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The Treatment of Wood (Lumber)-2% Copper Naphthenate in Kerosene a Treatment for Decay Fungi, Insects-Termites, Ants and Beetles

Earl A. Sealy[1*]

[1]PhD, Formerly of Lynn University, 3601 N Military Trail, Boca Raton, FL33431, U.S.A

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***Corresponding author:** Earl A. Sealy
PhD, Formerly of Lynn University, 3601 N Military Trail, Boca Raton, FL33431, U.S.A

Abstract **Review Article**

The major agents for wood decay are decay Fungi, Termites, Beetles and Ants. This article reviews the current methods for treating wood (lumber) which includes the use of heat treatment and chemicals. The chemicals procedures used to resist the agents of decay are mentioned. Each agent of decay is outlined as well as the best preventative measures to resist that agent of wood decay. Construction measures that would help prevent wood decay along with treatment plans are discussed. How each agent of decay causes the wood to rot is mentioned and its warning signs. These warning signs enable the treatment plan for each agent of decay. It is recommended that all lumber (wood) used in construction should be treated before use. There is recommendation for the discontinuation of some wood treatment chemicals because of their danger to humans and pets. 2% Copper Napthenate in Kerosene is highly recommended as a chemical combination that can be used to treat all agents of wood decay. This is important because some chemicals are specific to a particular agent of decay and in this regard more than one treatment is required to hinder the agents of wood decay. A treatment plan for the use of 2% Copper Napthenate in Kerosene is outlined and the use of a Modified Gedrian's Bath is proposed to treat wood at the commercial level. Engineering dimensions and temperature range for the use of 2% Copper Napthenate in Kerosene using the modified Gedrian's bath is explained. The dangers of using 2% Copper Napthenate in kerosene is explained but these dangers are superseded by the economics of its use and its broad spectrum against all agents of decay. It is noted the limitations of heat treatment.

Keywords: Decay, Fungi, termites, beetles, ants, lumber, wood, treatment, preservative, kerosene, Gedrian's Bath.

INTRODUCTION

Wood treatment refers to protecting wood from damage caused by moisture, decay fungi, insects-ants, termites and beetles. The aim of wood treatment is to extend the life of the wood. The substances used in the treatment of wood are called preservatives. For a wood preservative to be effective it must enter the cells of the wood. There are 16 commonly used wood preservatives, namely, Chromated copper arsenic, Creosote, Pentachlorophenol, Propiconazole, Triadimefon, Acid copper chromate, Alkaline copper quaternary, Borates, Copper azole, Copper Naphthenate, Sodium silicate based preservatives, Potassium silicate based preservatives, Bifenthrin spray preservatives, Linseed oil, Light Organic Solvent Preservatives, and Epoxy.

The methods of allowing the preservatives to enter the wood are by non-pressure processes and pressure processes. There are numerous non-pressure processes of treating wood, namely, brushing or spraying, dipping, soaking, steeping or by means of hot and cold bath. Other non-pressure methods are charring, applying preservative in bored holes, diffusion process, sap displacement, heat treatment, wood acetylation, and mud treatment. The pressure processes are those in which the treatment is carried out in closed cylinders with pressure. Such methods include the full cell process, the fluctuation pressure process, high pressure sap displacement and incision.

This article would review the organisms that cause wood damage, their methods of damaging the wood, preventative measures through the use of wood preservatives, methods used to get preservatives into the wood and heat treatment, the use of painting for moisture control, and the novel approach of using 2% Copper Naphthenate in Kerosene in a Modified Gedrian's Bath for preserving all types of wood.

Moisture Prevention and Control (External Elements)

Wood is a very popular building material for a wide variety of reasons. It is very available, replaceable, natural resource. It is easy to work with, cost efficient and available in different forms that offer varying degrees of flexibility, strength and size (Fitzgerald, 2007). Mold, fungi, termites, beetles and ants are encouraged into wood because of moisture related problems. The seeds of potential moisture problems are present in rainfall and humidity during the construction process and that released daily into the air, through cooking, showers, and air conditioning (Fitzgerald, 2007). Unfortunately, these problems can begin to develop deep within the structure of the home behind layers of plaster and dry wall, underneath tile and linoleum, bathroom plumbing, sink plumbing, tiles in the sink and bathroom, kitchen fixtures and plumbing, or growing unnoticed in attics and basements. Additionally, there are external elements that introduce moisture conditions to the wood and hence building structures. The most important external elements that affect the appearance of the wood are fluctuating climate conditions and weather effects such as the sun, rain, wind, snow and polluted air t(Protection of Wood against External Influences). To protect the wood from danger caused by various weather factors a large variety of paints are available. Paint is not a preservative. However, it helps to prevent decay by protecting wood from intermittent wetting, especially if applied to ends and edges as well as to exposed faces and so maintained as to allow the fewest possible cracks at joints (United States Department of Agriculture, 1986). Painting is not a substitute for good construction and maintenance. In warm moist climates, molds may develop on the paint, or on the dirt or small insects that adhere to it, and make it unsightly. Paints having a low oil content and much Zinc oxide is safest in this regard (United States Department of Agriculture, 1986).

Too high humidity leads to dimensional instability of wood, tensions in wood, tensions between a coating and wood and tensions in a paint film itself. Too much humidity causes cracking and peels off the coating and the coat losses its protective function. Temperature changes have influence on shrinking and extension of a paint film, as a consequence they increase the possibility of peel offs. Hence, in mountain areas with high temperature differences between day and night, damages are larger and more frequent.

Ultraviolet light causes degradation of the surface of the wood and depolymerisation of a paint film. Frequent rinsing of a pint film due to rainfalls may reduce its thickness and quality. Smog and various gases from the industrial areas are combined with rain and form acids which cause corrosion and wear off a paint film. As soon as first damages occur on the coating, one would have to renew it, as it would provide a longer term protection. Also against these damages wood may be effectively protected with a combination of construction and surface protection.

The coatings used for surface protection of exterior wood are generally divided into:

(a) Enamels
(b) Lacquers
(c) Stains

Enamels are film forming thick layered coatings, which completely cover wood texture and possible detects in wood. They contain a large quantity of pigments and are available in different colour shades. Their main advantage is water repulsion and low vapour permeability, which is at the same time a disadvantage with wood. When the wood is exposed to weather influences, the coating decays, and humidity comes into the wood through the film. When this happens there is a movement of the wood and microcracks appear in the coating film. When a large quantity of humidity accumulates in the wood it causes blisters and peel off of a coating film.

Lacquers are enamels without pigments, in the past they were used as interior coatings when they wanted to keep as natural a wood appearance as possible. At the application of lacquers similar problems appear as with enamels. Because lacquers do not contain pigments or fillers, it is necessary to protect wood from yellowing or darkening because it absorbs ultraviolet radiation. Ultraviolet light absorbers are usually added to lacquers. Lignin is the wood component most sensitive to lacquers. Lignin degradation results in a substance exuding to the surface of the wood which can be rinsed off. The result of rinsing with water and activation of ultraviolet rays is a quicker process colouring the surface of the wood into grey and the removal of young components. This is characteristic of the surface components. The degradation level of the wood is proportional to the exposure time to the sunlight. Direct exposure is the most intensive.

Stains are less pigmented coatings which form a thin film on wood and paint the wood surface transparent so that the wood’s structure is evident. Stains are water repulsive and due to their high permeability they enable “breathing’ to the wood. In these cases wood humidity fluctuates much more than at non-permeable or less permeable coatings (enamels). Due to weather influences stains slowly erode and the film thickness gets thinner. The advantage of stains is their easy application at renovation. Before repeated application the surface of the wood should be sand, wipe or refresh with one or two coats of stain.

To protect wood against external elements an annual inspection is recommended. Attention should be given to horizontal surfaces as they are more exposed to weather influences than vertical ones. The sky directions have an influence on the speed of decay; wood surface on the southern and western sides are more worn out than in the north and east. Attention should also be given to building furniture and damage caused by hail. Stain coating in this regard is the best treatment.

Fungal Decay of Lumber

Wood decay is caused by microorganisms called fungi. The major organisms is a group of fungi belonging to the species Serpula lacrymans. They are a group of fungi which digest the cellulose and hemicellulose in lumber (wood) (Palfreyman and Low, 2002). Fungal decay is spread by spores which are present in most buildings. The minimum moisture content of timber (lumber) for spore germination is between 28-30%. This fluctuates at higher levels for some groups of decay fungi. The relative humidity for fungal decay must exceed 95% (Ridout, 2000). It is easy to see fruiting bodies of fungi from which their spores are distributed (USDA, 1986). The fungal defects of timber (lumber and wood) can be observed by the following symptoms, Blue stain, Brown rot, Heart rot, sap stain, wet rot, white rot, and dry rot. Some fungi merely discolour wood, but decay fungi destroy the fiber (USDA, 1986). Decayed wood is often dry in the final stages, but not when decay is taking place, because the fungi cannot work fungi is a minor problem in the driest part of every country.

Two groups of fungi spread from moist soil or wood into dry wood by conducting water to wood through vine like structures (USDA, 1986). Occasionally, they cause great damage to buildings, but fortunately most fungi cannot conduct moisture in this way (USDA, 1986). Fungi that cause wood decay soften the wood, make it spongy or cause it to shrink or crack and crumble (USDA, 1986).Two kinds of fungi are responsible for structural failure-brown rot fungi and white rot fungi. When wood is infected with brown rot fungi, the wood darkens and cracks across the grain in a cubicle pattern. It eventually shrinks and become crumbly. When white rot fungi infects wood, the wood may lose colour and appear bleached. White rotted wood does not crack or shrink. It retains its outward shape and feels spongy (Kirker and Glaeser, 2017). A third but less important kind of decay called soft rot decay, occurs under very wet conditions or on wood surfaces that are alternatively wet and dry over a long period of time. Soft rot generally causes the outer surface of the wood to become soft when it is wet, but the zone immediately under the soft rot is typically still firm (Kirker and Glaeser, 2017). None of the fungi that cause wood decay produces the continuous, clear-cut tunnels or galleries characteristic of termite infestation (USDA, 1986).

The USDA (1986) outlined 12 errors in construction or maintenance that can lead to fungal wood decay.

1. Undrained soil and insufficient ventilation under basement less houses.
2. Wood such as grade stakes, concrete forms, or stumps left on in soil under houses.
3. Wood parts of the house in direct contact with the soil, especially at dirt- filled porches.
4. Wood parts embedded in masonry near the ground.
5. Use of young (untreated) and infected lumber.
6. Sheathing paper that is not sufficiently permeable to moisture vapour.
7. Inadequate flashing at windows, doors and roof edges.
8. Poor joinery around windows and doors, and at corners, and inadequate paint maintenance.
9. Lack of rain gutters and roofs without overhangs.
10. Unventilated attics.
11. Roof leaks; leaks around shower-bathtub combinations, kitchen fixtures and laundry rooms.
12. Failure to use preservative treated or naturally durable wood where moisture cannot be controlled.

