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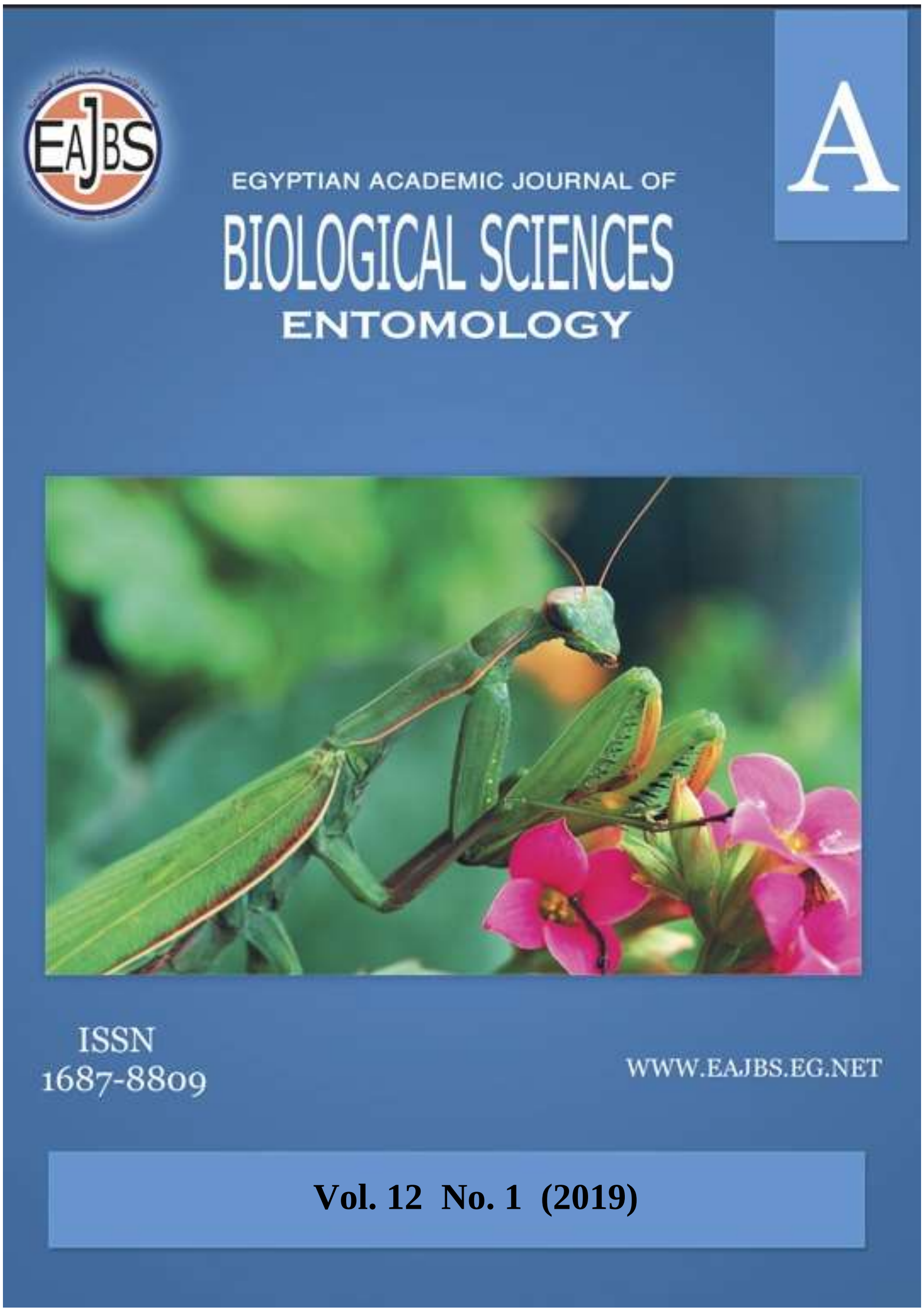

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Determining Efficacy and Persistence of the Wood Preservative Copper Chrome Arsenate Type C against The Wood Destroying Insects and Treated Wood Durability

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ABSTRACT

The wood preservative Copper chrome arsenate (CCA type C) is one of the most common wood preservatives in the world, its effectiveness depends on performance, leach resistance, depth of penetration and persistence within treated wood tissue. The persistence of the preservative copper chrome arsenate type C within four species of treated wood using full-cell pressure technique (double vacuum and pressure) and fixation of the preservative at 45˚C and 75% R.H was investigated. Bioassay tests were carried out to evaluate the performance of CCA-C treated wood against biological destruction and wood borers infestation using the powder post beetles *Lyctus africanus* (Lyctidae: Coleoptera). The treated wood samples at a concentration of 3% showed high resistance and durability against *L. africanus* attack through a period of four years, also the treated wood exposed to leaching process for two weeks showed resistance to *L. africanus,* which confirms the successful fixation of the CCA within the wood tissue and was not affected by leaching process. For all the tested treated wood species, the samples were free of *L. africanus* attack and no exit holes were recorded. It was found that, despite the cutting off treated wood blocks and exposing the internal parts (cross-section) of the wood to the beetles to lay eggs, wood is still resistant to beetles' infestation, which confirms the deepening of the preservative into treated wood, also the penetration depth of the preservative (CCA) inside the wood tissue was measured using Ferro-Cyanide Potassium as a copper reagent. It was observed that, the internal tissue color (cross-section) of the treated wood has been changed to brown as a result of the penetration of copper into the treated wood. According to elemental analysis of the concentration of CCA components within treated wood after 48 months, very large differences among all wood species in retaining of elements were observed. Arsenic is clearly the least stable element in wood tissue. copper was the most affected element by leaching for all wood species. However, the residual CCA level was sufficient enough to prevent attacks and decay by *L. africanus*.), Consequently, the full-cell pressure technique with (vacuum 30 in Hg) and the positive pressure of (10 bar) can be considered successful to preserve hardwood species against wood borers attack and maximize the penetration depth of the preservative within wood tissue.

