EFFECTIVENESS OF COPPER-CHROME-BORON AS WOOD PRESERVATIVE

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SALAMAH SELAMAT, ZAITUN SAID & FAUZIDAH AHMAD. 1993. Effectiveness of copper-chrome-boron as wood preservative. Kempas (*Koompassia malaccensis*) and meranti tembaga (*Shorea leprosula*) samples of two different sizes were treated with CCB and exposed at two test sites. CCA (6 %) was used as a reference preservative. A visual on-site assessment of decay on every test stake was made every three months for two years and every six months for each of the following years. The amount of preservative retained in the treated wood was determined by chemical analysis after 6 and 12 months exposure at the test site. The relationships between type of preservative, preservative concentration, test site and wood species were statistically determined. CCB preservative at the recommended concentration gave about the same degree of protection as CCA in ground contact.

Key words: CCB and CCA preservatives - full cell - kempas - meranti tembaga - durability

SALAMAH SELAMAT, ZAITUN SAID & FAUZIDAH AHMAD. 1993. Keberkesanan kuprum-kromium-arsenik sebagai bahan awit. Kempas (*Koompassia malaccensis*) dan meranti tembaga (*Shorea leprosula*) yang mempunyai dua saiz yang berlainan telah diawit dengan CCB dan didedahkan di tapak ujian. CCA (6%) digunakan sebagai bahan awit rujukan. Penilaian secara penglihatan mata kasar terhadap kadar pereput pada setiap batang kayu dilakukan setiap tiga bulan selama dua tahun dan setiap enam bulan pada tahun berikutnya. Kandungan bahan awit dalam kayu dipastikan dengan analisa kimia selepas 6 dan 12 bulan didedahkan ditapak ujian. Hubungkait diantara jenis bahan awit, kepekatan, tapak ujian dan jenis kayu telah dikenalpasti secara statistik. Bahan awit CCB pada kepekatan yang dianjurkan telah dapat memberi kadar perlindungan yang sama dengan CCA.

Introduction

Copper-chrome-arsenic (CCA) preservatives are the most popular chemicals used for effective treatment of wood in ground contact applications. These chemicals are effective against termites. Copper in the form of copper sulphate is very effective against fungus especially soft rot. The chemical interaction, with chromium as a fixation agent, between copper, arsenic (Richardson 1978),and wood carbohydrates (Dahlgreen & Hartford 1972, Pizzi 1990a) and wood lignin (Pizzi 1979, 1981; Kubel & Pizzi 1982) makes these preservatives water insoluble forming stable complexes/esters. For this reason, leaching of the wood cannot redissolve or remove the preservatives. The combination of copper, chromium and arsenic gives high protection against the broad spectrum of biodegrading agents. In Malaysia, CCA is the most important type of waterborne preservative used for pressure treated timber. The CCA treated timbers have been extensively put to indoor and outdoor uses since the 1960's (Daljeet 1982). However, due to the high toxicity of arsenic to human life, there is a need to find an alternative water borne preservative, especially for indoor applications. There are various attempts to overcome this problem, the best known being the replacement of arsenic with boron.

Some reports based on microbiological examination and marine borer assessments have indicated little difference between the performance of CCA and CCB treated timber (Cookson & Barnade 1984, Anonymous 1985, Eaton 1987).

In this study, boron was used to replace arsenic in combination with copper and chromium since boron is also good as an insecticide. The objective of this study was to determine the effectiveness of a CCB preservative with reference to 6% CCA is two different types of timber in contact with the ground.

Non-durable timbers of kempas (*Koompassia malaccensis*) and meranti tembaga (*Shorea leprosula*) were used in this study. Kempas is classified in strength group A which is widely used in heavy construction and as structural component and is easily treated with wood preservative. Meranti tembaga is widely used in light construction, difficult to treat and classified in strength group C (Wong 1982).

Material and methods

Test sites

Two different localities were choosen from the FRIM grave yard plots for this study. One plot was at a lower ground situated at 215 *m* above sea level with soil pH 4.84 and water holding capacity 63% in Jalan Jelutong and the upper ground situated at 279 *m* above sea level with soil pH 4.52 and water holding capacity 62.5% in Jalan Bukit Watson area. The total yearly rainfall was 2176, 2675 , 2998, 2415 and 2219 *mm* for the years 1986, 1987, 1988, 1989 and 1990 respectively.