To prevent decay the decay fungi should be kept from entering the lower part of the structure. The use of dry wood is most practicable and the building should be constructed in such manner it would be kept dry most of the time. Spores of decay fungi are airborne and always a treat to the wood. 20% moisture or more in the wood is a prerequisite for fungal growth. Air dry wood contains less than 20% moisture (USDA, 1986).

Old and sound lumber should be used at all times. Compared to green lumber, old and sound lumber has a better nail-holding capacity, shrinks and warps less, and is safer from fungal decay. During construction lumber should be stored off the ground to protect it from rain, and it is advisable to build sheds.

If green lumber is available it should be open-piled on the job and allowed to dry as much as possible before it is used. The piles should be supported off the ground, and the layers should be separated from each other by narrow strips of 1-inch dry lumber. Boards in each layer should be spaced such that they allow air to move around them on all sides. If the piles cannot be put under cover, slope them toward one end. Overlap the boards in the top layer and extend them out at the front and back to keep rain off the board beneath (USDA, 1986). The decision not to build a shed is not protective. Fungal spores are airborne and hence everywhere. Once conditions of adequate moisture is available the dormancy of the spores will be broken and they will germinate on the exposed lumber. These germinated spores initiates fungal growth and hence fungal rot. It is therefore essential to prevent wood (lumber) from getting wet on the job site.

For protection against rain and snow roof overhangs, slanted shingles, gutters and downspouts, as well as non-corroding metals should be used. Roofs with considerable overhang, both at eaves and gable ends, give more protection to the rest of the house (building) than those with a narrow overhang (USDA, 1986). A good roof overhang can do much to offset decay hazards in siding and around windows and doors (USDA, 1986). It is suggested that a roof overhang of 12 inches is desirable for a 1-story house (building)(USDA, 1986). In regions where heavy snow exists, the lower courses of shingles should be flashed (slanted) to keep melting snow from working into the walls. The snow will slide further from the wall foundation. Gutters and downspouts are particularly important for houses (buildings) without overhanging eaves. Horizontal wood surfaces or projections, including windows and doors should be covered with a non-corroding metal.

It should noted that architectural frills or novel forms of construction should be studied carefully to determine whether they will provide entrance points or pockets of moisture that will exist long enough to initiate fungal decay. Joints and exposed ends should be looked at carefully as these are ready points for the entrance of water. The sapwood of all species of trees from which lumber can be made is susceptible to fungal decay. The heart wood of most species of plants that produce lumber, recognized by its darker or redder colour is more durable but still at risk to fungal decay. Although the Douglas-Fir, Southern pine, and white oak heartwoods are considered moderately resistant to fungal decay they are very at risk without treatment. The following species of trees produce lumber that is resistant or very resistant to fungal decay, namely, cedar, red wood, bald cypress (old growth), catalpa, black cherry, chestnut, Arizona cypress, junipers, black locust, mesquite, red mulberry, burr oak, chestnut oak, post oak, Oregon white oak, gambrel oak, Osage orange, sassafras, black walnut, pacific yew, Huon pine, merbau, ironbark, eastern red cedar, Totara, Puriri and kauri (Wood Treatment, 2017; Wikipedia, 2017).

Paint is not a preservative. However, it helps to prevent fungal decay by protecting wood from intermittent wetting, especially if applied to ends and edges as well as exposed faces and so maintained as to allow the fewest possible cracks at joints (USDA, 1986). The intermittent wetting if not controlled by painting would allow moisture to enter ends, edges, exposed faces, and cracks and joints which would favor fungal spore germination and hence initiate fungal decay. Painting would allow the water through intermittent wetting to run off. Run off water containing spores would not be harmful to the lumber (wood) because they must be a catchment point for the spores on the lumber, that is, the spores must settle on the lumber to cause fungal decay. Painting has a disadvantage if it is placed on young wood, that is, wood not old and dry. Such wood when painted may favor fungal decay if spores are present before painting and the trapped moisture permits fungal spore germination and therefore initiate fungal decay. The procedure for young wood would be to treat if after allowing it to dry before painting. Painting is not a substitute for good construction and maintenance. Holes should not be filled with paper, putty or caulking and then painted to show a visible finished end to the construction. In warm moist climates or in rooms with very moist air, molds may develop on the paint, or on dirt, or small insects that adhere to it and make it unsightly (USDA, 1986). Paints containing a small percentage of oil and high Zinc oxide protect against molds and small insects (USDA, 1986).In regions mildew is common fungicides are sprayed on the painted building. 2% copper metal is a known fungicide (Wikipedia, 2017). One fungicide I recommend is 2% copper Naphthenate in kerosene. It is flammable and should be used with caution. The method of application is spraying.

To prevent fungal decay all wood use in construction must be treated. Regardless, to the natural resistant to fungal decay woods treatment would protect against the other organisms that cause wood decay. Despite its usage that is sills or plates, sleepers, joists, beams, and girders in or on concrete, and exposed porches and steps. Conclusively, for a wooden structure every piece of wood used must be treated. To be fully protected the wood must be fully impregnated with the preservative. The preservative I recommend is 2% Copper Naphthenate in Kerosene where the lumber would be treated before sale in a modified Gedrian's Bath. At the job site ends could be treated or brushing with the same compound.

To safeguard wood work in the foundation of a house from fungal decay the house should be built well above the ground (old type housing). If the foundation is low, sill, joists, floors and lower walls may suffer heavily from decay fungi that come from the soil. Fungal decay may also be hastened by moisture that comes up from the soil as vapour and condenses on the cold sills or the outer ends of joists when the outdoor temperature is low (USDA, 1986).

Drainage is another phenomenon to be accounted for in the prevention of fungal decay. Moist building sites should be well drained (USDA, 1986). The surface of the soil should slope away from the house, and downspouts should be discharged into approved drains or into masonry gutters or splash blocks that lead the water several feet away from the house (USDA, 1986). Dense shrubbery or vines planted too close to the house could interfere with drainage and air movement thus promoting the growth of fungi that can cause fungal decay (USDA, 1986).

For the greatest safety to permanent buildings, there should be no wood soil contact of any kind (USDA, 1986). Wood in buildings at the lower surface should be thoroughly with a suitable preservative to prevent fungal decay and wood decay caused by the other organisms-termites, ants, and beetles. Wood skirting should be kept off the soil by putting a lower concrete base under it; the same should be done with lattice, or it should be suspended above the soil with a clearance of at least 4 inches (USDA, 1986). Wood housings around plumbing and water pipes under the house should be done with treated lumber and there should be spaces to prevent fungal decay. For wood housing around pipes cold enough to sweat mineral insulation is preferable (USDA, 1986).

Good building practice requires that foundation walls supporting wood from construction should extend at least 8 inches above the finished grade, with at least 6 inches of the exterior wall exposed. This means that the bottom of sills or sleepers would be at least 8 inches above finish grade (USDA, 1986). The minimum interior clearance between the ground and the bottom of joists should be 18 inches and the girders 12 inches (USDA, 1986)

Places filled with dirt under concrete or masonry such as a porch floor frequently provides points entry for decay fungi (USDA, 1986). If the dirt under the porch comes up to the level of the sills, or joists of the house, due to low windows, these can be protected from contact with the soil by non-corrosive metal flashing or by building the porch as an independent unit separated from the house at all points by an air space 2 or 3 inches in width and covered at the top (USDA, 1986). A safe and perhaps easier method is to abandon the use of dangerous dirt fill, pour a reinforced concrete porch slab and the use of low windows. In the concrete porch slab a sufficient opening must be left to allow removal of wood forms and to serve as a permanent access for inspection. The dirt fill is dangerous because it can be the site of the initial attack to the house or building from other decay organisms-ants and termites. Low windows are a potential danger for burglary, thieves, and an easy access for soil organisms that can destroy the wood structure-termites and ants. Additionally, the spores of the fungi that cause fungal decay can adhere to the wooden structures in low windows due to moisture vapour from the soil. The adherence of the spores to the wooden structure can initiate spore germination and hence fungal decay.

Embedding wood in concrete near the soil is an invitation to fungal decay. This is especially true of stakes left projecting through the concrete. For slab on the ground construction, plates, sleepers and any wood in contact with the slab should be treated with a preservative. I recommend 2% Copper Naphthenate in Kerosene as the preservative to use. Spraying or brushing is the method to use. For cuttings. Protect wood posts resting on concrete floors from moisture by placing then or raised concrete bases and using treated wood.

If a wood floor is laid on a concrete slab, there should be a damp proof membrane either under, in the upper part of, or on the slab (USDA, 1986). The wood should be laid with treated wood. Linoleum or other vapour barrier coverings on wood floors increase the chance of trouble where moisture may rise through the slab from the ground beneath and cause fungal spores to germinate and initiate fungal decay. Vapour barriers are beneficial if placed where they will keep moisture from getting into the wood, but harmful if they keep moisture from getting out (USDA, 1986). Around houses with wood floors and masonry walls, the outside soil grade should be kept below the level of the joists unless the wall is thoroughly moisture proof. Joists or girders framed into masonry should have a I/2 inch air space on each side and at the ends, or the ends should be damp proof (USDA, 1986).

Under houses without cement basements, the soil supplies moisture vapour to the air. This moisture is potentially dangerous to the houses because house get wet and fungal spores can germinate and initiate fungal decay. In winter the moisture in the air under the house may condense on the cold sills and joist ends, just as the moisture in the air condenses on a glass of ice water. This “sweating” if continued, wet the wood to a point where fungal decay can be initiated. To avoid the problem with sweating and also to make inspections possible, leave a crawl space under house with at least an 18 inches clearance under joists (USDA, 1986).

According to USDA (1986) there are two ways to prevent condition. One way is to provide cross ventilation for all points of the crawl space by openings in the foundations or skirting on opposite sides of the buildings, best near the corners. For all houses, every 25 linear feet of wall should have a 1 square foot vent. If the vents have grills in them, count only the area of actual openings. If the vents have louvers, they should be 2 square feet for every 25 linear feet. If both louvers and 16 mesh screen is used there should be three openings per 25 linear feet of wall. Insect screens should cover all openings used. The insect screens will keep out termites and beetles. A ¼ inch mesh should also be used to keep out rodents. Because insect screens commonly become clogged with paint, dirt and cobwebs they should be inspected and clean regularly. Keep vents open in winter, with such insulation of pipes and floors as may be needed to protect from cold. The moisture sites of houses are the areas that require a lot of ventilation (occupied houses). It is important to note that when houses are not occupied and not heated during winter, condensation may occur on all floor members instead of being limited to those near the outside.

