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Cover photo—An elevated walkway in Palfrey's Glen State Natural Area near Merrimac, WI.

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Contents

Introduction

This report is an update to *Selection and Use of Preservative-Treated Wood in Forest Service Recreational Structures* (9523–1203–SDTDC, LeBow and Makel 1995). One of the main types of wood preservatives, chromated copper arsenate (CCA) has been voluntarily phased out for most uses around residential areas and other areas where human contact with preservative-treated wood is common. This updated report will discuss different preservative treatments to replace CCA and alternative materials that can be used instead of preservative-treated wood, such as decay-resistant heartwoods, plastic wood, and vinyl.

Wood is treated with preservatives to protect it from wood-destroying fungi and insects. Treating wood with preservative chemicals can increase the service life of wood by a factor of five times or more. Wood treated with commonly used wood preservatives can last 40 years or more in service. Preservative-treated wood (figure 1) is an economical, durable, and aesthetically pleasing building material and is a natural choice for many construction projects in the national forests.

When treated wood is used in field settings, the possibility of environmental contamination raises concerns. There is increasing pressure to be environmentally friendly and to reduce, restrict, or eliminate the use of wood preservatives because of the concern that toxic constituents may leach from the treated wood. This report will provide an overview of preservative systems, help readers understand the level of risk and status of the science involved in evaluating preservative systems, and provide some guidelines for using the products.

Figure 1—A stress-laminated road bridge constructed with creosote-treated wood near the Glade Creek Grist Mill in Babcock State Park, WV.

Types of Wood Preservatives

Wood preservatives have been used for more than a century. They are broadly classified as either waterborne or oil-type, based on the chemical composition of the preservative and the carrier used during the treating process. Some preservatives can be formulated for use with either water or oil solvents. Water-based preservatives often include some type of cosolvent, such as amine or ammonia to keep one or more of the active ingredients in solution. Each solvent has advantages and disadvantages that depend on the application.

Generally, wood preservatives also are classified or grouped by the type of application or exposure environment in which they are expected to provide long-term protection. Some preservatives have sufficient leach resistance and broad spectrum efficacy to protect wood that is exposed directly to soil and water. These preservatives will also protect wood exposed aboveground, and may be used in those applications at lower retentions (concentrations in the wood).

Other preservatives have intermediate toxicity or leach resistance that allows them to protect wood fully exposed to the weather, but not in contact with the ground. Some preservatives lack the permanence or toxicity to withstand continued exposure to precipitation, but may be effective with occasional wetting. Finally, there are formulations that are so readily leachable that they can only withstand very occasional, superficial wetting.

It is not possible to evaluate a preservative's long-term efficacy in all types of exposure environments and there is no set formula for predicting exactly how long a wood preservative will perform in a specific application. This is especially true for aboveground applications (figure 2) because preservatives are tested most extensively in ground contact. To compensate for this uncertainty, there is a tendency to be conservative in selecting a preservative for a particular application.

Figure 2—The Mocus Point Pack Bridge crosses the Lochsa River in the Clearwater National Forest, ID.

Oil-Type Preservatives

The most common oil-type preservatives are creosote, pentachlorophenol, and copper naphthenate. Occasionally, oxine copper and IPBC (3-iodo-2-propynyl butyl carbamate) also are used for aboveground applications. The conventional oil-type preservatives, such as creosote and pentachlorophenol solutions, have been confined largely to uses that do not involve frequent human contact. The exception is copper naphthenate, a preservative that was developed more recently and has been used less widely. Oil-type preservatives may be visually oily, or oily to the touch, and sometimes have a noticeable odor. However, the oil or solvent that is used as a carrier makes the wood less susceptible to cracks and checking. This type of preservative is suitable for treatment of glue-laminated stringers for bridges where cracks in the stringers could alter the bridges' structural integrity.

Creosote

Coal-tar creosote is effective when used in ground contact, water contact, or aboveground. It is the oldest wood preservative still in commercial use in the United States. It is made by distilling coal tar that is created when coal is carbonized at high temperatures (1,652 to 2,192 degrees Fahrenheit [900 to 1,200 degrees Celsius]). Unlike other oil-type preservatives, creosote usually is not dissolved in oil, but it does look and feel oily. Creosote contains a chemically complex mixture of organic molecules, most of which are polycyclic aromatic hydrocarbons. The composition of creosote varies because it depends on how the creosote is distilled. However, the small differences in composition in modern creosotes do not affect their performance as wood preservatives.

Creosote-treated wood is dark brown to black and has a distinct odor, which some people consider unpleasant. Creosote-treated wood is very difficult to paint. Workers sometimes object to creosote-treated wood because it soils their clothes and makes their skin sensitive to the sun. The treated wood sometimes has an oily surface. Patches of creosote sometimes accumulate, creating a hazard when it contacts the skin. Because of these concerns, creosote-treated wood often is not the first choice for applications such as bridge members or handrails, where there is a high probability of human contact.

However, creosote-treated wood has advantages to offset concerns with its appearance and odor. It has a lengthy record of satisfactory use in a wide range of applications and is relatively inexpensive. Creosote is effective in protecting both hardwoods and softwoods and improving the dimensional stability of the treated wood.

Creosote is listed in American Wood-Preservers' Association (AWPA) Standards for a wide range of wood products created from many different species of trees. The minimum creosote retentions required by the standards are in the range of 5 to 8 pounds per cubic foot (80 to 128 kilograms per cubic meter) for aboveground applications, 10 pounds per cubic foot (160 kilograms per cubic meter) for wood used in ground contact, and 12 pounds per cubic foot (192 kilograms per cubic meter) for wood used in critical structural applications, such as highway construction. With heated solutions and lengthy pressure periods, creosote can penetrate wood that is fairly difficult to treat. Creosote is suitable for treatment of glue-laminated members. Creosote treatment does not accelerate, and may even inhibit, the corrosion of metal fasteners.

Treatment facilities that use creosote are found throughout the United States, so this wood preservative is readily available. Creosote is classified as a Restricted Use Pesticide (RUP) by the U.S. Environmental Protection Agency (EPA). Producers of treated wood, in cooperation with the EPA, have created Consumer Information Sheets with guidance on appropriate handling and site precautions when using wood treated with creosote (appendix A). These sheets should be available for all persons who handle creosote-treated wood.

Pentachlorophenol

Pentachlorophenol has been widely used as a pressure-treatment preservative in the United States since the 1940s. The active ingredients, chlorinated phenols, are crystalline solids that can be dissolved in different types of organic solvents. A performance of pentachlorophenol and the properties of the treated wood are influenced by the properties of the solvent.

Pentachlorophenol is effective when used in ground contact, freshwater, or aboveground. It is not as effective when used in seawater. A heavy oil solvent (specified as Type A in AWPA Standard P9) is preferable when the treated wood is to be used in ground contact. Wood treated with lighter solvents may not be as durable.

Wood treated with pentachlorophenol in heavy oil typically has a brown color, and may have a slightly oily surface that is difficult to paint. It also has some odor, which is associated with the solvent. Pentachlorophenol in heavy oil should not be used when frequent contact with skin is likely (handrails, for instance). Pentachlorophenol in heavy oil has long been a popular choice for treating utility poles, bridge timbers, glue-laminated beams, and foundation pilings. The effectiveness of pentachlorophenol is similar to that of creosote in protecting both hardwoods and softwoods, and pentachlorophenol often is thought to improve the dimensional stability of the treated wood.

Pentachlorophenol is listed in the AWPA standards for a wide range of wood products and wood species. The minimum softwood retentions are 0.4 pounds per cubic foot (6.4 kilograms per cubic meter) for wood used aboveground, and 0.5 pounds per cubic foot (8 kilograms per cubic meter) for wood used in critical structural applications or in ground contact.

With heated solutions and extended pressure periods, pentachlorophenol can penetrate woods that are difficult to treat. Pentachlorophenol does not accelerate the corrosion of metal fasteners relative to untreated wood. The heavy oil solvent imparts some water repellency to the treated wood. Treatment facilities in many areas of the United States use pentachlorophenol in heavy oil, making it another readily available wood preservative.

Pentachlorophenol is most effective when applied with a heavy solvent, but it performs well in lighter solvents for aboveground applications. Lighter solvents also provide the advantage of a less oily surface appearance, lighter color, and improved paintability. The standards for aboveground minimum retentions for pentachlorophenol vary from 0.25 to 0.3 pounds per cubic foot (4 to 4.8 kilograms per cubic meter) for treatment of red oak to 0.4 pounds per cubic foot (6.4 kilograms per cubic meter) for softwood species.

Pentachlorophenol in light oil has some similarities to pentachlorophenol in heavy oil. It can be used to treat species of wood that are difficult to treat and it does not accelerate corrosion. Wood treated with pentachlorophenol in light oil may be used in recreational structures and in applications where human contact is likely, such as handrails, if a sealer such as urethane, shellac, latex, epoxy enamel, or varnish is applied. Wood treated with pentachlorophenol in light oil may be painted or stained after it dries. One disadvantage of the lighter oil is that the treated wood has less water repellency. Treatment facilities that use pentachlorophenol in light oil are not as numerous as those that use heavy oil.

Pentachlorophenol is classified as an RUP by the EPA. Producers of treated wood, in cooperation with the EPA, have created consumer information sheets with guidance on appropriate handling and site precautions for wood treated with pentachlorophenol (appendix A). These sheets should be available for all persons who handle wood treated with pentachlorophenol.

Copper Naphthenate

Copper naphthenate is effective when used in ground contact, water contact, or aboveground. It is not standardized for use in saltwater applications. Copper naphthenate's effectiveness as a preservative has been known since the early 1900s, and various formulations have been used commercially since the 1940s. It is an organometallic compound formed as a reaction product of copper salts and naphthenic acids derived from petroleum. Unlike other commercially applied wood preservatives, small quantities of copper naphthenate can be purchased at retail hardware stores and lumberyards. Cuts or holes in treated wood can be treated in the field with copper naphthenate.

Wood treated with copper naphthenate has a distinctive bright green color that weathers to light brown. The treated wood also has an odor that dissipates somewhat over time. Depending on the solvent used and treatment procedures, it may be possible to paint wood treated with copper naphthenate after it has been allowed to weather for a few weeks.

Copper naphthenate can be dissolved in a variety of solvents. The heavy oil solvent (specified in AWPA Standard P9, Type A) or the lighter solvent (AWPA Standard P9, Type C) are the most commonly used. Copper naphthenate is listed in AWPA standards for treatment of major softwood species that are used for a variety of wood products. It is not listed for treatment of any hardwood species, except when the wood is used for railroad ties. The minimum copper naphthenate retentions (as elemental copper) range from 0.04 pounds per cubic foot (0.6 kilograms per cubic meter) for wood used aboveground, to 0.06 pounds per cubic foot (1 kilograms per cubic meter) for wood that will contact the ground and 0.075 pounds per cubic foot (1.2 kilograms per cubic meter) for wood used in critical structural applications.

When dissolved in No. 2 fuel oil, copper naphthenate can penetrate wood that is difficult to treat. Copper naphthenate loses some of its ability to penetrate wood when it is dissolved in heavier oils. Copper naphthenate treatments do not significantly increase the corrosion of metal fasteners relative to untreated wood.

Copper naphthenate is commonly used to treat utility poles, although fewer facilities treat utility poles with copper naphthenate than with creosote or pentachlorophenol. Unlike creosote and pentachlorophenol, copper naphthenate is not listed as an RUP by the EPA. Even though human health concerns do not require copper naphthenate to be listed as an RUP, precautions such as the use of dust masks and gloves should be used when working with wood treated with copper naphthenate.

Oxine Copper (Copper-8-Quinolinolate)

Oxine copper is effective when used aboveground. Its efficacy is reduced when it is used in direct contact with the ground or with water. It has not been standardized for those applications. Oxine copper (copper-8-quinolinolate) is an organometallic compound. The formulation consists of at least 10-percent copper-8-quinolinolate, 10-percent nickel-2-ethylhexanoate, and 80-percent inert ingredients. It is accepted as a standalone preservative for aboveground use to control sapstain fungi and mold and also is used to pressure-treat wood.

