Wood Preservation

Commercial Pesticide Applicator Training

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About this manual

This manual was prepared for use in U.S. Environmental Protection Agency (EPA) Pesticide Applicator Training Programs and is intended to provide the information needed to meet the minimum EPA standards for certification of commercial applicators under the Federal Insecticide, Fungicide, and Rodenticide Act. It also prepares trainees for an examination, based on this manual, administered by state departments of agriculture. It is intended for use as a supplement to the Pesticide Applicator Training core manual in your state.

This manual does not provide all of the information you need for safe and effective use of pesticides. Examine the label for each pesticide you use. Labels must list directions, precautions and health information — all of which are updated regularly when a pesticide is registered for use. If information on a current pesticide label conflicts with information in this manual, follow the label. Manufacturers will supply additional information about products registered for use in your state.

Pesticide Applicator Training Programs are cooperative efforts. State departments of agriculture are the state lead agencies. State Extension programs are responsible for the content of the training. The EPA and state departments of conservation, health, natural resources, and transportation also contribute to the development of educational materials and participate in the training program.

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Wood Preservation

Commercial Pesticide Applicator Training

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University of Missouri Extension - 2008

Contents

Wood

Wood is an amazing renewable material with a multitude of uses. Look closely at a piece of wood and you will see a unique structure capable of moving fluids and nutrients up and down at the same time it provides structural support for the foliage that captures energy from sunlight through photosynthesis.

Wood exhibits a different appearance in each of three planes of a tree. The transverse plane, or cross section, shows annual growth rings and exposes the openings, or lumens, in the wood cells (Figure 1). The radial plane follows a line from the center of the tree outward, while the tangential plane represents a surface cut perpendicular to the radial direction, parallel to the bark (Figure 2). Unlike synthetic materials such as steel or plastic, wood has different properties in each of these planes, and it is this variation in properties that gives wood its unique attributes.

The distinct layers visible in the cross section are made up of cells, each with a cell wall and a lumen in the center. The outermost layer is the bark, which protects the living tree from injury and acts to retain fluids. Bark is often removed from wood products because it impedes fluid flow and can be attractive to many wood-boring beetles. Next is a thin layer containing the phloem, which transports nutrients, followed by a thin layer of cells called the cambium. This layer produces new cells on each side; one side produces phloem while the other divides inward to produce xylem.

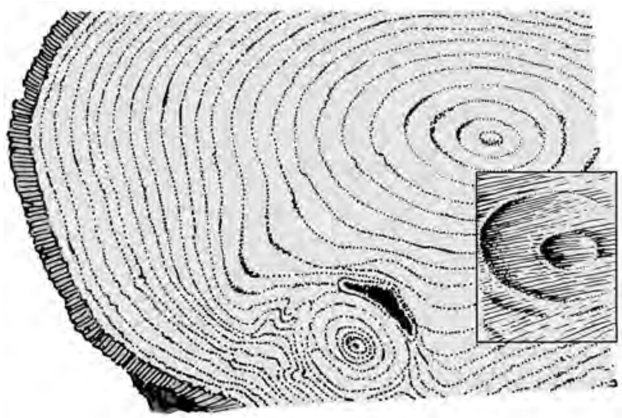
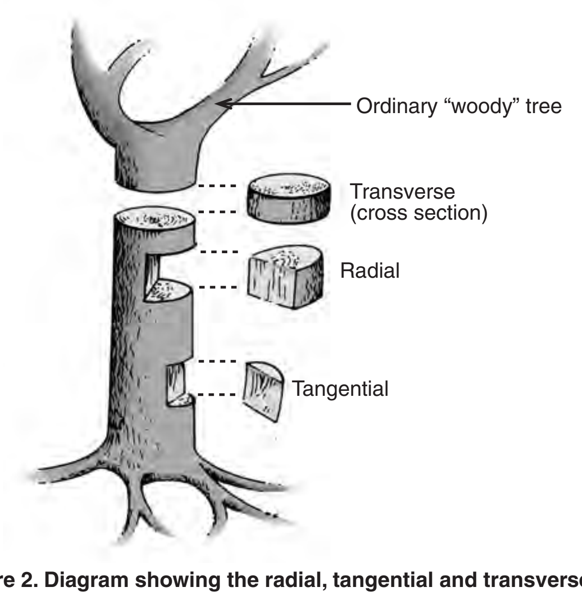
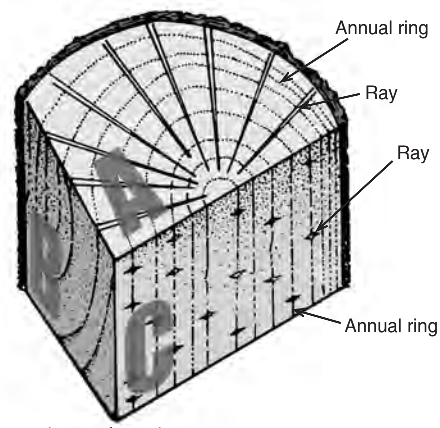


Figure 1. Cross section of a tree showing the bark, the xylem with its annual rings and the sapwood/heartwood zones.

Inside the cambium, making up the largest volume of a tree trunk or woody plant stem, is the xylem, which conducts water and provides structural support. Lumber primarily consists of the xylem, although some phloem may also be present on the outer edges of a board. The xylem in trees growing in temperate regions is laid down in rings, usually one ring per year. Early in the growing season, the cambium produces cells with thinner walls and larger openings. These cells, called earlywood, move large quantities of water to the developing foliage. As the season progresses and the water needs are reduced, the cambium produces cells called latewood, with thicker cell walls and smaller lumens. The dark bands of latewood in most temperate-zone trees produce the distinctive rings that we use to age trees (Figure 3).

As a tree grows, the outer xylem remains alive and capable of conducting fluids, but older xylem undergoes a decline that eventually leads to cell death. The outer living portion is called the sapwood, while the inner zone is called the heartwood. As the process of sapwood death occurs, parenchyma cells convert the stored sugars into compounds called extractives that can color the wood. Heartwood of most species differs in color from the sapwood, although this is not always true. The process of heartwood formation also tends to render the wood resistant to penetration of





Three planes of wood:
A.Transverse, **B**. Tangential, and **C**. Radial

Figure 2. Diagram showing the radial, tangential and transverse sections of a wood sample.

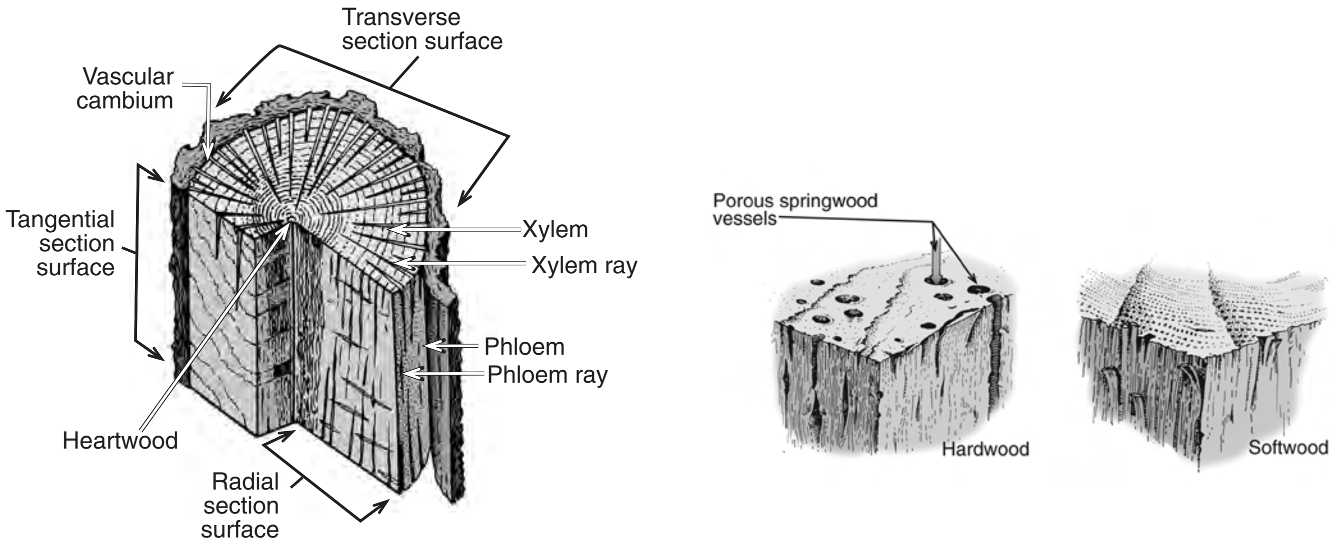


Figure 3. Cross sections of a typical tree, showing the anatomical features that affect fluid flow.

fluids. As a result, heartwood is resistant to preservative treatment. At the same time, some heartwood extractives are quite toxic and can render the heartwood resistant to degradation caused by biological agents. Sapwood of nearly all wood species has little or no resistance to degradation.

There are two broad groups of trees — conifers (gymnosperms) and hardwoods (angiosperms). Gymnosperms are the more ancient group and are distinguished by producing wood with two cell types, tracheids and parenchyma. Tracheids can be oriented either radially or longitudinally. Tracheids serve the dual function of conducting water and providing structural support. Parenchyma are storage cells that are typically found in assemblies called rays. Rays move materials, usually stored nutrients, laterally across the tree. Some rays can be quite large and visible to the naked eye, while those in other species are one cell wide and difficult to detect.

The foliage of most gymnosperms consists of needles, and they are often called evergreens. This is a misnomer because some gymnosperms do shed their foliage annually.

Angiosperms are more complex and contain three basic cell types: parenchyma, hardwood vessels, and fibers. Parenchyma in angiosperms function as storage cells, just as they do in gymnosperms. The hardwood vessels are generally larger than the fibers and conduct fluids up and down the tree. Fibers are thick-walled cells that provide structural support. These cells tend to be difficult to treat with preservatives, and undertreatment of fibers tends to render hardwood more susceptible to a specific type of decay termed soft rot.

Imagine wood as bundles of hollow straws that conduct fluids up and down. Imagine further that other pathways move fluids laterally between cells. These connections between cells are termed pits and they are generally the limiting factor in fluid flow. Pits can have a number of forms, but they are all basically a semipermeable membrane that allows water and small particles to move between cells. Preservative treatment is largely dictated by the condition of the pits. Woods with many closed pits will be difficult to treat. Sapwood of most wood species tends to have open pits, whereas heartwood pits are often closed and blocked with debris.

Agents of deterioration

Although the primary focus of this manual is chemical protection of wood, it is also important to understand the agents of deterioration and the requirements for biological attack to occur. Deterioration is generally defined as any negative effect on wood properties, including changes in color, strength or permeability.

There are two broad categories of deterioration: biotic and abiotic. Biotic deterioration is caused by living organisms, while abiotic deterioration is caused by nonliving agents. Often wood is damaged by both types of agents, and determining which is the primary cause can help identify the most appropriate solution.

Abiotic deterioration

Abiotic deterioration can be caused by a variety of agents, including weathering by sunlight (or ultraviolet light), mechanical wear, strong acids or bases, water, salts or fire. In all cases, abiotic deterioration is characterized by the absence of an associated biological agent.

Sunlight contains ultraviolet (UV) light and the energy in this light interacts with the wood polymers (particularly lignin) near the surface. This weakens the wood, which is then worn away over time. UV tends to darken light wood and lighten dark woods, although this damage is shallow. UV also tends to cause more damage in the earlywood than in latewood, often giving heavily weathered wood surfaces a washboard appearance.

Mechanical wear can occur from a variety of causes, but the two most common are abrasion and shock loading. Abrasion is common where wood is used for stairs or decks and generally occurs slowly, depending on the density of the wood. Damage due to repeated shock loading is typified by the wear seen in railroad ties, which are repeatedly stressed as train wheels pass over them. Over time the wood can separate across the annual rings. Railroad ties can also be affected by abrasion as rail tie plates cut into the wood.

Chemicals can also damage wood. For example, strong acids (low pH) attack cellulose and hemicellulose, leaving the wood a brownish color. Strong bases (high pH) attack the lignin, leaving the wood a bleached white color. Applying litmus paper to the wood surface is a relatively simple way to detect either agent. Repeated exposure to salts can damage wood surfaces as salt water absorbed by the wood evaporates, leaving salt in the cells. Repeated wetting and drying deposits so much salt that the cells literally explode, leaving strands of burst fibers on the wood surface. The damage is usually superficial and easily removed.

Wood surfaces can be discolored by a variety of oxidative stains. Iron, for example, will react with enzymes in the wood to produce various chemical discolorations. Most of these reactions require oxygen and usually develop shortly after sawing as oxygen contacts the freshly exposed wood surface. These stains have no effect on the material properties of the wood and they are often superficial, but they can be mistaken for the early signs of decay.

