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Chapter

Preservative Treatments on Wood and Their Effects on Metal Fasteners

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Abstract

Wood as a building material has characteristics that make it attractive environmentally compared to other materials. It is an economic, historical and sustainable material. Many species of wood are naturally resistant to the action of the organisms that degrade them. However, species with this natural resistance are unable to meet the demand for wood and wood-based products, which have been growing year by year. The scarcity of species resistant to biological degradation forced man to use other less durable species, mainly of rapid growth, from reforestation, such as some species of Eucalyptus and Pinus. These species have moderate or no resistance to attack by biological agents and require preservative treatments. And to increase the life span of these fast-growing woods, protecting them from fungi, insects and other xylophagous organisms, several preservative agents are used, these compounds being highly toxic to these biodeteriorating organisms. It is known that the effectiveness of traditional wood preservation systems is due to the biocidal effect of the products used, however, they pollute the environment. Thus, there is an increasing need to develop effective preservative chemicals, non-toxic to humans and the environment.

Keywords: Preservative treatment, xylophagous agents durability of wood, biodeterioration, treated wood in construction

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1. Introduction

Wood as a building material has characteristics that make it attractive environmentally compared to other materials. Because it is a material that consumes little energy for its processing, helps to reduce the greenhouse effect and has good characteristics of thermal and electrical insulation. The natural durability of wood and its preservation are two factors that largely determine its use, especially in tropical countries. Although there is a series of works on this subject, it is difficult to compare the results achieved, due to the numerous and different conditions, under which the experiments are conducted (**Figure 1**).

Wood has a range of use in rural and urban environments. However, due to its structure and chemical constitution, it is attacked by several deteriorating organisms. Among organisms, fungi and termites are responsible for the greatest damage to wood [1]. However, no species of wood, not even those of recognized natural durability, is capable of resisting, indefinitely, the weather, variations in

Figure 1.
Treated wooden posts. Source: https://images.app.goo.gl/3eKubCdjmWMQdV2z6.

environmental conditions, the attack of microorganisms and the action of man himself. Physical, chemical and biological agents, acting together or separately on wood, accelerate its degradation process [2].

Reforestation woods, also known as fast-growing from planted forests, are not resistant and require preservative treatments. Currently, about 70% of the wood consumed worldwide comes from reforestation. In civil construction, specifically in the production of wooden housing, Pinus sp. and Eucalipto sp., among the species of fast growing wood from planted forest, in the form of sawn wood, agglomerated sheets, plywood and round pieces [1, 2]. Reforestation species have moderate or no resistance to attack by biological agents and require preservative treatments. And, to increase the life span of these fast-growing woods, protecting them from fungi, insects and other xylophagous organisms, several preservative agents are used, these compounds being highly toxic to these biodeteriorating organisms.

The chapter provides a review of traditional preservatives and the alternatives that have been researched for protection against biodeteriorating agents in wood. It also includes investigations into the corrosion of metal fasteners in wood treated with preservatives, which are limited and take into account only the most common commercial preservatives.

2. Preservation of wood

Wood, when used, is no longer alive, so it will be exposed to decomposition or deterioration like any living thing. This effect can be caused by several agents, among them: biological (bacteria, fungi, insects, mollusks and crustaceans); physical (fire, heat and humidity); mechanical (cracks, wear and permanent deformation) chemical (acidic, saline substances, etc.). The biological factors that are of great importance for their form of action are fungal microorganisms, which start their attack on trees that have not yet been cut. Other types of fungi prefer trees already felled during the following 10 processes: cutting, transportation, unfolding, storage and end use of the piece of wood. Bacteria, on the other hand, need moisture to carry out their attacks. For this to occur it is necessary that the pieces of wood when cut down are in contact with water, and may be submerged or moistened, if put to use in humid environments. The insects, in turn, are found in trees that have not yet been felled, while other insects opt for trees that have already been felled or are in an advanced degradation process [3]. Marine drills are biodegradation agents that cause depreciation in fixed or floating pieces of wood that are submerged in brackish or salt water. These agents are divided into two groups: mollusks and crustaceans [4].

