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Biological Degradation of Wood: Mechanisms of Decay and Modern Protection Strategies – A Review

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Abstract: Wood is an efficient renewable material that has been extensively used in constructions, infrastructure and engineering products. However, in all of these applications the life of the service is significantly reduced due to biological degradation. Fungi, bacteria and insects are the main agents of the disintegration of wood, which thrive in favourable environmental conditions and take advantage of the lignocellulosic structure of the material. The current review provides an overview of the biological events that govern the degradation of wood, especially the fungal degradation, along with enzymatic and oxidative reactions. Moreover, it describes the effect of structural and chemical properties of wood on its resistance to decay, and thus provides a conceptual base on the appearance of biodeterioration.

The review provides a critical assessment of traditional and innovative wood protection approaches, which include existing preservative regimes, moisture - management approaches, wood-modification approaches and nano - enabled bio-based interventions.

Recent developments have brought about a paradigm shift in terms of integrated, biological responding protection concepts, where the material modification is co-ordinated with directed biological resistance. Although much has improved, the long-term sustainability, environmental compatibility, and cost-effectiveness are still problematic. The conclusion outlines the research directions that are important to perfect predictative service-life models and trigger the creation of the sustainable solution to the problem of the wood protection in the future.

Keywords: wood rot, Wood modification, Biological durability, biodeterioration.

Introduction

Wood is one of the most commonly used renewable resources in the construction, infrastructure, furniture and cultural heritage sectors due to its ability to provide higher strength-to-weight characteristics and a low embodied energy footprint and allow long-term carbon sequestration. However, its lignocellulosic polymers also make it intrinsically biodegradable: when favourable environmental conditions occur, wood can be very fastly accessed by diverse microorganisms and insects because of its carbon reserves (Zabel and Morrell, 1992; Schmidt, 2006). This dual nature, high utilitarian value and biological vulnerability, places management of biodeterioration as one of the main scientific and engineering demands to realise long-lasting wood performance of the building and product design in the modern world (Rowell, 2005; Lebow, 2010).

The biological degradation of wood is mostly influenced by fungi which includes white rot, brown rot and soft rot; bacteria and wood-destroying insects also play a major role in losses, especially when the environment of its operation is humid or in certain hazardous conditions (Schmidt, 2006; Blanchette, 2000). Complicated interactions between organism ecology and the availability of moisture/oxygen and accessibility of chemical components of cell-wall polymers, which contribute to cell-wall decay, manifest as microstructure (Fengel and Wegener, 1984; Zabel and Morrell, 1992). Rapid depolymerisation of brown-rot systems can be achieved with comparatively light mass loss and early and intense reductions in mechanical strength- which have been determined to be a major durability and safety issue with structural timber (Green and Highley, 1997). Recent developments in fungal biology and omics show that in functional diversity of wood-decay fungi, differences in enzymatic toolkits and oxidative processes are underlying the source of functional variations, and the reason policy makers need to adopt multiple degradation pathways, and not just one degradation mode that employs a single mechanism of inhibition (Eastwood et al., 2011; Arantes and Goodell, 2014).

In practical terms, the processes of biodeterioration are mainly controlled by the dynamics of moisture: most wood-degrading fungi need the wood moisture content to be above a certain threshold and under appropriate temperature/oxygen conditions. This means that durability is not a separate concept, and that design, detailing and surface performance can and should not be seen without it (Williams & Feist, 1999; Lebow, 2010). Recent durability models therefore focus on both of these complementary methods; avoidance (design strategies that keep the wood dry) and resistance (increase intrinsic resistance by treatment or modifying the material) (Lebow, 2010; Kirker and Lebow, 2021). Such principles gain even greater importance when engineered wood products are launched into more demanding use, where long service life and predictability are needed.

In the past, preservative treatment has played a critical role in making possible non-durable wood species to be used in exterior or ground-contact conditions. However, preservative technology has gone through dramatic shift based on changing expectations on matters relating to toxicity, leaching potential and end-of-life management (Freeman et al., 2003; Lebow, 2010). The abandonment of some of the old systems has heightened attention to more recent copper-based formulations and other substitute co-biocides, as well as enhanced evaluations of performance in harsh exposure regimes and against tolerant organisms (Freeman and McIntyre, 2008; Kirker and Lebow, 2021). At the same time, more global sustainability criteria have prompted a rise in the interest in alternatives of changing wood chemistry and physics to prevent moisture sorption and bio-susceptibility without necessarily using biocidal loading (Hill, 2006; Esteves and Pereira, 2009).