Fire is a major agent of wood deterioration. Heating wood above 450 degrees F (232 degrees C) produces combustible gases that ignite and consume the wood. Although wood is inherently flammable, large timbers provide some initial protection against fire as they char on the outside. This char initially limits flame spread, but continued exposure will result in complete combustion. Exposure to lower temperatures can also affect wood. Prolonged exposure to temperatures in excess of 130 degrees F (54 degrees C) causes the wood to darken and become brittle as heat gradually breaks down the hemicellulose, cellulose and finally the lignin. This process is generally slow, taking months or years to produce any measurable effect.

Biotic deterioration

Biotic deterioration, or biodeterioration, is caused by living organisms such as bacteria, fungi, insects, marine borers, birds and animals. Some organisms use wood as a food source, or as shelter, while others damage the wood as they seek food, such as insect larvae that may be inside the wood. These organisms all have specific requirements for survival:

- adequate moisture
- oxygen
- moderate temperature
- a food source

As with all biological agents, there are always exceptions. For example, many bacteria are anaerobic and can live without oxygen.

Water is an essential element for life. Wood can contain two types of water: bound and unbound. Bound water is water that is loosely bound in the wood cells and is largely unavailable to biodeterioration agents. This water, which is absorbed from the atmosphere, can be removed by drying in an oven. The amount of bound moisture in the wood varies with temperature and relative humidity. In most cases, moisture content of wood in buildings ranges from 12 percent to 19 percent by weight. For most woods, the maximum amount of bound water is between 25 percent and 30 percent of the wood mass. Above this level, free water collects in the cells and this water is available for biological agents. This point is generally called the fiber saturation point, and most biological organisms are unable to cause substantial deterioration below this moisture level. Builders have long exploited this moisture requirement by designing structures to shed water. For example, avoiding direct contact with soil, adding long roof overhangs that keep water off walls and coating wood with paint films to exclude water. Wood that cannot be protected by water must be either naturally durable or treated with a preservative.

Oxygen is essential for nearly all life-forms, except some bacteria, but the levels required by most wood-degrading organisms are much lower than the 20-21 percent found in the atmosphere. Lumber mills have long excluded oxygen from timber by soaking logs in ponds or spraying them with water before sawing (Figure 4). Although the primary function of storing logs in water is to limit development of drying checks, the practice also fills the wood cells with water, thereby excluding oxygen.

The range of temperatures in which biodeterioration can occur in wood is determined by the temperature range in which the damaging organisms can exist. Although some biological organisms can grow at temperatures near freezing and up to 140 degrees F (60 degrees C), most organisms have an optimum temperature range between 61 and 82 degrees F (16-28 degrees C). High temperature is often used to eliminate organisms either by steaming or kiln drying. The generally accepted lethal temperature for wood-

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Figure 4. Logs being sprayed with water to limit biological attack.

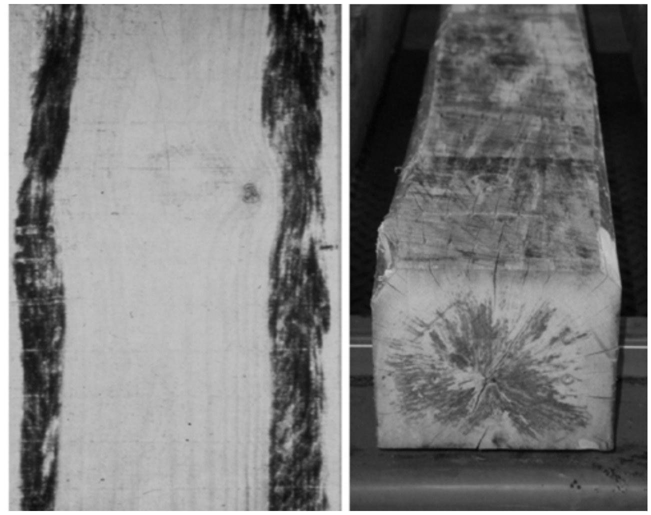

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Figure 5. Mold (left) on pine sapwood and stain (right) on a gum railroad tie.

inhabiting organisms is 155 degrees F (68 degrees C) for 1 hour, although many organisms succumb at much lower time-temperature combinations. For this reason, many treaters of wood for international commerce use 133 degrees F (56 degrees C) for treating wood to eliminate organisms before shipping. Exposure to extremely low temperatures -22 to -40 degrees F (-30 to -40 degrees C) can kill some insects, but most organisms can become dormant to survive low temperatures.

The food source involved in biodeterioration is most often one or more components of the wood, but organisms that use wood for nesting often obtain nutrients from other sources while some birds and animals may consume insects present in the wood.

One biodeterioration control mechanism is to alter the wood either by adding chemicals that kill the biodeterioration agent or by modifying the wood so that it cannot be degraded. This is wood preservation.

Types of biotic agents

Bacteria are primitive, single-celled organisms that attack a variety of materials, including wood. Bacteria degrading wood tend to exist in extreme environments that exclude other organisms. These environments include submerged wood or wood exposed to high temperatures. These organisms are generally slow acting, and the damage they cause is shallow.

Fungi attacking wood are broadly classified as molds, stain or decay fungi. Molds use the sugars and other nutrients that the tree stores in the ray cells. Mold filaments, or hyphae, are usually clear, but the spores they produce on the wood surface are pigmented and discolor the wood. These spores can be brushed from the wood surface, but the fungus is still alive in the wood. Molds do not affect wood strength but they increase permeability, making the wood wet more easily.

Stain fungi also use the stored compounds in the ray cells but their hyphae become brown pigmented as they age and these pigments render the wood a bluish color. Like molds, stain fungi make the wood more permeable, but unlike molds, the discoloration goes deep into the wood and cannot be easily removed (Figure 5).

Decay fungi are capable of affecting one or more of the structural polymers in wood. There are three broad groups of fungi: brown rot, white rot and soft rot fungi. Brown rot fungi attack hemicellulose and cellulose, causing the wood to become brown and fractured. Brown rot fungi cause large losses in the strength of wood at early stages of decay, often when there is little evidence of fungal attack. White rot fungi use all of the wood polymers, leaving the wood a bleached white color. White rot fungi tend to cause strength losses when decay becomes visible. Both brown and white rot fungi tend to cause decay within the wood where moisture conditions are relatively stable (Figure 6). A third type of decay, termed soft rot, occurs on the surfaces of wood in soil contact or in wet wood. Soft rot fungi are common in cooling towers and on wood in rich agricultural soils. Wood damaged by soft rot, as the name suggests, becomes

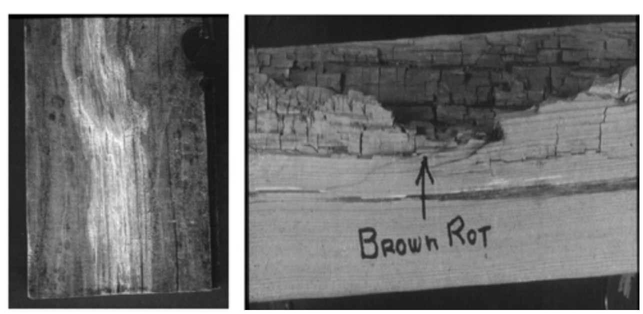

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Figure 6. Examples of wood damaged by white rot (left) and brown rot (right).

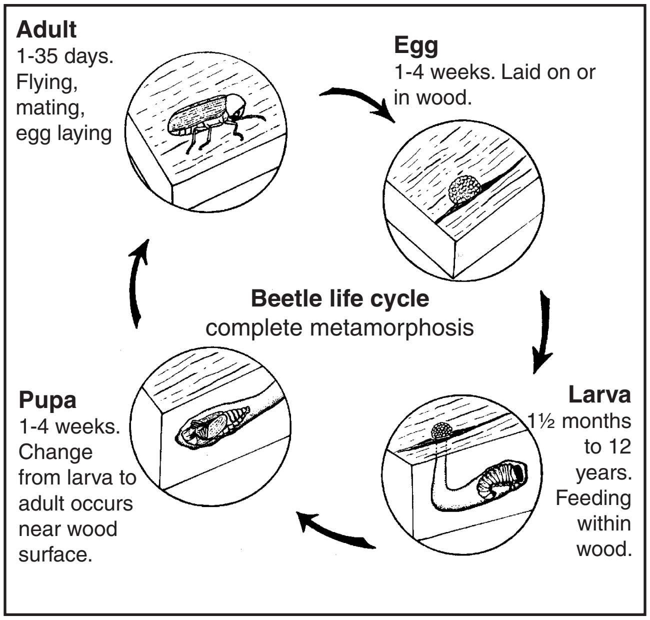

Figure 7. The life cycle of beetles is a complete metamorphosis, from egg to larva, pupa and adult.

softened and develops numerous cross breaks. The damage spreads slowly inward, weakening the wood. Soft rot fungi also tend to be more tolerant of many commonly used preservatives.

A variety of insects can attack wood, but beetles, ants and termites tend to be the most important. Most beetles attack freshly fallen trees. All beetles have a life cycle of complete metamorphosis in which an egg hatches into a larva, which tunnels through the wood (Figure 7). Although we often associate beetle damage with the adults, the larvae tend to cause most of the damage. The larva sheds its skin, or molts, through several stages, or instars, until it obtains enough energy from the wood. At this point, the larva enters a resting or pupal stage, during which the body metamorphosizes into the adult form.

Longhorn borers and metallic wood borers tend to lay their eggs on freshly cut, green, logs or timbers. The adults lay their eggs in cracks and crevices on the bark surface. The hatching larva then tunnel beneath the bark and mine the cambium for a period ranging from a few days to weeks. The larvae then plunge into the wood, where they feed for periods of up to 40 years. Longhorn, or roundheaded, borer adults have antennae that are at least one-third the length of their bodies, but are often much longer. The larvae tend to produce round or oval holes as they tunnel through the wood (Figure 8). Metallic wood borers, as their name implies, are often metallic green or bronze in color. The larvae produce D-shaped holes as they tunnel through the wood. The removal of the bark sharply reduces the attractiveness of the wood to either group of insects.

Bark beetles and ambrosia beetles attack living or recently killed trees. Bark beetles lay their eggs

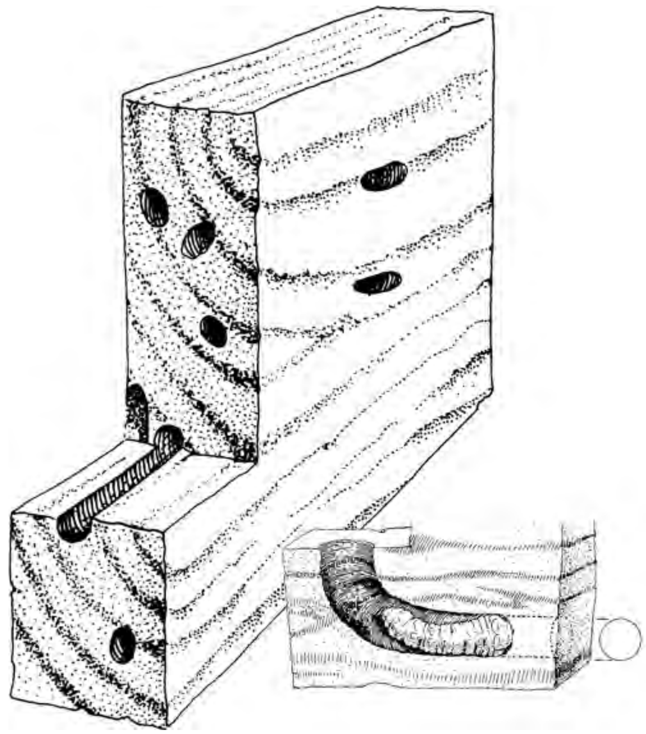

Figure 8. Examples of exit holes produced by emerging adult roundheaded wood borers.

beneath the bark and the hatching larvae tunnel outward between the bark and the xylem (see Figure 9). As they do so, the larvae cut off the flow of nutrients and, if enough beetles attack, the tree will die. The beetles cause little wood damage, but they generally introduce stain fungi that sharply reduce the value of any wood products.

Ambrosia beetles are attracted to wet wood. The adult tunnels into the wood and cuts side tunnels in the sapwood. The female lays an egg along with a small bit of fungus in each side tunnel (see Figure 9). The fungus grows into the wood and the hatching larvae feed on the fungus. The primary damage associated with ambrosia beetles is small tunnels and the associated fungal discoloration, although some ambrosia beetles can also kill small trees. Bark beetles and ambrosia beetles can complete one or more life cycles in a single season, whereas longhorn borers tend to have life cycles of 1 to 3 years. Some metallic wood borers have exceptionally long life cycles ranging from 2 to 40 years depending on the moisture and nutritional level of the wood.

Although most beetles attack wet, freshly killed trees, powderpost beetles have evolved to use dry wood, making them among the few wood-eating organisms that can attack wood that is below the fiber saturation point. These insects most likely evolved to use the dead sapwood in tree branches, but dry wood in a building provides an equally suitable habitat. There are three groups of powderpost beetles: Anobiidae, Bostrichidae and the Lyctidae.