Oxine copper solutions are greenish brown, odorless, toxic to both wood decay fungi and insects, and have a low toxicity to humans and animals. Oxine copper can be dissolved in a range of hydrocarbon solvents, but provides protection much longer when it is delivered in heavy oil. Oxine copper is listed in the AWPA standards for treating several softwood species used in exposed, aboveground applications. The minimum specified retention for these applications is 0.02 pounds per cubic foot (0.32 kilograms per cubic meter, as elemental copper).

Oxine copper solutions are somewhat heat sensitive, which limits the use of heat to increase penetration of the preservative. However, oxine copper can penetrate difficult-to-treat species, and is sometimes used to treat Douglas-fir used aboveground in wooden bridges and deck railings. Oilborne oxine copper does not accelerate corrosion of metal fasteners relative to untreated wood. A water-soluble form can be made with dodecylbenzene sulfonic acid, but the solution corrodes metals. Oxine copper is not widely used by pressure-treatment facilities, but is available from at least one plant on the West Coast.

Wood treated with oxine copper presents fewer toxicity or safety and handling concerns than oilborne preservatives that can be used in ground contact. Sometimes, it is used as a preservative to control sapstain fungi or incorporated into retail stains for siding, shingles, and cabin logs. Oxine copper is listed by the U.S. Food and Drug Administration (FDA) as an indirect additive that can be used in packaging that may come in direct contact with food.

Precautions such as wearing gloves and dust masks should be used when working with wood treated with oxine copper. Because of its somewhat limited use and low mammalian toxicity, there has been little research to assess the environmental impact of wood treated with oxine copper.

IPBC and Insecticides

IPBC (3-iodo-2-propynyl butyl carbamate) is not intended for use in ground contact or for horizontal surfaces that are fully exposed to the weather. It does provide protection for wood that is aboveground and partially protected from the weather. IPBC contains 97-percent 3-iodo-2-propynyl butyl carbamate that includes a minimum of 43.4-percent iodine. IPBC industrial fungicides are broad-spectrum fungicidal additives used in architectural coatings and construction applications (such as paints, stains, adhesives, caulks, and sealants), textiles, and plastic products to prevent dry film fungal growth. The IPBC preservative is included as the primary fungicide in several water-repellent-preservative formulations under the trade name *Polyphase* and sold at retail stores. Although oil-soluble formulations are discussed in this report, water-based formulations also may be used.

IPBC is colorless. Depending on the solvent and formulation, it may be possible to paint treated wood. Some formulations may have noticeable odor, but others may have little or no odor. IPBC is not an effective insecticide and is not used as a stand-alone treatment for critical structural members.

IPBC is listed as a preservative in AWPA standards, but no pressure-treated wood products have been standardized for IPBC. Dip-treating (a nonpressure process) with IPBC was standardized recently for ponderosa-pine millwork at a minimum retention of 950 parts per million (about 0.023 pounds per cubic foot [0.37 kilograms per cubic meter]). Soil block tests indicate that IPBC can prevent fungal attack of hardwoods and softwoods when it is used at a retention of 0.022 pounds per cubic foot (0.35 kilograms per cubic meter) or higher. After 9 years of aboveground exposure tests with pressure-treated Douglas-fir, ponderosa pine, and western hemlock results indicate that mixtures of IPBC and chloropyrifos can protect wood from decay at IPBC retentions as low as 0.05 pounds per cubic foot (0.8 kilograms per cubic meter).

Some pressure-treating facilities use a mixture of IPBC and an insecticide, such as permethrin or chloropyrifos, to treat structural members used aboveground that will be largely protected from the weather, although this practice is not a standardized treatment. These facilities are using IPBC retentions of 0.035 pounds per cubic foot (0.56 kilograms per cubic meter) or higher, with mineral spirits as the solvent. The advantage of this treatment is that it is colorless and allows the wood to maintain its natural appearance. This treatment is being used on Western species that are difficult to treat. Very few facilities are conducting pressure treatments with IPBC.

IPBC has relatively low acute toxicity for mammals and is not classified as an EPA RUP. However, workers should follow standard precautions, such as wearing gloves and dust masks, when working with wood treated with IPBC. Because IPBC typically has not been used for pressure treatment, there has been little evaluation of the environmental impact of wood treated with IPBC. It appears that IPBC degrades rapidly in soil and aquatic environments. It has low toxicity for birds, but is highly toxic to fish and aquatic invertebrates. The relatively low IPBC concentrations used in the wood and its rapid degradation in the environment would be expected to limit any environmental accumulations caused by leaching. Because IPBC usually is used with a light solvent, the preservative is not likely to bleed or ooze out of wood.

Waterborne Preservatives

Waterborne preservatives react with or precipitate in treated wood, becoming “fixed.” They resist leaching. Because waterborne preservatives leave a dry, paintable surface, they are commonly used to treat wood for residential applications, such as decks and fences. Waterborne preservatives are used primarily to treat softwoods, because they may not fully protect hardwoods from soft-rot attack. Most hardwood species are difficult to treat with waterborne preservatives.

These preservatives can increase the risk of corrosion when metals contact treated wood used in wet locations. Metal fasteners, connectors, and flashing should be made from hot-dipped galvanized steel, copper, silicon bronze, or stainless steel if they are used with wood treated with waterborne preservatives containing copper. Aluminum should not be used in direct contact with wood treated with waterborne preservatives containing copper. Borates are another type of waterborne preservative. However, they do not fix in the wood and leach readily if they are exposed to rain or wet soil. Borate treatment does not increase the risk of corrosion when metals contact preservative-treated wood.

Chromated Copper Arsenate (CCA)

CCA protects wood used aboveground, in contact with the ground, or in contact with freshwater or seawater. Wood treated with CCA (commonly called *green treated*) dominated the treated wood market from the late 1970s until 2004. Chromated copper arsenate has been phased out voluntarily for most applications around residential areas and where human contact is prevalent. The allowable uses for CCA are discussed in more detail in the *Recommended Guidelines* section.

The three standardized formulations are: CCA Type A, CCA Type B, and CCA Type C. CCA Type C (CCA–C) is the formulation used by nearly all treatment facilities because of its resistance to leaching and its demonstrated effectiveness. CCA–C is comprised of 47.5 percent chromium trioxide, 18.5 percent copper oxide, and 34.0 percent arsenic pentoxide dissolved in water.

CCA–C has decades of proven performance. It is the reference preservative used to evaluate the performance of other waterborne wood preservatives during accelerated testing. Because it has been widely used for so many years, CCA–C is listed in AWPA standards for a wide range of wood products and applications. The minimum retention of CCA–C in wood ranges from 0.25 pounds per cubic foot (4 kilograms per cubic meter) in aboveground applications to 2.5 pounds per cubic foot (40 kilograms per cubic meter) in marine applications. Most ground-contact applications require minimum retentions of 0.4 pounds per cubic foot (6.4 kilograms per cubic meter). Critical structural applications require minimum retentions of 0.6 pounds per cubic foot (9.6 kilograms per cubic meter). It may be difficult to obtain adequate penetration of CCA in some difficult-to-treat species. The chromium serves as a corrosion inhibitor. Corrosion of fasteners in wood treated with CCA is not as much of a concern as in wood treated with other waterborne preservatives that contain copper but do not contain chromium.

CCA contains inorganic arsenic and is classified as an RUP by the EPA. Producers of treated wood, in cooperation with the EPA, created the Consumer Information Sheet which has been replaced with the Consumer Safety Information Sheet that gives guidance on handling and site precautions at sites where wood treated with inorganic arsenic is used (appendix B). The consumer safety information sheet should be available to all persons who handle wood treated with CCA.

Ammoniacal Copper Zinc Arsenate (ACZA)

Ammoniacal copper zinc arsenate (ACZA) contains copper oxide (50 percent), zinc oxide (25 percent), and arsenic pentoxide (25 percent). ACZA is a refinement of an earlier formulation, ACA, which is no longer available in the United States. The color of the treated wood varies from olive to bluish green. The wood may have a slight ammonia odor until it has dried thoroughly. ACZA is an established preservative that is used to protect wood from decay and insect attack in a wide range of exposures and applications. Exposure tests showed that it protected stakes and posts that contacted the ground.

ACZA is listed in the AWPA standards for treatment of a range of softwood and hardwood species and wood products. The minimum ACZA retention is 0.25 pounds per cubic foot (4 kilograms per cubic meter) for above-ground applications and 0.4 pounds per cubic foot (6.4 kilograms per cubic meter) for wood that contacts the ground. A slightly higher retention, 0.6 pounds per cubic foot (9.6 kilograms per cubic meter), is required for wood used in highway construction and for critical structural components that are exposed to high decay hazard. The ammonia in the treating solution, in combination with processing techniques such as steaming and extended pressure periods at elevated temperatures, allow ACZA do a better job of penetrating difficult-to-treat species of wood than many other water-based wood preservatives.

ACZA is used frequently in the Western United States to treat Douglas-fir lumber and timbers used to construct secondary highway bridges, trail bridges, and boardwalks. The ACZA treatment can accelerate corrosion in comparison to untreated wood, requiring the use of hot-dipped galvanized or stainless steel fasteners. Treatment facilities using ACZA are located in Western States, where many native tree species are difficult to treat with CCA.

ACZA contains inorganic arsenic and is classified as an RUP by the EPA. Producers of treated wood, in cooperation with the EPA, have created consumer information sheets that suggest appropriate handling precautions and precautions at sites where wood treated with inorganic arsenic (appendix B) will be used. These sheets should be available to all personnel who handle wood treated with ACZA.

Alkaline Copper Quaternary (ACQ) Compounds

Alkaline copper quat (ACQ) is one of several wood preservatives that have been developed in recent years to meet market demands for alternatives to CCA. The fungicides and insecticides in ACQ are copper oxide (67 percent) and a quaternary ammonium compound (quat). Many variations of ACQ have been standardized or are being standardized. ACQ type B (ACQ–B) is an ammoniacal copper formulation, ACQ type D (ACQ–D) is an amine copper formulation, and ACQ type C (ACQ–C) is a combined ammoniacal-amine formulation with a slightly different quat compound.

Wood treated with ACQ–B is dark greenish brown and fades to a lighter brown. It may have a slight ammonia odor until the wood dries. Wood treated with ACQ–D has a lighter greenish-brown color and has little noticeable odor; wood treated with ACQ–C varies between the color of ACQ–B and that of ACQ–D, depending on the formulation. Stakes treated with these three formulations have demonstrated their effectiveness against decay fungi and insects when the stakes contacted the ground.

The ACQ formulations are listed in the AWPA standards for a range of applications and many softwood species. The listings for ACQ–C are limited because it is the most recently standardized. The minimum ACQ retentions are 0.25 pounds per cubic foot (4 kilograms per cubic meter) for aboveground applications, 0.4 pounds per cubic foot (6.4 kilograms per cubic meter) for applications involving ground contact, and 0.6 pounds per cubic foot (9.6 kilograms per cubic meter) for highway construction. The different formulations of ACQ allow some flexibility in achieving compatibility with a specific wood species and application. An ammonia carrier improves the ability of ACQ to penetrate into wood that is difficult to treat. For wood species that are easier to treat, such as southern pine, an amine carrier will provide a more uniform surface appearance.

All ACQ treatments accelerate corrosion of metal fasteners relative to untreated wood. Hot-dipped galvanized copper or stainless steel fasteners must be used. The number of pressure-treatment facilities using ACQ is increasing.

In the Western United States, the ACQ–B formulation is used because it will penetrate difficult-to-treat Western species better than other waterborne preservatives. Treatment plants elsewhere generally use the ACQ–D formulation. Researchers at the USDA Forest Service's Forest Products Laboratory in Madison, WI, are evaluating the performance of a secondary highway bridge constructed using Southern pine lumber treated with ACQ–D (Ritter and Duwadi 1998).