In that regard, the current protection strategies have become: (i) enhanced preservative systems and treatment technologies; (ii) non-biocidal moisture-regulation methods (e.g., barriers systems and water repellents); (iii) commercial wood modification pathways including thermal modification, acetylation, and furfurylation; and (iv) novel nano-based and surface-functional strategies that seek to attain greater penetration, release, or fixation of the active agents (Hill, 2006; Sandberg et al., 2017; Papadopoul The studies involving nanometal have revealed that sizes and dispersion of particles can affect the leach resistance and biological efficacy which opens prospects to improve durability and reduce the overall chemical loss to the environment (Kartal et al., 2009; Clausen et al., 2010). The recent synthesis reviews also indicate a rapid increase in the studies on nano-formulations and other advanced delivery concepts that seek to integrate efficacy with better environment-related performance and scalability (Ong et al., 2025). Recent systematic reviews highlighted the need to understand modern trends and future challenges in heterogeneous developmental sectors in a holistic analytical approach, by focusing on the interplay between structural conditions and economic determinants and long-term planning (Palani, 2025a; Palani, 2025b).

With this in mind, the present review focuses on: (1) a mechanistic foundation of wood biodeterioration, with its focus on fungus and microbial pathways that determine the strength loss and mass loss; and (2) the development of wood protection technologies over past conventional preservatives and towards modern and performance-based approaches involving material modification, moisture control, and novel nano-based technologies. The review aims to explain how mechanistic understanding might be used to guide the selection, optimisation and future development of wood durability solutions to both structural and non-structural uses by synthesising mechanisms of decay and protective principles (Goodell et al., 2003; Kirker and Lebow, 2021).

The Structural and Chemical Composition of Wood.

Wood is a natural, anisotropic, hierarchically structured biological composite, the performance and durability of which is basically dictated by its structural and chemical constitution. The organism has growth rings and oriented fibers on the macroscopic level which gives it direction-dependent mechanical and physical characteristics. On smaller scales, its cell structure and polymeric composition defines the moisture transport, chemical reactivity, and biological degradation vulnerability (Fengel & Wegener, 1984; Rowell, 2005).

Anatomically, wood is mainly composed of long cells tracheids in softwood and fibers, vessels and parenchyma cells in hardwood that are oriented to support the mechanical and transport of fluids. The cell wall itself, consists of a multilayered structure, i.e. the middle lamella, the primary wall and the secondary wall (S1, S2 and S3) comprising different microfibrils of various angles, chemical composition and functions (Sjöstriem, 1993). The lignin-containing middle lamella bonds the neighboring cells, whereas the secondary wall, and especially the S2 layer, influences the mechanical property and accessibility of wood to chemicals (Fengel and Wegener, 1984).

Wood chemically consists of lignocellulosic material with cellulose, hemicelluloses, lignin, as its major constituents as well as extractives and inorganic compounds in small proportions. Cellulose is a linear 14-glucan 14 -linked and 14 -linked glucan, crystalline microfibrils which give tensile strength and structural stability. Cellulose is comparatively resistant to enzymatic action due to its high level of polymerization and crystallinity, but once depolymerization starts; it can lose its strength rapidly even at low levels of mass loss (Rowell, 2005; Klemm et al., 2005).

Hemicelluloses are lower-molecular amorphous heterogeneous and branched polysaccharides compared to cellulose. Softwoods and hardwoods have different chemical makeup with glucomannans being the major component of softwoods and the xylans being the major component of hardwoods (Sjoholm, 1993). Hemicelluloses can be readily hydrolyzed and attacked by biology especially because of their amorphous structure and accessibility in the cell wall matrix. They therefore tend to be the first target in the fungal and bacterial degradation (Hill, 2006; Esteves and Pereira, 2009).

Lignin is a three-dimensional phenolic polymer with amorphous structure that is a by-product of p -coumaryl, coniferyl and sinapyl alcohols. It offers compressive, hydrophobic and microbial resistance to penetration especially in the middle lamella and secondary wall area (Boerjan et al., 2003). Although lignin plays a protective role, it can be selectively degraded by some species of fungi; most importantly, white-rot fungi, through oxidative enzyme systems and thus, evidences a dual processing of lignin as both a protective barrier and a biodegradable substrate under specified biological conditions (Kirk and Farrell, 1987; Blanchette, 2000).

