IMPACTS OF BLEACHING CHEMICALS AND OUTDOOR EXPOSURE ON CHANGES IN THE COLOR OF SOME VARNISHED WOODS

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This study was carried out to determine the changes of the surface color of Scots pine (*Pinus sylvestris* L.) and Oriental beech (*Fagus orientalis* Lipsky) woods after exterior conditioning. First, the samples were bleached with 25% NaOH and 17.5% H_2O_2. Afterwards, they were varnished with polyurethane and synthetic varnishes, and then they were exposed to exterior conditions for 12 months. Tests for color differences and metric chroma were done according to the ASTM D-2244 standard. It was deduced that exposure to exterior conditions causes color differences in samples, while bleaching with the given solution reduces that effects, and reverts the surface color to that of the natural control specimens. However, bleached specimens exposed to 12 months exterior conditioning had more discoloration than those of natural control samples. In conclusion, if the wood materials will be exposed to outdoors after bleaching, finishing process should be applied to surfaces in order to prevent further color change.

Key Words: Surface coatings; Metric chroma; Varnishes; Bleaching chemicals; Weathering

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INTRODUCTION

Unprotected wood is susceptible to weathering. Weathering leads to unfavorable changes in wood, i.e., discoloration, roughening, checking of the surface, destruction of mechanical and physical properties, and so on. Weathering of wood is known to depend on many environmental factors (Sudiyani et al. 1999).

Shortwave radiation of sunlight is more destructive to wood than weather factors, such as moisture, snow, freezing, etc. When connected with the effects of water and moisture, solar radiation can cause not only discoloration, but also decomposition of lignin, which is a major chemical component of wood (Kleive 1986). Weathering of wood is caused by various factors such as solar radiation, moisture, heat, atmospheric pollutants (e.g. acid rain, ozone, nitrogen oxides, and sulphur dioxide), and microorganisms (Hon and Feist 1993).

The main factor responsible for the weathering of wood is the ultraviolet component of solar radiation. As a consequence, the most prominent initial effect of weathering is photodegradation and depolymerisation of lignin, and this is followed by leaching of lignin fragments from wood surfaces by rain (Hon 2001)

Each type of wood has its own variation of color, texture, and grain pattern. Some cuts of solid wood and flitches of veneer may be lighter or darker than others. To obtain a uniform color in furniture, the wood is either bleached or dyed. In other words, the only way to avoid this discoloration is to bleach the wood or use a bleaching toner on the wood before finishing (Gerard 1983). There are two sets of reasons for the discoloration of wood. The first set includes damage, drying of branches, disease, etc. in live trees (Shigo and Hillis 1973). The second set involves chemical changes, e.g. oxidation, iron stains, fungi discoloration, and chemical stains occurring on wood cut from trees. Outdoor exposure especially causes darkening of unfinished natural wood surfaces (Forest Products Laboratory 1974). This may be remedied by bleaching chemicals. Bleaching is the removing of color pigments in the structure of wood using various bleaching chemicals and bleaching systems. While there are many bleaching agents available, the two most commonly used chemicals are sodium hydroxide (NaOH) and hydrogen peroxide (H_2O_2). The aims of bleaching on the wood surface before finishing are as follows (Ejechi Obuekwe 1996):

- to obtain a more uniform color or remove dark coatings within a panel or other assembled parts,
- to obtain lighter colors and retain all grain character,
- to control color and improve stability,
- to upgrade materials or make more "off" colored wood useable and upgrade the final product,
- to use several closely related species, such as oak or ash, or multiple species of wood if needed,
- to obtain better color stability and decrease the probability of fading or color change due to the chemical nature of some woods,
- to help bleached woods such as Scots pine and beech to perform better in light exposure, especially when chemical filtering agents (ultraviolet light exposure absorbents) are combined in the finishing system,
- to obtain controlled surface coatings and properties. This determines good quality and long lasting finishes (Engler 1989).

The objectives of this study were to investigate the effect of weathering conditions and varnish coatings on bleached and varnished Scots pine and beech wood surfaces and to measure their discoloration.

