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F.1

THE LEACHABILITY, FUNGAL RESISTANCE, AND MECHANICAL PROPERTIES OF WOOD TREATED WITH CCA AND CCB WOOD PRESERVATIVES[1)]

Ar.Gör.Dr. S. Nami KARTAL[2)]

Abstract

This study was performed to determine the effect of fixation time and temperature on the release rate of copper, chromium, and arsenic from treated wood, fungal resistance, and some mechanical properties of treated wood. At 20°C and higher moisture contents, leaching rate of preservative components decreased. In specimens treated with CCB and conditioned at 20°C/32-100% relative humidity, percentage of elements leached was less than that in specimens treated with CCA and also fixation rate increased significantly in CCB-treated specimens. In CCA treatments, weight losses by *Gloeophyllum trabeum* and *Postia placenta* were more than 5% in the fixation processes such as oven-drying at 120°C, and steaming at 80°C for 60 and 90 minutes while weight losses were less than 5% in the other fixation conditions. At re-drying temperatures of 20 and 70°C, CCA had no significant negative effect on the bending strength, MOE, and impact bending strength of the specimens.

1. INTRODUCTION

The interactions of CCA preservatives with wood during and after the treating process are complex and poorly understood, although aspects of these reactions have been extensively studied (LEBOW 1996). The fixation reaction is generally monitored by the reduction of Cr (VI) in the treated wood, but in the final analysis, the stability of the CCA components in the treated wood after all reactions are complete is the ultimate measure of the quality of the fixation reaction. There is also an interest in monitoring the leaching potential of treated wood before the fixation reactions are complete, because wood is generally removed from protected storage before the CCA components are completely stabilized (COOPER et al 1997).

The rate of fixation in CCA treated wood is affected by environmental conditions during following treatment. Temperature is one of the several parameters greatly affecting this rate. Ma-

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nipulation of temperature during and/or after treatment can significantly decrease the time required for fixation (FORSYTH 1993). Wood treated with CCA wood preservatives fixed under drying conditions requires longer fixation times compared to high humidity fixation conditions. Several studies showed that the fixation under high temperature conditions causes redistribution of chemicals between lignin and cellulose, and increases the leaching of CCA components (CONRADIE/PIZZI 1987; LEE et al 1993; BOONE et al 1995; KALDAS/COOPER 1996). CONRADIE and PIZZI (1987) showed that the amount of CCA leachate increased with an increase in drying temperature, generally an increase of more than four times, from 25°C to 120°C. KALDAS and COOPER (1996) found that CCA deposited during chromium reduction under low moisture content conditions was not as resistant to leaching as under high moisture contents conditions and there was significantly higher leaching of all components, and especially arsenic if the wood moisture content was lower than the fiber saturation point moisture content during fixation. In addition, BOONE et al. (1995) showed that better resistance to chromium and arsenic leaching from CCA-treated wood was obtained using a moderated kiln re-drying dry-bulb temperature with a short controlled fixation period and a high relative humidity rather than a drying schedule containing a low relative humidity. LEE et al (1993) showed that wood kiln-dried at high temperatures produced higher amounts of leached elements than the air-dried wood. ALEXANDER and COOPER (1993) stated that the rate of CCA fixation in wood was highly temperature dependent with relative humidity or wet bulb temperature playing an important role in the process and the effect of relative humidity could be explained by its effect on the surface temperature of wood, approaching the wet bulb temperature of the surrounding under drying conditions. In addition, UNG and COOPER (1996) showed that the rate of fixation was slowed substantially as a result of cooling of the wood surface under the drying conditions. However, as long as the wood moisture content did not drop below the fiber saturation point, any adverse effects on CCA leaching from the fixed wood did not appear. RUDDICK et al (1994) concluded that fixation process could be accelerated by high temperature although the presence of moisture is important to ensure fixation occurrence. Also they found that the leaching of preservative increased in the order, steam treatment <oven-dried=air-dried, and that increase the duration of steam fixation reduced the leached preservative. AVRAMIDIS and RUDDICK (1989) also stated that the wet bulb temperature is more important than the dry bulb temperature in determining the time required to fix the CCA, and the surface moisture content is a key parameter in determining the CCA fixation rate. ALEXANDER et al (1993) concluded that a high-wet bulb temperature is necessary to facilitate proper heat transfer in the wood, while also maintaining the moisture essential for the interactions of chromium with the other preservative components and wood. They also showed that the rates of fixation are significantly inhibited if the wood is allowed to dry extensively during the fixation process.

PEEK and WILLEITNER (1988) concluded that lower temperatures without steam cause increases leaching, due to a drying effect without promotion of fixation. They achieved almost complete fixation of Cr(VI) in pine by steaming the treated wood at 110°C for about 60 minutes and stated that steaming of freshly impregnated wood with chromium containing wood preservatives to accelerate fixation is a suitable method to minimize pollution. Also they found that using steam fixation methods, for softwoods the efficacy of the preservatives was not affected; in case of hardwoods treated with CCA, a certain reduction against soft rot fungi was noticed. CONRADIE and PIZZI (1987) stated that fixation at high temperatures reduces decay resistance of treated wood against wood degrading organisms because the decrease in biological performance is caused by chemical conversion reactions of the CCA preservative, such as conversion of the low solubility compounds into more soluble compounds which then leach, mobilization of the preservative with temperature due to plasticization of lignin. BOONE et al (1995) found that there was no significant influence in decay resistance among the seven re-drying schedules (74 and 60°C as maximum dry-bulb temperatures) in either groups of CCA-treated southern pine (all <5% weight loss).