The second way to prevent condensation is to place a vapour resistant cover over the ground in the crawl space. This stops at its source the moisture vapour that causes sweating and makes it possible to use smaller vents or to close all vents during cold weather without initiating fungal decay (USDA, 1986). A smooth surface roll roofing weighing 55 pounds or more per roll of 108 square feet has been used successfully under many houses (USDA, 1986). Roll out the roofing with 2-inch lap at the edges; no cementing is needed (USDA, 1986). Other vapour barrier materials such as 6-mil polyethylene may be used in this way, but good evidence is lacking on their effectiveness (USDA, 1986).

Covering the basement less house also increases the likeliness of moisture condensation in winter in attics, and possible fungal decay. Where the water supply enters the house at a temperature as low as 50 degrees F, there may be enough condensation of moisture on concealed pipes in walls and floor to favor fungal decay (USDA, 1986). In houses with such a supply system, insulate the cold water pipes before they are enclosed. It is important to note that ventilation cannot fill the need in such cases (USDA, 1986).

As was stated earlier, overhanging roofs and flashing help to protect wood from moisture that cause fungal decay. Some fungal is to be expected in porch steps, floors, railings, or pillars exposed to rain. This can be prevented by ventilation. Abundant ventilation should be supplied under porches, and the lower ends of stain carriages or stringer should be based on bricks, stone or concrete, and be well above the ground. Remember that, all wood should be treated with a preservative and painted or stained. The construction should be designed where possible to shed rainwater. The railings should be built so that the handrail extends over the top of the posts or balusters and keep them from taking rainwater through the ends. The porch floors slope towards the outside and make sure that frames for screens have openings through the bottom of the frame to let rainwater escape.

Wood preservation will have considerable protection for porch steps, floors, railings, or pillars and porches exposed to rain, provided the wood is dry at the time of the treatment and not put in direct contact with the ground. Where the entire length cannot be immersed, the ends may be dipped and sides liberally brushed. The lumber should be always treated after it is cut and fitted, but before it is put in place, so that all ends have the protection. Solutions of Pentachlorophenol, 5 percent, containing a water repellent, and Copper Naphthenate containing 2 percent of metallic copper, are among the preservatives that have given good results in dipping tests for service above ground. If the wood is to be painted mineral spirits or Naptha are good solvents (USDA, 1986). I recommend that the preservative and also water repellent to use would be 2% Copper Naphthenate in Kerosene. The 2% should be based on the copper metal and administered as above. It should be noted that the preservative/ water repellent is safe near humans and plants and is flammable, hence it should be used with caution.

A window sash may discolor or have fungal decay, especially in cold climates where water condenses on the inside of the glass in winter and runs down into the wood. A storm sash is effective in decreasing such condensation (USDA, 1986). To prevent moisture absorption by the wood, the sash should be primed and back puttied before glazing (USDA, 1986). Much of the sash and some of the window frames on the market have been dipped treated with a water repellent preservative which increases their resistance to fungi (USDA, 1986). Again I recommend the use of 2% Copper Naphthenate in Kerosene. The lower ends of window and door screens, if not treated by the manufacture can profitably be soaked for some time prior to painting to get the preservative into the joint. Any surfaces newly exposed when fitting should be given one or two heavy brush coats of the water repellent/preservative I mentioned earlier.

Garage doors should be built to shed water (USDA, 1986). Rails braces, or moldings are best placed on the inner face of the door. If on the outside, they trap water between them and vertical members. The use of treated doors or the application of a preservative to all surfaces and joints is recommended. Doors frames should not extend into the concrete (USDA, 1986). Any glass in the door should be set in putty, and the wood cleats bedded in putty (USDA, 1986). The overhead or lateral sliding type door is less exposed to conditions favoring fungi than the outward – swinging type (USDA, 1986).

Roofs without overhang or gutter let too much rain water run over the siding (USDA, 1986). Leaks in cornices, gutters, or downspouts can lead to fungal decay in the walls below them, in well maintained houses; however, frame walls well above the soil line suffer from fungal decay only when there is some unusual combination of the factors that permit the accumulation of water in the siding or the interior of the wall. According to USDA (1986) common sources of excessive moisture are green lumber, wet plaster, condensation in the wall of water vapour from the interior of the house during cold weather, rain driven by wind, and excessive running of lawn sprinklers against the lumber. According to the article one of the most important safeguards is to use only dry lumber free fungal spores or symptoms of fungal decay.

Flashing of non-corroding metal should be used to keep water out of the joints that are otherwise difficult to protect. Treated lumber with a preservative and water repellent would help in this regard.

Ornamental drop siding with rounded or slant lower edges, which lead water into joints, is not so safe as the more usual types shaped so that water drips from the lower edge of each board to the face of the siding board next below. Fungal decay of siding is the most frequent in ends that are butted against the trim, as at windows, doors, and corners. If the sidings ends are under the trim, as is common with drop siding, less moisture gets into the ends and there is less chance of fungal decay (USDA, 1986).

Some building papers, especially those with a continuous internal layer of asphalt or a shiny asphalt coating, greatly hinder the passage of moisture vapour. In a cold climate such vapour barriers help to keep the wall dry if put on the inner face of the studding (USDA, 1986). For sheathing paper outside the studding only "breathing'" papers should be used (USDA, 1986). Most asphalt saturated but uncoated papers weighing as much as 15 pounds per 100 square feet may be too impervious for sheathing paper. Insulating material having a vapour barrier surface should be placed in the wall so that the barrier surface is at the inner (warm) face of the wall (USDA, 1986).

It is always worth the expense of using treated siding wood because it increases the life of the wood. This by far overrides the expense of replacing-labour and materials. Also give all surfaces of siding board near the bottom of the wall an additional heavy brush or spray treatment with a preservative (2 % Copper Naphthenate in Kerosene) before painting. For greatest safety the lowest board should be 6 inches or more above the outside soil level (USDA, 1986).

In time, roof shingles deteriorate from weathering, mechanical wear, and fungal decay due to rain leaks, and improper flashing (USDA, 1986). Flashing sometimes is troublesome in sheathing and facia boards. Leaks may also occur near the eaves from the water that backs up under melting snow, unless flashing is carried up under lower shingles (USDA, 1986). Condensation on the lower surface of the roof of moisture vapour that comes from living quarters or moist soil under basement less houses also can lead to fungal decay. Such condensation is rare under slate or wood shingle roofs unless a non- breathing sheathing paper has been used in the roof. It is common in winter under asphalt roofing, and in cold climates, particularly if there is ceiling or roof insulation without an efficient vapour barrier below it (USDA, 1986).

Soil moisture under the house can be stopped at its source by a soil cover as mentioned earlier. Flues for ventilating basements or crawl spaces should never open under the roof. Vapour barrier paint on walls and ceilings of living quarters, or vapour barrier paper or foil just above the ceiling is helpful (USDA, 1986). Attics should be ventilated, with vents at opposite sides and preferably near the peak, with a total unobstructed area of 1/300 of the ceiling area (USDA, 1986). Multiply the vent area by 1.25 if the vents are covered by 1/8 inch mesh screen, or by 225 if louvers are also added. In addition to ventilation, flat roofs particularly need protection by vapour barriers properly placed, because it is often difficult to get free air movement under all parts of such roofs (USDA, 1986).

Plywood and the various fiberboards used in recent construction generally require the same precautions as lumber. Resin glues used in exterior grade plywood are fungus resistant but do not penetrate the wood enough to make it fungus proof. With either fiberboard or plywood, joint construction should be carefully designed to prevent the entrance of rain water (USDA, 1986). On edges of exposed plywood use a heavy coat of thick paint or other moisture resistant coating. Avoid or flash horizontal joints or water tables on the outside of walls because they often let rain water get in behind them. Use exterior grades of plywood not only in places exposed to rain but preferably also where the plywood is used as roof sheathing or over a crawl space beneath the house.

When heat insulation is used, the likelihood of moisture condensation and fungal decay in the structure may be increased. To counteract the situation, place a vapour barrier between the insulating material and the inside of the house (USDA, 1986). Tight vapour barriers on the outer (cold) surface of the insulation increase the chance of fungal decay.

A building frequently requires correction or compensation for short comings in the original construction. But even if the builder's job has been well done in every respect, inspection and continued care are needed (USDA, 1986). No kind of house will withstand long neglect. Rust stains around nail heads, paint peeling and blistering, paint discoloration at joints, and swelling and buckling of sidings are some of the signs that moisture is not being controlled (USDA, 1986). Leaks in roofs, gutters, or plumbing, and the clogging and the overflow of gutters, downspouts, or drains can lead to fungal decay. Cold pipes that sweat and moisten adjacent wood for long periods should be insulated. If ventilators under basement less houses/buildings are closed in winter be sure to open them in early spring to lessen the chances of fungal decay (USDA, 1986). Do not allow soil, trash, firewood, or lumber to pile up against walls or sills. Likewise, do not raise the exterior grade to the level that brings it dangerously close to the wood as this could initiate fungal decay (USDA, 1986).

If the house has a wood porch or steps, replacement of obviously decayed boards or bases of pillars should be made with treated wood. Localized decay in joints and bases of uprights may be arrested by flooding treatments of 2%Copper Naphthenate in kerosene. Decay in sash or window sills often means that there has been too much condensation of moisture on the inside of the glass; if this sweating cannot be sufficiently decreased by priming and back puttying the sash should be taken out and allow to stand with the bottom rail submerged in 2% Copper Naphthenate in kerosene. Any replacement sash should be factory treated or should be given a liberal soaking in the same preservative before it is installed or painted. If there is fungal decay in siding, the siding should be replaced with treated wood. If cracks open up in the siding so that water can run into them, caulk them with a caulking gun occasionally (USDA, 1986).

If there are unheated spaces under the first floor in which the net area of constantly open vents does not meet the requirements on ventilation to prevent condensation, the sills and ends of joists, particularly at the north side, should be examined in winter for fungal decay or visible moisture. The moisture may appear as conspicuous hanging drops, or simply a wet surface (USDA, 1986). Fungal decay that cannot be traced to excess moisture, leaks or soil contact is most definitely associated with ventilation.

In midwinter examine attics, in temperate zones, especially insulated attics, lacking the correct amount of ventilation. Examine for condensation moisture, or frost accumulation and fungal decay, especially at the eaves level at the north side of the house. If paint failures are especially troublesome on the north wall or dark stains (brown-rot) develop from moisture seeping out from under the siding, it is an indication of moisture condensation in the walls and fungal decay. Attic condensation difficulties can be corrected easily by increased ventilation (USDA, 1986). Increased ventilation, together with ventilation or soil cover is advised for crawl spaces, with vapour proofing can still be done for warm faces of the walls to make them safer from fungal decay.

Occasionally fungal decay is found to extend many feet from the nearest possible source of moisture (USDA, 1986). This is likely to mean that fungal decay is caused by one of the water conducting fungi which shows different symptoms from the major group the cause fungal decay. The symptoms are such that between two layers of wood, such as floor and subfloor, the fungi commonly produce root-like strands that are thicker and more conspicuous than the major group that cause fungal decay. The mistaken term “dry rot” is most often associated with these group of fungi. Proper ventilation or vapour barriers may limit their spread, but may not stop them entirely.

