Preservative Treatments for Building Components

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Abstract

The wood species most commonly used in construction have little natural durability Thus, they are treated with preservatives when used in conditions that favor biodeterioration. The type of preservative used varies with the type of wood product, exposure condition, and specific agent of deterioration. This paper discusses the characteristics of several preservative systems, which are grouped on the basis of their ability to protect wood in a range of exposure environments. Copper remains the primary biocide component used to protect wood used in contact with the ground or fully exposed to the weather, but preservatives containing boron or organic biocides are gaining importance for more protected applications. The treated wood industry continues to undergo a transition, moving from the use of broad-spectrum preservative systems toward preservatives that are more closely matched to the building application and exposure environment.

Introduction

The extent and type of protection needed for wood used in conditions that Favor biodeterioration varies, depending on the type of end use, exposure environment, and wood-attacking organism(s). In some applications, wood species with natural durability. such as cedar and redwood, provide sufficient protection. In most cases, however, protection is provided by the application of wood preservative biocides. The type or types of biocide applied is often dependent on the requirements of the specific application: preservative formulations may contain a combination of biocides to provide protection against a broad range of organisms. Although some preservatives are effective in almost all applications, they may be excessive for applications involving frequent human contact or for exposures that present only low to moderate biodeterioration hazards. Additional considerations include cost, potential odor, surface dryness, adhesive bonding, and ease of finish application (USDA 1999).

In an attempt to categorize the degree of deterioration hazard for various applications, many countries have developed 'hazard class' or 'use category' systems that specify the preservative formulations that are suitable in particular situations (Aston 2002). These categories may also specify the preservative retention (concentration in the wood) that is necessary for protection. For example, direct contact with soil or water is considered a severe deterioration hazard, and preservatives used in these applications must have a high degree of leach resistance and efficacy against a broad spectrum of organisms. These same preservatives may also be used at lower retentions to protect wood exposed in lower deterioration hazards, such as aboveground. The exposure is less severe for wood that is partially protected from the weather, and preservatives that lack the permanence or toxicity to withstand continued exposure to precipitation may be effective in those applications. Other formulations may leach so easily that they can only be used indoors. The determination of the suitability of a preservative formulation or retention for these deterioration hazard categories is not an exact science. Preservatives are often tested under severe conditions to shorten the time needed for evaluation, and it can be difficult to use these tests to predict performance in less severe exposures.

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Copper is the primary biocide in many wood preservative formulations used in ground contact because of its excellent fungicidal properties and low mammalian toxicity. Because some types of fungi are copper tolerant, preservative formulations often include a co-biocide to provide further protection. There is continued interest in the development of wood preservatives that contain no copper or other heavy metals. Such preservatives would depend on combinations of organic fungicides and insecticides of relatively low toxicity that are developed for agricultural uses. Development of such systems presents challenges because these organic compounds may be degraded by bacteria or other non-wood-attacking organisms. These challenges are particularly acute for wood used in ground-contact applications.

Historically, preservatives have also been classified by their solubility in either water- or oil-type solvents. This classification is becoming less relevant, as some preservatives can be formulated with either type of solvent while others may be emulsions or suspensions. Biocides in water-based preservatives typically are not water soluble, and co-solvents such as ethanol amine or ammonia may be used to solubilize the active ingredients. Water- and oil-type solvents each have advantages and disadvantages depending on the application. Oil-type preservatives, such as creosote and pentachlorophenol in heavy oil, are among the oldest wood preservatives (Lebow et al. 2004). These systems usually leave the wood surface dark brown, but they have the advantage of imparting some water repellency. They are commonly used for "heavy duty" applications such as utility poles, bridge timbers, railroad ties, and piles. Concerns about odor and surface cleanliness may limit their use in applications that involve frequent human contact.

