Cleaning Up Contaminated Wood-Treating Sites

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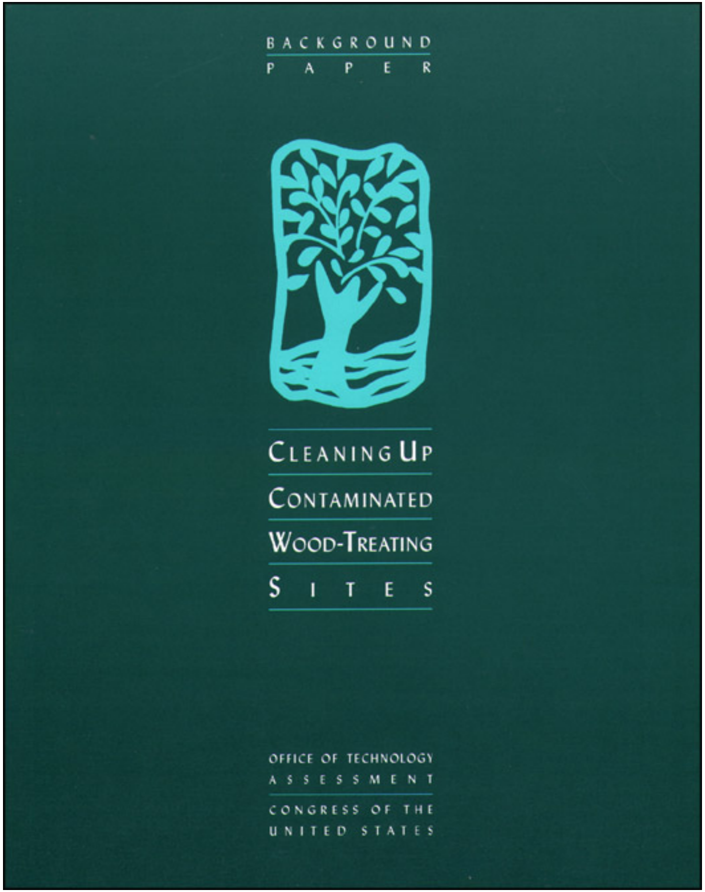

BACKGROUND PAPER

CLEANING UP CONTAMINATED WOOD-TREATING SITES

OFFICE OF TECHNOLOGY ASSESSMENT

CONGRESS OF THE UNITED STATES

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Foreword

The Texarkana Wood Preserving Company Superfund site is a former wood-treating site located in Texas that treated various wood products with chemical preservatives. These activities left behind contaminated soil and sludge, that led to contaminated groundwater. In 1990 Environmental Protection Agency (EPA) selected incineration as the means to clean up contaminated soil at this site. In 1994 Congressman Jim Chapman (D-Texas) asked the Office of Technology Assessment (OTA) to review alternative technologies that might be used instead of incineration at the Texarkana site. A second, separate study to assess the safety of incineration was also requested by Representative Chapman.

This report reviews technologies available for hazardous waste cleanup at wood-treating sites throughout the United States. OTA found that there are many Superfund wood-treatment sites located in this country that are very similar in terms of the contaminants present and the options selected for cleanup. OTA identified a range of such technologies that were selected and that could be applied to other sites in the future.

While OTA has not recommended specific technologies for the Texarkana site, it is clear that a number of them may be appropriate and could prove useful if more detailed site-specific studies and tests were carried out. While this study focused on the Texarkana site, decision makers and the public for other sites could benefit from this analysis during the process of selecting future cleanup strategies.

OTA appreciates the assistance and support it received for this effort from many contributors and reviewers. They provided OTA with valuable information critical to the completion of this background paper and important insights about its technical evaluations and projections. OTA, however, remains solely responsible for the contents of this report.

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Introduction and Summary

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In 1994 the Office of Technology Assessment (OTA) was asked to evaluate technical alternatives to incineration for cleaning up the Texarkana Wood Preserving Company Superfund site, in Texarkana, Texas. The 25-acre site, a former wood-treating facility in Bowie County, Texas, became an U.S. Environmental Protection Agency (EPA) Superfund site in 1986 (27). Wood products had been treated there with preservative chemicals over many decades. These activities left behind chemical preservatives as contaminates in soil, sludge, sediment, and groundwater (see box 1-1). Using information available in the late 1980s, the EPA selected incineration in a 1990 record of decision (ROD) to clean up soil, sludge, and sediments contaminated with wastes from wood-treating activities at Texarkana.

However, public opposition has prevented incineration from being used at this site. Recently EPA funds that had been allocated to building and operating an incinerator were returned, and today the only work at the site is ongoing environmental monitoring, and interim analyses (2). OTA was asked to find and evaluate possible alternatives to incineration that might be more acceptable to residents who live nearby.

This report identifies technologies available for organic hazardous waste cleanup at wood-treating sites throughout the country. OTA has identified a range of such technologies that have been selected in the past and could be applied to other sites in the future. OTA has not recommended specific technologies for the Texarkana Wood Preserving Company site. The applicability of a technology to a particular Superfund site has to be based on many site-specific factors. Nevertheless, it is clear that a number of the approaches identified by OTA may be appropriate and could prove useful if more detailed site-specific studies and tests were done. Although this study focused on the Texarkana site, decisionmakers and the public could benefit from this analysis in selecting future cleanup strategies for other sites.

EPA'S EXPERIENCE WITH WOOD-TREATING SITES

The Texarkana Wood Preserving Company site is a member of a class of sites that have similar histories and contaminants present. Today EPA

BOX 1-1: The Texarkana Wood Preserving Company Site

The 25-acre Texarkana site is a former wood-treating facility in Bowie County, Texas. Surrounding land use is industrial, residential, and agricultural. Since the early 1900s, several lumber-related businesses have operated at the site. Wood-treating operations using creosote began in 1954. By 1971 pentachlorophenol (PCP) was also in use for wood treatment.

State investigations from 1968 and 1984 showed the company to be negligent or delinquent in fulfilling various permit requirements. Removal actions from 1986 to 1988 included site access restrictions, constructing a berm, and pumping down the creosote-contaminated onsite processing ponds to prevent runoff and overflow.

The present record of decision addresses onsite contaminated soil near the processing ponds and contaminated groundwater in a shallow aquifer. Incineration with onsite disposal of ash was considered a proven technique by EPA. The future use of this site is expected to be industrial, and not residential. Remediation of groundwater in a deeper aquifer will be addressed in a future ROD. The primary contaminants of concern affecting the soil, sediment, sludge, and groundwater are organics including dioxin, polycyclic aromatic hydrocarbons (PAHs), pesticides, and phenols including PCP. The location of the site in a 100-year floodplain complicates cleanup of this site.

The cleanup levels for soil specified for the Texarkana site are 3 parts per million (ppm) carcinogenic PAHs, 2,350 ppm total PAHs, 150 ppm PCP, and 20 parts per billion (ppb) combined dioxins and furans equivalents. Any potential cleanup technology must meet these levels, or these levels must be adjusted.

The selected remedial action for this site includes

- excavating approximately 77,000 cubic yards of contaminated soil (includes any affected sediment and sludges) and onsite treatment using incineration,
- onsite backfilling of ash with the installation of a soil cover (capping) and revegetation,
- pumping and treatment of approximately 16 million gallons of contaminated groundwater from the shallow aquifer using carbon adsorption and reinjecting the treated water onsite into the shallow aquifer, and
- use of institutional controls, including site deed restrictions to limit land use.

According to the ROD, the estimated cost for this remedial action is $47,500,000. Depending on the remedy actually used, and the results of competitive bidding, the actual costs may be quite different.

SOURCE: Environmental Protection Agency, Region 6, “Record of Decision: Texarkana Wood Preserving Company Superfund Site,” Dallas, TX, September 1990; Hendrick, E., Senior Project Manager, EPA Region 6, Dallas, TX, written comments, August 9, 1995.

has considerably more experience with this type of site than it did in the late 1980s, when cleanup decisions were made about the Texarkana site. Since 1980, EPA has identified 56 Superfund wood-preserving sites in the United States, most of which are very similar to the Texarkana site (17). EPA has completed the process of selecting technologies and cleanup strategies for more than 30 of these sites. Chapter 2 of this report gives more details about EPA’s history with wood-treating sites.

Table 1-1 summarizes the wood-preserving chemicals and the selected cleanup remedies for these sites. Sites contaminated only by metal-containing wood preservatives such as chromated copper arsenate (CCA) were not included in this survey since this class of contaminant is not important at the Texarkana site. Table 2-1 in chapter 2 gives more information about these sites including contaminants present, size of the site, current land use around the site, and selected cleanup technologies. Current land use was

TABLE 1-1: Remedy Selection at Wood-Treating Sites,[a] by date of ROD

Site name ROD Date	Chemical Present	Remedy Selected
American Creosote 85-09-30	Creosote PCP[b]	Landfill disposal
Burlington Northern 86-06-04	Creosote	Bioremediation and capping
Westline site 86-07-03	Creosote	Incineration
Coleman Evans 86-09-25	PCP	Incineration of more contaminated soil
Baxter/Union Pacific 86-09-26	Creosote PCP	Barrier wall (plan for more permanent remedy)
United Creosoting 86-09-30	Creosote PCP	Temporary cap and apply innovative technology when available
Mid-South 86-11-14	Creosote PCP	Remove sludges & oils to offsite facility; stabilization of soil hot spots, then capping
Bayou Bonfouca 87-03-31	Creosote PCP	Incineration and offsite disposal
Midland Products 88-03-24	Creosote PCP	Incineration
L.A. Clarke 88-03-31	Creosote	Soil flushing, bioremediation
Brown Wood Pre. 88-04-08	Creosote PCP	Bioremediation; landfill disposal of heavily contaminated material
North Cavalcade 88-06-28	Creosote PCP	Bioremediation
Southern Md. Wood 88-06-29	Creosote PCP	Incineration
Broderick Wood 88-06-30	Creosote PCP	Incineration
South Cavalcade 88-09-26	Creosote	Incinerate oily wastes; soil washing & capping (or bioremediation if effective)
Libby 88-12-30	Creosote PCP	Bioremediation and capping
American Creosote 89-01-05	Creosote PCP	Incineration
Koppers/Galesbrg 89-06-28	Creosote PCP	Bioremediation and capping
Cape Fear Wood 89-06-30	Creosote	Soil flushing or thermal desorption
Koppers (Oroville) 89-09-13	Creosote PCP	Soil washing, bioremediation, and capping
Newsom Brothers 89-09-18	Creosote PCP	Incinerate worst material; offsite disposal of other soils
American Creosote 89-09-28	Creosote PCP	Bioremediation

(continued)

TABLE 1-1: Remedy Selection at Wood-Treating Sites,[a] by date of ROD (Cont'd.)

Site name ROD Date	Chemical Present	Remedy Selected
United Creosoting 89-09-29	Creosote PCP	Solvent extraction (critical fluid) with offsite incineration of residues
Havertown PCP 89-09-29	Creosote PCP	Landfill disposal
Texarkana Wood 90-09-25	Creosote PCP	Incineration
Coleman-Evans 90-09-26	PCP	Soil washing, bioremediation; solidification/stabilization, then capping
Cabot/Koppers 90-09-27	Creosote	Soil washing & bioremediation; then solidification/stabilization
J H Baxter Co 90-09-27	Creosote PCP	Bioremediation followed by solidification/stabilization if inorganics are found
Moss-American 90-09-27	Creosote	Incinerate sludges & oils; soil washing & bioremediation followed by capping
Arkwood, Inc 90-09-28	Creosote PCP	Soil washing (incineration if this fails)
Broderick Wood 91-09-24	Creosote PCP	Recycle oils (with incineration of residues)
Macgillis & Gibbs 91-09-30	Creosote PCP	Remove sludges & oils to offsite facility
Saunders Supply 91-09-30	PCP	Dechlorination of sludges & sediments; thermal desorption of soils
Idaho Pole 92-09-28	Creosote PCP	Soil wash & bioremediation, then capping
Koppers (Morrisv.) 92-12-23	PCP	Thermal desorption & dechlorination (incineration if this fails)
Popile, Inc. 93-02-01	Creosote PCP	Bioremediation and capping
American Creosote. 93-04-28	Creosote PCP	Incinerate sludges; bioremediation of soils
Rentokil Virginia 93-06-22	Creosote PCP	Incinerate sludges & oils (with dechlorination for dioxins); thermal desorption for soils, followed by capping
Montana Pole 93-09-21	Creosote PCP	Incinerate sludges & oils; soil flushing & bioremediation

NOTES:

[a] Additional wood-treating sites with primarily metals contamination are not included in this table.