MATERIAL AND METHOD

Wood Materials

Scots pine (*Pinus sylvestris* L.; also known as Scotch pine) and beech woods (*Fagus orientalis* Lipsky) were commercially purchased in Turkey. The density of the Scots pine was 0.49 g cm^{-3} and the density of beech was 0.54 g cm^{-3} (Ors and Keskin 2008). Test samples were selected from defect-free, knotless, normally grown wood.

Bleaching Chemicals

The bleaching chemicals were sodium hydroxide (NaOH) and hydrogen peroxide (H_2O_2). Acetic acid (CH_3COOH) was also used for neutralization. The properties of the chemicals used for bleaching are given in Table 1 (Keskin et al. 2004).

Table 1 Properties of the Color-Bleaching Chemicals

Chemicals	Density (g /cm3)	Viscosity (cP/4 mm at 20°C)	pH	solution concentrations in tests
NaOH (50 %)	1.131	65	13	%25
H_2O_2 (35 %)	1.081	55	5	%17.5
CH_3COOH	1.019	45	2	-

Preparing Test Samples

Wood specimens were cut from selected first grade flat-grained sapwood of Scots pine and beech 20mm×90mm×15mm in such a way that their surfaces were radial and showed no split, check, or discoloration. Specimens were cut in their final dimensions of 500mm× 80mm×12mm after conditioning to a constant weight. The specimens were mainly divided into three experimental groups: control groups, un-varnished-bleached, and varnished-bleached. The test samples were kiln-dried at 20°C± 2°C and 65%± 3% relative humidity for approximately three months. Wood specimen surfaces were smoothly planed and sanded uniformly with 100 and 150 grits (on Norton scale) sandpaper within 2 weeks of testing. After the sanding process, the test samples were prepared for bleaching.

The solutions used for bleaching were prepared as follows:
Solution I: 25% NaOH (125 g. (50%)NaOH was dissolved in 250 ml pure water)
Solution II: 17.5% H_2O_2 (43.7 g. (35%)H_2O_2 was dissolved in 250 ml pure water)

Bleaching chemicals were applied to the samples with a sponge. Eighteen percent solutions were prepared either by weight or by volume, depending on the characteristics of chemicals. This was done, first parallel to the grain, then across the grain, and finally parallel to the grain again. A few minutes later than the first application, 20% more solution was applied. The samples were kept for a day under room conditions to improve the effects of bleaching. The bleaching solutions were applied at a ratio of 100±10 ml/m^2 to the dust-free wood surface. Then the test samples with solutions I and II were neutralized with 15% CH_3COOH solution, and all the samples were washed with pure water (Uysal et al. 1999). After neutralization, all the samples were dried at 20°C±2°C and 65%±3% relative humidity to 12% humidity according to ASTM D 2244 (1993).

The test samples were varnished according to the ASTM-D 3023 (1981) after the bleaching process (ASTM D-1641, 1997). The surfaces of specimens were sanded with abrasive papers to remove the fiber swellings, and cleaned off before varnishing. The producer's definition was taken into consideration for the composition of solvent and hardener ratio, and one or two finishing layers were applied after the filling layer. Spray nozzle distance and pressure were adjusted according to the producer's definition and moved in parallel to the specimen surface at a distance of 20 cm. Varnishing was done at 20°C±2°C temperature and 65%±3% humidity conditions.

First, the filling varnish (viscosity 150 g m^{-2}) was applied and dried, it was then sanded with 220 grit number sandpaper. After that, the last layer of varnish coating (viscosity 150 g m^{-2}) was applied. The quantity of applied varnish was then determined with a balance having 0.01 g sensitivity.

Outdoor Exposure

After the varnishing process, dried samples were subjected to outdoor exposure between June 01, 2007 and June 01, 2008 in Karabuk-Turkey. The natural weathering plan was as follows: First season was July-August- September 2007; Second season was October-November-December 2007; Third season was January-February-March 2008; Fourth season was April-May-June 2008. The average temperature and total rainfall in the test site during the exposure period was 20.9°C, and 689.8 mm/m^3 (2007-2008). For natural weathering, the specimens were placed outside without any coverings.