The treatment needed for these fungi, is to trace the fungus back to its source of moisture, usually the ground, and cut off the connection. Often the fungus comes up through a brace, frame, wooden concrete form, or a grade stake that serves as a bridge to let moisture move from the soil to a joist or sill (USDA, 1986). Sometimes a joist is in direct contact with a tree stump that has been left under the house is the site of initiation of fungal decay. In other cases, the source from which the fungus is bringing its moisture may not easily located. These unique fungi sometimes get their moisture from the soil, without direct wood contact, through strands of mycelium that grow a foot or two above the surface level of the foundation walls, or through cracks in loosely built masonry.

Replace all decayed wood with new treated lumber and eliminate all sources of moisture that initiate fungal decay. Remove all tree stumps and pieces of wood from under and around buildings. These are possible habitable places for decay fungi and termites. When there is any doubt as to moisture proofing, especially if the original infection has spread rapidly, it is safest to remove also apparently sound wood 2 feet in each direction from the part appreciably decayed, and make replacements with wood that has been thoroughly impregnated with 2% Copper Naphthenate in Kerosene. Before putting new wood in place, give all adjacent old wood and masonry surfaces a heavy brush or spray treatment with the same preservative.

Lumber Destruction-Termites

Termites are eusocial insects that are classified at the taxonomic rank of infraorder Isoptera, or as epifamily Termitoidae within the cockroach order Blattodea. Like ants, bees, and wasps from the separate order Hymenoptera, termites divide labour among casts consisting of sterile male and female “worker” and “soldiers”. All colonies have fertile males called “kings” and one or more fertile females called “queens”.

Termites get their nutrition from eating cellulose in wood. They have microorganisms (protozoans and bacteria) in their stomach that help break down the cellulose that then can be digested by their metabolism (Termite Control, 2017; Fitzgerald, 2007). This is beneficial if termites are eating a decaying stump or fallen tree. However, when there are no fallen trees, termites will eat wood in homes. They readily attack (eat) untreated lumber. They are three major types of termites that destroy buildings and houses, namely Dry-wood termites, Damp-wood termites, Subterranean termites, and a variety of Subterranean termite, the Formosan termite.

Dry-wood Termites

Dry-wood termites are usually found in humid coastal, subtropical and some tropical regions (Termite Control, 2017; Log Home Care, 2017). The regions include California, Hawaii, Florida, Arizona, South and North Carolina, New Mexico, Texas, Alabama, Mississippi, Louisiana, Porto Rico and other Caribbean territories (Termite Control, 2017: Log Home Care, 2017). The dry wood termite colony consists of castes of reproductive (queens and kings), workers and soldiers. Each member of the caste performs a different biological function. The reproductive in the colony have 4 wings. They are no specialized workers in dry wood termite colony, instead the young reproductive and soldiers serve as workers until they mature. The workers make the majority of the termite colony. The reproductive have chewing mouth parts adapted for chewing wood and these workers do the wide spread destruction. The soldiers have powerful mandibles to attack their enemies usually ants.

Dry wood termites live in small social colonies of around 50 after one year, 700 after 4 years, and 3,000 after 15 years (Termite Control, 2017). On swarming they mate and fly to new dry areas; enter a small hole in the wood and form a new colony. Dry wood termites do not need a source of water that is produced from the digestion of cellulose (Termite Control, 2017). Dry wood termites infest dry un-decayed wood, such as lumber, dead limbs of native trees, shade and orchard trees, utility poles, posts and lumber in storage (Termite Control, 2017). Because of the low moisture requirement of dry wood termites they can tolerate dry conditions for prolong periods. Their nests are built entirely above ground and do not connect to the soil. Piles of their fecal pellets, which are distinctive in appearance, is a clue to their presence. From such areas winged reproductive seasonally migrate to nearby buildings and other structures usually on sunny days during autumn months. Dry wood termites can also infest furniture when swarming.

Termite Control (2017) outlined 5 typical signs of dry wood termite infestation, namely:

1. Shed wings
2. Ejected pellets
3. Galleries inside the wood
4. Swarming termites
5. Piles of their distinctive fecal pellets

There are two major methods of treating dry wood termites, such as

1. Structure fumigation
2. Direct wood treatment (spot treatments)

For structural fumigation I recommend covering the entire structure and spray heavily with 2 5 copper Naphthenate in Kerosene. Copper Naphthenate is a known insecticide and pesticide and kerosene is known to kill termites. One danger with kerosene is its flammable nature. For direct wood (spot treatment) I recommend the use of liquid/ aerosol- 2% Copper Naphthenate in kerosene sprayed into the galleries after drilling holes. Use ½ inch drills in large timbers and small drills elsewhere. For furniture the spot treatment is also essential. Remove outer coatings-paint/ varnish/stain with sand paper to expose holes form by galleries and spray heavily with 2 % copper Naphthenate in Kerosene. Again it should be noted that Kerosene is flammable. Untreated furniture can be treated by heavily spraying after (stripping) sanding with 2 5 Copper Naphthenate in Kerosene.

Damp Wood Termites

Damp wood termites are found in coastal areas of California, Washington, Oregon, Nevada, Florida, and the Florida Keys (Termite Control, 2017). Damp wood termites do not require contact with the soil to obtain moisture, but wood with a high degree of moisture is needed. Because of their high moisture requirements, they are most often found in cool, humid areas along the coast. Like other termites they digest cellulose and is associated with decay.

Damp wood termites winged reproductive are dark brown with brown wings. Soldiers have a flattened brown or yellowish brown head with elongated black or dark brown mandibles. Nymphs are cream colored with a characteristic spotted abdominal pattern caused by food in their intestines. The work of the colony is done by the immature soldiers or reproductives; there is no worker caste. Damp wood termite swarms are small.

Damp wood termites nest in wood buried in the ground. In nature they are commonly found in tree stumps and fallen tree branches, but in your home, the most likely areas to find them would be an older wood deck, leaky roof eaves, leaky showers, or tubs, or substructures with inadequate ventilation or plumbing leaks (Termite Control, 2017). The damp wood termite is much larger than the subterranean and dry wood termites. They can swarm periodically throughout the year, and it is common to see the swarming reproductives caught in spider webs next to exterior lights since they are instinctively attracted to light. It is common to see flight of damp wood termites in the evenings after rain. Damp wood termites produce distinctive fecal pellets that are rounded at both ends, elongate, but lacking clear longitudinal ridges common to dry wood termite pellets; flattened sides are noticeable. They can be observed with a hand lens. Damage in wood by damp wood termites can be identified by a velvety appearance in the galleries.

Heat treatment is one possible control measure for damp wood termites because they require a high moisture content in the wood (lumber) to be effective in destruction. Other correction or control methods the require construction adjustments and chemical treatments are:

1. Increase the ventilation in the affected area, reducing moisture and repair leaky showers and plumbing.
2. Make sure have proper drainage
3. Construction needs to be designed to avoid contact of wood and soil.
4. If the damp wood is not accessible to be removed, treat the area including damp wood and soil with combined insecticide and

termiticide, 2 % copper Naphthenate in Kerosene.

Subterranean Termites

In the majority of the U.S.A the term termites refers to subterranean termites (Log Home Care, 2017). As suggested by their names, subterranean termites spend most of their time in the soil, typically two or four feet below the surface. The subterranean termite colony typically consists of several hundred thousand termites that include workers, soldiers, reproductives, along with a king and a queen.

When foraging workers spread out from the nest, usually just beneath the surface of the ground, looking for food. They feed on cellulose including plant materials, dead tree roots and limbs, and the wood in a home. Since there are many thousands of feeding termites in a colony, subterranean termites can do a substantial amount of damage in a fairly short period of time (Log Home Care, 2017). In addition to cellulose subterranean termites are attracted to water. If these two elements can be combined in wet wood, an ideal environment is created for termite attack.

The first indication of subterranean termite infestation is usually the presence of mud tubes going up walls, piers or vertical surfaces. These tubes are developed by termites in order to maintain a moist environment. Because termites have soft bodies they rapidly lose water to dry air and the mud tubes give them protection from both predators and dehydration. Another sign of a subterranean termite infestation is a termite swarm within a home. Many people mistakenly identify swarming termites as flying ants but they can be differentiated. Ants have a narrow waist whereas the termite's body is fairly straight back to the abdomen.

When termites swarm in the thousands, a home owner's first impulse is to run for the can of pesticide and spray them down. There is no sensible reason to do this since all swarming termites will be dead in an hour or so. The best way to handle them is to vacuum them up. The presence of swarming termites in a home is a sure indication that a mature colony is located within or close to the structure. Cracked or bubbling paint, frass (termite dropping) mud tubes on exterior walls, and wood that sounds hollow when tapped are also indications that a home may be infested with termites (Fitzgerald, 2007).

Moisture control and the avoidance of wood to ground contact are the most important factors removing conditions attractive to termites. Preventative measures that can be taken during home construction to help protect against termite infestation include, (a) making sure that lumber and other wood components do not come in contact with the soil; (b) placing a moisture barrier under basements to keep area dry; (c) treating wood components with a pesticide (2 % Copper Naphthenate in kerosene) that make them unappealing to the termite palate, and (d) ensuring that the wood in the home envelope is kept as dry as possible. To make an already constructed home less attractive to termites, start by eliminating moisture problems and remove excess food sources like firewood, lumber, paper and tree stumps from the immediate surrounding area (Fitzgerald, 2007).

In the past, soil poisoning was about the only method used for protecting a house/building from subterranean termite attack. Because of the negative impact of these methods on the environment, many of the chemicals used 15 years ago are discontinued. The new soil termiticides fall into two basic categories, repellent and non- repellent (Log Care Home, 2017). The objective of a repellent soil termiticide is to form a barrier around the house/building/building material/ lumber that the termite will not penetrate. This is the type of treatment typically used in "pre-treatment' site applications prior to construction. In this regard I recommend 2% Copper Naphthenate in Kerosene as the pre-treatment chemical that should be used prior to construction. The method treatment for the lumber would involve a modified Gedrian Bath. Copper Naphthenate is a known insecticide and termiticide (pesticide) (Wood Preservation, 2017; EPA, 2017). Hence it will kill termites and insects. Kerosene is known to kill termites and ants (Personal Observation). Copper Naphthenate is also wood preservative and water repellent (Wood Preservation, 2017; Hoffmann *et al*., 2017). Kerosene being an oil is also a water repellent and would protect the wood once it has been absorbed into the wood.

In a remedial treatment situation 2 % Copper Naphthenate in Kerosene can be injected into the soil to the base of the foundation and poured into a trench around the foundation perimeter. One limitation with this procedure is that the soil will be disturbed. If the surroundings are not thoroughly treated by excessive spraying or pouring the termites will still find a path to the house/building.