Wood treated with water-based preservatives typically has a dry, paintable surface, and it may also have less odor than wood treated with some types of oil preservatives. Water-based treatments, however, do not improve the dimensional stability of the treated wood unless they are formulated with a water-repellent additive. Hardwoods treated with water-based preservatives that utilize copper as the primary fungicide may not be adequately protected from soft-rot attack. In addition. some water-based treatments may increase the susceptibility of metal fasteners to corrosion.

Preservatives Grouped by Exposure Hazard

Applications Protected from Liquid Water

An example of this type of application is framing lumher used in areas of high termite hazard. The primary threat in these applications is often insect attack. but protection against mold fungi or decay fungi may also be desirable. This section describes water-based preservatives that do not fix in the wood and thus are readily leachable. They provide adequate protection as long as the wood is not sufficiently wetted to leach the preservative.

Borate compounds

Borate compounds are the most commonly used unfixed water-based preservatives. They include formulations prepared from sodium tetraborate, sodium pentaborate, and boric acid, but the most common form is disodium octaborate tetrahydrate (DOT). DOT has higher water solubility than many other forms of borate, allowing the use of higher solution concentrations and increasing the mobility of the borate through the wood. Glycol is also used to increase solubility in some formulations. With the use of heated solutions, extended pressure periods, and diffusion periods after treatment, DOT is able to penetrate relatively refractory species such as spruce.

Borates are used For pressure treatment of framing lumber used in areas of high termite hazard, such as Hawaii, and as surface treatments for a wide range of wood products, such as log cabins and the interiors of wood structures. They are also applied as supplemental internal treatments via rods or pastes. At higher retentions, borates are used as fire-retardant treatments for wood. Boron has some important advantages, including low mammalian toxicity, activity against both fungi and insects, and low cost. Another advantage of boron is its ability to move and diffuse with water into wood that normally resists traditional pressure treatment. Wood treated with borates has no color or odor, is non-corrosive, and can be finished.

While boron has many potential applications in framing, it is not suitable for applications where the wood is exposed to frequent wetting unless the boron can somehow be protected from liquid water. In some countries, such as New Zealand, boron can be used in applications where occasional wetting occurs (Anon. 2005), and there is interest in the use of borates in slightly more exposed applications with coating requirements. There is also interest in dual treatments, in which borate treatment is followed by pressure treatment with a water-repellent oil-typepreservative.

Research continues to develop borate formulations that have increased resistance to leaching while maintaining biocidal efficacy. Various combinations of silca and boron have been developed that appear to somewhat retard boron depletion, but the degree of permanence and applicability of the treated wood to outdoor exposures has not been well defined.

Applications Used Aboveground with Partial Protection

The preservatives listed in this section provide adequate protection for wood that is aboveground and occasionally exposed to wetting. Wood used in this manner typically has some type of surface finish. The most common example of this type of application is millwork. Some aboveground applications that retain moisture and/or collect organic debris may present a more severe deterioration hazard, and a preservative from one of the following sections may then be more appropriate. Although preservatives used for millwork treatments were traditionally carried in light solvents to prevent dimensional changes in the wood, there is an increasing trend to move away from the use of light solvents because of economic and environmental concerns.

In this category, the distinction between oil- and water-based preservatives blurs, as many of these components can be delivered either with solvents or as microemulsions. The azole fungicides, such as tebuconazole and propiconazole, are becoming more widely used. Other azoles, including cypraconazole and azaconazole, are used in limited quantities.

Azoles: Propiconazole and tebuconazole

Propiconazole (PPZ) and tebuconazole (TEB) are triazole agricultural fungicides which are becoming widely used as components of preservative formulations. Although soluble in light organic solvents, they are commonly used in micro-emulsions. Wood treated with these azoles has little color and is readily paintable. PPZ and TEB are sometimes combined to provide improved efficacy against a wider range of fungi. Neither is highly effective in preventing growth by some types of stain fungi, and they may be combined with a preservative such as 3-iodo-2-propynyl butyl carbamate (IPBC) to improve protection. Their efficacy against soft-rot fungi is also less documented, but they are not usually used as the primary biocide in applications where soft-rot is a concern. Tebuconazole is used as a co-biocide component in a commercial ground contact copper azole wood preservative. Azoles do not protect against insect attack in situations where insects present a hazard, azoles may be combined with insecticides such as pyrethroids.

