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Evaluation of wood coating performance and volatile organic compounds

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Abstract:
The aim of this study was to evaluate the environment-performance relationship of surface coating applications on data obtained by measuring the emission rates of volatile organic compounds in polyurethane and water-based varnishes. For this purpose, polyurethane and water-based varnishes from five different companies were applied to the test samples of *Entandrophragma cylindricum* (sapele) and *Piptadeniastrum africanum* (dabema), both widely used in the production of urban furniture. Volatile organic compound, hardness and adhesion strength were measured during application. When evaluated in terms of performance, polyurethane varnishes showed superior hardness, while water-based varnishes demonstrated better adhesion after the UV test. The hardness values of polyurethane varnishes before and after the UV aging test were 15,9 s and 79,403 s, respectively, while forwater-based varnishes were , the values were 114,92 s and 75,406 s. The adhesion values of water-based varnishes were 2,885 MPa and 1,18 MPa before and after the UV aging test, and for polyurethane varnishes 3,13 MPa and 1,05 MPa for. When the environment-oriented results were evaluated, the ; emission values of volatile organic compounds in polyurethane varnish applications were found to be significantly higher than those in in water-based varnishes applications. While the total emission rate of volatile organic compounds detected in polyurethane varnishes was 53,63 mg/Nm^3, while only one brand of water-based varnishes showed a measurable emission value, recorded at 0,0057 mg/Nm^3. The volatile organic compounds emission values of other water-based varnishes were below the device detection limit (<0,0035 mg/Nm^3), and therefore could not be measured.

Keywords: Adhesion strength, *Entandrophragma cylindricum,* Emission rates, *Piptadeniastrum africanum,* Polyurethane varnish, surface coating, UV aging test, volatile organics compounds, water-based varnish, wood urban furniture.

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Introduction

Wood material has an important place in the development process of human life and culture. It has been used in many areas, especially as carrier elements, exterior cladding, flooring and roofing materials in various parts of buildings, bridges and scaffolding in industrial constructions and as urban furniture in streets and parks. It is observed that the consumption of wood material, which has an organic structure, has reached serious dimensions today. For this reason, surface coating applications are very significant to protect that the wood material, It can be protected against harmful factors by considering both limited forest resources and aesthetic values (Ulay and Budakci 2015, Zhu *et al.* 2023).

The surface coating systems applied to wood materials provide protection against deterioration caused by external weather conditions. Moreover, the colorants and pigments in these coating systems catalyze the wood, enhancing its resistance to UV rays from the sun. It's commonly observed that wood materials like benches and fences, when used in challenging outdoor environments, tend to have a relatively short service life. The primary reasons for this are the direct exposure of the material to external elements such as rain, snow, and sunlight (Williams *et al*. 1990, Hermann *et al*. 2023).

With the effect of the rapid concentration of life in cities, the need for urban furniture has been increasing rapidly in recent years. Wood materials are mostly used in the production of benches, country tables, children's playgrounds, arbours and pergolas, which are classified as urban furniture. In parallel with this increase in demand for urban furniture, the wood material utilized in production needs to fulfill technical, aesthetic, durable, and environmental requirements. For these reasons, volatile organic compounds, which are very important for the environment and human health, are released during the surface coatings applied to wooden products.

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It is a known fact that exposure to some volatile organic compounds (VOCs) above a certain rate poses a risk to the environment and human health. These VOCs are mainly classified as aromatics, aliphatics, ketones, chlorinated compounds and alcohols (Gulbag 2006, Calovi and Rossi 2023). It is necessary to determine the rates of volatile organic compounds released during surface coating applications and to investigate the positive and negative effects of these substances on product performance. Although there are studies on product performance properties after surface coating applications in the literature, there are not enough studies investigating the relationship between environment and performance.

The investigation aims to determine the changes in surface hardness values of products resulting from applications utilizing various surface coating materials and methods on different types of wood materials (Huang *et al*. 1997, Budakci 1997, Peker 1997, Ozen and Sonmez 1999, Sarica 2006, Soylamis 2007, Cakicier 2007, Pelit 2007, Akgun 2008, Kesik 2009, Dalyan 2010, Budakci *et al.* 2015, Hazir and Koc 2019, Hazir and Koc 2021). Determination of surface coating adhesion strength changes (Budakci 1997, Peker 1997, Huang *et al.* 1997, Ozdemir 2003, Cakicier 2007, Pelit 2007, Akgun 2008, Kesik 2009, Budakci and Sonmez 2010, Mercan 2012, Kocapinar 2014, Dilik *et al.* 2015, Ozdemir and Kocapinar 2015, Ayata and Cakicier 2018, Erdinler *et al.* 2019, Hazir and Koc 2019, Hazir *et al.* 2020a, Hazir *et al.* 2020b, Hazir 2021, Hazir and Koc 2021). As well as volatile organic compound measurements in indoor and outdoor environments, studies investigating the effects of these compounds on human health (Guney 2010,Yilmaz 2011, Toksoz 2012, Aydin 2013, Calovi and Rossi 2023). Determining the performance effects of volatile organic compounds on products by determining the ratios of volatile organic compounds released during or after surface coating applications in the furniture industry (Gur 1990, Chang and Zhishi 1992, Huang *et al*. 1997, Lee *et al.* 2003, Ho *et al.* 2011, Gennaro *et al.* 2015, Tesarova and Chech 2015, Seo *et al.* 2015, Zhu *et al.* 2016, Sassoli *et al.* 2017, Tong *et al.* 2018). In these studies, surface coating materials were applied

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to wood materials and surface performance properties such as hardness and adhesion were determined. It has been stated that these properties may vary according to the type of wood and application method. In addition, measurements of volatile organic compounds in indoor and outdoor environments were made for the environment and human health, and higher values were obtained in indoor environments and their harm to human and environmental health was stated. Especially in the urban furniture sector, no study has been found that investigates both the determination of volatile organic compounds during and after surface coatings and the effects of these compounds on the environment and performance.The main purpose of the study is to reveal the effect of surface coating materials on the environment, especially in terms of top surface coatings, of wood materials used in the production of urban furniture and the relationship between this effect and surface coating performance.

