Performance evaluation of preservative treatment on gloss of wood finishes exposed to UV light

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ABSTRACT

Wood products when exposed to external conditions often tend to lose the shine or gloss due to photo-oxidative degradation of wood surface due to sunlight (UV light) and moisture, which cause photochemical oxidative degradation of wood. Wood finishes protect the wood surface from external agents and improve its appearance and gloss. On external exposure, UV rays gradually degrade the film coating resulting in loss of gloss. The long-term exterior wood protection can be achieved by a successful combination of an appropriate preservative treatment followed by a compatible surface-coating. In this study, *Melia dubia* wood samples impregnated with Borax boric acid (BBA) and ZiBOC (Zinc-boron-copper) preservative and finished with polyurethane (PU), spirit shellac and wax finish were exposed to UV light and gloss reduction behaviour was studied. The gloss of samples was measured at 60 degree gloss head using a Tri micro gloss meter regularly for 600 hours duration of UV exposure. Observations and analysis shows the control samples (finished without preservative treatment) lost about 27,11 % to 38 % of the initial gloss after 600 h of UV exposure. Whereas the samples finished after preservative treatment shows reductions in the range of 6,23 % to 16,03 % of the initial values. Thus both the preservatives used in this study were found effective in maintaining the gloss of the finished surface against exposure to UV light.

Keywords: *Melia dubia*, gloss, polyurethane, shellac, wax polish, BBA, ZiBOC

INTRODUCTION

Wood is a widely used construction material since prehistoric times for both interior and exterior applications because of its appearance, ease of working, availability and strength. In spite of all these advantages, wood being a biological material is prone to degradation by various agencies. When exposed to outdoor weathering conditions, wood products tend to lose gloss due to photo-oxidative degradation of wood surface due to sunlight (UV light) and moisture. All wood components i.e. cellulose, hemicelluloses, lignin, and extractives are susceptible to photochemical degradation (Suleman and Rashid 1999). Fortunately, ultraviolet light penetrates the surface layer of wood upto a depth of 200 µm (Fiest *et. al.* 1990). The interaction of wood and UV light is essentially a surface phenomena in which free radical generated by light play a major role in surface deterioration and discoloration (Kalnins 1966). Wood finishes are used to protect the wood surface from weathering and to maintain appearance.

Wood finishes alone imparts superficial protection against deteriorating agents for a limited time, often less than 2 years (Williams *et. al.* 1996). However, wood surfaces can be stabilized against deterioration using a variety of chemical treatments before finishing (Chang *et al.* 1982, Feist and Williams 1991, Wilkinson 1979, Samani and Gupta 2011). This improvement is achieved by imparting a degree of resistance to the wood surfaces against photochemical degradation, dimensional changes and biological degradation. Feist and Williams (1991) reported that Chromated copper arsenate (CCA) treatment before the application of semi transparent stain extended its lifetime and durability. The percent loss in gloss of sample, that were finished after preservative treatment of copperised cashew nut shell liquid (CRCNSL) was found to be less than that of those finished without treatment when exposed to UV radiation, high humidity and external weather conditions (Samani and Gupta 2010a & b, 2011). Scots pine (*Pinus* *sylvestris* L.) and Oriental beech (*Fagus orientalis* L.) impregnated with tanalith-E, adolit-KD5, CCA and then finished with synthetic and polyurethane varnish showed color stability of impregnated and varnished wood specimens than untreated and solely varnished wood specimens after natural weathering (Turkoglu *et. al.* 2015). The photo stabilization of wood by copper treatments is attributed to the formation of carbonyl groups (Temiz *et. al.* 2005). Scots pine and chestnut impregnated with chromium-copper-boron (CCB) before polyurethane varnish and an alkyd-based synthetic varnish showed CCB impregnation greatly stabilized the surface color of both wood species in outdoor performances. It was concluded that long-term exterior wood protection can be achieved by a successful combination of an appropriate preservative treatment followed by a compatible surface-coating process (Yalinkilic *et. al.* 1999). *Pinus brutia* pre-impregnated with borates before varnish coating resulted in increased surface hardness and gloss and decreased coating adhesion. PU coated wood surfaces yielded higher gloss and as compared to synthetic varnish coated wood surfaces (Toker *et. al*. 2009).