Quaternary ammonium compounds

Didecyldimethyl ammonium chloride (DDAC) and alkylbenzyl ammonium chloride (BAC) are quaternary ammonium compounds that are widely used as bactericides, antiseptics, and fungicides. Both are used as the "quat" component of the ACQ wood preservative formulations, and DDAC is used as a component of anti-sapstain formulations. The quaternary ammonium compounds are colorless, nearly odorless, and can be formulated for use with either water- or oil-based carriers, although solvency is diminished in lighter aliphatic hydrocarbons such as mineral spirits. In Europe, BAC and DDAC are sometimes used in combination with azole preservatives and/or an insecticide, but they are not usually used as stand-alone preservatives.

Isothiazolone

Isothiazolones are a class of organic compounds often used for mold control. They are sometimes added to wood preservatives for this purpose and are also used as additives to paints and coatings. One of these compounds, 4,5-dichloro-2-N-octyl-4-isothiazolin-3-one (DCOI), has been evaluated fairly extensively and is currently used as a marine anti-fouling agent in paint films. As with other oil-soluble preservatives, the properties of wood treated with DCOI are somewhat dependent on the type of solvent used. The treatment may impart a light brown color to the wood. DCOI has a noticeable odor and the treated wood may have some odor, depending on the concentration of the treating solution. In some applications, skin sensitization can be a concern.

3-iodo-2-propynyl butyl carbamate

IPBC (3-iodo-2-propynyl butyl carbamate) is commonly used as an ingredient in anti-sapstain formulations or as a fungicide in water-repellent finishes for decks or siding. It is also used to treat millwork, and it may be combined with azoles to enhance efficacy against mold fungi. It may be used as either a solvent- or water-based formulation. IPBC is colorless, and depending on the solvent and formulation, the treated wood may be paintable. Some formulations may have a noticeable odor, but formulations with little or no odor are also possible. IPBC is not an effective insecticide, and it is not used as a stand-alone treatment for critical structural members. Some pressure-treating facilities are using a mixture of IPBC and an insecticide to treat structural members that are to be used aboveground and largely protected from the weather. Combinations of IPBC and chlorpyrifos, for example, have been used for many years in Hawaii to pressure treat I-joists, laminated veneer lumber, other engineered wood products. The advantage of this treatment is that it is colorless and allows the wood to maintain its natural appearance.

2-(thiocyanomethylthio) benzothiozole

TCMTB (2-(thiocyanomethylthio) benzothiozole) has been used for many years as an anti-sapstain formulation and millwork preservative. It has been formulated in both solvent-based and water-based forms; the solvent-based formulation is more prevalent for treatment of millwork.

Tributyltin oxide

Bis(tri-n-butyltin) oxide (TBTO) is a colorless to slightly yellow liquid preservative that is soluble in organic solvents but not soluble in water. It has been used extensively as an anti-fouling agent in marine paints, as a preservative in finishes, and in dip treatments for wood used in millwork. Used alone, TBTO is not effective in protecting wood placed in ground contact, but it is effective in protecting wood products that are used aboveground and partially exposed to the weather. The use of TBTO has declined in some areas because of concerns about the environmental and health effects of tin as well as the loss of preservative efficacy over time.