[b] Sites with PCP use can be expected to have some dioxin contamination.

included as an indicator of future land use. The basic features of the Texarkana site are similar to those of other wood-treating sites. Figure 1-1 shows how often the various technologies and strategies are chosen for the selected 40 sites. Usually more than one technology was selected to deal with various contaminated parts of a single site.

The wood-treatment industry, which treats wood with chemicals to preserve them from decay and insect damage, has operated in the United States for over 100 years (23). Many common and widely used wood products are produced by this industry, including railway ties, fencing posts, outdoor decks, telephone and util-

FIGURE 1-1: Frequency of cleanup strategies for wood-treating sites

Superfund cleanup strategies selected by EPA for 40 wood-treating sites contaminated with pentachlorophenol (PCP) or creosote. Many of these treatments are used together at a single site as part of a treatment train.

SOURCE: Office of Technology Assessment

ity poles, and other wood products intended for outdoor use.

Wood preserving typically involves treating the wood under pressure with the preservative chemicals pentachlorophenol (PCP), creosote, or chromated copper arsenate (CCA), usually dissolved in some suitable solvent (23). These activities often left behind widespread soil, sediment, sludge, and water contamination at the site. The preservative PCP always contains some dioxin and furan impurities, and creosote contains polycyclic aromatic hydrocarbons (PAHs). These compounds are considered by EPA and other health agencies to be likely human carcinogens (see boxes 2-1 and 2-2 in chapter 2 for more information about creosote, PAHs, PCP, and dioxins).

The presence of any one of these contaminants, including dioxins and furans present as impurities in PCP, has not necessarily dictated the use of any one technology such as incineration (see tables 1-1 and 2-1). Dioxins and furans, when they occur at contaminated wood-treating sites, are always in very much smaller concentrations compared with the primary site contaminants PCP or creosote. Dioxins and furans are present at a wood-treating site as low-level impurities contained in the PCP used at the site for wood preservation. This has led to very different cleanup strategies for this type of site compared with other sites where the primary contaminate is dioxins or furans. For an analysis of technologies for cleanup of dioxin contaminated soils, see the Office of Technology Assessment (OTA) background paper “Dioxin Treatment Technologies” (4). Table 1-1 also shows that before 1990, incineration was more commonly selected as the primary cleanup strategy. After 1990, incineration, if it was selected at all, appears to be only one part of an overall cleanup strategy. For example, incineration may be chosen for the cleanup of small, highly contaminated “hot spots” while bioremediation is chosen for dealing with the remainder of the site.

EPA’S PRESUMPTIVE REMEDIES FOR WOOD-TREATING SITES

EPA’s experience over the years with cleaning up wood-treating sites has led to an evolution and maturation in EPA’s cleanup approach. Some cleanup technologies that EPA now considers established were not seriously considered when decisions were made about the Texarkana site. EPA’s experience with this type of site has provided new cleanup options.

Today EPA formally recognizes wood-treating sites as a class of site that has similar problems and similar cleanup options. It recently summarized the variety of successful technologies and approaches that have proven useful for cleaning up wood-treating sites such as the Texarkana site. EPA refers to proven technologies for a class of sites as “presumptive remedies.” EPA reviewed successful cleanup strategies for wood-treating sites with similar characteristics, including the contaminants present, the environmental media affected by those contaminants, and the cleanup technologies selected (23). The fact that contaminated wood-treating sites had many features in common made it practical and useful for EPA to summarize successful cleanup technologies.

On the basis of this review of many full-scale cleanup projects at wood-treating sites, EPA concluded that a variety of demonstrated treatment technologies are capable of meeting stringent cleanup requirements (16,21,23). EPA presumptive remedies for contaminated soil, sludge, and sediments at wood-treating sites are bioremediation, thermal desorption, or incineration for organic contaminants, and immobilization for inorganic contaminants. Chapter 3 provides more information on how these technologies have performed with the various contaminants found at wood-treating sites. Although EPA focused mostly on technologies that had proven themselves in full-scale cleanup projects at contaminated wood-treating sites, it also considered certain other technologies that had less performance data available (21,23). EPA has not yet developed presumptive remedies for contaminated groundwater at these sites.

FOCUS OF OTA'S ANALYSIS

This report presents OTA's analysis of the treatment technologies and strategies selected by EPA for cleaning up contaminated soil at wood-treating sites. OTA's identification of these technologies is intended to capture the evolution since the mid-1980s of the approaches EPA has available to clean up contaminated soil, sludge, and sediments at these sites. OTA gathered information on various technologies selected for use to clean up Superfund wood-treating sites from two main sources. The first source was OTA's review of EPA's decisions and the technology selected for the cleanup of Superfund wood-treating sites as they are described in the ROD for each site. The second source was an analysis of the presumptive remedy strategy recently developed by EPA for wood-treating sites. Considering both of these sources, OTA concluded that EPA has selected at least 10 different approaches for cleaning up contaminants at such sites.

OTA did not try to compare the relative safety or hazards of these alternatives to incineration. Nevertheless, some concerns should be kept in mind when comparing the safety and hazards of incineration to any alternative. Concerns about possibly toxic emissions from incinerators used for cleaning up wood-treating sites are likely to apply equally or possibly even more to some of the alternative technologies reviewed by OTA. In most cases the emissions that would come from these alternative technologies are less well characterized than those for incineration.

Many alternative technologies are less mature; they have less of a record by which their relative safety can be judged. At some sites the technologies selected by EPA have not yet been fully implemented, and their success cannot be evaluated. Some alternatives may work well with certain types of sites, but poorly or not at all with others. Soil cleanup standards and relevant cleanup laws may vary for each site. Nevertheless, some of the alternatives evaluated by OTA will undoubtedly be useful alternatives to incineration for cleaning up contaminated soil, sludge, and sediment at wood-treating sites.

SUMMARY OF CLEANUP TECHNOLOGIES

OTA looked at the treatment strategies that EPA selected in 47 RODs for 40 different wood-treating sites. Table 1-1 summarizes this review, and figure 1-1 lists the various technologies and approaches selected by EPA, as well as how often they were selected. Chapter 2 gives further information about the various sites and the technologies selected for them, and chapter 3 provides more detailed information about the technologies and approaches.

In virtually every case, several different technologies and other approaches were selected in combination to make a complete site cleanup strategy. Sometimes one technology such as incineration or bioremediation was selected as the key technology for addressing the main contamination source. However, in general no single technology can clean up an entire wood-treating site, and a combination of control and treatment strategies is chosen (17). For example, capping a site and making some restrictions on future use **after** incineration or bioremediation was used in more than half the RODs reviewed by OTA. Capping involves providing some type of cover, made of clean soil and other materials, that isolates contamination from the environment and limits human exposure.

OTA also reviewed EPA's recently released presumptive remedies strategy for cleaning up contaminated soil, sludge, and sediments at wood-treating sites. This strategy is a summary of EPA's experience with technologies that have proven successful in full-scale cleanups of such sites (17). Only full-scale successfully demonstrated technologies and strategies were included in EPA's list of presumptive remedies, which eliminated some of the less mature technologies listed in figure 1-1. EPA selected as wood-treating site presumptive remedies bioremediation, thermal desorption, or incineration for organic contaminants; immobilization is the presumptive remedy for inorganic contaminants. Chapter 3 describes these technologies.

EPA concluded that bioremediation is the primary presumptive remedy for organic contaminants such as PCP or creosote. If bioremediation is not feasible, thermal desorption may be appropriate. For some situations, such as the treatment of sludge "hot spots" with very high concentration of contaminants, EPA concluded that incineration may be the best choice (17).

CONCLUSIONS

EPA today has a range of technologies and strategies available for addressing contaminated wood-treating sites. Some of the technologies were not available when EPA completed the ROD for the Texarkana wood-treating site in 1990; others were too new to have been evaluated thoroughly. Although every Superfund site has some unique characteristics and cleanup requirements, it is likely that some combination of technologies may be applicable as alternatives to incineration for cleaning up the Texarkana site. OTA found that typically several different technologies and control methods are put together for an overall cleanup strategy in order to meet the requirements of a specific wood-treating site. In virtually no wood-treating site reviewed by OTA was a single technology such as incineration or bioremediation selected as the only form of cleanup.

The availability of new strategies for cleaning up contaminants from wood-treating sites suggests that EPA could reexamine the cleanup decisions made in the 1990 ROD for the Texarkana site. This would be responsive to concerns among some in that community about those earlier decisions. However, there are significant risks with choosing alternatives to incineration. EPA cautions that some alternatives are good only for certain contaminants under specific conditions. They might be much less effective for other situations. Thus, an alternative technology should be selected only if it has been tested and proven under the specific conditions for the site where it is to be used. It should also be pointed out that EPA's chosen technology for a given site may not have been found in practice to be effective at that site. At some of the sites reviewed by OTA, according to some EPA officials, cleanup has not been completed or was not as successful as had been hoped.

Although some of these incineration alternatives have significant track records so that their possible use at a specific site can be evaluated, none are as mature and developed as incineration. For example, in its presumptive remedies strategy, EPA warns that the effectiveness of the primary presumptive remedy, bioremediation, is site and contaminant specific, requiring careful site characterization and treatability studies of appropriate scale. Thus, selection of some of these alternatives may carry with it a greater risk that cleanup goals for a specific site will not be adequately met.

The permanence of the cleanup offered by these alternative technologies is also a factor. Incineration was often selected by EPA in the past in part because it offered a **permanent** reduction in the concentrations of contaminants, including dioxins and furans in soil and sludge.

Some alternatives, such as bioremediation and capping, give less complete destruction of contaminants, even though they can offer adequate protection of human health and the environment by eliminating exposure. If the cleanup strategy selected leaves significant concentrations of contaminants **after** the cleanup is complete, it will be necessary to monitor the site for as long as the contaminants remain, possibly indefinitely.

Wood-Treating Sites and Their Cleanup

2

The wood-preserving industry treats lumber with various chemicals to protect against insect damage and decay. Chemically preserved wood is used in products for outdoor use such as railway ties, fencing, telephone poles, exterior plywood panels, and outdoor decks (23). The industry has operated in the United States for over 100 years, with sites often having operated for decades (23). Spills from the treatment process have left many of these sites heavily contaminated with the chemicals used to preserve wood.

U.S. Environmental Protection Agency (EPA) has identified 56 wood-treating sites among the Superfund sites in the United States (17). Because the processes that have been used at these wood-treating sites are generally so similar, the contamination and cleanup needs are also similar. Recognizing this, EPA has recently moved to standardize the process for selecting cleanup remedies. Following a thorough review of past experience with remedial activities, the Superfund program has developed a short list of preferred cleanup technologies or presumptive remedies for wood-treating sites. It is intended that presumptive remedies will be selected for future remedial actions at all wood-treating sites, except under unusual site-specific circumstances. Wood-treating sites are one of three categories of sites for which EPA has designated presumptive remedies.

For sites contaminated with preservatives such as those used at the Texarkana Wood Preserving site, EPA suggests bioremediation as the preferred cleanup remedy. If bioremediation is found to be infeasible, thermal desorption methods are to be considered. Incineration may be selected if bioremediation and thermal desorption are not feasible. In downplaying the role of incineration among the presumptive remedies, EPA stresses the difficulty in gaining public support, but recognizes the method's effectiveness.