Over time, history records some uses of wood and some preservation techniques, including several important passages. Perhaps the oldest is found in the Bible, in the passage that Noah was instructed to build an ark, large enough to house his family and animal couples to preserve. He also needed to store food for a period of at least 40 days. The bible contains instructions for caulking and preserving wood with bitumen. Bitumen was the oil that naturally flourished in the Middle East region. It was used as it appeared, in the form of tar. This method continued to be used by the Phoenicians on their sailing vessels. Since then, bitumen has established itself as a more traditional substance for the treatment of boat hulls, being perfected by the Greeks. Already, in the modern age, ships became the most important machines, being built with wood. Its preservation against degrading organisms required a lot of protection and conservation efforts. The most appropriate solution was reached at the end of the 18th century, when the hooves started to be covered with copper sheets, fixed on a hemp blanket and bitumen. Vegetable oils were used by the Romans to preserve and maintain the color of wood in civil works [5].

Wood preservation is defined as a set of products, methods and techniques designed to alter the durability of wood [3], which can be divided into:

- Indirect preservation - is the treatment of the environment in which the wood is being used;
- Biological preservation - involves the use of living organisms to preserve the attack of xylophagous organisms;
- Chemical preservation - it is the introduction of chemical products within the wood structure, aiming to make it toxic to the organisms that use it as a food source.

As the chemical preservation method is the most used method in construction, this will be detailed. Chemical preservatives were developed to be used in preservation methods in order to combat biological agents and thus prolong the life of the piece of wood and also, its resistance. Condoms are divided into oil-soluble products that use oil as a vehicle and water-soluble products that use water as a vehicle. The choice of the species, its use and the amount of wood will indicate the most appropriate treatment to be used, as well as the condom to be used [3]. Chemical preservative is the name given to certain substances or chemical formulations, of defined composition and characteristics, which applied to wood provide protection against biological degradation [4] and can be used preventively or curatively. Each condom is generally indicated to combat certain deteriorating agents and its dosage and treatment process to be used must be adequate [5].

According to [6], any substance capable of causing the poisoning of the cellular elements of the wood, making it resistant to the attack of fungi and insects is called a wood preservative. Condoms must have the following properties:

- Resistance to leaching and volatility: the product must have a long-lasting action on wood, it must be chemically stable and resist the risks of use which are leaching (rain, condensation water and soil water) and evaporation (heat action), in addition to not decomposing or changing when in contact with the constituents of the wood;
- Do not change the properties of the wood: the versatility of the use of wood is the result of its physical, chemical, mechanical, organoleptic and decorative characteristics, so the treated wood must not have its surface altered;

- Do not be corrosive: A corrosive product can cause esthetic damage and compromise the joints (straps, nails, screws, etc.);

- Do not increase the flammability of wood: one of the undesirable properties of wood is its ability to burn. Preservative products should not make it more flammable yet;

- Be affordable and available on the market: preserved wood must be competitive with other materials. It is not enough that the product is efficient, but that its use is viable, without compromising the final cost;

- Safe in relation to man and the environment: the toxicity of the condom must be restricted to xylophagous organisms, avoiding the intoxication of men and animals, as well as changes in the ecological balance. It should also not present odors when in contact with humans and animals.

It is unlikely that a chemical preservative will be able to combine all these related properties. As far as possible, the choice should fall on a product that has the greatest number of properties. The choice of this product will also depend on the situation in which the wood is used. For example, creosote has always been considered a very efficient condom, but it makes impractical the subsequent application of paints and varnishes on wood, as well as woods that will be close to man and animals, such as housing, furniture, food storage boxes, etc. Other products, such as boron derivatives, are very efficient preservatives and have low toxicity to humans and animals, but are highly leachable and do not stick to wood. Copper-derived products, on the other hand, have the same advantages, but are corrosive to metals, destroying parts in contact (nails, staples, hinges, etc.) [6].

