# THE EFFECT OF WEATHERING ON WOOD AND ITS PROTECTION

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## SUMMARY

When wood and wood products is exposed outdoor, above ground, it undergoes many complex processes such as: photo-degradation by ultraviolet and visible light; leaching, hydrolysis and swelling/shrinking by water/moisture (railfall, dew, snow, changes in humidity in the air); discoloration by staining fungi and molds. All of the above effects reduce the use and life-time of wood products. The appearance of unprotected wood changes considerably after only few months of wood's weathering exposure. To protect wood from deterioration by weathering, the most common way is to prevent weathering factors from reaching the wood. Wood coatings including paints, stains, and similar materials provide good protection to wood by partly or completely obstructing the light to reach wood and excluding water from wood. Wood preservatives such as chromated copper arsenate (CCA), ammoniacal copper quat (ACQ), acid copper chromate (ACC), mainly protect wood from damages by microorganism. Chemical modification of wood may cause change in wood properties, hence improve weathering resistance significantly. This paper discussed the influence of outdoor weathering including photo degradation, water/moisture degradation and fungal degradation on the performance of wood in detail. The chemical and physical changes of wood exposed outdoors are described, and methods for protecting exposed wood surfaces are summarized.

**Keywords: blue stain, outside weathering, photo-degradation, protection, water/moisture.**

## 1. INTRODUCTION

Wood is a degradable natural polymer. The degradation is considerably rapid when wood is exposed outdoor without any protection. We see many examples of effects of weathering on wood. The rough, grey appearance of old barns, wood shake roofs, and drift wood are typical examples of weathered wood (Williams, 2005). It has been widely established that sunlight (UV, visible and IR light), moisture (dew, rain, snow and humidity), organism (staining and mold) are the most important causes, often acting simultaneously for weathering degradation (Hon, 2001).

It is primarily the ultraviolet (UV) portion of the solar spectrum that initiates the process we refer to as weathering. It is a photo-oxidation or photochemical degradation of the wood surface. The degradation starts immediately after the wood is exposed to sunlight. First, the color changes, then the surface fibers loosen and erode, but the process is rather slow. It can take more than 100 years of weathering to decrease the thickness of a board by 5 - 6 mm. In addition to the slow erosion process, other processes also occur. The wood may develop checks and a raised grain. Mildew will colonize the surface and discolor the wood. If boards contain compression or juvenile wood, cross-grain cracking may develop. The boards may warp and cup, particularly in decking applications. These other weathering factors such as mildew growth, checking, splitting, and warping, are often more important than the photo-oxidation (Williams, 2005).

## 2. DEGRADATION OF WEATHERING WOOD

### 2.1. Photodegradation

Solar irradiation (particularly UV, but also visible light) is the most devastating component in degrading wood by physical and chemical actions during external weathering. UV light can penetrate into wood to a depth of approximately 75 μm and visible light approximately 200 μm. In the electromagnetic spectrum, UV light with wavelength between 295 and 400 nm is the most effective to contribute to weathering (Hon, 1981, Derbyshine and Miller, 1981). The degradation process is initiated by the formation of free radicals due to light absorption by wood polymers. Lignin is a good light absorber having a broad absorption band in UV and visible region (Hon, 1994). The light absorbing abilities of cellulose and hemicellulose are significant weaker than lignin. Lignin contributes with 80 - 95%, carbonhydrates with 5 - 20% and extractive with about 2% to the total UV absorption of wood (Norrström, 1969). The consequences of photochemical reactions on wood surfaces are loss of methoxyl content of lignin, photo-dissociation of carbon-carbon bonds and formation of carbonyl based chromophoric groups. Phenolic hydroxyl groups in lignin react with light rapidly to produce phenolic radical, which in turn transforms into *o*- and *p*-quinonoide structures by demethylation or by cleavage of the side chain and formation of colored unsaturated carbonyl based chromophoric groups resulting in the color change, and yellowing of wood surface (Hon, 2001).

Pandey (2005) reported the results of degradation of wood surfaces of *Pinus roxburghii* (chir pine,) by an UV visible xenon source. The changes in color of wood surfaces were analyzed and correlated with lignin decay and carbonyl formation estimated using FTIR and fluorescence measurements. FTIR spectra of *P. roxburghii* irradiated for different periods are shown in Figure 1.