Besides structural polymers wood is also a source of extractives that include phenolics, terpenes, fats, waxes, and resins which will greatly affect natural durability. The extractives of some extractives can act as antifungal or insect -repellant, enhancing the natural resistance of some species, whilst others can enhance the hygroscopicity or nutrient levels (Rowell, 2005; Schultz and Nicholas, 2002). Extractives also vary significantly across and within species and are difficult to generalize in terms of durability predictions due to the wide variation in quantity and chemical nature of extractives produced by a single tree, or by anatomy or polymer structures alone.

The close contact between these chemical constituents in the nanoscale architecture of cell wall regulates moisture sorption behavior, which is a very important requirement in biological degradation. Water serves as a medium of transportation of enzymes and metabolites as well as as a plasticizer that enhances the mobility and accessibility of polymers (Salmen, 2004). Therefore, biodeterioration resistance can be greatly increased by modifications to change cell-wall chemistry, or by means of decreasing hygroscopicity such as acetylation or thermal modification, even without the addition of toxic biocides (Hill, 2006; Sandberg et al., 2017).

On the whole, the knowledge about the structural and chemical structure of wood is a basis of the interpretation of decay process and assessment of protection scales. The biological degradation of wood cannot be said to be caused by a single factor but is more of a summation of the effects of cell-wall structure, polymer chemistry, extractives content, and moisture interactions. This combined view is paramount to the connection of basic material characteristics with the degradation mechanisms and defense technologies mentioned in the following chapters.

Mechanisms of Biological Wood Degradation

Biological degradation of wood is a complex multisystemic process, which is demonstrated through interactions between wood cell-wall polymers and a broad number of microorganisms, most of them being fungi and bacteria. These organisms use wood as a carbon source and therefore they start degrading structural polymers in both an enzymatic and non-enzymatic pathway. Subsequent degradation process is dependent on the organismal identity, environmental factors, and accessibility of certain chemical elements in the wood structure (Zabel and Morrell, 1992; Schmidt, 2006).

The rotting of wood by fungus is a conspicuous and easily visible process. Historically, wood-degrading fungi are classified into the categories of white-rot, brown-rot, and soft-rot, depending on different preferences of polysaccharide and lignin constituents and the different types of cell-wall degradation. This means that every functional group has a unique set of enzymes and degradation cascades that affect the structural integrity and physicochemical properties of the wood respectively in different ways (Green and Highley, 1997; Blanchette, 2000).

White-rot mushrooms can break down lignin, cellulose and hemicellulose to great degrees. This has been supported by a system of oxidative enzyme that consists of lignin-modifying enzymes like lignin peroxidase, manganese peroxidase, and laccase (Kirk and Farrell, 1987; Hatakka, 1994). Subsequent lignin depolymerisation results in the wood becoming more porous and hence exposing the polysaccharide substrates and thus increasing the enzymatic hydrolysis that follows. White-rot fungi can either be co-degraders of all major polymers or target particular components and generate a characteristic decay pattern and cause changes in wood chemistry, which rely on taxonomic identity and environmental conditions (Schmidt, 2006; Eastwood et al., 2011).

Brown-rot fungi, conversely, are primarily depolymerising cellulose and hemicelluloses and leave a relatively stable lignin framework, but with chemical modifications. This is enabled by an oxidative enzymatic system that also comprises of lignin-modifying enzymes which include lignin peroxidase, manganese peroxidase and laccase (Kirk and Farrell, 1987; Hatakka, 1994). The consequent lignin degradation elevates porosity consequently exposing polysaccharide substrates and enhancing the resultant enzymatic hydrolysis. White-rot fungi can be co-degraders of all major polymers or can selectively degrade certain components depending on species identity and environmental conditions thus generating unique decay patterns and wood chemistries (Schmidt, 2006; Eastwood et al., 2011).