The samples were placed for exposure at 45º facing to the south on their tangential surfaces. Before the test samples were put on a weathering test stand, each test sample had rough dimensions of 550 x 100 x 12 mm. The samples were put 50 cm above the ground and organic matter such as grass was avoided around the stand. After the weathering process, the samples first were climatized at 23 ± 2ºC and 50 ± 5 % relative humidity for 24 hours according to ASTM D 1641. Then the samples were cut to 100 x 100 x 10 mm net dimensions. Finally, the color and Metric Chroma (darker or lighter color) were evaluated (Ozcifci and Ozpak 2008).

Colour assessments were performed complying with principles referred under ASTM D-2244 with the use of a Minolta CR-231 colourimeter (tristmulus colourimeter). The experiment device was calibrated in such a manner that the parameters a= 4.91, b =−3.45, C = 6.00, and H = 324.9◦ were matched to white colour standard. The metric chroma (C) value was used as determining agent during assessment of the data. Metric chroma is the color or color change, where main color components are defined (Fig. 1). (Minolta CR-231, 1995). Metric chroma is calculated as in formula 1. Color measurements were made at random points, inside 9 cm from the ends, and 4.5 cm from the sides. Color measurements were made for all of the samples at the end of each three month season (totally 12 months period of outdoor exposure).

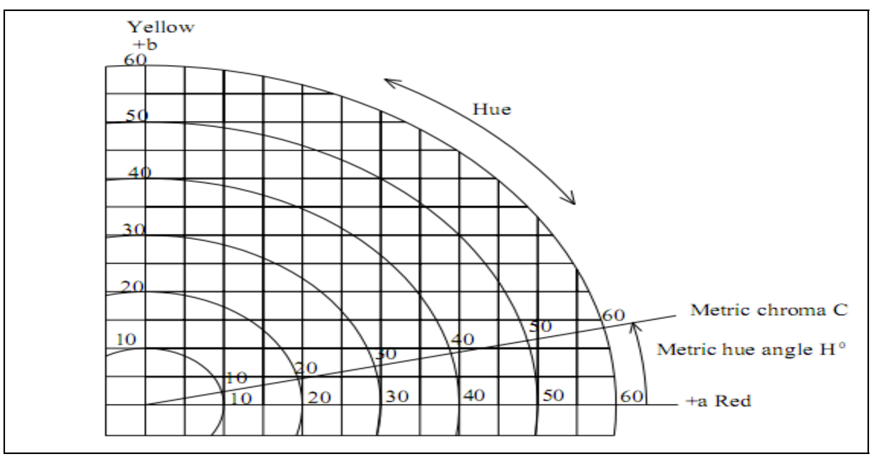

Figure 1. Metric chroma (Minolta CR-231)

Metric Chroma $C = \sqrt{(a^*)^2 x (b^*)^2}$ (1)

Statistical Analysis

By using 2 different types of wood, 2 methods of bleaching chemicals +1 control specimen, 2 types of varnish, and 5 samples for each parameter, a total of 80 samples were prepared. Multiple variance analysis (MANOVA) was used to determine the differences in metric chroma and total color change values of samples. The Duncan test was used to determine the significant differences between groups.

RESULTS AND DISCUSSION

The highest metric chroma value was obtained in control and bleached–unexposed wood (see in Tables 2 and 3 first column), and the lowest in bleached wood that was exposed to outdoor conditions for 12 months.

The layer thickness was 107.15 µm in the polyurethane varnish and 90.18 µm in the synthetic varnish. The differences in thickness of the varnish layers may have depended on the differences between the softwood and hardwood. A similar result has been described in the literature (Ozcifci and Ozpak 2008).