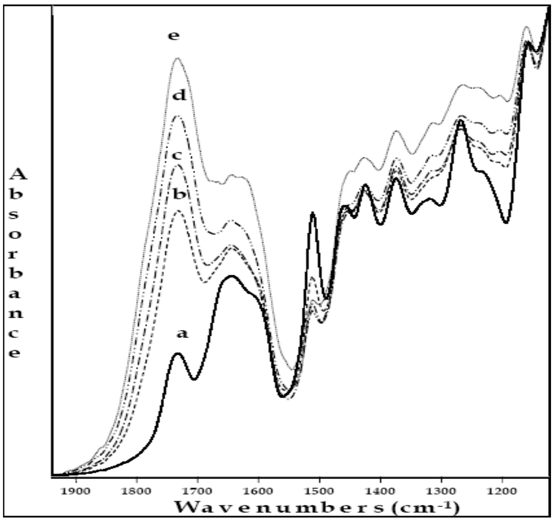

**Figure 1. FTIR spectra of *P. roxburghii* irradiated for: (a) 0 hour, (b) 20 hours, (c) 50 hours, (d) 100 hours and (e) 300 hours (Pandey 2005)**

A comparison of spectra of exposed and unexposed wood showed significant decrease in the intensity of lignin aromatic absorption band at 1511 cm$^{-1}$, which is accompanied by a successive increase in the intensity of carbonyl absorption at 1734 cm$^{-1}$. The intensities of peaks associated with carbohydrates are not significantly affected by irradiation. The rate of lignin decay was calculated by determining the ratio of lignin reference band at 1511 cm$^{-1}$ against carbohydrate reference bands at 1375 and 1158 cm$^{-1}$. Since photo-degradation has no significant effect on the intensity of carbohydrate peaks, these carbohydrate bands were used as internal reference for calculating lignin decay due to light irradiation. Similarly the relative increase in the proportion of carbonyl groups during irradiation was calculated by taking ratio of intensity of carbonyl band at 1734 cm$^{-1}$ against carbohydrate reference peaks. The lignin/carbohydrate ratio was reduced and the ratio of carbonyl/carbohydrate was increased when exposure time was increased from 0-300h.

The color changes at wood surfaces are mainly due to the formation of carbonyl (C=O) groups due to photo-degradation of lignin. The color changes of wood during light irradiation were correlated very well with the lignin decay and formation of carbonyl groups generated during photo-degradation of wood. Therefore, the degree of photo-degradation of wood surfaces can be assessed by fluorescence measurements directly from wood surfaces. Estimation of changes in chemical composition of wood surfaces due to photo-degradation can be carried out by measuring CIELAB parameters (Pandey, 2005, Petrillo et al., 2019).

Hon (1994) used Southern yellow pine (*Pinus* spp.) to study the effect of UV light and acid rain on wood component. Wood specimens (from earlywood) were microtomed into a thin section with dimensions of 12 mm x 45 mm x 10 µm. Since wood is susceptible to UV degradation, an increase in carbonyl groups, based on the calculation using the FTIR relative absorption peak ratio of 1,735 $cm^{-1}$/895 $cm^{-1}$, was observed when wood specimens were irradiated with UV light (without acid) at ambient temperature. Thus, when wood surfaces were exposed to UV light, carbonyl group content increased and lignin content decreased simultaneously (similar to Pandey's results). These changes were accelerated when they were also exposed to a dilute sulfuric acid solution-a laboratory simulation of acid rain especially at 65°C and 65% relative humidity. The higher concentrations of acid, the more carbonyl groups were detected. Cellulose and hemicelluloses are more susceptible to acid reaction than lignin.

Evans (1988) used weight loss to assess the deterioration of thin wood veneers during weathering. It is indicated that significant weight losses resulting from degradation of the lignocellulosic matrix rather than from losses of water soluble extractives occurred during exposure. The high weight losses of thin veneers after weathering appeared to result from extensive breakdown of the ligno cellulosic matrix. The increasing isolation of hexose sugars following aqueous extraction may result from depolymerization of cellulose or hemicellulose. Lignin in accord with previous observations of the chemical changes in wood during natural weathering appeared to be rapidly degraded during exterior exposure.

In a later work by Evans et al. (1996), Radiata pine veneers and blocks were exposed to natural weathering under Australian summer conditions over a period of 30 days. Infrared spectroscopy revealed that there was perceptible surface delignification after 4 hours exposure, substantial surface delignification after 3 days exposure and almost complete surface delignification after 6 days. Rapid lignin degradation was also suggested by measurements of the acid insoluble lignin content of weathered veneers. Viscometry determinations on holocellulose samples from weathered veneers and unweathered controls indicated significant depolymerisation of cellulose after 4 days exposure.