The effects of waterborne preservative treatment on the mechanical properties of wood appear to be directly related to many factors, such as species, mechanical property, chemical type, retention, post-treatment drying, temperature, size and grade of material, initial kiln-drying temperature, and incising. It is generally accepted that waterborne preservative treatments reduce the mechanical properties of wood. This effect is exaggerated when wood treated with waterborne preservatives is processed at high temperatures either before, during, or after treatment (WINANDY 1995; WINANDY 1996). The effects of re-drying on the mechanical properties of treated wood have been studied by many researchers (WINANDY et al 1989; WINANDY 1989, 1994, 1995, 1995; WINANDY/LEBOW 1997). WINANDY et al (1992) found that tensile strength was not significantly affected by initial kiln-drying temperature but it was reduced when CCA-treatment was followed by high temperature re-drying. In addition, no significant changes in MOE, modulus of rupture (MOR), or work to maximum load (WML) were attributable to any re-drying schedule (74 and 60°C as maximum dry-bulb temperatures) and it was concluded that drying wood in a high-RH environment could result in an accelerated strength loss in wood if this environment is too severe and for too long (BOONE et al 1995). WINANDY et al (1985) found that in southern pine wood treated to CCA retentions of up to 16 kg/m^3 and dried at temperatures of <60°C, neither MOE and MOR, nor WML were affected, but in the wood dried at temperatures of >80°C, MOE was not affected, MOR and WML were reduced 11% and 37%, respectively.

In general, CCA-C wood preservative has been used to investigate the effects of accelerated fixation processes on the leaching characteristics, biological performance, and mechanical properties of treated wood by many researchers. The objective of this study was to examine the effects of the fixation processes on the leachability of CCA Type II and CCB (Triolith CB) preservative components, which are currently the predominant wood preservatives for many applications in Turkey, biological effectiveness against brown and white rot fungi, and some mechanical properties of treated wood (*P. sylvestris* L.).

2. MATERIALS AND METHODS

2.1 Leachability of CCA and CCB elements

Scots pine (*Pinus sylvestris* L.) trees were harvested from Duzce (Bolu, Turkey) for the research. Boards were cut immediately from sapwood portions of the trees to prevent attacks of bluestain fungi. The boards were allowed to dry under conditions at 20±2°C and 65±5% relative humidity (RH). Sapwood blocks (19 mm) were cut from the boards according to AWPA E10-91 standard method (AWPA 1997) and all blocks were conditioned to 12% MC at 20±2°C and 65±5% RH. For treatments, 1.0% CCA Type II ($CuSO_4$, $K_2Cr_2O_7$, and As_2O_5) and CCB ($CuSO_4$, $K_2Cr_2O_7$, and H_3BO_3) (Triolith CB) solutions were used. The blocks were treated in a desiccator with 1.0% solutions at 100 mm Hg of vacuum subjecting to AWPA E10-91 standard method (AWPA 1997). Then the blocks treated were weighed and immediately wiped with a damp cloth. In order to obtain the desired wood moisture contents (MCs), the blocks were subjected to each of the modified fixation procedures used by KALDAS and COOPER (1996), and CONRADIE and PIZZI (1987) before (Table 1, Table 2, and Table 3). In the first group of fixation conditions (Table 1), the blocks were conditioned over saturated salt solutions ($CuSO_4$, KBr, $NaHSO_4$, and $CaCl_2$ for 25, 20, 13, and 7% wood MCs, respectively) and in a conditioning room to obtain the desired wood equilibrium MCs (EMC). After the fixation times in the post-treatments conditions were achieved, two replicate samples of six blocks for each fixation condition were subjected to AWPA E11-97 standard leaching test (AWPA 1997). The leachates collected from the 2-week leaching cycle were analyzed for chromium, copper, and arsenic with a Perkin Elmer 5100 PC atomic absorption spectrometer (AAS) using flame atomization for higher concentrations of the elements and graphite furnace atomization for lower concentrations. The percentage of elemantal losses was calculated using the cumulative amount (μg) of each element in the leachate and total amount added to the blocks during preservative treatment, based on preservative solution uptake.

2.2 Fungal resistance of treated wood

In order to investigate the effects of the post-treatment conditions used on the biological performance of CCA and CCB-treated wood against decay fungi, the soil-block test was carried out according to AWPA E10-91 (AWPA 1997). In the tests, brown rot fungi *Gloeophyllum trabeum* (Pers. ex Fr.) (Madison 617-R), and *Postia placenta* (Fries) M.Larsen et Lombard (Madison-698) and white rot fungus *Coriolus versicolor* (L.) Quel. (CTB 863 A IH) were used. Twelve replicate samples (unleached and leached) of each fixation process were conditioned, steam-sterilized, weighed, and expozed to test fungi. The duration of the test was selected 12 weeks for the brown rot fungi and 16 weeks for the white rot fungus to achieve reasonable weight losses. After exposure to test fungi at 27°C and 70% RH, the surface fungus mycelium was removed, the samples re-conditioned, and weight losses were calculated from the conditioned weights of the blocks immediately before and after testing.

2.3 Mechanical properties of treated wood

In investigation of the influence of elevated temperatures during fixation cycles, only CCA-treated wood was used. Scots pine specimens (20x20x350 mm) for the bending strength and MOE, and (20x20x300 mm) for the impact bending were cut from the sapwood portions of the boards. The specimens were treated with 1.0% CCA solution using a modified full-cell treatment process at 600 mm Hg of vacuum (30 minutes), 8 kp/cm^2 of pressure (60 minutes), and 600 mm Hg of final vacuum (15 minutes). After preservative treatment, the specimens were either air-dried at 20±2°C and 65±5% RH for 720 hours or kiln-dried at 70±2°C in an oven for 72 hours. Then, all specimens were stored at 20±2°C and 65±5% RH until being achieved constant weights in the specimens prior to mechanical tests. All mechanical tests were carried out according to the Turkish Standards (TSE 1976).

3. RESULTS AND DISCUSSION

3.1 Leachability of CCA and CCB elements

The blocks treated with 1.0% CCA and CCB solutions and subjected to the AWPA leaching test had average 6.8–7.9 kg/m^3 and 6.9–7.5 kg/m^3 for CCA and CCB, respectively.

The leaching results belonging to the post-treatment conditions-I show that at 20±2°C and low wood MCs during fixation processes, the leaching losses of all CCA components increased although in the CCB fixation course, leaching losses were less than those of CCA. At 20±2°C, the lowest leaching rate was obtained under the 65% RH and 12% MC fixation conditions for CCA. As losses in Process 1 and 2 (65% RH/12% MC) were highly lower than those of the other fixation conditions. For Cu losses, the lowest leaching rate was achieved in Process 1, 2 (65% RH/12% MC) and 5 (84% RH/20% MC) (Table 1). At 20±2°C, from 100% RH to 65% RH, elements losses reduced and then from that point element losses began to raise for CCA and CCB (for 14 day and 20 day fixation courses). Figure 1 shows that the relationship between realtive humidty and percentage of leached elements from CCA-treated samples. It is clear that after 65% RH, percentages of leached of Cr, Cr, and As elements were increased due to lack of moisture in wood. This means that at a specific temperature, permenance of preservative elements are also affected at a specific RH.