Color Parameters

Under natural weathering conditions, weight loss might be partly due to microbial attack that was observed or not tested. The test was followed for 12 months in all natural weather. The results showed that color change was prominent for untreated and treated specimens under natural weather conditions ($\alpha = 0.05$). The values of total color change (ΔE^*) and metric chroma (C), a^* (redness), and b^* (yellowness) of samples according to species of woods are given in Tables 2 and 3.

Results in Tables 2 and 3 indicated that the highest increase in total color change (ΔE^*) in both pine and beech woods was obtained in bleached and synthetic varnished samples as 45.41 and 48.24, respectively. Here, NaOH may have dissolved the extractives in the wood materials. When the time of exposure was increased, the total color change also increased. More total color changes were observed in varnished samples exposed to weathering conditions compared to the unvarnished ones.

Statistical Results

The differences among the factors were important. Results of analysis of variance (MANOVA) showed that bleaching solutions, weathering time, and varnish type affected the total color change and glossiness. Weathering processes and solutions were statistically significant at the 95% confidence level (Table 4 and 5). Standard deviations of values are given in Tables 2 and 3.

Duncan test results are given in Table 6 to indicate the importance of differences between the groups.

According to the Duncan test results it was found that the differences between the chemical types were significant for both Scots pine and beech. As it can be seen from Table 6, for varnish type, because the total color change values of the control and polyurethane varnished Scots pine were in the same group, the differences between them were insignificant. Differences in total color change between the unvarnished and control groups for beech wood were insignificant. Also differences between the total color change polyurethane and synthetic varnished beech were insignificant, too.

Graphical Results

According to Fig. 2, NaOH solution gave the highest total color change value (ΔE) in synthetic varnished pine wood after the fourth season. H_2O_2 solution did not cause as much total color change as the NaOH.