In another research, Evans et al. (2007) indicated that wood exposed to the weathering increases the checking. Check numbers and dimensions were greater in samples exposed to the full solar spectrum than in samples exposed under filters that blocked the transmission of UV, visible or infra-red radiation. Samples that were shielded from more energetic wavelengths developed less checking. Checks developed in the rays and propagated at the interface between adjacent tracheids, close to the middle lamella. Their findings also suggested that water-repellent treatments designed to prevent wood exposed outdoors from checking should contain additives that restrict the surface photodegradation of wood.

### 2.2 Water/moisture degradation

Wood exposed to the weather undergoes degradation due to the effects of light and water. Water plays an important role in weathering since cyclic changes in moisture content generate stresses leading to checking and splitting. Water may also accelerate surface degradation by leaching products of photodegradation and loss in strength of wood strips during weathering (Evans and Banks, 1988; Sudiyani et al., 1999).

The deterioration of wood is closely related to water/moisture. The change of wood moisture content often results in swelling or shrinking of wood. Such dimensional movement in the wood is anisotropic, thereby causing micro-checking. These micro-checking can be gradually enlarge by the freezing and thawing of absorbed water in the checking. When the rich lignin-middle lamellas are degraded (the photo degradation occurs preferentially in this area of wood) and the degraded fragments are subsequently removed by water, the wood cell will de-bonded each other. One these loose cells are removed by water, the fresh layer of wood underneath will be exposed to weathering (Xie, 2005). Because latewood is denser, harder, smother, and darker in earlywood, and its cells have thicker walls and smaller cavities, the weathering process yields more erosion in earlywood than that in latewood (Williams, 2005). Weathering deterioration of earlywood and latewood is shown in Figure 2. Figure 3 describes a mechanism enhancing light scattering in lignin.