The percentages of leached Cr, Cu, and As elements belonging to the post-treatment conditions-II are shown in Table 2. Compared to the leaching results which belong to the post-treatment conditions-I for CCA, As losses were higher than the other elements as the leaching losses in the post-treatment conditions-I. It is clear that CCA and CCB preservatives have showed similar effects on the amount of Cr leached at temperatures of 20, 50, 60, 80, and 120°C. In Figure 2 and 3, the relationship between the temperature applied and total amount of Cr from CCA and CCB-treated samples is illustrated for both direct oven and air- dry/oven-dry treatments, respectively. For both CCA and CCB preservatives, in the air-drying/oven-drying processes, element losses were generally less than those in the direct oven drying processes. In addition, in both processes, after 80°C, almost all element losses of CCA and CCB preservatives began rising.

Table 3 shows leaching results obtained from steam fixation courses (post-treatment conditions-III). Compared to post-treatment conditions-I and II, in general, Cr and Cu losses were less. For Cr, the lowest leaching rate was achieved in Process 23 (steaming at 80±2°C for 60 minutes and oven drying at 60±2°C for 48 hours) for CCA, and in Process 22 (steaming at 80±2°C for 90 minutes and oven drying at 60±2°C for 48 hours) for CCB.

3.2 Fungal resistance of treated wood

Table 4 shows that the weight losses of the unleached and leached blocks treated with CCA due to soil-block test using test fungi *G.treabeum, P.placenta, and C.versicolor*. In the untreated control blocks, the weight losses were 61.80%, 69.50%, and 38.60% for *G.trabeum, P.placenta, and C.versicolor*, respectively. The lowest weight losses were obtained in Process 13, 15, 22, and 24, Process 15, and 22, and Process 12, 13, 20, 21, 22, and 23 for *G.trabeum, P.placenta, and C.versicolor*, respectively. Steaming without oven drying (Process 18, 19, 20, and 21) caused more weight losses in both unleached and leached blocks for *G.trabeum, and P.placenta*. Moreyer, in Process 16 and 17 (oven drying at 120±2°C for 48 hours, and air drying at 20±2°C for 48 hours followed by oven drying at 120±2°C for 48 hours), the highest weight losses achived for *G.trabeum*, and *P.placenta*. In general, the weight losses by *C.versicolor* were less than those by *G.trabeum*, and *P.placenta*.

The weight losses of the unleached and leached blocks treated with CCB due to soil-block test using *G.trabeum* and *C.versicolor* test fungi are shown in Table 5. Compared to the results belonging to CCA presevative, in CCB preservative less weight losses were achieved for *G.trabeum* *test* fungus.The lowest weight losses were obtained in Process 11 for *G.treabeum*, and in Process 13 for *C.versicolor*. In the CCA treated specimens, the weight losses increased after 80°C by *G.trabum* and *P.placenta*. For *C.versicolor*, the weight losses increased after 60°C. In the CCB treated specimens, the weight losses increased after 100°C both fungi used.

Figure 4 shows that the relationship between temperature and weight losses in CCA-treated samples. Increase in weight losses can be seen as the heat treatment temperature increases. There are several reasons for the effect of drying temperature on the biological performance of CCA-treated wood. Following three main effects can be presented: (a) conversion of the elements into easily soluble components, (b) conversion of the elements into biologically inactive components, and (c) movement of the reaction sites in wood components to which CCA is fixed (CONRADIE/PIZZI 1987).

3.3 Mechanical properties of treated wood

Table 6 shows bending strength, MOE, and impact bending values of the untreated (control), water-treated, and CCA-treated specimens, and retention levels of the specimens treated with 1.0% CCA. No significant ($p<0.05$) difference was found between the mean properties of two red-drying temperatures for each treatment (control, water, and CCA 1.0%). In the specimens treated with 1.0% CCA and dried at 70±2°C, the bending strength, MOE, and impact bending were reduced about 1%, 7%, and 12%, respectively although these differences were statistically insignificant. This might be a result of that initial drying temperatures, re-drying temperatures, and duration of exposure were not severe.

4. CONCLUSIONS

At 20°C, the rate of leaching of the elements from the specimens increased significantly as the wood MC decreased during the fixation processes. CCB wood preservative showed better leaching rates compared to CCA. Also, it might be concluded that CCB-treated wood specimens require less fixation times. On the other hand, when compared to the other preservative components, As was the most leached element. This trend was obtained by KALDAS and COOPER (1996), COOPER, et al. (1997), and LEE et al. (1993) before. The most resistant element to the leaching course was Cr. The fixation at the temperatures of 100 and 120°C caused more significant element losses than those at 50, 60, and 80°C, especially As losses increased significantly. In addition, the best leaching rates were obtained by steaming and in general, the results from the specimens treated with CCA and CCB were very similar.

It was noted that there was no significant effect on the biological resistance among the fixation temperatures used despite the fact that the weight losses increased as the fixation temperature increased.

Since the initial drying temperature and subsequent re-drying temperature were not high, the mechanical properties were not significantly affected. The AWPA Subcommittee T-2 imposed in 1989 a limitation on post-treatment kiln-drying temperature of 88°C in Standard C-2 and in 1991, that limit was lowered to 74°C in Standards C-2 and C-22 (WINANDY 1995; AWPA 1997).