Brown-rot fungi on the other hand actively break down cellulose and hemicelluloses and leave behind a relatively intact lignin scaffold that has been chemically altered. This leads to high levels of mechanical weakening in the initial stages of the decay process which in most cases is accompanied by significant mass loss (Green and Highley, 1997). An encapsulated Fenton reaction is the most common brown-rot reaction that produces highly reactive hydroxyl radicals that can cleave polysaccharide chains in a non-enzymatic reaction (Goodell et al., 1997; Arantes and Goodell, 2014). This oxidative cascade also allows brown-rot fungi to overcome size constraints of hydrolytic enzymes and be able to effectively hydrolyse crystalline cellulose subunits.

Originally soft-rot fungi are mainly found in less favourable conditions than basidiomyctes, including too damp, hot, or impregnated with chemicals. The main degraders of cellulose and hemicelluloses in this category are Ascomycota and Deuteromycota, which degrade by either localized cavities in the secondary cell wall or by eroding surfaces (Nilsson et al., 1989; Schmidt, 2006). Even though soft-rot is slower than brown-, or white-,rot, it may be important in a long-term ground exposure, under wet conditions or extreme circumstances, when other genera of fungi are dormant.

Bacterial role, especially in wet or anaerobic conditions like marine, wetland and burrowed timber is eminent in wood degradation. Although bacterial degradation is not usually very destructive compared to fungal degradation in the short run, it might trigger a catastrophic structural disharmony in the long term (Daniel and Nilsson, 1998; Singh and Kim, 2005). Bacterial activity usually targets on the available polysaccharides and pit membranes making the wood matrix increasingly permeable and, hence, colonisation by fungi that harbours formation of aerobic conditions again.

Water is central to increased degradation in all biological agents. It does not only regulate enzymatic activity, but also leads to cell-wall swelling, to augmenting enzyme and low-molecular-weight oxidant diffusion and to releasing proteins, hence, reducing gel-electric interactions (Salmen, 2004; Zelinka et al., 2010). The temperature, oxygen and nutrient availability, further regulate the biological activity and together determine the hazard conditions to which one of the decomposition mechanisms prevails.

Molecular mechanism Wood biodegradation involves hydrolytic degradation of glycosidic bonds in polysaccharides, oxidative degradation of lignin and oxidative degradation of carbohydrates. All of these processes define the rate of deterioration, remaining wood chemistry, and later changes in the physical and mechanical functionality (Arantes and Goodell, 2014; Eastwood et al., 2011). As a result, a profound knowledge of these mechanisms is crucial to a designing of efficient protection strategies, which can be the inhibition of certain enzymatic reactions, limitation of access to water, or alleviation of oxidative activity.

On the whole, biological degradation of wood is a heterogeneous and species-specific process, which depends mostly on the chemical composition of wood, the pore structure of a cell wall and other environmental conditions. A mechanistic explanation of the processes of fungal and bacterial decomposition can provide a scientific input into assessing the effectiveness of traditional preservation methods and the development of new, specific preservation strategies, as explained in the following chapters.

Biological Agents that cause Wood Decay.

A wide range of organisms that use wood polymers as energy and carbon sources causes the biological degradation of wood. These biologic agents vary significantly in their physiology, enzyme potential, ecological needs, and manner of wood decay. Some of them, including fungi, are the most common agents of decay in wood, although bacteria and insects also have significant auxiliary or context-dependent roles, especially in specialized environmental conditions (Zabel and Morrell, 1992; Schmidt, 2006).

The most important agents that contribute to structural and chemical degradation of wood in the terrestrial environment are the wood-decaying fungi. They are mostly the basidiomycetes and ascomyctes and can colonize the wood when adequate moisture, oxygen and suitable temperatures are present. As it was explained earlier in the preceding chapters, the common classification has been made on fungi as white-rot, brown-rot and soft-rot depending on the type of their decay and their specificity to the substrate (Blanchette, 2000; Schmidt, 2006). Their extracellular enzyme and low-molecular-weight oxidant secretion permits entry into the wood cell wall to degrade resistant complex polymers by their action (Kirk and Farrell, 1987; Eastwood et al., 2011).

White-rot fungi are the main agents of lignin degradation in forest ecosystems, they are also one of the most important agents of the global carbon cycle. Other species like Phanerochaete chrysosporium and Trametes versicolor have highly active oxidative enzymes that are able to mineralize lignin to carbon dioxide and water (Hatakka, 1994; Kirk and Farrell, 1987). Brown-rot fungi, on the other hand, like Gloeophyllum trabeum and Postia placenta specifically break down polysaccharides causing rapid loss of strength in building and outdoor construction timbers (Green and Highley, 1997). Soft-rot ascomyctes dominate and basidiomyctes are suppressed in inhospitable conditions such as high moisture, high temperature or preservative-treated wood (Nilsson et al., 1989).