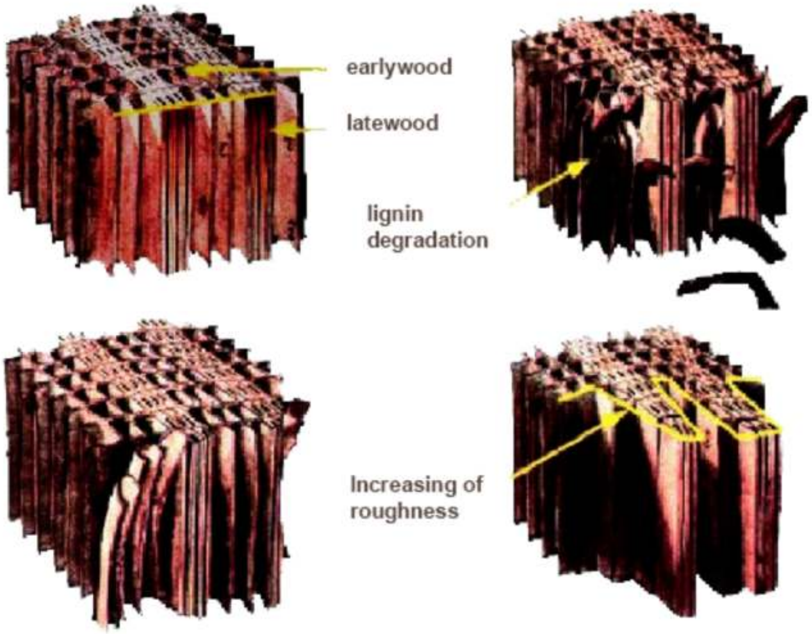

**Figure 2. Mechanical breakdown of wood exposed to solar irradiation (Xie, 2005)**

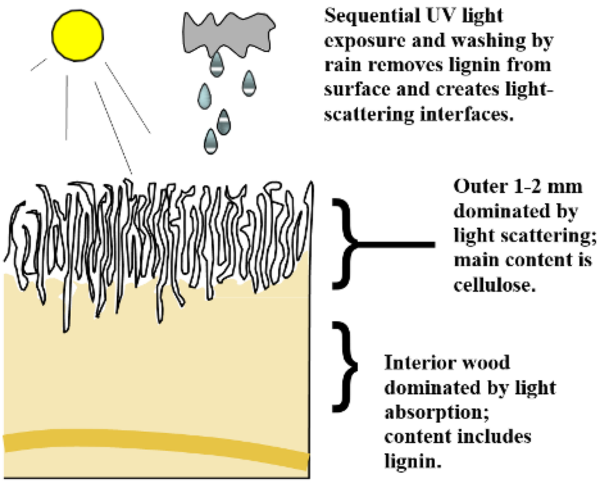

**Figure 3. Schematic description of mechanism by which enhanced light scattering in a lignin-depleted, friable surface layer (1 to 2 mm) of weathered wood can protect the underlying lignin-containing wood from exposure to UV light. The curved tan line low in the drawing is meant to suggest an annual ring (latewood) (Kropat et al., 2020)**

In the study of Sudiyani et al. (1999), the lignin content in the albizzia wood surface decreased significantly after exposure to various weathering conditions, especially in the presence of water irrespective of natural or artificial conditions. Xylose, which was a main component of hardwood hemicellulose xylan, showed the same reduction tendency after weathering. The major effect of weathering on wood surfaces was delignification, and lignin and hemicelluloses were easily decomposed by UV irradiation. Cellulose was assumed to be protected from photodegradation because coexisting lignin preferentially absorbed UV light and prevented cellulose from being activated by UV. However, the chemical composition of wood after natural weathering without rainfall demonstrated that the action of water was not negligible, as seen by the decreased lignin and hemicellulose contents. It was assumed that UV irradiation of wood surfaces decomposed lignin and formed low-molecular-weight lignin fragments, which would be water-soluble. Water flashing would leach away the lignin fragments together with hemicelluloses as water-soluble lignocellulosic materials. Therefore, the wood surfaces became rich in cellulose, which was confirmed by the increased relative content of glucose after natural and artificial weathering. On the other hand, the lignin content of sugi wood did not decrease as markedly as was observed in albizzia wood. Lignin and mannose contents were significantly changed by weathering conditions. The decreased mannose content revealed a reduction of hemicellulose content in the exposed wood because glucomannan is a major component of hemicellulose in softwood. The relatively increased glucose content suggested that cellulose was kept on the wood surfaces even after being exposed to weathering, as in albizzia wood. The chemical analysis for both wood species showed an acceleration effect by water flashing on the reduction of lignin and hemicellulose contents. It was noteworthy that there was a marked difference in the resistance against water during weathering between albizzia and sugi; sugi wood was more resistant to lignin and hemicellulose reductions. Aromatic units of lignin in softwoods and hardwoods are composed of guaiacyl and guaiacyl-syringyl, respectively. The susceptibility to weathering deterioration might be different for the two lignin types, with sugi lignin not easily removed during weathering because of side reactions such as condensation. The changes in hemicellulose contents suggested that hemicelluloses would be removed along with lignin. Lignin and hemicellulose are present in wood cell walls as a ligninhemicellulose matrix, so lignin decomposition would accelerate the loss of hemicelluloses in the matrix during exposure to water.

Generally, deterioration of wood exposed to weathering has been believed to be mainly due to the decomposition of lignin in cell walls. Water such as rainfall was thought to play an important role, causing the formation of checks, cracks, and new surfaces, which are then exposed to UV irradiation during shrinking and swelling. Consequently, the decomposed lignin components would be easily leached out from the cell walls accompanied by erosion and discoloration (Sudiyani et al., 1999).

### 2.3. Fungal degradation

Fungi which cause discoloration and disfigurement of wood in storage and in service are generally described as staining fungi while those that grow superficial on wood are called molds. They are the most common microorganism found on weathered wood. These fungi do not decay wood, i.e. do not degrade the wood cell wall cellulose, do not reduce the strength of wood to any significant degree but they may increase the permeability of wood. However, the development of stain in timber and the emergence of molds on its surface are considered of great economic importance to the timber and wood preserving industries because of losses in commercial quality of the product (Eaton and Hale, 1993).

Moisture content is probably the most important factor in determining the rate and extent of sapstain/mold infection in wood. In soft wood timber maintained in temperature conditions, fungal colonization of wood with an initial moisture content of 100 - 130% will take placed. These fungi are early colonizers of freshly felled timber. Their carbon source requirements are met mainly by the soluble sugars and starch in the wood cell lumens but they also feed on breakdown products derived from the decay activities of other organisms (Eaton and Hale, 1993).

