropriate federal and state laws; and the community's acceptance of the remedy being considered. Using these criteria, EPA has generally selected incineration as the remedy for many large, complex Superfund sites contaminated with PCBs or dioxin—two compounds that pose significant threats to human health and the environment. (See app. III for a further discussion of incineration technology.)

Under CERCLA, incinerators at Superfund sites must comply with applicable technical requirements contained in federal regulations. In particular, the incineration of dioxins is governed by regulations issued under the Resource Conservation and Recovery Act of 1976 (RCRA), as amended. Similarly, the incineration of PCBs is governed by regulations issued under the Toxic Substances Control Act (TSCA).

[5]Because some sites may have both PCB and dioxin contamination, these numbers may not be added together to yield a total number of PCB- and dioxin-contaminated sites.

EPA's Efforts to Encourage the Development and Use of Innovative Technologies

EPA has established two offices to encourage the development and use of innovative technologies. One is the Superfund Innovative Technology Evaluation (SITE) program, which evaluates cleanup or waste removal technologies. The second is the Technology Innovation Office (TIO), which acts as a clearinghouse for information on innovative cleanup technologies. In addition, EPA has issued guidance that encourages the consideration of innovative technologies for cleaning up Superfund sites.

These efforts do not focus on specific contaminants such as PCBs and dioxin but are designed to promote the development and use of innovative technologies for all types of contaminants. Overall, in 1994, EPA selected innovative technologies in about 20 percent of its decisions on remedies for all Superfund sites. For PCB- and dioxin-contaminated sites, EPA selected innovative treatment technologies to a lesser extent than at other Superfund sites.

Superfund Innovative Technology Evaluation Program

EPA established the Superfund Innovative Technology Evaluation program in 1986 to accelerate the development and encourage the routine use of innovative technologies.[6] Under the SITE program, EPA enters into cooperative agreements with private technology developers who, after refining their technologies on a small scale, may demonstrate them, with support from EPA, at Superfund sites. The SITE program periodically publishes reports containing engineering, cost, and performance information for the technologies evaluated. For example, in fiscal year 1995, SITE spent about $12 million to demonstrate 11 technologies. None of these treated a PCB- or dioxin-contaminated site.

Superfund officials involved in cleaning up sites stated that SITE's reports on demonstrations often focus on the science of the innovative technologies and provide only limited information on potential implementation problems. For example, the Superfund site manager at one site we visited told us that SITE had initially been extremely positive about the scientific potential for one of its demonstrated technologies at that site. However, after learning about the site's specific characteristics, SITE officials decided the technology was inappropriate for that site.

These criticisms remain, although Superfund program officials stated that they had begun to work with SITE in 1993 to make its information more useful, and as a result, additional information has been added to SITE's

[6]The Superfund Amendments and Reauthorization Act of 1986 (SARA) directed EPA to establish a research and development program for innovative treatment technologies.

technology demonstration reports. SITE program officials noted that resource constraints require them to set priorities for the scope of demonstrations conducted and thus limit the information that can be provided.

Technology Innovation Office

In 1990, EPA established the Technology Innovation Office to increase the use of innovative treatment technologies. TIO serves as an information clearinghouse to provide (1) prospective technology vendors with information on the extent and nature of sites needing cleanup and (2) cleanup officials with information on the availability of innovative technologies. In addition, TIO attempts to identify why innovative technologies are not being used more frequently. In fiscal year 1995, TIO spent about $2 million to carry out these responsibilities.

To serve as an information clearinghouse, TIO maintains several databases containing information on innovative technologies and innovative technology vendors. However, Superfund officials told us that the cost and performance data contained in TIO's database of innovative technology vendors is vendor-supplied and TIO does not validate it. TIO officials stated that these data are supposed to be only the starting point for identifying potential innovative technologies and that TIO does not have the resources to validate the data. In addition, TIO officials believe that requiring vendors to supply independently validated data might exclude some innovative technology vendors.

TIO officials, however, recognize that those responsible for cleaning up hazardous waste sites need reliable cost and performance data and have taken actions to address this problem. For example, working through the Federal Remediation Technologies Roundtable, composed of major federal agencies that carry out remediation research and projects, a guide to documenting remediation projects' cost and performance was developed. This guide, which all member agencies have agreed to use, provides project managers with standard procedures for collecting and reporting project information.

TIO also attempts to encourage the use of innovative technologies by identifying why innovative technologies are not being selected more often at Superfund sites. For example, TIO published a study[7] in April 1995 which showed that Superfund cleanup officials were often eliminating innovative

[7] Feasibility Study Analysis, Volume 1: Findings and Analysis, prepared for the Technology Innovation Office by Environmental Management Support, Inc., Silver Spring, MD, Apr. 21, 1995.

technologies from the remedy selection process without fully considering them. That study, based on 205 sites, found that EPA conducted tests to assess the potential performance of innovative technologies at only 47 sites (less than 25 percent) of the 205 sites. When these tests were conducted, however, innovative technologies were used in about 45 percent of the remedies selected. Superfund officials said that even though guidance encourages the testing of innovative technologies, such tests were not performed in a large number of cases because of time constraints and funding limitations. TIO staff are now considering a number of actions to address these and other problems identified in the report.

EPA's Guidance on the Use of Innovative Technologies

EPA has issued guidance encouraging greater use of innovative technologies at all Superfund sites where such remedies can provide a viable means for treatment. For example, in guidance issued in June 1991, EPA urged staff responsible for selecting Superfund remedies to consider innovative technologies in their technology evaluations for all sites (including those contaminated with PCBs and dioxin), even when the cost and performance of the innovative technologies were uncertain. The guidance also encouraged EPA project managers to use on-site tests to assess the potential performance of innovative technologies at sites. Furthermore, it provided for expedited funding to facilitate early testing of innovative remedies.

EPA officials told us that they are considering revising the guidance to increase the use of on-site tests to determine the potential performance of innovative technologies. However, the officials stated that they want to avoid becoming too prescriptive because the testing of innovative technologies may not be appropriate for all sites.