Historically, the oldest synthetic chemical preservative consists of tar, which consists of a by-product of the carbonization of wood, peat, lignite, oil shale and coal. Creosote was patented by the Englishman John Bethell in 1838 for the treatment of wood exposed to the weather, such as sleepers and transmission poles [7]. Creosote is defined as a tar distillate, extracted from stone coal at high temperatures; and it can also be produced from oil [8].

CCA's history began in 1933, when a wood engineer, Sonti Kamesam, made a discovery that saved the lives of countless coal miners: the injection of arsenic and copper into wooden beams prevents rot. Arsenic, a classic poison kills insects that feed on wood, while copper kills fungi. Kamesan's discovery was to add chromium to this formula, thereby linking the two toxic metals in the cell walls of the wood. The result was to obtain stronger props in the humid underground tunnels, through which they extract the coal. Kamesam's invention not only extended the miners' life expectancy, but also reduced deforestation [9]. CCA is highly effective in protecting wood against a wide variety of wood-degrading organisms, as well as being inexpensive, water-soluble, and resistant to leaching. Since its discovery, many types of CCAs have been introduced, and today the most common formulation contains a mixture of arsenic pentoxide (As2O5), chromium trioxide (CrO3), and cupric oxide (CuO), which can differ in the amount of each component. Lately it has suffered serious restrictions, due to occupational risks resulting from chronic exposure to CCA, and is being banned in several countries, such as Germany, France, England and, recently, the United States [7].

CCB is a mixture of copper sulphate, boric acid and potassium dichromate, which was created to replace CCA, with the advantages of less environmental impact and risk to operators, and the possibility of treatment in open tanks; but highly leachable [7]. The preservatives based on copper, azoles and quaternary

Preservative	Benefits	Disadvantages
Creosote	• Low Cost; • Not Leachate – insoluble in water.	• Exudation problem; • Cannot be used in applications requiring finishing.
CCA	• Highly effective; • Cheap; • Soluble in water; • Resistant to leaching.	• High toxicity due to the presence of arsenic and chromium; • Environmental restrictions.
CCB	• Effective; • Cheap; • Soluble in water; • Less environmental impact compared to CCA.	• Greater leaching; • Toxicity due to the presence of chromium.
Azoles AND quaternary ammonium	• Low toxicity; • Resistant to leaching.	• High cost; • Greater susceptibility to moldy fungi.
Boron compounds	• Effective; • Cheap; • Soluble in water.	• Highly leachable.

Table 1.
Advantages and disadvantages of the main preservative products.

ammonium have variations in their formulations, do not contain chromium and arsenic and can be alternatives in situations where the CCA has restrictions. The azoles and ammonium quaternaries were mentioned as potential substitutes for CCA at the 39th International Forum on Wood Preservation, held in Istanbul, Turkey, in 2008. The international event is considered a reference in the wood preservation sector, presenting the main trends and the most important research results worldwide. These condoms, however, when compared to CCA, present some problems, such as high cost, less fixation power and consequent greater leaching, in addition to greater susceptibility to moldy fungi, requiring the application of additives to control this type of fungus.

Borates are a group of preservatives that were rediscovered in the 1980s, including their salts, such as sodium octaborate, sodium tetraborate, and sodium pentaborate, which are water-soluble. Boron compounds offer the most effective wood preservative systems available today, combining the broad-spectrum properties of effectiveness against bacteria, fungi and insects with low toxicity in mammals. The obstacle is that they remain soluble in water and are easily leached from treated wood [9]. Currently, the fight against fungi in wood has been driven by the use of fungicides such as creosote, CCA (chrome-plated copper arsenate) and CCB (chrome-plated copper borate). Although such compounds have efficient fungicidal actions, the tendency is to be replaced, due to their high toxicity. **Table 1** shows the advantages and disadvantages of the main preservative products used.