Table 1 : Percent elements leached from the blocks treated with CCA and CCB (Post-treatment conditions-I).*

Tablo 1 : CCA ve CCB ile emprenye edilen örneklerden elementlerin yıkanma miktarları (işlem şartları-I)

Process No / Proses No	Fixation Conditions / Fiksasyon Şartları: Temperature / Sıcaklık (°C)	Fixation Conditions / Fiksasyon Şartları: MC / Rutubet (%)	Fixation Time / Fiksasyon Süresi (days / gün)	CCA Retention / CCA Retensiyonu (kg/m³)	Percent Elemets Leached / Yıkanan Element Yüzdesi: Cr	Cu	As	CCB Retention / CCB Retensiyonu (kg/m³)	Percent Element Leached / Yıkanan Elemen Yüzdesi: Cr	Cu
1	20 ± 2	12	14	7,621	0,57	2,07	4,13	7,411	0	1,54
2	20 + 2	12	21	7,852	0,60	2,21	3,45	7,118	0	2,01
3	20 ± 2	Saturated Doygun Şart	2	7,118	7,89	12,97	26,24	7,227	0	0
			4	7,201	4,79	10,66	27,93	7,186	0,73	1,81
			8	7,735	3,05	3,58	9,55	7,046	0,75	0
			10	7,311	1,21	3,40	7,03	7,116	0	0
			14	7,584	0,77	3,13	6,00	7,187	0	3,07
4	20 ± 2	26	2	6,972	9,29	17,83	26,12	7,218	0,84	4,54
			4	7,222	7,79	12,50	17,47	6,989	0	3,76
			8	6,881	5,27	7,75	12,64	7,168	0	0
			10	7,103	2,14	4,58	8,95	7,000	0	0
			14	6,813	0,74	4,67	8,15	7,126	0	0
5	20 ± 2	20	2	7,172	5,88	7,00	21,36	7,169	0,75	1,79
			4	7,399	2,48	3,10	10,49	7,285	0,83	1,40
			8	7,543	2,05	2,81	9,30	7,268	0	0
			10	7,352	1,21	2,41	8,86	7,190	0	0
			14	7,525	0,61	2,43	6,79	6,996	0	0
6	20 ± 2	14	20	6,897	3,44	11,19	18,67	7,230	0,81	4,86
			40	7,260	1,62	10,06	17,46	7,200	0,72	3,55
			60	7,021	1,56	9,35	13,83	7,186	0	1,61
			85	7,341	1,51	7,76	12,01	6,979	0	0
7	20 ± 2	7	20	7,190	12,40	18,50	34,13	7,219	0,92	1,38
			40	7,059	10,05	17,28	28,79	7,000	1,06	1,42
			60	7,122	5,77	13,89	23,49	7,124	0	0
			80	6,892	5,29	3,00	18,00	7,300	0	0
			100	7,112	4,99	8,37	15,09	7,183	0	1,41

***Each value represents average value of two replicate samples of six blocks.**

Her değer altı adet örnekten olşmuş iki yıkama grubunun ortalamasını gösterir.

Table 2 :Percent elements leached from the blocks treated CCA and CCB (Post-treatment conditions-II).*

Tablo 2 : CCA ve CCB ile emprenye edilen örneklerden elementlerin yıkanma miktarları (işlem şartları-II).

Process No / Proses No	Fixation Conditions / Fiksasyon Şartları	CCA Retention (kg/m^3) / CCA Retensiyonu (kg/m^3)	Percent Elements Leached / Yıkanan Element Yüzdesi			CCB Retention (kg/m^3) / CCB Retensiyonu (kg/m^3)	Percent Elements Leached / Yıkanan Element Yüzdesi	
			Cr	Cu	As		Cr	Cu
8	Oven drying at 50 ± 2 C for 72 hours 72 saat 50 ± 2 C de kurulma	7,337	1,53	4,49	12,63	7,289	1,46	5,63
9	Air drying at 20 ± 2 C for 48 hours followed by Oven drying at 50 ± 2 C for 72 hours 48 saat 20 ± 2 C ve 72 saat 50 ± 2 C de kurutma	7,298	1,01	3,37	9,23	7,310	1,20	4,21
10	Oven drying at 60 ± 2 C for 72 hours 72 saat 60 ± 2 C de kurutma	6,967	1,46	5,00	10,33	7,112	1,34	4,16
11	Air drying at 20 ± 2 C for 48 hours followed by Oven drying at 60 ± 2 C for 72 hours 48 saat 20 ± 2 C ve 72 saat 60 ± 2 C de kurutma	7,116	1,15	3,68	11,55	7,216	1,15	3,59
12	Oven drying at 80 ± 2 C for 72 hours 72 saat 80 ± 2 C de kurutma	6,992	1,66	9,37	16,04	7,128	1,54	7,15
13	Air drying at 20 ± 2 C for 48 hours followed by Oven drying at 80 ± 2 C for 72 hours 48 saat 20 ± 2 C ve 72 saat 80 ± 2 C de kurutma	7,398	1,34	5,75	15,99	6,896	1,59	5,93
14	Oven drying at 100 ± 2 C for 48 hours 48 saat 100 ± 2 C de kurutma	7,174	5,63	16,56	14,96	7,125	5,46	12,63
15	Air drying at 20 ± 2 C for 48 hours followed by Oven drying at 100 ± 2 C for 48 hours 48 saat 20 ± 2 C ve 48 saat 100 ± 2 C de kurutma	7,366	3,83	11,88	19,89	7,122	4,72	15,94
16	Oven drying at 120 ± 2 C for 48 hours 48 saat 120 ± 2 C de kurutma	7,344	8,34	16,19	23,82	7,109	9,28	9,33
17	Air drying at 20 ± 2 C for 48 hours followed by Oven drying at 120 ± 2 C for 48 hours 48 saat 20 ± 2 C ve 48 saat 120 ± 2 C de kurutma	7,580	5,83	1,72	28,76	6,910	7,16	4,80

***Each value represents average value of two replicate samples of six blocks.**

Her değer altı adet örnekten olşmuş iki yıkama grubunun ortalamasını gösterir.

Table 3 :Percent elements lecahed from the blocks treated CCA and CCB (Post-treatment conditions-III).*

Tablo 3 : CCA ve CCB ile emprenye edilen örneklerden elementlerin yıkanma miktarları (işlem şartları-III).