Gloss is an attribute of finished surfaces that gives them shiny or lustrous appearances. Gloss of a finish depends upon the gross structure of the wood, porosity, alignment of fibers and the degree of surface preparation besides the quality of the finishing composition used (Collier 1967). Timber species also differ in their hardness, resinous or oily nature and degree of porosity, thus demanding different finishing treatments. Commonly used finishes on wood include spirit shellac (natural polymer), polyurethane (artificial polymer) and wax finish. Polyurethane (PU) is a very tough and durable finish. It is a slow drying finish and it forms a harder, tougher and thicker film. Spirit shellac is a quick drying and transparent finish. Unlike PU, it does not form a hard or water proof film. Wax Polish is designed to help preserve and prevent the wood from drying out and fading. With added conditioning oils, it enhances the natural beauty and depth of the grain. UV rays degrade the film (coating) gradually resulting in a reduction of gloss on surface.

Amidst this background, a study was undertaken to evaluate the reduction in gloss and coating thickness of different finishes when applied on preservative impregnated *Melia dubia* wood surface by UV exposure. The finishes used are Polyurethane, spirit shellac, and Wax polish. *Melia dubia* wood is impregnated with borax-boric acid (BBA) and ZiBOC (Tripathi 2013) preservatives. *Melia dubia* is emerging as a potential timber species as it is fast growing and possesses good strength. It is raised in plantations and the main utility of this tree is in timber and variety of industries including wood pulp, construction and plywood. The wood is non durable in nature and requires preservative treatment to enhance its service life.

MATERIAL AND METHODS

Procurement of *Melia composita* logs was done at Forest Research Institute, Dehradun (latitude: 30º19 N and longitude: 78º04 E) and same was subjected to conversion and seasoning. The specimens used for this purpose were of dimension 15 cm (Length) x 7,5 cm (Width) x 1,25 cm (Thickness). Relatively straight grained and defect free specimens free from insects, borers, termite attack or any other notable microbial contamination were chosen so as to obtain optimum result. A total of 54 numbers of specimens were taken. The samples were divided into three groups each having 18 specimens. Out of 54 specimens 18 samples were treated with 4 % solution of Borax-boric acid. Another 18 samples were treated with 4 % solution of ZiBOC preservative and remaining 18 samples were taken as control i.e. without preservative treatment. The samples were treated by vacuum pressure method by giving 50 lbs pressure for 45 minutes with initial and final vacuum. After each treatment, the samples were taken out and the excess preservative was blotted out with filter paper and specimens were weighed immediately to determine the preservative uptake and retention (IS 401 2001). The amount of preservative solution absorbed by specimens (retention value R in Kg/m³) was calculated as follows:

Retention (R) = $(\frac{GC}{V} * 10)$ Kg/m^3

Where, G = Mass of the treating solution absorbed by block in gm

C = Mass of the preservative present in 100 g of the treating solution in gm

And, V = Volume of the test block in cm^3.

The samples were then air dried to 12 % – 15 % moisture content. The samples were first sanded with sand papers of grit sizes 60, 80, 100 and 120 in that order to obtain smooth surface. No filler was used as the study was aimed to analyze the effect of UV exposure on the performance of different finishes alone as well as on preservative treated wood samples. After sanding the three commercial grades polishes i.e. Polyurethane (PU), sprit shellac and wax polish were applied to the surface of the samples as given in table 1. Finished samples with and without preservative treatment were then placed in a UV chamber having a UV source (30 W, 254 nm) and were exposed for upto 600 h.

Table 1. Sample distribution

Preservative	Finishes			
	Sprit shellac	Wax	PU	Total
ZiBOC	6	6	6	18
BBA	6	6	6	18
Control (Untreated)	6	6	6	18
				54

Gloss measurements were carried out at 60 degree gloss head using a Tri micro gloss meter manufactured by sheen instrument. The gloss meter was calibrated each time before taking the reading. Several readings were taken on each surface and the mean values were calculated. A coating thickness measurements were made by using Posi Tector 200 by Defelsko is used to measure dry film thickness. The gloss values and film thickness were measured after every 200 h, 400 h and 600 h of UV exposure to understand the gloss reduction pattern.

After completion of each exposure time, the reductions in gloss values and film thickness were calculated as the difference between the initial and the final values for each time period. The percent reductions in gloss and film thickness were also calculated to understand the pattern of reduction under UV exposure.