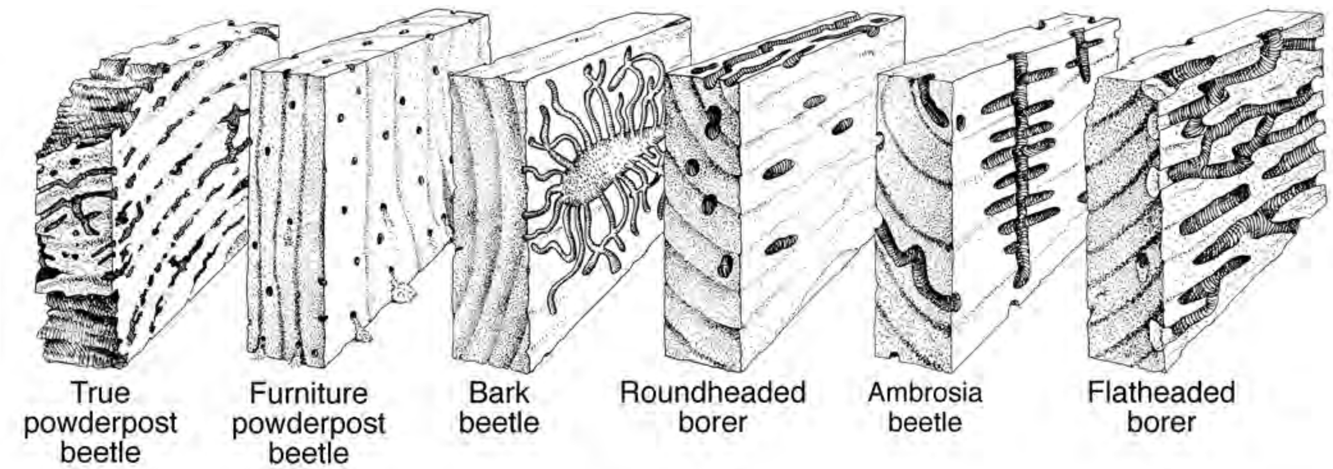

Figure 9. Examples of wood damaged by various wood-boring beetles (not to scale).

Anobiid beetles are small (⅛ to ¼ inch in diameter) and red to brown in color. The female deposits eggs in cracks or crevices of dry wood and the larvae hatch and tunnel inward, leaving little evidence of their presence. As they tunnel they produce a powdery excrement called frass. Once they obtain enough energy, the larvae pupate and the adults emerge from the wood, leaving holes 1⁄16 to ⅙ inch in diameter. The life cycle takes 2 to 10 years and the exit hole is often the first sign of an infestation. These beetles attack both hardwoods and softwoods and generally prefer wood with a moisture content of about 15 percent.

Bostrichid beetles also infest sapwood of both hardwoods and softwoods but can survive at lower moisture levels. Bostrichid exit holes tend to be slightly larger (1⁄16 to 5⁄16 inch in diameter) and the larval galleries tend to be more tightly packed with frass.

Lyctid beetles, or true powderpost beetles, are common in the sapwood of many hardwoods. The adults prefer woods with larger pores such as oaks, ashes, hickories and walnut. The adult lays eggs in the pores and the hatching larvae tunnel into the wood, where they mine for 1 to 2 years before emerging through 1⁄32- to ⅛-inch-diameter holes. There is some evidence that adults can mate inside the wood without emerging.

Powderpost beetles tend to be a problem in untreated, uncoated wood that is used in locations that are not regularly inspected, such as barns and covered bridges. Beetle damage can be limited by treating wood or by applying a sealing finish that limits the ability of the hatching larvae to tunnel into the wood.

Termites and ants are important recyclers of woody materials. Both are social insects with highly structured caste systems that center on the queen, whose primary function is to lay eggs. Workers search for food, rear the young and excavate the wood to produce galleries. In some colonies, soldiers are also present and guard the colony from invaders.

Termites differ from ants in that termites use wood as a food source. Symbiotic organisms called protozoa in the termite gut digest the cellulose. Three groups of termites are found in North America: subterranean, drywood and dampwood termites. All three groups are largely confined to the areas south of 50 degrees N latitude, although they may occur sporadically above this zone where human activity has created suitable conditions.

Subterranean termites, as the name implies, live underground, but they can also move into wood near the ground. The workers tunnel into the wood, carrying soil upward to wet the wood. Termite workers (Figure 10) feed nearly continuously and tunnel widely in search of suitable wood. They are also capable of producing earthen tubes over nonwood structures, such as foundations, to reach wood above ground. Termites are rarely seen outside the nest and avoid light. Often, the first sign of attack is a mud tunnel over a wall or the wood will collapse because it has been hollowed out. As colonies enlarge, they begin to produce new queens and kings. These winged adults emerge from the colony and fly to new locations to start colonies. These adults, called alates, often fly toward the light in windows, where they lose their wings. Collections of wings on windowsills are a critical sign of infestation.

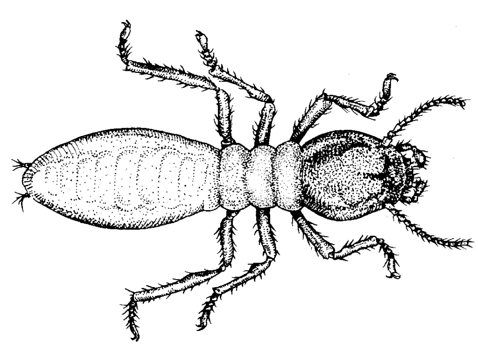

Figure 10. Subterranean termite workers, the most common caste in a colony, have soft, creamy-white bodies without wings.

Subterranean termites are widely distributed across the United States, causing an estimated $2 billion in damage annually. In addition to the native subterranean termites, another species, the Formosan termite has been introduced from Southeast Asia. The typical native subterranean termite colony reaches a population approaching a million workers. Formosan termites colony sizes approach 5 million to 7 million workers and are much more aggressive. Although they are largely confined to the Gulf Coast states and the southern Atlantic coast, they are gradually expanding their range northward, often when infested wood is moved into new regions.

Dampwood termites live in wet wood that does not have to be in contact with the soil. These termites are much larger than subterranean termites, but their colonies are relatively small (less than 2,000 workers) and they do not live long in dry wood. Although they are native to the Pacific Northwest and Florida, they are occasionally transported in green lumber to other regions. They are easily eliminated by removing the moisture sources and drying the wood.

Drywood termites, as the name implies, live in dry wood (10-13 percent moisture content) and are native to the southwestern United States. They are rarely seen outside the nest, but they often clear the residual droppings or frass out of their colonies through holes called kickholes, and this is generally the first sign of an infestation. Drywood termites are difficult to control; most often a tent must be placed over a house while a fumigant is introduced. Sulfuryl fluoride is the most common treatment for these insects. Screening of vents can help reduce the risk of infestation.

Ants do not use wood as food, but instead construct tunnels in wood to rear their larvae and forage for food outside the nest (Figure 11). Unlike termites, carpenter ants in houses are often found outside the nest, in kitchens, for example, where they collect water and feed on food scraps. Carpenter ants can be difficult to exclude from a structure because they do not consume wood.

Carpenter ants and termites are often confused with one another but there are several key differences that make it easy to distinguish these important household pests (Table 1).

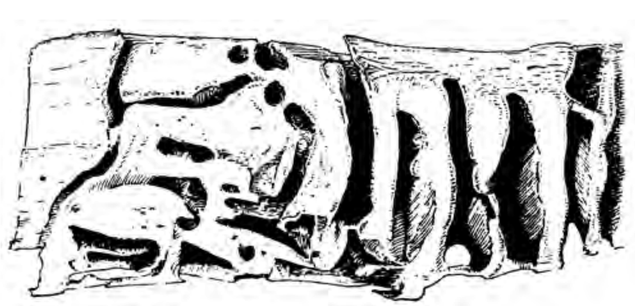

Figure 11. Example of wood damaged by carpenter ants and carpenter ant workers.

Table 1. Differences between carpenter ants and termites.

Characteristics	Carpenter ants	Termites
Color of workers	Black with red	White
Wings on reproductives	2 Pairs, unequal length	2 Pairs, equal length
Body segments	Constrictions between segments	No constrictions
Food source	Insects, nectar	Wood
Workers outside nest	Yes	No

Marine borers attack wood in salt water. There are three types of marine borers: shipworms, pholads and gribbles. Shipworms and pholads are both mollusks and begin life as free-swimming larvae that settle on the wood surface and tunnel in. Shipworms become long and wormlike, sometimes growing to a length of 5 feet. Pholads remain near the surface of the water surrounding a ship or wooden structure and filter feed from the water. Pholads tend to remain clamlike their entire lives. Both shipworms and pholads are trapped once they enter the wood. Gribbles, or *Limnoria*, are mobile crustaceans that tunnel into the wood surface. Clearly, marine borers are not a problem except near salt water, but a considerable volume of wood is treated to resist these organisms (Figure 12).

Some animals can also damage wood. Voles and porcupines can sometimes gnaw wood in search of salt. Similarly, farm animals will chew on wooden stalls, fences and troughs. This damage can be difficult to prevent because the animals do not use wood as food. Oil-based preservatives tend to be more repellent than water-based preservatives in this instance.

Various birds, especially woodpeckers, also cause wood damage. Excluding woodpeckers can be extremely difficult because they do not consume wood as food. Woodpeckers vary in both the amount of damage they cause and the reason they cause it. Woodpeckers excavate wood to produce nesting

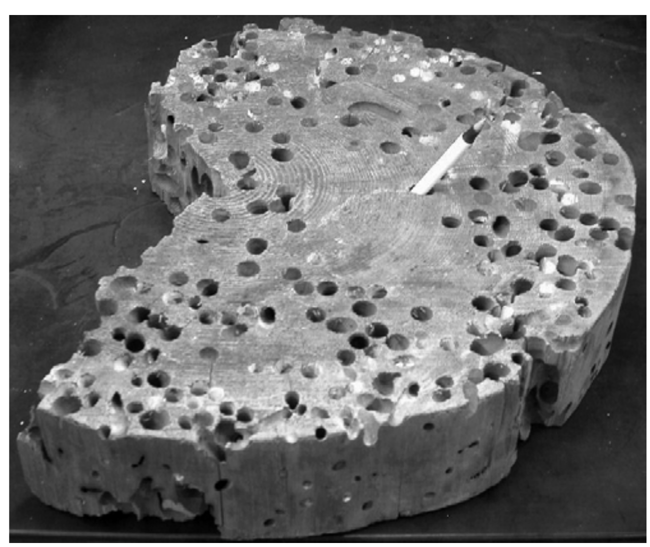

Figure 12. Wood damage caused by shipworms.

cavities as well as temporary roosts and to forage for insects in the wood. Woodpeckers frequently forage in poles in search of carpenter ants. A pileated woodpecker can excavate a nest cavity in a few hours. These birds are generally protected and cannot be disturbed on the nest. A number of techniques have evolved for preventing attack, but heavy-gauge hardware cloth appears to be most effective. Even this material, however, is no match for a determined bird.

Preventing wood deterioration

The primary focus of this manual is wood preservation, but it is important to remember that chemical treatment represents only one approach to wood protection. Processes that limit any of the biological factors can also limit deterioration.

Designing to exclude water is the most widely used method for preventing deterioration. Besides the use of paints and caulking, construction features such as foundations that raise the wood away from the soil, long roof overhangs, steeply sloping roofs, and gutters and drainage to move water away from the structure all help limit the risk of wetting. Moisture avoidance is critical for wood performance because wood tends to wet far quicker than it dries. All of these features help keep the wood moisture content at 17 percent or lower, well below the point where biodeterioration can occur. Most building decay occurs when moisture accumulates either because of leaks or because of condensation from interior moisture. Most building codes only require the use of treated wood in locations where decay is most likely to occur, such as the plate attaching the house to the foundation, but for the most part wood in houses does not need treatment.

Another alternative to treatment is the use of naturally durable woods. As trees grow, the older sapwood dies and undergoes the process of heartwood formation. In this process, the storage compounds are converted to a variety of phenolic compounds. In some species, these compounds are toxic to fungi, insects or marine borers. Species such as redwood, cedars, black walnut or Osage orange all produce naturally durable wood (Table 2). These materials tend to perform best out of soil contact, and there can be considerable variation in durability between trees of a given species and even within the same tree.

A variety of alternative materials are substituted for wood, including steel, concrete, plastics, and wood-plastics and wood-plastic composites. All of these materials have certain advantages over wood, but all are also produced from nonrenewable resources. The major disadvantage of steel is the large amount of energy required for production. This makes steel products less attractive from a carbon production perspective.

Steel has been substituted for posts, poles and even building framing. An important consideration when using steel where wetting will occur is corrosion. Steel can be coated with zinc alloys to slow this process. One of the major advantages of steel is its uniform material properties, which allow steel structures to be designed to tighter tolerances than comparable wood structures.

Table 2. Examples of naturally durable commercial wood species.