Another category of biological agents that is implicated in the degradation of wood is bacteria especially in waterlogged, anaerobic, or marine environments. Even though bacterial decay, in general, is slower and less visually impressive than fungal decay, it can also dramatically change the microstructure of wood over extended time periods (Daniel and Nilsson, 1998; Singh and Kim, 2005). Bacteria prefer to attack available carbohydrates, pit membranes and middle lamella areas, which enhances the porosity and permeability. Such bacterial preconditioning can lead to the consequent fungal colonization under the conditions of a change in the environment to prefer aerobic decay (Blanchette et al., 1990).

Insects that destroy wood are one of the greatest biological hazards to wood, particularly in warm and temperate areas. One of the most damaging insects is the termites, which have the ability to reduce the structure to ruins by eating up wood materials that contain cellulose. Symbiotic microorganisms in their digestive system increase their efficiency and help them to break down cellulose and hemicellulose (Watanabe and Tokuda, 2010; Brune, 2014). Powderpost beetles (Lyctus spp.), and wood-boring beetles (Anobium spp.) are also known to cause the rotting of wood especially in old-timber and vintage buildings (Creffield, 1996; Hickin, 1971).

Environmental factors have a strong effect on the activity and dominance of these biological agents. The most important parameter is the availability of moisture because most fungi need a content of moisture in wood above the fiber saturation, and insects are usually restricted by over-wet or dry environment (Zabel & Morrell, 1992; Lebow, 2010). Biological susceptibility and decay progression is further modulated by temperature, the availability of oxygen, species of wood and the availability of natural or added protective compounds.

Finally, biological agents that cause wood deterioration include fungi, bacteria, and insects, which cause biodeterioration in different but occasionally inter-dependent ways. Spreading the protection of wood should therefore consider this biological diversity and address the particular organisms that are concerned with the targeted service environment. The ecology and behavior of these agents are necessary to understand and predict the life expectancy of the service and the correct preservation or modification strategy.

Traditional and Modern Wood Protection Strategies

Biological degradation of timber is one of the factors that have historically been a critical necessity in order to extend the service life, and allow timber to be used in harsh environments. Since moisture, organism type and wood chemistry greatly affect biodeterioration, the protection measures have developed in order to counter these factors by taking a mixture of chemical, physical and material protection measures (Zabel & Morrell, 1992; Lebow, 2010). In the past, timber conservation depended greatly on the use of preservatives that are mostly chemical in nature but in the modern day, there has been a growing trend in the use of preservatives that are environmental friendly, durable and less toxic.

The main premises of the traditional timber preservation techniques are impregnation of timber with the biocidal preservatives, which are aimed at preventing fungal growth and insect attack. Early preservation systems featured oil-borne systems like creosote and pentachlorophenol which was quite durable in extreme exposure environments but gave rise to concerns with regard to human health and environmental persistence (Freeman et al., 2003; Lebow, 2010). Later to be dominant, waterborne preservatives, such as chromated copper arsenate (CCA) were shown to be effective and could fix into the wood structure. Nevertheless, the regulatory measures on systems containing arsenic and chromium led to major modifications on the usage of preservatives, especially in residential use (Freeman & McIntyre, 2008).

Most of the contemporary conventional preservatives are copper-based, including alkaline copper quaternary (ACQ), copper azole (CA), and micronized copper preparations. Copper is a broad-spectrum fungicide but organic co-biocides increase its efficacy on copper-tolerant fungi (Freeman and McIntyre, 2008; Kirker and Lebow, 2021). In spite of the fact that such systems offer good protection, the problem of corrosion of metals, leaching, and environmental loading remains a reason to consider alternative or complementary approaches in the sphere of research.

Design-based and physical protection of timbers are a vital part of timber durability management. Such methods aim at reducing the water absorption and keeping the environment hostile to biological activity by architectural elaboration, paint and water-resistant treatments (Williams and Feist, 1999; Lebow, 2010). Although these techniques do not kill decay organisms (as such), they profoundly decrease the risk of the onset of the decay process and are frequently used in respect with preservative treatments to reach long-term performance.