INTRODUCTION

One of the most common wood preservatives in the world is copper chrome arsenate (CCA) which belongs to waterborne preservatives group used to extend the lifetime of the wood due to protection from natural degradation by termites, wood-borers such as Lyctidae, Cerambycidae, Anobiidae, marine borer and decay by soft rot fungi and bacteria. (Connell *et al.,* 1990 & Eaton and Hale 1993). There are three different types of CCA preservative: Type A, B and C. The most common is type C which is composed of 34.0% As_2O_5, 47.5% CrO_3 and 18.5% CuO, (AWPA Standard 1997). Copper chrome arsenate (CCA) was registered for outdoor uses, such as telegraph poles, decking and fencing, landscaping and building structures. Timber treated with CCA was also used in residential, school and playground, etc. In the United States, type C is the most predominant in treating wood products where this type appears to offer the best combination of performance and leach resistance. Most generated data in the past for CCA leaching in service has been from formulations other than CCA–C. All of the components of CCA (arsenic, copper, and chromium) play important roles in preservation efficacy. Chromium fixes the other two elements to cellulose, lignin and other components of wood. The primary role of chromium in CCA fixation is a part of complex series of reactions driven by reduction the hexavalent chromium to trivalent state. These reactions result in the insolubilization (stability) of CCA components in the wood so that they resist leaching and provide lengthy service, even when the wood is placed in ground contact. The components of CCA react with one another and with wood by reactions termed "fixation". Copper and arsenic are important to the preservation efficacy of CCA because of their toxicity to fungi and insects. Copper is an excellent fungicide, and arsenic is especially effective against insects and helps to provide protection against some copper-tolerant fungi (Dahlgren and Hartford 1972, Bull 2001, Cooper and Mac Vicar 1995, Lebow 1996, Hingston *et al*. 2000& Kim *et al.* 2008).

One of the most important characteristics of CCA is its ability to fix within the wood and resist leaching, successful fixation will minimize leaching of metals from the wood (Anderson *et al*., 1991). Copper chrome arsenate leaves the wood surface relatively clean, paintable, and free from objectionable odor and can be combined with fire retardant chemicals (Tillot and Coggins 1981). In California, Chromated copper arsenate (CCA) has been used to treat lumber to extend the lifetime of CCA-treated wood (Nico *et al*., 2004). The CCA-C treated poles were evaluated visually for protection and it was found that poles became resistant to Florida environmental conditions for more than 50 years of exposure (Lena *et al*., 2006).

In this study, we used the Adults of the powder post beetle *Lyctus africanus* (Lyctidae: Coleoptera) to test (evaluate) the durability of treated wood with CCA-C 3%, as *L. africanus* is one of the most serious and destructive pests of timber and timber products, including furniture (Helal 1980). *L. africanus* causes severe damages to seasonal hard wood, wooden floors and furniture (Creffield 1996). Moussa 1977 mentioned that it attacks timber in building, furniture and stored timber. Research findings in Israel indicated that the main damage was to furniture made of plywood, door-frames and picture frames, approximately 95% of the infestation was caused by *L. africanus* and the remaining 5% by three other Lyctus species **(**Halperin and Geis 1999). The lyctid beetles determine their preferred hosts by vessel size of the host to oviposit their ovipositor, moisture content of wood and quantity of starch content (Peters *et al*., 2002). The vessel size of the sapwood is an important factor in host preference. The lyctidae beetles decide to oviposit their eggs depending on the vessel size, females taste wood and lay eggs in the starchy wood (Ito 1983). Also, the study by (Kartika and Yoshimura 2013) confirmed the importance of starch and sugar to attract adult females of *L*. *africanus* to lay their eggs on starchy sites. The main signs of an active infestation are small accumulations of fine powder below exit holes in infested wood. They also stated that true powder post beetles (*L. africanus*) only attack the sapwood of large-pored hardwoods such as oak, ash, hickory, myrtle, elm, maple and mahogany etc. (Batt 1989**)** surveyed *L. africanus* Lesne. from, Poinciana, peach, acacia, mulberry, sissoo, mango, fig, willow, oak and sesbania trees as well as bamboo and cotton stalks.

This study aims to evaluate the efficacy and persistence of CCA type C as a wood preservative by full-cell pressure technique (double vacuum and pressure) to prevent biological destruction by termite and wood borers. By using four hardwood species, namely; Poinciana, Acacia, Lebbeck and Sissoo, *Lyctus africanus* was used to test the resistance of these wood to decay.

MATERIALS AND METHODS

1. Mass Rearing of *L. africanus*:

Pure culture for the lyctid beetle *L. africanus* was reared on poinciana wood, beetles cannot digest cellulose and hemicellulose and attack the cell contents such as starch, sugars, and proteins therefore, Poinciana wood was cut through the cold months (from Dec. to Feb.) through the period of trees dormancy, where the wood was suitable to infestation as was stated by (Helal 1984).

2. The Structure of the Used Device in Full-Cell Pressure Treatment:

A new device was designed to carry out this treatment which consists of a cylinder of iron (50×35cm), the cover is joined with seven tight nails. One side of the device connects with two hoses with valves; one of them is connected to a vacuum pump and the other is connected to an air compressor. The device is supplied with a manometer to measure the pressure. The other side is supplied with heater thermostat to regulate temperature (Fig.1) (Ali 2013).