By determining the volatile organic compound ratios emitted by the surface coating materials applied on the wood samples to the atmosphere, the effects of these substances on the environment were determined. Then, the relationship of these effects with adhesion and hardness, which are surface coating performances, was investigated.

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Materials and methods

Experimental procedure

This experimental procedure includes five steps to determine the environmental performance in wood surface coatings. These steps were;

Sapele (*Entandrophragma cylindricum* (Sprague) Sprague) and dabema (*Piptadeniastrum africanum* (Hook.f.) Brenan) wood species, which are widely used in the production of urban furniture, were chosen as the experimental material.

Polyurethane and water-based varnishes were selected from 5 different varnish companies as surface coating materials. These surface coating materials were applied to the wood samples in appropriate standards.

Volatile organic compounds (VOCs) released during the application process that may be harmful to the environment were determined and their emission values were measured.

Then the wood samples were subjected to UV aging test in the laboratory. Hardness values and adhesion strength tests were performed on the surfaces of the control and test samples and their performance values were determined.

Finally, the environmental effects of varnishes used in surface coating applications and the relationship between these effects and surface coating performance; Analysis of Variance (ANOVA), Tukey test, Lack of Conformity test and Adjusted coefficient of determination (Adj-R^2) values were used from statistical methods.

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Preparation of wood samples

In this study, sapele (*Entandrophragma cylindricum* (Sprague) Sprague) and dabema (*Piptadeniastrum africanum* (Hook.f.) Brenan) wood species were selected according to the principles specified in TS ISO 3129 (2021). These woods were dried sufficiently in drying ovens and their humidity ratio was brought to 15 ± 3 % humidity values. The surfaces of the woods were planed and passed through a calibrated sanding machine. Then, timbers measuring 140 mm x 75 mm x 5 mm were cut. The woods consist of 160 test and control samples in total (Figure 1).

Figure 1: Wiew of wood samples.

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Sanding and varnishing application processes

Primer application

Before applying the primer coating process, the front and back surfaces of the 140 mm x 75 mm x 5 mm samples, which were coarsely sanded with 80 grit sandpaper, were treated with 150 grit sandpaper. The sanding dust formed was removed from the wood surfaces with an air gun. Then, in polishing workshops with an ambient temperature of 15 °C - 30 °C, with a paint spray gun with a nozzle of 1,8 mm - 2,2 mm from the bottom and an air pressure of 200000 Pa - 250000 Pa, within the framework of ASTM D3023-98 (2017) principles from a distance of

20 cm - 30 cm and keeping the gun perpendicular to the surface, 80 ml - 120 ml per 1 m². Primer coating material was applied on wood surface. Since the powder drying of the product is 1 h and the touch dryness is 2 h, it was kept for 2 h at 20 °C and 65 % relative humidity after the front surface applications. Then, when the woods were dry to the touch, they were reversed and the same process was repeated for the front surface.

Final coat varnish application

The filling varnish application process was completed, and the front and back surfaces of the woods were left to dry for 4 h at 20 °C and an average of 65 % relative humidity, and intermediate sanding was applied with 220 grit sandpaper (Figure 2). After the sanding dust formed is removed from the wooden surfaces with an air gun, in an environment with an application temperature of 15 °C - 30 °C, 200000 Pa - 250000 Pa, 100 ml per 1 m², with an air pressure paint spray gun with 1,8 mm - 2,2 mm nozzle from the bottom 150 ml of top coat surface coating material has been applied. Since the powder drying of the product is 1 h and the touch dryness is 2 h, it was kept for 2 h at 20 °C and 65 % relative humidity after the front surface applications. Then, when the woods were dry to the touch, they were reversed and the same process was repeated for the front surface.

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Figure 2: Varnishing application processes on wood samples.

Within the scope of the research, 5 different brands of polyurethane and water-based varnishes, which are especially preferred in the production of urban furniture and resistant to outdoor conditions, were used. In the tests carried out within the scope of the test study, the brands of these companies were coded with the letters R, H, K, U and S. The physical and chemical properties of the polyurethane and water-based varnishes used are shown in the Table 1 and Table 2.

Table 1: Properties of applied water based varnishes.

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Varnish types	Viscosity	Density	VOC Content
R brand liner	12 s 4 mm viscosity cup at 20 °C	1,02 g/cm^3 at 20 °C	EU defined limit value for the product (Cat A/e): 130 g/l (2010). This product contains up to 50 g/l VOC
R brand varnish	12 s 4 mm viscosity cup at 20 °C	1,04 g/cm^3 at 20 °C	EU defined limit value for the product (Cat A/e): 130 g/l (2010). This product contains up to 50 g/l VOC
U brand varnish	(D4 / 20 °C): 11 s -13 s	1,02 -1,04 g/cm^3 at 20 °C	Unspecified
H brand varnish	53 s (DIN4 20 °C)	1,03 g/cm^3 at 20 °C	<1 %
K brand varnish	160 s- 185 s D4, 20 °C	1,01 ± 0,005 g/cm^3, 20 °C	Product 0 g/l maximum Contains VOCs
S brand varnish	45 s - 55 s with DIN 4 container at 20 °C	43 % ± 2 Solids Amount	Unspecified

Table 2: Properties of applied polyurethane varnishes.