Zinc naphthenate

Zinc naphthenate is used extensively as a component in over-the-counter wood preservative products. It can he formulated as either a solvent-borne or water-based preservative. Unlike copper naphthenate, zinc napthenate imparts little color to the wood and thus is more compatible with transparent finishes. When zinc naphthenate is formulated in light solvent, the treated wood may also be paintable. But, wood treated with zinc naphthenate may have a noticeable odor, limiting its indoor use. Zinc is not as effective a fungicide as copper, and zinc naphthenate is not typically used as a stand-alone preservative for exposed structural members. Zinc naphthenate has some preservative efficacy, and it may be sufficient to protect wood used aboveground and partially protected from the weather. In Mississippi, zinc naphthenate pressure treatments have been shown to extend the life of exposed stakes, and brush treatments of a water-based zinc naphthenate significantly improved the performance of pine fully exposed to the weather (Barnes et al. 2004). Zinc naphthenate, however, was less effective in protecting hardwoods. The addition of a water-repellent component to the treating solution appears to increase the efficacy of zinc naphthenate treatments.

Applications Used Aboveground But Fully Exposed to Weather

The preservatives listed in this section generally may not provide long-term protection for wood used in direct contact with soil or standing water, hut they are effective in preventing attack in wood exposed aboveground, even if it is directly exposed to rainfall. A typical example of this type of application is decking. The preservatives listed in the following section also can be used at lower, aboveground retention levels. Some aboveground applications that retain moisture and/or collect organic debris may present a deterioration hazard similar to ground contact. Preservatives discussed in the following section may be more appropriate for such applications, especially in critical structural members.

Oxine copper (copper-8-quinolinolate)

Oxine copper is an organometallic preservative comprised of 10 percent copper-8-quinolinolate and 10 percent nickel-2-ethylhexoate. It is characterized by low mammalian toxicity and is permitted by the U.S. Food and Drug Administration for treatment of wood used in direct contact with food (e.g., pallets). The treated wood is greenish-brown and has little or no odor. It can be dissolved in a range of hydrocarbon solvents but provides longer protection when delivered in heavy oil. Oxine copper solutions are somewhat heat sensitive, which limits the use of heat to increase preservative penetration. But, adequate penetration of difficult-to-treat species can still he achieved, and oxine copper is sometimes used for treatment of the aboveground portions of wood bridges and deck railings. Oil-borne oxine copper does not accelerate corrosion of metal fasteners relative to corrosion on untreated wood.

Pentachlorophenol (light solvent)

The performance of pentachlorophenol and the properties of the treated wood are influenced by the properties of the solvent. 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, lighter color, and improved paintability. Pentachlorophenol in light oil can he used to treat relatively refractory wood species, and it does not accelerate corrosion. One disadvantage of the lighter oil is that less water repellency is imparted to the wood. Although pentachlorophenol in light oil provides a dryer surface, the same active ingredient is present, and this treatment may not be appropriate for applications where exposure to humans is likely.

Applications in Direct Contact with the Ground or Fresh Water

These preservatives exhibit sufficient toxicity and leach resistance to protect wood in contact with the ground, in fresh water, or in other high moisture, high deterioration hazard applications. These preservatives are also effective in preventing decay in other, less severe exposures, but they may not be well-suited to those applications because of cost, color, toxicity, odor, or other characteristics.

Acid copper chromate

Acid copper chromate (ACC) is an acidic water-based preservative that has been used 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 is light greenish-brown and has little noticeable odor. Tests on stakes and posts exposed to decay and termite attack indicate that wood well-impregnated with ACC gives acceptable service. It may be susceptible to attack by some species of copper-tolerant fungi, and consequently its use is sometimes limited to aboveground applications. It may be difficult to obtain adequate penetration of ACC in some of the more refractory wood species such as white oak and Douglas-fir. This is because ACC must be used at relatively low treating temperatures and because rapid reactions of chromium in the wood can hinder further penetration during longer pressure periods. The high chromium content of ACC. however, has the benefit of preventing much corrosion that might otherwise occur with an acidic copper preservative. The treatment solution utilizes hexavalent chromium: chromium is converted to the more benign trivalent state during treatment and subsequent storage of the wood. This process of chromium reduction is the basis for fixation in ACC, and it is dependent on time, temperature, and moisture.