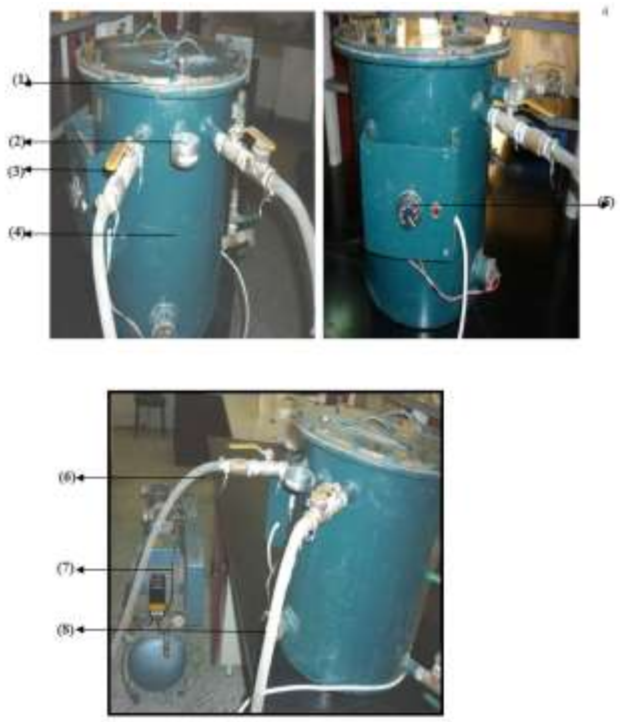

Fig. 1 (A, B& C): - The device used in the treatment of wood species by full-cell pressure technique double vacuum pressure.

(1) The cover is installed by gaskets (and seven nails tighten cover on device (2) Manometer to measure pressure /bar (3) Valve for closing and opening (4) Cylinder of iron (5) Heater thermostat to regulate the temperature. (6) The hose is connected to a compressor for pressure (7) Compressor for pressure (8) hose is connected with The pump for vacuum.

3. Full-cell Pressure Treatment Using CCA-C Preservative:

3.1 Wood and CCA-C Preparation:

(I)Four wood species: ***Acacia arabica***, ***Poinciana regia***, ***Albizia lebbeck*** and ***Dalbergia sissoo*** were selected and 30 blocks for each wood species from sapwood 20×40×80 mm were prepared (peeling, cutting and kiln drying at 105˚C for 24 hours).

(II) Copper Chrome Arsenate type-C preservative:34.0% As_2O_5, 47.5% CrO_3 and 18.5% CuO. was prepared as solution with 3% concentration in distilled water.

2.3.2. Method of treatment: Thirty blocks for each wood species were put in the cylinder; then initial vacuum was applied (30 in HG) using a vacuum pump to evacuate the air out of the cylinder and from the wood cells, this creates more space for preservative by avoiding back pressure and increase the overall pressure difference that helps to drive the preservative fluid into the timber Then, the cylinder is flooded with a liquid preservative hot to 75˚C under vacuum for 30 minutes, to ensure greater fixation (Hedley *et al.,* 1999). Then the positive pressure of 10 bar was applied using the compressor and held for 1.5 hours to force the liquid into the wood replacing the air. The pressure was then released and the remaining preservative was drained. `

3.3 Fixation. After treatment, each block was wrapped with plastic bag to fix the CCA components within wood tissue under fixation conditions (45˚C) and 95%R.H. for one week to resist leaching.

3.4. Leaching Test:

Leaching test is the most obvious method used to evaluate the progress of fixation. After fixation and dryness, each wood species blocks were divided into two groups; The first group (15 blocks for each wood species) was exposed to leaching test according to AWPA 1997 as follows :15 blocks were placed in 750 ml distilled water, the leachate water was removed and replaced with fresh distilled water after 6, 24, 48 and thereafter every 48-hour intervals, for total 14 days. The other group was left without leaching. Full-cell pressure treatment process, fixation and leaching test were carried out through the period from January to February 2015.

4. Laboratory Tests: Laboratory tests are faster than field tests and are often the first step in evaluating durability of wood products.

Testing the efficiency of the wood preservative CCA-C against wood-destroying insects *L. africanus.*

4.1. First: Bioassay Tests.

The most important parameter for judging the performance of a newly developed preservative system is the bioassay tests. Hence. The CCA-C protection period could be estimated by bioassay tests depending on the number of emerged beetles from treated wood exposed to beetles' attack and the period of CCA persistence against new infestation by borers compared to control.

(I). Persistence period of CCA-C against Lyctus beetles in treated wood, and efficacy of the preservative after exposure to leaching process: From each group (leached and un-leached), ten replicates for each wood species were placed each of them in a glass jar, exposed to ten couples of beetles *(L. africanus*) and covered with muslin cloth fixed by rubber bands. The glass jars were examined weekly for beetles' emergence (Progeny). This procedure was repeated three times every year through the period from 4/2015 to 8/2018 (artificial infestation was carried out three times a year throughout four years).

(II). Continuous exposure to beetles attacks (Exposing treated wood to frequent beetles attack): To allow beetles to survive on treated wood all the time, wood was exposed to successive attacks of beetles. From each group (leached and un-leached), four replicates for each wood species, each of which was placed in a glass jar and was exposed to 10 couples of beetles. Exposure to beetles was repeated weekly for three months (from 1/6/2017 to 31/8/2017). Observations were made for beetles' emergence and recorded.

(III). Evaluation of the penetration depth of the preservative CCA-C in wood based on bioassay tests: - The effectiveness of a wood preservative depends on several treatment factors, one of which is the depth of its penetration into the wood. Inadequate chemical penetration may allow insects to lay their eggs through cracks and pores in the thin shell of the treated wood in order to reach the internal. To evaluate the depth of penetration biologically; from each group (leached and un-leached), four replicates for each wood species, each of which has been divided into two equal parts in order to expose the internal parts (cross-sections) to the beetles' attack. Then, each two parts (cross-section) were exposed to ten couples of beetles in a jar. All jars were checked weekly to detect and count the number of exit holes. Depending on the number of exit holes (emerged beetles), we can determine if the preservative has penetrated the internal tissue or not. Wood exposure to beetles was carried out three times through the 2018 year. At the same time of each exposure, three untreated blocks (control) for each wood species were exposed to ten couples of beetles in glass jars as a control.