Per cent loss in gloss after UV exposure is calculated as:

Percent loss in Gloss (%) = $\frac{(Initial\ Gloss - Final\ Gloss)*100}{Initial\ Gloss}$

Per cent loss in film thickness (micron) after UV exposure is calculated as:

Percent loss in coating thickness (%) = $\frac{(Initial\ coating\ thickness - Final\ coating\ thickness)*100}{Initial\ coating\ thickness}$

The statistical analysis was carried out using SPSS and Duncan subsets were formed to find out which treatments differ significantly.

RESULTS AND DISCUSSION

Table 2 shows the average gloss of preservative treated and untreated (control) samples finished with sprit shellac, PU and wax finish. Results show that in untreated samples maximum gloss is obtained in PU followed by shellac finished specimens. The minimum gloss is shown by wax polish applied specimens. The gloss increases significantly when finish is applied over preservative treated wood. ZiBOC treatment has resulted in more increase in gloss compared to BBA treatment.

TABLE 2: Average gloss (GU) values of preservative treated and control samples of *Melia dubia* treated with different finish

Finishing treatment	**Preservative**			**Percent increase in Gloss**	
	Untreated	**BBA**	**ZiBOC**	**BBA**	**ZiBOC**
Wax polish	38,76 ^{a} (2.15)	45,89 ^{bc} (3.29)	49,57 ^{cd} (3.27)	18,39	27,88
Sprit shellac	42,13 ^{ab} (3.52)	53,17 ^{d} (2.95)	53,26 ^{d} (4.11)	26,20	26,41
Polyurethane	73,81 ^{e} (2.92)	83,29 ^{f} (3.17)	89,48 ^{g} (3.57)	12,84	21,23

SD values are given in parenthesis, Values with same alphabet denotes homogeneous subsets

The analysis of variance also indicated that the treatments (Control and treated Specimens) were different ($p \leq 0,05$). It was inferred from Duncan's subsets (Table-2), that statistically there is significant improvement in gloss of the treated specimens over the controls. Seven Duncan subsets were formed and results shows maximum gloss is obtained in PU coating over raw and preservative impregnated wood and all treatments are significantly different. However maximum percent increase in gloss was observed in ZiBOC treated wood finished with wax polish followed by shellac finish over ZiBOC treatment.

TABLE 3: Average coating thickness (microns) values of preservative treated and control samples of *Melia dubia* treated with different finish

Finishing treatment	**Preservative**			**Percent increase in coating thickness**	
	Untreated	**BBA**	**ZiBOC**	**BBA**	**ZiBOC**
Wax polish	54,17 ^{a} (3.54)	70,23 ^{b} (2.71)	72,03 ^{b} (4.29)	29,64	32,97

Sprit shellac	56,7 ^{a} (3.94)	72,62 ^{b} (2.78)	70,32 ^{b} (4.13)	28,07	24,02
Polyurethane	75,87 ^{b} (3.46)	85,21 ^{c} (3.83)	93,13 ^{d} (3.01)	12,31	22,74

SD values are given in parenthesis, Values with same alphabet denotes homogeneous subsets

Table 3 shows the average film thickness of preservative treated and untreated samples finished with sprit shellac, PU and wax finish. Result shows PU forms thick coating over the samples as compared to other two finishes. In control specimen maximum thickness is obtained in PU finished samples followed by shellac and wax finished specimens.

The mean coating thickness ($p \leq 0,05$) of the specimens were statistically analysed at 5 % significance level. It was inferred from Duncan subsets (Table-3), that statistically there was significant difference in coating thickness of control and preservative treated finished samples. Maximum coating thickness is obtained in PU coating over ZiBOC followed by PU coating over BBA, both are significantly different from each other and other treatments. The difference between other treatments i.e. Wax and shellac coating over BBA and ZiBOC and PU over untreated wood is not significant. However maximum percent increase in coating thickness is obtained in ZiBOC treated wood finished with wax polish.

TABLE 4 shows the gloss (Gloss Unit) of preservative treated and control samples coated with different finishes before and after UV exposure. From table it can be inferred that the gloss decreases with the increase of UV exposure time. However loss in gloss in samples without preservative treatment is more as compared to preservative treated finished specimens. In untreated specimens sprit shellac showed highest loss in gloss, as compared to the other two finishes. PU showed lowest loss in gloss after UV exposure. It is important to note that PU has highest initial gloss when applied on untreated wood specimens.