Sapstain of freshly felled timber: The mature hyphae of sapstaining fungi are brown in color but when wood is extensively colonized by these fungi, the wood appear blue to black because of light diffraction.

Blue stain in service: In contrast to sapstain, the development of blue stain in service is common in processed wood which takes up moisture periodically. The typical appearance of blue stain may take the form of patches of black discoloration on the wood surface sometimes erupting through paint films or clear varnish. On wood exposed out door, the surface rapidly takes on grey appearance which may take longer in hardwood than softwood.

Molds on freshly felled wood: The vegetative hyphae are usually hyaline and utilize available starch and sugars in superficial parenchyma tissue. The hyphae of molds are colorless, so they do not discolor wood, however the spores produced by molds discolor wood surface. Molds are simply removed by brushing or planning the wood surfaces (Bowyer and Haygreen, 1996).

In the study of Oberhofnerová et al. (2017), weathering characteristics of 9 softwoods and hardwoods species (spruce, pine, Douglas fir, larch, oak, black locust, maple, poplar and alder) during twelve months of exposure in the climatic conditions of Central Europe were determined. The mould growth was first observed at maple, poplar and alder samples after the fourth month of weathering. After 6 months of weathering, wood samples (mostly Douglas fir wood) showed formation of numerous cracks which basically ran in the direction of wood fibres. Mould and blue-stain fungi growth was observed in those species that are not durable against fungal attack (EN 350-2: 1994) such as maple, poplar and alder samples, especially after the fourth month of exposure. Faster attack of biotic factors was caused by higher mean temperature and the total precipitation after the fourth month of weathering.

## 3. WOOD PROTECTION AGAINST WEATHERING PROCESS

Wood is readily degraded by weathering, without any protection, the service life of the weathering wood is considerably limited. To protect wood from deterioration by weathering, the most common way is to prevent weathering factors from reaching the wood. The invasion of microorganism may be reduced by treating wood with preservatives. Wood coatings provide good protection to wood by partly or completely obstructing the light to reach wood and excluding water from wood. Chemical modification of wood may also cause change in wood structure, improve weathering protection. Therefore, the protecting strategies are categorized into three parts:

### 3.1. Wood preservatives

Wood preservatives mainly protect wood from damages by microorganism. The common wood preservatives can be divided into two groups: oil-borne preservatives such as creosote and water-borne preservatives. Under environmental pressure, more water-borne preservatives are developed, mainly preservatives containing copper, such as chromated copper arsenate (CCA), ammoniacal copper quat (ACQ), acid copper chromate (ACC), etc (Xie, 2005).

Feist and Williams (1991) reported the efficiency of CCA and chromium trioxide treatments in decreasing the effect of weathering of unfinished Sounthern pine wood and improving the durability of semitransparent and solid-color stains applied to the treated wood. Unfinished and finished southern pine sapwood specimens treated with either CCA or chromium trioxide were exposed to accelerated weathering. Small amounts of chromium salts on the wood surface greatly decreased erosion of the wood caused by ultraviolet-light-catalyzed degradation. Pressure treatment with CCA provided long-term protection against erosion for unfinished wood. Treatment of the wood surface with a brush-applied solution of chromium trioxide also decreased erosion but lower than the wood treated with CCA. The CCA treatment penetrated the wood and deposited more chromium at the surface than did the chromium trioxide surface treatment.

The study of Altay et al. (2020) was aimed to investigate the effects of weathering on some surface characteristics such as color and surface roughness changes of Scots pine impregnated with copper-containing chemical such as Wolmanit CX-8 (WCX-8), varnished with synthetic varnish (SV), cellulosic varnish (CV), and polyurethane varnish (PV) were investigated. Results showed that while the WCX-8 impregnated and PV coated Scots pine specimens showed better color stability than other treatment groups after weathering, only CV coated Scots pine gave the most negative effect on color stability. While, the untreated (control) wood surface turned from red to green and yellow to blue respectively, after weathering, other all treatment groups gave reddish and yellowish tone after weathering. Weathering conditions increased the surface roughness of control (untreated) and other all treatment groups. The control group gave a rougher surface than other treatment groups after weathering. Surface roughness increases were the lower for CV coated Scots pine wood than other treatment groups. The results showed that while WCX-8 impregnation before varnishing gave better color characteristics, generally it caused to increase the surface roughness of Scots pine after weathering.

Water repellent preservatives give slight protection during early stage of the weathering by decreasing the amount of degradation products washed from the surface. In addition, they also increase the resistance to the attack of fungi (Williams, 2005).