EPA's Use of Innovative Technologies

EPA's most recent data show that EPA selected innovative technologies in about 20 percent of all decisions on remedies made in 1994, up from 6 percent in 1986. However, EPA is using fewer innovative technologies at PCB- and dioxin-contaminated sites than at Superfund sites overall. At sites with PCB contamination, EPA selected innovative technologies that fully treat the contamination at about 10 percent of the sites for which a cleanup technology was selected. In addition, EPA selected innovative technologies that extract the PCB contamination (but do not destroy it) at another 20 percent of the sites for which decisions on cleanup technologies have been made. For these sites, the PCB contamination will have to be treated further with another remedy—such as incineration. For dioxin-contaminated sites, EPA selected innovative cleanup technologies 3 percent of the time.

EPA Has Identified Limited Options for Cleaning Up PCBs and Dioxin

Even though EPA has generally not used innovative technologies for PCB- and dioxin-contaminated sites, it has identified several technologies that have the potential to clean up PCBs and dioxin in the future. However, to be effective, some of these technologies may have to be used in combination. Accordingly, EPA has recently recognized that for some sites, previous decisions on cleanup technologies should be changed if new technologies that provide more efficient and cost-effective cleanups have been developed.

Innovative Technologies for PCB and Dioxin Contamination

EPA has identified technologies that have the potential to become alternatives to incineration for PCB and dioxin contamination in the future. However, EPA believes that these technologies are currently not viable options for cleaning up most PCB- and dioxin-contaminated sites because they are still at their early stages of development. Many of these technologies have been used only in laboratory studies designed to generate data on their potential. Other innovative technologies are relatively more advanced; they have been tested, selected, or actually used to treat PCBs or dioxin at some small, uncomplicated sites and have generated some cost and performance data. However, these technologies still lack the well-documented cost and performance data, under a variety of site conditions, needed to expand their consideration and use.

Innovative technologies that could potentially clean PCB and dioxin contamination can generally be grouped into three categories: (1) those that destroy the contamination, (2) those that extract the contamination (which still must be treated), and (3) those that simply contain or immobilize the contamination in place.[8] Innovative remedies that destroy contamination, such as dechlorination, destroy PCB and dioxin molecules by removing chlorine. Technologies that extract contamination may use, for example, a chemical solvent or heat to remove the contaminants from soil or other media. The remaining concentrated contaminants generally require further treatment—such as incineration—but the extraction process reduces the volume of waste that must be treated. Technologies that immobilize hazardous waste may, for example, stabilize the contaminant by using a substance, such as cement, that will bind with and

[8]Each of these broad technological categories contains a number of individual technologies offered by different technology developers and contractors. For example, each extraction technology developer would have its own methods and equipment for extracting contamination.

solidify the contaminated media. (See app. IV for a further explanation of innovative technologies.)

Use of Innovative Technologies in Combination

For many of these innovative technologies to be effective at complex sites, EPA must use a combination of different technologies, thus increasing the complexity and uncertainty of the cleanup. For example, to fully clean a site, an extraction technology, which removes and concentrates the contaminant, would have to be used in combination with a destruction technology, which destroys the concentrated contaminant. Also, because some innovative technologies work only on specific contaminants, a site with multiple contaminants would require the use of multiple innovative technologies to address each contaminant. The TIO study cited earlier found that innovative technologies were often being eliminated from consideration at sites because of the need to use combinations of technologies and the resulting uncertainty of success.

EPA's Proposal to Reevaluate Decisions on Remedies

In October 1995, as part of its administrative reforms, EPA proposed that the decisions on cleanup technologies at selected sites be reevaluated to take advantage of the cost savings made possible by new technologies. EPA's proposal recognized that some remedies selected in the past, while correct at the time, may not be the cleanup method the agency would select now. In a September 1995 report, the Office of Technology Assessment (OTA) also concluded that EPA should reexamine some of its previous decisions on cleanup technologies on the basis of the availability of new technologies.[9]

Barriers to the Use of Innovative Technologies

Several factors, often inherent in any unproven technologies, have inhibited the further development and widespread use of innovative technologies at PCB- and dioxin-contaminated sites. These factors include (1) regulatory standards, (2) the technical limitations of technologies, (3) the lack of sufficient cost and performance data, (4) the lack of incentives for private industry to invest in innovative technologies, and (5) EPA's general preference for technologies it believes to be effective.

Regulatory Standards

For the treatment of PCBs and dioxin, EPA sets standards that are based in part on the performance of incinerators. These standards are based on the

[9]This study, Cleaning Up Contaminated Wood-Treating Sites, OTA-BP-ENV-164, Sept. 1995, was done in response to your request to examine the public safety effects of incineration.

effectiveness of incineration, not necessarily the health risk associated with the specified cleanup level. Generally, innovative technologies have been successful in meeting these standards only at certain smaller PCB- or dioxin-contaminated sites where the concentration levels of the contaminant were low and under relatively controlled conditions.

Recognizing this barrier, EPA recently proposed amendments to its regulations for PCBs to allow more flexibility in the cleanup standards.[10] Specifically, the proposal would allow, in addition to performance-based standards, other cleanup standards, including health-based ones, which may be potentially easier for innovative technologies to meet. EPA is currently reassessing the health risks from dioxin. EPA officials told us that any regulatory changes will occur after that reassessment is complete.

Technical Barriers

Technical barriers have also limited the application of innovative technologies for PCBs and dioxin. Because most innovative technologies are at their early stages of development, they generally are not yet suited for cleaning up sites with highly toxic contaminants (such as PCBs or dioxin), large amounts of contaminated materials, high concentrations of the contaminants, or multiple contaminants. In addition, innovative technologies' performance generally depends on the physical and chemical characteristics of the contaminated material, such as moisture levels, clay and silt content, and the presence of other chemical substances. As a result, EPA has generally used innovative technologies only at PCB- and dioxin-contaminated sites with low levels of contamination and uniform conditions. The use of innovative technologies at dioxin-contaminated sites has been even more limited than at PCB-contaminated sites because dioxin tends to be difficult to remove from soil and is typically present in a variety of contamination settings (i.e., different types of soils and environmental conditions).

Limited Cost and Performance Information

Many innovative technologies are still not fully developed or tested. Because most of these technologies have not gone through full-scale application, data on their cost, performance, and suitability under various site conditions are generally not available. EPA officials told us that they believe technologies must be used multiple times under a variety of conditions before their cost and performance data are reliable.

[10]Disposal of Polychlorinated Biphenyls, Proposed Rule, 59 Federal Register 62788 (Dec. 6, 1994).