Copper Azoles (CBA–A and CA–B)

Copper azole is another recently developed preservative formulation that relies primarily on amine copper, but with additional biocides, to protect wood from decay and insect attack (figure 3). The first copper azole formulation

Figure 3—Pressure-treated lumber stockpiled at a lumberyard. Lumber treated with ACQ–D and CA–B has become widely available.

developed was the copper azole type A (CBA–A), which contains 49-percent copper, 49-percent boric acid, and 2-percent tebuconazole. Type A is no longer used in the United States. The copper azole type B (CA–B) formulation was standardized recently. CA–B does not contain boric acid. It is comprised of 96-percent copper and 4-percent tebuconazole. Wood treated with either copper azole formulation has a greenish-brown color and little or no odor.

Tests showed that the copper azole formulations protected stakes in the ground from attack by decay fungi and insects. The formulations are listed in the AWPA standards for treatment of a range of softwood species. Minimum CA–B retentions in the wood are 0.10, 0.21, or 0.31 pounds per cubic foot (1.6, 3.4, or 5 kilograms per cubic meter) for wood used aboveground, contacting the ground, or in critical structural components, respectively.

Copper azole is an amine formulation. Ammonia may be added at the treating plant when the copper azole is used on Western species that are difficult to treat. This formulation is often used to treat Douglas-fir. Formulations with ammonia slightly darken the surface appearance and initially affect the odor of the treated wood.

Copper azole treatments increase the rate of corrosion of metal fasteners relative to untreated wood. Appropriate hot-dipped galvanized steel, copper or stainless steel fasteners, connectors, and flashing are recommended. Although copper azole was introduced to North America recently, almost 100 treating facilities now use this preservative.

Borates

Borate compounds are the most commonly used unfixed waterborne preservatives. Unfixed preservatives can leach from treated wood. They are used for pressure treatment of framing lumber used in areas with high termite hazard, and as surface treatments for a wide range of wood products, such as cabin logs and the interiors of wood structures. They are also applied as internal treatments using rods or pastes. At higher rates of retention, borates also are used as fire-retardant treatments for wood.

Boron has some exceptional performance characteristics, including activity against fungi and insects, but low mammalian toxicity. It is relatively inexpensive. Another advantage of boron is its ability to diffuse with water into wood that normally resists traditional pressure treatment. Wood treated with borates has no added color, no odor, and can be finished (primed and painted).

While boron has many potential applications in framing, it probably is not suitable for many Forest Service applications because the chemical will leach from the wood under wet conditions. It may be a useful treatment for insect protection in areas continually protected from water.

Inorganic boron is listed as a wood preservative in the AWPA standards, which include formulations prepared from sodium octaborate, sodium tetraborate, sodium pentaborate, and boric acid. Inorganic boron is also standardized as a pressure treatment for a variety of species of softwood lumber used out of contact with the ground and continuously protected from water. The minimum borate (B_2O_3) retention is 0.17 pounds per cubic foot (2.7 kilograms per cubic meter). A retention of 0.28 pounds per cubic foot (4.5 kilograms per cubic meter) is specified for areas with Formosan subterranean termites.

Borate preservatives are available in several forms, but the most common is disodium octaborate tetrahydrate (DOT). DOT has higher water solubility than many other forms of borate, allowing more concentrated solutions to be used and increasing the mobility of the borate through the wood. With the use of heated solutions, extended pressure periods, and diffusion periods after treatment, DOT can penetrate species that are relatively difficult to treat, such as spruce. Several pressure treatment facilities in the United States use borate solutions.

Although borates have low mammalian toxicity, workers handling borate-treated wood should use standard precautions, such as wearing gloves and dust masks. The environmental impact of borate-treated wood for construction projects in sensitive areas has not been evaluated. Because borate-treated wood is used in areas protected from precipitation or water, little or no borate should leach into the environment. Borates have low toxicity to birds, aquatic invertebrates, and fish. Boron occurs naturally at relatively high levels in the environment. Because borates leach readily, extra care should be taken to protect borate-treated wood from precipitation when it is stored at the jobsite. Precipitation could deplete levels of boron in the wood to ineffective levels and harm vegetation directly below the stored wood.

Borate-treated wood should be used only in applications where the wood is kept free from rainwater, standing water, and ground contact.

Other Waterborne Preservatives

Other waterborne preservatives have been introduced recently on the commercial market. They have not been on the market long enough to have long-term performance studies completed. Their effectiveness or performance has not been established. This publication only describes preservatives that have been evaluated and standardized by the American Wood-Preservers' Association (AWPA), the primary standard-setting body for pressure-treated wood. To become standardized by the AWPA, preservative-treated wood must undergo a series of rigorous tests to ensure its durability. These tests include several years of outdoor exposure in a climate with severe biodeterioration hazards. The results of these tests are reviewed by AWPA members who represent government agencies, universities, commercial chemical suppliers, and treatment companies. Be wary of purchasing wood that has been treated with a preservative that has not been standardized for that application by either the AWPA or another major standard-setting body, such as the American Society for Testing and Materials (ASTM).

Preservatives That Are No Longer Available Commercially

Several preservative formulations that have been used in the past were not available commercially in 2005. The wood preservative industry has become more dynamic because of economic factors and regulations. The following preservative formulations are included in this report because they may become available in the future and because they have been used to treat existing structures.

Ammoniacal Copper Arsenate (ACA)

ACA was an older formulation of ACZA that didn't contain zinc. It has not been available in the United States for many years and is not likely to be produced in the future. ACA should be replaced with ACZA in older guidelines and specifications.

Acid Copper Chromate (ACC)

Acid copper chromate (ACC) has been used as a wood preservative in Europe and the United States since the 1920s. ACC contains 31.8-percent copper oxide and 68.2-percent chromium trioxide. The treated wood has a light greenish-brown color and little noticeable odor. During tests, stakes and posts that were impregnated with ACC held up well when exposed to decay and termite attack, although they may have been susceptible to attack by some species of copper-tolerant fungi.

ACC is listed in the AWPA standards for a wide range of softwoods and hardwoods, with a minimum retention of 0.25 pounds per cubic foot (4 kilograms per cubic meter) for wood used aboveground and 0.5 pounds per cubic foot (8 kilograms per cubic meter) for wood that contacts the ground. In critical structural applications, such as highway construction, AWPA listings for ACC are limited to signposts, handrails and guardrails, and glue-laminated beams used aboveground. It may be difficult to obtain adequate penetration of ACC in some of the wood species that are difficult to treat, such as white oak or Douglas-fir. The high chromium content of ACC prevents much of the corrosion that might otherwise occur with an acidic copper preservative.

ACC does not contain arsenic, but the treatment solution does use hexavalent chromium. The chromium is converted to the more benign trivalent state during treatment and storage of the wood. This process of chromium reduction is the basis for fixation in ACC, and depends on time, temperature, and moisture. Fixation standards or BMPs (best management practices) have not been developed for ACC, because of its relatively low usage. As a general guide, the fixation considerations discussed for CCA can be applied to ACC, but the fixation times must be extended because of ACC's higher chromium content. In 2005, only one manufacturer had a registration for ACC, and it was not being marketed.

Ammoniacal Copper Citrate (CC)

Ammoniacal copper citrate (CC) uses copper oxide (62 percent) as the fungicide and insecticide, and citric acid (38 percent) to help distribute copper within the wood structure. In 2004, CC was withdrawn from the AWPA standards because it was not being used.

Copper Dimethyldithiocarbamate (CDDC)

Copper dimethyldithiocarbamate is a reaction product formed in wood that has been treated with two different solutions. It contains copper and sulfur compounds. CDDC protects against decay fungi and insects. It has not been standardized for use in seawater. CDDC is standardized for treatment of southern pine and some other pine species at copper retentions of 0.1 pound per cubic foot (1.6 kilograms per cubic meter) for wood used aboveground or 0.2 pound per cubic foot (3.2 kilograms per cubic meter) for wood that contacts the ground. CDDC-treated wood has a light brown color and little or no odor. CDDC was introduced several years ago, but because of the expense of converting plants for its use and of the two-step treatment process, CDDC-treated wood was not available commercially in 2005.

Summary of Preservative Properties

Table 1 summarizes the properties of the most commonly used preservatives.

Table 1—The properties and uses of common preservatives.

Standardized use	Preservative	Solvent characteristics	Surface/handling restrictions	Color	Odor	Fastener corrosion
All uses	Creosote	Oil-type	Oily, not for frequent human contact	Dark brown	Strong, lasting	No worse than untreated
All uses	Ammoniacal copper zinc arsenate	Water	Dry, but contains arsenic	Brown, possible blue areas	Mild, short term	Worse than untreated wood
All uses	Chromated copper arsenate	Water	Dry, but uses are restricted by the EPA*	Greenish brown, weathers to gray	None	Similar to untreated wood
All uses (except in seawater)	Pentachlorophenol in heavy oil	No. 2 fuel oil	Oily, not for frequent human contact	Dark brown	Strong, lasting	No worse than untreated wood
All uses (except in seawater)	Copper naphthenate	No. 2 fuel oil	Oily, not for frequent human contact	Green, weathers to brownish gray	Strong, lasting	No worse than untreated wood
All uses (except in seawater)	Alkaline copper quat	Water	Dry, okay for human contact	Greenish brown, weathers to gray	Mild, short term	Worse than untreated wood
All uses (except in seawater)	Copper azole	Water	Dry, okay for human contact	Greenish brown, weathers to gray	Mild, short term	Worse than untreated wood
Aboveground, fully exposed	Pentachlorophenol in light oil	Mineral spirits	Dry, okay for human contact if coated	Light brown, weathers to gray	Mild, short term	No worse than untreated wood
Aboveground, fully exposed	Oxine copper	Mineral spirits	Dry, okay for human contact	Greenish brown, weathers to gray	Mild, short term	No worse than untreated wood
Aboveground, partially protected (such as millwork)	IPBC + permethrin	Mineral spirits	Dry, okay for human contact	Colorless	Mild, short term	No worse than untreated wood
Indoors (usually for insect protection)	Borates	Water	Dry, okay for human contact	Colorless, blue dye often added	None	No worse than untreated wood

*A few uses of chromated copper arsenate are still allowed for treatment of sawn products less than 5 inches thick (12.7 centimeters, such as dimension lumber). Pilings, poles, large timbers, and plywood are still allowed for highway construction.—*Courtesy of USDA Forest Service, Forest Products Laboratory*

Treatment Processes

Methods that preserve wood generally are either:

- Pressure processes, in which the wood is impregnated in closed vessels at pressures considerably higher than atmospheric pressure
- Processes that do not involve pressure

Pressure Processes

In commercial practice, wood usually is treated by immersing it in preservative in an apparatus that applies high pressure, driving the preservative into the wood. Pressure processes differ in details, but the general principle is the same. The wood is carried on cars or trams into a long steel cylinder, which is closed and filled with preservative. Pressure forces the preservative into the wood until the desired amount has been absorbed and has penetrated relatively deeply. Commonly, three general pressure processes are used: full cell, modified full cell, and empty cell. Commercial treaters often use variations or combinations of these processes.

Full-Cell Processes

The full-cell (Bethel) process is used when the goal is for wood to retain as much of the preservative as possible. For instance, it is a standard procedure to treat timbers with creosote using the full-cell process to protect the timbers from marine borers. Waterborne preservatives sometimes are applied by the full-cell process. Preservative retention can be controlled by regulating the concentration of the treating solution. The steps in the full-cell process are:

1. Wood is sealed in the treatment cylinder and a preliminary vacuum is applied for a half an hour or longer to remove the air from the cylinder and as much air as possible from the wood.

2. The preservative (at ambient temperature or higher, depending on the system) is pumped into the cylinder without breaking the vacuum.

3. After the cylinder is filled, pressure is applied until the wood will take no more preservative or until the required retention of preservative has been achieved.