### 3.2. Paint and stains

Wood exposed to the weather can be protected by paints, stains, and similar materials. Paints provide the most protection because they are generally opaque to the degradative effects of UV light and protect wood to varying degrees against water. Paint performance may vary greatly on different woods. Pigmented stains also provide durable finishes (Feist, 1990).

Weathering of wood gives surface which can not hold paint very well, but the weathered surface can accept penetrating stain extremely well (Williams, 2005). Evans et al. (1996) used a tape test to assess the adhesion of acrylic latex primers to weathered blocks. The adhesion of exterior acrylic primers decreased on weathered wood surfaces and was significantly lower on specimens that were weathered for 5 to 10 days. An oil-modified acrylic primer showed greater adhesion to weathered wood surfaces.

Semitransparent stain on southern pine pressure treated with CCA had longer service life than similar wood treated with brush-applied chromic acid prior to staining (Feist and Williams, 1991). Clear finishes (urethane, expoxides, etc) do not work outside because they do not protect against UV, therefore the wood under the finish is deteriorated. When the finish cracks, moisture easily moves in, molds and stain start growing (Goodell, 2007).

A properly applied paint system gives the greatest protection to wood surface against UV radiation. The pigments in the paint block the UV radiation and the paint film retards water absorption. The less pigment a stain or paint has in it, the less UV protection will be provided (Goodell, 2007).

### 3.3. Chemical modification

Chemical modification of wood aims at enhancing various wood properties such as durability, moisture sorption, dimensional stability, strength and hardness. Moreover, it imparts stability towards UV-radiation, improvement of weathering performance and reduction of flammability. Various types of chemical compounds have been used for the modification of wood including anhydrides, acid chlorides, carboxylic acids, isocyanates, aldehydes, alkyl chlorides, lactones, nitriles and epoxides (Rowell, 2005). The chemicals may fill in the cell lumen, cell wall or have reaction with abundant hydroxyl groups of lignin, cellulose, hemicellulose in the cell wall. The cell wall modification made the wood dimensionally stable and restricts check and warp, the lumen fill help hold degradation product in place, thus significant improving UV resistance.

Feist et al. (1991) reported that the erosion of accelerated weathering of the wood cell-wall modification with acetic anhydride, lumen fill with methyl methacrylate, and a combination of these two treatments was reduced from 40 to 85% compared to that of untreated wood (aspen). Chemical analysis before and after accelerated weathering showed that ultraviolet degradation caused a large loss of surface lignin and xylose (from xylans) in control specimens. Both acetylation and methacrylate treatments, or a combination of these two, reduced the loss of surface lignin with subsequent reduction in weathering. Acetylation, especially at 18 weight-percent gain, reduced the loss of xylans during accelerated weathering.

At the condition of natural weathering, the treatment with dimethylol dihydroxyethyleneurea (DMDHEU) reduced discoloration and crack of wood surface, and prevented surface erosion in particular on the area of earlywood compared to untreated wood (Scots pine). The fungi on the panels treated with DMDHEU grew less than in untreated panels after outdoor weathering. FTIR evidences revealed that wood treated with DMDHEU did not long-term protect lignin from weathering degradation (Xie, 2005; Xie et al., 2008; Pfeffer et al., 2012).

Rapp and Peek (1999) treated Scots pine sapwood (*Pinus sylvestris* L.), Norway spruce (Picea abies L.), English oak heartwood (*Quercus robur* L.) and Douglas fir heartwood (*Pseudotsuga menziesii France*.) with melamine resin or coated with varnish, and exposed them to natural weathering without ground contact for two years. The melamine resin, even in low concentrations provided distinctive protection against photochemical wood degradation by weathering and infestation by wood staining fungi, but did not protect wood against cracking and moisture.

Beech (*Fagus sylvatica* L.) veneers were treated with two formulations based on N-methylol-melamine (NMM): (1) NMM solution (NMM-1, 10% solid content), (2) fatty acid modified NMM dispersions containing paraffin (with an aluminium salt as catalyst, mNMM-2, 5% solid content). Five veneers were glued with a phenol formaldehyde adhesive to produce plywood. The plywood specimens were weathered outdoors over a period of 18 months according to EN 927-3. The treatment of veneers with NMM-1 and mNMM-2 improved the weathering performance of plywood produced thereof as compared to those from control veneers. The treatments reduced discoloration and fungal staining as well as cracking, deformation and discoloration of uncoated and coated plywood panels during 18 months outdoor weathering conditions. These effects are mainly attributable to the reduction in water uptake, which increases dimensional stability (Trinh et al., 2012). The similar results were found in the study of Nguyen et al. (2007) for Beech (*Fagus sylvatica* L.) wood.