EPA found that one of the reasons why innovative technologies are not selected more often is that the information necessary to make cleanup decisions is not readily available. As a result, EPA and private industry officials responsible for cleaning up PCB- and dioxin-contaminated Superfund sites have been reluctant to choose unproven innovative technologies. To overcome this reluctance, EPA entered into a cooperative agreement with Clean Sites[11] to demonstrate full-scale applications of innovative technologies at several federal facilities. The goal of the agreement is to demonstrate innovative technologies at real sites in order to generate actual performance data. Seven demonstrations are currently under way; however, data are not yet available on their outcomes.

Lack of Incentives to Invest in Innovative Technologies

Uncertainties about both the market for PCB and dioxin cleanups and future regulatory standards for cleanups also create a disincentive for private industry to invest in innovative technologies. The production of PCBs stopped in 1977, and the number of sites known to be contaminated with dioxin is relatively small. In addition, industry officials are uncertain how clean EPA will require PCB- and dioxin-contaminated sites to be in the future. Because the promulgation of new environmental standard often takes many years, investors often choose to wait rather than invest in innovative technology. They worry that if they invest money in a new technology, by the time the new standards come into effect, the technology might be obsolete.

EPA's Reliance on Incineration to Clean up PCB and Dioxin Contamination

EPA officials said that in light of the above barriers, they have chosen to rely on incineration to clean up PCB-and dioxin-contaminated sites. EPA officials told us that they have selected incineration because it meets EPA's existing regulatory standards, can perform under a variety of conditions, and has been successfully demonstrated in full-scale applications. They added that using a demonstrated technology becomes particularly important for PCB- and dioxin-contaminated sites because these two compounds are highly toxic and very difficult to treat.

Conclusions

The existence of hazardous waste sites with threatening contaminants such as PCBs and dioxin requires EPA to make tough choices about appropriate remedies. EPA must attempt to clean up sites expeditiously while protecting human health and the environment. Faced with this task,

[11]Clean Sites is a nonprofit corporation whose mission is to improve the cleanup of hazardous waste sites.

EPA officials have come to rely on incineration, a remedy they trust, to clean up sites with contaminants as hazardous as PCBs and dioxin. However, EPA also must convince communities that incineration is safe to gain their acceptance of its use.

While EPA's attempts to develop innovative technologies have not yet identified any that can clean complex sites contaminated with PCBs and dioxin, it has identified several that have the potential for future use. Accordingly, we agree with EPA's recent proposal to revisit its decisions on remedies at certain sites that could benefit from significant technological advancements.

Agency Comments

We provided copies of a draft of this report to EPA for its review and comment. On November 21, 1995, we met with EPA officials, including a Senior Process Manager from EPA's Office of Emergency and Remedial Response and officials from EPA's offices of Pollution Prevention and Toxics, Research and Development, and Solid Waste and Emergency Response, to obtain their comments on our draft. These officials generally agreed with the facts and findings in the report. They also suggested a number of technical corrections, which we incorporated into the report.

Scope and Methodology

You asked us to identify (1) what EPA has done to encourage the development and use of alternative, or "innovative," technologies at all contaminated sites, including those contaminated with PCBs and dioxin; (2) whether EPA has identified innovative technologies that can be used at PCB-and dioxin-contaminated sites; and (3) what factors have limited the use of innovative technologies at PCB- and dioxin-contaminated sites. To address the three objectives, we interviewed EPA officials at SITE and TIO, Risk Reduction Engineering Laboratory, Air and Environmental Research, Regions I, VI, and VII, and the Offices of Solid Waste, Emergency and Remedial Response, Research and Development, and Pollution Prevention and Toxics. We contacted representatives of three major industry groups, environmental consulting firms, and academia. Also, as you requested, we visited three Superfund sites with PCB or dioxin contamination and their applicable EPA regional office in order to provide an illustration of EPA's process for making decisions on remedies. In addition, we obtained and analyzed documents and data from EPA and the other individuals we contacted. Our work was performed in accordance with generally accepted government auditing standards between October 1994 and December 1995.

As arranged with your offices, unless you publicly announce its contents earlier, we will make no further distribution of this report until 10 days after the date of this letter. At that time, we will send copies of the report to other appropriate congressional committees; the Administrator, EPA; the Director, Office of Management and Budget; and other interested parties. We will also make copies available to others upon request. Should you need further information, please call me at (202) 512-6112. Major contributors to this report are listed in appendix V.

Peter F. Guerrero
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Protection Issues

Contents

Abbreviations

ATSDR	Agency for Toxic Substances and Disease Registry
BCD	base catalyzed decomposition
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DRE	destruction and removal efficiency
EPA	Environmental Protection Agency
NCP	National Contingency Plan
NPL	National Priorities List
OSWER	Office of Solid Waste and Emergency Response
OTA	Office of Technology Assessment
PCB	polychlorinated biphenyls
PICs	products of incomplete combustion
POHC	principal organic hazardous constituents
ppb	parts per billion
ppm	parts per million
RCRA	Resource Conservation and Recovery Act
SARA	Superfund Amendments and Reauthorization Act
SITE	Superfund Innovative Technology Evaluation program
S/S	solidification and stabilization technologies
TIO	Technology Innovation Office
TSCA	Toxic Substances Control Act

Three Case Studies

We visited three sites where both incineration and innovative technologies were considered during the remedy selection process. The Environmental Protection Agency (EPA) plans on using incineration at two of these sites—Texarkana, Texas, and Times Beach, Missouri. EPA had initially selected incineration at New Bedford, Massachusetts, but yielded to public pressure and is now searching for an alternative remedy. We did not evaluate whether EPA made the correct decisions, but we did discuss with the EPA regional officials responsible for each site why they, at least initially, chose incineration rather than an alternative technology.

The Texarkana Wood Preserving Company Site

The Texarkana Wood Preserving Company Superfund site is a 25-acre abandoned wood preserving facility in Texarkana, Texas. (See fig. I.1.) EPA placed the site on its National Priorities List in 1986. The cleanup effort at Texarkana is led by the state of Texas and is primarily federally funded. The site is contaminated with chemicals that are commonly found at wood preserving sites. The contamination occurred when wood preserving chemicals were dumped into storage ponds used for the wood treating operations. Approximately 77,000 cubic yards of soil, sludge, and sediment and 16 million gallons of groundwater are contaminated primarily with dioxin, polynuclear aromatic hydrocarbons, and pentachlorophenol. The site contains some areas of heavy contamination, particularly in the sludge. Further complicating the cleanup efforts, the Texarkana site is in a floodplain. The site lies in a mixed-use residential, industrial, and agricultural area.