4. After pressure has been applied for the specified time, the preservative is pumped from the cylinder.

5. A short final vacuum may be used to remove dripping preservative from the wood.

Modified Full-Cell Processes

The modified full-cell process is basically the same as the full-cell process except that it uses lower levels of initial vacuum and often uses an extended final vacuum. The amount of initial vacuum is determined by the wood species, material size, and retention desired. Residual air in the wood expands during the final vacuum to drive out part of the injected preservative solution. For this reason, modified full-cell schedules are sometimes called *low-weight* schedules. They are now the most common method of treating wood with waterborne preservatives.

Empty-Cell Processes

The empty-cell process is designed to obtain deep penetration with a relatively low net retention of preservative. The empty-cell process should always be used for treatment with oil preservatives if it provides the desired retention.

Two empty-cell processes, the Rueping and the Lowry, are commonly employed; both use the expansive force of compressed air to drive out part of the preservative absorbed during the pressure period. The Rueping empty-cell process, often called the empty-cell process with initial air, has been widely used for many years in Europe and the United States. The following general procedure is employed:

1. Air under pressure is forced into the treatment cylinder, which contains the wood. The air penetrates some species easily, requiring just a few minutes of application pressure. In treating the more resistant species, the common practice is to maintain air pressure from half an hour to 1 hour before pumping in the preservative, although the need to maintain air pressure for longer than a few minutes does not seem to be fully established. The air pressures employed generally range between 25 to 100 pounds per square inch (172 to 689 kilopascals), depending on the net retention of preservative desired and the resistance of the wood.

2. After the period of preliminary air pressure, preservative is forced into the cylinder. As the preservative is pumped in, air escapes from the treatment cylinder into an equalizing tank (also known as a Rueping tank) at a rate that keeps the pressure constant in the cylinder. When the treatment cylinder is filled with preservative, the treatment pressure is increased above the initial air pressure and is maintained until the wood absorbs no more preservative, or until enough preservative has been absorbed for the required retention of preservative.

3. At the end of the pressure period, the preservative is drained from the cylinder, and surplus preservative is removed from the wood with vacuum. From 20 to 60 percent of the total preservative injected into the cylinder can be recovered after the vacuum has been applied.

Treating Pressures and Preservative Temperatures

The pressures used in treatments vary from about 50 to 250 pounds per square inch (345 to 1,723 kilopascals), depending on the species and the ease with which the wood takes the treatment; pressures commonly range from about 125 to 175 pounds per square inch (862 to 1,207 kilopascals). Many woods are sensitive to (and could be damaged by) high treatment pressures. Heated preservatives are used sometimes to improve penetration, but the elevated temperatures can affect the wood's properties and the stability of the treatment solution. The AWPA specifications require that the temperature of the preservative during the entire pressure period not exceed 120 degrees Fahrenheit (49 degrees Celsius) for ACC and CCA and 150 degrees Fahrenheit (60 degrees Celsius) for ACQ–B, ACQ–D, ACZA, CBA–A, CA–B, and CDDC. The maximum temperature for inorganic boron is 200 degrees Fahrenheit (93 degrees Celsius). Please refer to the *Wood Handbook* for more information on treating pressures and temperatures.

Penetration and Retention

Penetration and retention requirements are equally important in determining the quality of preservative treatment. Penetration levels vary widely, even in pressure-treated material. In most species, heartwood is more difficult to penetrate than sapwood. In addition, species differ greatly in the degree to which their heartwood may be penetrated. Incising (perforating the surface of the wood with small slits) tends to improve the penetration of preservative in many refractory species, but species that are highly resistant to penetration will not have deep or uniform penetration, even when they are incised. When the heart faces of these species are not incised, penetration may be as deep as $^1/_4$ inch (6 millimeters), but often is not more than $^1/_{16}$ inch (1.6 millimeters).

Experience has shown that even slight penetration has some value, although deeper penetration is highly desirable to prevent untreated wood from being exposed when the wood checks, particularly for important members that are costly to replace. The heartwood of coastal Douglas-fir, southern pines, and various hardwoods, although resistant, will frequently show transverse penetrations of 6 to 12 millimeters (1⁄4 to 1⁄2 inch) and sometimes penetrations that are considerably deeper.

Complete penetration of the sapwood should be the ideal in all pressure treatments. This penetration often can be accomplished in small-size timbers of various commercial woods. With skillful treatment, it may be obtained in pilings, ties, and structural timbers. However, the operator cannot always ensure complete penetration of sapwood in every large piece of round material with thick sapwood, such as poles and piles. Specifications permit some tolerance for less than complete penetration. Refer to the AWPA standards for required penetration and retention of various species and treatments.

Nonpressure Processes

The numerous nonpressure processes differ widely in the penetration and retention levels that may be achieved, and in the degree of protection they provide. When similar retention and penetration levels are reached, the service life of wood treated by a nonpressure method should be comparable to that of wood treated by a process that uses pressure. Nevertheless, nonpressure treatments, particularly those involving surface applications, generally do not produce results as satisfactory as those produced by pressure treatments. The nonpressure processes do serve a useful purpose when more thorough treatments are impractical or when little protection is required.

In general, nonpressure methods consist of:

- Surface application of preservatives by brushing or brief dipping
- Soaking wood in preservative oils or steeping it in solutions of waterborne preservatives
- Diffusion processes using waterborne preservatives
- Vacuum treatment
- Other miscellaneous processes

Surface Applications

The simplest treatment is to dip wood into preservative or to brush preservative on the wood. Preservatives that have low viscosity when cold should be used, unless the preservative can be heated. The preservative should be flooded over the wood rather than merely painted. Every check and depression in the wood should be thoroughly filled with the preservative. Any untreated wood that is left exposed will provide ready access for fungi.

Rough lumber may require as much as 10 gallons of oil per 1,000 square feet (40 liters of oil per 100 square meters) of surface. Surfaced lumber requires considerably less oil. The transverse penetration usually will be less than 1⁄10 inch (2.5 millimeters), although in easily penetrated species, end-grain (longitudinal) penetration will be considerably deeper. The additional life obtained by such treatments will be affected greatly by the conditions of service. For treated wood that contacts the ground, service life may be from 1 to 5 years.

Dipping wood for a few seconds to several minutes in a preservative provides more assurance that all surfaces and checks will be thoroughly coated with the preservative. In addition, dipping usually produces slightly deeper penetration. Window sashes, frames, and other millwork commonly are treated by dipping them in a water-repellent preservative, either before or after assembly. Transverse penetration of the preservative applied by brief dipping is very shallow, usually less than a few hundredths of an inch (a millimeter). The exposed end surfaces at joints are the most vulnerable to decay in millwork products. Good end-grain penetration is especially important.

Dip applications provide very limited protection to wood that contacts the ground or that is used in very moist conditions. They provide very limited protection against attack by termites. However, they do have value for exterior woodwork and millwork that is painted, that does not contact the ground, and that is exposed to moisture just for brief periods.

Cold Soaking and Steeping

Cold soaking well-seasoned wood for several hours or days in low-viscosity preservative oils or steeping green or seasoned wood for several days in waterborne preservatives has provided varying levels of success for fenceposts, lumber, and timbers.

Pine posts treated by cold soaking for 24 to 48 hours or longer in a solution containing 5 percent of pentachlorophenol in No. 2 fuel oil have had an average life of 16 to 20 years or longer.

The sapwood in these posts was well penetrated with retention levels of the preservative solution ranging from 2 to 6 pounds per cubic foot (32 to 96 kilograms per cubic meter). Posts of woods such as birch, aspen, and sweetgum treated by this method have deteriorated much more quickly than treated pine posts.

Preservative penetration and retention levels obtained by cold soaking lumber for several hours are considerably better than those obtained by brief dips. However, preservative retention levels seldom equal those obtained by pressure treatment, except in cases such as the sapwood of pines that has become highly absorbent because of infection by molds and stains.

Steeping wood in waterborne preservatives has had very limited use in the United States, but it has been used for many years in Europe. When seasoned wood is treated, both the water and the preservative salt soak into the wood. When green wood is treated, the preservative only enters the wood by diffusion. Preservative retention and penetration levels vary widely. The process generally is not recommended when more reliable treatments are practical.

Diffusion Processes

Diffusion processes may be used with green or wet wood. These processes employ waterborne preservatives that will diffuse out of the water in a treatment paste (or treatment solution) into water in the wood.

The double-diffusion process developed by the Forest Products Laboratory has produced good results in tests of fenceposts and standard 2- by 4-inch (38- by 89-millimeter) stakes, particularly for full-length immersion treatments. This process consists of steeping green or partially seasoned wood first in one chemical solution, then in another.

The two chemicals diffuse into the wood, and react to precipitate an effective preservative with high resistance to leaching. The process has had commercial application in cooling towers and fenceposts where preservative protection is needed. The chemicals evaluated by the Forest Products Laboratory for the double-diffusion process are not registered by the EPA for this type of application.

Other diffusion processes involve applying preservatives to the butt or around the groundline of posts or poles. The preservative can be injected into standing poles at the groundline with a special tool, applied on the poles' surface as a paste or bandage, or poured into holes bored in the pole at the groundline. These treatments are valuable for untreated standing poles and for treated poles when preservative retention levels are inadequate.

Vacuum Processes

The vacuum process, or *VAC–VAC* as it is called in Europe, has been used to treat millwork with water-repellent preservatives and to treat construction lumber with waterborne and water-repellent preservatives.

In treating millwork, the objective is to use a limited quantity of water-repellent preservative and obtain retention and penetration levels similar to those obtained by dipping for 3 minutes. The vacuum process treatment is included in WDMA I.S. 4–05 for *Water Repellent Preservative Non Pressure Treatment for Millwork*.

After a quick, low initial vacuum, the cylinder is filled with preservative under vacuum, the vacuum is released and preservative soaks into the wood, followed by a final vacuum. The treatment is better than the 3-minute dip treatment. Penetration and retention are better, and the surface of the wood dries quickly, leaving it ready for glazing, priming, and painting. The vacuum treatment is also reported to be less likely than dip treatment to leave objectionably high levels of preservative in bacteria-infected wood, referred to as *sinker stock*.

When pressure treatment is not required, lumber intended for buildings may be treated by the vacuum process. The process uses a higher initial vacuum and a longer immersion or soaking period than used in treating millwork.

Preservative retention is harder to control in vacuum treatment than in empty-cell pressure treatment. However, the concentration of waterborne preservatives can be adjusted to provide good control over retention levels during vacuum treatment.

Other Nonpressure Processes

Several other nonpressure methods of various types have been used. Some involve applying waterborne preservatives to living trees. The Boucherie process for treating green, unpeeled poles has been used in Europe for many years. This process involves attaching liquid-tight caps to the butt ends of the poles. A waterborne preservative is forced under hydrostatic pressure into the cap and into the pole.

A tire-tube process is a simple adaptation of the Boucherie process used for treating green, unpeeled fenceposts. In this treatment, a section of used inner tube is fastened tight around the butt end of the post to make a bag that holds a solution of waterborne preservative. This process has limitations in the United States because preservative can leak into the soil at the treatment site.

Refer to the *Wood Handbook* for more information on treatment processes.

Alternatives to Treated Wood

Alternatives to treated wood are being used more frequently. Examples of alternatives to treated wood are native decay-resistant woods, exotic decay-resistant woods, composite woods (plastic woods), vinyl, and rubber (figure 4). Only the heartwood of decay-resistant species is durable. The decay resistance of the heartwood of native species is listed and described in the *Wood Handbook* and AASHTO standard specification, *M 168*.

Figure 4—Alternatives to treated wood include rubber wood and solid- and hollow-core plastic-wood composite decking.

Table 2 lists the advantages and disadvantages of different alternatives to treated wood.

Table 2—Advantages and disadvantages of five alternatives to treated wood.