In addition to the technologies that EPA now identifies as presumptive remedies, a number of other innovative technologies have been selected for use at wood-treating sites in recent years. OTA has reviewed 47 records of decision (RODs) for 40 Superfund wood-treating sites to investigate the selection of remedies. This chapter provides a description of the contaminants typically found at wood-treating sites, a list of the remedies that have been selected at Superfund wood-treating sites, and a summary of EPA's recent efforts to standardize the remedy selection process at wood-treating sites. The remedial technologies are described in greater detail in chapter 3.

WOOD-TREATING SITES

The wood-preserving industry pressure treats wood with chemicals that protect against insects and fungus. Just a few preserving chemicals have been widely used by the industry. The oldest preservative process treats wood with creosote, a tarry liquid derived from coal (see box 2-1) (17). Pentachlorophenol (PCP) became widely used as a preservative after 1950, although its purchase and use is now restricted (see box 2-2) (17). Metal salts made from chromium, copper, arsenic, or zinc (e.g., chromated copper arsenate [CCA]) are now the most frequently used preservatives. The metal salts present special cleanup problems that we do not consider in this paper.

Almost 60 wood-preserving sites are on the National Priorities List, which lists facilities eligible for cleanup under the Superfund program. Hundreds more may have been abandoned and are in need of cleanup. Most of these sites present similar cleanup problems (see the descriptions of five Superfund wood-treating sites presented in boxes 2-3 through 2-7). The older sites in need of cleanup typically used creosote and PCP. The treatment process produced significant spillage, waste sludges, and contaminated wastewater. The Texarkana Wood Preserving site is typical of the many wood-treating sites that have used creosote and PCP over a number of decades.

At these sites, wood was generally treated under pressure with creosote or PCP in a heated oil-based solution (21,23). After treatment, the wood was removed from the pressure chamber and allowed to drip dry outside, resulting in large volumes of contaminated soil. Other treatment wastes include wastewater and sludges. Wastewater was generated as a condensate in the treatment process and also by rinsing tanks and equipment. After separation of recoverable chemicals, wastewater was often spread onsite or stored in evaporation ponds. An oily sludge gradually accumulates in wastewater evaporation areas and also in treatment cylinders and storage tanks. This sludge was historically dumped into unlined pits onsite. Sludge pits found at wood-treating sites can contain very high concentrations of the preservative chemicals, which may limit treatment options for these areas (17).

The preservatives PCP and creosote are found as contaminants, alone or in combination, at nearly all abandoned wood-treating sites in the United States (21,23). Both of these materials can be hazardous to human health. Creosote contains polycyclic aromatic hydrocarbons (PAHs). Commercial grades of PCP always contain small amounts of dioxins and furans as impurities. It is thought that additional dioxins might be generated by heating PCP solutions (17). The dioxins, furans, and PAHs are considered by EPA and other health agencies to be likely human carcinogens (see boxes 2-1 and 2-2).

BOX 2-1: Creosote and Polycyclic Aromatic Hydrocarbons

Creosote has been widely used as a preservative in the wood treatment industry for more than a century. It is an oily, translucent, brown-to-black liquid with a sharp smoky or tarry odor. Creosote is produced from high-temperature carbonization of bituminous coal. It is not a single chemical, but rather a complex mixture, containing several thousand compounds. It is about 85 percent polycyclic aromatic hydrocarbons (PAHs), along with phenolic compounds (about 10 percent) and a variety of other related chemicals.

The PAHs contained in creosote are a group of more than 100 related chemicals that are both manmade and naturally occurring. They are found in crude oil, coal, coal tar pitch, and road and roofing tar. Although in pure form a single PAH is usually a white or pale green solid, they almost always occur as a mixture of PAHs. Typically, human exposure involves exposure to a mixture of PAHs.

The human health effects of the individual PAHs found in creosote vary. About 17 PAHs have been studied extensively. These 17 are considered the most harmful, the most likely to be involved in human exposure, and the most frequently identified at Superfund sites. People living near waste sites contaminated with PAHs may be exposed to them by contact with contaminated air, water, or soil. Most PAHs that enter the body are excreted in feces and urine within a few days.

PAHs are considered by EPA and other public health organizations to be human carcinogens. The Department of Health and Human Services (DHHS) has determined that certain PAHs “may reasonably be anticipated to be carcinogens.” The International Agency for Research on Cancer (IARC) has determined that certain PAHs “are possibly carcinogenic to humans.” EPA has determined that certain PAHs “are probable human carcinogens.”

Reports with humans show that individuals exposed to PAHs by breathing or skin contact for long periods can develop cancer. Some PAHs cause tumors in laboratory animals when breathed, eaten, or after long periods of skin contact. Mice fed high levels of certain PAHs during pregnancy had difficulty reproducing and so did their offspring. Offspring from pregnant mice fed PAHs showed other harmful effects, including birth defects, although there is no information about similar effects in humans.

PAHs have low water solubility, but they can contaminate underground water that comes into contact with soil contaminated by them. They have been found in some U.S. drinking water supplies. PAHs can evaporate, but most will stick to solid particles in soil. In soil, most PAHs can break down in weeks to months, mostly because of microorganisms, although very large PAH molecules are more stable. Some wood-treatment sites have cleanup standards only for those PAHs considered to be carcinogenic while other sites may focus on all the PAHs present.

SOURCE: U.S. Environmental Protection Agency, Office of Research and Development, *Contaminants and Remedial Options at Wood Preserving Sites*, prepared by Foster Wheeler Enviresponse, Inc., EPA/600/R-92/182 (Washington, DC: October 1992); U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, “Presumptive Remedies for Soils, Sediments, and Sludges at Wood Treater Sites,” EPA/540/F-95/006 (Draft), Washington, DC, May 1995; and U.S. Department of Health & Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, “Toxicological Profile for Polycyclic Aromatic Hydrocarbons (PAHs),” draft, Atlanta, GA, October 1993.

BOX 2-2: Pentachlorophenol

Pentachlorophenol (PCP) has been used for many years as a preservative in the wood treatment industry. It is a manufactured substance not occurring naturally in the environment. PCP was formerly one of the most heavily used pesticides in the United States. Today its purchase and use is restricted to certified applicators, and it is used industrially as a wood preservative for power line poles, fence posts, etc. Before restriction, PCP was widely used as a wood preservative. It is made by only one company in the United States. Pure PCP is a white crystalline material, but the commercial grade form usually found at waste sites is dark gray to brown.

Commercial grade PCP used for treating wood is a mixture of many related compounds. It contains PCP (85 to 90 percent); 2,3,4,6-tetra chlorophenol (4 to 8 percent), more highly chlorinated chlorophenols (2 to 6 percent), and dioxins and furans (about 0.1 percent). Dioxins and furans are also mixtures of various related compounds. The principal dioxins and furans found in commercial grade PCP have six to eight chlorine atoms present in their structures. The most toxic dioxin and the one of greatest regulatory concern is 2,3,7,8-tetrachloro-p-dioxin (TCDD), which contains four chlorine atoms in its structure.

Analysis of commercial PCP produced in the U.S. has not found TCDD. But some wood-preservation methods use PCP at higher temperatures, which might produce traces of TCDD from the PCP itself. Octachloro-dibenzo-p-dioxin (the dioxin containing 8 chlorine atoms) is by far the largest dioxin contaminant, while the most toxic dioxin, TCDD, occurs only at trace or below detection levels. According to EPA, octachloro-dibenzo-p-dioxin is about 1000-fold less toxic than TCDD. In any event, EPA recommends that site managers should ensure that sampling for dioxins and furans is conducted at all wood-treating sites known to have used PCP.

Public health agencies consider that PCP, at most, might be a human carcinogen. The International Agency for Research on Cancer (IARC) determined PCP is not classifiable as to its carcinogenicity to humans, while EPA classified PCP as a “probable human carcinogen”. Large doses of PCP can cause death, and long-term exposure to lower levels can cause damage to liver, kidneys, blood, and nervous system.

However, there is no convincing evidence from epidemiological studies that PCP causes cancer in humans, although it does cause cancer in some laboratory animals fed large doses for long periods. Many, but not all, of the harmful effects of PCP may be due to the impurities in the commercial grade, including dioxins and furans. Although pure PCP might not be a human carcinogen, the small amounts of dioxins and furans found in the commercial grade of PCP might account for its apparent animal carcinogenicity.

The physical properties of PCP are such that it will not evaporate very quickly from contaminated soil or sludge. The most significant human exposure comes through breathing and skin contact, and it does not seem to accumulate in the human body, but is excreted in urine. After environmental release onto soil or sludge, most PCP will tend to slowly move with any water that contacts that contaminated soil or sludge. PCP will tend to stick to soil particles. It is broken down in soils and surface waters by microorganisms and in surface waters and air by sunlight.

SOURCE: U.S. Environmental Protection Agency, Office of Research and Development, *Contaminants and Remedial Options at Wood Preserving Sites*, prepared by Foster Wheeler Enviresponse, Inc., EPA/600/R-92/182 (Washington, DC: October 1992); U.S. Department of Health & Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry. “Toxicological Profile for Pentachlorophenol,” draft, Atlanta, GA, October 1992; U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, “Presumptive Remedies for Soils, Sediments, and Sludges at Wood Treater Sites,” EPA/540/F-95/006, PB 95-963410 (Draft), Washington, DC: May 1995.

BOX 2-3: The American Creosote Works Site, Pensacola, Florida

The 18-acre American Creosote Works (Pensacola plant) site is in a dense, moderately commercial and residential area of Pensacola, Florida. A wood-preserving facility operated at this site from 1902 to 1981. During this time, process wastewater containing pentachlorophenol (PCP) was discharged into unlined, onsite surface impoundment ponds. Before 1970, these impoundment ponds were allowed to overflow through a spillway into neighboring bays. After 1970, wastewater was discharged to designated onsite spillage areas. Additional discharges occurred during periods of heavy rainfall when the ponds overflowed.

In March 1980, the city found considerable quantities of oily, asphaltic, creosote material in the groundwater near the site. Because of the threat posed to human health and the environment, EPA and the state performed an emergency cleanup in 1983. This included dewatering the ponds, treating the water, and discharging treated water into the city sewer system. The sludge in the ponds was then solidified and capped.

EPA signed a record of decision (ROD) in 1985 requiring all onsite and offsite contaminated solids, sludge, and sediment to be placed in an onsite RCRA-permitted landfill. A second ROD, signed in 1989, addresses remediation of contaminated surface soil. A future ROD will address treatment of contaminated subsurface soil, sludge, and groundwater. The primary contaminants of concern affecting the surface soil are organics, including dioxins, carcinogenic polycyclic aromatic hydrocarbons (PAHs), and PCP.

The selected remedial action for this site includes

- excavating and treating 23,000 cubic yards of PAH-contaminated soil using solid-phase bioremediation at an onsite land treatment area. Dissolved oxygen, pH, nutrients, and soil moisture content will be monitored,
- disposal of treated soil onsite in the excavated areas or by spreading the soil over the entire site,
- spraying collected drain water over the treatment area to moisten soil,
- repairing fences around the site, monitoring the site cap, and
- implementing groundwater use restrictions.

The estimated cost for this approach is $2,275,000.

SOURCE: Environmental Protection Agency, Region 4, “Record of Decision: American Creosote Works Inc. Site,” Atlanta, GA, January 5, 1989.

BOX 2-4: The Koppers Site, Oroville, California

The Koppers site is a 200-acre operating wood-treating plant in Butte County, California. Nearby land use is mixed agricultural, residential, commercial, and industrial. Although there is a history of wood-treating operations at the site, they were greatly expanded in 1955 when Koppers Company, Inc., became the owner and operator. Pentachlorophenol (PCP), creosote, and chromated copper arsenate (CCA) solution are among the chemicals that have been used at this site.

Wastewater discharge and other site activities have resulted in contamination of unlined ponds, soil, and debris. PCP was detected in onsite groundwater in 1971 and in residential wells in 1972. Pursuant to a state order, Koppers conducted cleanup activities from 1973-74, including groundwater pumping and discharge to spray fields and offsite disposal of contaminated debris, and process changes, including construction of a wastewater treatment plant. In 1986, Koppers provided nearby residents an alternate water supply for domestic uses.