Test stakes

Two sizes of 0.75 × 0.75 × 24 *in* and 1.5 × 0.25 × 24 *in* were used in this study to determine the best size of the wood samples which would give the fastest decay result. Forty wood samples of each species, size, preservative (chemical), preservative (chemical) concentration and location combination at the moisture content of 20% were prepared according to Table 1. The weight of each stake was determined immediately before commencement of the full cell treatment.

Table 1. Conditions of wood samples*

Species	Size (*in*)	Preservative	Preservative Concentration % m/v	Location of test site
Kempas	1.5 × 0.25 × 24	CCB	5, 6, 8	Lower ground & Upper ground
	0.75 × 0.75 × 24	CCA	6	Lower ground & Upper ground
Meranti tembaga	1.5 × 0.25 × 24	CCB	5, 6, 8	Lower ground & Upper ground
	0.75 × 0.75 × 24	CCA	6	Lower ground & Upper ground

* 40 replicates for each sample size, type of preservative, preservative concentration and test site.

Wood preservative

The compositions of the preservatives were as follows :

Preservative	Active ingredient	Composition (% m/m)
CCA type 2	$CuSO_4.5H_2O$	32.3
	$K_2Cr_2O_7$	41.5
	$As_2O_5.2H_2O$	19.7
CCB paste	$CuSO_4.5H_2O$	32.3
	$K_2Cr_2O_7$	45.0
	H_3BO_3	20.0

Three concentrations were selected for CCB at 5, 6 (recommended concentration) and 8% m/v. CCA at 6% m/v was used as a reference preservative. The 6% concentration of CCA was selected because it was found effective to protect kempas of size 2 × 2 × 24 *in* (Daljeet & Dahlan 1991) at the same test plots.

Method of treatment

The wood preservatives were impregnated into the samples by full-cell treatment using the schedule below:

Initial vacuum	=	720	*mHg*
Initial vacuum period	=	45	*in*
Flooding time	=	15	*in*
Pressure	=	14.06	*Kgm*^{2}
Pressure period	=	2.5	*h*
Drain	=	10	*min*
Final vacuum	=	720	*mmHg*
Final vacuum period	=	10	*min*

Each wood sample was weighed immediately after treatment. The holding period between time of treatment and time of installation was eight weeks to allow fixation of the preservatives under shade. Immediately after this period, six pieces of wood samples from each set were ground for chemical content determination at zero month exposure.

Sample handling after treatment

The 34 wood samples from each set of factor combination were exposed at the sites in April 1986. Handling of test stakes after the treatment including installation in test plots and inspection of specimens and the grading system were based on the Standard Method of Evaluating Wood Preservatives by Field Tests With Stakes, ASTM D1758-74 (Anonymous 1974). Inspection was made every three months for the first two years and every six months following the installation. In this report data at 3, 9, 15, 21, 30, 42 and 60 months are presented.

Chemical analysis of treated timber

Three replicates from each set of wood samples were collected after 6 and 12 months exposure from the test plots for chemical content determination.

After these periods, only the destroyed samples were taken for fungal or insect (if assessible) identifications followed by chemical content determination.

The amounts of copper, chromium and arsenic in sample were determined using Malaysian Standard 821 (Anonymous 1983). The Japanese Standard (Anonymous 1986) was used for boron determination. The atomic absorption spectrophotometer model Shimadzu AA-670 was used for chemical content determination.

Results and discussion

The amounts of preservatives absorbed by the wood samples after full cell treatment are shown in Table 2. The statistical analysis of the data using Anova shows that there are significant interaction effects at 5% level of significance between all factors (wood species, sample size, type of chemical and chemical concentration) tested, except for one of the six two - factor interactions, namely SI × C as shown in Table 3.

The results indicate that the effects of wood species, sample size and type of preservative used in the experiment varied among the concentrations of the preservatives. It was also found that the effect of preservatives and concentration varied among the sample size.