3. Sustainable alternatives as preservatives for wood

Since the early 1990s, the search for viable alternatives in the area of wood protection has intensified around the world. Historically, the wood preservation industry has used three major conservation systems for the pressure treatment of wood: pentachlorophenol, creosote and water-based arsenic. The main factors that drove changes in treatment technology and conservation systems worldwide were: environmental concerns, including air and water quality standards, the effect of treated wood on humans and other organisms, and the energy crisis, especially when it comes to oil-based preservative systems. Of these, environmental concerns are prevalent [10].

The classic concept of wood preservation is based on the principle of toxicity, that is, impregnation with biocides to prevent biological degradation. However, chemical control can induce the resistance of fungi, bacteria and insects to biocides, as well as potential health and environmental risks. Effective traditional preservatives are based on metals, such as copper, chromium, zinc, arsenic, boron and fluorine, and compounds such as creosote and amines [11]. For environmental reasons, both the preservation of traditional wood and the use of resistant wood species are subject to political and consumption restrictions. It is known that the effectiveness of traditional wood preservation systems is due to the biocidal effect of the products used, however, consequently, they pollute the environment. In addition to the risks involved in the use of such materials, there is a growing concern with the problems arising from the flow of wood at the end of its commercial life [9]. Thus, there is a growing need to develop effective antifungal chemicals, non-toxic to humans and the environment.

In addition to the risks involved in the use of wood treated with toxic products, there is a growing concern about the problems that arise in the elimination of wood after the end of its commercial life. Systems for improving the durability of wood must be sustainable in production and use. In addition to this, treated wood products must, at the end of their useful life, be suitable for the production of energy by combustion or composting or for use as a source of secondary fibers from related industries, without presenting any problems related to the residual chemicals from their treatment [9].

Derivatives of plants, such as oils, have been used for generations to improve the appearance and to prolong the useful life of wooden products, such as furniture, walking sticks, etc. However, the use of products derived from plants became less attractive for wood protection when synthetic and inorganic compounds were introduced, as they were shown to be more effective against wood decaying organisms [12]. The development of research on wood preservatives is in a critical phase, being necessary its direction for the analysis of products with less environmental impact and competitive cost [13].

The deterioration of wood is, therefore, caused by a combination of chemical, biological and physical processes, and water that plays an important role in all cases. Deterioration and discoloration caused by fungi, and to a lesser extent by bacteria, are an important source of losses [9]. For wood to be attacked by fungi and insects, four factors must be present: water, oxygen, temperature and nutrients. So, to avoid the attack of these organisms, some researchers have been aiming at removing one of these factors [14]. Searches for alternatives range from substances of natural origin and/or plant extracts, to systems that inhibit one of the factors that favor the development of these organisms. Despite the proven efficiency of some environmentally friendly alternatives for the treatment of wood, economic viability makes its use difficult.

In more significant quantities, many studies exploring natural extracts as preservatives for wood. Derived from a number of plants and various parts of the plant, such as bark, wood, leaves, seeds and fruits, they have been examined for their wood-protecting properties in many studies. Among plant extracts, there are essential oils from aromatic plants, extracts from poisonous plants [15], and oils extracted from seeds/grains. And yet, the extracts of the wood itself such as tannin, starch, dyes, oils, resins, waxes and fatty acids. Isolated, or in combination with solvents and other additives, some natural products can perform well in preserving wood [5].

Among the studies on extractives, cinnamon leaf extracts have proven to be highly effective against fungi and wood termites and can potentially be developed into excellent organic preservatives [16–19]. According to the authors, cinnamon oil proved to be highly effective when used in ethanol, but its activity decreased when mixed with water. The addition of surfactants to the cinnamon oil/water combination did not produce a completely stable solution.

Hashim et al. [20] obtained promising results in the evaluation of the resistance of the extracts of the leaf, fruit, wood, bark, seed and flower of *Cerbera odollam* to deterioration by fungi and termites. Further studies are also needed to compare properties with commercial synthetic preservatives; Jain et al. (2011) verified the effectiveness of methanolic extracts from leaves and barks of Cleistanthus collinus and *Prosopis juliflora* to inhibit the growth of white rot and brown rot fungi.