Over the last few decades, the world has witnessed the development of wood modification technologies that have become one of the key types of contemporary protection measures. Wood modification as opposed to traditional preservatives seeks to modify the chemical or physical characteristics of the wood cell wall in order to mitigate hygroscopicity and the biological vulnerability of the wood. One such process is the thermal modification, such as heating wood at high temperatures under controlled conditions resulting to the degradation of the hemicelluloses, and the decrease in equilibrium moisture content. It has been proven that in many cases thermally modified wood has better dimensional stability and decay resistance, but mechanical properties may decrease (Esteves and Pereira, 2009; Sandberg et al., 2017).

Wood durability is further increased by chemical processing methods like acetylation and furfurylation which permanently alter the hydroxyl groups on the wood or impregnate the cell walls with polymerised resins. Acetylated wood has demonstrated a high level of resistance to fungal organisms and higher dimensional stability without the use of toxic biocides and this makes it a model of environmentally oriented durability solutions (Hill, 2006; Rowell, 2005). Furfurylation also provides resistance to decay by loading the cell wall with polymerised furfuryl alcohol, but issues of complexity and cost of the process remain (Sandberg et al., 2017).

In more recent times, nanotechnology-based strategies of protecting woods have received more attention. Nanometeral particles like nano-zinc oxide and nano copper have been shown to have superior surface area, penetration and changes in the leaching behaviour in comparison to the conventional formulations (Kartal et al., 2009; Clausen et al., 2010). Such properties may result in a higher biological effect of lower retention. Moreover, nano-enabled systems can provide a chance to control release and enhancement of active components, yet, the long-term effects on the environment and scalability are still under research (Papadopoulos and Taghiyari, 2019).

Another research direction of interest in the current timber preservation studies is bio-based and environmental friendly preservatives. These methods are fungal-oxidative system antagonists (plant-derived extractives, antioxidants, and enzyme-inhibitors) as opposed to exclusively toxic alternatives (Schultz et al., 2004; Schultz and Nicholas, 2002). Although promising, numerous bio-based systems have issues to do with consistency, their ability to last in extreme conditions, and commercialisation on a grand scale.

In general, the modern system of timber protection is characterized by a change in the one-solution approaches to the ideas of integrated durability, which combines the changes in the wood material, moisture regulation, and specific biological inhibition. The choice of a suitable protection strategy is based on the desired service environment, regulation and the sustainability goals. Further technology innovations in the areas of material science, microbiology, and environmental evaluation should result in a further enhancement of timber protection technologies and help to promote further usage of timber as a long-lasting and environmentally-friendly construction material.

Discussions and Future Projections.

One of the major limitations to the long-term efficacy and dependability of wood as a structural and functional substance is biological degradation. The review shows that the process of wood decay turns out to be a complicated interaction between wood chemistry, cellular structure, environment, and activity of various biological agents- fungi, bacteria and insects (Zabel and Morrell, 1992; Schmidt, 2006). These interactions can only be understood in a mechanistic way to predict the service life and to come up with appropriate ways of protecting against them.

The development of the science of wood has significantly broadened the scope of the research into the process of decay, which occurs at the molecular and microstructural scale, indicating that particular organisms utilize a particular enzymatic and oxidative pathway to break wood polymers down. Such observations explain why there is no universal protection strategy that can be effectively used in all exposure situations and why it is important to shape durability solutions to specific exposure environment and biological risks (Arantes and Goodell, 2014; Eastwood et al., 2011).

The current protection of wood has also changed the use of broad-spectrum toxic preservatives to some more integrated and sustainable methods. There is a significant opportunity to improve the durability and reduce environmental impact by using wood-modification technologies, better copper-based systems, moisture-management strategies, new nano-enabled and bio-based treatments (Hill, 2006; Sandberg et al., 2017; Kirker and Lebow, 2021). However, there are still, various challenges in terms of long-term performance, cost, scalability, regulatory acceptance.

Future studies are to focus on the combination of mechanistic decay models with reality of service conditions, providing the protection system with a smaller environmental footprint, and improving predictive engineering tools of service-life analysis. Further collaboration of material science, microbiology, and environmental assessment will play an important role in promoting the increased and sustainable use of wood in current construction and engineering projects.

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