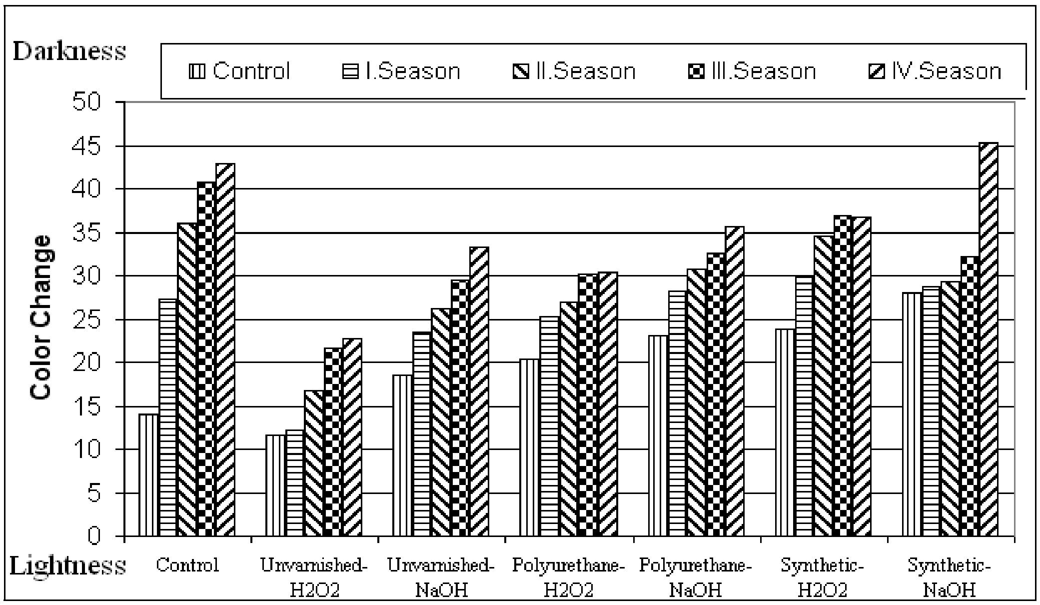

Figure 2. Values of total color change for Scots pine

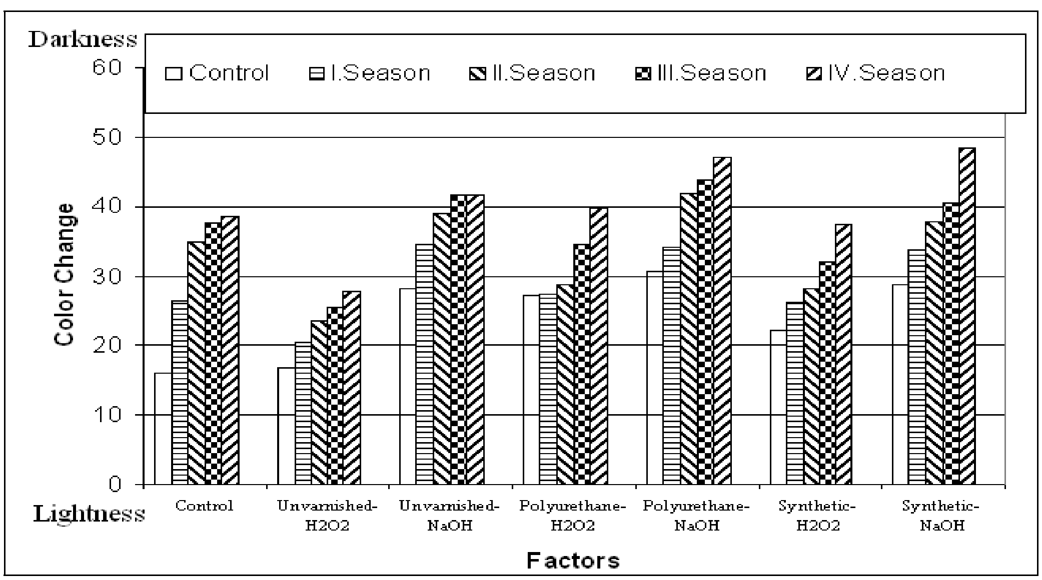

Figure 2. Values of total color change for beech

Table 2. Values of Total Color Change (*ΔE**), (*a**), (*b**) and Lightness (*L*) of Weathered Scots Pine

Varnishes	Bleaching chemicals	Seasons	ΔE*	Std.	L	Std.	a*	Std.	b*	Std.
Control	Unbleached	Natural	14.02	1.20	3.43	1.00	5.84	0.62	20.22	1.01
		I	27.32	5.82	2.30	0.16	6.11	0.65	22.77	0.73
		II	35.93	0.45	1.79	0.08	6.74	0.74	25.12	1.17
		III	40.68	6.37	1.19	0.06	6.92	1.75	27.70	1.03
		IV	42.96	5.43	1.16	0.05	7.44	0.64	29.44	0.84
	Average	Change (%)	53%		77%		12%		32%	
Un-varnished and bleached	H_2O_2	Control	11.57	1.63	3.69	0.79	6.73	1.71	22.13	1.22
		I	12.14	3.62	3.16	0.22	7.18	0.49	23.41	1.12
		II	16.64	1.25	2.59	0.28	7.93	1.58	26.64	1.28
		III	21.61	1.54	2.06	0.32	8.12	0.63	28.19	1.13
		IV	22.74	4.50	1.40	0.23	8.39	1.58	29.53	0.74
	Average	Change (%)	50%		56%		20%		25%	
	NaOH	Control	18.47	1.95	2.08	0.34	3.10	0.75	20.70	1.03
		I	23.54	1.21	1.84	0.14	4.19	0.64	23.44	0.84
		II	26.14	2.09	1.79	0.27	4.67	0.88	23.62	0.99
		III	29.39	2.03	1.29	0.09	4.76	0.42	23.45	0.73
		IV	33.21	9.52	1.25	0.07	4.92	0.59	23.72	0.92
	Average	Change (%)	45%		33%		27%		13%	
Polyurethane varnish	H_2O_2	Control	20.38	4.69	45.2	13.4	7.84	0.74	23.03	1.34
		I	25.23	2.84	36.9	8.89	7.99	0.57	23.57	0.98
		II	26.87	1.00	24.1	0.94	8.17	0.26	26.71	0.31
		III	30.22	6.28	31.5	0.40	8.37	0.49	28.38	0.98
		IV	30.28	3.02	31.1	0.14	8.53	0.50	29.22	1.40
	Average	Change (%)	33%		32%		9%		21%	
	NaOH	Control	23.06	0.97	49.4	5.61	3.31	0.69	21.33	0.71
		I	28.12	1.60	37.1	3.24	4.11	0.58	22.83	1.12
		II	30.77	0.83	33.5	0.80	4.37	0.88	23.62	1.16
		III	32.46	2.14	31.2	0.33	4.88	0.42	23.45	1.11
		IV	35.66	1.42	31.0	0.18	5.11	0.81	16.72	1.40
	Average	Change (%)	35%		37%		36%		24%	
Synthetic varnish	H_2O_2	Control	23.78	2.75	40.1	14.3	5.07	0.77	18.53	1.12
		I	30.05	1.79	35.3	4.69	4.76	0.42	21.78	0.53
		II	34.54	1.69	26.5	4.71	2.22	0.59	21.92	1.24
		III	36.90	3.80	24.7	2.17	2.58	0.67	22.58	0.89
		IV	36.65	3.03	24.2	1.67	2.23	0.58	23.15	1.11
	Average	Change (%)	36%		40%		56%		22%	
	NaOH	Control	27.98	1.10	58.2	4.43	5.84	0.88	23.39	0.82
		I	28.65	1.60	46.6	3.02	4.12	0.91	23.11	0.73
		II	29.29	1.08	36.2	1.39	3.34	0.86	18.86	0.92
		III	32.20	2.25	34.6	1.46	3.10	0.57	17.54	1.37
		IV	45.21	5.32	33.1	0.87	2.89	0.74	16.23	0.81
	Average	Change (%)	40%		44%		51%		31%	