Following a 1987 explosion and fire at a PCP wood-treatment process facility, EPA issued a removal order requiring cleanup of fire debris and removal and stabilization of surface soil.

The present record of decision (ROD) addresses the remaining contamination in onsite soil and groundwater affected. The primary contaminants of concern are polycyclic aromatic hydrocarbons (PAHs), PCP, dioxins and furans, and metals including arsenic and chromium.

The selected soil remedy includes

- onsite biodegradation of 110,000 cubic yards of PCP-contaminated soil,
- excavation and soil washing of 200,000 cubic yards of soil contaminated with wood-treating wastes with disposal of treated soil onsite and treatment of residual contamination in the washing fluid in an onsite treatment facility,
- installation of a low-permeability cap over the wood-treating process area (an interim remedy) and down gradient extraction wells, and
- excavation and chemical fixation of 4,000 cubic yards of soil contaminated with metals, followed by onsite disposal.

The groundwater remedy includes pumping and treatment of approximately 22,000,000 cubic yards of groundwater using activated carbon, reinjection of treated waste to the groundwater, and formalization of the provision of an existing alternate water supply and extension, if needed, of the water supply during implementation of the remedy.

According to the ROD the estimated cost for this cleanup strategy was $77,700,000.

EPA has had some difficulties implementing bioremediation at the Koppers site. It found that the soil excavated for a bioremediation treatability study was contaminated with more dioxin than anticipated. This caused the cancellation of the treatability study and a switch to a removal action, placing soil in a RCRA-approved landfill. The soil washing pilot test showed that soil washing was not capable of meeting cleanup standards. Bioremediation effectively destroyed PCP but was not effective in reducing dioxins. The owner is reevaluating soil remedies for the remainder of this site.

SOURCE: U.S. Environmental Protection Agency, Region 9, “Record of Decision: Koppers Co. Inc. (Oroville Plant) Site,” San Francisco, CA, September 1989; Fred Schauffler, Project Manager, EPA Region 9, Oroville, CA, personal communication, July 13, 1995 and written comments, August 8, 1995.

BOX 2-5: The Koppers Site, Morrisville, North Carolina

The 52-acre Koppers Morrisville site is a wood-laminating facility in Morrisville, Wake County, North Carolina. Surrounding land use is a mixture of commercial, light industrial, and rural residential. The site has been used by lumber companies since 1896. In 1962, Koppers began treating wood at the site using pentachlorophenol (PCP) and isopropyl ether injected into wood. Process wastes were put into unlined lagoons. Koppers discontinued wood treatment in 1975, but past wood-treatment processes and associated disposal activities have left the site contaminated with PCP, dioxins, and isopropyl ether affecting the soil, groundwater, and surface water.

In 1989, in response to state studies of water contamination from the site, nearby residents began using public water lines instead of wells to obtain drinking water. In 1990, EPA required extensive studies of the soil, groundwater, drainage pathways, and ponds, and also determined that additional studies were needed to further assess contamination of the surface soil in the lagoon and wood-treatment process areas. In 1992, EPA completed a record of decision (ROD) for the site that specified incineration as the primary remedy and base-catalyzed decomposition (BCD) as the “contingency remedy” whose use would be dependent upon the results of a treatability study. One driving force for providing for an alternative to incineration was the strong interest of the community.

The primary strategy was offsite incineration of soil involving

- excavation of contaminated soils from lagoon and process areas and transportation to an offsite permitted incineration facility,
- extraction of contaminated groundwater from within the plume via extraction well(s) and piping it to an onsite carbon adsorption treatment unit,
- use of institutional controls including fencing of the pond, lagoon, and wood-treatment process areas.

Base-catalyzed dehalogenation was selected as a contingency cleanup strategy. According to the 1992 ROD, BCD could substitute for offsite incineration if it proved itself in treatability studies. BCD would involve the excavation of contaminated soils from the lagoon and process areas, and transportation to an onsite BCD treatment system,

According to the ROD, the estimated cost for the selected cleanup strategy was $11,500,000.

The treatability study with BCD was completed in August 1993. The results showed that BCD was effective in treating soil contaminated with both PCP and dioxins. However, it may be premature to consider BCD a general technology for wood-treatment site cleanup. The size of this demonstration was very small compared to other wood-treatment sites. According to the site engineer at Koppers, the BCD demonstration involved only 700 cubic yards of soil; the amounts of soil requiring treatment at some of the largest contaminated wood-treatment sites are as much as 100 times larger (see table 2-1). Another concern raised by one EPA wood treatment site manager is that the results from this BCD trial seem to show significant stack emissions, presumably from the thermal desorption stage, that are equal to or greater than those that would be seen if incineration had been used instead of BCD.

For BCD to be considered successful at this site, it had to achieve 7 parts-per-billion (ppb) or lower dioxin levels in the treated soil. However, the soil levels were fairly low to begin with and dioxin soil concentrations were probably not very important for the choice of BCD as a soil cleanup technology.

(continued)

BOX 2-5: The Koppers Site, Morrisville, North Carolina (Cont'd.)

The neighboring community was brought into the treatability study process. More than 100 citizens were invited to observe the results of the BCD treatability study. According to one EPA official involved with the study, the citizen involvement was very helpful in the overall process of developing the alternative. A new ROD has been approved that specifies BCD as the primary means of treating contaminated soil. Koppers as the principal responsible site owner, is in the process of awarding a contract to build a full-scale onsite BCD treatment facility.

SOURCE: U.S. Environmental Protection Agency, Region 4, "Record of Decision: Koppers Site (Morrisville Plant)," Atlanta, GA, December 1992; B. Hudson, Site Engineer, Koppers Superfund site, Morrisville, NC, personal communication, April 12, 1995; E. Hendrick, Site Manager, EPA Region 6, Dallas, TX, personal communication, April 12, 1995.

BOX 2-6: The Arkwood, Inc., Site, Omaha, Arkansas

The 15-acre Arkwood site is a former wood-treatment facility in Boone County, Arkansas. Land use in the vicinity of the site is primarily agricultural and light industrial. Approximately 200 residences are located within 1 mile of the site, and 35 domestic water supply wells are within 1.5 miles of the site. Groundwater on or near the site is highly susceptible to contamination as a result of underground cavities, enlarged fractures, and conduits that hinder monitoring and pumping.

From 1962 to 1973, Arkwood operated a pentachlorophenol (PCP) and creosote wood treatment facility at the site. In 1986, the site owner dismantled the plant. State investigations conducted during the 1980s documented PCP and creosote contamination in surface water, soil, debris, and buildings throughout the site. Contaminated surface features at the site include the wood-treatment facility, a sinkhole area contaminated with oily waste, a ditch area, a wood storage area, and an ash pile.

In 1987, EPA ordered the site owner to perform an immediate removal action that included implementing site access restrictions, such as fencing and sign postings.

The present record of decision (ROD) addresses remediation of all affected media and provides the final remedy for the site. The primary contaminants affecting the soil, sludge, debris, and groundwater are organics including PCP, polycyclic aromatic hydrocarbons (PAHs) and dioxins.

The selected remedial action for this site includes

- excavating approximately 21,000 cubic yards of contaminated soil and sludge followed by soil washing,
- onsite incineration of approximately 7,000 cubic yards of materials that exceed cleanup levels,
- incineration of any free oil wood-treating material,
- using washed and decontaminated materials and any residual ash for backfilling,
- covering the site with a soil cap and planting revegetation,
- site access restrictions including fencing, and
- monitoring of drinking and groundwater and connecting affected residences to municipal water lines.

According to the ROD, the cost of this approach would be $10,300,000.

SOURCE: U.S. Environmental Protection Agency, Region 6, "Record of Decision: Arkwood, Inc. Site," Dallas, TX, September 1990.

BOX 2-7: The United Creosoting Site, Conroe, Texas

The 100-acre United Creosoting site in Conroe, Montgomery County, Texas, is occupied by a residential subdivision, a distributing company, and a construction company. From 1946 to 1972, the United Creosoting Company operated a wood preserving facility at the site. Pentachlorophenol (PCP) and creosote were used in the wood-preservation process, and process wastes were stored in waste ponds.

During 1980, the county used soil and waste pond backfill from the site on local roads. After residents living near the improved roadways experienced health problems, the county sampled and compared leachate composition from the affected roadways and the site. They determined that leachate from both the site and the roadways was contaminated with PCP. Roadway soil was subsequently removed and disposed of using land farm treatment.

In 1983, in response to contaminated stormwater runoff from the former waste pond areas, the property owner was directed under terms of an EPA Administrative Order to regrade contaminated soil, divert surface water drainage away from the residential portion of the site, and cap the contaminated soil.

The present record of decision (ROD) specifies a final remedy for contaminated soil at the site and complements a 1986 ROD that determined that no action was necessary to remediate shallow groundwater. The primary contaminants of concern affecting the soil are organics including polycyclic aromatic hydrocarbons (PAHs), PCP, and dioxins.

The selected remedial action for this site includes

- excavation and onsite treatment of 94,000 cubic yards of soil containing contaminants that exceed target action levels using critical fluid extraction with liquid propane,
- offsite incineration of residues containing the concentrated contaminants produced by this technology,
- recycling or discharge of wastewater generated during the treatment process, and
- spreading treated soil on the commercial portion of the site, and backfilling residential areas with clean fill.

According to the ROD, the estimated cost for this remedial action is $22,000,000. However, based on a signed contract for a major portion of the remedial activities and estimates for the remainder of the work, the expected cost of this cleanup is now expected to exceed $34,000,000.

SOURCE: U.S. Environmental Protection Agency, Region 6, “Record of Decision: United Creosoting Co. Site,” Dallas, TX, September 1989; Hendrick, E., Senior Project Manager, EPA Region 6, Dallas, TX, written comments, August 9, 1995.

Sometimes residues of the preserving chemicals can be found at a site in a nearly pure form (21,23). Typically though, the highest concentrations of waste contaminants are found near treatment areas and waste pits (23). At many wood-treating sites, the primary contamination has moved through the soils into nearby ground and surface waters (23). Because PCP and most PAHs have very low water solubility and were often used after being dissolved in oil, the contaminants can form non-aqueous phase liquids (NAPLs) when they come in contact with ground or surface water (23). This means that the contaminant is in a liquid form that either floats on or sinks below water it contacts. Contaminants in the form of NAPLs are particularly difficult to locate and treat.

EPA AND WOOD-TREATING SITES

Since 1980, EPA has classified 56 wood preserving sites as Superfund sites (17). At about 40 of these sites, EPA has completed the process of selecting a cleanup strategy for the soil, sludge, sediments, and water contaminated by wood-treatment wastes. EPA's process for selecting a cleanup strategy at a Superfund site is described in the ROD, which summarizes the basis for the decision and describes the remedial strategy. EPA's work with wood-treating sites has produced about 47 RODs for 40 such sites. The details of these sites, the cleanup strategies selected by EPA, and the current land use of the area surrounding the site are summarized in table 2-1. Current land use was included as an indicator of future use of a contaminated site.

Not surprisingly, the similarity in the contamination across wood-treating sites has resulted in the selection of similar treatment and remediation strategies. At least 10 approaches have been selected by EPA for cleaning such sites. For the treatment of contaminated soil, sludge, and sediments at wood-treating sites, table 2-1 shows that EPA has generally selected from among the following strategies: bioremediation, incineration, thermal desorption, soil washing or flushing, chemical dechlorination, solvent extraction, site capping, solidification and stabilization techniques, construction of barrier walls, and disposal in RCRA authorized landfills. Figure 1-1 in chapter 1 shows how often EPA selected various strategies for dealing with soil, sludge, and sediments at 40 wood-treating sites as revealed in 47 RODs.

Incineration was a frequently selected remedy during the period from 1986 to 1990. Since 1990, the selected remedy is much more likely to have been bioremediation (perhaps in combination with soil washing or with limited incineration of the most contaminated wastes), thermal desorption, or chemical dehalogenation. Groundwater at wood-treating sites is typically dealt with by pump-and-treat methods in conjunction with ongoing monitoring. According to EPA, a general approach now used at wood-treating sites is bioremediation to remove creosotes and PCPs from soil, followed by capping and immobilization to deal with residual dioxins or metals (i.e., to ensure they do not leach from the soil). The Libby Groundwater site (see table 2-1) is one place where such an approach is being tried (1).