Species common name	Latin name
Redwood	*Sequoia sempervirens*
Western redcedar	*Thuja plicata*
Alaska cedar	*Chamaecyparis nootkatensis*
Port Orford cedar	*Chamaecyparis lawsoniana*
Eastern whitecedar	*Thuja occidentalis*
Eastern/Western juniper	*Juniperus virginiana/occidentalis*
Black walnut	*Juglans nigra*
Osage orange	*Maclura pomifera*
White oak	*Quercus alba*
American chestnut	*Castanea dentata*
Black locust	*Robinia pseudoacacia*
Greenheart	*Ocotea rodiaei*
Ekki	*Lophira alata*

Concrete can be substituted for wood in a variety of applications where weight is not a factor. Like steel, one of the main attributes of concrete is uniform material properties. Concrete is often reinforced with steel, which can be susceptible to corrosion.

Both concrete and steel require a considerable amount of energy to produce. Although both claim to be capable of performing for longer periods than wood, emerging data on wood suggests that wood poles can provide 60 to 80 years of service life, well within the ranges claimed by these alternative materials.

Plastics and wood-plastic composites have recently emerged as wood alternatives. These materials have greater resistance to water absorption than wood. Both of these materials can be made using recycled plastics, and this was one of the first reasons for producing these products — to provide an outlet for plastics collected through community-mandated recycling programs. Although plastics are considered to be resistant to biodeterioration, they can be degraded by sunlight, and UV inhibitors must be added to the plastic to avoid embrittlement. Plastics, by themselves, also tend to be too flexible for many applications, although these products can be used as decking if extra support is used beneath the deck. Adding wood particles can stiffen plastics, and these wood-plastic composites (WPCs) have emerged as an attractive marriage of two very different materials. Most WPCs are approximately 60 percent wood, while plastic and various additives that aid in extrusion make up the remaining 40 percent. Although WPCs have excellent attributes, including availability in an array of colors and shapes and dimensional stability, they also tend to be much heavier than wood and there is increasing evidence that the wood in these materials can degrade. Some manufacturers now add a wood preservative, zinc borate, to WPCs to avoid this problem.

Treatments

For centuries, supplemental treatments have been applied to wood to prolong its useful life. Carpenters dabbed various oils and extracts on wood columns used to support temples, and ancient shipbuilders learned the value of tars and pitch for excluding water. Most of the treatments were ineffective, and it was not until the early 1800s that the first truly effective preservatives were developed. Ironically, these developments predated the understanding that wood decay is caused by fungi, a discovery not made until the 1880s. Thus, our ability to protect wood preceded our understanding of why these treatments work.

The goal of preservative treatment is to provide an envelope of protection against fungal, insect, marine borer or physical attack. The extent of this envelope depends on the organisms involved, the inherent decay resistance of the wood and the expected service life of the wood.

Wood preservatives can be applied to wood in a variety of ways, primarily depending on the intended use. Treatments can be arbitrarily divided into short-term applications, those expected to provide up to 6 months of protection, and long-term applications. Longer protection generally requires the deposition of more chemical deeper into the wood, and this need for deeper treatment drives the choice of delivery method.

Uniformity of treatment depends on many factors, including the treatment solution characteristics, the wood species and the treatment method.

The treatment solution can affect the results in a number of ways. More viscous (thicker) solutions will tend to penetrate into wood for shorter distances because penetration will be limited by permeability of the pits in the wood. Heating reduces the viscosity of the treatment solution, improving penetration. Because surface tension can also affect uptake, adding surfactants that reduce surface tension can also improve uptake. Finally, some treatment chemicals readily react with wood and these reactions can reduce the amount of chemical in the treatment solution. This selective absorption strips chemical from the solution, leaving a weaker solution that is then used to treat other wood. It can also result in blockage of the pits or it can result in a very steep preservative gradient from the surface to the interior of the wood.

Wood characteristics have a major effect on treatment. Wood is differentially permeable in three planes; treatment moves most readily longitudinally, then radially, and finally tangentially. Thus, the end grain of a board will absorb much more chemical than the side grain. Side grain penetration is often limited to a few millimeters and care must be taken to limit damage to this fragile shell. The primary barrier to fluid flow is the pit, which connects cells and allows fluids to move in the living trees. Pits can be open or they can be closed and encrusted with debris that limits flow. Sapwood pits are generally open, while heartwood pits tend to aspirate or close, sharply limiting fluid flow. Flow also differs among cell types in hardwoods. Vessels tend to allow ready flow longitudinally, while fibers tend to restrict flow. This differential receptivity can result in uneven distribution of preservative. Wood moisture content can also influence treatment. For example, poor treatment of hardwood fibers leads to a higher risk of soft rot attack. Wet wood tends to be difficult to treat, although dip or spray treatments can provide short-term protection. Conversely, it can be difficult for fluids to penetrate into very dry woods because the pits will tend to close. Most treatments work best on wood with a moisture content between 15 percent and 40 percent. Treatment method can also have a major effect on solution uptake and distribution and will be discussed in more detail later.

Short-term protection

In general, short-term protection involves applying a surface coating to the wood. Typical application methods include brushing, dipping for short periods (30 to 60 seconds) or spraying. All three methods depend on capillary uptake of preservative solution through exposed pores in the wood. Penetration of solution is generally shallow and this is acceptable because these systems are not intended to last long but primarily to prevent entry of fungal spores or insects that land on the surface.

Brushing is generally used by homeowners to provide supplemental wood protection. The process usually consists of flooding the surface with solution, brushing it to ensure complete coating and allowing this to stand for 30 seconds before brushing away the excess solution to ensure complete coating. On vertical surfaces, where solution will rapidly run off, applying several coats of chemical serves a similar purpose.

Dipping is often used to produce a thin shell of treatment that protects products such as window frames and freshly sawn lumber. Dipping allows for more uniform coating of the wood surfaces and greater penetration than brushing. Spaying will generally produce shallower treatments but the concentration of chemical applied can be increased to improve the preservative loading.

The most common uses for dipping or spraying are for treatments of freshly cut lumber to protect against stains and mold. These systems are designed to coat the wood surface to limit germination of fungal spores or to inhibit tunneling by insects (Figure 13). As a result, little penetration into the wood is required.

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Figure 13. Examples of dip and spray systems for protection of wood against fungal stain.

Long-term protection

Long-term protection is usually applied where the wood is expected to last decades or longer in its eventual application. In general, this requires that more chemical be applied and that it be placed more deeply in the wood. The degree of treatment required in these applications depends on the wood involved, the environment to which it will be exposed, and, to a lesser extent, the chemical used. The methods employed for longer-term protection range from long soaking periods to pressure treatment.

Dip treatments have long been used for protecting wood exposed above ground. The most common application is the 3-minute dip used to treat wood for windows and doorframes. The wood in these exposures is usually protected by coatings and is not exposed to soil. As a result, dipping delivers a sufficient amount of chemical to protect the wood in this exposure. The majority of treatment penetrates along the end grain and this is where moisture is most likely to collect in service.

Soaking, which is essentially dipping for extended periods, has long been used to treat posts and other low-value wood. The materials to be treated are debarked and then placed in the treating solution for 24 to 48 hours. Usually only the portion of the post that will be in soil contact is treated. Soaking produces deeper preservative penetration than shorter dipping but usually does not completely treat the sapwood.

The thermal process is a slight advance on soaking. In this process, the wood is heated for 8 to 16 hours in the treating solution, and then the solution is withdrawn for a short time before being reintroduced. Pumping tends to cool the solution slightly and the cooler solution contacting the hot wood creates a partial vacuum near the wood surface, drawing solution into the wood. The result is a slightly higher loading than is provided by soaking alone. The thermal process is typically used to treat poles of thin sapwood species such as western redcedar, and to a lesser extent, Douglas-fir. Normally, the treating solution is oil-based because water-based solutions tend to evaporate during this process. Thermal treatments were once performed in open vats, but concerns about emissions of volatile organic compounds from the hot oil along with a desire to reduce heat loss (and thus lower energy costs) have resulted in this process being moved to closed vessels.

Vacuum treatments are not widely used in North America but are sometimes employed for window treatments. In these processes, the wood is placed in a treatment vessel or retort and a vacuum is drawn to remove as much air as possible from the wood. The treating solution is then added as the vacuum is released, drawing solution into the wood. In most industrial processes, this sequence is repeated to produce a so-called vac-vac treatment.

Pressure treatments were developed in the 1830s by John Bethell, a British civil engineer working for the British navy. In the original full cell process, wood is placed in a pressure vessel, a vacuum is drawn over the wood and the treating solution is added (Figure 14). Pressure is raised and held until a sufficient quantity of chemical is injected into the wood. This amount of chemical is called the gross injection. At the end of the process, the pressure is released and the treatment solution drained out of the vessel. Pressure inside the wood carries excess preservative to the surface. The amount of treatment solution leaving the wood depends on the amount of residual pressure and is called kickback. The gross injection minus the amount lost due to kickback is the net injection, or retention. Retention is normally expressed as pounds per cubic foot of wood or kilograms per cubic meter.

The full cell process delivers the maximum amount of treatment solution for a given depth into

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Figure 14. Example of a pressure treating facility showing a retort as well as storage tanks in the background.

the wood. It is used to deliver high loadings of oil-type preservatives for extreme environments or with water-based systems where the concentration of chemical in the treating solution can be adjusted to produce the desired loading.

The empty cell processes were developed at the turn of the 20th century as a means of reducing the amount of chemical delivered into the wood. Developed primarily for oil-based materials for terrestrial (land-based) applications, these processes eliminate the initial vacuum but still use pressure.

In the Rueping process, the solution is added to the vessel and then the pressure is raised and held until the desired uptake has been achieved. Because no air was removed from the wood by vacuum at the start of the process, any air in the wood is compressed at the center of the wood. As pressure is released, this air expands, carrying chemicals out of the wood. This increased kickback reduces the net retention.

In the Lowry process, a small amount of initial air pressure is applied before the treating solution is introduced. This process introduces more air in the wood, which further increases the amount of kickback at the end of the process, thereby reducing retention.

The Rueping and Lowry processes are primarily used to treat utility poles, timbers, railroad ties and other materials with oil-based preservatives. In all three pressure processes, the treatment times and vacuum/pressure levels are manipulated to produce the desired retention at the required depth in the wood. Processes can vary widely with wood species and the treatment chemical. The process is sometimes viewed as part science, part art.

In addition, the processes can include steaming before treatment to condition the wood, making it more receptive to treatment or post-treatment steaming to clean the wood surface and reduce the risk of chemical migration in service.

Treating equipment

The equipment required for application of preservatives to wood depends on how the wood will be used. In all cases, the application must be consistent with the EPA label and any additional state requirements.

Dipping systems can be relatively simple tanks made of an appropriate material that will not corrode or otherwise degrade in the presence of the treatment system. There are a variety of designs, a majority of which allow for dipping of whole units of material. The tank may have automatic hold-downs to keep boards from floating and an automatic timer so that lumber is only treated for a specified time. The tank should be on an impervious surface surrounded by a dike that is sufficient to capture any spills. The system should also be covered to limit evaporation or dilution by rainfall. In colder climates, it may be necessary to provide heat to avoid freezing. It is also helpful to have an area where units can be set at an angle after dipping to allow excess solution to drain from the wood and this drippage should be captured and reused (if possible). Finally, the system should be designed so that forklifts cannot drive through areas where solution has dripped because the tires carry this chemical throughout the plant. An important aspect of dip tank operation is to maintain proper solution concentration, but it is also important to limit the amount of soil and sawdust that collects in the tank because these can absorb chemicals and may pose a disposal challenge.

Spray systems are commonly used to treat freshly cut lumber with antistain chemicals. They consist of a high-pressure, low-volume or ultralow-volume pump with hoses connected to nozzles that are configured to produce a uniform spray on all four sides of a board as it passes through the spray system. These systems are normally positioned just after the planer so that the freshly exposed surface is immediately protected. Spray systems usually use higher chemical concentrations than dip systems to overcome the limited amount of liquid that is absorbed during treatment. The chemicals that run off the boards are usually collected, filtered to remove any contaminants (e.g., soil and sawdust) and reused. Spray systems tend to require higher maintenance because of the need to maintain solution concentration, the effects of contaminants, and most important, the tendency for nozzles to clog. When this happens, hundreds or even thousands of boards can be incompletely treated and this mistake is often discovered weeks or even months later when finished material starts to stain.

As with the dip system, the spray system must be configured so that any runoff is captured and recycled. This is usually accomplished by placing catch basins beneath the lumber chain. In addition, care must be taken to avoid drifting of the spray. Curtains around the sprayer along with proper ventilation are important components of a properly designed system.

The remaining treatments are all performed in closed vessels equipped with various pumps and gauges. The central focus of thermal and pressure processes is the treatment vessel or retort. Commercial retorts can range in size from 4 to 12 feet in diameter and up to 200 feet in length. The entire treating plant is usually set on an impervious material (e.g., sealed concrete) and there are points around the plant where monitoring wells are established so that water can be periodically collected and analyzed so that any contamination can be detected before it spreads. The retort is connected to vacuum and pressure pumps and these, in turn, are connected to storage tanks containing the treating solution. The vessels and storage tanks are equipped with sensors that monitor temperature, pressure and solution level. These gauges allow the operator to open or close the appropriate valves to maintain the desired treating conditions. The treatment vessel is usually in a covered structure to avoid rainwater contamination.