4.2. Second: Chemical methods

(I). Measuring the penetration depth of the preservative in wood tissue using a CCA reagent:

The depth of penetration was determined using Ferro cyanide potassium as a reagent for copper. For each wood species, three blocks each of which was cut into two equal parts. After that, the internal tissues (cross-sections) of each part were sprayed with Ferro cyanide potassium, then the color of the wood was observed. If the color changed to brown, (According to the following equation), this is a guide for the penetration of copper element into the wood, thus penetrating the CCA into the treated wood. This experiment was carried out after 48 months of treatment to determine the depth of penetration.

$$Cu\ So_4 + K_4[Fe(CN)_6] \longrightarrow \underset{\text{Brown precipitate}}{Cu_2\ [Fe(CN)_6]\downarrow} + 2K_2So_4$$

(II). Determination of CCA-C residues (Arsenic, Copper and Chromium) in treated wood:

Samples of treated wood were prepared by using three blocks for each wood species, after 48 months of treatment. Three samples(replicates) were prepared. Each Sample was ground and mixed well. This process was repeated twice for the two groups (leached and un-leached wood). The residual of copper, arsenic and chromium were determined using Atomic absorption spectroscopy.

5. Statistical analysis

Data were statistically analyzed using the SPSS program, version 16.0 (SPSS, 2007), analysis of variance to study the effect of wood species on the residual of the three elements ((arsenic, copper, and chromium))within wood tissue. Mean values of elements concentration were separated by the least significant difference (LSD)Test when significant F values were obtained ($P<0.05$). T-test was used to determine the effect of leaching on residues of elements by comparison between elements concentrations in leached wood and un-leached wood.

RESULTS

3.1. The Bioassay Tests

(I). Persistence period of CCA-C against Lyctus beetles in treated wood, and efficacy of the preservative after exposure to leaching process:

Data in Table 1 showed that 3% CCA type C by full-cell pressure technique gave the treated wood the resistance against *L. africanus'* attack through the period from 4/2015 till now (treated wood was exposed to *L. africanus* attack twelve times through four years). While the untreated wood of the four species was infested and the mean number of exit holes ranged from 177 to 299.3 for Poinciana block, 109 to 160.8 exit holes for lebbeck, 42.3 to 80 exit holes for acacia block and 15 to 30.5 exit holes for sissoo block. According to leaching process, the leaching process did not affect the effectiveness of the preservative, where treated wood exposed to leaching for two weeks showed the same resistance, while, the untreated wood (control with leaching) was infested and mean number of exit holes ranged from 166.8 to 296 for poinciana block, 99 to 167.3 for lebbeck, 38.3 to 77 for acacia block and 10 to 31 exit holes for sissoo wood (Fig. 2).

Table (1) The persistence period of CCA-C against *Lyctus africanus* beetles in treated wood using a full-cell pressure treatment technique, and efficacy of the preservation after exposure to leaching

Wood species	Date of exposure	The first year (2015)			2016			2017			2018		
		4/2015	6/2015	8/2015	4/2016	6/2016	8/2016	4/2017	6/2017	8/2017	4/2018	6/2018	8/2018
		Mean number of emerged beetles/log											
Poinciana regia	The 1st group	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero
	The 2nd group	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero
	First control	183.25	235.5	299.25	184.8	286	259.8	177	229.3	260.5	185.25	257.5	248.7
	Second control	294.3	245	273.8	217	209	199	166.8	241	296	255	179	236.8
Albizia lebbeck	The 1st group	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero
	The 2nd group	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero
	First control	135.3	116	155.3	129.25	159	144	128.3	142.5	121	137	109	160.8
	Second control	119	132.3	141.8	144	171	167.3	122	154.3	110	99	115.3	147
Acacia arabica	The 1st group	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero
	The 2nd group	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero
	First control	60	49	49.25	42.3	63.5	58.3	47.8	67.5	59.8	66.8	80	75
	Second control	38.3	55	44	61	77	48	39	55.5	40.25	49	53	69
Dalbergia sissoo	The 1st group	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero
	The 2nd group	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero
	First control	17.3	24	20.5	18.8	26.8	15.3	25.8	14.5	15	18.3	30.5	24
	Second control	19	16	12.5	15.3	10	13	21.8	14.3	23	26	16	31

The 1st group (wood treated with CCA –C without leaching four years ago); The 2nd group (wood treated with CCA –C then exposed to leaching four years ago. First control(untreated wood did not expose to leaching),second control(untreated wood and exposed to leaching).

(II). Continuous exposure to beetles' attacks (Exposing treated wood to frequent beetles attack): Treated wood was exposed to beetles twelve times (weekly) through a period of three months. It was found that despite the presence of beetles on wood continuously and their attempts to damage wood, wood still resistant to infestation and there are no exit holes on treated wood, while the mean number of exit holes from untreated wood ranged from 252.3to 311.5 for Poinciana, 121.5 to 168.3 for Lebbeck, 40.5 to 72.25 for Acacia and from 17 to 24.5 for Sissoo block. (Table 2).

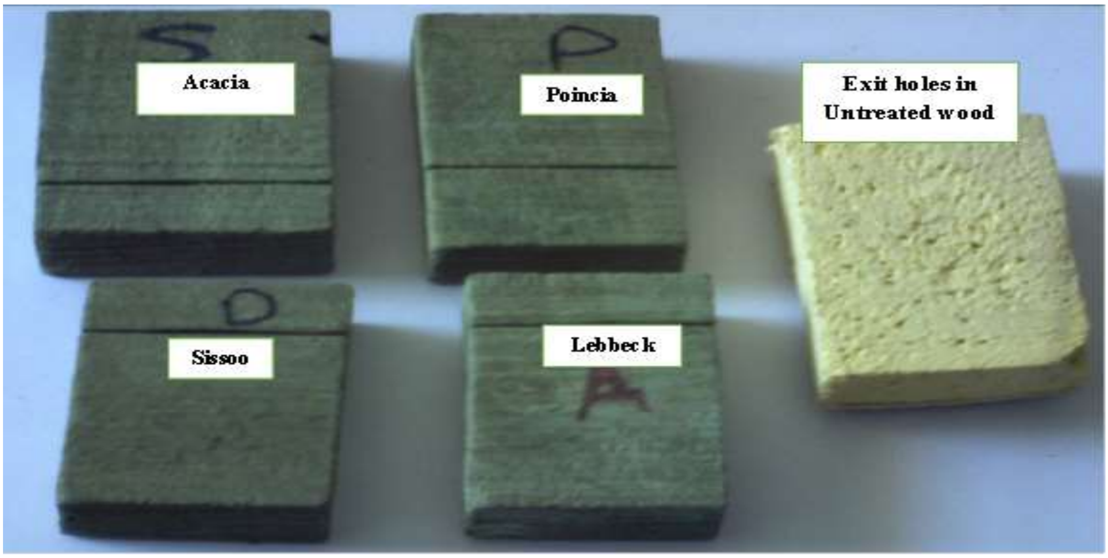

Fig. (2): Four species of treated wood with CCA type C 3% and were not attacked by the powder post beetles compared to untreated wood (in the right side).