Generally no single technology can be used to clean up an entire wood-treating site (8). Rather, as in most of the RODs reviewed by OTA, a combination of treatment technologies and control methods will be required. Boxes 2-3 through 2-7 illustrate the variety of technologies selected, although many of these have not yet been fully implemented. Often some contamination will remain even after cleanup, and various institutional or engineering control strategies must be used to prevent exposure to the remaining contamination. For example, the combination of bioremediation or incineration followed by site-capping (covering the site with a liner and clean soil) and restrictions on future site use was used in more than half the cases.

In some cases a sequence of cleanup remedies in a "treatment train" may be needed to address the various contaminants. For example, when metallic wastes are mixed with organic (PCP and creosote) contaminants, bioremediation or thermal desorption to remove the organics may be followed by immobilization to control the metallic waste (10). A variety of treatments may also be used to clean up different areas of a contaminated site. Hot spots can be particularly difficult to clean. A site manager may prefer to excavate sludges, perhaps incinerating this material, while applying bioremediation to the less contaminated soils (1). These combined approaches have been specified in the remedial actions for wood-treating sites reviewed by OTA.

The selection of a technology as documented in a ROD does not necessarily mean that the technology proved effective. In many cases, cleanup has not been completed at the sites reviewed by OTA; in other cases, an unsuccessful trial of the selected technology has led to a change in plans.

EPA'S PRESUMPTIVE REMEDY APPROACH

EPA has found that most wood-treating sites have very similar characteristics (21,23). EPA has determined that it is useful to group wood-treating sites together based upon their common characteristics, such as the contaminants present, the environmental media affected by those contaminants, and the cleanup technologies selected (23). Past experience with such sites can be summarized to streamline future site investigations and remedy selection (21,23).

As part of an effort to accelerate cleanup at Superfund sites, the EPA Superfund program is putting together a group of cleanup strategies that have been used successfully at similar sites in the past (21,22,23). EPA has also reviewed other technologies that have less available performance data but nevertheless may be appropriate or useful for wood-treating sites (21, 23).

EPA calls these proven cleanup technologies for common site types presumptive remedies. Presumptive remedies are technologies for common types of sites selected on the basis of historical patterns of remedy selection and EPA's scientific and engineering expertise (23). EPA's presumptive remedies program uses Superfund program experience in an effort to streamline cleanup (23). The presumptive remedy approach focuses only on proven technologies. In general the approach would not consider a small-scale demonstration such as pilot plant demonstrations as sufficient proof for a recommended presumptive remedy (1). However, some other technologies with more limited performance data are also considered by EPA (21,23).

EPA's presumptive remedies for treating soil, sludge, and sediments at wood-treating sites with organic contamination from creosote and PCP are bioremediation, thermal desorption, and incineration. Immobilization is the presumptive remedy for treating inorganic contaminants at sites where metallic salts have been used (23). The presumptive remedy process is a decision-making strategy for selecting among these remedies. EPA expects to use this process at all wood-treating sites and expects to select one of the remedies unless there are unusual site-specific circumstances. Bioremediation should be chosen unless it is shown to be infeasible. Incineration should be selected only if bioremediation and thermal desorption have both been shown to be infeasible. So far, EPA's presumptive remedy approach for wood-treating site cleanup covers only the contaminated soils, sludges, and sediments at wood-treating sites. EPA is currently working on presumptive remedies for groundwater cleanup at wood-treating sites (23).

According to EPA's presumptive remedy analysis for wood-treating sites, incineration is the most technically developed and proven technology (see table 2-2); however, it was not designated by EPA as the primary presumptive remedy because of the difficulty in getting public support for incineration. The other technologies, including bioremediation, have track records indicating they may be appropriate for this type of site; however, the selection of technologies that are less proven or less capable than incineration will always bring a greater risk of failure to achieve cleanup goals.

EPA divided the presumptive remedy project for wood-treating sites into two parts. One project was directed toward summarizing cleanup of PCP and creosote contamination. A second effort was to evaluate dioxin cleanup issues separately, but EPA has not yet completed this aspect of the problem (1). Thus, the wood-treating site presumptive remedies documentation from EPA does not specifically address the dioxin issue (1). For example, bioremediation might have some limitations as a remedy for sites like Texarkana, where PCP has been used. It might give excellent results for cleaning up the PCP and creosote, but it is not likely to adequately clean up the associated dioxins. Other approaches may be needed to supplement bioremediation in such cases, such as soil capping and site use restrictions (1).

EPA warns that the remediation technologies considered in its presumptive remedy strategy are at different stages of technical maturity—from proven to innovative to emerging. Application of a specific technology to clean up a wood-treating site requires careful matching with specific site conditions. Estimates of treatment costs for more mature technologies such as incineration and bioremediation can be quite reliable, but estimates for innovative and emerging technologies can be less reliable. Incineration and biological treatment are proven at the commercial scale (17). Nevertheless, most alternatives, including biological treatment and thermal desorption, require site-specific treatability tests to ensure they will work (17).

As a practical example of the risks of using less mature technologies, the wood-treating site project was the first presumptive remedy approach attempted by EPA, but because of delays it will be the third one actually published (1). The main delay was caused by questions about the efficacy of bioremediation, the primary presumptive remedy indicated for wood-treating sites (1). Although bioremediation has been selected for a number of wood-treating sites, it has only been completed at very few sites (1). Moreover, there have been some failures with bioremediation, sometimes caused by simple oversights by the site managers and facility operators, such as overlooking the proper monitoring of soil pH (1). Bioremediation also may have difficulty achieving very stringent cleanup levels sometimes required for carcinogenic PAHs.

SUMMARY

In summary, contaminated wood-treating Superfund sites are a common type of site in the United States. The wood-treating processes and the types of chemicals used as wood preservatives were very similar at all wood-treating sites, thus the contamination problems and the technologies and strategies that appear to work at these sites are also similar. EPA's decisions about how to clean up contaminated wood-treating sites show that, in general, about 10 technologies or strategies are used at these sites, almost always in combination. EPA has analyzed wood-treating site cleanups and, based on success stories, recommends about a half dozen different technologies as presumptive remedies for cleaning up such sites. EPA warns that most of these alternative technologies will not work in all situations and that a site-specific analysis almost always will be required. Nevertheless, it appears that decisionmakers have a range of options for addressing cleanup problems at wood-treating sites.

TABLE 2-1: Cleanup Strategies Selected by EPA for Superfund Wood-Treating Sites

Site Name Location ROD No. ROD Date	Chemical used[a]	Primary contaminants	Current land use	Site area/ acres	Vol. material to be treated	Remediation strategy[b]
American Creosote Pensacola, FL FLD008161994 85-09-30	Creosote, PCP	PAHs	Commercial & residential	12	?	RCRA landfill of soil and sludges
American Creosote Pensacola, FL FLD008161994 89-09-28	Creosote, PCP	PAHs, PCPs, Dioxins	Commercial & residential	18	23,000 yd^3 soil	Bioremediation of soil
American Creosote Jackson, TN TND007018799 89-01-05	Creosote, PCP	PAHs	Partially developed	60	?	Incineration of sludges offsite at a fixed facility or onsite in a mobile incinerator
American Creosote Winnfield, LA LAD000239814 93-4-28	Creosote, PCP	PAHs, PCP	Mixed agricultural, residential, & recreational	34	25,000 yd^3 highly contaminated sludge, 250,000 yd^3 soil	Incineration of sludge; bioremediation of soil
American Crossarm & Conduit Chehalis, WA WAD057311094 93-06-30	Creosote, PCP	PAHs, PCP, dioxins	Commercial, light industrial, residential, & recreational	?	?	Remove most highly contaminated soil; capping; institutional controls
Arkwood, Inc. Omaha, AR ARD084930148 90-09-28	Creosote, PCP	PAHs, PCP, Dioxins	Agricultural & light industrial	15	21,000 yd^3 soil & sludge, 3,000 gal sinkhole liquids	Soil washing or incineration onsite if washed soil exceeds PCP, dioxin, or PAHs cleanup levels; pump and treat oily sinkhole liquids; monitor groundwater
Baxter/Union Pacific Tie Treating Laramie, WY WYD061112470 86-09-26	Creosote, PCP	PAHs, PCP	?	140	?	Slurry barrier wall to delay offsite movement of contaminated groundwater and surface soils while planning and implementing more permanent remedies
Bayou Bonfouca Slidell, LA LAD980745632 87-03-31	Creosote	PAHs	?	55	150,000 yd^3 sediment	Incineration, capping

(continued)

TABLE 2-1: Cleanup Strategies Selected by EPA for Superfund Wood-Treating Sites (Cont'd.)

Site Name Location ROD No. ROD Date	Chemical used[a]	Primary con-taminants	Current land use	Site area/ acres	Vol. material to be treated	Remediation strategy[b]
Broderick Wood Products Co. Denver, CO COD000110254 91-09-24	Creosote, PCP	PAHs, PCP, Dioxins	Predominately industrial	64	2,170 yd^3 sludge, 500 gal oil	Transport sludge and oil to a RCRA recycling facility; offsite incineration of recycler residues (amended remedial action)
Broderick Wood Products Co. Denver, CO COD000110254 88-06-30	Creosote, PCP	PAHs, PCP, Dioxins	Primarily industrial	64	4,000 yd^3 sludge, 31,000 yd^3 soil	Incineration onsite of sludge; groundwater monitoring
Brown Wood Preserving Live Oak, FL FLD980728935 88-04-08	Creosote, PCP	PAHs	Rural & light agriculture	55	11,500 tons soil	Biodegradation and transport of most severely contaminated soil and sludge to a RCRA hazardous waste facility; and ground-water monitoring
Burlington Northern Brainerd/Baxter, MN MND000686196 86-06-04	Creosote	PAHs	Industrial & residential	?	9,500 yd^3 soil	Bioremediation of soil and sludge; capping with a RCRA-approved cover
Cabot/Koppers, Gainesville, FL FLD980709356 90-09-27	Creosote	PAHs	Commercial & residential	99	6,400 yd^3 soil	Soil washing and bioremediation followed by solidification and stabilization; pumping and treatment of groundwater; monitoring ground-water and surface water
Cape Fear Wood Preserving Fayetteville, NC NCD003188828 89-06-30	Creosote	PAHs	Industrial, agricultural, and residential	9	?	Soil flushing or a low thermal desorption process
Coleman Evans, Jacksonville, FL FLD991279894 86-09-25	PCP	PCP	Residential & light commercial & industrial	11	9,000 yd^3 soils and sediments	Incineration of more contaminated soil; groundwater pump and treat

(continued)

TABLE 2-1: Cleanup Strategies Selected by EPA for Superfund Wood-Treating Sites (Cont'd.)