Alkaline copper quat

Alkaline copper quat (ACQ) is one of several water-based copper-based preservatives that were developed as an alternative to chromated copper arsenate (CCA). The fungicides and insecticides in ACQ are copper oxide (67%) and a quaternary ammonium compound (quat). Multiple variations of ACQ have been standardized or are in the process of standardization. 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–amineformulation with a slightly different quat compound. Wood treated with ACQ-B has a dark greenish-brown color that fades to a lighter brown, and it may have a slight ammonia odor until the wood dries. Wood treated with ACQ-D is lighter brown and has little noticeable odor. The appearance of wood treated with ACQ-C lies between that of wood treated with ACQ-B or ACQ-D, depending on the formulation. Stakes treated with these three formulations have demonstrated resistance against decay fungi and insects when exposed in ground contact. The multiple formulations of ACQ allow some flexibility in achieving compatibility with a specific wood species and application. When ammonia is used as the carrier, ACQ has improved ability to penetrate into difficult-to-treat species. But, if the wood species is readily treatable, such as southern pine sapwood, an amine carrier can be used to provide a more uniform surface appearance.

Ammoniacal copper zinc arsenate

Ammoniacal copper zinc arsenate (ACZA) is a water-based Preservative that contains copper oxide (50%). zinc oxide (25%). and arsenic pentoxide (25%). It is a refinement of an earlier formulation (ACA) that is no longer in use. The color of the treated wood varies from brown to bluish-green. The wood may have a slight ammonia odor until it is thoroughly dried after treatment. The ammonia in the treating solution, in combination with processing techniques such as steaming and extended pressure periods, allows ACZA to obtain better penetration of difficult-to-treat wood species than do many other water-based wood preservatives. Treating facilities using ACZA are currently located in the western United States, where many native tree species are difficult to treat with other water-basedpreservatives.

Chromated copper arsenate

CCA was once the most commonly used of all wood preservatives and until very recently represented over 90 percent of the sales of water-based wood preservatives in the United States. It has since been withdrawn from most residential applications. There are several formulations with varying ratios of copper, chromium, and arsenic. One common formulation is comprised of 47.5 percent chromium trioxide, 18.5 percent copper oxide, and 34.0 percent arsenic pentoxide dissolved in water (CCA Type C). CCA has decades of proven performance in field trials and in-service applications. In accelerated testing, CCA is still the reference preservative used to evaluate the performance of other water-based wood preservatives. As with ACC. it may be difficult to obtain adequate penetration of CCA in some wood species that are difficult to treat. Temperature limitations during treatment and rapid reaction of chromium within the wood structure can hinder penetration during longer pressure periods. But, chromium serves as a corrosion inhibitor, and corrosion of fasteners in CCA-treated wood is not as much of a concern as it can he with some chromium-free alternativepreservatives.

Copper chromium boron

In copper chromium boron (CCB), the arsenic in CCA is replaced with boric acid. This preservative was developed as a direct response to toxicity concerns with the arsenic in CCA. In addition to lower toxicity, boric acid has the advantage of migrating more deeply into the wood after treatment. Because boric acid is leachable, it may be depleted from the surface of the wood, rendering the wood vulnerable to attack by copper-tolerant fungi. The chromium in CCB provides the benefit of reduced corrosion.

Copper azole

Copper azole is another recently developed water-based preservative formulation that relies primarily on amine copper, along with co-biocides, to protect wood from decay and insect attack. The first copper azole formulation contained 49 percent copper, 49 percent boric acid, and 2 percent tebuconazole. More recently, a formulation containing 96 percent copper and 4 percent tebuconazole has been used. Wood treated with either copper azole formulation is greenish-brown and has little or no odor. Although listed as an amine formulation, copper azole may also be formulated with an amine–ammonia formulation. Ammonia may be included when the copper azole formulations are used to treat refractory species, and the ability of such a formulation to adequately treat Douglas-fir has been demonstrated. The inclusion of ammonia, however, is likely to have slight effects on the surface appearance and initial odor of the treated wood.