Material	**Description**	**Advantages**	**Disadvantages**
Native decay-resistant woods	Redwood, cedar, juniper, bald cypress, pacific yew, chestnut, black locust, osage orange, black walnut.	Resistant to decay and insects. Attractive. Dimensionally stable. Provides a use for invasive species, such as locust and juniper.	Expensive. Surfaces may be soft (susceptible to denting and scratching). Susceptible to moisture. Life expectancy is not as long as that of treated wood.
Exotic decay-resistant woods	Includes mahogany and a variety of ironwoods (Ipe), also known as Pau Lope.	Durable. Resistant to decay and insects. Attractive. Virtually knot free. Resistant to water.	Expensive. Difficult to work with (requires predrilling for fasteners). Environmental concerns (except for lumber certified by the Forest Stewardship Council).
Composites (plastic woods)	Solid material made of wood , fibers and recycled grocery bags recycled milk jugs, or virgin plastic.	Doesn't split or chip. Variety of colors to choose from. Less need for sealing or staining. Requires little maintenance. Free of knots.	Expensive. Unnatural appearance. Generally not rated for structural use. (Usually, wood is used for structural supports and subframes.) Susceptible to mildew, mold, and stains. Color fades in sunlight. (Some products are reinforced with fiberglass and meet ASTM standards.)
Virgin vinyl	Hollow building material, a molecularly bonded blend of 100-percent virgin, hi-polymer resin. (Some are made with UV inhibitors to prevent damage from sunlight and impact modifiers for greater strength.)	Doesn't warp, split, chip, or rot. Variety of colors to choose from. Never needs sealing or staining.	Expensive. Unnatural appearance. Not rated for structural use. (Wood is required for structural supports and subframes.)
High-density polyethylene (HDPE)	Thermoplastic.	Weather resistant. Can be cut or drilled cleanly. No grain to split or chip. No need to predrill lumber. Suitable for agricultural uses. Good at low temperatures. Impact resistant. Excellent chemical resistance.	Susceptible to stress cracking. Not as stiff as polypropylene. High mold shrinkage. Poor UV resistance. Not rated for structural use. (Wood is required for structural supports and subframes.)
Rubber lumber	Composed of 50-percent plastic and 50-percent old tires.	Durable. Impervious to water. Resistant to insects. Resistant to UV rays. Variety of colors. Uses recycled materials.	Unnatural appearance. Color isn't guaranteed to last. Not rated for structural use. (Wood is required for structural supports and subframes.)

—Courtesy of the U.S. Environmental Protection Agency with the addition of information on the naturally decay-resistant hardwoods.

Leaching and Its Effects on the Environment

All wood-preservative treatments contain active ingredients that protect the wood from insects and fungi. Preservatives intended for use outdoors (figure 5) have chemical properties that are intended to keep the active ingredients in the wood and minimize leaching. Past studies indicate that a small percentage of the active ingredients of all types of wood preservatives leach out of the wood.

Figure 5—Stairs on the Falls of Hills Creek Trail in the Monongahela National Forest, WV.

The amount of leaching from a particular product used in a specific way depends on factors such as fixation conditions, the preservative's retention in the wood, the product's size and shape, the type of exposure, and the years in service. Some ingredients in all preservatives are toxic at high concentrations to a variety of organisms. Laboratory studies indicate that the levels of preservatives leached from treated wood generally are too low to create a biological hazard.

In recent years, several studies have been conducted on preservative releases from structures and on the environmental consequences of those releases. For instance, the Forest Service, the Bureau of Land Management, and industry partners cooperated to study the environmental impacts of waterborne preservatives that leached from wood used to construct a wetland boardwalk (USDA Forest Service Forest Products Laboratory 2000). The construction project was considered a *worst case* because a lot of treated wood was used and the site had high rainfall.

Separate boardwalk test sections were constructed using untreated wood and wood treated with ACQ–B, ACZA, CCA–C, or CDDC. Surface soil, sediment, and water samples were removed before construction and at intervals after construction to determine the concentrations and movement of preservative elements that leached from the boardwalk. Aquatic insect populations in the vegetation, in sediments, and on artificial substrates were monitored.

During the first year, each of the preservatives evaluated released measurable amounts of copper, chromium, zinc, or arsenic into rainwater collected from the wood. Each preservative also appeared to elevate soil and sediment levels of the elements used in the preservative. In some cases, levels appeared to peak soon after construction. In other cases, levels appeared to increase during the course of the year.

With few exceptions, the elevated concentrations were confined to areas near the boardwalk. These levels of environmental accumulation did not appear to have any measurable biological impact. Although seasonal fluctuations in insect populations were noted, none of the invertebrate taxa evaluated were significantly reduced in the wetlands surrounding any of the treated wood.

Brooks (2000) evaluated the environmental effects of timber bridges treated with either CCA–C, pentachlorophenol, or creosote. In that study, bridges that had been in service for several years were evaluated by comparing upstream and downstream levels of preservative concentrations in sediments and populations of aquatic insects at the same sampling locations.

The two bridges treated with pentachlorophenol were in forested areas in Washington and Oregon. The Washington site appeared to contain low levels of pentachlorophenol, although the concentrations detected were approaching the lower detection limit of the instrumentation. No biological effects would be expected at those levels, and none were detected.

At the bridge treated with pentachlorophenol in Oregon, sediment samples were collected underneath the bridge and 3 feet (0.9 meter) downstream from the bridge. These samples contained slightly elevated levels of pentachlorophenol. Small decreases in several biological indices were noted directly under the bridge, but these decreases appeared to be related to differences in stream bottom habitat. No adverse effects on biological organisms were noted when a laboratory bioassay was conducted on sediments collected under the bridge (Brooks 2000).

Two CCA-treated bridges in Florida were also evaluated, one over a saline bay and the other over a freshwater marsh (Brooks 2000). The bridge over the bay was in the final stages of construction, while the bridge over the marsh had been built 2 years before. Some samples of sediments removed within 10 feet (3 meters) of the newly constructed bridge contained elevated levels of copper, chromium, and arsenic. The patchy nature of the samples with elevated levels and the observation of wood chips in the sediments led Brooks to suspect that at least a portion of the elevated samples contained treated wood sawdust. Despite the elevated levels of CCA detected in the sediments, no adverse biological effects were observed.

Very slightly elevated copper, chromium, and arsenic levels also were noted in sediments within 10 to 20 feet (3 to 6 meters) of the 2-year-old bridge, but again, no adverse biological effects were observed. In this case, the population and diversity of aquatic insects actually appeared to increase closer to the bridge.

Brooks also evaluated two creosote-treated bridges in agricultural areas in Indiana. One had been in service for about 2 years and the other for about 17 years. In each case, elevated levels of polycyclic aromatic hydrocarbons were detected in sediments 6 to 10 feet (1.8 to 3 meters) downstream from the bridges. Levels of polycyclic aromatic hydrocarbons at the newer bridge approached levels of concern. No significant effect on insect populations was noted downstream from the newer bridge. The population and diversity of aquatic insects appeared to be reduced within 20 feet (6 meters) downstream from the older creosote-treated bridge.

The author postulated that this trend was caused by the deposition of maple leaves in this area and was not a response to the polycyclic aromatic hydrocarbons that had been released (Brooks 2000). Sediments from that area did not adversely affect aquatic invertebrates in a laboratory bioassay, supporting Brooks' hypothesis.

The release and biological impacts of creosote also have been evaluated for newly installed six-piling dolphins (clusters of pilings used as moorings or bumpers) installed in the waters of Sooke Basin on Vancouver Island, BC, Canada (Goyette and Brooks 1998). Polycyclic aromatic hydrocarbon contamination was detected within 25 feet (7.5 meters) downstream from the piling, and significant biological effects were noted within 2.1 feet (0.65 meters) of the perimeter of the structure. Slight biological effects were noted in laboratory bioassays of sediments from up to 6.6 feet (2.0 meters) downstream from the pilings, but not in samples of organisms collected there (Goyette and Brooks 1998).

These recent studies of the environmental impact of treated wood reveal several key points:

- All types of treated wood evaluated release small amounts of preservative components into the environment. These components can be detected in soil or sediment samples.

- Shortly after construction, elevated levels of preservative components sometimes can be detected in the water column. Detectable increases in soil and sediment concentrations of preservative components generally are limited to areas close to the structure.

- The leached preservative components either have low water solubility or react with components of the soil or sediment, limiting their mobility and the range of environmental contamination.

- The levels of these components in the soil immediately adjacent to treated structures can increase gradually over the years.

Although elevated preservative levels have been detected in sediments adjacent to treated wood in aquatic environments, Brooks (Brooks 2000, USDA Forest Products Laboratory 2000) did not find any measurable impact on the abundance or diversity of aquatic invertebrates associated with those sediments. In most cases, levels of preservative components were below levels that might be expected to affect aquatic life. Samples with elevated levels of preservative components tended to be limited to fine sediments beneath stagnant or slow-moving water where the invertebrate community is somewhat tolerant of pollutants.

All construction materials, including the alternatives to treated wood, have some type of environmental impact. Leaching from plastic and wood-plastic composites has not been studied as thoroughly as that from treated wood, but one study found that over 70 different contaminants were released from one type of recycled plastic lumber (Weis and others 1992). Releases from recycled plastic may depend on the types of chemicals that were stored in the containers originally. Production of concrete and steel requires mining (Mehta 2001), consumes energy, and contributes to the production of greenhouse gases.

Conditions with a high potential for leaching and a high potential for metals to accumulate are the most likely to affect the environment. For typical Forest Service applications, these conditions are most likely to be found in boggy or marshy areas with little water exchange. Water at these sites has low pH and high organic acid content, increasing the likelihood that preservatives will be leached from the wood. In addition, the stagnant water prevents dispersal of any leached components of preservatives, allowing them to accumulate in soil, sediments, and organisms near the treated wood.

Riparian zones, wetlands, and meadows may provide essential habitat for key species during critical periods of their life cycles. Boardwalks and fishing platforms are commonly used in these areas. The challenge is to use the most durable, esthetically pleasing, cost-effective materials available, while still protecting sensitive ecosystems.

Recommended Guidelines

The following guidelines can help field employees select wood preservatives that are most appropriate for their projects (figure 6).

Selecting a Wood Preservative

The type of preservative that is most appropriate depends on the species of wood being treated, the type of structure, the cost, the availability of treated wood, and the specific area where the wood will be used.

Wood Species

Generally, hem-fir (hemlock and fir) and southern pine can be treated adequately with any of the commercial wood preservatives, although copper napthenate has not been standardized for use with hem-fir. CCA is not recommended for treatment of Douglas-fir, which is more readily treated with oil-type or ammoniacal preservatives. CCA is not recommended for treating hardwoods that will contact the ground.

Types of Structures

Although appearance is not a major concern in many applications, wood treated with ammoniacal copper preservatives (ACZA, ACQ–B) may not be colored as uniformly as wood treated with other waterborne preservatives. However, ammoniacal preservatives allow better penetration and treatment of larger material, such as pilings and timbers—especially those made from Douglas-fir.

Often, large glue-laminated timbers (those used in bridge supports, for instance) are treated with oil-type preservatives, such as pentachlorophenol and copper naphthenate to reduce problems with checking and cracking. Laminated members, except for those that are small and straight, should not be treated with waterborne preservatives. The characteristic odor and appearance of oilborne preservatives may make them less desirable in areas of frequent human contact, such as handrails or decks.

In marine construction, or construction in areas with brackish water, such as ocean estuaries, only creosote,

Figure 6—A viewing platform in the Garden of the Gods in the Shawnee National Forest, IL.

CCA, and ACZA are approved for use. In some areas south of a line connecting San Francisco and Virginia, dual treatments of creosote and one of the waterborne treatments may be needed to prevent attack by the different types of marine borers.

Ecosystem Sensitivities

Although largely undocumented, some preservatives may be more appropriate than others in sensitive ecosystems (figure 7). For example, CCA has a much lower copper content than other waterborne preservatives (except the borates). Although there is no evidence at this time to suggest that any of the wood preservatives leach enough copper to harm terrestrial or freshwater ecosystems, CCA may pose less of a threat to aquatic ecosystems than preservatives with more copper.