Site Name Location ROD No. ROD Date	Chemical used[a]	Primary contaminants	Current land use	Site area/ acres	Vol. material to be treated	Remediation strategy[b]
Coleman Evans Jacksonville, FL FLD991279894 90-09-26	PCP	PCP	Residential, light commercial & industrial	11	27,000 yd^3 soil & sediment	Soil and sediment washing; bioremediation, solidification, and stabilization of fines or sludges; covering the solidified mass; pumping and recovering groundwater
Havertown PCP Site Haverford Twp, PA PAD002338010 91-09-30	Creosote, PCP	PAHs, PCP, Dioxins	Mixed residential & commercial	12-15	?	Interim remedies include free product recovery wells, an onsite groundwater treatment plant, and monitoring groundwater
Havertown PCP Site Havertown, PA PAD002338010 89-09-29	Creosote, PCP	PAHs, PCP, Dioxins	Commercial & residential	12-15	200 barrels soil, 6,000 gal wastewater	Offsite land disposal of soil; oily debris and wastewater stored; multimedia monitoring
Idaho Pole Co. Bozeman, MT MTD006232276 92-09-28	Creosote, PCP	PAHs, PCP	Light industrial	50	42,000 yd^3 soil	Bioremediation, soil flushing, capping
J H Baxter Co. Weed, CA CAD000625731 90-09-27	Creosote, PCP	PAHs, PCP, Dioxins	Operating wood site, pasture, woodland, & residential	33	>41,000 yd^3 soil	Biological treatment and chemical fixation of contaminated soil; groundwater pumping with biological treatment; multimedia monitoring
Koppers (Morrisville) Morrisville, NC NCD003200383 92-12-23	PCP	PCP, Dioxins	Commercial, light industry, & rural residential	52	2,930 yd^3 soil	Offsite incineration; treatability studies for dechlorination as a contingency remedy
Koppers Co., Inc., (Oroville Plant) Oroville, CA CAD009112087 89-09-13	Creosote, PCP	PAHs, PCP, Dioxins	Operating wood site, agricultural, residential, commercial, & industrial	200	334,000 yd^3 soil, 22,000,000 yd^3 groundwater	Biodegradation in situ or washing of soil; capping; pump and treat groundwater
Koppers Co., Inc. Galesburg, IL ILD990817991 89-06-28	Creosote, PCP	PAHs, PCP	Sparsely populated	105	15,200 yd^3 soil	Bioremediation

(continued)

TABLE 2-1: Cleanup Strategies Selected by EPA for Superfund Wood-Treating Sites (Cont'd.)

Site Name Location ROD No. ROD Date	Chemical used[a]	Primary contaminants	Current land use	Site area/ acres	Vol. material to be treated	Remediation strategy[b]
Koppers Co., Inc. Texarkana, TX TXD980623904 88-09-23	Creosote, PCP	PAHs, PCP	Residential	62	3,300-19,400 yd^3 soil	Soil washing, offsite disposal
Koppers Co., Inc. Texarkana, TX TXD980623904 92-03-04	Creosote, PCP	PAHs, PCP	Residential	62	?	Soil washing; relocating residents; deed restrictions
L.A. Clarke and Son Fredericksburg, VA VAD007972482 88-03-31	Creosote	PAHs	na	40	118,000 yd^3 soil	Soil flushing and in-situ biodegradation; sediments biodegradation; landfarming excavated surface soil, sediments, and subsurface wetland soil; and groundwater monitoring
Libby Groundwater Contamination Site Libby, MT MTD980502736 86-09-26	Creosote, PCP	PAHs, PCP	Active lumber & plywood mill	?	?	Reduce human exposure to contaminated groundwater by continuing and expanding a "buy water" plan sponsored by the onsite company; monitoring
Libby Groundwater Contamination Site Libby, MT MTD980502736 88-12-30	Creosote, PCP	PAHs, PCP, Dioxins	Residential areas & businesses	?	>30,000 yd^3 soil & debris	Biodegradation of soil and debris; recycling and incinerating recovered NAPLs; capping; groundwater bioremediation; groundwater monitoring
Macgillis & Gibbs Co / Bell Lumber Pole New Brighton, MN MND006192694 91-09-30	Creosote, PCP	PCP, PAHs, Dioxins	Residential & commercial	24	100,000 gal. PCP waste oil & sludges	Removing and separating PCP waste oil and sludges; wastewater bioremediation; groundwater pump and treat

(continued)

TABLE 2-1: Cleanup Strategies Selected by EPA for Superfund Wood-Treating Sites (Cont'd.)

Site Name Location ROD No. ROD Date	Chemical used[a]	Primary contaminants	Current land use	Site area/ acres	Vol. material to be treated	Remediation strategy[b]
Mid-South Mena, AR ARD092916188 86-11-14	Creosote, PCP	PAHs, PCP	?	57	80,000 yd^3 soil	Hot spot stabilization; RCRA cap; oil and sludges transported to a RCRA facility; groundwater pump and treat; and groundwater monitoring
Midland Products Ola, AR ARD980745665 88-03-24	Creosote, PCP	PAHs, PCP	?	37	<24,600 yd^3 soil, sediments & sludges, 450,000 gal groundwater, 620,000 gal. lagoon fluids	Thermal destruction of contaminated soils, sludges, and sediments; waste- and groundwater pump and treat
Montana Pole and Treating Butte, MT MTD006230635 93-09-21	Creosote, PCP	PAHs, PCP, Dioxins	Primarily industrial	?	262,000 yd^3 soil, 9,100 yd^3 debris, 26,500 gal sludge LNAPs, and oil	Bioremediation of soil hot spots; soil flushing and in-situ bioremediation; incinerate offsite sludge, NAPLs, and oil; bioremediation or UV oxidation of groundwater
Moss-American Kerr-Mcgee Oil Co. Milwaukee, WI WID039052626 90-09-27	Creosote	PAHs	Railroad loading & undeveloped parkland	88	210,000 yd^3 soil & sediment	Soil washing and bioremediation; covering remaining soil; removing pure-phase liquid wastes for offsite incineration; and groundwater monitoring
Newsom Brothers Old Reichold Columbia, MS MSD980840045 89-09-18	Creosote, PCP	PAHs, PCP	Primarily residential	81	30,300 yd^3 soil, 7,300 yd^3 sediment, 650 yd^3 tar-like waste	Offsite disposal of soil and sediment; offsite incineration of tar and soil and sediment containing RCRA hazardous wastes. No remedial action planned for groundwater

(continued)

TABLE 2-1: Cleanup Strategies Selected by EPA for Superfund Wood-Treating Sites (Cont'd.)

Site Name Location ROD No. ROD Date	Chemical used[a]	Primary contaminants	Current land use	Site area/acres	Vol. material to be treated	Remediation strategy[b]
North Cavalcade Street Site North Cavalcade, TX TXD980873343 88-06-28	Creosote, PCP	PAHs	Residential, commercial, & industrial	21	22,300 yd^3 soil, 5,600,000 gal groundwater	Biodegradation in situ of soil (after pilot testing); groundwater pump and treat; offsite incineration of groundwater NAPLS
Popile, Inc. El Dorado, AR ARD008052508 93-02-01	Creosote, PCP	PAHs, PCP, other organics	Mixed rural, residential, and commercial	41	165,000 yd^3 soil and sludge	Bioremediation and capping; slurry walls to contain groundwater
Reilly Tar & Chem. St. Louis Park, MN MND980609804 90-09-28	Creosote	PAHs	Residential	80	?	Pump and treat; groundwater monitoring
Rentokil Virginia Wood Preserving Richmond, VA VAD071040752 93-6-22	Creosote, PCP	PAHs, PCP, Dioxins	Light industrial, commercial, & residential	?	70 yd^3 sediment & sludge, 12,400 yd^3 soil	Incinerate sediment and sludge offsite (with dechlorination for dioxins); pump and treat surface and groundwater; low-temperature thermal desorption for soil; capping treated soil; monitoring groundwater
Saunders Supply Co. Chuckatuck, VA VAD003117389 91-09-30	PCP	PCP, Dioxins	Mixed residential & commercial	7.3	25,000 tons soil	Dechlorination of sediment; low-temperature thermal desorption of soil and sediment; monitoring groundwater
Selma Pressure Treating Co. Selma, CA CAD029452141 88-09-24	PCP	PCP, dioxins	Agricultural, residential, and industrial	<4	16,100 yd^3 soil	Solidification/stabilization, capping

(continued)

TABLE 2-1: Cleanup Strategies Selected by EPA for Superfund Wood-Treating Sites (Cont'd.)

Site Name Location ROD No. ROD Date	Chemical used[a]	Primary contaminants	Current land use	Site area/ acres	Vol. material to be treated	Remediation strategy[b]
South Cavalcade Street, Houston, TX TXD980810386 88-09-26	Creosote	PAHs	Residential, commercial, & industrial	66	30,000 yd^3 soil, 50,000,000 gal groundwater	Soil washing and capping; groundwater and soil washings pump and treat; offsite incineration or recycling of NAPLs; groundwater monitoring. Bioremediation of soil and groundwater if PRP demonstrates equivalent performance and costs
Southern Maryland Wood Treating Hollywood, MD MDD980704852 88-06-29	Creosote, PCP	PAHs, PCP, Dioxins	Agricultural & residential	25	102,000 yd^3 soil & sediment	Incineration onsite of soil, sediments, and tank liquids; ground and surface water pump and treat; multimedia monitoring
Texarkana Wood Preserving Co. Texarkana, TX TXD008056152 90-09-25	Creosote, PCP	PAHs, PCP, Dioxins	Industrial, residential, agricultural	25	77,000 yd^3 soil, sediments & sludges, 16,000,000 gal groundwater	Incineration onsite of soil, sediment, and sludges; pump and treat groundwater
United Creosoting Conroe, TX TXD980745574 89-09-29	Creosote, PCP	PAHs, PCP, Dioxins	Currently occupied by a company & residential subdivision	100	94,000 yd^3 soil	Critical fluid extraction onsite of soil; offsite incineration and disposal of the liquid organic concentrate residues from critical fluid extraction; air monitoring
United Creosoting Conroe, TX TXD980745574 86-09-30	Creosote, PCP	PAHs, PCP, Dioxins (no tetra)	Business & residential	100	?	Dispose of the soils contaminated when an appropriate facility or innovative technology becomes available; temporary cap over consolidated soils

(continued)

TABLE 2-1: Cleanup Strategies Selected by EPA for Superfund Wood-Treating Sites (Cont'd.)

Site Name Location ROD No. ROD Date	Chemical used[a]	Primary contaminants	Current land use	Site area/ acres	Vol. material to be treated	Remediation strategy[b]
Westline Site Westline, PA PAD980692537 86-07-03	Creosote	PAHs	na	40	710 yd^3 soil	Incineration of deposits with a high heating value and low ash content; transport wastes to offsite RCRA facility
Wyckoff Co./ Eagle Harbor, Bainbridge Island, WA, WAD009248295 92-09-29	Creosote, PCP	PAHs, PCP	Primarily residential	40	<7,000 yd^3 sediment	Solidification/ stabilization; offsite disposal if necessary; capping

TABLE 2-2: Evaluation of Presumptive Remedies for Wood-Treating Sites

Contaminants at Site	Presumptive Remedy Selected	Efficiency of Contaminant Removal
PCP	Incineration	90-99% (B,P,F)[a]
Creosote	Thermal desorption	82-99% (B,P,F)
Creosote and PCP, PCP and CCA, Creosote and CCA, or	Bioremediation	Average of 87% for PAHs and 74% for halogenated phenols and creosols (P)
Creosote, PCP, and CCA	Immobilization	80-90% TCLP[b] (B,P,F)
CCA	Immobilization	80-90% TCLP (B,P,F)

SOURCE: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, "Presumptive Remedies for Soils, Sediments, and Sludges at Wood Treater Sites," EPA/540/F-95/006 (Draft), Washington, DC, May 1995.

NOTES:

[a] Performance efficiencies have been demonstrated in benchmark (B), pilot scale (P), or (F) final remedies.

[b] The toxicity characteristic leaching procedure is a test of the effectiveness of immobilization methods.

Remediation Technologies for Wood-Treating Sites

3

The following are short descriptions of some of the major cleanup technologies and strategies used by EPA for cleaning wood-treating sites. Remedies are divided into three groups: destruction technologies; separation and concentration technologies; and immobilization, engineering, and institutional controls.

The remediation technologies described here are at different stages of technical maturity. Evaluations of the effectiveness and potential problems in applying mature technologies such as incineration and bioremediation can be quite reliable. Evaluations of innovative and emerging technologies are much less reliable. For that reason, the selection of a less mature technology as a cleanup remedy will always require a trial demonstration to show that it works at the specific site. Such demonstrations are crucial, because unique local characteristics of soils and contamination can have unanticipated effects on performance. It should also be realized that some combination of treatment and control strategies is likely to be required for site cleanup, rather than any single technology.

DESTRUCTION TECHNOLOGIES

Destruction technologies use thermal, chemical, or biological means to chemically alter contaminants to non toxic or less toxic forms. Table 3-1 summarizes the effectiveness of some destruction technologies for contaminants found at wood-treatment sites.