Varnish types	Viscosity	Density	VOC Content
R brand hardener	Unspecified	1,026 g/cm^3 +/- 0,05 20 °C	Unspecified
R brand varnish	25 s -30 s 4 mm viscosity cup	0,941 g/cm^3 +/- 0,05 20 °C	Unspecified
U brand varnish	150 s - 160 s 20 °C	1,0 -1,04 kg/l, 20 °C	Unspecified
H brand varnish	Kinematic (room temperature): <0,205 cm2/s Kinematic (40 °C) :>0,205 cm^2/s	1 g/cm^3 at 20 °C	2010/75/EU: 60,9 w/w 612 g/l
K brand hardener	Unspecified	1 ± 0,02 g/cm^3, 20 °C	The product contains a maximum VOC of 560 g/l
K brand varnish	95 s - 100 s D4 20 °C	0,99 ± 0,05 g/cm^3, 20 °C	The product contains a maximum VOC of 500 g/l
S brand hardener	30 % Solids Content	0,93 g/cm^3 20 °C	Directive 2010/75/EC: 60 %- 651 g/l
S brand varnish	120 +/- 2 s TF4	0,94 g/cm^3 20 °C	Directive 2010/75/EC: 55 %-517 g/l

Sampling and analysis of volatile organic compounds (VOC)

Activated carbon sampling method was used in the sampling of volatile organic compounds (VOC) within the scope of the research and the principles in TS ISO 16200-1 (2001) standard were applied. Gas samples were adsorbed from the chimney to the activated carbon sorbent tubes with the help of a Gilian-Gilair Plus brand device with a low flow air aspiration pump while the varnishing processes were carried out in the polishing shop. Volatile organic compounds absorbed into the tubes were analyzed by Gas chromatography method. In addition to this, flue gas velocity and humidity values were measured. VOC sampling and analysis processes are shown schematically in Figure 3.

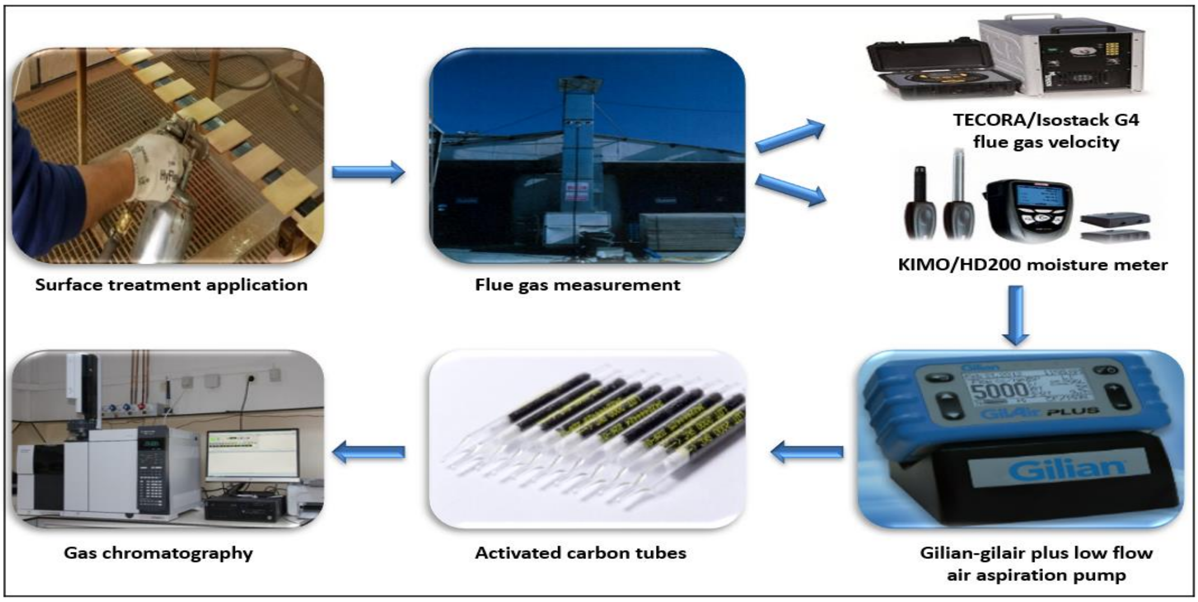

Figure 3: Schematic representation of VOC sampling and analysis processes.

UV Aging application

Experiment samples were subjected to accelerated UV test in a suitable construction and material laboratory by the principles of TS EN ISO 16474-3 (2021) standard (Table 3), at 1 cycle: 6 h, intermediate control: 500 h and test duration: 727 h. The changes in these examples are based on the TS 423-2 EN 20105-A02 (1996) standard; The fading and discoloration of dark and light colors compared to the original on the gray scale were analyzed by visual evaluation. UV aging test application is shown in Figure 4.

Table 3: Exposure to fluorescent-UV laboratory light source

Application period	Lamp type	Radiation	Black panel temperature °C
5 h dry	UVA - 340	0,83 W / m²/ nm 340 nm	60 ± 3
1 h water spray		the lamp is off	25 ± 3

Figure 4: UV aging test application.

Surface coating performance tests

Adhesion strength measurement

The adhesion strength of the surface coating materials applied to the wooden samples was measured with a pneumatic tester (Figure 5). By measuring the surface of each sample, adhesion strength values were obtained according to the principles of ASTM D 4541 (2022) standard.