Table (2) The durability of treated wood with CCA-C 3% against the attack of lyctus beetles (weekly continuous attack) during the period from 1/6/2017 to 31/8/2017.

Wood species	Date of exposure	6/2017				7/2017				8/2017			
		The 1st week	The 2nd week	The 3rd week	The 4th week	The 1st week	The 2nd week	The 3rd week	The 4th week	The 1st week	The 2nd week	The 3rd week	The 4th week
		Mean number. of emerged beetles/ log											
Poinciana regia	The 1st group	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero
	The 2nd group	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero
	Control	252.25				311.5				266			
Albizia lebbeck	The 1st group	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero
	The 2nd group	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero
	Control	121.5				152				168.3			
Acacia arabica	The 1st group	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero
	The 2nd group	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero
	Control	40.5				72.25				62.5			
Dalbergia sissoo	The 1st group	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero
	The 2nd group	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero
	Control	17				20.3				24.5			

The 1st group (wood treated with CCA –C without leaching four years ago); The 2nd group (wood treated with CCA –C then exposed to leaching four years ago).

(III). Evaluation of the penetration depth of the preservative CCA-C in wood tissue based on bioassay tests: - The performance of any wood preservative is largely measured by the penetration depth of preservatives within the treated wood tissue. It was found that, despite the cutting off treated wood blocks and exposing the internal parts (cross-section) of the wood to the beetles to lay eggs, wood is still resistant to beetles' infestation, which confirms the deepening of the preservative within the treated wood, where there was no damage to the treated wood and no exit holes were recorded, while, exit holes were recorded from the control. (Table 3).

Table 3 Evaluation of the penetration depth of CCA inside wood using bioassay test depending on the number of emerged Lyctus beetles

Date of exposure	4/2018	6/2018	8/2018
	Mean No. of emerged beetles/block		
Wood species			
Poinciana regia			
The 1st group	Zero	Zero	Zero
The 2nd group	Zero	Zero	Zero
Control	190.5	269.75	299
Albizia lebbeck			
The 1st group	Zero	Zero	Zero
The 2nd group	Zero	Zero	Zero
Control	127.3	111.8	160
Acacia arabica			
The 1st group	Zero	Zero	Zero
The 2nd group	Zero	Zero	Zero
Control	52.8	64.3	48.5
Dalbergia sissoo			
The 1st group	Zero	Zero	Zero
The 2nd group	Zero	Zero	Zero
Control	19.5	20.8	28.3

The 1st group (wood treated with CCA –C without leaching four years ago);
The 2nd group (wood treated with CCA –C then exposed to leaching four years ago.

3.2. Second: Chemical Methods:

(I) Measuring the penetration depth of the preservative in wood tissue using a CCA reagent:

It is clear that the internal tissue colour has changed to brown in the treated wood after spraying with Ferro-Cyanide Potassium, while in the untreated wood, the tissue color is still normal (Fig. 3). This is a clear indicator of copper penetration into the wood and thus the other components (chromium and arsenic), which confirms the success of the full-cell pressure technique .

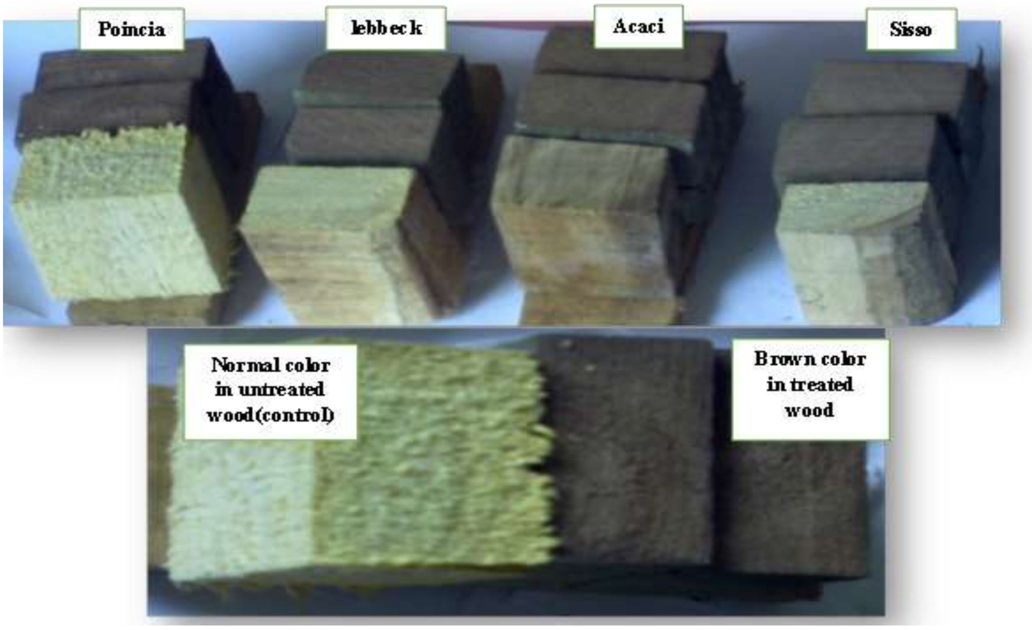

Fig. (3): Figure shows the pigmentation of the internal tissues of the wood in a brown color due to the use of Ferro-Cyanide Potassium as a copper reagent compared to untreated wood(control).