Incineration

Incineration, perhaps the oldest waste treatment technology, uses very high temperatures to burn waste materials. Incineration exposes organic contaminants in soils, sludges, sediments or other materials to very hot temperatures, greater than 1,000°F, in the presence of air (7,17). These conditions result in the combustion (burning) and destruction of organic wastes. A secondary combustion chamber (afterburner) may be used to help ensure that unburned organics do not enter the flue gases. Flue gases are then quickly cooled to below 350°F to minimize the possibility of organics (like dioxin) reforming in stack emissions. Gases are then treated in air pollution control equipment to remove particulates and acids

TABLE 3-1: Effectiveness of Destruction Options for Contaminants at Wood-Treating Sites

	Destruction options		
Contaminant	**Incineration**	**Dechlorination**	**Bioremediation**
Dioxins/furans	✓	✓	✗
PCP and related materials	✓	✧	✧
PAHs	✓	✗	✓
Metallic compounds	✗	✗	✗

✓ = Demonstrated effectiveness ✧ = Potential effectiveness ✗ = No expected effectiveness

SOURCE: U.S. Environmental Protection Agency, Office of Research and Development, *Contaminants and Remedial Options at Wood Preserving Sites,* EPA/600/R-92/182, (Washington, DC: October 1992).

before release through the stack. Incineration, either onsite or offsite, was selected as part of the cleanup strategy in 18 of 47 records of decision (RODs) for wood-treatment sites reviewed by OTA. However, in some instances, public concerns about the use of incineration have delayed its application.

Incineration has effectively treated soil, sludge, sediment, and liquids containing all of the organic contaminants found at wood-treating sites, and is considered by EPA to be proven at the commercial scale. If a site cleanup requires destruction of dioxins or furans, incineration is among a limited group of effective technologies (17). According to EPA, a "substantial body of trial burn results and other quality assured data verify that incineration can remove and destroy organic contaminants (including dioxins and furans) to the parts per billion or parts per trillion level" (17,23). It has been shown in practice to achieve more stringent cleanup levels than can be consistently attained by any other wood-treatment site remedy (23). Incineration may be particularly effective for treating highly contaminated hot spots such as the sludge pits that are often present at wood-treatment sites. For these reasons, EPA has recently designated incineration as one of the presumptive remedies to be considered in treating organic contaminants in soils, sludges, and sediments at wood-treating sites.

Incinerators have been designed to handle a wide variety of materials (e.g., soil, rubble, sludges) and large volumes of material. Still, practical difficulties with incineration may occur in treating materials that have high moisture content, high levels of corrosive material, or elevated levels of toxic metals (21,23). Onsite incineration is also unlikely to be economical for treating small volumes (less than 5,000 cubic yards) because of the high costs of setting up and testing the incinerator (21,23).

Effective incineration requires control and monitoring of operating conditions, emissions, and residues. Emissions and residues that may be of concern include the treated soils, wastewater from air pollution control equipment, materials captured from flue gases, and stack emissions. Metals in soils cannot be destroyed by incineration; they remain in treated soils and ash. If solid residues contain excessive amounts of toxic metals, they must be treated with a stabilization or solidification process or disposed of in a suitable landfill. Wastewater from the air pollution control equipment will contain captured particulates, trace organics, and caustics that will require treatment (e.g., carbon adsorption, filtration) before discharge. Flue gases may contain metals, other particulates, and acids. These can be largely removed with the air pollution control systems that often include wet scrubbers, electrostatic precipitators, and filter bag houses. One primary public concern has been the possibility of emission of dioxins and other toxic organics from the stack. Careful attention to proper operating temperatures and residence times in the incinerator can greatly limit the amount of these unburned organics entering the flue gas. While the public has been skeptical about incinerators and questioned whether design standards will be maintained in actual operations, safe operation does appear attainable with carefully designed and operated technology.

Bioremediation

Bioremediation refers to the use of microorganisms (bacteria and fungi) to break down organic chemical contaminants (15,17,18). It is a process analogous to decomposing plant material in a compost heap. Organic chemicals are ultimately broken down to carbon dioxide, water, or methane, or converted to microbial cell material. Most practical methods rely on existing soil microorganisms, rather than introduced cultures of microorganisms. Bioremediation is considered a relatively mature technology. As a result of past experience, EPA has designated bioremediation as the primary presumptive remedy for the treatment of organic contaminants in soils, sludges, and sediments at wood-treating sites (17,21,23). It has been selected for use at 17 of the 47 wood-treating sites reviewed by OTA.

In-situ bioremediation treats soils in place, with no excavation required. The in-situ methods generally rely on existing soil microorganisms, adding nutrient- (e.g., nitrogen) enriched water to stimulate microbial growth. It is often used in conjunction with a groundwater pumping and soil-flushing system. In this system, water is injected into the soil to circulate nutrients and oxygen. The groundwater is then recovered, cleaned, and reintroduced. In appropriate circumstances, in-situ methods have shown promise for treating soils containing the polycyclic aromatic hydrocarbons (PAHs) and pentachlorophenol (PCP) contaminants typically found at wood-preserving sites. In-situ bioremediation alone is not effective with very concentrated masses of contaminants. However, even in those circumstances it may be effective when used in combination with other technologies.

Ex-situ technologies treat excavated soils in controlled conditions where moisture, temperature, pH, oxygen, and nutrients can be adjusted to encourage rapid microbial action. Ex-situ methods include the slurry-phase and solid-phase processes. **Slurry phase** bioremediation mixes excavated soil or sludge with water in tanks or lagoons, adding nutrients while controlling oxygen, pH, temperature, etc. **Solid-phase** bioremediation (sometimes called land treatment or land farming) places contaminated soil in a lined bed, with nutrients added. Composting is a variation of solid-phase bioremediation that allows for treatment of highly contaminated wastes by diluting contaminated soil with a bulking agent such as manure or straw. The increased volume of treated material is a disadvantage. The solid-phase methods have been widely used for hazardous waste treatment and have been demonstrated successful on petroleum refinery wastes and at wood-treating sites with creosote-contaminated soil and sludge. These methods do require attention to the potential for secondary groundwater and air pollution. A drainage treatment system may be required to control leaching chemicals, and a cover may be needed if volatile organics could be released to the air while soils are being mixed or spread. Although in-situ bioremediation is cheaper, ex-situ bioremediation results in faster and usually better performance.

In pilot scale studies, bioremediation has achieved cleanup efficiencies averaging 87 percent for PAHs and 74 percent for halogenated phenols (23). However, the effectiveness of bioremediation is site and contaminant specific and the method should be selected only after careful site characterization. Bioremediation will not necessarily work for hot spots (such as sludge ponds) with very high concentrations of creosote, PCP, and related contaminants. Material from these hot spots might have to be removed for treatment by other methods. Although in theory it is feasible to dilute such hot spots with uncontaminated soil and then treat with bioremediation, most site managers prefer to excavate the hot spots and ship the material off site for incineration or RCRA-approved disposal. Bioremediation may be appropriate for the remainder of the site. Bioremediation is not suitable for treatment of sites with high levels of inorganic contamination, such as the chromated copper arsenate (CCA) used at some wood-treatment plants. There are no solid data on the effectiveness of bioremediation for dioxins or furans. When these contaminants are present, a general approach is to use bioremediation to reduce PCP and PAH levels to below action levels in soil, and then rely on capping and immobilization to deal with metals or any remaining dioxins. Bioremediation also works less well for the largest PAH molecules, those with more than 4-rings in their structure.

Chemical Dechlorination

Chemical dechlorination (also called dehalogenation) uses special chemical mixtures to treat contaminated soil, sediment, sludges, and oils (10,13,17,20). A chemical reaction caused by the additives removes chlorine atoms from pollutants such as pentachlorophenol, dioxins, or furans. In general, removing chlorine from such chemicals converts them to less toxic products. At wood-treating sites, dechlorination must generally be used in combination with other technologies such as thermal desorption or bioremediation since the methods do not work with nonchlorinated materials such as the PAHs. Dechlorination has been selected as a cleanup technology in 2 of the 47 wood-treatment site RODs reviewed by OTA.

Although not yet considered a fully proven technology by EPA, dechlorination does have some track record of success for the treatment of the dioxin, furan, and PCP contaminants often found at wood-treatment sites. Dechlorination will not be useful for treating PAHs, which do not contain chlorine. If site cleanup requires destruction of dioxins, then dechlorination is one of very few techniques that are capable of remediation (17). EPA data show that wood-treatment site wastes containing dioxins and furans treated with alkali polyethylene glycolate (APEG) for 45 minutes at 160°F showed greater than 99 percent destruction of the dioxins and furans (10). However, there is some concern that incomplete dechlorination of the heavily chlorinated dioxins typically found at wood-treating sites (containing up 8 chlorine atoms) could result in the production of much more toxic forms of dioxins including the most toxic 2,3,7,8-tetrachloro-p-dioxin (TCDD, see box 2-2 in chapter 2).

Dechlorination can be used with a variety of soil types, although some soils may be more expensive to treat than others (10). The presence of heavy metals and high soil moisture (greater than 20 percent) may require special treatment, and high organic and clay content may require extended reaction times (21,23). EPA considers that for each site the special chemical mixture formulation and optimum process conditions must be determined using treatability studies (10). Chemical dehalogenation of soil can be expensive because excavation is required and large quantities of reagents are used (10).

The dechlorination technology is dominated by a number of patented, proprietary processes. One category of methods uses chemical reagents referred to as alkali polyethylene glycolate (APEG) (17). A related approach is the base-catalyzed decomposition (BCD) process, which uses sodium bicarbonate or similar base mixed in a heated reactor to treat chlorine-containing pollutants (17).

In the typical APEG process, soil or sludge is mixed with the reagent to form a slurry. The slurry is heated in a closed reactor to promote a chemical reaction. During the reaction, chlorine atoms in the contaminants are replaced, making a water-soluble substance that can be washed from the treated soil. After treatment, residual APEG chemicals are recovered from the soil and reused. The treated soil is washed and the washwater filtered through activated carbon to remove the dechlorinated pollutants. The carbon filter and spent reagent can be incinerated or sent for landfill disposal. To work properly, APEG dechlorination depends on very good mixing of the chemical reagent and the contaminated materials, requiring that soils be excavated and perhaps crushed. High moisture content in the soil can reduce the effectiveness of the method. High clay content will increase the amount of chemical reagent required. Because of the high cost of polyethylene glycol, increased reagent use adds significantly to cleanup expenses.

The BCD process was developed in an attempt to address some of the practical problems experienced with APEG methods. It uses cheaper treatment chemicals; its efficiency is less affected by soil moisture and particle size; and there are reduced volumes of waste for disposal. Contaminated materials are heated in the presence of a base (sodium bicarbonate or sodium hydroxide) and a hydrogen donor compound such as oil. Hydrogen replaces chlorine atoms in the pollutant molecule. One proprietary BCD process in use at a wood-treating site is a combination of dechlorination technologies with thermal decomposition, in a two-stage treatment (3). The first stage is thermal desorption of soil, in which organic contaminants are evaporated and partially decomposed. At this stage, BCD chemicals (e.g., sodium bicarbonate) are added to enhance evaporation and to provide partial dechlorination. The contaminants are driven from the soil as vapors and particulates and then captured in an oil solution. The remaining gases are vented to the atmosphere (3). Contaminants trapped in the scrubbing oil are periodically treated in a chemical reactor for further dechlorination, again using BCD chemicals. The addition of BCD chemicals to the soils in the initial thermal desorption stage is claimed to be better than basic thermal desorption, but more results are needed to confirm the advantage (3).

There are four main residuals from dehalogenation that can be of concern: the treated soil, residual reagents, air emissions, and washwater. Treated soils will contain some amount of the treatment chemicals along with reaction byproducts from the original pollutants. Although the treatment compounds do not appear to be toxic, they may require further treatment, such as chemical neutralization or incineration, before disposal. The reaction byproducts in treated soil have not been well characterized (10). Air emissions released during the heating and mixing of the contaminated soils must be captured through condensation or filtration. The efficiency in removing contaminants from the off gases is not well known. Washwater used to clean the soils after treatment will contain traces of contaminants and process chemicals, and may also require treatment.