Similarly, preservatives without arsenic may pose less of a threat to mammals (including construction workers) than those that do contain arsenic. Once again, there is no evidence that wood preservatives containing arsenic harm people or other mammals if they are used as intended.

Wood treated with oilborne preservatives often produces an oily surface sheen when installed in stagnant freshwater environments. This may be unacceptable in some situations. Waterborne preservatives may be more appropriate when the treated wood will have extensive contact with freshwater.

As more information is obtained about the leaching rates and biological impacts of treated wood, it will be possible to make more informed decisions about the appropriate use of wood preservatives in sensitive ecosystems. Managers can use computer models at the Western Wood Preservers Institute Web site (*http://www.wwpinstitute.org*) to help them make decisions about the use of treated wood in aquatic ecosystems.

Purchasing Treated Wood Products

Regardless of the type of preservative, the wood should be treated properly and allowed to fix before it is placed in service.

Figure 7—A boardwalk on the Trail of Blue Ice in the Chugach National Forest, AK.

Treatments

The AWPA Commodity (C) Standards have been replaced by the Use Category System (UCS) Standards U1 and T1. The new basic standard for specifying treated wood products is U1. The new basic standard with all of the requirements for producing treated wood is T1. The UCS was developed as a format revision of the Commodity (C) Standards. The UCS contains descriptions of the service conditions for use categories, a guide to commodity specifications for the end uses of treated wood, a list of AWPA standardized preservatives, and various commodity specifications relating to specific product types, such as sawn products, utility poles, pilings, or fire-retardant applications. The UCS helps specifiers and users select the appropriate treatment.

Simplicity is the primary advantage of the UCS. All treated wood products can be placed into one of five use categories, based on the hazard of biodeterioration and expected product performance. Products treated with fire retardants are placed in their own use category class.

With changes taking place rapidly in the wood-treatment industry, it is more important than ever to ensure that wood is treated to standard specifications. The U.S. Department of Commerce American Lumber Standard Committee (ALSC) accredits third-party inspection agencies for treated wood products. Updated lists of accredited agencies can be found on the ALSC Web site (*http://www.alsc.org*). The easiest way to know whether wood has been treated to standard specifications is to look for a quality mark or the symbol of an ALSC-accredited agency on the front or back of the end tag. Avoid wood that is purported to be *treated to refusal* (treated until it will no longer absorb preservative).

Incising is a technique that increases preservative penetration and retention in species such as Douglas-fir. Douglas-fir should be incised regardless of the type of preservative used. Incising is especially important in larger material, such as timbers, that contact the ground. Smaller material that is not in contact with ground or water, such as decking, may perform adequately in some applications without incising. Although the AWPA Standards do not require southern pine to be incised, incising is beneficial when larger dimension material is treated. Larger pieces of material often have at least one face with exposed heartwood that preservatives have a hard time penetrating. The availability of incised southern pine is extremely limited. Table 3 summarizes the use categories for treated wood, while table 4 summarizes the standard preservative formulations and retentions for typical Forest Service applications.

Table 3—Service conditions for use category designations. This summary was prepared by the American Wood-Preservers' Association and is used with the association's permission.

Use category	Service conditions	Use environment	Common agents of deterioration	Typical applications
UC1	Interior construction, aboveground, dry	Continuously protected from weather or other sources of moisture	Insects	Interior construction and furnishings
UC2	Interior construction, aboveground, damp	Protected from weather, but may be subject to sources of moisture	Decay fungi and insects	Interior construction
UC3A	Exterior construction, aboveground, coated, rapid water runoff	Exposed to all weather cycles, but not exposed to prolonged wetting	Decay fungi and insects	Coated millwork, siding, and trim
UC3B	Exterior construction, aboveground, uncoated, or poor water runoff	Exposed to all weather cycles, including prolonged wetting	Decay fungi and insects	Decking, deck joists, railings, fence pickets, and uncoated millwork
UC4A	Ground contact or freshwater, noncritical components	Exposed to all weather cycles, normal exposure	Decay fungi and insects	Fence, deck, and guardrail posts, crossties, and utility posts (low-decay areas)
UC4B	Ground contact or freshwater, components that are critical or difficult to replace	Exposed to all weather cycles, high decay potential, includes saltwater splash	Decay fungi and insects, increased potential for biodeterioration	Permanent wood foundations, building poles, horticultural posts, crossties, and utility poles (high decay areas)
UC4C	Ground contact, freshwater, critical structural components	Exposed to all weather cycles, severe environments, extreme decay potential	Decay fungi and insects, extreme potential for biodeterioration	Land or freshwater pilings, foundation pilings, crossties, and utility poles (severe decay areas)
UC5A	Salt or brackish water and adjacent mud zone, northern waters	Continuous marine exposure (saltwater)	Saltwater organisms	Pilings, bulkheads, and bracing
UC5B	Salt or brackish water and adjacent mud zone, New Jersey to Georgia, and south of San Francisco	Continuous marine exposure (saltwater)	Saltwater organisms, including creosote-tolerant *Limnoria tripunctata*	Pilings, bulkheads, and bracing
UC5C	Salt or brackish water and adjacent mud zone, south of Georgia, Gulf Coast, Hawaii, and Puerto Rico	Continuous marine exposure (saltwater)	Saltwater organisms, including *Martesia* and *Sphaeroma*	Pilings, bulkheads, and bracing
UCFA	Fire protection as required by codes, aboveground, interior construction	Continuously protected from weather or other sources of moisture	Fire	Roof sheathing, roof trusses, studs, joists, and paneling
UCFB	Fire protection as required by codes, aboveground, exterior construction	Subject to wetting	Fire	Vertical exterior walls, in-roof surfaces, or other types of construction that allow water to drain quickly

Table 4—Standardized preservative formulations and retentions for typical Forest Service applications. Specified retentions may vary with wood species and particular applications. These formulations are listed in the AWPA standards. PCF stands for pounds per cubic foot.

		RETENTION, PCF (kg/m^3)		
Preservative	**Percentages of active ingredients**	**Aboveground (UC3)**	**Ground contact (UC4A)**	**Critical structural (UC4C)**
CCA–C	19% CuO, 47% CrO_3, 34% As_2O_5	0.25 (4.0)	0.40 (6.4)	0.60 (9.6)
ACQ–B and D	67% CuO, 33% DDAC[1]	0.25 (4.0)	0.40 (6.4)	0.60 (9.6)
ACQ–C	67% CuO, 33% BAC[2]	0.25 (4.0)	0.40 (6.4)	0.60 (9.6)
CA–B	96% Cu, 4% Azole[3]	0.10 (1.7)	0.21 (3.3)	0.31 (5.0)
CBA–A	49% Cu, 2% Azole[3], 49% H_3BO_3	0.20 (3.3)	0.41 (6.5)	0.61 (9.8)
ACZA	50% CuO, 25% ZnO, 25% As_2O_5	0.25 (4.0)	0.40 (6.4)	0.60 (9.6)
Creosote	Creosote is the sole active ingredient.	8.0 (128)	10.0 (160)	12.0 (192)
Pentachlorophenol	Pentachlorophenol is the sole active ingredient.	0.40 (6.4)	0.50 (8.0)	0.50 (8.0)
Copper naphthenate	Copper naphthenate is the sole active ingredient.	0.04 (0.6)[4]	0.06 (0.96)[4]	0.075 (1.2)[4]
Oxine copper	50% Cu-8[5], 50% Nickel-2-ethylhexoate	0.02 (0.32)	Not recommended	

[1] Didecyldimethylammoniumcarbonate
[2] Alkylbenzyldimethylammoniumchloride
[3] Tebuconazole
[4] Expressed as retention of metallic copper
[5] Copper-8-quinolinolate

Best Management Practices

The active ingredients of various waterborne wood preservatives (copper, chromium, arsenic, and zinc) are water soluble in the treating solution, but resist leaching when placed into the wood. This resistance to leaching is a result of chemical fixation reactions that render the toxic ingredients insoluble in water. The mechanism and requirements for these fixation reactions differ, depending on the type of wood preservative.

For each type of preservative, some reactions occur very rapidly during pressure treatment, while others may take days or even weeks, depending on storage and processing after treatment. If the treated wood is placed in service before these fixation reactions have been completed, the initial release of preservative into the environment may be much greater than when the wood has been conditioned properly.

Concerns about inadequate fixation have led Canada and European countries to develop standards or guidelines for fixing treated wood. Although oil-type preservatives do not undergo fixation reactions, the amount of environmental release still depends on treatment practices. With oil-type preservatives, preservative that is bleeding or oozing out of the treated wood is a particular concern. This problem may be apparent immediately after treatment. Such members should not be used in bridges or other aquatic applications. In other cases, the problem may not become obvious until after the product has been exposed to direct sunlight. This problem can be minimized by using treatment practices that remove excess preservative from the wood.

BMP standards are being developed to ensure that treated wood is produced in a way that will minimize environmental concerns and human health concerns (Pilon

2002). The Western Wood Preservers Institute (WWPI) has developed guidelines for treated wood used in aquatic environments (Western Wood Preservers Institute 1996).

Purchasers should specify and require assurance that the material they buy has been produced in compliance with *Best Management Practices for the Use of Treated Wood in Aquatic Environments*, USA version, revised January 1996, a publication of the Western Wood Preservers Institute and the Canadian Institute for Treated Wood. Publication of a new edition is scheduled for the end of 2006. Although these practices have not yet been adopted by the industry in areas outside the West Coast, purchasers in other areas can require that these practices be followed. Commercial wood treatment firms are responsible for meeting conditions that ensure fixation and minimize bleeding of preservatives, but persons buying treated wood should make sure that the firms have done so.

CCA—The risk of chemical exposure from wood treated with CCA is minimized after chemical fixation reactions lock the chemical in the wood. The treating solution contains hexavalent chromium, but the chromium reduces to the less toxic trivalent state within the wood. This process of chromium reduction also is critical in fixing the arsenic and copper in the wood. Wood treated with CCA should not be exposed to precipitation or other sources of environmental moisture until the fixation process is complete or nearly complete. The rate of fixation depends on temperature, taking only a few hours at 150 degrees Fahrenheit (66 degrees Celsius) but weeks or even months at temperatures below 60 degrees Fahrenheit (16 degrees Celsius). Some treatment facilities use kilns, steam, or hot-water baths to accelerate fixation.

The BMP for CCA stipulates that the wood should be air seasoned, kiln dried, steamed, or subjected to a hot-water bath after treatment. It should be evaluated with the AWPA chromotropic acid test to determine whether fixation is complete (AWPA Standard A3-11, 2005). There is some concern in the treatment industry that the chromotropic acid test may be overly conservative because it requires more than 99.5 percent of the chromium to be reduced to the trivalent form. However, the chromotropic acid test is the only standardized test available now.

ACZA and ACQ–B—The key to achieving stabilization with these preservatives is to allow ammonia to volatilize. This can be accomplished by air or kiln drying. The BMPs require a minimum of 3 weeks of air drying at temperatures higher than 60 degrees Fahrenheit (16 degrees Celsius). The drying time can be reduced to 1 week if the material is conditioned in the treatment cylinder. At lower temperatures, kiln drying or heat is required to complete fixation. There is no commonly used method to determine the degree of stabilization in wood treated with ACZA or ACQ–B, although wood that has been thoroughly dried is acceptable. If the wood has a strong ammonia odor, fixation is not complete.

ACQ–C, ACQ–D, and Copper Azole—Although these newer formulations are not in the current BMPs, they will be included in the 2006 revisions. Proper handling and conditioning of the wood after treatment helps minimize leaching and potential environmental impacts. Amine (and ammonia in some cases) keeps copper soluble in these treatment solutions. The mechanism of copper's reaction in the wood is not completely understood, but appears to be strongly influenced by time, temperature, and retention levels.