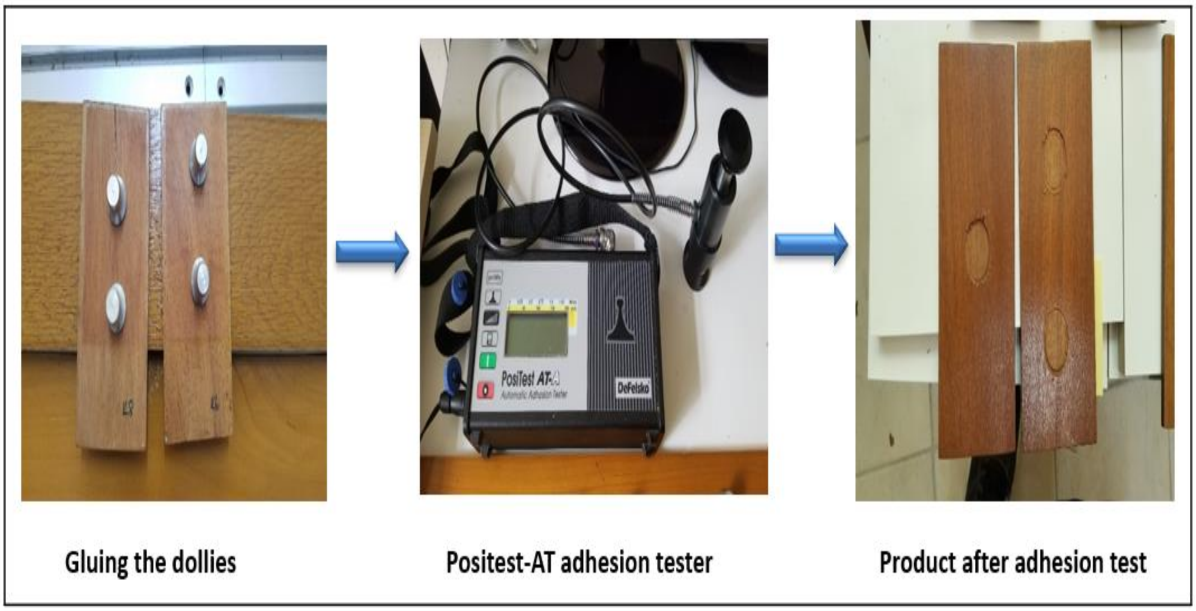

Figure 5: Adhesion test applications.

Coating hardness measurement

Pendulum hardness tester was used to determine the hardness of the varnish dry film. The damping technique was used to evaluate the dry film hardness of the varnish by measuring the oscillation amplitude of the pendulum during the test application. The applications were carried out according to the principles of the ISO 1522 (2022) standard.

Statistical procedure

In order to support the normal distribution on the samples, surface hardness and adhesion values were determined by making 30 measurements. To investigate whether there is a significant difference on the surfaces of the samples; The normality assumption of the distribution of the hardness and adhesion values of the surfaces was tested and the normality tests of the obtained values were examined with the Anderson-Darling test. Analysis of variance and Tukey test were applied to evaluate the effective parameters.

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Analysis of variance

Analysis of variance (ANOVA) based F-test was applied to evaluate the significance factor on the surface properties of the surface treated wood material. This analysis investigates the following for each parameter are given in Equation 1 and Equation 2:

$$\begin{aligned} &H_0 : U_1 = U_2 = \ldots = U_\alpha \\ &H_1 : U_i \neq U_j \ \textit{for at least one pair}\,(i, j) \end{aligned} \quad (1)$$

The F value is calculated by:

$$F_0 = \frac{\frac{SS_A}{\alpha - 1}}{\frac{SS_E}{N - \alpha}} = \frac{MS_A}{MS_E} \quad (2)$$

The terms of (α-1) and (N-α) are the degrees of freedom and the error degrees of freedom for the parameter A, respectively. MS_A and MS_E are indicated the sum squares of means and errors for the variable A, respectively. The null hypothesis is rejected when the F_0 is higher than critical value of $F_{\alpha,\alpha-1,N-\alpha}$, where α is the level of the significance.

Tukey's test

It is among the tests that are used in cases where the number of observations in each group is equal, and that controls trial errors when the errors resulting from mean comparisons are constant. One of the most important features of this test is that it can control the increase in trial errors as the number of groups in trials increases, and trial errors show the closest value to the

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true value even if the number of observations is not equal. In addition, this test is widely used because it reveals even the smallest differences between the means (Mason *et al.* 2003).

Lack of conformity test

The lack of fit test assumes that there is a doubt that the relationship between the independent variable and the response variable will be explained with a line when the assumptions of independence, normality, and constant variance are met (Equation 3).

$$F_0 = \frac{\frac{SS_{LOF}}{(m-2)}}{\frac{SS_{PE}}{(n-m)}} = \frac{MS_{LOF}}{MS_{PE}} \qquad (3)$$

Adjusted coefficient of determination

In the evaluation of mathematical models, both the adjusted coefficient of determination and the coefficient of determination should be evaluated together. The reason for this is that in some cases the coefficient of determination is insufficient to explain the model, and in some cases it can be misleading. If it turns out that the variable added to the model is not significant, the

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adjusted coefficient of determination guides whether the model is significant or not (Equation 4).

$$R^2_{Adj} = \frac{\frac{SS_{Res}}{(n-p)}}{\frac{SS_T}{(n-1)}} \qquad (4)$$

Results and discussion

The values obtained such as volatile organic compounds released during the applications, surface hardness and adhesion strength of the woods after the tests are given in Table 4. 30 x 3 measurements were made for each product and the results were evaluated by ANOVA analysis. To reduce variation, measurements were made in random order.