Std: Standard deviation

Table 3. Values of Total Color Change (ΔE^*), (a^*), (b^*), and Lightness (L) of Weathered Beech Wood

Varnishes	Bleaching chemicals	Seasons	ΔE^*	Std.	L	Std.	a^*	Std.	b^*	Std.
Control	Unbleached	Natural	15.99	4.25	2.39	1.08	6.84	0.91	18.11	1.15
		I	26.39	3.68	1.34	0.18	9.11	0.81	20.56	0.68
		II	34.77	4.21	1.55	0.20	9.74	0.68	23.01	1.22
		III	37.54	1.42	1.16	0.05	9.92	1.12	24.38	1.15
		IV	38.53	2.11	1.14	0.05	10.40	0.45	25.29	0.78
	Average	Change (%)	61%		53 %		35%		38%	
Un-varnished and bleached	H_2O_2	Control	16.79	1.86	2.65	0.22	9.73	1.39	19.17	1.42
		I	20.38	2.86	2.35	0.56	10.20	0.81	20.23	1.26
		II	23.54	0.67	2.30	0.18	10.13	1.21	23.52	1.38
		III	25.28	2.77	1.30	0.05	11.12	0.70	26.81	1.72
		IV	27.69	2.54	1.26	0.05	11.41	1.77	27.60	0.91
	Average	Change (%)	41%		52 %		19%		30%	
	NaOH	Control	28.19	3.98	2.13	0.16	6.20	0.90	19.58	1.16
		I	34.43	3.23	1.06	0.27	7.31	0.81	21.27	0.96
		II	39.04	1.42	1.74	0.40	7.78	0.73	21.52	0.89
		III	41.53	0.78	1.13	0.05	7.81	0.44	21.37	0.76
		IV	41.60	1.27	1.10	0.00	7.99	0.51	21.61	0.86
	Average	Change (%)	32%		48 %		25%		10%	
Polyurethane varnish	H_2O_2	Control	27.03	2.07	45.33	6.38	10.74	0.94	22.28	1.58
		I	27.26	2.12	31.25	9.61	10.99	0.81	21.71	0.88
		II	28.72	1.30	25.37	1.52	11.37	0.74	24.62	0.77
		III	34.49	1.54	24.38	0.27	11.47	0.73	25.30	0.89
		IV	39.79	2.08	24.13	0.12	11.23	0.82	25.81	1.76
	Average	Change (%)	31%		47 %		33%		12%	
	NaOH	Control	30.65	1.72	44.65	9.12	6.42	0.82	19.71	0.69
		I	34.08	2.57	33.65	2.67	7.23	0.71	19.59	1.22
		II	41.79	2.29	26.16	1.24	7.54	0.69	21.72	1.37
		III	43.72	3.44	24.55	0.60	7.98	0.40	21.64	1.21
		IV	47.16	2.20	23.21	0.25	8.33	0.79	15.38	1.57
	Average	Change (%)	37%		48 %		25%		21%	
Synthetic varnish	H_2O_2	Control	22.08	2.16	65.99	11.1	8.26	0.83	17.62	1.12
		I	26.22	1.82	40.24	6.56	7.86	0.57	19.83	0.53
		II	28.13	1.29	37.38	2.82	5.34	0.63	19.77	1.24
		III	32.06	3.44	34.06	1.82	5.18	0.76	20.28	0.89
		IV	37.38	2.71	33.41	0.74	5.46	0.44	21.09	1.11
	Average	Change (%)	40%		50 %		38%		20%	
	NaOH	Control	28.63	2.07	51.95	5.50	8.14	0.76	21.56	0.79
		I	33.57	4.15	43.44	5.41	7.10	0.91	21.28	0.88
		II	37.91	1.92	34.05	5.34	6.52	0.91	16.49	0.69
		III	40.34	5.16	31.41	0.81	6.22	0.57	15.68	1.45
		IV	48.24	1.43	30.05	0.31	5.91	0.58	14.46	0.18
	Average	Change (%)	42%		58 %		37%		33%	