Among natural oils, flaxseed oil is considered one of the natural treatments with the best result, as it is dry, providing good impermeability and protection. In addition to isolated flaxseed oil [5], studies have shown that combinations with copper-chromium [21], and with boron [22] provide better protection results, as it reduces the leaching of the incorporated biocides.

In addition to flaxseed oil, other sources of study as a preservative for wood are oils extracted from the seeds of neem (*Azadirachta indica* A. Juss) and castor oil (*Ricinus communis*). All neem-based products are completely natural, being non-toxic to humans, pets and the environment. The fruits, seeds, oil, leaves, peels and roots of the neem have the most varied antiseptic and antimicrobial uses. Research shows that neem oil is effective against fungi, parasites, insects, some bacteria and viruses [8, 11, 23]. Castor oil, on the other hand, has been studied to improve the persistence of neem oil in wood, since, after twenty days in contact with the soil, neem oil deteriorates, making it difficult to use for the treatment of wood, in which the active ingredients of the substances used for this purpose, must persist for a long time in the treated parts [11, 24, 25].

Bark of many tree species is a rich source of antioxidant and antimicrobial agents, such as waxes, resins, tannins and other extracts [12]. Heartwood extracts from a wide range of plant and tree species show activity against fungi and insects, and many potentially can serve as wood protection agents, alone or in combination [26]. Vegetable or natural tannins are extracts that can be found in various parts of plants, such as wood (heartwood) and bark. Tannins, due to their antifungal properties, have been tested as alternatives to immunizers for wood. They already have applications in the tanning of hides, in the oil industry, as a dispersing agent to control the viscosity of clays in the drilling of wells, being also used in the treatment of water supply and waste, and in the manufacture of paints and adhesives [1]. The research covers the effectiveness of different types of tannins that have been proven to successfully inhibit wood decay fungi, such as wood immunizers, alone [2, 4, 27–31]; combined with other chemicals with established antifungal efficacy [26]. However, one of the biggest problems observed with tannins and their derivatives is that they are difficult to stick to the wood after treatment, although attempts have been made to retain them using additives [12, 28].

When considering the bark as a source of organic biocides, remember that the bioactivity of bark extracts from different sources varies, as has been shown in studies involving the evaluation of antifungal properties of the bark from various species. For the heartwood, in addition to the chemical composition of the extractable products, the durability of the heartwood is related to the quantity and distribution of extractable products within the wood fabrics. In highly durable species, extractives are not only present in cell lumens, but also impregnate cell walls and membranes and it is the combination of chemical substance and physical factors that determine the durability of wood species [32].

Extracts that exhibit antifungal activity, such as the extracts of mimosa bark (Acacia mollissima) and quebracho (*Schinopsis lorentzii*) [33], as well as the essential oils of *P. graveolens* and their fractions [34], and the mistletoe leaves and extracts of lichen [35], extracts from the heartwood of Teak (*Tectona grandis*) [36], extracts of propolis [37] and extracts from the peel of fruits and vegetables [38] have great potential with preservatives for wood. As can be seen, research with natural extracts has been extensive and has proven to be effective in resisting biodeterioration, but its leaching of wood into the environment remains a challenge to be overcome.

In the literature, some alternatives of by-products under study with interesting characteristics such as wood preservatives are:

- Chitosan - By-product of the crustacean processing industries such as shrimp, crab and lobster;

- Okara – Organic by-product produced from the manufacture of soybeans and tofu;

- Extracts of residues related to coffee - a by-product of the coffee roasting process;

- Crude Tall Oil (CTO) and its derivatives - By-product of Kraft pulping.

Research shows that chitosan has been shown to minimize the attack of fungi, however, few studies have been carried out on the application of chitosan to wood [21, 39–43]. According to the authors, chitosan is a low-cost, naturally occurring, nontoxic, edible and biodegradable polysaccharide, which has been found in a wide variety of natural sources (crustaceans, fungi, insects, annelids, mollusks, coelenterates, etc.). It is usually a by-product of the crustacean processing industries (shrimp, krill, crab and lobster). According to [43], the fungicidal effect of chitosan is well documented in the literature, the most accepted model being the one related to the polycationic nature of the polysaccharide that interacts with anionic sites of the cell walls of the fungi. Such interaction is mediated by electrostatic forces, causing changes in the permeability of cell membranes and osmotic instability.