Table 4: UV aging test results

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Wood Type	Varnish Type	Control Samples	727 Hours UV Post - Aging Samples			
		Hardness	Adhesion	Hardness	Adhesion	Total VOC
Sapele	Polyurethane based-H	115,5	2,65	83,2	1,32	53,63
	Water based-H	116,8	3,01	77,27	1,22	0,0035
	Polyurethane based-S	111,5	3,67	78,63	1,01	23,04
	Water based-S	115,9	2,74	80,03	1,2	0,0035
	Polyurethane based-K	120	2,86	78,17	1,14	10,94
	Water based-K	107,1	2,17	74,03	1,21	0,0035
	Polyurethane based-Ü	116,6	3,1	89,63	0,64	50,67
	Water based-Ü	121	1,92	73,53	1,62	0,0035
	Polyurethane based-R	110	2,29	75,9	1,09	26,19
	Water based-R	110,1	3,15	71,17	0,88	0,0057
Dabema	Polyurethane based-H	116,5	4,01	77,37	1,19	53,63
	Water based-H	119,7	3,26	80,1	1,11	0,0035
	Polyurethane based-S	115,9	3,11	79,23	1,14	23,04
	Water based-S	117,3	3,3	76,43	1,1	0,0035
	Polyurethane based-K	123	3,39	76,97	1,04	10,94
	Water based-K	109,1	2,99	73,23	1,14	0,0035
	Polyurethane based-Ü	120,3	2,99	79,77	0,9	50,67
	Water based-Ü	120,4	3,17	79,4	1,09	0,0035
	Polyurethane based-R	109,9	2,32	75,2	1,01	26,19
	Water based-R	111,8	3,16	68,87	1,23	0,0057

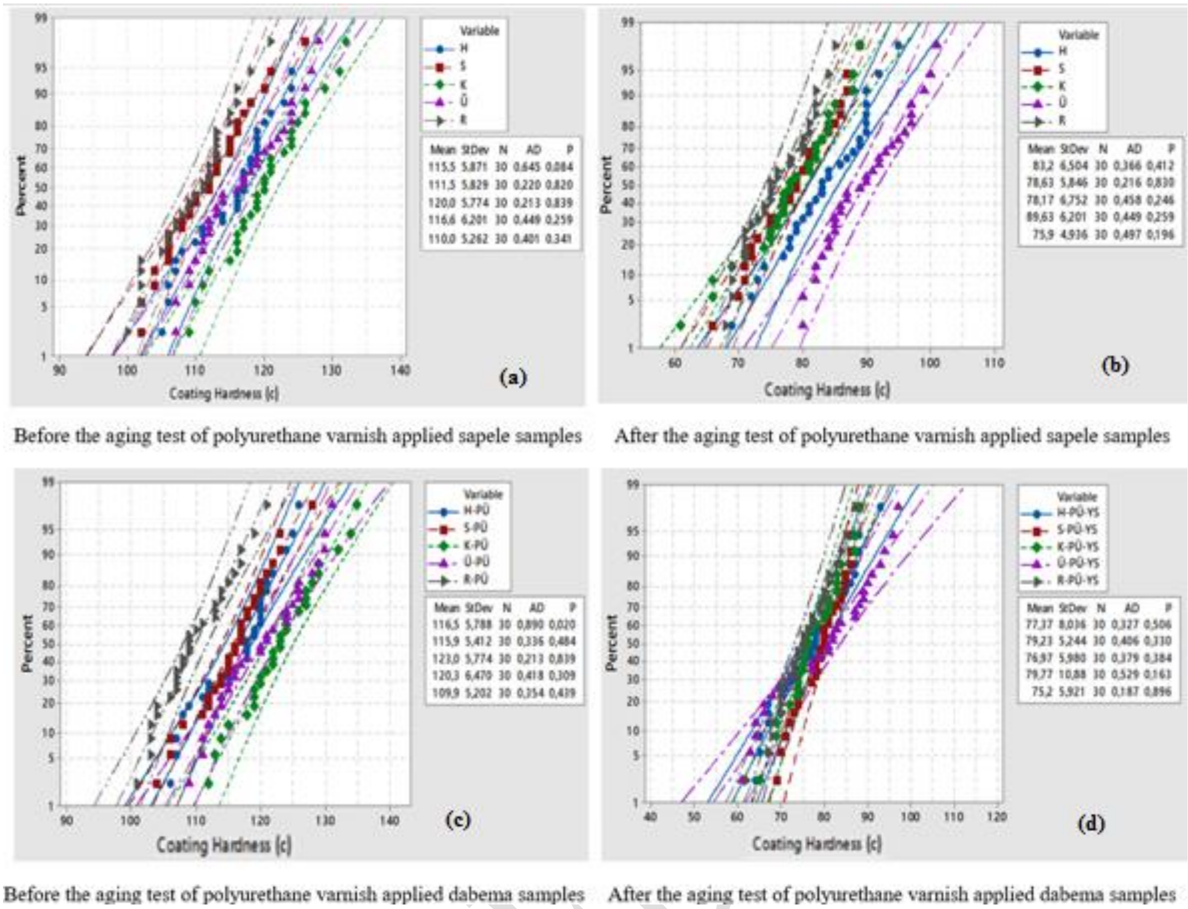

Figure 7: Probability plot of the coating hardness strength values of the samples applied with polyurethane-based varnish before (a and c) and after (b and d) the UV aging test.

As seen in Table 4, TVOC (Total Volatile Organic Compounds) values; The highest is 53,63 mg/Nm^3 in H brand polyurethane varnish, 50,67 mg/Nm^3 in U brand polyurethane varnish, 26,19 mg/Nm^3 in R brand polyurethane varnish, 23,04 mg/Nm^3 in S brand polyurethane varnish and K brand polyurethane varnish and it was determined as 10,94 mg/Nm^3. In water-based varnishes, the highest value of 0,0057 mg/Nm^3 was obtained in R brand varnish, while the VOC values measured in H, U, S and K water-based varnish brands were below the device reading limit (<0,0035 mg/Nm^3). No value could be determined as it was below.