The newest technology in soil treatments is development of non-repellent termiticides. The foraging termites do not detect these products and they freely pass through the treated soil. The termites while foraging carry minute amounts of the toxicant back to the nest and eventually the termite colony is eliminated. This is the same objective of termite baits. In this regard I recommend that it is possible to coat 2% Copper Naphthenate in Kerosene with a cellulose type material as a non-repellent termiticide and bait.

Formosan Termites

Recently, an imported species of termites, the Formosan termites has invaded Southern and Southwestern, U.S.A. The Formosan termite is a variety/race of subterranean termites with colonies of over a million individuals. The caste system is similar to other subterranean termites. Because of their colony size they can cause significant structural damage in a matter of months. Formosan termites tend to establish aerial infestations with nests called cartons that have no contact with the ground. This is one reason for their difficulty in control. Formosan termites need the same set of conditions to survive as other subterranean termites. Their prevention and control methods are therefore similar as for subterranean termites with one exception, the aerial nests. I recommend that aerial infestations be sprayed heavily with 2% Copper Naphthenate in Kerosene. All possible paths to the building should be destroyed and protected with 2% Copper Naphthenate in Kerosene. All moisture related problems should be addressed.

Lumber Destruction- Beetles

There are beetles from four families that are associated with wood decay. The four families are Lyctidae, Bostrichidae, Anobiidae, and Cerambycidae. They all require some moisture content in the wood. In the case of Cerambycidae, fungal destruction is associated with their attack on the wood/lumber. As insects they go through complete metamorphosis, that is, eggs, larvae, pupae, and adults. The larvae do the majority of the damage as they diet include starch, sugar and protein in the sap wood. The larvae of Cerambycidae can digest cellulose.

Lyctidae-True Powder-post Beetles

The adults of this beetle family are very small, less than ¼ inch in size. They are flattened and reddish brown to black in colour. The larvae are white, cream coloured and C shape with dark brown heads. The larvae create tunnels in the wood and become pupae. When they become adults, they bore through the wood pushing a fine powdery dust out. The holes they shaped can be considered as pin holes which are round and about 1/32-1/16 inch in diameter.

The adults attack wood by boring into the wood and depositing their eggs. Their diet is starch, sugar and protein in the sap wood of the lumber. Wood that contains more than 6% moisture is readily attacked but not wood with less than 6% moisture. The average lifecycle of this beetle is one year. This wood boring beetle is most widespread in the United States of America. On many occasions infestations are built into structures from infested lumber, that is, untreated lumber. The beetles are capable of re-infesting the same lumber that has been treated.

There are four major characteristics of Lyctidae beetle attack (Termite Control, 2017).

1. The presence of extremely fine, flour like powder falling from the surface of holes in the wood.
2. The frass left by the wood borers contain pellets with a course texture and a tendency to stick together.
3. When inspecting damage, be sure to distinguish between old damage and active beetle infestations.
4. Remember- recently formed holes, and frass (sawdust like) are light in colour and clear in appearance while old holes and frass are dark in colour.

Bostrichidae-False Powder-post Beetle

False powder post beetles are larger than other families of powder post beetles so their exit holes are larger. The adults are 1/8 to 1-inch long, cylindrical, and reddish brown to black. The adults bore into the wood to lay eggs, leaving a hole larger that is 1/8 inch in diameter. They usually attack wood less than 10 years old. The larvae are curved and wrinkled and their diet is dependent on the starch in the wood. They are common in soft wood but can attack hardwood. They require a moisture content in wood of between 6-30% to be effective. They complete their lifecycle in one year. Most of this species does not re-infest wood after it has been treated, so the damage is limited to one generation. The speed of damage can be considerable. They commonly infest oak, firewood and furniture. The characteristics of Bostrichidae beetle infestation are:

1. Holes that contain no frass.
2. Galleries that contain frass.
3. Frass tightly packed in galleries, stuck together and meal like.
4. No visible pellets are seen.

Anobiidae (Anobid Powderpost Beetle –Furniture and Deathwatch Beetle)

The Anobiidae beetle consists of two types of beetles found in the United States of America- namely the furniture beetle and the death watch beetle. The furniture beetle is found mostly in the eastern half of the U.S.A and infests structural timbers (lumber). The death watch beetle is found throughout the U.S.A and it attacks building timbers. The name death watch comes from the ticking sound that the adult makes inside infested wood that is audible during a still night. It is considered a mating call.

The adults of Anobiidae beetles are 1/8 to ¼ inch long. They are red to dark brown in colour and oval in shape. The adults lay their eggs in the cracks and crevices of old wood. As soon as the eggs hatch, the larvae burrow into the wood where they live and tunnel for a year or more. The larvae form tunnels in both soft woods and hard woods and require a moisture content in wood of 13-30%. The larvae are slightly curved and wrinkled, with tiny hairs on their body. The life cycle of these beetles averages 1-3 years. The larvae can digest cellulose and the holes left are round and 1/16 -1/8 inches in diameter. The larvae like softwoods and are common in crawl spaces and basements and infest pine used as framing lumber. Infestations can become so severe that loss of structural strength to sills, joists and sub flooring occurs. Re-infestation is common with these beetles in crawl space areas that are poorly ventilated where humidity is absorbed in the wood.

The characteristics of anobiidae beetle infestations are:

1. A ticking sound in the still of the night.
2. Holes with powdered frass that is fine to course.
3. Small pellets on the outside of holes
4. Tunnels in the wood that can be recognized by a hollow sound when knocked with a screw driver or ice pick.

Cerambycidae- (Old House Borer)

The old house borer is one of the most common in this family. It is normally found in older houses due to the use of untreated or infested wood. The adults are brownish black to black, slightly flattened and about ¾ to I inch long. The adults lay their eggs in the lumber and the larvae once formed hollow out galleries in the wood. The larvae digest cellulose. The average life cycle of the beetles are one to three years, but can take up to twelve years if nutritional and environmental conditions are unfavorable. The exit holes for the adults are ¼ to 3/8 inch in diameter, but the damage may occur several years before spotting such holes. If such a situation is not recognized for many years, there will be no structural relevance to the building. The building would be in shells. Fungal decay increases the rate of these beetles' infestation because the larvae develop faster.

The characteristics of Cerambycidae beetle infestation are:

1. Gallaries in wood.
2. Tunnels with powder (frass) that are like sawdust and tightly packed.
3. No pellets.
4. Hollows in the wood that can be recognized by knocking or using an ice pick.

The general inspection procedures for beetles are the following:

1. Inspect periodically all exposed wood surfaces for characteristics expressed earlier and probe them for evidence of internal damage-evidence of beetle infection is a hollow.
2. Evidence of beetle attack will be more common in attics, crawl spaces, unfinished basements, and storage areas.
3. To be certain that the infestation is active (not old damage or old frass), there should be fresh frass the colour of newly sawed wood, or live larvae or adults in the wood. There will be observable through probe sections- use hand lens and an ice pick.

General Control and Recommended Treatment for Beetles

1. Reduce moisture content through ventilation to less than 13%. Moisture meter can be used to determine the moisture level in the wood which should be less than 6%. Central heat, vapour barrier, and good ventilation can help control moisture. Open windows and stop or reduce the use of the air conditioner as natural ventilation reduces moisture content.
2. If practical remove infected wood and replace with wood treated with a preservative (2% Copper Naphthenate in Kerosene), or treat area heavily by spraying with the above mentioned preservative and insecticide (2% Copper Naphthenate in Kerosene).

Lumber Destruction (Carpenter Ants)

Carpenter ants are common household pests in the United States of America and world- wide. Carpenter ants are quite large ranging in size from ¼ to ¾ inch and be dark brown to black or red-red brown to yellowish in colouration (Illinois Department of Public Health, 2017; Warner and Scheffrahn, 2014; Jacobs, 2017; Termite Control, 2017). The carpenter ant being a social insect has a caste system. The ant colony has a wingless queen, many sterile wingless female workers, white legless larvae, white eggs and tan pupae cocoons. At certain times wing female and males are produced (Jacobs, 2017: Termite Control, 2017). Usually a colony does not produce winged males and queens (the reproductives) until it is several years old and has about 2,000-3,000 workers (Jacobs, 2017). It is not unusual for a carpenter ant colony to contain between 3,000-10, 000 individuals (Illinois Department of Public Health, 2017; Termite Control, 2017). Approximately 200-400 winged ants (swarmers) develop during the warm months, remain in the nests through winter, and leave the nest the following spring or early summer (Jacobs, 2017; Illinois Department of Public Health, 2017). Swarming generally occurs after three to six years when the colony contains 3,000 or more ants (Termite Control, 2017). The swarmers' purpose is to mate and in the case of females fly to a new location, lay eggs and establish a new colony. The laying of eggs is done by the queen which starts the new colony (Illinois Department of Public Health, 2017). The nest is usually located in a cavity in the soft, moist, decaying wood of a hollow tree, wood piles, logs, stumps and sometimes several feet above the ground (Jacobs, 2017; Illinois Department of Public Health, 2017). A new queen lays 15-20 eggs, which produce the first brood of offspring and whitish (tan) soft bodied, legless larvae which later become the sterile female workers (Jacobs; 2017).

The development from egg to worker requires a short time, a minimum of just 60 days. The workers of the first brood are small because they are nourished only from the food reserves that are stored in the queen's body (Jacobs, 2017). When the workers reach adulthood, the queen's only function is the laying of eggs. The adult workers forage for food, enlarge the nest, and feed and care for the queen and her subsequent larvae. They eat dead insects, small invertebrates, honeydew secreted by aphids and scale insects and other sweets (Jacobs, 2017; Termite Control, 2017). They regurgitate this food and feed the larvae as well as the queen. Workers in the succeeding broods are larger because the foraging workers feed them (Jacobs, 2017). The ants hibernate (are inactive) during winter, but they are will be active if a nest is located in a heated portion of a building (Jacobs, 2017). Carpenter ants do not use wood as food but excavate wood for nest construction (Illinois Department of Public Health, 2017; Termite Control, 2017).

A carpenter ant colony is usually composed of a series of nests (Illinois Department of Public Health, 2017; Termite Control, 2017). The main nest or parent nest is usually located outdoors and sometimes several feet above the ground. The nest contains the queen, some workers, larvae and pupae (Illinois Department of Public Health, 2017). The main nests may be joined by sub-nests or satellite nests, containing workers, older larvae, and pupae. The colony's reproduction takes place in the main (parent) nest where the queen lays the eggs. Larvae hatched from the eggs, are cared for, and later may be transported to satellite nest, where the larvae undergoes pupation, and complete their metamorphosis to become adult workers.