Copper stabilization in the copper azole formulations is extremely rapid (within 24 hours) at the lowest retention—0.10 pounds per cubic foot (6.4 kilograms per cubic meter)—but slows considerably at higher retentions unless the material is heated to accelerate fixation. As a general rule, wood that has thoroughly dried after treatment is properly stabilized.

Pentachlorophenol, Creosote, and Copper Naphthenate—The BMPs for pentachlorophenol treatment stress thorough drying of the wood before treatment and the use of an empty-cell process. In an empty-cell process, the air pressure is applied to the wood before the preservative is introduced to the treatment cylinder. After the pressure period, a final vacuum should be used, as well as a final steaming or an expansion bath similar to that described for the creosote treatments.

For creosote, the BMPs stipulate use of an expansion bath and final steaming period at the end of the charge.

- *Expansion Bath*—Following the pressure period, the creosote should be heated 10 to 20 degrees Fahrenheit (–12 to –7 degrees Celsius) above the press temperatures for at least 1 hour. Creosote should be pumped back to storage and a minimum vacuum of 24 inches of mercury (–81kPa) should be applied for at least 2 hours.

- *Steaming*—After the pressure period and once the creosote has been pumped back to the storage tank, a vacuum of not less than 22 inches of mercury (–74 kPa) shall be applied for at least 2 hours to recover excess preservative. Release the vacuum back to atmospheric pressure and steam for a 2-hour period for lumber and timbers and 3 hours for pilings. The maximum temperature during this process shall not exceed 240 degrees Fahrenheit (116 degrees Celsius). Apply a second vacuum of not less than 22 inches of mercury (–74 kPa) for a minimum of 4 hours.

The BMPs for copper napthenate are similar to those for creosote and pentachlorophenol. The recommended treatment practices for treatment in heavy oil include using an expansion bath and/or final steaming, similar to that described for creosote. When No. 2 fuel oil is used as the solvent, the BMPs recommend using a final vacuum for at least 1 hour.

Buyers can take steps to ensure that wood will be treated according to the BMPs described above. Proper fixation may take time. Material should be ordered well before it is needed so that the treatment firm can hold the wood while it fixes. If buyers order wood in advance, they may be able to store it under cover, allowing further drying and fixation. In general, allowing the material to air dry before it is used is a good practice for ensuring fixation, minimizing leaching, and reducing risk to construction personnel. With all preservatives, inspect the wood for surface residue. Wood with excess surface residue should not be placed in service.

Use of a Treated Wood Product

Site selection, construction, and handling practices can help to minimize the risks of using wood products treated with preservative.

Site Selection

1. Stay as far away from surface water as possible, because contaminants move less freely in soil than water.

2. Place trail crossings of sensitive ecosystems at their narrowest points (minimizing the use of treated wood in sensitive areas).

3. Minimize the number of stream crossings (minimizing the use of treated wood over water).

4. Review the guidelines for particular environmentally sensitive species.

Phaseout of CCA for Residential Uses

The EPA worked with pesticide manufacturers to voluntarily phase out CCA use for wood products around the home and in children's play areas. Effective December 31, 2003, no wood treater or manufacturer may treat wood with CCA for residential uses (with certain exceptions).

CCA has been used to pressure treat lumber since the 1940s. Since the 1970s, the majority of the wood used in outdoor residential settings has been treated with CCA. Although pressure-treated wood containing CCA is no longer being produced for most residential uses, including decks and playground equipment, structures and facilities may continue to be used even if they were constructed with wood treated with CCA before the voluntary phaseout. An oil-based stain can help lock the CCA in place. See *http://www.safe2play.org/assets/docs/factsheet.pdf*.

Allowable Uses of CCA-Treated Wood for Forest Service Projects

The EPA's guidance for the use of CCA is the best source of information on allowable uses. See the Web site: *http://www.epa.gov/oppad001/reregistration/cca/awpa_table.htm.*

Decking, railing (figure 8), and rail posts must be built out of materials that are not treated with CCA. Forest Service applications where wood can be treated with CCA following the 2001 AWPA standards include:

- Highway bridges, (refer to C14, all members listed for highway bridge construction are allowed).
- Piles for bridges, boardwalks, and viewing platforms (refer to C3).
- Marine construction for saltwater use (refer to C18).
- Round posts and poles used in building construction (refer to C23).
- Sawn timber, 5 by 5 inches (about 13 by 13 centimeters) and larger, used to support residential and commercial structures (refer to C24).
- Structural glue-laminated members (refer to C28). (Treated dimensional lumber for both glue- and nail-laminated members may also be included under this standard.)
- Structural composite lumber (refer to C33).
- akes (refer to C34), and round ts and poles (refer to C23).

gure 8—A bridge
iling on the Trail
Blue Ice in the
hugach National
orest, AK.

- Signposts (refer to C14), wood for highway construction.
- Horse stables, hay storage buildings, and equipment storage (refer to C16).
- Corrals/fences (refer to C16), wood used on farms, such as fence posts, round, half-round, and quarter-round fence rails. (Fence planks must be materials that were not treated with CCA.)

The list is partial; other uses may be allowed.

Construction, Handling, and Field Treatment

Excessive exposure to inorganic arsenic and wood treated with other preservatives may be hazardous to human health. Persons working with treated wood should take a number of precautions:

- Saw, sand, and machine the treated wood outdoors. Wear a dust goggles, and gloves.
- Clean up all sawdust, scraps (figure 9), and other construction debris thoroughly and dispose of it in the trash (municipal solid waste). Do not compost or mulch sawdust or scraps of treated wood.
- Do not burn treated wood. Toxic chemicals may be in the smoke and ashes.
- After working with the wood, wash all exposed areas (especially the hands) thoroughly with soap and water before eating, drinking, using the toilet, or using tobacco products.
- Wash work clothes separately from other household clothing before wearing them again.

These precautions will reduce your exposure from inhaling or ingesting sawdust, protect your eyes from flying particles, and prevent exposure to toxic smoke and ash. For more suggestions on avoiding unnecessary exposure to treated wood, the EPA has identified some common sense tips. Before working with treated wood, always consult the Wood Preservative Science Council's *Inorganic Arsenical Pressure-Treated Wood* consumer safety information sheet Web site *(http://www.ccasafetyinfo.com),* or call 800–282–0600 to listen to the information or have the consumer information sheet faxed to you.

Figure 9—A tub can be used to collect sawdust when drilling preservative-treated wood. Collecting debris during construction helps to minimize environmental impacts.

During construction, any holes or cuts that penetrate untreated wood should be treated with preservative. AWPA Standard M4 provides guidance for field treatment. Typically, copper naphthenate is used. Be careful not to drip or spill preservative where it will contaminate the environment. Whenever possible, treat the exposed surface before assembling the structure at a sensitive area. Do not place field-treated wood into water or soil before all excess preservative has been wiped off or has soaked into the wood.

Disposing of Treated Wood

Be careful to collect sawdust and other wood waste and remove it from the worksite. Treated wood is not listed as a hazardous waste under Federal law. It can be disposed of in any waste management facility authorized under State and local law to manage such material.

Treated wood must not be burned in open fires or in stoves, fireplaces, or residential boilers, because the smoke and ashes may contain toxic chemicals. Treated wood waste from commercial and industrial sources (construction sites, for example) may be burned only in commercial or industrial incinerators or boilers in accordance with State and Federal regulations.

Generally, treated wood can be reused in a manner that is consistent with its original intended end use. The industry publication *Management of Used Treated Wood Products (http://www.wwpinstitute.org/mainpages/disposaloftreated.shtml)* addresses some of the legal questions regarding the disposal and reuse of treated wood. For more information, please contact the waste management agency in your State: *http://www.epa.gov/epaoswer/osw/Stateweb.htm.*

State and local jurisdictions may regulate the use, reuse, and disposal of treated wood and treated wood construction waste. Users should check with State and local authorities for any special regulations relating to treated wood. Information about regulations in some areas also can be obtained by contacting the Western Wood Preservers Institute or the Treated Wood Council.

Material Safety Data Sheets

Material safety data sheets (MSDS) are designed to provide workers and emergency personnel with information about the proper procedures for handling or working with a particular substance. These sheets include information about the materials, such as physical data (melting point, boiling point, flash point, and so forth), toxicity, health effects, first-aid treatment, reactivity, storage, disposal, protective equipment, and spill or leak procedures. This information is particularly important after a spill or other accident. The sheets can be requested from wood treatment firms or from chemical suppliers. A partial list of chemical suppliers and wood treatment firms is included in the section on Web sites.

Corrosiveness of Treatments

Because the pressure-treated wood industry has been phasing out CCA and using alternative chemicals for treatment, the potential corrosiveness (figure 10) of alternative wood preservatives needs to be considered. Hot-dipped galvanized fasteners meeting the ASTM A153 standard and connectors meeting the ASTM A653 Class G185 sheet-steel standard are recommended for protection against the effects of moisture when treated wood is used.

Aluminum should not be used in direct contact with wood treated with copper-based preservatives. One fastener manufacturer, Simpson Strong-Tie, has conducted its own tests. Simpson found that some of the alternative treatments were slightly more corrosive than CCA. A report can be found at on Simpson's Web site: *http://www.strongtie.com/productuse/corrosion.html.*

The Forest Service Forest Products Laboratory is studying the corrosiveness of alternative wood preservatives and may provide some guidance.

Figure 10—This metal plate used in a stress-laminated bridge constructed with preservative-treated wood shows the early signs of corrosion.—*Photo courtesy of James Wacker*

Web Sites

Associations

American Wood-Preservers' Association
Web site: *http://www.awpa.com/*

Forintek Canada Corp./Canadian Wood Council
Web site: *http://www.durable-wood.com/*

Southern Pine Council
Web site: *http://www.southernpine.com/*

Western Wood Preservers Institute
Web site: *http://www.wwpinstitute.org/*

Government Agencies

U.S. Environmental Protection Agency
Web site: *http://www.epa.gov/oppad001/reregistration/cca/*

USDA Forest Service Forest Products Laboratory
Web site: *http://www.fpl.fs.fed.us/*

USDA Forest Service Missoula Technology and Development Center *Facilities Toolbox* Web site: *http://www.fs.fed.us/t-d/toolbox/haz/haz15.htm* (Username: t-d, Password: t-d)

Preservative Manufacturers

Borax
Web site: *http://www.borax.com/wood/*

Chemical Specialties, Inc.
Web site: *http://www.treatedwood.com*

Osmose, Inc.
Web site: *http://www.osmose.com/wood/usa/*

Wolmanized Wood by Arch Wood Protection, Inc.
Web site: *http://www.wolmanizedwood.com/*

Others

Simpson Strong-Tie
Web site: *http://www.strongtie.com/*

Other Sources of Information

Technical

Stan Lebow
USDA Forest Service Forest Products Laboratory
One Gifford Pinchot Dr.
Madison, WI 53705–2398
Phone: 608–231–9411
Fax: 608–231–9508
E-mail: *slebow@fs.fed.us*
Web site: *http://www.fpl.fs.fed.us/rwu4723*

Standards

American Wood-Preservers' Association
P.O. Box 361784
Birmingham, AL 35236–1784
Phone: 205–733–4077
Fax: 205–733–4075
E-mail: *email@awpa.com*
Web site: *http://www.awpa.com/*

Window & Door Manufacturers Association
1400 East Touhy Ave., Ste. 470
Des Plaines, IL 60018
Phone: 847–299–5200
Fax: 847–299–1286
E-mail: *admin@wdma.com*
Web site: *http://www.wdma.com/*

Trade Associations

Suppliers of different types of treated wood can be found by contacting local lumberyards or the trade associations that work with manufacturers of treated wood, including:

Southern Pressure Treaters Association
P.O. Box 3219
Pineville, LA 71361
Phone: 318–619–8589
Fax: 318–619–8589
Web site: *http://www.spta.org/*

Timber Piling Council
Phone: 800–410–2070
Fax 206–275–4755
Web site: *http://www.timberpilingcouncil.org/*

Treated Wood Council
1111 19th St. NW., Ste. 800
Washington, DC 20036–3603
Phone: 202–463–4025
Fax: 202–463–2059
E-mail: *jeff_miller@treated-wood.org*

Western Wood Preservers Institute
7017 NE. Hwy. 99, Ste. 108
Vancouver, WA 98665
Phone: 360–693–9958 or 800–729–WOOD
Fax: 360–693–9967
Web site: *http://www.wwpinstitute.org/*

Wood Preservative Science Council
P.O. Box 183
Manakin-Sabot, VA 23103
Phone: 804–749–8016
Fax: 804–749–8017
Web site: *http://www.woodpreservativescience.org/*

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Appendix A—EPA-Approved Consumer Information Sheets for Wood Pressure Treated With Pentachlorophenol or Creosote

PENTACHLOROPHENOL

Consumer Information

This wood has been preserved by pressure-treatment with an EPA-registered pesticide containing pentachlorophenol to protect it from insect attack and decay. Wood treated with pentachlorophenol should be used only where such protection is important. Pentachlorophenol penetrates deeply into and remains in the pressure-treated wood for a long time. Exposure to pentachlorophenol may present certain hazards. Therefore, the following precautions should be taken both when handling the treated wood and in determining where to use and dispose of the treated wood.