Another by-product that has shown satisfactory environmentally favorable results is the hydrolyzed enzymatic okara (OK), which is an organic waste produced from the manufacture of soy milk and tofu. The formulation studied as a preservative for wood is Okara combined with other products such as copper chloride, sodium borate or ammonium hydroxide [44].

Another alternative presented with the capacity to reduce the growth of fungi that rot the wood was the silver skin of the coffee [45]. The silvery skin of the coffee is a by-product of the coffee roasting process and this has caused a significant suppression of the growth of all fungi. This was not just because of caffeine, but also because of other chemicals present in the residual extracts, which demonstrated that spent coffee can be used as a source of green chemicals in wood preservative formulations.

Tall Oil Crude (CTO), Tall Oil or Talol or resin oil is the generic name for products derived from residual, smelly, gummy and black liquor. It is found and extracted from the residual liquor from the Kraft cooking process for the production of paper and cellulose, known as "black liquor" and considered one of

Preservative under study	Benefits	Disadvantages
Natural extractives	• Resistance to proven biodeterioration.	• Easily leached; • Many types studied and few with more detailed information.
Chitosan	• Resistance to proven biodeterioration; • Biodegradable; • Inexpensive – by-product of the crustacean processing industries.	• Little investigated.
Okara	• Resistance to proven biodeterioration; • Inexpensive – Organic by-product produced from the manufacture of soybeans and tofu.	• Easily leached; • Little investigated.
Coffee–related waste extracts	• Resistance to proven biodeterioration; • Inexpensive – a by-product of the coffee roasting process.	• Little investigated.
+*Crude Tall Oil* (CTO)	• Resistance to proven biodeterioration; • Inexpensive – Kraft pulping by-product.	• Little investigated; • Exudation problem.

Table 2.
Some advantages and disadvantages of the main preservative products under study.

the cheapest, renewable natural oils on the world market, as it is an industrially generated product, not depending on weather and soil, but on the production of cellulose and kraft paper. The yield and composition of Tall Oil may vary, as they are influenced by the quantity of extracts, the quality and species of the wood, and the storage time before cooking. It is not composed of pure triglycerides, like other vegetable oils, but a mixture of fatty acids, resin and unsaponifiable acids (for example, sterols, waxes, hydrocarbons). The amount of these components varies with age, wood species, geographic location, and also with all operations before and during the pulping process.

Investigations made with Tall Oil indicate its potential as a protective agent for wood. Those surveyed who focused on the search for an alternative as a preservative for wood in Tall Oil indicated that the preventive effect is related to the hydrophobic properties, with the high concentration of oleic acid, with the presence of unsaponifiables, with the stability when the acidity index and the saponification index [9, 46–53]. These factors may be indicative of increased resistance to biodeterioration to a greater or lesser degree.

Table 2 shows the advantages and disadvantages of the main preservative products being researched. Much information about these alternatives that are being researched still needs to be investigated.

4. Corrosion of metal fasteners embedded in treated wood

Corrosion of metals in contact with wood has been studied for more than 80 years. However, the durability of metal components attached to wood treated with preservatives has become a concern. The rate and amount of corrosion depends on the metal, the conductivity of the wood, the duration of wet conditions and the type of preservative used. Studies on the corrosivity of wood preservatives in metal fastening components are limited and take into account only the most common commercial preservatives such as Chromed Copper Arsenate (CCA), Ammoniacal Copper Arsenate (ACA), Alkaline Copper Quaternary (ACQ), Creosote and chromed copper borate (CCB) (**Figure 2**).