TABLE 4: Loss in gloss (Gloss Unit) of preservative treated and control samples after UV exposure

Treatment	Gloss (GU)				Percent loss in Gloss after 600 h
	Before UV exposure	After 200 h	After 400 h	After 600 h	
Wax polish	38,76	34,46	30,87	25,78	33,48
ZiBOC + Wax polish	49,57	48,26	44,65	41,62	16,03
BBA+Wax polish	45,89	43,78	40,93	37,22	18,89
Polyurethane	73,81	64,33	58,02	53,80	27,11
ZiBOC+ Polyurethane	89,48	82,93	85,37	83,90	6,23
BBA+ Polyurethane	83,29	80,65	78,58	75,30	9,59
Spirit shellac	42,13	37,97	32,0	26,12	38,0
ZiBOC + Spirit shellac	53,26	51,27	49,08	45,52	14,53

BBA + Spirit shellac	53,17	50,88	48,70	44,72	15,89

The ability to withstand the effect of UV exposure was studied through calculating the percent loss in gloss after UV exposure. On an average, the control samples (finished without preservative treatment) lost about 27.11 % to 38 % of the initial gloss after 600 h of UV exposure. Whereas the samples finished after preservative treatment showed reductions in the range of 6.23 % to 16.03 % of the initial values. Result shows when finishing treatment is done over preservative treatment the loss in gloss reduced significantly after UV exposure. However the performance of ZiBOC preservative is better than BBA treatment. The minimum reduction in gloss was observed in PU applied over ZiBOC treated wood. This implies that preservative treatment of wood enhances the surface appearance properties and results in higher gloss values when finish is applied over it. Further it protects the wood surface from deterioration on exposure to UV radiations as evident from lower loss in gloss values of preservative treated finished wood as compared to untreated finished specimens. Earlier studies on finished wood after CCA, CCB and ammonium copper quat treatment reported similar results of photo stabilization of wood after weathering (Turkoglu *et. al*. 2015, Temiz *et. al*. 2005, Yalinkilic *et. al*. 1999, Samani and Gupta 2010a).

Table 5: Reduction in coating thickness (microns) of preservative treated and control samples after UV exposure

Treatment	**Film thickness (microns)**				**Percent loss in Film thickness after 600 h**
	Before UV exposure	After 200 h	After 400 h	After 600 h	
Wax polish	54,17	50,83	46,02	38,90	28,18
ZiBOC + Wax polish	72,03	70,35	68,75	65,95	8,44
BBA+ Wax polish	70,23	67,97	65,36	62,07	11,61
Polyurethane	75,88	72,72	68,67	66,15	12,82
ZiBOC + Polyurethane	93,13	91,66	89,97	87,85	5,66
BBA+ Polyurethane	85,21	78,53	75,33	72,47	9,64
Spirit polish	56,73	53,33	50,92	47,60	16,09
ZiBOC +Spirit polish	70,32	68,12	65,17	62,50	10,81
BBA+Spirit polish	72,62	70,02	66,37	62,25	14,27

Values with same alphabet denotes homogeneous subsets

Table 5 shows reduction in coating thickness (microns) of preservative treated and control samples after UV exposure. From table it can be inferred that the coating thickness decreases gradually with the increase of UV exposure time. However the reduction in coating thickness is more in samples without preservative treatment as compared to preservative treated finished specimens. In untreated specimens wax polish showed highest reduction in coating thickness, as compared to the other two finishes. PU showed lowest reduction in coating thickness after UV exposure. It is important to note that PU has highest initial gloss and also lowest reduction in gloss after UV exposure when applied on untreated and preservative treated wood specimens.

Preservative treatment before the application of finishes resulted in reduction in coating thickness significantly after UV exposure. The performance of ZiBOC preservative is better than BBA treatment in preventing the loss of coating thickness of UV exposed specimens. The minimum reduction in coating thickness was observed in PU applied over ZiBOC treated wood specimens.

CONCLUSIONS

The gloss and coating thickness of *M. dubia* specimens increases significantly when finish is applied over preservative treated wood. Maximum gloss and coating thickness is obtained in PU treatment. Both preservative has performed better than control in preventing the reduction in gloss and coating thickness by UV exposure. The ZiBOC preservative treatment has performed better than BBA treatment after UV exposure.

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