Use Site Precautions

- Logs treated with pentachlorophenol should not be used for log homes.
- Wood treated with pentachlorophenol should not be used where it will be in frequent or prolonged contact with bare skin (for example, chairs and other outdoor furniture), unless an effective sealer has been applied.
- Pentachlorophenol-treated wood should not be used in residential, industrial, or commercial interiors except for laminated beams or building components that are in ground contact and are subject to decay or insect infestation and where two coats of an appropriate sealer are applied. Sealers may be applied at the installation site. Urethane, shellac, latex epoxy enamel, and varnish are acceptable sealers for pentachlorophenol-treated wood.
- Wood treated with pentachlorophenol should not be used in the interiors of farm buildings where there may be direct contact with domestic animals or livestock that may crib (bite) or lick the wood.
- In interiors of farm buildings where domestic animals or livestock are unlikely to crib (bite) or lick the wood, pentachlorophenol-treated wood may be used for building components which are in ground contact and are subject to decay or insect infestation and where two coats of an appropriate sealer are applied. Sealers may be applied at the installation site.
- Do not use pentachlorophenol-treated wood for farrowing or brooding facilities.
- Do not use treated wood under circumstances where the preservative may become a component of food or animal feed. Examples of such sites would be structures or containers for storing silage or food.
- Do not use treated wood for cutting boards or countertops.
- Only treated wood that is visibly clean and free of surface residue should be used for patios, decks, and walkways.

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- Do not use treated wood for construction of those portions of beehives that may come into contact with the honey.
- Pentachlorophenol-treated wood should not be used where it may come into direct or indirect contact with public drinking water, except for uses involving incidental contact such as docks and bridges.
- Do not use pentachlorophenol-treated wood where it may come into direct or indirect contact with drinking water for domestic animals or livestock, except for uses involving incidental contact such as docks and bridges.

Handling Precautions

- Dispose of treated wood by ordinary trash collection or burial.
- Treated wood should not be burned in open fires or in stoves, fireplaces, or residential boilers because toxic chemicals may be produced as part of the smoke and ashes. Treated wood from commercial or industrial use (e.g., construction sites) may be burned only in commercial or industrial incinerators or boilers rated at 20 million British Thermal Units/hour or greater heat input or its equivalent in accordance with State and Federal regulations.
- Avoid frequent or prolonged inhalation of sawdust from treated wood. When sawing and machining treated wood, wear a dust mask. Whenever possible, these operations should be performed outdoors to avoid indoor accumulations of airborne sawdust from treated wood.
- When power-sawing and machining, wear goggles to protect eyes from flying particles.
- Avoid frequent or prolonged skin contact with pentachlorophenol-treated wood.
- When handling the treated wood, wear long-sleeved shirts and long pants and use gloves impervious to the chemicals (for example, gloves that are vinyl-coated).
- After working with the wood, and before eating, drinking, and using tobacco products, wash exposed areas thoroughly.
- If oily preservatives or sawdust accumulates on clothes, launder before reuse. Wash work clothes separately from other household clothing.

CREOSOTE

Consumer Information

This wood has been preserved by pressure treatment with an EPA-registered pesticide containing creosote to protect it from insect attack and decay. Wood treated with creosote should be used only where such protection is important. Creosote penetrates deeply into and remains in the pressure-treated wood for a long time.

Exposure to creosote may present certain hazards. Therefore, the following precautions should be taken both when handling the treated wood and in determining where to use the treated wood.

Use Site Precautions

- Wood treated with creosote should not be used where it will be in frequent or prolonged contact with bare skin (for example, chairs and other outdoor furniture) unless an effective sealer has been applied.
- Creosote-treated wood should not be used in residential interiors.
- Creosote-treated wood in interiors of industrial buildings should be used only for industrial building components that are in ground contact and are subject to decay or insect infestation and for wood-block flooring. For such uses, two coats of an appropriate sealer must be applied. Sealers may be applied at the installation site.
- Wood treated with creosote should not be used in the interiors of farm buildings where there may be direct contact with domestic animals or livestock that may crib (bite) or lick the wood. In interiors of farm buildings where domestic animals or livestock are unlikely to crib (bite) or lick the wood, creosote-treated wood may be used for building components that are in ground contact and are subject to decay or insect infestation if two coats of an effective sealer are applied. Sealers may be applied at the installation site.
- Coal-tar pitch and coal-tar pitch emulsion are effective sealers for creosote-treated wood-block flooring. Urethane, epoxy, and shellac are acceptable sealers for all creosote-treated wood. Do not use creosote-treated wood for farrowing or brooding facilities.
- Do not use treated wood under circumstances where the preservative may become a component of food or animal feed. Examples of such use would be structures or containers for storing silage or food.
- Do not use treated wood for cutting boards or countertops.

CREOSOTE

- Only treated wood that is visibly clean and free of surface residues should be used for patios, decks, and walkways. Do not use treated wood for construction of those portions of beehives that may come into contact with the honey.
- Creosote-treated wood should not be used where it may come into direct or indirect contact with public drinking water, except for uses involving incidental contact such as docks and bridges.
- Do not use creosote-treated wood where it may come into direct or indirect contact with drinking water for domestic animals or livestock, except for uses involving incidental contact such as docks and bridges.

Handling Precautions

- Dispose of treated wood by ordinary trash collection or burial.
- Treated wood should not be burned in open fires or in stoves, fireplaces, or residential boilers, because toxic chemicals may be produced as part of the smoke and ashes. Treated wood from commercial or industrial use (e.g., construction sites) may be burned only in commercial or industrial incinerators or boilers in accordance with State and Federal regulations.
- Avoid frequent or prolonged inhalation of sawdust from treated wood. When sawing and machining treated wood, wear a dust mask. Whenever possible, these operations should be performed outdoors to avoid indoor accumulations of airborne sawdust from treated wood.
- When power-sawing and machining, wear goggles to protect eyes from flying particles.
- Avoid frequent or prolonged skin contact with creosote-treated wood; when handling the treated wood, wear long-sleeved shirts and long pants and use gloves impervious to the chemicals (for example, gloves that are vinyl-coated).
- After working with the wood and before eating, drinking, and using tobacco products, wash exposed areas thoroughly.
- If oily preservative or sawdust accumulates on clothes, launder before reuse. Wash work clothes separately from other household clothing.

Appendix B—Consumer Safety Information Sheet: Inorganic Arsenical Pressure-Treated Wood (Including CCA, ACA, and ACZA)

For additional information, call toll-free: 800–282–0600, or go to the Web site: *http://www.ccasafetyinfo.com/.*

Consumer Information

This wood has been preserved by pressure-treatment with an EPA-registered pesticide containing inorganic arsenic to protect it from insect attack and decay. Wood treated with inorganic arsenic should be used only where such protection is important.

Inorganic arsenic penetrates deeply into and remains in the pressure-treated wood for a long time. However, some chemical may migrate from treated wood into surrounding soil over time and may also be dislodged from the wood surface upon contact with skin. Exposure to inorganic arsenic may present certain hazards. Therefore, the following precautions should be taken both when handling the treated wood and in determining where to use or dispose of the treated wood.

Use Site Precautions

- All sawdust and construction debris should be cleaned up and disposed of after construction.

- Do not use treated wood under circumstances where the preservative may become a component of food or animal feed. Examples of such sites would be use of mulch from recycled arsenic-treated wood, cutting boards, counter tops, animal bedding, and structures or containers for storing animal feed or human food.

- Only treated wood that is visibly clean and free of surface residue should be used for patios, decks, and walkways.

- Do not use treated wood for construction of those portions of beehives, which may come into contact, with honey.

- Treated wood should not be used where it may come into direct or indirect contact with drinking water, except for uses involving incidental contact such as docks and bridges.

Handling Precautions

- Dispose of treated wood by ordinary trash collection. Treated wood should not be burned in open fires or in stoves, fireplaces, or residential boilers because toxic chemicals may be produced as part of the smoke and ashes. Treated wood from commercial or industrial use (e.g., construction sites) may be burned only in commercial or industrial incinerators or boilers in accordance with State and Federal regulations.

- Avoid frequent or prolonged inhalation of sawdust from treated wood. When sawing, sanding and machining treated wood, wear a dust mask. Whenever possible, these operations should be performed outdoors to avoid indoor accumulations or airborne sawdust from treated wood.

- When power-sawing and machining, wear goggles to protect eyes from flying particles.

- Wear gloves when working with the wood. After working with the wood, and before eating, drinking, toileting, and use of tobacco products, wash exposed areas thoroughly.

- Because preservatives or sawdust may accumulate on clothes, they should be laundered before reuse. Wash work clothes separately from other household clothing.

About the Authors

James "Scott" Groenier, professional engineer, began working for MTDC as a project leader in 2003. Scott earned a bachelor's degree in civil and environmental engineering from the University of Wisconsin at Madison and a master's degree in civil engineering from Montana State University. He worked for the Wisconsin and Illinois State Departments of Transportation and with an engineering consulting firm before joining the Forest Service in 1992. He worked as the east zone structural engineer for the Eastern Region and as a civil engineer for the Ashley and Tongass National Forests before coming to MTDC.

Stan T. Lebow is a research scientist for the Durability and Wood Protection Research Unit at the Forest Service Forest Products Laboratory in Madison, WI. He conducts research in a range of areas involving wood protection, including the treatability and durability of new wood preservatives and the environmental impacts of wood treated with preservatives. He also is active in the standards-setting process of the American Wood-Preservers' Association. Before joining the Forest Service in 1993, he was the senior research scientist for the Department of Forest Products at Oregon State University, where he received his Ph.D. in 1992.

Library Card

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Provides an overview of:

- Wood preservatives
- Treatment processes used with wood preservatives
- Alternatives to treated wood
- Studies that have determined how much preservative leaches into the environment and its effects
- Guidelines for the use of preservatives and treated wood

Keywords: ACA, ACZA, best management practices, boardwalks, boric acid, CCA, construction, consumer information sheets, copper arsenate, copper chrome arsenates, copper naphthenate, creosote, corrosion, disposal, environmental impact, facilities, leaching, pentachlorophenol, pressure treatments, recreation, retention, standards, structures, trail bridges, wood chemistry, wood preservation, wood preservatives

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For additional information about selection and use of preservative-treated wood, contact Scott Groenier at MTDC.
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Electronic copies of MTDC's documents are available on the Internet at: *http://www.fs.fed.us/eng/t-d. php.*

Forest Service and Bureau of Land Management employees can search a more complete collection of MTDC's documents, videos, and CDs on their internal computer networks at: *http://fsweb.mtdc. wo.fs.fed.us/search/.*

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