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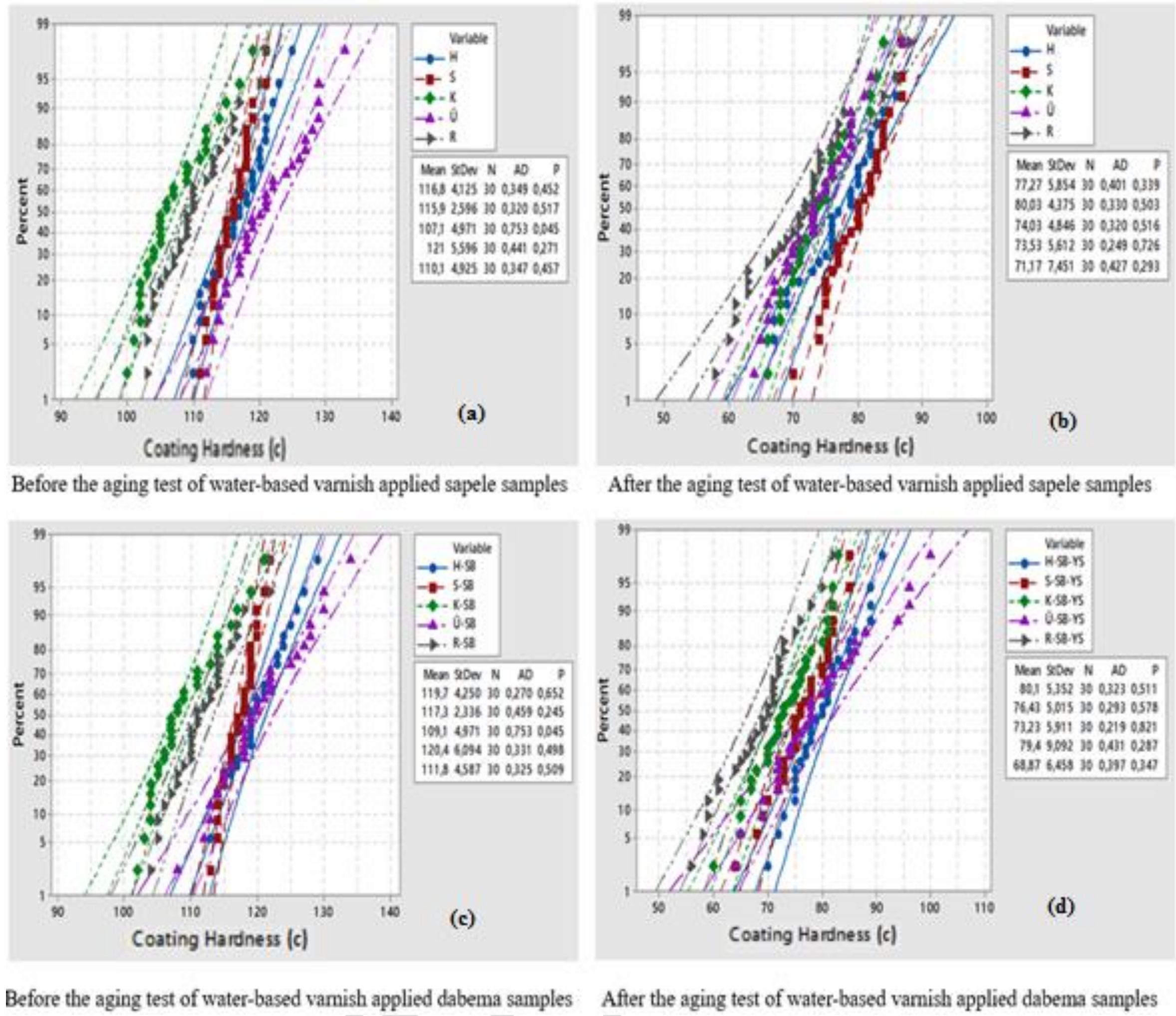

Figure 8: Probability plot of the coating hardness strength values of the samples applied with water-based varnish before (a and c) and after (b and d) the UV aging test.

The results of analysis of variance of surface hardness result is shown in Table 5. According to the results ; varnish brands and UV aging were found to be important parameters on surface coating hardness . In addition, performance values for hardness; R^2(R-square) value was determined as 99,71 % and Adj-R^2(Adjust R-sqaure) value was computed as97,20 %.

Table 5: Result of ANOVA for hardness strength.

Parameters	DF	Adj SS	Adj MS	*F*-Value	*P*-Value
Wood type	1	0,5	0,5	0,04	0,843
Varnish type	1	62,5	62,5	5,71	0,075
Varnish brands	4	333,5	83,4	7,61	0,037
UV-aging test	1	14450,3	14450,3	1319,05	0,001
Error	4	43,8	11	-	-
Total	39	15237	-	-	-

(DF:Degrees of freedom; Adj SS: Adjust sum of squares; Adj MS: Adjust meaon of squares; F-Value:Value on the F distribution; P-Value: Value of probability.)

Adhesion strength analysis of variance results is shown in Table 6. According to the results ; Wood species and UV aging were found to be important parameters on adhesion strength. In addition, performance values for adhesion strength; R^2 and Adj R^2values were determined as 95,55 % and 54,32 %, respectively

Table 6: Result of ANOVA for adhesion strength.

Parameters	DF	Adj SS	Adj MS	*F*-Value	*P*-Value
Wood type	1	0,3642	0,3642	8,23	0,046
Varnish type	1	0,0126	0,0126	0,28	0,622
Varnish brands	4	0,6652	0,1663	3,76	0,114
UV-aging test	1	34,0095	34,0095	768,83	0,001
Error	4	0,1769	0,0442	-	-
Total	39	38,7335	-	-	-

The main influence of factors on surface hardness is shown in Figure 9. According to the results obtained; It was observed that the wood type had no effect on the film hardness. In terms of varnish types, it has been determined that polyurethane varnishes have better film hardness than water-based varnishes, and the hardness performance values of water-based varnishes are below the average. When varnish brands are compared, it is seen that the U and H brand varnishes show close hardness values to each other and are above the average values, the S brand varnish performs close to the average value, the K and R brand varnishes are below the average values, and the lowest hardness value is the R brand varnishes. On the other hand, it was determined

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that the film hardness of the samples, which were subjected to the UV aging test, was greatly reduced.