(II) Determination of CCA-C residues (Arsenic, Copper and Chromium) in treated wood:

According to the first group (un-leached wood): Results of the statistical analysis showed highly significant differences between the capability of wood species to the retention of CCA components. It was found, the persistence of the arsenic element was the highest in Dalbergia followed by Lebbeck, Poinciana and then Acacia was the least. According to residues of Chromium element was the highest in Lebbeck followed by Sisso then Poinciana followed by Acacia. Copper was the most persistent within Poinciana followed by Sissoo, Lebbeck then Acacia. In general, Acacia is clearly the least species in the retention of elements **(Table 4, Fig. 4).** Using LSD test showed the differences between all mean values of elements concentration between all wood species are significant differences.

According to the second group (treated wood which, were exposed to the leaching process for fourteen days): There are also statistically significant differences between wood species in the retention of elements. There are significant differences between all mean values of elements concentration between all wood species, except the difference between the mean values of the copper element between Lebbeck and Sissoo was insignificant. (Table 5, Fig. 5).

According to leaching, it is clear that there is an obvious difference between the residues of the three elements in the two groups (leached and un-leached wood). The residues are less in the group that was exposed to leaching. Using T-test to determine the effect of leaching on elemental residues in leached wood species, by comparison, it was found that there are statistically significant differences between the means of residues for each element between the two groups where the calculated t-value is greater than the table value at an alpha level of 0.05.

. After calculating the percentage of loss for each element as a result of leaching process, it is clear that copper was the most affected element by leaching for all wood species where the percentage of loss reached 56% with Poinciana wood while the other two elements varied according to each wood species as a result of the interaction between wood tissue and element which leads to different leaching of the same element for different species. These results agree with those reported by (Taylor and Cooper 2003) who studied leaching of CCA from lumber exposed to natural rain and found that copper was the most affected element by leaching. (Pizzi 1990, Kartal and Lebow 2001& Sabiha *et al.*, **2015**) also stated differences in chemical composition and extractive contents of wood, especially the amount and type of lignin which can affect the rate of fixation and preservative leachability (Table. 6).

Table 4 Analysis of treated wood samples with CCA-C for residues of elements by Atomic Absorption

Element residues (ppm)	Wood species				±SEM	LSD 0.05
	Poinciana regia	*Albizia lebbeck*	*Acacia arabica*	*Dalbergia sissoo*		
As	**471.5[c]**	**494.5[b]**	**427.5[d]**	**527.5[a]**	**11.04**	**7.963**
Cr	**4735[c]**	**7600[a]**	**3885[d]**	**5605[b]**	**415.82**	**30.724**
Cu	**5232.4[a]**	**2647.4[c]**	**1667.4[d]**	**2922.4[b]**	**394.14**	**19.496**

Means with a common letter are not significantly different (P < 0.05; LSD test).

Table (5) Analysis of treated wood samples with CCA-C (Leached wood) residues of elements by Atomic Absorption

Element residues (ppm)	Wood species				±SEM	LSD 0.05
	Poinciana regia	*Albizia lebbeck*	*Acacia Arabica*	*Dalbergia sissoo*		
As	**399.5[c]**	**457.8[a]**	**383.3[d]**	**435.5[b]**	**8.89**	**9.364**
Cr	**4635[c]**	**5860[a]**	**3070.03[d]**	**4815[b]**	**300.62**	**34.643**
Cu	**2297.4[a]**	**1727.4[b]**	**1167.4[c]**	**1732.4[b]**	**120.49**	**27.336**

Means with a common letter are not significantly different (P < 0.05; LSD test).

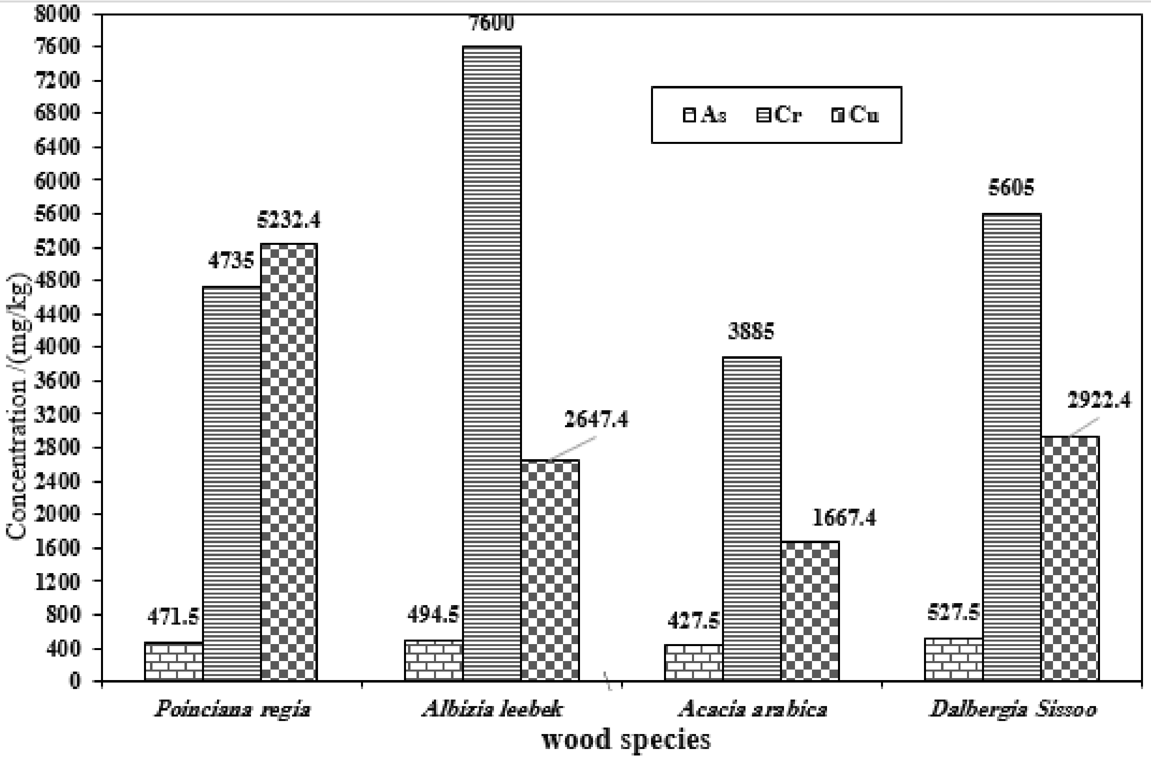

Fig. (4) Residues of copper, chromiun and arsenic elements in treated wood.