Std: Standard deviation

Table 4. Multiple Variance Analysis of Weathered Scots Pine Wood

Source of Variance	Sum of square	Degrees of freedom	Mean Square	F Value	P ≤0.05
Varnishes	18076.85	2	9038.43	388.97	0.000
Chemicals	359.91	1	359.91	15.49	0.000
Weathering Time	28477.97	4	7119.49	306.39	0.000
Varnishes * chemicals	1216.60	2	608.30	26.18	0.000
Varnishes * weathering time	20998.34	8	2624.79	112.96	0.000
Chemicals * weathering time	653.18	4	163.29	7.03	0.000
Varnishes * chemicals* weathering time	892.80	8	111.60	4.80	0.000
Error	5693.06	245	23.24		
Totally	137909.79	280			

Table 5. Multiple Variance Analysis of Weathered Beech Wood

Source of Variance	Sum of square	Degrees of freedom	Mean Square	F Value	P ≤0.05
Varnishes	810.75	2	405.37	58.18	0.000
Chemicals	12612.50	1	12612.50	1810.12	0.000
Weathering Time	498.60	4	124.65	17.89	0.000
Varnishes * chemicals	918.53	2	459.26	65.91	0.000
Varnishes * weathering time	2658.50	8	332.31	47.69	0.000
Chemicals * weathering time	5038.86	4	1259.72	180.79	0.000
Varnishes * chemicals* weathering time	689.84	8	86.23	12.38	0.000
Error	1707.10	245	6.97		
Totally	322967.68	280			

Table 6. Results of Duncan's Multiple Range Test

Scots pine			Beech		
Chemicals	Mean	H.G.	Chemicals	Mean	H.G.
H_2O_2	20.95	a	H_2O_2	25.50	a
Control	27.38	b	Control	30.64	b
NaOH	27.86	c	NaOH	39.99	c
Varnish type	Mean	H.G.	Varnish type	Mean	H.G.
Unvarnished	20.95	a	Unvarnished	30.15	a
Control	27.38	b	Control	30.64	a
Polyurethane	27.86	b	Synthetic	33.94	b
Synthetic	30.23	c	Polyurethane	34.14	b
weathering time	Mean	H.G.	Weathering time	Mean	H.G.
Control	14.03	a	Control	30.82	a
I	28.82	b	I	32.05	b
II	28.60	c	II	32.36	b
III	32.78	d	III	33.42	c
IV	33.22	d	IV	33.56	c