Process No	Fixation Conditions	CCA Retention (kg/m³)	Percent Elements Leached		CCB Retention (kg/m³)	Percent Elements Leached	
			Cr	Cu		Cr	Cu
Proses No	Fiksasyon Şartları	CCA Retensiyonu (kg/m³)	Yıkanan Element Yüzdesi		CCB Retensiyonu (kg/m³)	Yıkanan Element Yüzdesi	
			Cr	Cu		Cr	Cu
18	**Steaming at 80 ± 2 C for 90 minutes** 90 dakika 80 + 2 C de buharlama	7,426	0,92	3,70	7,300	0,81	3,13
19	**Steaming at 80 ± 2 C for 60 minutes** 60 dakika 80 + 2 C de buharlama	7,770	0,95	4,73	7,218	0,82	3,52
20	**Steaming at 80 ± 2 C for 30 minutes** 30 dakika 80 + 2 C de buharlama	7,600	0,77	4,78	7,116	0,74	3,59
21	**Steaming at 80 ± 2 C for 15 minutes** 15 dakika 80 + 2 C de buharlama	7,360	0,79	4,92	7,128	0,74	3,55
22	**Steaming at 80 ± 2 C for 90 minutes and Oven drying at 60 ± 2 C for 48 hours** 90 dakika 80 ± 2 C de buharlama ve 48 saat 60 + 2 C de kurutma	7,861	0,69	3,58	7,000	0	5,95
23	**Steaming at 80 ± 2 C for 60 minutes and Oven drying at 60 ± 2 C for 48 hours** 60 dakika 80 ± 2 C de buharlama ve 48 saat 60 + 2 C de kurutma	7,417	0,75	3,75	7,100	0,74	6,31
24	**Steaming at 80 ± 2 C for 30 minutes and Oven drying at 60 ± 2 C for 48 hours** 30 dakika 80 ± 2 C de buharlama ve 48 saat 60 + 2 C de kurutma	7,410	0,94	3,65	7,486	0,89	6,02

***Each value represents average value of two replicate samples of six blocks.**

Her değer altı adet örnekten olşmuş iki yıkama grubunun ortalamasını gösterir.

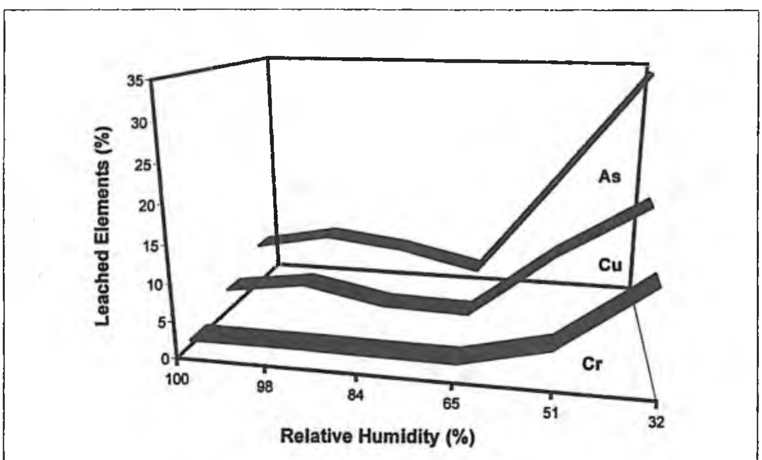

Figure 1 :Relationship between relative humidty and percentage leached elements from CCA-treated samples.

Şekil 1 : CCA ile emprenye edilen örneklerden yıkanan element yüzdeleri ve ortam bağıl nemi arasındaki ilişki.

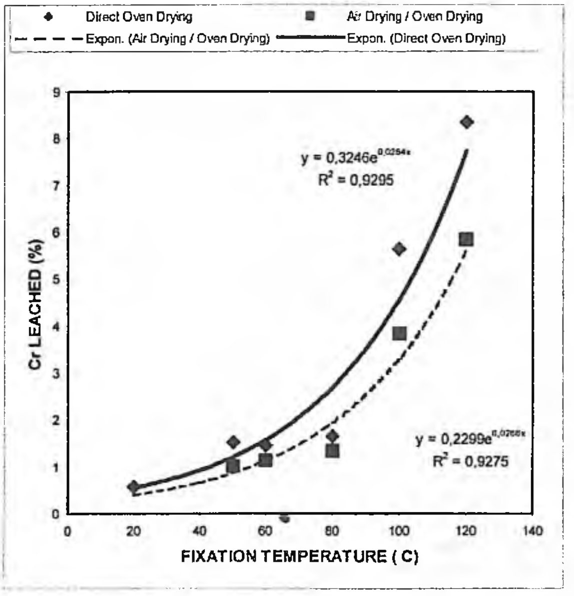

Figure 2 :The relationship between drying temperature and percent Cr leached in CCA treatment.
Şekil 2 : CCA ile işlemlerde kurutma sıcaklığı ve yıkanan Cr yüzdesi arasındaki ilişki.

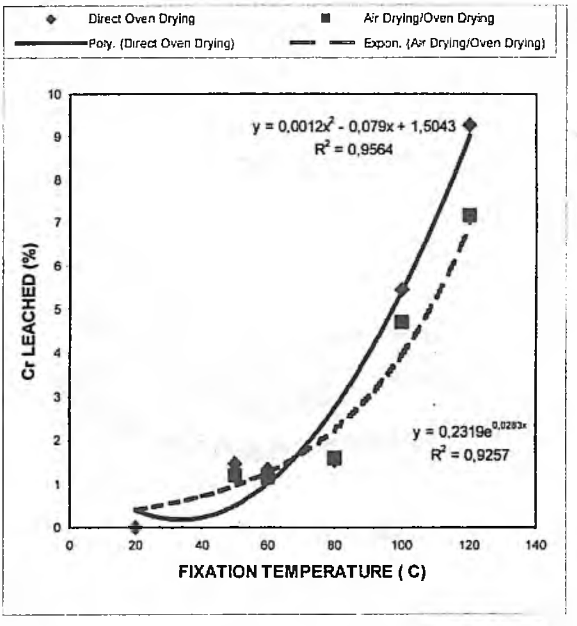

Figure 3 :The relationship between drying temperature and percent Cr leached in CCB treatment.
Şekil 3 : CCB ile işlemlerde kurutma sıcaklığı ve yıkanan Cr yüzdesi arasındaki ilişki.