Further analysis using Duncan's Multiple Range Test (DMRT) indicates that kempas samples gave better preservative loading than meranti tembaga samples after full cell process regardless of the other three factors (at alpha 0.05). Samples treated with CCA preservative differred significantly from those treated with CCB when using thin sample size. Samples treated with 8% m/v gave significantly

Table 2. The amount of preservative solution absorbed by the wood samples after full cell process

				Preservative loading ($kg\ m^{-3}$) based on	
Species	Size	%m/v	Preservative	solution absorbed	a.i*
Kempas	B	5	CCB	289.4	14.5
		6	CCB	289.1	17.4
		8	CCB	336.7	26.9
		6	CCA	329.4	19.6
Kempas	A	5	CCB	297.3	14.9
		6	CCB	334.3	20.1
		8	CCB	336.5	26.9
		6	CCA	315.8	18.9
Meranti tembaga	B	5	CCB	267.2	13.4
		6	CCB	307.8	18.5
		8	CCB	324.1	25.9
		6	CCA	311.4	18.7
Meranti tembaga	A	5	CCB	274.7	13.7
		6	CCB	317.3	19.1
		8	CCB	325.6	26.1
		6	CCA	312.6	18.8

Note: A = 0.75 x 0.75 x 24 *in*
B = 1.5 x 0.25 x 24 *in*
* = concentration of active ingredient.

Table 3. Statistical analysis of variance of chemical loading and chemical retention after full cell process (significance at 5% probability)

		Chemical Loading		Chemical Retention	
Source	DF	Mean Square	F Value	Mean Square	F Value
SP	1	5559.85	465.95*	15.89	291.66*
SI	1	38.57	3.23ns	0.16	3.02ns
CON	2	13295.95	1114.32*	882.60	16202.24*
C	1	13.26	1.11ns	0.04	0.71ns
SP*SI	1	1128.92	94.61*	3.45	63.30*
SP*CON	2	1898.65	159.12*	4.56	83.66*
SP*C	1	447.50	37.50*	2.64	48.44*
SI*CON	2	78.05	6.45*	0.30	5.50*
SI*C	1	15.77	1.32ns	0.05	0.87ns
CON*C	2	1350.81	113.21*	6.56	20.39*
SP*SI*CON	2	437.65	36.68*	1.63	29.85*
SP*SI*C	1	1578.28	132.27*	5.59	102.54*
SP*CON*C	2	334.32	28.02*	1.64	30.11*
SI*CON*C	2	247.97	20.78*	0.81	14.91*
SP*SI*CON*C	2	1228.64	102.97*	4.46	81.86*
ERROR	48	2.61			
CORRECTED TOTAL	71				

Note: SP = species; SI = sample size; CON = preservative concentration
C = type of preservative; ns = not significant; * = significant

better preservative loading than when treated with 6% m/v and 5% m/v at all factor levels tested.

The grade indices for the wood samples after exposure to the ground at different periods are shown in Figures 1 to 8. All meranti tembaga samples (Figures 1 to 4) and untreated kempas samples (Figures 5 to 8) were totally destroyed after 60 months exposure. These figures show that not only the type of preservative but also the wood species has a significant effect on the durability of the wood as supported by the statistical analysis.

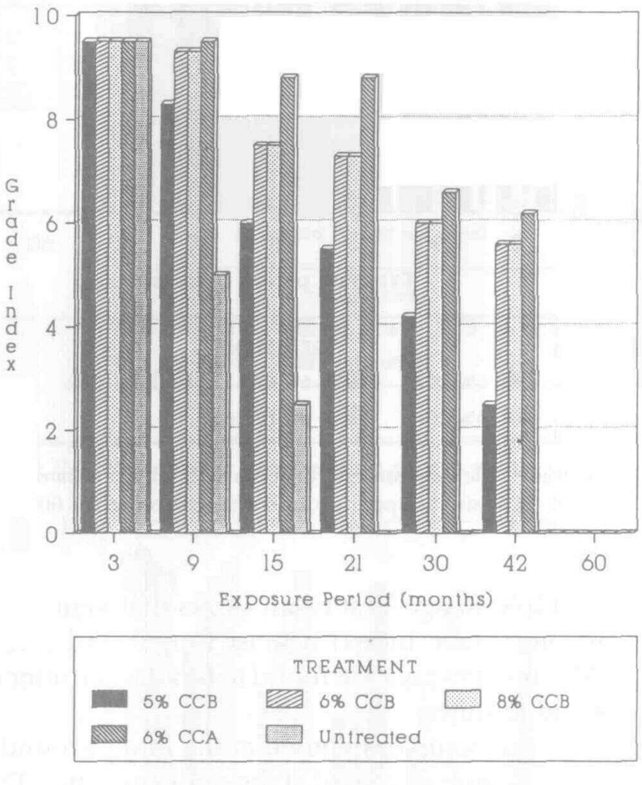

Figure 1. The grade index assessment for meranti tembaga (*shorea leprosula*) of 1.5 × 0.25 × 24 *in* size at lower ground after exposure for 60 months