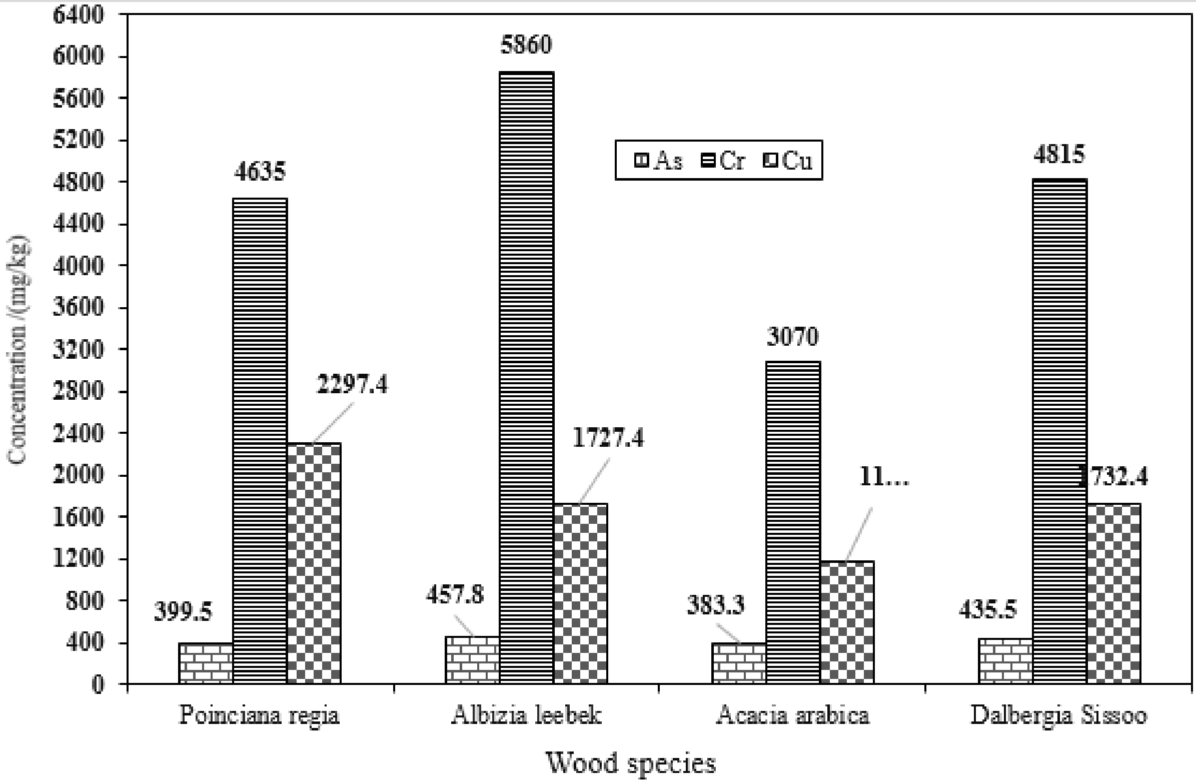

Fig. (5): Residues of Copper, chromium and arsenic elements in treated wood and exposed to leaching

Table (6) Comparison Between the residues within leached and un leached wood samples to show the effect of leaching on the loss of CCA-C components

Element residues (ppm)	Wood species	Element residues (ppm)		Loss as a result of leaching $\frac{A-B}{A} \times 100$
		The1st group(A)	The 2nd group(B)	
As	*Poinciana regia*	471.5	399.5	15.3%
	Albizia lebbeck	494.5	457.8	7.4%
	Acacia Arabica	427.5	383.3	10.3%
	Dalbergia sissoo	527.5	435.5	17.4%
Cr	*Poinciana regia*	4735	4635	2.1%
	Albizia lebbeck	7600	5860	22.9%
	Acacia arabica	3885	3070.03	21.0%
	Dalbergia sissoo	5605	4815	14.1%
Cu	*Poinciana regia*	5232.4	2297.4	56.1%
	Albizia lebbeck	2647.4	1727.4	34.8%
	Acacia arabica	1667.4	1167.4	30.0%
	Dalbergia sissoo	2922.4	1732.4	40.7%

The 1st group (wood treated with CCA –C without leaching four years ago); The 2nd group (wood treated with CCA –C then exposed to leaching four years ago.

DISCUSSION

For all the tested and treated wood species, the samples were free of *L. africanus* attack till the end of the study (four years). The treated wood samples at a concentration of 3% CCA-C showed high resistance against *L. africanus* attack through a period of four years. Our results are in partial agreement with (Mankowski *et al.*, 2017) who stated that treating incised wood with CCA-C can provide long-term protection for southern pine Heartwood as well as Engelmann spruce Heartwood and Douglas-fir Heartwood. This is an evidence of the fixation of the preservative inside wood tissue and that leaching with water had not any effect on the fixation and efficacy of preservative against the powder post beetles, in spite of cutting treated wood cuts into equal parts and exposing of the internal parts to beetles' attack, wood still resistant against the beetles' attack, which indicates to the deepening of the preservative in the interior of the wood. These results are in partial agreement with those reported by (Cookson 2007) who compared the performance of CCA and creosote against marine borer and found that the best performance pile was eucalyptus doubled-treated with CCA and creosote. And also agree with (Abd-El-Latif *et al.*, 2014) who found that treating wood with CCA type C 3% by double vacuum and pressure gave stakes completely protection for poinciana, willow, mulberry, Casuarina and poplar against subterranean termite *Psammoteres hypostoma* for two years.