In more recently designed plants, the plant operation is computer controlled. The operator will enter the amount of wood and the target retention into the system, which then sets the time parameters and targets for uptake to achieve the desired result.

The wood is loaded on small rail cars called trams that can be rolled into the retort on rails. Some retorts open at both ends, allowing trams to be pushed through for easier loading, while others open only at one end. In all cases, the area where the trams containing freshly treated wood are placed has a sealed concrete surface called a drip pad. The drip pad is designed to capture any solution that drips from the wood following treatment. Freshly treated wood normally remains under cover on a drip pad for 24 to 48 hours after treatment. It is important to avoid moving material from the drip pad onto unprotected surfaces. For example, even walking across a drip pad can result in contamination of other areas.

Modern treating plants are also designed to capture all rainwater as well as any process water generated during treatment. Plants that use water-based preservatives can use their wastewater to make up new solutions, while other plants can evaporate as much water as possible and then dispose of any sludges or solids according to the appropriate disposal regulations. Treating plants fall under a number of regulations, including the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), the Clean Air Act, the Clean Water Act, and Superfund. In addition, there may be stricter state regulations. It is critical to be are aware of these.

Preparing wood for treatment

It is generally necessary to prepare wood for treatment. Preparation can include removing the bark, removing moisture and making all cuts or holes before treatment. Other pretreatment activities can have a major impact on the performance of the finished product.

Bark removal

Bark provides excellent protection to the living tree, but it poses a major impediment on the finished product. Bark remains attractive to many insects, which lay their eggs either on or beneath the bark surface. In addition, bark is extremely resistant to fluid flow and will block the movement of preservatives into the wood. As a result, nearly all wood treatments require that the bark be removed before treatment. Bark can be removed manually but this is costly and time consuming. More often, bark is removed by shavers or ring debarkers. It is important to inspect the wood surface carefully to make sure that small pieces of bark are removed.

Fluid removal

The sapwood of freshly felled trees generally contains a large amount of water, reflecting the function of the wood as the conducting element between the roots and leaves. Sapwood moisture contents typically range from 80 to 150 percent by weight and the presence of this excessive moisture can interfere with the movement of some wood preservatives. The exceptions are the water-diffusible chemicals such as boron or fluoride, which can move or diffuse from high to low concentrations into the wood. In generally, however, it is necessary to reduce the moisture content in the wood before treatment.

Drying can be accomplished in several ways. The simplest method is to stack the wood off the ground with spacing between individual members to allow for airflow. Air seasoning has been used for hundreds of years and can be effective where the wood is not subjected to repeated wetting from rainfall. The disadvantages of air-seasoning are that it takes time, requires some space for storage of seasoning wood, and most important, can allow fungi and insects to invade the wood while it is seasoning (Figure 15). This makes it especially important to subject the wood to some form of sterilization either before or during treatment. These processes generally involve the application of heat.

Kiln drying involves placing the wood in a large chamber where the temperature, relative humidity and airflow can be controlled. The goal is to create a driving force for the evaporation of water from the wood surface. Kiln drying is normally used for higher value materials such as lumber or poles. This process can also be used after treatment to remove excess moisture and thereby reduce shipping weight and limit the risk of drying defects after treatment.

While air seasoning and kiln drying are the most common seasoning methods, moisture content can also be reduced using steam conditioning. In this process, the wood is heated with live steam for 12 to 20 hours. Heating drives moisture out of the wood and creates a steep moisture gradient from the interior to the surface. The process is primarily used for larger poles and timbers and reduces the moisture content in the outer 50 mm to 20-40 percent moisture content. The process, however, is energy intensive, and therefore more costly than other methods. It also creates an excess of water that must be processed in the plant system. Often, this material is used as a diluent or as make-up water for water-based treatments used in the plant.

The target moisture content for treatment depends to a great extent on the wood species and the

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Figure 15. A well laid out air-seasoning area should be free of vegetation with graveled areas, wood off the ground, no woody debris and spacing that allows for even airflow to facilitate drying.

chemical. Kiln-dried lumber generally has a moisture content of 17 percent, but many wood species can be treated at moisture contents ranging from 20 percent to 40 percent. The problem with treatment at higher moisture levels is the tendency for the moisture to be distributed unevenly. This results in variable penetration of preservative, which can lead to in-service decay in the undertreated zones.

Preservative treatment, no matter how deep it goes, is really a barrier against biological attack. The goal of treatment is to protect a sufficient shell of wood to support the end-use. This may mean that a sapstain treatment need only penetrate a short distance into the wood because it is intended only to keep spores from germinating and growing into the wood. Conversely, the depth of treatment for a utility pole must be much greater because the product must resist a variety of pests for a long time.

An important part of ensuring that the protective barrier is maintained is to make sure that any fabrication such as cutting to length or drilling holes is performed before treatment. This process ensures that the barrier remains intact. In addition, where field fabrication is required after treatment, it is important that some type of supplemental preservative be brushed on the cut surface to protect the exposed wood. While this treatment will never be as effective as the initial treatment, it will slow the progress of any degrading organisms.

In some instances it may be difficult to penetrate the wood of a particular species. This may be because some species produce a high percentage of heartwood that is difficult to treat or it may be some other wood characteristic that limits fluid uptake. A number of processes have been developed to improve treatment in these species. The most commonly used method for improving treatment of lumber and timbers is incising, a process of driving sharp knife-like teeth into the wood to a given depth (usually slightly shallower than the required depth of treatment). The holes created by incising expose end grain to the preservative fluid (Figure 16). Because fluids tend to flow more readily along the grain than across it, incising improves the depth of treatment. Incising is required for treatment of many wood species from the western United States, such as Douglas-fir and the commercial species group called hem-fir. It is generally not required for the treatment of southern, ponderosa or red pine.

The other methods for improving treatment are primarily used for larger timbers and poles. Kerfing involves cutting a saw kerf from the surface to the pith of a timber or pole. This kerf is made before treatment, and the resulting well-treated kerf acts to relieve the stresses normally associated with drying. Kerfed timbers and poles tend to develop few other checks that might penetrate beyond the original preservative barrier. The result is a well-treated timber with a reduced risk of internal decay.

An alternative treatment for poles is to drill holes completely through the poles. These holes are regularly spaced from 3 feet below the intended soil level to 2 feet above and are positioned to produce nearly compete preservative treatment of the heartwood in that zone. There are two approaches to this process. In through boring, the holes are only drilled on one face of the pole but they are drilled completely through the pole. In radial drilling, holes are spaced completely around the pole but they are only drilled inward to a depth of 75 to 100 mm. In both cases, the goal is to

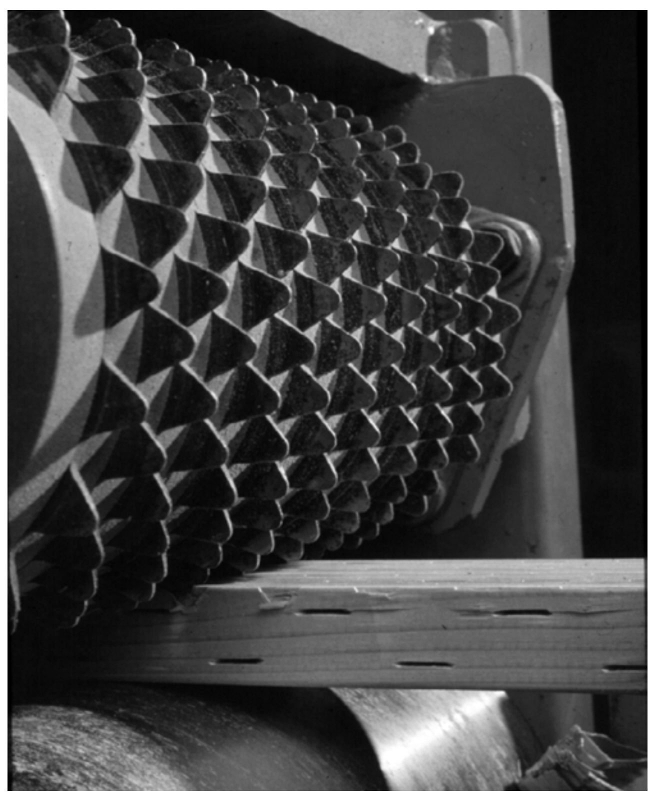

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Figure 16. Incising wood increases the effectiveness of preservative treatment.

protect a sufficient shell of treated wood in the critical ground line zone to protect the pole from failure.

Chemicals for wood treatment

A variety of chemicals are available for wood treatment. All the chemicals are pesticides and should be handled and applied as specified on the label. It is a violation of federal law (FIFRA) to use a pesticide in a manner inconsistent with the instructions on its label. In this manual, we will discuss both general- and restricted-use pesticides. General-use pesticides may be purchased and used by individuals without any special certification or licensing. Restricted-use pesticides, however, are available for purchase and use only by certified pesticide applicators or persons under their direct supervision.

Wood preservatives can be classified in various ways. For simplicity, we will divide them by application, although there will be some overlap because some chemicals can be used for more than one purpose.

Stain/mold protection

The pesticides available for antistain/antimold treatments are generally water-soluble, or miscible with water. For decades, the most commonly used chemical for this purpose was sodium pentachlorophenate (Na-PCP). Na-PCP was used until the late 1980s when it was listed as a restricted-use pesticide. This action, coupled with increasing worker complaints, led to the gradual substitution of alternative compounds.

3-iodo propynyl butyl carbamate (IPBC)

Carbamates have a long history of use as fungicides – pesticides that control molds and other fungi. IPBC is effective against a variety of fungi and has been used as a paint additive, millwork treatment and as an antistain/antimold treatment. This compound is available in both oil- and water-based formulations.

Didecyldimethylammonium chloride (DDAC)

DDAC is one of a number of quaternary ammonium compounds (QACs) that have activity against fungi. QACs are derived from the rendering of animal carcasses and have been used for several decades for decay protection of wood in aboveground applications as well as for mold and stain prevention of freshly cut lumber. QACs can be formulated in both oil and water but are most commonly used in water. These compounds are not effective against all fungi and tend to work best in combination with other fungicides.

Chlorothalonil

Chlorothalonil has been used for decades as a seed treatment, but it is also effective as an antistain/antimold treatment. This compound is marginally soluble in water but can be produced as a stable emulsion.

Tebuconazole

Tebuconazole is a triazole – a group of compounds that affect the ability of fungi to produce sterols, which are essential for cell wall synthesis. Triazole compounds have exceptionally low toxicity to humans and other mammals.

Oxine copper

A complex of copper with a quinoline compound, oxine copper (also called copper-8-quinolinolate) is one of the only compounds allowed for the treatment of wood in direct contact with food. It is used for floors of refrigerated trucks, food crates, pallets and picnic tables.

Isothiazolone

There are a number of substituted isothiazolones used for crop protection as well as mold prevention on pressure-treated lumber. These compounds are primarily used as an additive in other wood preservatives, but they have been proposed for pressure treatment of wood. These compounds have provided excellent protection in long-term field tests, but some users can become sensitized with extended exposure.

Folpet

Folpet has a long history of use as an agricultural fungicide and has also been used as a component in antistain compounds as well as some over-the-counter wood stains and finishes.

Long-term wood protection

Protection of wood for periods longer than 6 months or in locations where wetting is likely to occur requires the use of more active compounds delivered deeper into the wood at higher loadings than those used for stain and mold treatment. Long-term protection can be accomplished in some applications by dipping or soaking, but pressure treatment is generally necessary for adequate performance.

As with short-term protectants, the chemicals used in the treatments can be divided into oil- and water-soluble systems. The oil-based systems can be further divided into those using relatively volatile solvents such as mineral spirits that evaporate from the wood surface, and those using heavier oils that remain in the wood for decades after treatment.

Creosote

Creosote is a byproduct of the production of coke from coal for use in the steel industry. This preservative is actually a mixture of 200 to 400 different compounds that are produced by condensing the vapors produced during coking. Creosote was first patented for wood preservation in the 1930s by John Bethell, primarily as a marine wood preservative. Its uses grew until the 1930s, when it was the most widely used wood preservative. Creosote is effective against fungi, insects and most marine borers. The primary drawbacks of creosote are the oily texture of the treated wood surface and the tendency for workers in contact with both the chemical and treated wood to become sensitized to the sun (i.e., they more easily sunburn). In addition, creosote contains many polycyclic aromatic hydrocarbons and there are environmental as well as health concerns about several of these compounds as suspected carcinogens. Creosote itself, has never been shown to be carcinogenic, and extensive environmental monitoring indicates that while it migrates away from treated wood, it does so at levels that have little or no negative effect in most applications.

Creosote is a restricted-use pesticide, which means that it is only available for purchase and use by certified pesticide applicators or persons under their direct supervision. Creosote is primarily used to treat railway ties, utility poles, marine piling and some bridge timbers. In general, these uses limit the risk of human contact.