Ants in these satellite nests are the ones that normally do structural damage to home and buildings (Termite Control, 2017). A satellite nest is often established in an area where wood has become moist. Common indoor sites include, wood around a leaking chimney flashing, attics, skylights, bathtubs, poorly sealed window sills, poorly sealed door frames, porch supports, columns, soffits, wood siding and shingles, leaky roofs, sinks, and hollow spaces like the void behind dishwashers, girders, joists or wall studs, areas where the wood may be wet or damp because of poor ventilation, overflowing or leaking gutters and downspouts, and condensation from water pipes or leaking bath tubs, showers, and appliances (Jacobs, 2017; Illinois Department of Public Health, 2017; Termite Control, 2017). Carpenter ants will also nest in fiberglass and foam insulation (Illinois Department of Public Health, 2017). Cracks and crevices may be used by satellite ants to start a nest (Termite Control, 2017). It is important to note that the damage caused by carpenter ants is not as extensive as that caused by termites (Termite Control, 2017).

Carpenter ants in a home (building) can originate from outdoors or indoors. It is important to determine their origin. According to researchers (Illinois Department of Public Health, 2017; Jacobs, 2017; Termite Control, 2017) the following are characteristic of carpenter ants indoor infestation:

1. Sawdust accumulates where the ants are tunneling-Look for piles of coarse stringy wood particles, dead insect parts, and other debris that are shifting from cracks in the siding, behind moldings, and all areas where wood can become moist due to leaks, condensation and poor ventilation.
2. This "sawdust" or "frass" are shredded fragments of wood that has been ejected from tunnels. Sometimes this evidence is not seen and taking an ice pick probing the wood may reveal the excavated tunnels.
3. Also, you could take a blunt end of an ice pick and tap along base boards and other wood surfaces listening for the hollow sound of damage wood.
4. If a nest is near by many times the carpenter ants will respond by making a "rustling" sound within the nest similar to crinkling of cellophane.
5. The tunnels (galleries) of carpenter ants are smooth sided and contain no soil particles or faecal pellets.

The prevention, control, and treatment of carpenter ants require situational adjustments and chemical treatments with an insecticide/pesticide and preservative.

Situational Adjustments are:

1. Since carpenter ants require wood and moisture efforts should be made to reduce the availability of these-Remove stumps, logs, and waste wood within 100 yards of the home (building). Carpenter ants are known to travel up to 100 years.
2. Monitoring wires and cables connecting the house to utility poles as their serve as bridges for the carpenter ants to your home/building.
3. Do not allow vegetation, especially evergreen shrubs and trees, to be in contact with the house/building. They serve as sources and bridges for the carpenter ants to infest the house/building.
4. Store fire wood away from the house and off the ground, and take to the interior of the house/building only when needed.
5. Keep wooden parts of the house/building and other structures dry by making necessary repairs to roof, flashing, gutters, downspouts, and other moisture related areas.
6. Replace any water damage and decaying wood with wood treated with a water repellant and a preservative (2% copper Naphthenate in Kerosene).
7. Keep the moisture content of the wood below 15%. Carpenter ants are not known to infest wood/lumber with a moisture content lower than 15%.

8. Keep exterior wood surfaces well painted and sealed.
9. Seal holes through which pipes and wires enter the house (caulking). Also cracks in foundation, gaps around doors and windows should be sealed.
10. No wood of a house/building should be in direct contact with the soil. However, wood of a house/building that is close to the soil should be heavily treated with an insecticide and water repellent (2% Copper Naphthenate in Kerosene).
11. Place a moisture barrier (plastic sheet) over soil in the crawl spaces and under wooden porches, and provide adequate ventilation for such spaces.

The infestation with carpenter ants is indicative of water damage and wood decay. There are a number of chemical treatments available to control and exterminate carpenter ants. I recommend that 2% Copper Naphthenate in Kerosene can serve both purposes. Copper Naphthenate is also a preservative. As a repellant insecticide I suggest that the infested areas can be heavily sprayed with 2% Copper Naphthenate in kerosene, and as a preventative treatment repeated every four (4) months. As a non-repellent treatment 2% Copper Naphthenate in kerosene could be used as a bait after the solution has been encapsulated in a sugary coating. The ants will then share the capsule with their colony thereby eliminating them. The places that should be baited and treated include high moisture areas such as water damage soften wood, windows, door frames and sills, tub enclosure walls, kitchen and bathtub plumbing walls and all other areas where moisture related problems can occur.

Chemicals and Procedures in Lumber Treatment

There are a number of different (chemical) preservatives and processes (also known as timber treatment, lumber treatment, pressure treatment or heat treatment) that can extend the life of wood, timber, wood structures or engineered wood. These generally increase the durability and resistance of the wood, timber, wood structures or engineered wood, from being destroyed by decay fungi, termites, beetles or carpenter ants. The treatment of wood has been practiced for a long time (centuries)(Richardson, 1978). There are records of wood preservation dating back to ancient Greece during Alexander the Great's rule, where bridge wood was soaked in olive oil. The Romans used tar to protect their ship hulls by brushing oil on the wood. During the industrial revolution wood preservation became a cornerstone of the wood processing industry (Wikipedia, 2017). Inventors and scientists such as Bethel, Boucherie, Burnett and Kyan made historic developments in wood preservation, with wood preservative solutions and processes (Wikipedia, 2017). Commercial pressure treatment began in the latter half of the 19^{th} century with the protection of railroad crossties with creosote. Over 70 years ago, Dr. Karl Wolman invented the process of infusing preservative deeply into wood products. To date, a large industry has grown up around his quest to invent a wood that can be long lasting (Natural Handyman's home Repair Articles, 2017). Pressure treatment is a process that force chemical preservatives deep into the wood.

The use of heat treatments to modify the properties of wood is not a new phenomenon. Tiemann (1920) showed that the drying of wood at high temperatures decreased the equilibrium moisture and the consequent swelling of wood. Kollmann (1936) used high temperature densification by a hot press and call the process "Lignostone." According to Morsig (2000) a similar product of laminated compressed wood was marketed in Germany under the name "Lignifol." Stamm and Hansen (1937) reported that equilibrium moisture, swelling, and shrinking of wood decreased with heating in several gases. In the United States of America, Seborg and colleagues (1945) created a similar product which they called "staypack". Stamm *et al*., (1946) reported a heat-treatment to improve wood dimensional stability without densification and called the process " staywood." None of these products had much success in the commercial market, probably due to the availability of high quality wood. Nevertheless, heat treatment was not completely forgotten, and several studies were presented some years later by Seborg *et al*., (1953), kollmann and Schneider (1963), kollmann and Fengal (1965), Noack (1969), Fengel (1966 a, and b), D'Jakonor and Koneplera (1967), Nikolor and Encev (1967), Burmester (1973; 1975), Rusche (1973 a and b), Giebeler (1983), and Hillis (1984).

More recently a renewed interest in the heat treatment of wood has begun. According to Boonstra (2008) this renewed interest is due to the declining production of durable timber, to the increasing demand for sustainable building materials, to the deforestation of especially sub-tropical forest, governmental restrictive regulation reducing the use of toxic chemicals. Wood preservation through the use of chemicals employed different methods to get the chemicals into the wood. The commonly used chemical preservation are: Chromated Copper Arsenic, Creosote, Pentachlorophenol.

Propiconazole, Triadimefon, Acid Copper chromate, Alkaline copper Quaterernary, Borates, Copper Azole, Sodium Silicate-based preservatives, Bifenthrin Spray preservatives, linseed Oil, Light organic Solvent Preservatives, Epoxy and 2% copper Napthenate.

Chromate Copper Arsenate is a mixture containing copper, arsenic, and chromium compounds. There are three different types of mixtures varying in the percentage of weight of each compound. Type 1 contains 61% chromium, 17% copper and 22% arsenic and sold by the trade names Greensalt, Langwood, Edalith. Type 2 contains35.3% chromium, 19.6 copper, and 41.5% arsenic and by the trade names Biliden CCA, koppers CCA-B, Osmose K-33 and Koppers CCA-C. Type 3 contains 47% chromium, 19.6% copper and 34% arsenic and sold by the trade names Wolman CCA, Wolmanac CCA, and Chrom-ar-cu (Hoffman *et al*., 2017). All three types are equally effective and are used to treat lumber, plywood and timbers where cleanliness is important. In chromated copper arsenate treatment, copper is the primary fungicide, arsenic is the secondary fungicide, arsenic is a secondary fungicide and insecticide and chromium is a fixative which also provides ultraviolet (UV) light resistance (Wikepedia, 2017). In the pressure treatment process, an aqueous solution of chromate copper arsenate is applied using vacuum and pressure cycle and the treated wood is then stacked and dry. During the process, the mixture of oxides reacts to form insoluble compounds, helping with leaching (Wikipedia, 2017).

Chromated copper arsenic gives wood a greenish tint that eventually weathers to gray, although a new process has been developed giving chromated copper arsenic treated wood a brown colour (Hoffman *et al*., 2017). Arsenic is the compound used in rat poison and is therefore toxic to humans. Chromated copper arsenic is so toxic that the Environmental Protection Agency, over 20 years, imposed strict guidelines regarding the manufacturing practices of companies using Chromated Copper Arsenate.

In the last decade concerns were raised that the chemicals may leached from the wood into surrounding soil, resulting in concerns higher than naturally occurring background levels. Recently a study cited in Forest Products Journal found that 12-13% of the Chromated Copper Arsenic leached from treated wood buried in compost during a 12 month period. Once these chemicals have leached from the wood, they are lightly to bind to soil particles, especially in soils with clay or soils that are more alkaline than neutral (Wikipedia, 2017). In the United States of America the U.S Consumer Product Safety Commission issued a report in 2012 stating that the exposure to arsenic from direct contact with Chromated Copper Arsenate treated wood may be higher than previously thought. The Environmental Protection Agency (EPA)(2004)in a voluntary agreement with the lumber industry began restricting the use of Chromated Copper Arsenic in treated lumber (timber) in residential and commercial construction, with the exception of shakes and shingles, permanent wood foundations, and certain commercial applications. The effort was to reduce the use of poisonous arsenic and improve environmental safety, although the EPA was careful to point out that they had not concluded that Chromated Copper Arsenate treated wood structure in service posed an unacceptable risk to the community. Additionally, the EPA did not call for the dismantling or removal of existing Chromated Copper Arsenate treated structures.

The Australian Pesticides and Veterinary Medicines Authority (APVMA) (2006) restricted the use of Chromated Copper Arsenate for preservative for the treatment of timber used in certain applications. According to the (APVMA) chromate copper arsenic should no longer be used to treat wood in "intimate human contact" applications such as children's play equipment, furniture, residential decking and hand railing. Chromated Copper Arsenate is allowed to be used in Australia for low contact residential, commercial applications and all other situations. The APVMA considers the restrictions a precautionary measure and like the USEPA did not recommend the dismantling or removal of existing Chromated Copper Arsenate treated structures.