Figure I.1: Remaining Structures of the Wood Treating Operations at Texarkana

Although there are no immediate risks, the site presents potential health risks in the future if left untreated. EPA determined that nearby residents are not currently at risk of adverse health affects—a residential community lies about one-third of a mile from the site. However, groundwater contamination is continuing to spread at the site. The spread could threaten drinking water if contamination reaches a deeper aquifer. In addition, surface run-off and leachate from the soil could potentially contaminate a nearby creek. EPA has estimated increased cancer risks for potential trespassers and for other persons if the site is used for other purposes in the future.

In 1990, EPA chose incineration on the basis of its assessment that it would be the most effective remedy for the type and combination of contaminants at the Texarkana site. Although EPA analyzed other options, it believed that incineration was the only technology that would reduce the contaminants to a level below health-based standards. According to EPA regional officials, to reach the cleanup standards using other technologies would require combining two or more technologies. They added that using multiple innovative technologies would raise the uncertainty level associated with new technologies even further. These standards are based on ensuring the safety of future industrial workers on the site. In addition, EPA officials judged that incineration was the best remedy for high levels of dioxin and for wood treating chemicals in general.

EPA considered the following alternative remedies for the Texarkana site: biological and chemical treatment, solidification, placing a protective cover over the site to reduce the spread of contaminants (capping), and off-site incineration. (See app. IV for a discussion of the innovative technologies.) EPA officials believed that chemical or biological remedies would not work successfully on all contaminants or achieve the agency's cleanup goals. They were also concerned about the possibility that biological or chemical degradation could produce a more toxic form of dioxin. EPA eliminated solidification because the technology was not expected to reduce the volume or toxicity of the waste to the same degree as the other treatments and because of the difficulty in solidifying the type of contaminants present at the site. EPA eliminated capping because it would not provide a permanent treatment, and the site's location on a flood plain increased the risk of continued release of contaminants. According to the EPA project manager, a cap at this site could be guaranteed only for about 6 years. In addition, the local community wanted the land usable for future industry, making solidification and capping inappropriate options because the contamination would still be on site. EPA decided against off-site incineration because of its high cost—the estimated cost was more than four times greater than on-site incineration.

EPA estimates that the planned incineration project will cost approximately $43 million and take approximately 2-1/2 years to fully clean the site. According to the project manager, EPA is in the process of conducting an analysis of incineration at the site to determine the potential health risk of the cleanup to nearby residents.

Currently, EPA is planning to take some measures to enhance safety at the site and to prevent the spread of contamination, in advance of full-scale cleanup efforts. According to the project manager, EPA plans to remove the structures on the site—the remnant of the wood preserving operation. It also plans to build a berm along the side of the site that borders a creek to prevent run-off from spreading, if necessary. These efforts by themselves, however, will not stem the spread of groundwater contamination.

Times Beach and Eastern Missouri Superfund Sites

The Times Beach Superfund site is a 0.8 square mile area located approximately 20 miles southwest of St. Louis, Missouri, in a mixed-use residential and agricultural area. The contamination at Times Beach, a formerly incorporated town, resulted from spraying unpaved roads for dust control with waste oil contaminated with dioxin in the early 1970s. In 1982, after severe flooding of the adjacent Meramec River, EPA discovered elevated dioxin concentrations on the surface of the former town's roadways. EPA paid approximately $30 million to buy the town and relocate its 2,240 residents. EPA placed Times Beach on the National Priorities List in 1983. In 1988, EPA estimated that dioxin levels in approximately 13,600 cubic yards of soil exceeded standards of 20 parts per billion (ppb) or less. Currently, the site is completely vacant and fenced.

EPA decided to address Times Beach and 26 other sites in eastern Missouri with similar dioxin contamination as a single response action in its cleanup plans. The waste oil hauler who sprayed Times Beach with dioxin-contaminated waste oil also sprayed the other 26 sites, which included streets, parking lots, and horse arenas. Because the dioxin contamination at each of these locations originated from the same source, EPA decided that it can be destroyed effectively by the same treatment. In addition, all but 3 of the 27 sites lie in the St. Louis metropolitan area. As a result, EPA determined that a combined response action for all 27 sites would be cost-effective and protective of human health and the environment. EPA estimated that a total of approximately 100 thousand cubic yards of contaminated material from all 27 sites will require treatment.

After analyzing several permanent cleanup options, EPA decided to excavate and incinerate the dioxin-contaminated material at Times Beach and the 26 eastern Missouri sites. For several years, EPA evaluated the effectiveness and safety of several different options and treatment technologies, including chemical and biological treatment. In 1988, EPA concluded that excavating and treating dioxin-contaminated material in a temporary incinerator at Times Beach was the most acceptable remedy of the various alternatives. EPA believed incineration would be protective of human health and the environment, cost-effective, attain applicable or relevant and appropriate requirements, and utilize permanent solutions to the maximum extent practicable. In addition, EPA believed incineration was the only method with the demonstrated ability to clean the large quantities of soil, storage bags, and other types of contaminated material found at the 27 dioxin-contaminated sites and reach the specified residential cleanup levels.

In 1990, a consent decree signed by EPA, the state of Missouri, and Syntex, the corporation responsible for the cleanup, implemented EPA's 1988 cleanup choice. The decree dictated cleanup responsibilities for each party involved. Under its terms, EPA had to excavate and transport dioxin-contaminated material from the 26 eastern Missouri sites to Times Beach, the site of the temporary incinerator. Syntex had to excavate and incinerate dioxin soil from Times Beach and to incinerate dioxin-contaminated material from the other eastern Missouri sites.

Several stages in the cleanup process for the 27 eastern Missouri sites have already been completed. EPA has excavated contaminated material at 10 of the eastern Missouri sites and placed approximately 67 thousand cubic yards of material in temporary storage buildings until completion of the incinerator. (See fig. I.2.) In addition, Syntex has completed several components of the work required by the consent decree, including demolition and disposal of structures and debris in Times Beach, construction of a ring levee to protect the incinerator subsite from floods, construction of an interim storage facility at Times Beach, and excavation and storage of approximately 21,000 cubic yards of dioxin-contaminated soil. Currently, Syntex subcontractors at the site have completed construction of the temporary incinerator. EPA expects that testing of the incinerator will begin in October or November of 1995 and full-scale operation will begin early 1996.