Pentachlorophenol (Penta)

Penta was developed in the 1930s and represents one of the first synthetic organic wood preservatives. This compound was originally synthesized by the chlorination of phenol and, from the 1950s onward, was widely used for utility poles, timbers, lumber and an array of other uses. It was also widely misused both in terms of materials treated and the potential for human contact. Penta is broadly toxic to fungi and insects but is not effective against marine borers. Its primary drawback is the presence of dioxins as contaminants. Dioxins are a broad class of chlorinated compounds that are produced as a byproduct of the chlorination process, some of which have been classified as highly toxic (the dioxin in Agent Orange, for example). As a result of concerns over both the presence of dioxins and the toxicity profile of penta itself, the EPA classified penta as a restricted-use pesticide. The current uses for penta include utility poles, bridge timbers and foundation piling. Penta has provided exceptional service in these applications and the industry has shifted its manufacturing processes to sharply reduce the contaminant dioxin levels.

Copper naphthenate

Copper naphthenate was first developed in the late 1800s but was only used as a wood preservative in the 1940s. Naphthenic acids are derived from certain petroleum sources and these naphthenic acids can be reacted with copper to produce a copper soap. Copper naphthenate is effective against fungi and insects but has little efficacy against marine borers. It is currently a general-use pesticide, meaning that a license is not required for its use. Copper naphthenate can be purchased over the counter and this system is among the most widely used preservatives for the so-called do-it-yourself market. Copper naphthenate is also used for pressure treatment of utility poles, bridges, and, most recently, some railway ties. It is primarily regarded as a penta replacement based on its lower toxicity (about 1/10 less toxic to humans than penta) and absence of dioxins.

Oxine copper

Oxine copper was described above as a short-term protectant, but this compound can also be solubilized in organic solvents where it is used to treat picnic tables, truck bed bodies and wood that is intended for use in direct contact with foods. Its primary attribute is its overall low toxicity to nontarget organisms, but its high cost in comparison with other organic solvent-based systems sharply limits its use.

Water-based systems

In the early 20th century, water-based systems such as copper, zinc, and mercuric chloride were widely used for protection of railway ties and other products. Creosote and later penta eliminated these uses, but water-based systems made a major resurgence from the 1960s onward as homeowners sought clean, paintable treated wood to construct fences, decks and the other features of outdoor living. Water-based treatments now represent over 60 percent of the wood treated in North America.

The majority of water-based treatments use heavy metals, particularly copper. Copper is broadly effective against fungi and insects as well as most marine borers. It is also relatively nontoxic to humans, as evidenced by its use in plumbing, jewelry and a host of other applications.

Acid-based waterborne preservatives

There are two acid-based preservative systems used in North America and both contain copper and chromium. Generally, chromic acid is used to solubilize copper oxide in these systems. The pH of the wood is relatively low (pH 3-4) but the chromium has some anticorrosive benefits.

Chromated copper arsenate (CCA)

Chromated copper arsenate (CCA) was developed in India in the 1930s. This system is among the first designed preservatives. Copper is an excellent fungicide, although some fungi can tolerate high levels of this metal. Arsenic is an excellent insecticide and provides some protection against copper-tolerant fungi. Taken together, copper and arsenic would present a reasonable preservative, but this combination would tend to wash from the wood. The addition of chromium represented a stroke of genius because hexavalent chromium will react with wood components as it is converted to the trivalent state to become “fixed” to the wood. At the same time, chromium reacts with copper and arsenic. The result is a complex that is highly resistant to leaching, paintable, inexpensive and broadly effective.

By the 1990s, CCA was the most widely used preservative in the world; however, it was not without its issues. “Fixed” is a relative term and some copper and arsenic must always be available in order for the system to protect the wood. These small amounts of chemical, particularly arsenic, caused public concern. In addition, failure on the part of industry to ensure complete chromium reduction led to further concerns because hexavalent chromium is a known carcinogen, although the trivalent form is of little concern. The first response in the 1980s was to restrict the use of CCA to licensed applicators, although this had no effect on the ability of the public to use the treated product. While numerous tests showed that the levels were far below those considered capable of causing effects in humans, extensive protests and litigation led the industry to voluntarily cancel registrations for all residential applications of CCA. At present, CCA is only available for industrial applications such as utility poles, piling and timbers.

Acid copper chrome (ACC)

The second acid-based system is acid copper chrome (ACC). ACC has been available for decades, but its use has largely been limited to treatment of wood used in industrial cooling towers. Like CCA, ACC depends on the reaction of chromium with wood, but this system uses much higher loadings of copper to produce similar protection. Thus, the fixation periods necessary to completely reduce the chromium and immobilize the copper were somewhat longer. At present, ACC is a restricted-use pesticide limited to industrial applications.

The other approach to producing waterborne heavy metal preservatives is to use alkaline systems. Ammonia or amine compounds can be used to solubilize copper, thereby avoiding the need for hexavalent chromium. There are a number of alkaline-based copper compounds used for wood treatment.

Ammoniacal copper zinc arsenate (ACZA)

Ammoniacal copper zinc arsenate (ACZA) is the oldest of the alkaline copper compounds currently in use. It was developed in the 1970s as an improvement on an existing system, ammoniacal copper arsenate. ACZA uses ammonia to solubilize copper, arsenic and zinc. As with CCA, the multiple metals provide broad protection against fungi, insects and marine borers. ACZA is primarily used in the western United States to treat Douglas-fir and other species that are difficult to treat. The ammonia tends to swell the wood and dissolve materials that block flow at the pits. As a result, ACZA can produce much deeper and more uniform treatment than the acid-based systems. As with CCA, ACZA is a restricted-use pesticide and its application is largely limited to industrial products such as poles, highway guardrail posts and timbers.

The other two alkaline copper compounds are not restricted-use pesticides.

Alkaline copper quaternary compound (ACQ)

Alkaline copper quaternary compound (ACQ) is a mixture of copper and a quaternary ammonium compound. Two quaternary compounds, or quats, can be used for this system: DDAC was described under short-term protection chemicals; benzalkonium chloride is another quat that has been used for short-term prevention of fungal stains. It is less widely used in ACQ than DDAC. The combination of copper and the quat takes advantage of the broad effectiveness of copper with the ability of the quat to protect the wood against copper-tolerant fungi. ACQ can be formulated using either ammonia or amine (usually ethanol amine). Ammonia is usually added at low levels to treat more difficult-to-treat woods but it also tends to leave an odor. ACQ systems have been available since the 1990s, but their use has increased markedly with the removal of CCA from the market. ACQ currently represents about two-thirds of the waterborne residential market.

Copper azole

Copper azole is the other alkaline copper compound. The azole — usually tebuconazole, although propiconazole can also be used — is added to protect against copper-tolerant fungi. Like ACQ, copper azole can be formulated using either ammonia or amines to solubilize the copper. Copper azole currently represents about one-third of the residential market for treated wood.

Both ACQ and copper azole have similar performance characteristics. For effectiveness that approaches that of CCA, the copper level in these systems is nearly doubled. At the same time, there is no chromium to help fix the copper. While this poses little risk to humans, the increased availability of copper means that more copper can leach from the wood once it is placed in service. Methods for reducing this risk have been developed and will be discussed later; however, the result is a system that can pose a higher risk in some aquatic environments.

The other important performance difference between CCA and the alkaline copper compounds is the pH of the treated wood and its association with increased corrosion. While CCA-treated wood can cause slight corrosion to iron fasteners, this problem can be easily addressed by using galvanized connectors. The alkaline-based copper systems pose a greater challenge to metal fasteners, and manufacturers have begun to produce more heavily galvanized fasteners or to switch to stainless steel to avoid corrosion.

Other waterborne systems

Boron

Boron has long been known to be effective against fungi and insects. This element has low toxicity to humans and is readily dissolved in water. Borates also have the advantage of being able to diffuse into the wood after treatment. Thus, they can be used to impregnate woods that generally resist conventional treatment. However, this ability comes with the downside that boron can also move out of the wood with moisture. Thus, boron is not suitable for uses where wetting will occur. Boron-treated wood is currently used for sill plates as well as for the interior applications where the risk of insect attack, notably termites, is high.

The removal of CCA from the residential market has created tremendous interest in alternative wood preservatives. While many of these compounds are unsuitable for commercial use or are ineffective, some are worth mentioning because they may appear in some markets.

Insecticidal treatments

Although we tend to think of wood preservation as providing broadly effective systems to protect wood, there are many applications where the risk of decay is low and the primary risk is from insects, particularly termites. Although borates are widely used in this application, other compounds are used in special markets. Permethrin and imidicloprid are both used to protect wood against termite attack. These compounds are most often used in solvent-based systems for treatment of wood-based composites where the use of water-based systems such as alkaline copper or borates would produce unacceptable swelling and deformation. Both compounds are widely used in over-the-counter insecticide formulations and are therefore general-use pesticides.

Silicates

Solutions of sodium or potassium silicate, called waterglass, have been sold as wood preservatives for decades. These products claim to have low toxicity against nontarget organisms, to be able to penetrate deeply and to become fixed to the wood. Numerous trials have shown that these compounds are not fixed and that they are generally not effective wood preservatives.

Dimensional stabilization and heat treatment

Dimensional stabilization and heat treatment are two among a variety of emerging European technologies for wood protection that may eventually be transferred to North America. **Dimensional stabilization** is not new; it was first proposed in the 1950s and involves either bulking the wood with compounds that restrict moisture uptake or reacting the wood with compounds that limit access of moisture into the wood polymers. In both cases, the uptakes required are substantial, ranging from 20 to 30 percent by weight, making the processes costly and unlikely to replace conventional treatment. **Heat treatment** involves heating wood at high temperatures (>410 F or 210 C) in the absence of oxygen to remove the decay-susceptible compounds and make the wood less able to sorb moisture. These treatments are also expensive and tend to reduce some wood properties, notably resistance to shock loading. Like stabilization, heating is likely to serve a specialized market in North America.

Remedial treatments

Although most wood preservatives are intended as initial treatments, a variety of chemicals have been developed to protect wood that is already in service. These systems were developed to provide supplemental protection as products age. The most common uses for these systems are protection of bridges and utility poles although they can be used in other wood applications if the label allows (Figure 17). Remedial treatments can be broadly divided into external and internal treatments, although there is some overlap.

External treatments

External treatments are typically applied to the wood surface. They are often used to control soft rot below the ground line, but they may also be used to protect exposed wood surface from weathering and decay.

The systems used to protect wood below the ground usually contain mixtures of compounds that

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Figure 17. Damage due to internal decay (left) and external decay (right) on large timbers can be arrested by remedial treatment.

are designed both to produce a surface barrier to limit the risk of fungi invading from the soil and to move into the wood for short distances, killing any established fungi. Many of these systems contain a water-diffusible component that can move into the wood and an oil-soluble component that stays near the surface. The external preservative systems are primarily intended to supplement the original protection. They are applied by digging around a pole to a depth of 18 to 24 inches (45 to 61 cm), removing any softened wood and applying the supplemental treatment (Figure 18). Some of these systems are applied as pastes and then covered with a plasticized kraft paper, while others are fully contained wraps with the chemical premeasured onto a plastic-backed wrap. The following compounds are among those used in external ground line treatments:

Copper naphthenate: as either an oil-soluble or amine- (water) soluble compound. Both systems tend to move only a short distance into the wood to provide protection against renewed fungal attack.

Copper hydroxide: more water-soluble than copper naphthenate but still used primarily for surface protection.

Borate: capable of moving into the wood for 10 to 50 mm to eliminate fungi established away from the surface. Tends to remain in the wood for relatively short time periods (3 to 5 years).

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Figure 18. Example of an external supplemental preservative system used to arrest external decay at ground line.

Fluoride: like boron, capable of moving into the wood with moisture. For unknown reasons, fluoride tends to stay in the wood for longer periods than boron.

Other external treatments

A variety of surface treatments are used to protect woods in decks and shingle roofs. These systems often contain wax for water-repellency, UV inhibitors to slow photodegradation of the wood surface, and a fungicide. Many of these systems are borne in organic solvents although concerns about volatile organic compound emissions have encouraged the development of water-based systems. Protecting wood using surface treatments is extremely challenging and most topical preservative formulations will provide only 1 to 2 years of protection to a deck and slightly longer protection to a vertical surface. The use of pigmented formulations can enhance protection, but the primary problem is depositing enough material into the wood.

Internal treatments

In some species, it is not possible to completely treat the heartwood even using elevated pressures. Once these treated products are placed in service, they begin to check as the wood seasons. The checks can penetrate beyond the original depth of treatment, exposing untreated heartwood to fungal and insect attack. If left untreated, the result can be a hollow structure surrounded by a thin shell of treated wood that can fail under load. Arresting this attack poses a major challenge, given that it was not possible to treat the wood using a combination of elevated pressure and vacuum; however, a number of products have been developed to help overcome this problem. These materials all depend on their ability to diffuse through the pits of the heartwood at levels that can eliminate decay fungi and remain in the wood for a sufficient time period to limit the risk of reinfestation. In most applications, steep sloping holes are drilled, beginning at or near ground line and moving upward 6 to 8 inches (15 to 20 cm) and around the pole 120 degrees. The treatment is added to these holes, which are then plugged with tight-fitting wood or plastic plugs. The moisture in the pole activates the compounds, which then move above and below the treatment site to kill any decay fungi established in the wood. The rate and degree of movement as well as the protective period afforded vary with the chemical used. The typical retreatment cycle for pole is 10 years, although shorter time periods may be necessary under severe conditions.