Copper HDO

Copper HDO is an amine copper water-based preservative that has been used in Europe but is not yet used in the United States. The active ingredients are copper oxide, boric acid, and copper-HDO (bis-(N-cyclohexyl-diazenium dioxy)copper). The appearance and handling characteristics of wood treated with copper HDO are similar to that of other amine copper-based treatments. Copper HDO is also referred to as copper xyligen.

Coal-tar creosote

Coar-tar creosote is the oldest wood preservative still in commercial use. It is made by distilling the tar obtained after high-temperature carbonization of coal. Unlike other oil-type preservatives, creosote is not usually dissolved in oil, but it has properties that make it look and feel oily. Creosote contains a chemically complex mixture of organic molecules, most of which are polycyclic aromatic hydrocarbons (PAHs). The composition of creosote depends on the method of distillation and is somewhat variable. The small differences in composition within modem creosotes, however, do not significantly affect its performance as a wood preservative. Creosote-treated wood is dark brown to black and has a noticeable odor, which some people consider unpleasant. It is very difficult to paint creosote-treated wood. Workers sometimes object to creosote-treated wood because it soils clothes and photosensitizes the skin upon contact. Because of these concerns, creosote-treated wood is often not the first choice for applications where there is a high probability of human contact. This is a serious consideration for treated members that are readily accessible to the public. But, creosote-treated wood has advantages to offset concerns about its appearance and odor. It has a lengthy record of satisfactory use in a wide range of applications and a relatively low cost. Creosote is also effective in protecting both hardwoods and softwoods, and it is often thought to improve the dimensional stability of the treated wood. With the use of heated solutions and lengthy pressure periods, creosote can be fairly effective at penetrating even fairly difficult-to-treat wood species. Finally, creosote treatment does not accelerate, and may even inhibit, the rate of corrosion of metal fasteners relative to corrosion on untreated wood.

Pentachlorophenol (heavy oil)

Pentachlorophenol has been widely used as a pressure treatment since the 1940s. The active ingredients, chlorinated phenols, are clystalline solids that can be dissolved in different types of organic solvents. The performance of pentachlorophenol and the properties of the treated wood are influenced by the properties of the solvent. The heavy oil solvent is preferable when the treated wood is to be used in ground contact because wood treated with lighter solvents is not as durable in such exposures. Wood treated with pentachlorophenol in heavy oil is typically brown and may have a slightly oily surface that is difficult to paint. It also has some odor, which is associated with the solvent. Like creosote, pentachlorophenol in heavy oil should not be used in applications where frequent contact with skin is likely (i.e., hand rails). Pentachlorophenol in heavy oil has long been a popular choice for treatment of utility poles, bridge timbers, glued-laminated beams, and foundation piling. Like creosote, it is effective in protecting both hardwoods and softwoods, and it is often thought to improve the dimensional stability of the treated wood. With the use of heated solutions and extended pressure periods, pentachlorophenol is fairly effective at penetrating difficult-to-treat species. It does not accelerate corrosion of metal fasteners relative to untreated wood, and the heavy oil solvent helps to impart some water repellency to the treated wood.

Copper naphthenate (heavy oil)

The preservative efficacy of copper naphthenate has been known since the early 1900s. and various formulations have been used commercially since the 1940s. Copper naphthenate is an organometallic compound formed as a reaction product of copper salts and petroleum-derived naphthenic acids. It is often recommended for field treatment of cut ends and drill holes made during construction with pressure-treated wood. Wood treated with copper naphthenate initially 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 copper naphthenate treated wood after it has been allowed to weather for a few weeks. Like pentachlorophenol, copper naphthenate can be dissolved in a variety of solvents, but it has greater efficacy when dissolved in heavy oil. Although not as widely used as creosote and pentachlorophenol treatments, copper naphthenate is increasingly used in the treatment of utility poles. Copper naphthenate has also been formulated as a water-based system and is sold commercially in this form for consumer use. The water-based formulation helps to minimize concerns about odor and surface oils, but it is not currently used for pressure treatment.