Figure I.2: Storage Buildings Containing Dioxin-Contaminated Materials From One of the Eastern Missouri Sites

New Bedford Harbor Superfund Site

The 18,000-acre New Bedford Harbor Superfund site in Massachusetts is an urban tidal estuary consisting of a harbor and bay that are highly contaminated with PCBs and heavy metals. Manufacturers in the area used PCBs while producing electric capacitors from 1940 to 1978 and discharged PCB-containing waste into the harbor. The contamination of the sediments in the harbor and bay areas has resulted in closing the area to lobstering and fishing and has limited recreational activities and harbor development. EPA placed New Bedford Harbor on the National Priorities List in 1983.

EPA planned to address the cleanup of New Bedford Harbor in two stages, starting with the cleanup of the "hot spot" area. EPA defined the hot spot as the area where the concentration of PCBs in the sediment was 4,000 parts per million (ppm) or greater. The PCB concentrations in the hot spot, an area of approximately five acres, ranged between 4,000 ppm and over 200,000 ppm. The volume of hot spot sediments that required treatment represented approximately 45 percent of the total PCB mass in the sediment in the entire New Bedford Harbor site.

EPA identified over 90 potential technologies for cleaning New Bedford Harbor. After EPA narrowed its list, it conducted detailed studies on several innovative technologies to assess their potential for success at the New Bedford hot spot. After evaluating the alternatives it believed feasible, EPA decided in 1990 to use dredging and on-site incineration to clean up the hot spot.

EPA believed that dredging and on-site incineration was the preferred option to protect public health and the environment and to permanently reduce the migration of contaminants throughout the site. (See fig. I.3.) On the basis of its analyses, EPA determined that incineration, considered a proven technology, would achieve the best balance among the criteria used by EPA to evaluate the alternatives. These criteria included both long- and short-term effectiveness, implementability, overall protection of human health and the environment, and compliance with federal and state applicable or relevant and appropriate requirements. On the other hand, the many uncertainties about the performance of innovative technologies at the New Bedford hot spot sediments made these technologies unlikely candidates for the site. For example, EPA was uncertain about the performance and adequacy of innovative technologies given the silt/clay composition and high water content of the New Bedford sediments. Soil composition and water content are factors that could compromise the performance of innovative technologies.

Figure I.3: Dredging Facility at New Bedford Hot Spot

As EPA proceeded with its plans to incinerate hot spot sediments, opposition from environmental and local community groups to EPA's plans to incinerate grew. The public's main concern was the potential health risk from dioxin emissions coming from the incinerator. In response to the community's growing opposition, in 1994 EPA canceled the incineration part of the Corps of Engineers' contract to clean the hot spot. The cancellation costs of the incineration contract were approximately $5 million dollars, and there may be additional costs.

After the cancellation of EPA's incineration plans, the agency started new efforts to identify alternative cleanup technologies for the site. With public participation, EPA narrowed candidate cleanup options to (1) solidification/stabilization, (2) chemical destruction, and (3) a separation technology such as thermal desorption followed by chemical destruction. EPA plans to conduct detailed studies on at least two chemical destruction technologies and at least two solidification technologies. The agency expects to issue its final decision on the cleanup for the hot spot in approximately 3 years.

Dioxin and Polychlorinated Biphenyls Contamination

Dioxin and PCBS (polychlorinated biphenyls) are highly toxic contaminants of particular concern because of their potentially adverse effects on human health and their degree of permanence in the environment. EPA classifies dioxin as a probable human carcinogen. Dioxin has the potential to invoke a wide range of harmful effects in relatively small doses, as compared with other toxic compounds. Some PCBS, having a chemical makeup similar to dioxin's, have the potential for many of the same effects.

Dioxin

Dioxin and dioxin-like substances are not purposely manufactured but are unintentional by-products of combustion and chemical processes. The four main sources of dioxin are (1) the formation during incineration of materials that contain chlorine (such as the incineration of municipal and medical waste); (2) industrial and other processes that employ chlorine (such as chlorinated bleaching of wood pulp for paper manufacturing); (3) chemical manufacturing and related processes, including the manufacture of chlorine and chlorinated substances; and (4) redistribution of existing contamination—because dioxin tends to accumulate in soil and sediment, dioxin contamination may become redistributed through contaminated dust. In addition, dioxin emissions may also result from the incineration of materials already contaminated with dioxin. In this scenario, some of the dioxin-contaminated material remains intact through the incineration process and is emitted from the stack.

Exposure to dioxin occurs daily, mainly through dietary intake of meat, dairy products, fish, and shellfish. Dioxin is present in all media, particularly in soil and sediment, which transfer the contaminant to plants and animals. Researchers believe that the presence of dioxin in the food chain is primarily the result of dioxin air emissions depositing from the atmosphere on soil, plants, and bodies of water. In addition, some individuals may be exposed to even higher dioxin levels from other sources; these include occupational exposures, exposure to a distinct local source (for example, a chemical manufacturing plant, or a municipal or medical incinerator), exposure of nursing infants from mothers' milk, or frequent consumption of dioxin-contaminated fish from a particular source.

Health effects have been associated with exposure to dioxin. Dioxin is considered a probable human carcinogen, according to laboratory studies on animals and observation of humans beings exposed to dioxin. In addition, it has been associated with other adverse effects, including reproductive, developmental, immunological, and endocrine changes. In high doses, dioxin causes chloracne, a serious skin condition. The adverse effects of dioxin are contingent upon dose and length of exposure. Dioxin is present in humans at birth in small concentrations and accumulates, increasing as individuals age. The exact level at which health effects will occur is uncertain.

EPA began a scientific reassessment of dioxin and dioxin-related compounds in 1991. The reassessment summarizes and evaluates available research to provide a comprehensive survey of the sources of dioxin, the levels of exposure, and the potential health effects. It also identifies gaps in dioxin research. The preliminary conclusions of the reassessment strengthen the evidence that dioxin can cause human health effects even at low levels of environmental exposure. In September 1994, EPA issued two draft reports based on this work which have been released for public comment: Estimating Exposure to Dioxin-Like Compounds and Health Assessment Document for 2,3,7,8 Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds.