In Europe a directive in (2003) restricted the marketing and use of arsenic, including Chromated Cooper arsenate treated wood. According to the directive Chromated Copper Arsenate treated wood is not to be used in residential or domestic constructions. However, the directive permitted the use of chromate copper arsenate treated wood to be used for such things as bridges, highway safety fencing, electric and telephone poles. In England (2012) the Department for the Environment, Food and Rural Affairs classified timber treated with chromated copper arsenate as a hazardous waste.

I recommend the use of chromate copper arsenate be discontinued in the treatment of all timber (lumber). Arsenic is too potent a person to human and should not be used. I suggest that the fungi, insecticide, and wood preservative to use is 2% copper Naphthenate in Kerosene. In this mixture cooper is the fungicide, naphthenate is the insecticide, pesticide and preservative. Kerosene is also insecticide that kills ants and termites and it is a water repellant.

Creosote is one of the oldest wood preservatives, and was originally derived from a wood distillate, but now-a- days, virtually all creosote is manufactured from the distillation of coal tar. Creosote is the first wood preservative to gain industrial recognition over 100 years ago and is still widely used today. Creosote is a tar-based preservative that is used to protect industrial timber components where long service life is essential such as utility poles and railroad ties. Creosote is a regulated pesticide and not normally sold to the general public. The wood treated with creosote is done through the thermal process or by brushing, or spraying. Because creosote is not sold to the general public there is a need for a mixture the general public can use. Here I recommend the use of 2% copper naphthenate in Kerosene.

Pentachlorophenol, like creosote is an oil preservative and is an oil preservative and is toxic to all wood destroying organisms. Pentachlorophenol, also known as penta or PCP, must be dissolved in petroleum oils or more volatile organic solvents such as mineral spirits, liquefied petroleum gas, and methylene chloride in order to treat wood. The more volatile substances will evaporate leaving only pentachlorophenol, the preservative present. Treating solutions normally contain 5% PCP by weight. Depending on the solvent used, PCP treated wood will vary from light to dark brown in colour. PCP has been used extensively in the millwork industry and in treating posts and poles (Utility poles). As a registered pesticide PCP is not sold to the general public. Again we need a preservative for public use and I recommend 2% Copper Naphthenate in Kerosene.

Propiconazole has been approved by the United States Environmental Protection Agency for preserving wood used in millwork, shingles and shakes, plywood, structural lumber, timbers, and composites that are used in above ground applications only. Propiconazole by itself is not an insecticide, hence it cannot protect against insect damage-termites, ants, and beetles. Propiconazole have been approved for surface application (spraying or brushing) or pressure treatment of siding, plywood, millwork, shingles and shakes above ground, structural lumber and timbers. Such rigorous treatment should be done using a broad based preservative and a water repellant and not just a fungicide like propiconazole. Therefore I recommend such treatment should be done with 2% Copper Naphthenate in Kerosene, an insecticide, fungicide, pesticide and water repellant.

Triadimefon is a triazole fungicide that was first registered as a wood preservative by EPA in 2009. Triadimefon has been approved by the EPA for preserving wood based composite products and those intended for above ground and in ground contact such as wood decking, patio furniture, millwork, guardrails, utility poles, foundation pilings, and fences. Triadimefon is applied by the dip or pressure treatment method. It is important to note that a fungicide like Triadimefon has been given to broad an approval. The treatment process approved for Triadimefon should be afforded a broad base pesticide like 2% Copper Naphthenate in Kerosene that can protect against-fungal decay, termite, ants and beetle infestations and is also a water repellent. Too much credit was given to a preservative (triadimefon) that only that only has fungicidal effects.

Acid Copper Chromate (AAC) is a water borne wood preservative. Copper being the most active ingredient is a fungicide. Acid copper chromate is not an insecticide. Acid copper chromate is a leach resistant preservative recommended for industrial and commercial use. Noting that Acid copper Chromate has only fungicide effects I recommend 2% Copper Naphthenate in Kerosene which has fungicidal effects and preventative against termites, ants, and beetles.

Alkaline Copper Quaternary (ACQ) is a water borne wood preservative that protect against fungal decay as well as termite, ants, and beetle infestations (destruction), that is, it is a fungicide and insecticide. It is also safe to humans based on its components copper oxide and quaternary ammonium compounds. Being a water based preservative ACQ leaves a dry paintable surface. ACQ is registered to be used on lumber, timber, landscape ties, fence posts, utility poles, land, freshwater and marine pilings, sea walls, decking, wood shingles, and other wood structures. Although ACQ supplies protection against all four organisms associated with wood decay-fungi, termites, ants and beetles- it is not a water repellent and leaching can be a problem. Additionally, it is expensive, and as a result I recommend a cheaper and thus more affordable mixture 2% Copper Naphthenate in Kerosene which gives similar protection and is a water repellent.

Borates (boric acid, oxides and salts) are effective wood preservatives and are supplied under numerous brand names throughout the world. Borate preservatives can protect wood from destroying ants, beetles, termites and decay fungi (Forintek Canada Corporation, 2002). One of the most common compounds used is disodium octaborate tetrahydrate (DOT). DOT is specially formulated as a water based wood preservative registered for used by agencies in Asia, North America and Europe. It is registered to be used on furnishings, and interior construction, such as framing, sheathing, sill plates, furring strips, trusses and joists. Borate treated wood should only be used where it is protected from major water exposure. Because borates are diffusible; the preservative can move out of the wood under severe wetting. For example, if borate treated wood is placed in a continuous stream of water, the preservative will slowly migrate out leaving the wood unprotected (Forintek Canada Corporation, 2002). Borate treated wood is of low toxicity to humans and does not contain copper or other heavy metals. Carr *et al.*, (2005) developed organoborates which are much more resistant to leaching, while providing timber with good protecting from termite and fungal attack. The cost of the production of organoborates will limit their widespread take up but they are likely to be suitable for certain niche applications, especially where low mammalian toxicity is of paramount importance. Borates while being protective against all four organisms that cause wood decay are leachable in the presence of water and the wood can become unprotected. Borates are not a water repellent. Even painting or staining would not help significantly as they can crack and peel leaving crevices and open spaces where water can enter the wood. As a result I recommend the use of 2% Copper Naphthenate in

Kerosene which can protect against all organisms that cause wood decay and is a water repellent.

Copper Azole is a water based wood preservative that prevents fungal decay and insect infestations in wood. It is a fungicide and insecticide. Copper azole is widely used throughout the united States of America and Canada and is registered for treatment of millwork, shingle and shakes, siding, plywood, structural lumber, fence posts, building and utility poles, decks, mailboxes, swing sets, Oceanside boardwalks, land and fresh water pilings, and other wood products that are used above ground, ground contact and freshwater as well as in salt water splash (marine) decking applications (EPA, 2017; Fitzgerald, 2007). Copper azole is safer to human than other toxic preservatives. Copper azole is water borne and the preservative is forced into the wood using pressure treatment. The use of copper as the main element in copper azole has made its use in pressure treatment more expensive (Fitzgerald, 2007). In an attempt to manage the escalating cost of using copper azole pressure treated wood manufactures have started offering wood options with different levels of pressure treated protection (Fitzgerald, 2007). Because of its high expense copper azole will be eventually be phase out. It is advisable not to give consumers less than the highest form of protection. I therefore recommend a more cost effective and adequate treatment (2% Copper Naphthenate in Kerosene). Kerosene is a water repellent and copper azole is not. 2% Copper Naphthenate in kerosene is also protective against fungal decay and infestations-ants, termites and beetles.

Sodium Silicate based preservatives are produced by fusing sodium carbonate with sand or heating both ingredients under pressure. It is protective against insects and hence is an insecticide. The preservative also have flame resistant properties and is easily washed out of the wood by moisture. It is non-toxic to humans. Because sodium silicate based preservatives are not fungicidal and so do not protect against fungal decay it falls short of being a comprehensive preservative. It can be removed from wood by moisture leaving the wood unprotected. I therefore recommend 2% Copper Naphthenate in Kerosene to be effective because it is an insecticide, fungicide, a water repellent and a non-leachable preservative.

Potassium silicate based preservatives are made from European natural paint fabricants to produce potassium silicate. The compounds are made with boron compounds, cellulose, lignin and other plant extracts. The common are effective (protective) against insects and fungi. They are used for surface application (spraying or brushing) with minimal impregnation. Because the application of these preservatives are only surface oriented they can easily be remove by agents such as snow, rain, moisture and condensation. One aspect of a good wood preservative is it penetration in the wood. This is not so with potassium based preservatives. I therefore recommend 2% Copper Naphthenate in Kerosene which has all three factors for a preservative treatment to be effective, that is, retention, penetration and uniformity. Hence it will be absorbed throughout the wood and can be retained because it is a water repellent. 2% Copper Naphthenate in Kerosene is preservative against all four organisms that cause wood decay- fungi, termites, ants and beetles.

Bifenthrin spray preservatives are water based bifenthrin preservatives which were developed to improve insect resistance in timber. Bifenthrin preservatives are insecticides. The method of application of a bifenthrin preservative is by spraying and it only penetrates the outer 2mm of the timber cross section. Again there is a problem with penetration. For a preservative treatment to be effective more than half of the cross section of the lumber (timber) should be penetrated. Another concern with bifenthrin based preservatives is that they are not fungicides and therefore are not effective against fungal decay a major concern in wood decay. In this regard I recommend the use of 2% Copper Naphthenate in kerosene which can penetrate the wood entirely given time (10-12h) by soaking/steeping in a modified Gredrian bath at room temperature. AS a surface application (spraying or brushing) at the construction sites for cut ends it will be more than adequate as penetration is possible to be more than one inch. 2% Copper Naphthenate in kerosene is also an insecticide, fungicide, wood preservative, and water repellent.

Linseed oil has in recent years, been incorporated in preservative formulations as a solvent and water repellent to envelop treat timber. In Australia and New Zealand this involves just treating the outer 5mm of the cross section of the timber with preservative, for example an insecticide like permethrin in 25:75 ratio mixture leaving the core untreated. Envelope treatments are significantly cheaper as they use far less preservative but are not as effective as Chromated Copper Arsenate or Light Organic Solvent preservatives. Because preservatives used normally do not protect against all organisms that cause wood decay in one treatment or does not afford complete penetration of the timber, it is better to use a preservative and a solvent- water repellent that can protect against all organisms that cause wood decay and give complete penetration of the wood by soaking dipping given time. I therefore recommend that such a preservative would be 2% Copper Naphthenate in Kerosene.