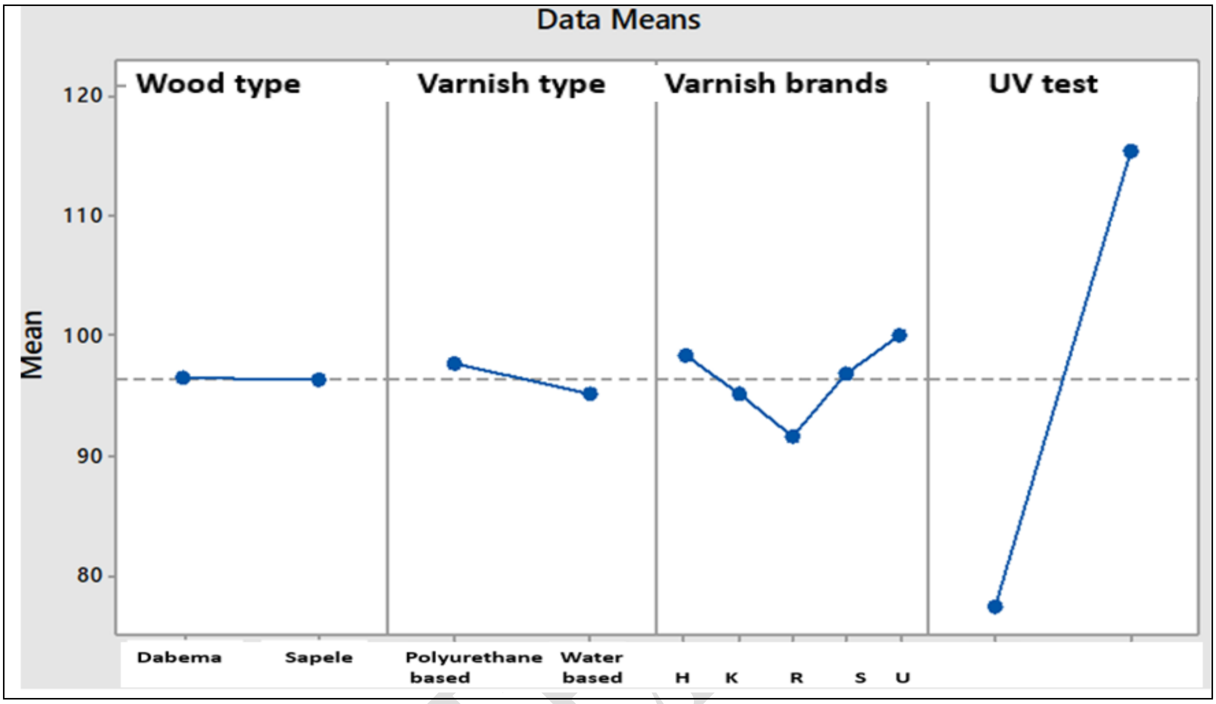

Figure 9: Main effect of factors on surface coating hardness.

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At 95 % confidence level, within the scope of Tukey test pairwise comparison analysis results; The effect of UV on surface hardness is shown in Table 7, the effect of varnish brands in Table 8, the effect of varnish types in Table 9 and the effect of wood species in Table 10. According to the results :

(1) UV aging test has an effect on the film hardness value;

(2) U and R brand varnishes were no effect on the film hardness value, while H, S and K brand varnishes were effect on the film hardness value;

(3) It was observed that the varnish type and wood type were not effect on the film hardness value;

Table 7: Tukey test result of coating hardness for UV aging test

UV-Aging Test	Sample size (N)	Mean	Grouping
Applied	20	115,42	A
Not Applied	20	77,406	B

Table 8: Tukey test result of coating hardness for varnish brands

Varnish Brands	N	Mean	Grouping
U	8	100,079	A
H	8	98,305	AB
S	8	96,865	AB
K	8	95,2	AB
R	8	91,618	B

Table 9: Tukey test result of coating hardness for varnish types

Varnish Type	N	Mean	Grouping
Polyurethane based	20	97,663	A
Water based	20	95,163	A

Table 10: Tukey test result of coating hardness for wood types

Wood Type	N	Mean	Grouping
Dabema	20	96,523	A
Sapele	20	96,303	A

The main effect of factors on adhesion strength is shown in Figure 10. According to the results obtained; It was seen that the wood species had an effect on the adhesion, and the dabema wood species had an adhesion strength value above the average. In terms of varnish types, it has been determined that water-based varnishes are slightly better than polyurethane varnishes in terms of adhesion strength, and the adhesion strength values of polyurethane varnishes are slightly below the average. When varnish brands are compared, it has been seen that the adhesion strength values of H and S brand varnish are above the average value, and H brand varnish shows the best adhesion strength performance. It was determined that U, R and K brands were below the average values, and the lowest adhesion strength value was in the K brand. On the other hand, it was determined that the adhesion strength values of the samples, which were subjected to the UV aging test, were greatly reduced.