PCBs

Polychlorinated biphenyls (PCB) are similar to dioxin as they are in the same class of chemicals. However, unlike dioxin, PCBs were intentionally manufactured (from the 1920s to the 1970s in the United States), mainly for use as an insulating fluid in electrical equipment. The production and use of PCBs was widespread, causing large amounts to be released into the environment. They were used primarily because of their stability and resistance to decomposition, which have caused them to persist in the environment even though they are no longer manufactured.

Because of the stability of PCBs, many routes of exposure are possible. The primary source of human intake of PCBs is through food—mainly fish, but also meat and dairy products. Other sources of exposure include inhalation and dermal contact. As with dioxin, exposure to PCBs may cause health effects. In its most toxic forms, PCBs are carcinogenic in laboratory animals and are considered a probable human carcinogen. Some forms of PCBs can have the same toxicity as dioxin (known as dioxin-like PCBs). PCBs are also associated with reproductive and immunologic changes in some people who are exposed to the contaminant. According to EPA researchers, the incomplete destruction of PCBs during incineration of the contaminant may pose the most significant of health threats because of the potential dioxin formation and emissions.

In 1993, the Agency for Toxic Substances and Disease Registry (ATSDR) convened an expert panel to evaluate the public health implications of treating and disposing of PCB-contaminated waste. The panel concluded that although the safety of incinerating PCB-contaminated waste is not certain, information on the safety and effectiveness of alternative technologies is also limited. The panel affirmed that no single type of alternative technology can remediate all PCB-contaminated wastes. In addition, it recommended that further research is needed to study the health effects of PCBs.

Incineration Technology

Incineration is the burning of substances by controlled flame in an enclosed area or compartment. During the process of incineration, hazardous organic wastes[12] fed into an incinerator are converted to simpler forms, principally carbon dioxide and water, reducing their volume and toxic qualities. EPA regulates incineration under its authority to regulate hazardous waste.

Pursuant to the Resource Conservation and Recovery Act (RCRA), as amended by the Hazardous and Solid Waste Amendments of 1984, EPA in the late 1980s and early 1990s promulgated land disposal restrictions to bar the disposal—except under very restrictive conditions—of untreated hazardous waste. As land disposal became increasingly expensive due to the restrictions, other disposal options, such as incineration, became increasingly attractive. In many cases, the disposal of waste through incineration has become the most economical and, in some cases, the only option for certain hazardous wastes. EPA has encouraged regulated burning as a treatment option and considers incineration to be the best demonstrated available technology for many wastes. By the late 1980s, incineration was also playing an important role in the cleanup of many Superfund sites, where it has been used for treating contaminated soils and other wastes removed from the site.

The Incineration Process

Incineration involves four basic steps: (1) wastes are prepared and fed into the incinerator; (2) wastes are burned, converting organic compounds into residual products in the form of ash and gases;(3) ash is collected, cooled, and removed from the incinerator; and, (4) gases are cooled, cleaned, and released to the atmosphere through the incinerator stack.

During incinerator operations, wastes are fed into the incinerator in batches or in a continuous stream. This flow of wastes is generally referred to as the waste feed. The wastes are then burned in the combustion chamber, which is designed to maintain and withstand extremely high temperatures. As the wastes are heated, they are converted from solids or liquids into gases. The gases are mixed with air and passed through a hot flame. As the temperature of the gases rises, the organic compounds in the gases begin to break down and recombine with oxygen from the air to form stable inorganic compounds, such as carbon dioxide and water. Depending on the waste composition, other inorganic

[12]Organic compounds are those that are composed of carbon, hydrogen, and sometimes other elements.

compounds, such as the acid gas hydrogen chloride, may form. This entire process is called combustion.

In many incinerators, combustion occurs in two combustion chambers. The combustion of more easily burned organics is completed in the first chamber. For compounds that are difficult to burn, combustion is completed in a secondary combustion chamber, or afterburner, after the compounds have been converted to gases and partially combusted in the first chamber.

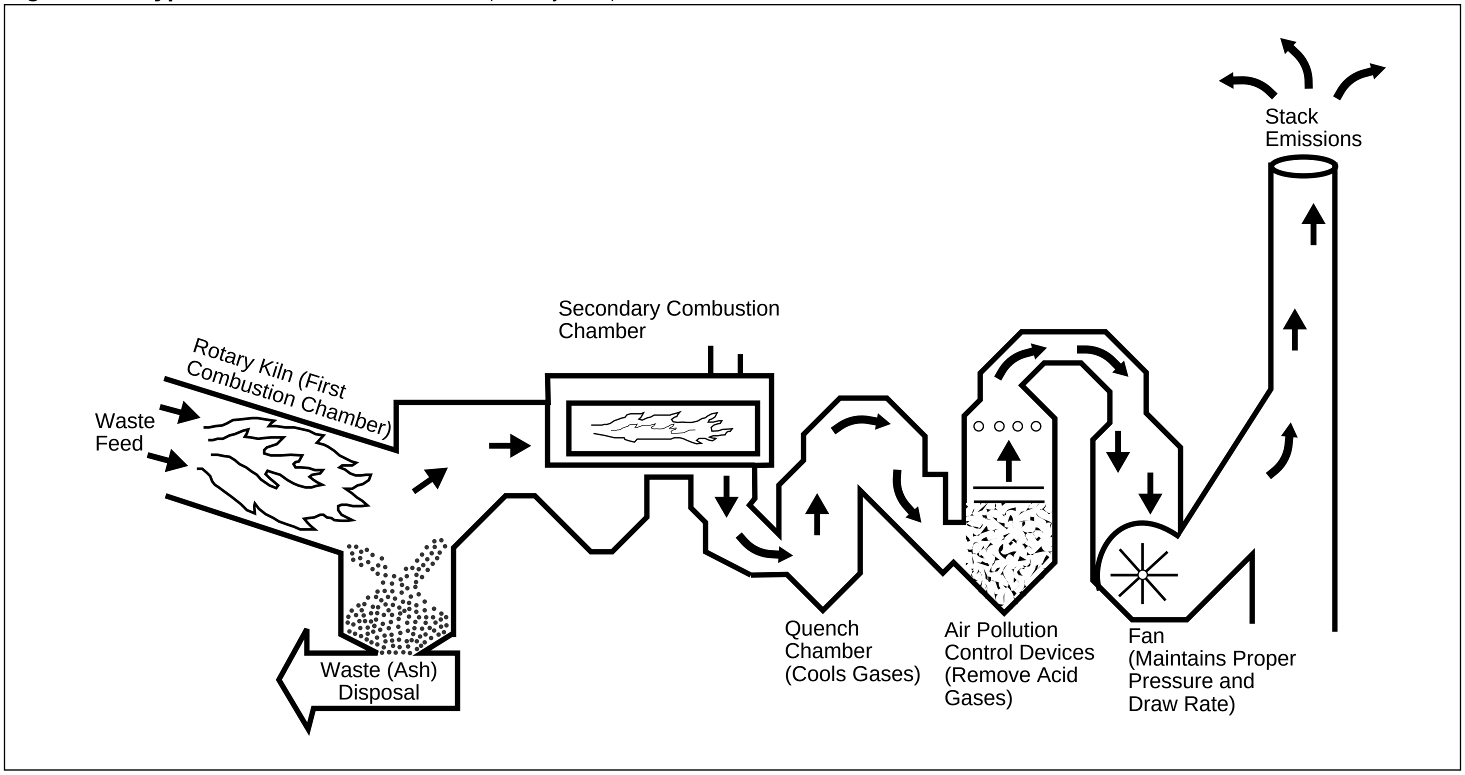
Combustion yields two residual products: solids, in the form of ash, and gases. Ash is an inert inorganic material composed primarily of carbon, salts, and metals. During combustion, most ash collects at the bottom of the combustion chamber; some ash, however, is carried along with the gases as small particles, or particulate matter. Ash removed from the bottom of the combustion chamber is considered, by regulation, a hazardous waste. Combustion gases are composed primarily of carbon dioxide and water, plus small quantities of other gases such as carbon monoxide and nitrogen oxides. Following combustion, the combustion gases move through various devices that cool and cleanse the gases before they are released to the atmosphere through the incinerator stack.