Light Organic Solvent Preservatives (LOSP) is a class of timber treatments that use white spirit or light oils such as kerosene, as the solvent carrier to deliver the preservative compounds into the timber. Insecticides such as permethrin, bifenthrin, and deltamethrin are used. In Australia and New Zealand, the most common formulations are permethrin as an insecticide, and propaconazole and tebuconazole as the fungicide. These formulations although chemical preservatives contain no heavy metal compounds. LOSPs have disadvantages due to high cost and long process times associated with vapour recovery systems. LSOPs have been emulsified into water based solvents and the timber swells during treatment removing many of the advantages of LSOP formulations. The procedure is expensive because at least two preservatives must be used to protect the wood against all four microorganisms involved in wood decay. Another expense is the LSOP and the system of treatment. As an alternative I recommend the use of 2% Copper naphthenate in kerosene as the treatment for timber. In this case one compound would be used as the insecticide, fungicide and pesticide (2% Copper naphthenate). The carrier solvent and water repellent would be kerosene priced at less than 50 cents per gallon. The methods of treating would be soaking/steeping in a modified Gredrian bath (commercial treatment) and job site application spraying or brushing.

Epoxy resins are usually thin with a solvent such as acetone and used as a preservative and a sealant for wood. The solvents used in this case is expensive. Epoxy is also expensive and its traditional use is to seal wood. Regardless of the protection they give the wood industrial and commercial use has not gained momentum. I therefore recommend a more cost effective treatment would be 2% Copper Naphthenate in Kerosene.

Copper Naphthenate is a Danish invention of 1911 and has been used as a preservative and water repellent for more than 100 years (Wikipedia, 2017). Copper Naphthenate has been used to treat fences, canvas nets, green houses, utility poles, railroad ties, landscape timbers, wooden structures in ground contact, and water contact (EPA, 2017; Wikipedia, 2017). The known methods of application of Copper Naphthenate are brush, dip, spray or pressure treatment to the wood. Copper naphthenate is a fungicide, insecticide and a pesticide (Wikipedia, 2017; EPA, 2017). Copper naphthenate is registered by the EPA as a non-restricted use pesticide (insecticide and fungicide), hence it can be used by the general public. The American Wood Protection Association (AWPA)(2017) recommended a minimum of 2% copper metal for material originally treated with copper naphthenate.

The use of Copper naphthenate in oil is not new. A 50 year study presented by the AWPA in 2005 revealed that copper naphthenate in oil, provided excellent protection for posts, with life spans now calculated to exceed 60 years, with 50% of the copper naphthenate being retained in the wood Copper naphthenate is safe near humans and plants (Hoffman *et al*., 2017). Kerosene is a water repellent, solvent- Light organic solvent preservative-that kills termites and ants. With this, I recommend 2% Copper naphthenate in kerosene as a public, commercial and industrial preservative and water repellent for all uses of timber/lumber. In the home or job setting it can be applied by spraying, dipping or brushing. In commercial lumber treatment setting I recommend steeping or soaking in a modified Gedrian's bath. Steeping is a process developed by John Kyan in the 19th century where wood was submerged in a tank of water preservative mix and allowed to soak for a period of time (days to weeks). The depth of retention depended on the species of wood, wood moisture, preservative and soak duration. The Gedrian's bath, patented by Charles A. Sealy, involves treatment by immersing wood in successive baths of hot and cold preservatives. Each bath may last 4 to 8 hours or in some cases longer. The temperature of the preservative in the hot bath should be between 60 to 110 degrees centigrade, and 30-40 degrees centigrade in the cold bath. The average penetration depths achieved in this process ranged from 1.2 to 2.0 inches. Both water borne and oil borne was used with this method.

For the modified Gedrian's bath I recommend steeping/soaking the timber (lumber or wood) in a tank containing 2% Copper naphthenate in kerosene. 2% copper metal by weight should be used. The steeping/soaking time should 10-12 hours at room temperature 25-30 degrees centigrade. The tank should be 30 feet long, 4 feet wide and 6 feet deep. The advantage of such a system is that the preservative can be used to treat more than one set of wood (lumber or timber). One major disadvantage of this treatment is that kerosene is flammable. Hoffman *et al*., (2017) outlined three factors that are important for a preservative to be effective; (a) retention, (b) penetration and (c) uniformity. In the case of 2% copper naphthenate in kerosene the retention would be at least 50% since it is non-leachable, the penetration would be more than 2.0 inches, and since the entire piece of lumber (wood) would be immersed the spread of the preservative would be uniformed. The advantage of using kerosene is that it would be more favourable to an oil based paint with high zinc oxide that can protect against molds. Pieces of wood on the job site should burnt if 2% Copper naphthenate in kerosene is used as the preservative and water repellent. It is possible that the treatment of lumber with 2% Copper naphthenate in kerosene could give wood a 50 year lifespan.

Esteves and Pereira (2009) reviewed the heat treatment process and came to the following conclusions:

1. The number of heat treating companies and processes are increasing, and the commercialization of the heat treated wood is also growing.
2. Heat treatment changes the chemical composition of wood leading to mass loss.

3. Hemicelluloses are the most effected compounds. The degradation starts by deacetylation, and the released acetic acid acts as a depolymerization catalyst, which further increases polysaccharide decomposition. Acid catalyzed degradation leads to the formation of formaldehyde, furfural, and other aldehydes. Furfural and hydroxymethylfurfural are the degradation products of pentoses and hexoses, respectively. At the same time hemicelluloses undergo dehydration reactions with the decrease of hydroxyl groups.
4. Cellulose is more resistant to heat, which is attributable mainly to the crystalline fraction. Cellulose crystallinity increases due to the degradation of amorphous cellulose.
5. In lignin polycondensation reactions occurs with other cell wall components, resulting in further cross linking, contributing to an apparent increase in lignin content. The cleavage of the ether linkages, especially B-0-4, leads to the formation of free phenolic hydroxyl groups, and alpha and beta carbonyl groups, which are responsible for linking via formation of methylenic bridges. The methoxyl content decreases and the new reactive sites on the aromatic ring can lead to further condensation reactions.
6. Extractives are degraded or leave the wood at the same time that new extractable compounds emerge from wood degradation.
7. The reasons for the decrease of the equilibrium moisture are as follows: There is less water absorbed by the cell walls as a result of chemical change with a decrease of hydroxyl groups; there is enhanced inaccessibility of cellulose hydroxyl groups to water molecules due to increase of cellulose crystallinity; and cross linking occurs in lignin.
8. Dimensional stability increases due to cross-linking in lignin, due to the destruction of several hydroxyl groups, and due to decreased affinity with water in the case of treated wood. The reason for the improvement cannot be due to cross linkages because treated wood shrinks in organic solvents such as pyridine or DMSO, as has been reported.
9. Heat treatment improves wood durability, increasing rot resistance, except in contact with soil, and slightly to weathering and insects, but has little or no effect on termite resistance. Several reasons for the improvement of rot resistance have been reported: the transformation of hemicelluloses, which change from hydrophilic and easily digestible to hydrophobic molecules, and the fungal enzymatic systems do not recognize the substratum, the lower fiber saturation point which, by itself, leads to better resistance against biological degradation, and there are changes in the external conditions affecting the microenvironment that affect the decay mechanism of heat treated wood. It is also mentioned that there might be an esterification of cellulose due to the acetic acid released by the degradation of hemicelluloses.
10. Heat treatment affects the anatomical structure of wood. Tangenical holes and cracks, deformation on libriform fibres and the collapse of vessels have been reported.
11. The down side of heat treatment is the degradation of mechanical properties. The effect of MOE is small, whereas static and dynamic bending strength and tensile strength decrease. Brittleness of wood increases with the deterioration of fracture properties due to the loss of amorphous polysaccharides. The degradation of hemicelluloses has been identified as the major factor for the loss of mechanical strength, but also the crystallization of amorphous cellulose might play an important role. Polycondensation reactions of lignin, resulting in cross linking, have been mentioned as having a positive impact mainly on longitudinal direction.
12. Wood becomes darker, wettability and thermal conductivity decrease, and the finishing and gluing process need special attention.
13. An effective quality control measure is still under development for the use of treated wood, but it is clear that it must be different from what has been used in the case of untreated wood.

CONCLUSION

Wood is a very popular building material for a wide variety of reasons. It is a readily available, replaceable, natural resource. It is also easy to work with, cost-efficient, and available in different forms that offer varying degrees of flexibility, strength, and size (Fitzgerald, 2007). Wood is a natural resource and serves as food for termites, fungi and beetles. Carpenter ants do not eat wood but tunnels through the wood to make nests.

Wood decay, which begins as a moisture related problem, is caused by fungi, and insects-termites, ants and beetles. Wood treatment refers to the process of protecting wood (lumber/timber) against one or all of the organisms that cause wood decay. The chemicals used to treat wood are called preservatives and different methods of getting the preservatives into the wood are used. Preservatives are usually water borne or oil borne. Water borne preservatives can leach out of the wood if exposed to water or constant wetting. The benefit of oil based treatments is that they are non-leachable if the wood is exposed to flowing water or wetting over time. Some preservatives are water repellents or are carried in solvents which are water repellents.

The commonly used preservatives all fall short of their effectiveness to the public: there are either limited in their use; there are water borne and leachable; oil borne and only a fungicide or insecticide-seldom both; some are expensive and not widely used. I recommend 2% Copper naphthenate in kerosene to be used as a preservative, insecticide, fungicide (pesticide) and water repellent. In this regard it protects against the external elements that would influence wood decay as well as all the organisms causing wood decay-fungi, termites, ants, and beetles. It is recommended to be used with all wood (lumber/timber) used in construction-millwork, shingles and shakes, siding, structural lumber, fence posts, building and utility posts, decks, mailboxes, swing sets, Oceanside board walks, land and freshwater pilings, furnishings, and interior construction such as framing, sheathing, furring strips, trusses, joists, railroad ties, other wood products that are used above ground, wood used in contact with ground, and fresh water as well as in salt water splash (marine)decking applications. However, 2% copper naphthenate in kerosene is not recommended for use in wood used to store and carry agricultural produce, that is, crakes, containers, or children playsets or cribs. The kerosene will get into the agricultural produce and may make individuals sick. Children might rest their hands on the playsets or cribs and then put their hands in their mouths and this could make them ill.

Periodic checks for the organisms that cause wood decay should be performed every 4 months in areas where moisture can be a problem, poor ventilation and condensation can occur. Follow the recommendations for detecting each type of organism as outlined earlier in the review. Replace wood and treat the infested area with 2% Copper naphthenate in kerosene. Also correct all moisture related problems. All wood (lumber/timber) used in construction in the United States of America and world- wide should treated. This far overrides the expense of replacing. The treatment of wood with 2% copper naphthenate in kerosene should give wood (lumber/timber) a lifespan of at least 50 years.

Heat treatment has little effect on termites and should be used with caution since termites are a major problem in wood decay. Even if wood can be initially heat treated to a moisture content of less than 6% that would protect against all of the organisms which cause wood decay it does not prevent the wood from absorbing moisture again through its usage and hence become susceptible to wood decay. The applicable building requirements should be implemented to protect against all four organisms that cause wood decay-fungi, termites, ants, and beetles.

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