Chlorothalonil (heavy oil)

Chlorothalonil (CTL) has been used for decades as a broad spectrum agricultural fungicide. More recently, it has been proposed for use as an oil-based wood preservative comprised of approximately 96 percent tetrachloroisophthalonitrile. CTL is colorless, but the appearance of the treated wood depends on the solvent used. CTL has low solubility in some organic solvents. When CTL is used in heavy oil solvent, the color of the treated wood is brown, and the wood may have a slightly oily surface that is difficult to paint. The low solubility of CTL limits the solution concentrations. Availability of wood treated with CTL is currently limited.

Oligomeric alkylphenol polysulfide

Oligomeric alkylphenol polysulfide (PXTS) is a recently developed and somewhat unique preservative system. It is an oligomer formed by the reaction of cresylic acid and sulfur chlorides in the presence of excess sulfur. PXTS is solid at room temperature, but it becomes liquid when heated to above approximately 58°C. It can also be dissolved and diluted in some aromatic and organic chlorinated solvents. PXTS was initially developed as an alternative to creosote, but it may have potential for other applications as well. The treated wood is light brown.

Marine (Seawater) Applications

Marine borers present a severe challenge to preservative treatments. Some preservatives that are very effective against decay fungi and insects do not provide protection in seawater. The preservatives most commonly used to protect wood in marine environments are forms of creosote, as well as the water-based preservatives that contain copper and/or arsenic. Properly applied, creosote effectively prevents attack by all marine borers except the gribble *Limnoria tripunctata.* Water-based preservatives such as CCA or ACZA effectively protect against attack by shipworms (*Teredo* and *Bankia* spp.) and gribbles (*Limnoria* ssp.) but do not protect against pholads (*Martesia* spp.). Because no single preservative is effective against all marine borers, dual treatments may be required in some locations. Dual treatments involve an initial treatment with a water-based preservative followed by a conventional creosote treatment. Dual treatments are more expensive than single treatments. For both creosote and water-based treatments, much higher preservative retentions are required to protect against marine borers than are needed to protect wood in terrestrial or freshwater applications. Physical barriers such as plastic sleeves or wraps have also been used to protect piling, but these systems are vulnerable to breaches from mechanical damage. They are most effective when applied to piles that have been pressure treated with preservatives.

Treatments for Wood Composites

Many structural composite wood products, such as glued-laminated beams, plywood, parallel strand lumber, and laminated veneer lumber, are typically pressure treated with wood preservatives in a manner similar to that used for lumber. By contrast, flake- or fiber-based composites are often protected by adding preservative to the wood furnish during manufacture. The most commonly used preservative for these types of composites is zinc borate (Laks 2004). Zinc borate is a white, odorless powder with low water solubility that is added directly to the furnish or wax during panel manufacture. Zinc borate has greater leach resistance than the more soluble forms of borate used For pressure treatment, and thus it can be used to treat composite siding products that are exposed outdoors but partially protected from the weather. Another preservative used to protect composites is ammoniacal copper acetate, which is applied by spraying onto oriented strandboard flakes before drying (Laks 2004).

Insecticidal Additives

Many preservative formulations, such as those that contain copper, have insecticidal activity. In other formulations, insecticidal components may be incorporated for certain applications. These insecticides may include synthetic pyrethroids, such as permethrin and cypermethrin, or chloronicontinyl, neonicotinoids, pyroles, and insect growth regulators. The insecticidal additives permethrin, chlorpyrifos, and imidachlorprid are used in the United States.