Table 4 :Weight losses of the leached and unleached blocks treated with CCA.
Tablo 4 : CCA ile emprenye edilen yıkanmış ve yıkanmamış örneklerde ağırlık kayıpları.

Process No / Proses No	Fixation Conditions* / Fiksasyon Şartları	Retention (kg/m^3) / Retensiyon (kg/m^3)		Weight Losses (%) / Ağırlık Kayıpları (%)					
				G.trabeum		*P.placenta*		*C.versicolor*	
		I	II	I	II	I	II	I	II
-	CONTROL SAMPLES KONTROL ÖRNEKLERİ	-	-	61,80	60,00	69,50	68,70	38,60	35,80
2		7,418	7,852	1,80	2,90	2,00	3,20	1,20	1,60
8		7,364	7,337	2,60	3,40	2,80	3,20	0,80	1,00
9		7,563	7,298	1,70	2,00	1,80	2,80	0,60	1,00
10		7,648	6,967	1,80	3,00	1,50	2,70	0,40	1,10
11		7,389	7,116	1,00	2,70	1,30	3,00	0,60	1,20
12		5,545	6,992	2,20	3,30	2,00	2,50	0	0,90
13		7,680	7,398	0,80	2,40	1,30	2,00	0	0,50
14		7,511	7,174	2,00	3,80	2,50	4,60	1,20	2,80
15		7,300	7,366	0,70	3,00	1,00	3,80	2,60	2,00
16		7,589	7,344	3,10	5,70	3,80	5,90	2,50	3,10
17		7,403	7,580	3,00	4,20	3,60	5,00	2,30	3,10
18		7,509	7,426	4,80	5,60	5,20	6,80	1,00	1,80
19		7,700	7,770	4,00	5,10	4,30	5,70	0,70	1,80
20		7,540	7,600	2,00	2,70	2,50	2,90	0	1,30
21		7,300	7,360	1,30	2,00	2,00	3,00	0	0,70
22		7,785	7,861	0,80	1,20	1,20	1,80	0	0,80
23		7,530	7,417	0,80	1,00	2,10	2,30	0	0
24		7,500	7,410	1,20	2,20	2,30	3,10	1,10	1,80

For fixation conditions, refer to Table 1-3.

Fiksasyon şartları için Tablo 1-3 e bakınız.

I: Unleached, II: Leached samples.

I: Yıkanmamış, II: Yıkanmış örnekler.

Each value represents the mean value of two replicate samples of four blocks.

Her değer, dört örnekten oluşan iki test grubunun ortalamasını gösterir.

Table 5 :Weight losses of the leached and unleached blocks treated with CCB.
Tablo 5 : CCB ile emprenye edilen yıkanmış ve yıkanmamış örneklerde ağırlık kayıpları.

Process No / Proses No	Fixation Conditions* / Fiksasyon Şartları	Retention (kg/m³) / Retensiyon (kg/m³) I	II	Weight Losses (%) / Ağırlık Kayıpları (%) G.trabeum I	G.trabeum II	C.versicolor I	C.versicolor II
	CONTROL SAMPLES KONTROL ÖRNEKLERİ	-	-	61,80	60,00	38,60	35,80
2		6.888	7.118	1.30	2.50	0.70	1.30
8		7,114	7,289	2,00	3,00	1,20	1,80
9		7.000	7.310	1.90	2.40	0.80	1.00
10		7,120	7,112	1,80	2,50	1,00	1,70
11		7.105	7.216	0.80	1.70	0	1.00
12		7,108	7,128	1,50	2,10	0,5	1,10
13		7.298	6.896	1.00	2.00	0	0.80
14		7,103	7,125	1,30	2,30	0,90	2,00
15		7.300	7.122	3.10	4.40	2.00	3.20
16		6,954	7,109	3,80	5,00	2,50	3,20
17		7.105	6.910	3.00	4.50	2.50	3.00

*** For fixation conditions, refer to Table 1-3.**
Fiksasyon şartları için Tablo 1-3 e bakınız.
I: Unleached, II: Leached samples.
I: Yıkanmamış, II: Yıkanmış örnekler.
Each value represents the mean value of two replicate samples of four blocks.
Her değer, dört örnekten oluşan iki test grubunun ortalamasını gösterir.

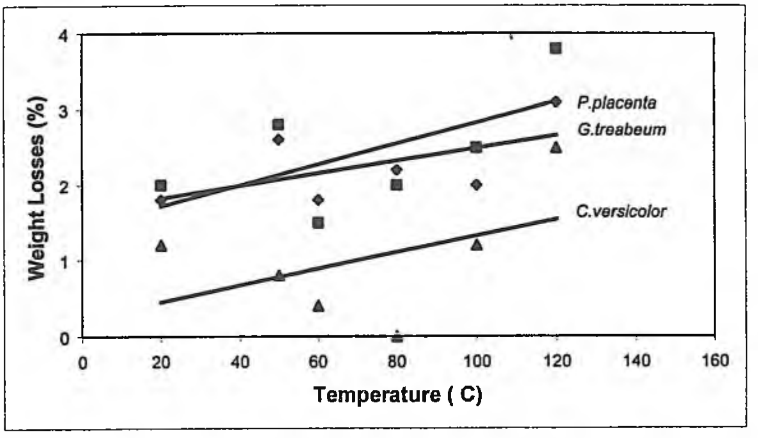

Figure 4 :Relationship bewteen temperature and weight losses in CCA-treated samples after soil-block tests.
Şekil 4 : CCA ile emprenye edilen örneklerde ağırlık kayıpları ve ortam sıcaklığı arasındaki ilişki.

Table 6 : Mechanical properties of untreated, water-treated, and CCA-treated specimens.

Tablo 6 : Kontrol, su ve CCA ile emprenye edilen ve tekrar kurutma işlemi uygulanan örneklerde mekanik özellikler.