There are two approaches to internal remedial treatment. The first is based on the use of water-diffusible compounds such as boron or fluoride, while the other is based on the use of volatile gases, or fumigants.

The water-diffusible compounds include fused boron rods and sodium fluoride rods (Figure 19). Boron, as discussed earlier, has low toxicity to humans and is widely used in other wood preservative applications. Fluoride has a slightly higher toxicity profile but has been used as a wood preservative for almost a century.

Boron is heated to elevated temperatures to produce a molten material that is poured into a rod-shaped mold and allowed to cool. The rods can be inserted into the treatment holes and the boron is released as the rod absorbs moisture from the surrounding wood. The rate of release can vary with the moisture of the wood and it generally takes 2 to 3 years to reach effective levels, but the treatment appears to provide 10 to 12 years of continued protection.

Fluoride works in much the same way as boron, except that sodium fluoride is pressed into chalklike rods, which are inserted into the treatment holes. These rods are less dense than fused borate rods, but field trials indicate that this treatment is also capable of moving with moisture to control fungal attack. Boron rods have no restrictions on application while fluoride is a restricted-use pesticide and must be applied by a certified applicator.

Fumigants represent an alternative approach to internal decay control. These chemicals are usually applied in solid or liquid form and then either decompose or volatilize to produce gaseous compounds that diffuse through the wood. Fumigants tend to move farther and faster than water-diffusible compounds and have little need for water for diffusion. In addition, there is evidence that these chemicals interact with the wood and remain detectable for many years (3 to 10 years) after treatment. The negative aspects of fumigants are their higher toxicity profile than boron or fluoride and their volatility. There are currently four fumigants registered for remedial wood treatment and one fumigant, methyl bromide, that is registered for space fumigation. All are restricted-use pesticides.

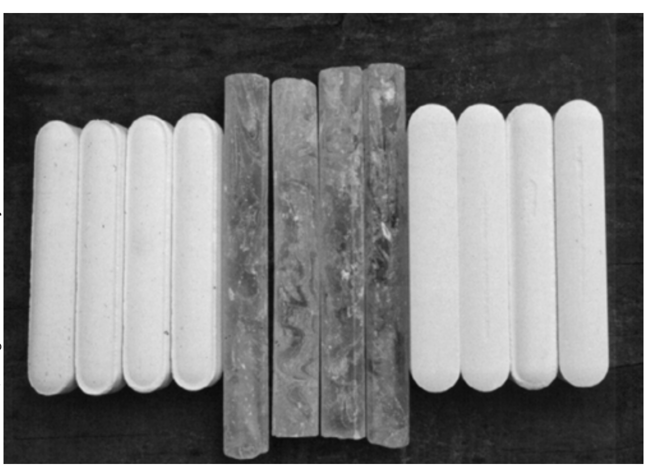

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Figure 19. Examples of solid rods used for internal remedial treatment systems.

Chloropicrin (trichloronitromethane) is by far the most effective of the fumigants. It is capable of moving long distances through woods that normally resist liquid penetration. It remains at effective levels in wood poles for 10 to 20 years after treatment. Chloropicrin is strong lacrymator (tearing agent) and workers exposed to as little as 1 part per million can be affected. It is highly toxic in enclosed spaces and applicators must wear full protective breathing gear. Despite these restrictions, chloropicrin is used to treat transmission poles away from inhabited areas although its use has declined as a result of costly signage requirements on vehicles transporting this material.

The remaining three fumigants are all based on the same active ingredient: methylisothiocyanate (MITC). MITC is active against fungi and insects. In its pure form, MITC is a crystalline solid that sublimes to a gas that moves long distances through wood. Like chloropicrin, MITC has strong interactions with the wood and remains at effective levels for 3 to 10 years after treatment, depending on the formulation used.

Metam sodium (40 percent aqueous sodium n-methyldithiocarbamate) is among the more easily handled liquid fumigants. This compound decomposes in the wood to produce MITC along with a number of other, less toxic compounds. The rate of decomposition is fairly low and, as a result, metam sodium tends to be the least effective of the fumigants. It is often used because it is inexpensive and provides the required 7 to 10 years of protection. The main drawbacks of this chemical are its sulfur odor and its causticity. Many workers complain because they receive skin burns when they spill chemical on their shoes during application. The chemical seeps through their shoes and burns the skin. Proper personal protective gear and careful application can help mitigate but not eliminate this problem.

Pure MITC is also available in aluminum tubes. The tube is opened and inserted into the treatment hole where it will volatilize over time and move into the wood. The rate of release varies with climate (temperature), but numerous field trials have shown that this system provides longer protection than metam sodium and reduces the risk of worker exposure.

Dazomet (also know as basamid) is a crystalline solid that, like metam sodium, must decompose in wood to release MITC. Unlike metam sodium, however, this process is much slower and results in a protective period that can range from 7 to 12 or more years. The primary advantage of this system is its safety — there is little or no odor and the material is available in either powder or pellets. The system can also be tailored to the degree of decay present. Copper naphthenate can be added to the hole at the time of treatment to accelerate the rate of dazomet decomposition to MITC, thereby producing faster fungal control.

Specifications for wood treatment

As with any widely used commodity, there are a number of specifications for the use of treated wood products. The specifications are largely limited to vacuum and pressure treatment, although some specifications have also been developed for dip treatments of windows.

The main standards-writing body for treated wood products is the American Wood Protection Association (AWPA). AWPA Standards are developed through a consensus process involving chemical suppliers, wood treaters, users of the intended product and researchers. The ultimate goal of the process is to protect the consumer while producing a product that is effective at a reasonable cost. The AWPA standardizes preservative systems and then these systems are applied to commodities exposed to varying degrees of risk for decay. This so-called use category system considers the actual risk to which a product will be exposed using a scale from 1 to 5 and is similar to “hazard classes” that are used elsewhere in the world. Basically, the higher the use category, the higher the risk of attack and the more protection required.

The lowest use category is U1, which includes interior exposures with no risk of wetting (Table 3). The protection required here is primarily from social insects such as termites. Most pressure-treated wood is treated for exposures in use categories U3 and U4. U5 is the highest category and designates wood to be used in marine applications where the risk of attack is extremely high.

In practice, users of a treated product would choose their chemical, then determine their risk of decay to select the appropriate use category. For example, someone building a deck might choose U3 and an alkaline copper compound for the treatment. The required penetration and retention of chemical are then dictated by the use category. The goal of this process was to simplify specification for those unfamiliar with the standards.

In addition to the AWPA, the International Code Council (the organization that developed the International Building Code (IBC) that applies throughout most of the United States) has recently become involved in treated wood specification. In this case, the proponent (usually a chemical company) submits data to the ICC, which reviews the data, and, if they feel the data are adequate, will allow that product to be including in the building codes. This approach is considerably faster than AWPA standardization because there are, as yet, no definitive minimum data requirements. As a result, for best performance, it is probably prudent to specify products that have both ICC and AWPA standardization.

The National Window and Door Manufacturers Association (NWDMA) promulgates standards for doors and fenestration (window) products. In general, all exterior-use windows and doors produced under the auspices of this association through their Hallmark Program must be preservative treated. Virtually all treatments under this standard are dip or soak systems that depend on capillary movement into the end grain of the wood. The goal is to protect wood joints, which tend to be the areas most likely to be at risk of decay. This system entails regular assessment of treatment solutions to ensure that adequate levels of chemical are applied.

Protecting the environment

Most wood preservatives used in the United States are inherently toxic. The highest risk associated with these chemicals is during the application process. The U.S. Environmental Protection Agency (EPA) recognizes this risk and has promulgated regulations that affect operation of treatment plants. In addition, the U.S. Occupational Safety and Health Administration (OSHA) oversees worker safety requirements. All of these requirements are designed to minimize the risk to the applicator and protect the environment.

The label and the material safety data sheet (MSDS)

Before you use any chemical, you should read both the material safety data sheet (MSDS) and the product label. The label provides detailed instructions concerning uses, application rates, safety gear required, disposal options and what do in the event of a spill. The label is the law. It is unlawful to use a pesticide outside the label instructions (Figure 20).

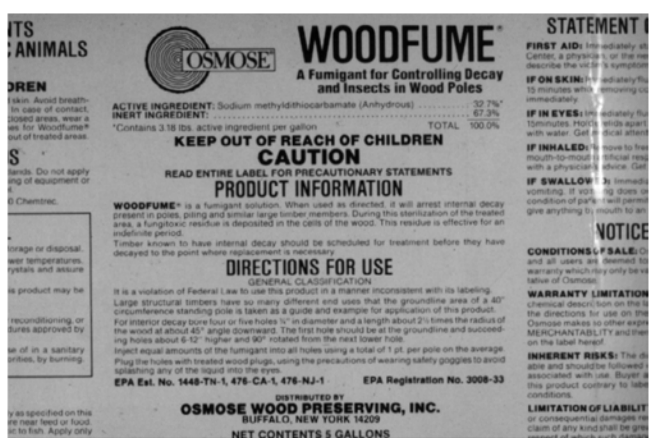

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Figure 20. Example of a pesticide label.

Table 3. Use categories for specifying treated wood according the American Wood Protection Association Standards.

Use category	Risk	Pests of concern	Applications
UC1	Interior construction, above ground dry	Termites and beetles	Interior construction, furnishing
UC2	Interior construction, above ground damp	Decay fungi and insects	Interior construction
UC3A	Exterior construction, above ground, coated and rapid water runoff	Decay fungi and insects	Coated millwork, siding, trim
UC3B	Exterior construction, above ground, uncoated or poor water runoff	Decay fungi and insects	Decking, deck joists, railings, fence pickets, uncoated millwork
UC4A	Ground contact or freshwater, noncritical components	Decay fungi and insects	Fence, deck and guardrail posts, cross ties & utility poles (low decay hazard areas)
UC4B	Ground contact or freshwater, critical components or difficult replacement	Decay fungi and insects with increased potential for biodeterioration	Permanent wood foundations, building poles, horticultural posts, crossties and utility poles (high decay hazard areas)
C4C	Ground contact or freshwater, critical structural components	Decay fungi and insects with extreme potential for biodeterioration	Land & freshwater piling, foundation piling, cross ties and utility poles (severe decay areas)
UC5A	Salt or brackish water and adjacent mud-zone, Northern waters	Saltwater organisms	Piling, bulkheads, bracing
UC5B	Salt or brackish water and adjacent mud-zone, NJ to GA, south of San Francisco, CA	Saltwater organisms including creosote tolerant *Limnoria tripunctata*	Piling, bulkheads, bracing
UC5C	Salt or brackish water and adjacent mud-zone, South of GA, Gulf Coast, Hawaii and Puerto Rico	Saltwater organisms including *Martesia* and *Sphaeroma* spp.	Piling, bulkheads, bracing

The MSDS provides additional information on toxicity, components in the system, first aid, personal protective equipment, handling, storage, transportation of materials and disposal. A manufacturer must provide an MSDS for any pesticide sold, and there should be a copy of that MSDS on file at your work facility. The MSDS should be available for workers to examine and they should be encouraged to read both the label and the MSDS.

Storage of wood preservatives

The label will provide specific guidelines for storage of a given pesticide. In addition, consulting with the appropriate state regulator may be helpful. In general, pesticides should be stored away from other materials, especially foods. Tanks or containers should be stored in a facility capable of containing any spills and should be sufficiently heated or cooled to avoid freezing or overheating. Chemical storerooms should be dry and well ventilated and should have the appropriate signage denoting the types of chemicals present.

Personal protective equipment

All pesticides can be dangerous at some level and an important part of working with these chemicals is to minimize personal exposure. The best way to do this is to carefully plan all operations involving use of chemicals and to remain alert. In addition, wearing the proper clothing and gear can help minimize your risk of exposure. The personal protective equipment (PPE) required for handling individual chemicals can vary widely, but there are several key features (Figure 21). First, the face is one of the most sensitive areas for chemical exposure either through eye contact or inhalation. Wearing protective eye gear is the first step in minimizing the risk of contact. The type of eyewear required depends on the chemical in use and the risk involved, but it is a good habit to always wear protective eyewear when on the plant site.

