

# Remediation Technologies for Wood-Treating Sites

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**T**he 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

Contaminant	Destruction options		
	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 suit-

able 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 to 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

Contaminant	Separation options			
	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 con-

taminants, 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, pro-

cesses 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 engi-

neering 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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