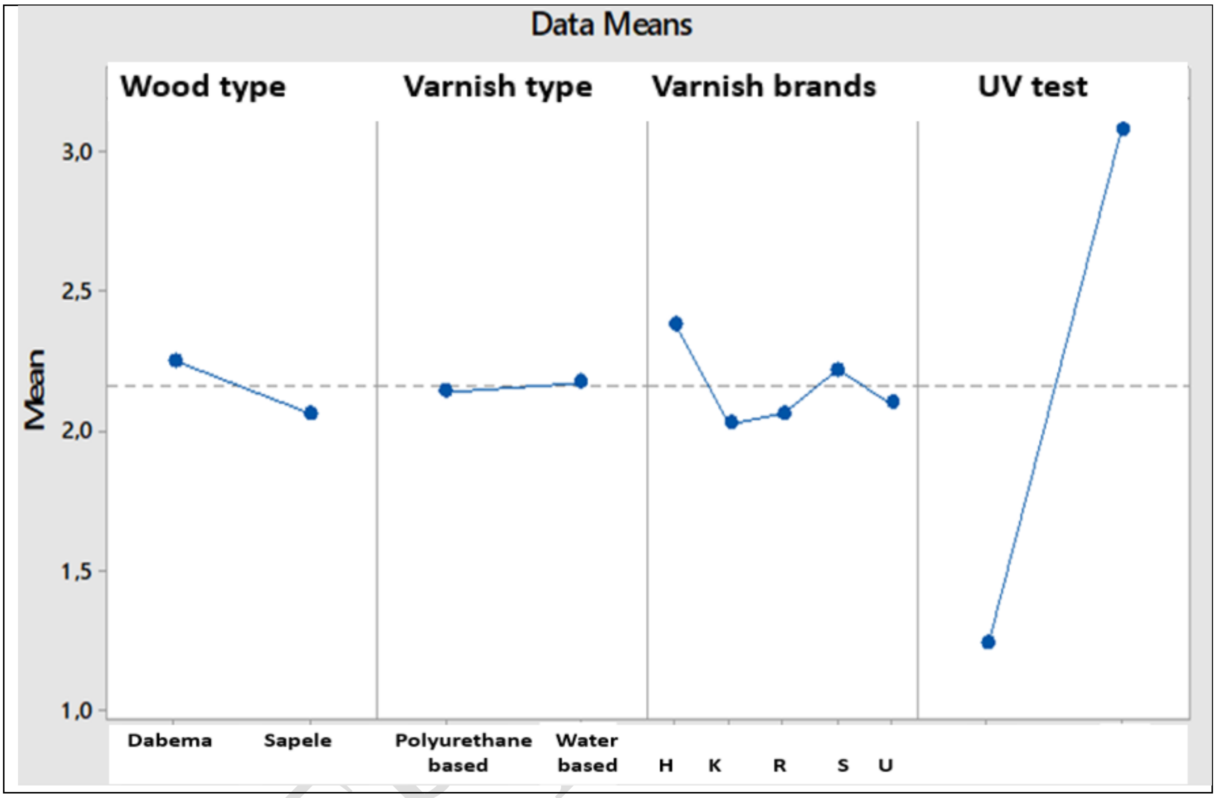

Figure 10: Main effect of factors on surface coating adhesion strength.

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At 95 % confidence level, within the scope of Tukey test pairwise comparison analysis results; The effect of UV on adhesion strength is shown in Table 11, the effect of varnish brands in Table 12, the effect of varnish types in Table 13 and the effect of wood species in Table 14. According to the results:

(1) It has been observed that UV aging test was effect on adhesion strength.

(2) It was observed that U, H, S, K and R varnishes were noteffect on adhesion strength.

Table 11: Tukey test result of adhesion strength for UV aging test

UV	N	Mean	Grouping
Yes	20	2,256	A
No	20	2,065	B

Table 12: Tukey test result of adhesion strength for varnish brands

Varnish Brands	N	Mean	Grouping
U	8	2,383	A
H	8	2,223	A
S	8	2,103	A
K	8	2,064	A
R	8	2,03	A

Table 13: Tukey test result of adhesion strength for varnish types

Varnish Type	N	Mean	Grouping
Polyurethane based	20	3,083	A
Water based	20	1,239	B

Table 14: Tukey test result of adhesion strength for varnish types

Wood Type	N	Mean	Grouping
Dabema	20	2,256	A
Sapele	20	2,065	B

Conclusions

In this study, sapele (*Entandrophragma cylindricum* (Sprague) Sprague) and dabema (*Piptadeniastrum africanum* (Hook.f.) Brenan) were selected as test metarials. Polyurethane

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and water-based varnishes were selected from 5 different varnish companies as surface coating materials. Volatile organic compounds that were released during the application process and could harm the environment were determined and their emission values were measured. Then the wood samples were subjected to UV-aging test in laboratory environment. The performance values were determined by performing hardness and adhesion strength tests on the surfaces of the control and test samples.

When the results were evaluated based on performance; The performance properties of the applied polyurethane and water-based varnishes were determined to be superior to each other. After the UV-aging test, it was observed that the surface hardness values of polyurethane varnishes and the surface adhesion performance values of water-based varnishes were better.

The hardness value of polyurethane varnishes was determined as 115,9 s before UV, 79,403 s after UV, 114,92 s before UV and 75,406 s after UV of water-based varnishes.The adhesion value of water-based varnishes was determined as 2,885 mPa before UV, 1,18 mPa after UV, and 3,13 MPa before UV and 1,05 MPa after UV for polyurethane varnishes. After the UV test applications, it was observed that all performance values decreased.

Polyurethane varnishes were found to have significantly higher emission values of volatile organic compounds compared to water-based varnishes. The emission values of some water-based varnish brands were so low that the measuring instruments could not detect it.

When the results were evaluated in terms of environment-performance; Although water-based varnishes, which were more harmless in terms of human and environmental health, have minimum VOC emission values, it was determined that their performance values are at a good level.

Authorshıp contrıbutıons

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U. G.: Conceptualization, data curation, investigation, resources, validation, writing – original draft, writing – review & editing, formal analysis, funding acquisition, methodology, software.

K. H. K.: Conceptualization, data curation, investigation, resources, validation, writing – original draft, writing – review & editing, project administration, supervision.

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