Among the conditions considered, treatment with H_2O_2 solution gave the lowest color change (12.14) for pine wood. According to seasons, the fourth season gave the highest total color change in treatments with NaOH solutions. Each of the bleaching solutions decreased the metric chroma. This could have resulted from the effect of pH values of H_2O_2. Bleaching is the removal or decolorization of chromophoric groups in the structure of wood using various acidic chemicals and bleaching systems (Ejechi 1996) (see in Figs.1 and 2).

In this study, the highest color changes occurred in bleached wood specimens after the fourth season. This could be explained as moisture loss in wood or the effect of solution groups. The catalyzing effect of ultraviolet waves, and other outdoor factors causes lignin and cellulose structures to degrade in wood, and it was seen that metric chroma (*C*) values decreased clearly in samples treated with the NaOH solution in both wood species. A statistically significant difference was observed compared to control samples with respect to weathering time.

Metric chroma was the highest in beech and the lowest in Scots pine. According to varnish type, metric chroma was the highest in polyurethane varnish and the lowest in synthetic varnish. According to bleaching solutions, metric chroma was the highest in H_2O_2 and the lowest in NaOH. This might be due to the texture of wood materials, layer properties of varnishes, and applying period (2-3 min) of the bleaching process (Keskin and Atar 2007. 2008). As a matter of fact, different results were obtained depending on the weathering periods. Average values according to wood type, varnishes, and weathering period are given in Table 2 and 3.

The highest total color change value (ΔE^*) was obtained after the fourth season with the NaOH solution on beech wood. The NaOH solution caused higher total color change in comparison with the H_2O_2 on Scots pine wood, too. It was observed that the total color change on beech wood was higher than the total color change on Scots pine wood. NaOH solution caused a slight decrease in redness of Scots pine, while the H_2O_2 solutions caused much more change toward green after the fourth season. However, when the H_2O_2 solution was used, the red tint of the sample totally disappeared (a* = 0.01). There was no important color changes in yellowness (b*) after bleaching. While sodium hydroxide solutions caused a slight increase of yellowness of Scots pine, it caused a slight decrease in yellowness of beech wood.

It was seen that weathering time decreased the *a** (redness) value, depending on the interaction of wood species and solution type. But, the highest *a** value (50-58%) was observed in the control samples. Similar results have been described in the literature (Ozcifci and Ozpak 2008).

CONCLUSIONS

Of the wood species considered, beech wood showed the highest color change. This means that dark-colored surfaces might increase with the weathering of wood by increasing the surface temperature, which causes an increase in the rate of moisture desorption and photochemical degradation (Meijer 2001).

After the varnishing, the effects of the bleaching solution treatments on the metric chroma of the varnish layer were important. The main impact was due to the varnish structure. Therefore, the average metric chroma of control samples treated with bleaching solutions were found to be 14.02 and 42.96, respectively. NaOH solution reduced the total color change of varnished wood by 31 to 61% and the metric chroma of varnish layers by 33-77%.

Hydrogen peroxide solution caused the highest increase in *b** (yellowness) of Scots pine wood, while sodium hydroxide caused a decrease. According to this, it is seen that there were statistical significant differences between treatment groups and an unexposed and bleached group.

After the fourth season, synthetic varnish showed a dark surface coating. But polyurethane varnish gave a lighter surface. Compared to control samples, the bleached and weathered surface gave more colorized surfaces, so if the NaOH solution is used alone as a bleaching solution, it causes darkening of wood materials. To avoid such effects, NaOH can be mixed with H_2O_2 solution, and the new mixed solution can be used as a bleaching chemical.

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Modified-Wood Before and After Weathering*l

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