In some operations, inhalation of dusts or fine vapors may pose a hazard. If so, wearing a mask with filters appropriate for the chemical hazard may be advisable. It is important that any face mask fit properly and that the filters be regularly checked to ensure that they function as designed. All respirators should be approved by the National Institute of Occupational

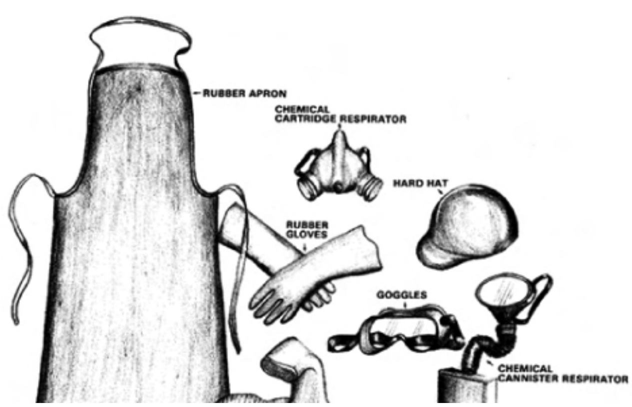

Figure 21. Examples of personal protective equipment (PPE) used in wood treatment operations. Be sure to read the label, the MSDS and manufacturer's instructions to be sure you are using the proper PPE for the chemicals in use at your facility.

Safety and Health for the intended application.

The next most common pathway for a worker to be exposed to hazardous chemicals is through the hands. Anyone working near chemicals should wear gloves composed of an appropriate material and should regularly check the gloves for leaks. Gloves made of leather or other absorbent materials are not acceptable because they can hold absorbed chemicals closer to the skin, thereby increasing the risk of exposure rather than reducing it. Check the label for the appropriate type of gloves for the chemical you are using.

Figure 22. Proper attire for a worker entering the area around the treatment cylinder door.

One of riskiest parts of chemical application occurs when the operator opens the treatment cylinder door or enters the cylinder. The risk is higher because there is an increased likelihood of contact with concentrated chemical. In those instances, the operator should be wearing overalls, a jacket, gloves, boots and a respirator. The types of respirator and other materials will depend upon the preservative used (Figure 22. Once again, the label should be your guide.

Hygiene

An important part of reducing the risk of pesticide exposure is personal hygiene. Simple activities such as thoroughly washing your hands with warm water and soap before eating can limit the risk that chemical contamination on your hands will wind up in your stomach. Similarly, washing before smoking cigarettes reduces the risk of chemical uptake.

A further step to limit chemical exposure is to regularly change your work clothes and to make sure that your clothes are washed separately from those of others in your family. Ideally, clothing used at work should be washed on site or through a commercial facility equipped to handle chemically contaminated clothing.

You should also remove your gloves and wash your hands when moving from a contained area where chemicals are used to other portions of the facility such as a front office. Your gloves may contain chemicals that will be spread as you open doors, answer the phone and move through the facility.

Finally, it is just poor practice to eat, drink, smoke or chew tobacco while handling pesticides. The risk of inadvertent ingestion of chemicals is much too great and is easily avoided.

Disposal

The EPA and various state and local authorities regulate disposal of preservative solutions or water generated during treatment processes as pesticides. The label is the first place to look for information about disposal; however, it is important to consult other resources. Contacting the state Department of Agriculture, Department of Natural Resources or Department of Environmental Quality can avoid serious environmental consequences and legal ramifications of improper disposal of treatment materials.

Empty pesticide containers should be triple rinsed and recycled or disposed of in a manner that is acceptable to local or state authorities. Do not reuse containers for purposes other than their original intended use.

Disposal of treated wood falls into a different category than disposal of treatment chemicals. Within the original treatment facility, treated wood waste – which can include materials that break during handling – must be dealt with like any other chemical waste in the plant under the Resource Conservation and Recovery Act (RCRA).

Once the wood has been placed in service; however, those rules no longer apply. The consumer information sheets for each wood preservative generally specify suitable disposal methods for a given product at the end of its useful life. The first approach is to seek methods for reuse in similar applications. For example, a pole might become a parking barrier or be cut into fence posts. Some utilities have even sawn discarded poles into lumber; however, this is generally only feasible with western redcedar or Douglas-fir, which have large quantities of untreated heartwood. The next approach would be to send the material to a municipal solid waste facility that has a liner and leachate collection. It is important to avoid sending treated wood to construction and demolition facilities because these facilities are generally not lined. More important, many of these operations sort their wood to be burned for energy generation. Treated wood should never be burned for disposal, except in a regulated facility capable of generating the high temperatures necessary complete combustion. To date, creosoted wood can be burned in such facilities, and there are a few facilities that will burn penta-treated wood. None of these materials should be burned in open fires because incomplete combustion can produce toxic gases.

Consumer information sheets

Although treated wood products are not a labeled pesticide, the primary manufacturers of the chemicals used to treated these products have agreed to develop a Consumer Awareness Program. An important part of this program is to provide a consumer information sheet (CIS) that describes the proper use of these materials as well as the protective measures that should be used when handling treated wood. The CIS is important because knowledgeable consumers of treated wood products are more likely to use those products safely.

Glossary

Angiosperm: Plants that produce their seed within fruit; angiosperm trees are also referred to as hardwoods.

Bound water: The water in the wood that is attached to the polymers in the cell wall and is not in a liquid state. Bound water is usually considered to represent up to 27-30 percent by weight of the wood (as compared with free water).

Boulton seasoning: A process for removing water from wood by boiling the wood in oil under a vacuum.

Brown rot: A type of wood decay characterized by attack of cellulose and hemicellulose leaving the wood darkened and with numerous crossbreaks perpendicular to the grain.

Cellulose: A long-chain, repeating polymer of glucose that accounts for the tremendous strength of wood.

Clean Air Act: Federal legislation that regulates the release of potential pollutants into the air.

Clean Water Act: Federal legislation that regulates the release of potential pollutants into surface and groundwater.

Conifer: A tree species characterized by producing seeds in cones or strobili. Many, but not all, species have needles.

Consumer information sheets: Until recently, CISs were distributed to customers purchasing treated wood. They contained information on safe handling of the product.

Deterioration: Any negative effect on the properties of a material.

Diffusion: The process by which materials move from higher to lower concentrations.

Empty cell treatment: A process where pressure is applied to wood before adding treatment solution, then the press is further raised. The process results in lower retentions of preservative.

Environmental Protection Agency (EPA): The federal agency charged with regulating, among other things, the use of pesticides.

Extractive: Compounds other than the three primary polymers that can be extracted from the wood.

Fibers: Long cells in angiosperms that provide strength to the wood.

Federal Insecticide, Fungicide and Rodenticide Act (FIFRA): Federal legislation regulating the sale, distribution and use of pesticides in the United States.

Fixation: The process whereby a wood preservative reacts with the wood or other compounds to become resistant to leaching.

Free water: Liquid water present in the wood. For most species, liquid water is present when the wood moisture content exceeds 27-30 percent (wt/wt).

Full cell treatment: Pressure treatment process whereby the wood is subjected to a vacuum, the treatment solution is added, then pressure is raised. Designed to produce maximum uptake of treatment chemical.

Fumigant: A biocide that moves through materials in the gaseous phase.

General-use pesticide: A pesticide that may be purchased and used by individuals without any special certification or licensing. Compare with "restricted-use pesticide."

Gribbles: Common name for a marine borer in the genus *Limnoria,* which are free-living crustaceans that attack wood surfaces in saline waters.

Gymnosperm: Technical name for conifers. Means "naked seed."

Hardwoods: Tree species that are angiosperms. Has no relation to the hardness of the wood.

Heartwood: Nonliving portion of a tree. Heartwood results as sapwood dies. Some heartwoods contain toxic chemicals that give the wood exceptional resistance to biological attack.

Hemicellulose: A wood polymer containing a mixture of sugars, depending on the species. Hemicellulose is less resistant to degradation than cellulose.

Incising: A process to improve wood treatment by driving metal teeth into the wood to increase the amount of end grain exposed to fluid flow.

Kerfing: A process to reduce checking of wood by making a saw cut from the wood surface towards the pith before preservative treatment.

Kickback: The chemical that is forced out of the wood as pressure is released at the end of the pressure treatment process.

Label: The document attached to a pesticide. The label provides directions for effective product performance while minimizing risks to human health and the environment. It is a violation of federal law (FIFRA) to use a pesticide in a manner inconsistent with the instructions on its label.

Lignin: A complex heteropolymer of repeating units of phenyl propane. Considered to be the material that binds cellulose and hemicellulose together.

Material safety data sheet (MSDS): Required for all chemicals. Contains information on properties of a material, including toxicity, handling procedures and what to do in case of an accident.

Molds: Fungi that produce pigmented spores on the surfaces of materials. For the purposes of lumber, mold fungi usually do not discolor wood but their spores mar the surface appearance. Some molds can produce toxic compounds, but these fungi are mostly irritants.

Net injection: The amount of treatment chemical remaining in the wood. Usually calculated as:

$$\frac{\textit{Gross injection} - \textit{Kickback}}{\textit{Wood volume}}$$

Oxidative stain: Any of a group of reactions between oxygen and compounds in the wood that lead to discoloration. These stains usually occur on wet wood stored for long periods.

Personal protective equipment (PPE): Any item used by personnel working with pesticides to protect them from possible exposure. PPE includes clothing, respirators, eye protection or any other equipment that limits chemical exposure.

Phloem: The external cells on a tree that function to move nutrients between the leaves and the roots.

Pholads: Clamlike mollusks that attack wood in warmer salt water. Pholads do not use wood as food, only for shelter.

Pits: Connections between cells in the wood that allow fluids to move through the tree. Pits can be simple, semibordered or bordered.

Protozoa: Single-celled organisms that live in the digestive tract of many insects, including termites, and aid in cellulose digestion.

Resource Conservation and Recovery Act (RCRA): Federal legislation that regulates the disposal of material, especially chemicals.

Retention: The amount of chemical delivered into the wood; usually expressed as weight of chemical per unit volume.

Restricted-use pesticide: A pesticide that is available for purchase and use only by certified pesticide applicators or persons under their direct supervision. This designation is assigned to a pesticide product because of its relatively high degree of potential human or environmental hazard. Compare with "general-use pesticide."

Retort: A vessel used to treat wood using vacuum or pressure processes.

Reuping tank: A tank that is used to contain treatment solution and where pressure or vacuum can be applied.

Sapwood: The living part of the wood in a tree that conducts fluids.

Sill plate: The wood that is attached to the foundation to secure a structure. This wood is usually pressure treated with preservatives.

Soft rot: A type of wood degradation caused by many soil inhabiting fungi in which the S-2 cell wall layer is selectively degraded either by erosion or by formation of diamond shaped cavities. Soft rot normally occurs on the wood surface, especially in wet soils.

Softwood: Common name for gymnosperms. Does not denote hardness of wood.

Stain: Any discoloration of wood.

Superfund: Federal legislation – the Comprehensive Environmental Response, Compensation and Liability Act (commonly known as Superfund) – that established a funding mechanism for cleaning up contaminated industrial sites.

Symbiosis: Any relationship where two organisms interact and each gains from the interaction.

Thermal treatment: Any of the processes where wood is heated in oil, then cooler oil is added to create a vacuum that draws solution into the wood. Normally used for western redcedar poles.

Toxic Substances Control Act (TSCA): Federal legislation that governs the manufacture and use of toxic industrial chemicals. TSCA excludes drugs, pesticides, cosmetics and radioactive agents.

Tracheid: The primary longitudinal cell type in gymnosperms that functions for both structure and fluid transport.

UV damage: Ultraviolet light is a component of sunlight that releases energy into wood, leading to degradation of lignin. Causes the typical graying of wood exposed to sunlight.

Vessel element: The conducting elements in angiosperms.

Viscosity: Resistance of a fluid to flow.

White rot: A type of fungal decay characterized by loss of all three wood polymers with the wood becoming bleached and white at the advanced stages of attack.

Wood modification: Any process that that alters the wood to change its properties including reactions between polymers, bulking of wood cells or other processes that reduce the risk of biodegradation with pesticides.

Xylem: The conducting tissue in the sapwood of the tree.

Emergency Telephone Numbers

Regional Poison Center 1-800-222-1222

For pesticide poisoning emergencies, state poison centers provide service that is free of charge to the public and is available 24 hours a day, seven days a week.

Environmental Emergency Response

For pesticide spill emergencies

Iowa - Iowa Department of Natural Resources 515-281-8694
Kansas - Department of Public Health Protection, Bureau of Environmental Remediation 785-296-1503
Missouri - Department of Natural Resources 573-634-2436
Nebraska - Department of Environmental Quality 402-471-2186

National Pesticide Safety Team Network (Chemtrec) 1-800-424-9300

The National Agricultural Chemicals Association has a telephone network. This network can tell the applicator the correct contamination procedures to use to send a local safety team to clean up the spill. An applicator can call the network toll-free at any time.

National Pesticide Information Center 1-800-858-PEST

Call the NPIC network toll-free.

U.S. Environmental Protection Agency (EPA) 913-281-0991

All major pesticide spills must by law be reported immediately to the U.S. Environmental Protection Agency, Region VII Office, 901 N. 5th Street, Kansas City, KS 66101. The following informatiaon should be reported:

1. Name, address, and telephone number of person reporting
2. Exact location of spill
3. Name of company involved and location
4. Specific pesticide spilled
5. Estimated quantity of pesticide spilled
6. Source of spill
7. Cause of spill
8. Name of body of water involved, or nearest body of water to the spill area
9. Action taken for containment and cleanup

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