Grinins et al. (2021) investigated the effect of phenol-formaldehyde (PF) resin treatment on the weathering stability and biological durability of birch plywood. Silver birch (*Betula pendula*) veneers were vacuum-pressure impregnated with four different PF resins with average molecular weights (Mw) of 292 (resin A), 528 (resin B), 703 (resin C), and 884 g/mol (resin D). The aging properties of PF resin modified birch plywood were analyzed using artificial weathering with ultraviolet (UV) light, UV and water spray, and weathering under outdoor conditions. It was not possible to compare weathering processes under artificial conditions to processes under outdoor conditions. However, the weathering stability of birch plywood treated with PF resins A, B, and C, scored better than plywood treated with commercial resin D (regardless of solid content concentration [%]).

## 4. CONCLUSIONS

The middle lamella between the wood cells has a higher lignin content than the cell wall and degrades faster than the cell wall. The α-carbonyl sites in the lignin have been shown to be quite labile to absorption of UV radiation. The formation of free radicals initiates a series of oxidative degradation reaction. The cross-link density of lignin decreases, resulting in loss of lignin. Water plays a crucial role in washing the degradation products from the surface, leaching hemicelluloses, abrading the surface, and causing checking. It is also generally accepted that mold (mildew) such as Aureobasidium pullulans, the most common microorganism found on weathered wood, does not have the enzymes to degrade lignin or polysaccharides. Molds cause more appearance problems than actual degradation of wood; however, aggressive cleaning methods to remove them using strong chemicals and/or power-washing can greatly accelerate the loss of wood fiber from wood surfaces.

Much research has been done to reduce the photochemical degradation caused by UV radiation and water during weathering. There is considerable going on study to develop new stabilizers, such as hindered amine light stabilizers (HALS) which serves as free radical scavenger to trap the free radicals, thus reducing the risk of free radical degradation.

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# ẢNH HƯỞNG CỦA CÁC YẾU TỐ THỜI TIẾT ĐẾN GỖ VÀ CÁC BIỆN PHÁP BẢO VỆ GỖ

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## TÓM TẮT

Khi gỗ và các sản phẩm từ gỗ được sử dụng ngoài trời, trên mặt đất, các sản phẩm này chịu ảnh hưởng đồng thời của nhiều yếu tố môi trường như: quá trình quang hóa gây ra bởi ánh sáng mặt trời; quá trình thuỷ phân, bào mòn, trương nở và co rút gây ra bởi các yếu tố thuộc về nước/độ ẩm (nước mưa, sương, tuyết và thay đổi độ ẩm trong không khí); quá trình biến màu gây ra bởi sự xâm nhập của các loại nấm... Tất cả những ảnh hưởng trên làm giảm khả năng và thời gian sử dụng của sản phẩm gỗ. Bề mặt của gỗ thay đổi đáng kể chỉ sau vài tháng sử dụng ngoài trời. Do đó, để giảm các tác động của môi trường ngoài trời đến gỗ và các sản phẩm từ gỗ, biện pháp phổ biến nhất là ngăn cách bề mặt gỗ với môi trường như sơn phủ bề mặt. Các chất bảo quả như chromated copper arsenate (CCA), ammoniacal copper quat (ACQ), acid copper chromate (ACC) có khả năng bảo vệ gỗ khỏi các tác nhân sinh học. Bên cạnh đó, các giải pháp biến tính gỗ, làm thay đổi cấu trúc tế bào gỗ, đã và đang được nghiên cứu, đã chỉ ra nhiều kết quả khả quan cho việc nâng cao khả năng chống chịu các điều kiện môi trường cho gỗ và các sản phẩm từ gỗ biến tính. Bài báo này thảo luận chi tiết ảnh hưởng của các yếu tố môi trường ngoài trời đến gỗ bao gồm những thay đổi về vật lý và hóa học của gỗ, đồng thời các biện pháp bảo vệ gỗ khi sử dụng ngoài trời cũng được trình bày ở đây.

**Từ khóa: bảo vệ, nấm biến màu, nước/độ ẩm, quang hóa, thời tiết ngoài trời.**

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