A well-designed and operated hazardous waste incinerator will destroy all but a small fraction of the organic compounds contained in the waste. Complete combustion, however, is only a theoretical concept since the development of a 100-percent efficient incinerator is not possible. The three critical factors that determine the completeness of combustion in an incinerator are (1) the temperature in the combustion chamber; (2) the length of time wastes are maintained at high temperatures; and (3) the turbulence, or degree of mixing, of the wastes and the air.

Because combustion is never complete, incinerator emissions gases may also contain small quantities of organic and inorganic compounds from both the original waste and compounds formed during the combustion. These “new” organic compounds form from the breakdown and recombination of the original compounds and are called products of incomplete combustion or PICs. PICs are formed during the combustion of any organic material, such as when wood is burned in a wood stove or when gasoline is burned in an automobile engine. Among the types of compounds found in analyses of PICs are very small quantities of dioxins and dibenzofurans. Among the inorganic compounds not present in the original waste are carbon monoxide and nitrogen oxides, both of which are always formed as a result of combustion.

Among the most common types of hazardous waste incinerators is the rotary kiln incinerator. Rotary kiln incinerators are versatile and can accept gases, liquids, sludges, slurries, and solids either separately or simultaneously, either in bulk or in containers. Because of this versatility, rotary kilns are commonly used to treat a variety of wastes. The kiln is a cylindrical shell mounted on its side at a slight angle to the horizontal. As the kiln rotates and the wastes travel down the slope, the organic chemicals in the waste convert into gases and partially combust. The gases then pass into the afterburner or secondary combustion chamber where further combustion takes place. Ash residue is removed from the lower end of the kiln. (See fig III.1.) Mobile incineration systems are generally constructed using the rotary kiln incinerator design. These systems are hauled to a site on flat-bed trucks, then assembled and tested. Although smaller than most stationary facilities, they operate on identical principals.

Figure III.1: Typical Incinerator Processes (Rotary Kiln)



Source: EPA.

Hazardous Waste Incinerator Regulations

EPA developed performance standards for the incineration of hazardous wastes on the basis of research on incinerator air emissions and health and environmental risk studies. All incinerators emit gases through a stack as the final step in the incineration process. The quantity of pollutants in these emissions is the major determinant of the risk of incineration. The performance standards thus address and attempt to control the various emissions from the stack. Under EPA's regulations, an incinerator must be able to burn wastes and cleanse combustion gases so that only very small quantities of pollutants are emitted through the stack. EPA's principal measure of incinerator performance is destruction and removal efficiency (DRE). Destruction refers to the combustion of waste, while removal refers to the cleansing of the pollutants from the combustion gases before they are released from the stack. For most organic wastes, a DRE of 99.99 percent is required; however, for PCBs and dioxins, a DRE of 99.9999 percent is required, which means that no more than one molecule of the compound is released to the air for every 1 million molecules entering the incinerator.

Because it is not technically feasible to monitor DRE results for all organic compounds that may be contained in a waste feed, an incinerator must demonstrate that it can achieve the performance standards for selected hazardous compounds, called principal organic hazardous constituents (POHC), which the permitting agency designates in the permit. These POHCs generally are selected from among the wastes the applicant is seeking approval to burn on the basis of their high concentration in the waste feed and their difficulty to burn in comparison with other organic compounds in the waste feed. According to the theory of incineration followed by EPA, if the incinerator achieves the required destruction and removal efficiency for the POHCs, then the incinerator should achieve the same or better destruction and removal efficiencies for organic compounds that are easier to incinerate.

The incinerator performance standards in EPA's RCRA regulations include emissions of the designated organic compounds, hydrogen chloride, and particulate matter. Specifically, those performance standards for the incineration of dioxin require (1) a minimum DRE of 99.9999 percent; (2) generally, removal of 99 percent of hydrogen chloride gas from the incinerator's emissions; and (3) a limit of 180 milligrams of particulate matter per dry standard cubic meter of gas emitted through the stack.

Before a final permit to operate the incinerator is issued, a trial burn generally is required. The trial burn tests the incinerator's ability to meet all applicable performance standards when burning a waste under specific operating conditions. The operating conditions include such things as the rate and composition of the waste feed, the temperature that must be maintained in various areas of the incinerator, and the gas flow rate. To obtain a final operating permit, the trial burn results must demonstrate that the incinerator can meet the performance standards contained in its permit.