Wood and metal are compatible in most construction and furniture uses and few corrosion problems occur. However, if there is sufficient moisture at the wood-metal interface, corrosion with susceptible metals can be expected. Corrosion of metal in contact with wet wood is an electrochemical process. The rate and amount of corrosion depends on the metal, the conductivity of the wood and the duration of wet conditions. Factors that can increase the rate of metal corrosion in wood include wood species, the presence of external corrosive contaminants and wood preservative treatment.

The oldest study found was from 1934, which studied the corrosion of wire claws on wood treated with zinc chloride and exposed to moderately humid conditions in Madison. He declared that the corrosion of the wire claws in the wood treated with zinc chloride was significant, and some efforts to protect the wood, such as painting and adding sodium chlorate, were ineffective in reducing corrosion rates [54]. After a few decades, Baker [55] proposed a mechanism for corrosion of metals in contact with wood treated with a preservative. The wood preservatives that Baker studied contained cupric ions that are thermodynamically unstable in the presence of steel and galvanized steel. The mechanism involves transporting cupric ions through the wood to the metal surface where they are reduced. In addition, the mechanism was aqueous, since the corrosion rate depended heavily on the moisture content of the wood.

According to Graham [56] since 2004, wood preservatives seek to remove wood treated with chromed copper arsenate (CCA) from the market, citing concerns about arsenic and chromium contained in CCA. Wood preservatives have introduced a number of preservative treatment substitutes, including alkaline copper type C (ACQ-C), alkaline copper type D carbonate (ACQ-D carbonate), micronized copper quantum (MCQ), copper azole (CuAz), copper and zinc ammonium arsenate (ACZA), sodium octaborate sodium borate tetrachloride (SBX / DOT) and zinc borate, which are currently in commercial use. Published studies indicate that most preservative treatments are, in general, more corrosive than CCA. For example, the carbonate ACQ-D, CuAz and ACZA showed more than twice the corrosivity of CCA [57]. SBX/DOT and zinc borate treatments have been shown to be slightly less corrosive than CCA [56].

Of the alternative treatments for CCA two of the most used are copper azole (CuAz) and acrylated copper quaternary (ACQ). The increased use of alkaline copper quaternary (ACQ) and copper azole (CuAz) as wood preservatives, replacing chrome-plated copper arsenate (CCA), for residential construction has raised concerns about the corrosion performance of fasteners. ACQ and CuAz are believed

Figure 2.
Embedded corroded metal fasteners. Source: https://www.pikist.com/free-photo-socdl/pt.

to be more corrosive than CCA due to the higher percentage of copper in these preservatives and the absence of chromium and arsenic; both are known as corrosion inhibitors [57].

In general, boron-based wood preservatives have been proposed as environmentally friendly alternatives to copper-based preservatives, as they have relatively low toxicity, and do not contain potentially harmful heavy metals, and their handling is safer. Research has shown that boron compounds are less corrosive than copper compounds. Based on these considerations, wood preserved with boron does not present a higher risk of corrosion for steel fasteners than copper-based preservatives and there is a reasonable expectation that the long-term corrosion rate will be lower [58].

Based on the various studies addressed, it can be said that wood preservatives, ACQ and CuAz, presented as alternatives to CCA, are up to 2 times more corrosive than CCA due to the higher percentage of copper in these preservatives and absence of chromium and arsenic; both are known as corrosion inhibitors. CCB is less corrosive than CCA. These results show that research for the development of sustainable wood preservatives must cover the corrosivity of the fixing components that are used in wood, both for civil construction and furniture.

5. Concluding remarks

Based on the various studies cited, the search for alternatives to current condoms has been efficient, but not effective, that is, a viable alternative for existing products has not yet been found. Many sustainable alternatives have high efficiency against biodeteriorating fungi, however they are easily leachable, that is, they do not stick to wood. Those that have a good fixation on the wood, however, do not present the desired resistance. Thus, research is still needed to develop a sustainable product, with high resistance to decaying fungi and with excellent fixation on wood.

In parallel, corrosion of treated wood fasteners can limit applications, reduce consumer satisfaction and generate costly returns or increase fastening costs if stainless steel or other costly fastening devices are specified to avoid future problems. This could lower the timber from the market for some applications.

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