Initial Drying Temp °C / Başlangıç Kurutma Sıcaklığı °C	Treatment / İşlem	Redrying Temp. °C / Tekrar Kurutma Sıcaklığı °C	Duration Of Exposure (hours) / Kurutma Süresi (saat)	Moisture Content (%) / Rutubet Miktarı (%)	Bending Strength (N/mm²) / Egilme Direnci (N/mm²) Mean / Ortalama	SD / std sapma	Ratio* / Oran	Density (g/cm³) / Yoğunluk (g/cm³)	MOE (N/mm²) / Elastikiyet Modülü (N/mm²) Mean / Ortalama	SD / std sapma	Ratio* / Oran	Density (g/cm³) / Yoğunluk (g/cm³)	Impact Bending (Nm/cm²) / Şok Direnci (N/mm²) Mean / Ortalama	SD / std sapma	Ratio* / Oran	Density (g/cm³) / Yoğunluk (g/cm³)
20 ± 2	Control Kontrol	20 ± 2	720	12	66,878	3,53	1,00	0,538	10302,168	716,91	1,00	0,538	6,18	2,96	1,00	0,539
20 + 2		70 + 2	72	12	64,977	3,60	0,97	0,534	10168,457	731,46	0,99	0,534	6,28	3,38	1,02	0,540
20 ± 2	Water Su	20 ± 2	720	12	66,918	4,57	1,00	0,535	10522,108	774,57	1,02	0,535	5,79	3,41	0,94	0,538
20 + 2		70 + 2	72	12	65,936	4,06	0,99	0,535	10148,739	698,99	0,99	0,535	5,49	4,47	0,89	0,537
20 ± 2	CCA %1 %1 CCA	20 ± 2	720	12	67,142	4,44	1,00	0,539	10658,957	829,16	1,03	0,539	5,89	4,04	0,95	0,541
20 + 2		70 + 2	72	12	66,567	3,60	1,00	0,541	9961,761	895,20	0,97	0,541	5,20	3,49	0,84	0,543

*** Ratio of observed post-exposure value to control, 20 ± 2 °C initially air-dried control value.**

Elde edilen değerin kontrol örneğindeki değere oram.

°F = °C * 1.8 + 32

1 N/mm² = 1.02 kp/cm², 1 kp/cm² = 98066.5 Pa = 14.223 psi, 6.894x103 Pa = 1 psi

SD = Standard deviation

SD=Standard sapma

Each value represents the average of 30 samples.

Her değer 30 örneğin ortalamasını gösterir.

CCA VE CCB EMPRENYE MADDELERİ İLE KORUNAN AĞAÇ MALZEMENİN YIKANMA, DAYANIKLILIK VE DİRENÇ ÖZELLİKLERİ

Ar.Gör.Dr. S. Nami KARTAL

Kısa Özet

Bu araştırmada, fiksasyon işlemlerinin CCA ve CCB emprenye edilen sarıçam diri odunundan yıkanan element miktarları, mantarlara karşı dayanıklılık ve bazı mekanik özellikler üzerine etkileri belirlenmiştir. Çalışmada 20°C'den 120°C ve %0 bağıl nemden %100 bağıl neme kadar değişik kurutma ve buharlama metodları ile Cu, Cr ve As elementlerinin ağaç malzemeye fiksasyonu temin edilmiş ve standard yıkanma testleri ile yıkanma miktarları belirlenmiştir. 20°C'de ve yüksek bağıl nem ortamlarında ve buharlama ile CCA ile emprenye edilen örneklerden elementlerin yıkanma miktarları büyük oranda azaldığı ve CCB emprenye maddesi ile emprenye edilen örneklerde genel olarak yıkanma değerlerinin CCA ile karşılaştırıldığında daha düşük olduğu belirlenmiştir. CCA ile emprenye edilen ve yüksek sıcaklıklarda fiksasyon işlemleri uygulanan örneklerde mantarlara karşı etkinlikte azalamalar belirlenmiştir. 70°C'de tekrar kurutma işlemlerinin mekanik özellikler üzerine önemli etkiler yaapmadığı tespit edilmiştir.

1. GİRİŞ

Bu çalışmada, CCA ve CCB emprenye maddeleri ile emprenye edilmiş saıçam (*Pinus sylvestris* L.) odununda fiksasyon ve tekrar kurutma işlemlerinin, emprenye maddelerinin oluşturan Cr, Cu ve As elementlerinin yıkanmaya karşı dirençlerine, odunun mantarlara karşı dayanıklılığına ve mekanik özellikleri üzerine etkileri araştırılmıştır.

Araştırma konusu olan sarıçam örnekleri Düzce Orman İşletme Müdürlüğü'nden alınan ağaçlardan elde edilmiştir. Çalışmada emprenye işlemlerinde %1 konsantrasyonda hazırlanan tuz esaslı CCA Tip-II ve CCB (Triolith CB) emprenye maddeleri kullanılmıştır.

Emprenye maddelerinin yıkanma ve fiksasyon özelliklerinin belirlenmesi AWPA E11-87 ve E10-91 standardlarına göre gerçekleştirilmiştir. Denemelerde 19x19x19 mm boyutlarında hazırlanan örnekler kullanılmış ve emprenye edilen bu örneklere çeşitli fiksasyon işlemleri uygulanmıştır. Bu fiksasyon işlemleri değişik sıcaklık ve bağıl nem şartlarına sahip ortamlarda gerçekleştirilerek, uygulanan sıcaklık derecelerinin elementlerin odundan yıkanma hızlarını ne şekilde etkilediği araştırışmıştır.

CCA ve CCB emprenye maddeleri ile emprenye edilmiş ağaç malzemeye uygulanan çeşitli fiksasyon işlemlerinin malzemenin dayanıklılık özellikleri üzerine etkilerinin belirlenmesi, AWPA E10-91 standardından yararlanılarak, "soil-block" test yöntemiyle gerçekleştirilmiştir. 12 ve 16 hafta olarak belirlenen test sürelerinin sonunda, kontrol örenkleri, emprenye edilmiş, yıkanmış ve yıkanmamış örneklerde *G.trabeum*, *P.placenta* ve *C.versicolor* test mantarlarının degradasyonu sonucu oluşan ağırlık kayıpları belirlenmiştir.