The trial burn results are also used to establish the final operating conditions that will be included as part of the facility's permit. Because the trial burn involves the measurement of the incinerator's performance under different sets of operating conditions, the trial burn results verify the incinerator's ability to meet the performance standards under one or more of these conditions and thus can be used to determine what is an acceptable range of operating conditions for the final permit. The final operating permit specifies only those operating conditions under which the incinerator has proven it can meet the performance standards.

These operating conditions are important because it is not technically feasible to directly and continuously measure certain aspects of performance, such as destruction and removal efficiency, and certain emissions. On the basis of the results of the trial burn, the permit may specify different operating conditions for different types of waste feeds or specify ranges or minimum or maximum levels for different parameters, such as temperature. Under EPA's regulatory approach, as long as the incinerator operates within these ranges, it is assumed to be operating under the same conditions as during the successful trial burn and thus to be in compliance with the environmental performance standards. Toxic Substances Control Act (TSCA) regulations have comparable requirements for the incineration of PCBs.

Innovative Treatment Technologies

While incineration is the only established technology for the treatment of most PCB- and dioxin-contaminated sites, EPA and the industry are developing and testing several innovative technologies that could become viable alternatives to incineration, particularly after further development. Some of these innovative technologies, like incineration, destroy the waste; some of them change its chemical composition so that it is no longer hazardous; and some of them immobilize the waste so that although it may still be hazardous, it will be less likely to move into the air, soil, or water or other waste. The following are the most recognized alternatives to incineration for PCBs and dioxin.

Bioremediation: Bioremediation refers to the breakdown of contaminants into less harmful and usually less toxic forms by natural microorganisms. It can be performed at a higher rate in the presence of oxygen, or more slowly under near oxygen-free conditions. Historically, PCBs have been considered resistant to biodegradation. However, the results of lab studies and environmental monitoring studies indicate that PCBs biodegrade in the environment but at a very slow rate. In addition, bioremediation of highly chlorinated substances can result in highly toxic forms of dioxin. To date, EPA has not found a bioremediation process that can accelerate the biodegradation of PCBs to rates necessary to make such a process commercially viable for use in site cleanups. Similarly, limited information from field work on the biodegradation of dioxin has shown that the process can be significantly lengthy.

Chemical Dechlorination: This process destroys or detoxifies certain contaminants, such as PCBs and dioxin, by gradually removing chlorine atoms. The conditions that most commonly determine the efficacy and cost of dechlorination methods include the size of soil particles, the soil's moisture content, the organic carbon contents of the soil, and the cleanup level required. In addition, under certain circumstances, dechlorination can generate highly toxic dioxin. A well-known dechlorination technology is base catalyzed decomposition (BCD). EPA developed BCD to detoxify chlorinated organics such as PCBs and dioxin. It uses two different technologies—thermal desorption (described later in this appendix) followed by a chemical process to separate and detoxify organic contaminants. It is an efficient, relatively inexpensive treatment process for PCBs and potentially capable of treating PCBs at virtually any concentration. However, the process can be expensive for high PCB concentrations because it requires a larger dose of the chemicals necessary to neutralize the chlorine. Field data on the performance and cost of BCD for PCBs and dioxin are very limited. In addition, EPA officials responsible for administering the Toxic Substances Control Act regulations have not yet had an opportunity to assess whether BCD is acceptable as a remedy for PCBs.

Soil Washing: Soil washing mixes, washes, and rinses the soil to separate contaminants, such as PCBs, adhering to soil particles. Because it is not a destruction technique, this technology does not present a final solution for the disposition of toxic and hazardous materials. The technology is designed for volume reduction of contaminated material. Its effectiveness depends on factors such as the size of soil particles and humic and silt or clay content of the soil. Multiple washings may be necessary to achieve acceptable contamination levels. In addition, there is need for further management of the concentrated contaminant. While limited work has been done on the effectiveness of soil washing for PCBs, no work has been done for dioxin.

Solidification/Stabilization: Solidification and stabilization technologies focus primarily on limiting the solubility or mobility of contaminants, generally by physical means rather than by chemical reaction. Waste solidification technologies encapsulate the contaminants in a solid material—such as portland cement or asphalt. Waste stabilization technologies convert the contaminants into a less soluble, mobile, or toxic form by adding a binder to the waste, such as cement kiln dust or fly ash. Historically, solidification and stabilization technologies have been used to treat metals and other inorganic compounds. With currently available technology, it is generally easier to successfully solidify or stabilize inorganic compounds than organic compounds, such as PCBs and dioxin. More recently, some work has been done on the applicability of solidification and stabilization to organics, such as PCBs. Although no solidification or stabilization treatment currently offered is considered by EPA to be an acceptable alternative incineration for PCBs and dioxin, EPA believes the technology has potential.

Solvent Extraction: Using a solvent, such as propane, solvent extraction separates hazardous contaminants from soil and sediment. This process reduces the volume of the hazardous waste that requires treatment. The application of this technology represents only a transfer of the contaminant from one medium (soil) to another (solvent) but does not provide for the contaminant's ultimate destruction. The ultimate removal of PCBs depends on the number of stages employed and the feed concentration. Many variables, such as soil type and moisture content, influence the system's performance. For example, water and fine-grained materials inhibit some solvent extraction processes. In addition, after extraction is complete, some solvent remains in the treated sediment. This residual solvent may pose a separate problem if the solvent is toxic or highly explosive.

Thermal Desorption: Thermal desorption treats contaminated soils by heating the soil at relatively low temperatures between 300 and 1,000 degrees fahrenheit. The heat separates the contaminants from the soil. The contaminants then require further treatment. The effectiveness and cost of this technology vary and depend on site characteristics such as the moisture content of the soil and the concentration and distribution of the contaminants. In addition, thermal desorption can generate residual that should be monitored and may require further treatment.

Vitrification: All existing vitrification technologies use heat to melt the contaminated soil or sediment, which forms a rigid, glassy product when it cools. The volume of the end product is typically 20 to 45 percent less than the volume of the untreated soil or sediment. Organic compounds, including PCBs, are destroyed by the high temperature during vitrification. Vitrification may also have application to special types of dioxin contamination if current developments can be successfully tested. However, the effectiveness of vitrification for both PCBs and dioxin is difficult to assess at this point.[1]

[1] On October 31, 1995, EPA issued an operating permit to the Geosafe Corporation to use in-situ vitrification for treating PCB-contaminated soil.

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