SEPARATION AND CONCENTRATION TECHNOLOGIES

Separation and concentration technologies are designed to remove contaminants from the bulk of the soils, allowing these cleaned soils to be returned to the site, and concentrating the contaminants in a smaller volume of soil or solvent. The contaminants are not destroyed, but concentration allows them to be treated efficiently by other destructive means such as incineration or bioremediation. Various distinct technologies fit into this broad category, some of treating excavated soils and others allowing treatment of soils in situ. Options for treating excavated soils include soil washing, solvent extraction, and thermal desorption. Soil flushing is used to treat contaminated soils in place, often in combination with bioremediation. Table 3-2 summarizes the effectiveness of some separation and concentration options with contaminants found at wood-treatment sites.

Soil Washing

Soil washing is a water-based process for removing contaminants from excavated soil (17,19). Contaminants are removed both by dissolving them in the wash solution and by concentrating them in a smaller volume of soil fines (the very smallest, silt-like, soil particles). Contaminants tend to bind to clay and silt particles, which can be separated from larger particles and sand. The particle size separation techniques are similar to those used in sand and gravel operations. Various additives (e.g., detergents and acids) can be used in the water to increase the efficiency of separation. The large fraction of clean soil can often be returned to the site. In other cases, a combination of treatment technologies may be required. The concentrated contaminants in the separated silts and clays will require treatment by another tech-

Table 3-2: Effectiveness of Separation Options for Contaminants at Wood-Treating Sites

	Separation options			
Contaminant	**Soil washing**	**Solvent extraction**	**Thermal desorption**	**Soil flushing**
Dioxins/furans	✧	✧	✓	✧
PCP & related materials	✧	✧	✓	✧
PAHs	✧	✓	✓	✧
Metallic compounds	✓	✗	✧	✧

✓ = Demonstrated effectiveness ✧ = Potential effectiveness ✗ = No expected effectiveness

SOURCE: U.S. Environmental Protection Agency, Office of Research and Development, *Contaminants and Remedial Options at Wood Preserving Sites,* EPA/600/R-92/182, (Washington, DC: October 1992).

nology, such as incineration or bioremediation. The washwater is cleaned by conventional wastewater treatment methods and then reused in the process.

The success of soil washing treatment is closely tied to the characteristics of the soils. Separation works best for soils with relatively large percentages of coarse sand and gravel. Soils with high levels of clay and silt are poor candidates for soil washing because little reduction in volume of contaminated material can be accomplished.

A wide variety of chemical contaminants can be removed from soils by soil washing techniques. According to EPA documents, treatability studies at seven wood treatment sites show that soil washing is effective for removing PCP, PAHs, and metals from contaminated soil. As of 1992, soil washing or soil flushing had been selected as a remedy in 11 out of 47 RODs at wood-treating sites. Greater than 95 percent removal efficiencies have been achieved in recent pilot scale tests (17). However, the effectiveness of the technology at a particular site does not guarantee its effectiveness elsewhere. Site-specific bench or pilot scale treatability tests are always required to determine the best operating conditions and wash fluid compositions.

Solvent Extraction

Solvent extraction uses organic solvents to remove contaminants from excavated soils and sludges, much like in a dry cleaning process (11,17). The solvents are organic fluids, compared to soil washing which uses water as a solvent. Solvent extraction is most appropriate for the removal of organic contaminants. Contaminants are extracted in the solvent, then concentrated for disposal by other means. There are three general types of processes, distinguished by the types of solvent used: conventional solvents, near-critical or liquefied gases, and critical solution temperature (CST) solvents.

In conventional solvent extraction methods, alcohols, alkanes, ketones, and similar liquids are used to remove contaminants. The solvent is mixed with the contaminated material. After mixing, the liquid is removed and any residual solvent is driven from the soil by steam or heat. The collected solvent, now containing contaminants, is sent to an extractor. The solvent is then evaporated and collected for reuse, leaving a concentrated residue of contaminants. Near-critical fluid or liquefied gas processes use butane, propane, carbon dioxide, or other gases that have been liquefied under high pressure. These materials seem to diffuse into soil better than standard solvents, helping remove contaminants. The solvent extracts the contaminants and rises to the top of the chamber, where it is collected. As pressure is lowered, the contaminants separate from the solvent, allowing the solvent to be reused. CST systems rely on the unique ability of some materials to mix with water and extract contaminants at one temperature and to separate from water at another temperature.

Solvent extraction is not a destructive technology. The extracted contaminants may require further treatment before disposal. Further, there are a number of waste streams to be considered. Any water separated from the soils will need treatment. Solvent systems are designed to work without air releases, but there must be concern with the possibility of releases of the volatile solvents. The treated soils may also have significant traces of solvent, depending on the care taken in driving out the residual solvent during processing.

According to EPA, treatability studies at five different sites show that solvent extraction is very effective for removing PCP, PAHs, and, in one case, dioxin and furans from contaminated soil (17). The technology is generally not effective at removing metals contamination. Solvent extraction, using liquefied propane, has been selected as the remedy at only one Superfund wood-treatment site reviewed by OTA.

Thermal Desorption

Thermal desorption uses heat and agitation to evaporate and separate but not destroy organic contaminants from soil, sludge, or sediments (12). Some additional technology is needed for contaminant destruction. Thermal desorption systems include rotary dryers, thermal screws, vapor extractors, and distillation chambers. All these systems heat the contaminated material to between 200 and 1,000°F to evaporate, physically separate, and concentrate the organic contaminants (12, 17). Thermal desorption was selected as part of the cleanup strategy in 3 of 47 RODs for wood-treatment sites reviewed by OTA. It has recently been designated by EPA as one of the presumptive remedies appropriate for wood-treating sites.

Unlike other processes, such as incineration, that destroy contaminants, thermal desorption is a contaminant separation process only (12). The advantage of thermal desorption is that the volume of the separated contaminants that will require eventual destruction or storage is substantially reduced by the process. Separated contaminants, contained in the off-gas from thermal desorption systems (containing vaporized contaminants, particulates, and water vapor) require subsequent treatment by some other technology, such as incineration, dehalogenation, or chemical neutralization. The contaminants are usually captured by condensation or on activated carbon. Also, specific key organic contaminant classes can be selectively evaporated and removed with thermal desorption by carefully controlling the treatment temperature (12).

Thermal desorption has a proven record for treating contaminated soils, sludges, and sediments. According to EPA, thermal desorption has been shown in treatability studies at two sites to be effective for removing PAHs and PCP from contaminated soil (17). It can successfully treat PCP and creosote materials, but not inorganics such as CCA (23). EPA considers thermal desorption an appropriate alternative technology for cleaning up PCP and creosote at wood-treatment sites in cases where bioremediation is not feasible (23). Difficulties may occur in treating materials that have elevated levels of halogenated organic contaminants or contain mercury or corrosive materials (21,23). Vendor data indicate thermal desorption technology can process up to 70 tons per hour (12). However, EPA considers thermal desorption a less mature technology that requires site-specific treatability tests to ensure it will work at a particular site (12).

Some thermal desorption systems are suitable for removing dioxins and furans from soils. Thermal desorption is one of several technologies EPA considers useful in cases of dioxin or furan contamination (17). However, thermal desorption of some PCP and related compounds may actually form dioxins and furans at certain temperatures (23), much as they can form in incinerator flue gases. Treatment systems must be designed to minimize dioxin formation and to remove these compounds from the off gases. A full-scale proof of performance test with analysis for dioxins should be done.

All thermal desorption systems require that the contaminated soil, sediment, or sludge first be dug up and transported to the system, processes that may require physical enclosure for dust control (12). At sites that are heavily contaminated with organics or with high moisture content soil, thermal desorption may not be cost effective (7). Very wet soil may require dewatering before treatment. Thermal desorption has not performed well in soils that are tightly aggregated, largely clay (clay or silt soil may generate excessive dust), or that contain large amounts of rock fragments (12).

▮ Soil Flushing

Soil flushing is an in-situ treatment using water (perhaps with additives) to extract contaminants from soils (9,17). Water is injected or soaked into the soil. An underground collection system allows removal of the flush water and prevents contaminated water from spreading offsite. It is often used together with in situ bioremediation. The contaminated flushing water will also require treatment.

Soil flushing is considered an innovative technology with limited experience as to its effectiveness. It can be used for the treatment of wood-preserving sites, but treatability studies must precede its selection as a cleanup remedy. Two treatability studies have shown it to be moderately to highly effective at removing creosote and other organics from wood-treating sites. In combination with in-situ bioremediation, soil flushing may prove to be a very cost-effective remedy for sites contaminated with PCP and PAHs. The soil flushing may remove high levels of contamination that might otherwise interfere with successful bioremediation.

IMMOBILIZATION TECHNOLOGIES AND INSTITUTIONAL CONTROLS

▮ Physical Isolation and Capping

Even after the best cleanup of a wood-treatment site some contaminants will remain. Because of this, various long-term control strategies such as fencing, restricting future use, and site capping are used to prevent future human exposure to remaining contamination. Institutional and engineering controls, such as soil caps and liners, fences and warning signs, and deed restrictions are used to reduce potential human exposure. Ongoing monitoring of remaining contaminants at a site is required to ensure that the controls continue to work. Various site-restriction strategies were specified in 14 of 47 RODs for wood-treatment sites reviewed by OTA. Site capping was specified in 24 of 47 RODs.

Physically capping a site is particularly useful to complete the overall protection of a complete wood-treatment cleanup strategy (23). A simple cap may involve covering the treated area with uncontaminated soil and putting in suitable plants. More sophisticated capping may involve a bedding layer, a gas-collecting layer, a clay composite barrier, a geomembrane (plastic) composite barrier, a drainage layer, a protective layer, a vegetative layer, an asphalt-hardened cap, or a concrete-hardened cap (17, 23).

These capping techniques can limit direct human exposure, allow for better water runoff and drainage, and limit surface water infiltration and groundwater contamination. A general approach, used for example at the Libby Groundwater site, is to use bioremediation for soil to reduce PCP and PAH levels to below action levels, then rely on capping and immobilization for dioxins. Control of dioxins and furans may be considered adequate if the contaminated soil meets leaching characteristic criteria (1).

▮ Solidification or Stabilization

Solidification and stabilization techniques can be used to reduce the mobility of residual contaminants in soils (14, 17). Solidification refers to techniques that embed the waste into a solid material. Stabilization refers to techniques that chemically alter or bind the material to reduce its mobility. Portland cement, fly ash and lime, and other cement-like materials are commonly used. The material can be injected into the soil and mixed in to depths of up to 100 feet. The result can be a solid mass or a granular material resembling soil.

These immobilization techniques are most frequently used for the control of inorganic contaminants such as the metal compounds used at some wood-treating sites. Immobilization has also been successfully used for cleanups of PAH and PCP wastes, although this solution always leaves the concern for future risk since the contaminants are left on the site. It is not a conventional treatment for sites with high levels of organic contamination. However, solidification or stabilization can be used as part of a successful treatment train, following soil washing or bioremediation.

One of the difficulties with these techniques is in evaluating their long-term performance. Periodic monitoring may be necessary to make sure that the technology is continuing to prevent the leaching and spread of contamination. The effectiveness of the technique is measured primarily in its ability to reduce the leaching of toxic chemicals from the soils.

Removal of Contaminated Materials

An obvious remedy for contaminated material, including waste oils, debris, sludge, or soil, is to transport it to a new site. For some situations—for example highly contaminated sludge hot spots or contaminated oil—excavation, transportation, and incineration offsite may be appropriate. However, according to EPA, it is usually too expensive to ship quantities greater than 5,000 cubic yards of contaminated soil offsite for disposal, and pretreatment may be required before shipment to another treatment facility (21, 23). Removal and offsite disposal or treatment, including incineration, was specified in 12 of 47 RODs for wood-treatment sites reviewed by OTA.

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