The statistical analysis of variance of these data at different levels of preservative concentration is shown in Table 4. The results of this analysis show that three of the two - factor interactions are non-significant (SPC × LOC, LOC × SIZE, SIZE × CHEM). Further more, there are highly significant effects between the three- and four- factor interactions (except for SPC × SIZE × CHEM). The interaction of all factors tested is not significant at all different preservative concentrations.

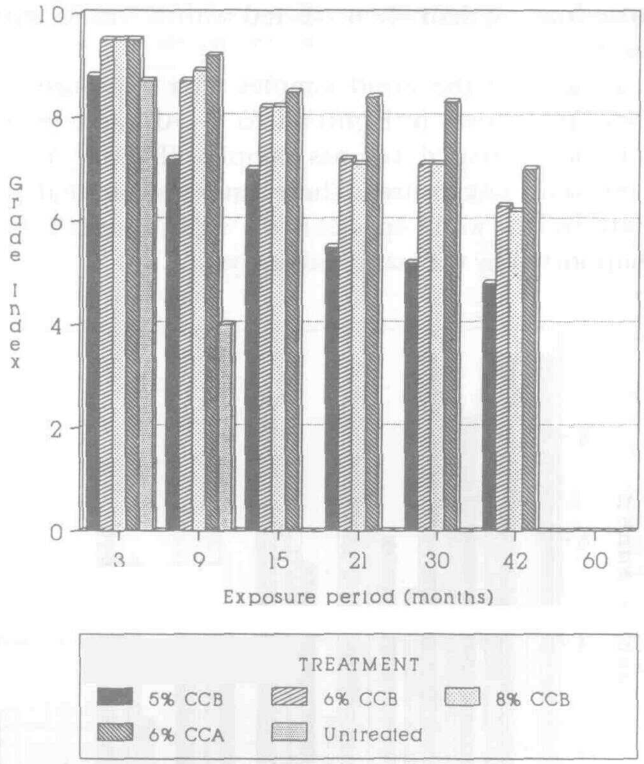

Figure 2. The grade index assessment for meranti tembaga (*Shorea leprosula*) of 1.5 × 0.25 × 24 *in* size at upper ground after exposure for 60 months

The Duncan's Multiple Range Test result shows that kempas was significantly resistant (based on the grade index) against fungus and insect compared to meranti tembaga. Meranti tembaga was found to be attacked after exposure on the ground by soft rot and termites.

This test also shows that samples exposed at the lower ground were destroyed significantly faster than samples exposed at the upper ground. The total amounts of CCA and CCB in the treated wood (Figures 9 - 12) as dry salt retention show that both types of preservative were leached out faster at the lower ground at any level of chemical concentration, wood species or sample size. The solubility of As, Cu and Cr is pH dependent (Bergholm 1990). Less sunlight passed through the lower ground than through the upper ground due to the tree crown above the plot. This condition might be more conducive to termite and fungal attack (Gunther 1976).

Further analysis using DMRT shows that kempas samples treated with CCA were not significantly different from kempas sample treated with CCB up to 21 months exposure . It was only up to three months for meranti tembaga. After these periods samples treated with CCA were significantly more durable than those with CCB.