It is clear that, for all wood species, arsenic residues were the lowest in all wood species compared with its first percentage in the CCA-C formula (34%), so it is clear that arsenic is clearly the least stable element in wood tissue. This result agrees with those reported by Raghuyal *et al.*, 2012 who stated that arsenic was the quickest to lose and chromium being the most resistant to the loss of CCA elements. The results are also in an agreement with Dawson- Andoh *et al.*, 2002 who reported that arsenic was the most unfixed element in Appalachian hardwood because of the insufficient availability of chromium for complexation. These losses of the three elements are probably related to the volatilization and leaching of CCA constituents over time. This agrees with Ferrarini *et al.*, 2015 who compared the concentration of the CCA elements in pole removed from service and new poles and found that the losses of the three elements into the environment with the time of service as a result of volatilization and leaching. Although, residual CCA level was sufficient enough to prevent attack and decay by the powder post beetles.

CONCLUSION:

Treating wood with CCA-C by full-cell pressure technique gave the four hard wood species the resistance against *L. africanus* during four years, also despite the high susceptibility of Poinciana wood, it became resistant to infestation after the treating with 3% CCA-C. Treated wood, which was exposed to the leaching process for two weeks showed resistance to the infestation by *L. africanus* indicating the success of the fixation process. According to the penetration depth of preservative, based on two ways to evaluate penetration of the preservative; bioassay tests and the use of a reagent, results revealed that full cell pressure technique with (vacuum 30 in Hg) and positive pressure of (10 bar) is suitable to maximize the penetration depth of the preservative in the four hardwood species. According to elemental analysis of the CCA components, a highly significant difference among all wood species in the retention of elements was observed. Arsenic was the least stable in wood tissue. Acacia wood is clearly the least species in the retention of elements. Leaching has a significant effect on the loss of elements, copper was the most affected element by leaching for all wood species. Residual CCA level was sufficient enough to prevent attack and decay by the powder post beetles. Therefore, considered wood treatment with the previous way appropriate to preserve hardwoods, as a result of the success of this method to preserve and persist within four species of susceptible wood species (*Acacia arabica, Poinciana regia, Albizia lebbeck* and *Dalbergia sissoo*), thus this way can be considered successful to preserve the other hardwoods species against wood borers attack.

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ARABIC SUMMERY

تحديد كفاءة (فعالية) و بقاء حافظ الاخشاب (زرنيخات الكروم النحاسية) من النوع C ضد الحشرات المدمرة للأخشاب ومتانة الأخشاب المعالجة

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يعتبر حافظ الاخشاب زرنيخات الكروم النحاسية (Copper Chrome Arsenate) واحد من أكثر حافظات الاخشاب شيوعا في العالم ، وتعتمد فعاليتها على الأداء ومقاومتها للغسيل، وعمق اختراقها في النسيج الخشبي و البقاء داخل أنسجة الأخشاب المعالجة. تم دراسة بقاء حافظ الأخشاب CCA من النوع C داخل أربعة أنواع من الأخشاب المعالجة باستخدام تقنية الضغط الكامل للخلايا (التفريغ و الضغط) ثم تثبيت المادة الحافظة عند 45 م° و 75٪ رطوبة نسبية. وأجريت الاختبارات الحيوية bioassay لتقييم أداء الاخشاب المعالجة ب CCA-C ضد التدهور الحيوي والإصابة بناخرات الاخشاب بتعريض الاخشاب المعالجة لخنافس ليكتس الساحقة للأخشاب *Lyctus africanus* (Lyctidae: Coleoptera). .

أظهرت العينات الخشبية المعالجة بـ CCA-C عند تركيز 3٪ مقاومة عالية ومتانة ضد هجوم *L. africanus* خلال فترة أربع سنوات، كما أظهر الخشب المعالج المعرض لعملية الغسيل لمدة أسبوعين مقاومة لـ *L. africanus* ، مما يؤكد التثبيت الناجح للمادة الحافظة(CCA) داخل الأنسجة الخشبية وعدم تأثرها بالغسيل. بالنسبة لجميع أنواع الأخشاب المعالجة التي تم اختبارها كانت العينات خالية من أي هجوم *L. africanus* حيث أظهر الخشب المعالج درجة عالية من التحمل و لم يحتوي على أي ثقوب خروج للخنافس .

وجد انه على الرغم من تقطيع الاخشب المعالجة الى أجزاء متساوية و كشف الاجزاء الداخلية (المقاطع العرضية) لهجوم الخنافس فأن الخشب لا زال مقاوما للإصابة مما يؤكد تعمق المادة الحافظة داخل الخشب المعالج، أيضا تم قياس عمق الاختراق للمادة الحافظة (CCA) داخل الأنسجة الخشبية باستخدام حديدو سيانيد البوتاسيوم باعتباره كاشف لعنصر النحاس، لوحظ تغيير لون الأنسجة الداخلية (المقطع العرضي) من الخشب المعالج إلى اللون البني نتيجة لاختراق النحاس في الخشب مما يؤكد اختراق كل مكونات الـCCA داخل انسجة الخشب. بالنسبة للمتبقي من مكونات ال CCA داخل الخشب المعالج بعد 48 شهرا، لوحظت اختلافات كبيرة جدا بين جميع أنواع الخشب في الاحتفاظ بالعناصر(الكروم و النحاس و الزرنيخ). من الواضح أن الزرنيخ هو العنصر الأقل استقرارًا في الأنسجة الخشبية بينما كان النحاس العنصر الأكثر تأثراً بالغسيل لجميع أنواع الخشب. ومع ذلك ، كان المستوى المتبقي من ال CCA كافيا لمنع هجوم *L. africanus.* ، و بناء على ما سبق، يمكن اعتبار تقنية ضغط الخلايا الكاملة بالتفريغ (vacuum 30 in Hg) والضغط لـ (10 bar) ناجحين للمحافظة على أنواع الخشب الصلد ضد هجوم حفارات الخشب وتعظيم عمق الاختراق للمادة الحافظة داخل الأنسجة الخشبية.