CCA emprenye maddesi ile emprenye ve tekrar kurutma işlemlerinin ağaç malzemenin direnç özellikleri üzerine etkilerinin belirlenmesinde, %1 CCA çözeltisi ile emprenye edilen örnekler kullanılmıştır. Emprenye işlemlerinde dolu hücre metodu kullanılarak, örneklerde 9.6 kg/m^3'lük emprenye maddesi retensiyonu hedeflenmiştir. Örneklere daha sonra 20 ve 70°C (72 saat) sıcaklıklarda tekrar kurutma işlemleri uygulanmıştır. Örneklerin eğilme direnci, elastikiyet modülü ve dinamik eğilme direnci değerleri bulunarak, gerek emprenye maddesinin, gerekse 70°C sıcaklıkta yapılan tekrar kurutma işlemlerinin etkileri belirlenmiştir.

Uygulanan çeşitli fiksasyon işlemleri sonucunda CCA ve CCB çözeltileri ile emprenye edilen örneklerden, artan fiksasyon sıcaklığı ve yüksek odun rutubetlerinde yıkanan element kayıplarında azalmalar olduğu ve buharlama ile fiksasyon metodlarında yıkanma miktarlarının belirgin olarak düştüğü her iki emprenye maddesi için belirlenmiştir. Ayrıca, CCB ile emprenye edilen ve 20°C sıcaklıkta ve %32 ile %100 bağıl nem ortamlarında yapılan fiksasyon işlemlerinde CCA ile emprenye edilen örneklere karşılık daha düşük yıkanma miktarları elde edilmiş ve daha kısa fiksasyon süreleri saptanmıştır.

Genel olarak, CCA çözeltisi ile emprenye edilen örneklere uygulanan fiksasyon işlemlerinde sıcaklık artışı ile birlikte her 3 test mantarına karşı elde edilen ağırlık kayıplarında artışlar belirlenmiş ve bu durum CCB emprenye maddesi için *G.trabeum* 'da elde edilen ağırlık kayıplarında da gözlenmiştir. Bununla birlikte, yüksek sıcaklık uygulamalarından önce yapılan 20°C sıcaklıkta bekletmenin ağırlık kayıplarını azaltabileceği sonucuna varılmıştır. Ayrıca, CCA ile olan işlemlerde, buharlama sürelerinin 90 dakikadan daha aşağılara düşürülüşü ve 80°C sıcaklıkta buharlama işlemlerinden sonra 60°C sıcaklıkta 48saat süreyle yapılan kurutma işlemleri ile ağırlık kayıplarında azalmalar olduğu tespit edilmiştir.

CCA çözeltisi ile emprenye işlemlerinden sonra 70°C sıcaklıkta 72 saat süreyle yapılan tekrar kurutma işlemlerinin genel olarak ağaç malzemenin mekanik özelliklerinde değişiklikler yapmadığı belirlenmiş olmasına rağmen, eğilme direnci için 20 ve 70°C sıcaklıkta fiksasyon işlemi uygulanan kontrol örneklerindeki farklılıkların istatistik bakımdan %5 güven düzeyinde anlamlı olduğu bulunmuştur. Yine eğilmede elastikiyet modülü değerleri için, %1 CCA çözeltisi ile emprenye edilen ve 20 ve 70°C sıcaklıklarda tekrar kurutma işlemleri uygulanan örneklerdeki farklılıkların istatistik bakımdan %1 güve düzeyinde anlamlı olduğu belirlenmiştir.

Fiksasyon reaksiyonları iyonik reaksiyonlar olup, fiksasyon işlemleri esnasında ortamdaki sıcaklık, bağıl nem ve ağaç malzemenin rutubeti bu reaksiyonları olumlu ya da olumsuz yönde etkileyebilmektedir. Fiksasyon işlemlerinde ortamın bağıl nemi düşük olduğunda, ortam havasının ısı kapasitesi de düşmekte ve ağaç malzemeye ısı taşınım hızı da azalmaktadır. Ortamın bağıl neminin düşük olduğu fiksasyon işlemlerinde ağaç malzeme yüzeyine ulaşan termal enerji odun yüzeyindeki suyun buharlaşmasında tüketilmekte ve malzemenin iç kısımlarına kadar ulaşmamakta ve fiksasyon reaksiyonlarını hızlandıracak şekilde sıcaklığı yükseltememektedir. Suda çözünen emprenye maddelerinin fiksasyon reaksiyonları üzerine yapılan çok sayıda araştırmaya göre, kuru termometre sıcaklık derecesi 55°C ve bağıl nem %95 olduğu takdirde ağaç malzemede fiksasyon reaksiyonlarının tamamlanması için 16-30 saate gereksinim varken, bağıl nem %67'e düştüğünde 30, %50'ye düştüğünde ise 48 saatten fazla bir süreye gereksinim duyulmaktadır. Genel olarak hızlı ve yüksek kaliteli fiksasyonu garanti etmek için fiksasyonun yüksek bağıl nem ortamlarında yapılması önerilebilir. Zaman açısından kısıtlamaların olmadığı durumlarda, oda sıcaklığında %65 bağıl nemde 14 veya 21 gün bekleme tercih edilebilir. Fakat hızlandırılmış bir fiksasyon işlemi istendiğine, 50-60°C sıcaklıklarda ve %65'in üstündeki bağılnem ortamlarında yapılan kurutma işlemleri uygun fiksasyon metodları olarak belirtilebilir. Bununla birlikte, ortamda yüksek oranda bağıl nemin ve sıcaklığın garanti edilmesi bakımından buharlama işlemleri de önemli fiksasyon metodlarıdır. Suda çözünen tuzlarla 16 kg/m^3'lük retensiyon miktarlarından daha düşük seviyelerde emprenye işlemlerinden sonra açık havada kurutmanın ağaç malzemenin mekanik özelliklerinde çok az bir etkiye neden olabilmektedir. Krom içeren emprenye maddelerinin ve takra kurutma işlemlerinin etkisi özellikle çok yüksek kutu termometre sıcaklıklarında ortaya çıkabilmektedir. 1989 yılında AWPA T2 alt komitesi tarafından, suda çözünen emprenye maddeleri ile emprenye edilmiş ağaç malzemenin tekrar kurutma işlemlerinde 88°C üst limit olarak kabul edilmiş,1991 yılında ise bu limit AWPA C-2 ve C22 standardlarında 74°C sıcaklığa düşürülmüştür.

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