Specification and Quality Assurance

Most countries have some type of standard-setting body that lists preservative systems that have shown efficacy. In the United States, the American Wood-Preservers' Association (AWPA) is the primary standard-setting body, but there is also overlap with standards developed by the American Society for Testing and Materials (ASTM), the Window and Door Manufacturers Association (WDMA), and other organizations. To guide selection of the types of preservatives and loadings appropriate to a specific end-use, the AWPA recently developed Use Category System (UCS) standards (AWPA 2005). The UCS standards simplify the process of finding appropriate preservatives and preservative retentions for specific end-uses. They categorize treated wood applications by the severity of the deterioration hazard. The lowest category, Use Category 1 (UC1), is for wood that is used in interior construction and kept dry, whereas UC2 is for interior wood that is completely protected from the weather but is occasionally damp. UC3 is for exterior wood used aboveground, and UC4 is for wood used in ground contact in exterior applications. UC5 includes applications that place treated wood in contact with seawater and marine borers. Using the UCS standards only requires knowledge about the intended end-use of the treated wood. A table in the UCS standards lists most types of applications for treated wood and provides the appropriate Use Category and Commodity Specification. The Commodity Specification lists all of the preservatives standardized for that Use Category, as well as the appropriate retention and penetration requirements. The user needs only specify that the product be treated according to the appropriate Use Category.

As the treating industry adapts to the use of new wood preservatives. it is more important than ever to ensure that wood is being treated to standard specifications (Lebow et al. 2004). Many countries have some type of independent oversight or inspection program to help ensure quality control. In the United States, the American Lumber Standard Committee (ALSC) in the U.S. Department of Commerce accredits third-party inspection agencies for treated-wood products. Quality control overview by ALSC-accredited agencies is preferable to simple certification by a treating plant or other claims of conformance made by the producer without inspection by an independent agency. The ALSC Treated Wood Program currently has six accredited independent third-party agencies headquartered throughout the United States and Canada. Updated lists of accredited agencies can be obtained from the ALSC website (www.alsc.org). The use of treated wood with such third-party certification may be mandated by applicable building code regulations. Wood treated in accordance with quality assurance programs will have a quality mark or stamp of an accredited inspection agency. In addition to identifying information about the producer, the stamp indicates the type of preservative, retention level, and intended exposure conditions. Retention levels are specific to the type of preservative, species, and intended exposure conditions. Detailed specifications for different treatments can be found in the applicable standards of AWPA (2005) and ASTM (2005). The ASTM specifications for pressure treatment of timber products are listed in ASTM D 1760.

Conclusions

A wide range of preservative formulations are used to protect wood. These formulations can be loosely grouped by the severity of deterioration hazard in which they are effective in protecting wood. Some preservative systems can protect wood in almost all exposure environments, but may not be optimum for all applications. Additional factors such as cost, appearance, odor, volatility, and toxicity must be considered in matching a preservative to a particular end-use application. The United States and other countries have developed use-category-type standards that provide guidance in matching preservative treatments to appropriate end-uses. The wood preservation industry continues to evolve, with emphasis on using low toxicity preservatives and more closely matching the degree of protection to the intended end-use. As additional types of preservative systems enter the market, it is particularly important to use only those preservatives that have been evaluated and standardized by nationally recognized standard-setting organizations. In addition, it is important to select products that have been treated in accordance with standard specifications.

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Wood Protection 2006

Wood Protection 2006

Edited by H. Michael Barnes

Professor; Department of Forest Products,
Mississippi State University, Mississippi, USA

March 21–23, 2006
Omni Royal Orleans Hotel
New Orleans, Louisiana, USA

Sponsored by Arch Wood Protection, Inc.,
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The opinions expressed are those of the authors and do not necessarily represent those of the Forest Products Society.

ISBN 1-892529-48-3

Publication No. 7229

inted in the United States of America.

0703300