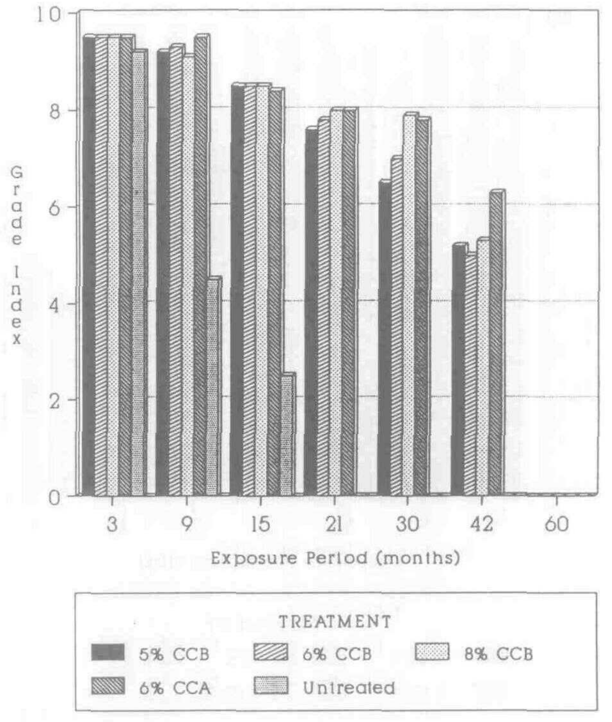

Figure 3. The grade index assessment for meranti tembaga (*Shorea leprosula*) of 0.75 × 0.75 × 24 *in* size at lower ground after exposure for 60 months

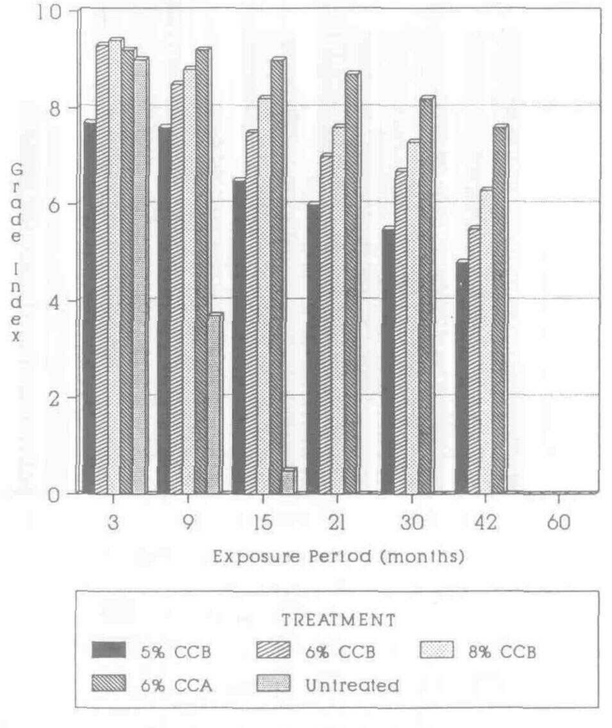

Figure 4. The grade index assessment for meranti tembaga (*Shorea leprosula*) of 0.75 × 0.75 × 24 *in* size at lower ground after exposure for 60 months

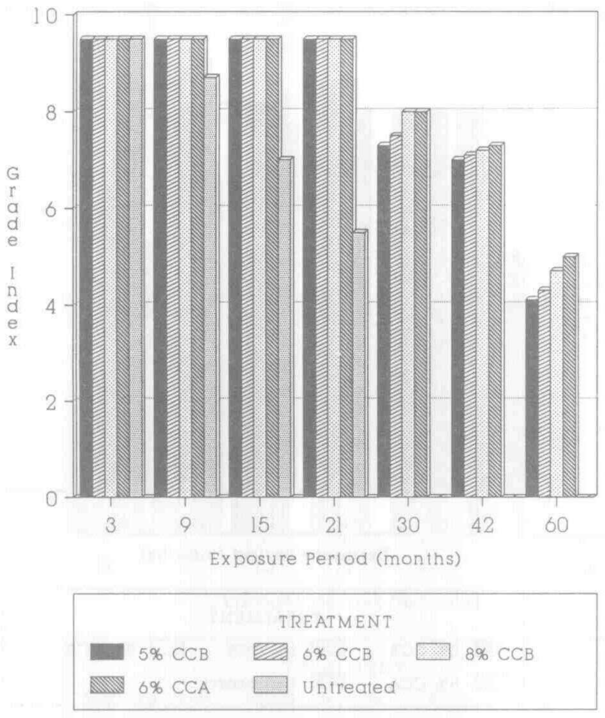

Figure 5. The grade index assessment for kempas (*Kompassia malaccensis*) of 1.5 × 0.25 × 24 *in* size at lower ground after exposure for 60 months

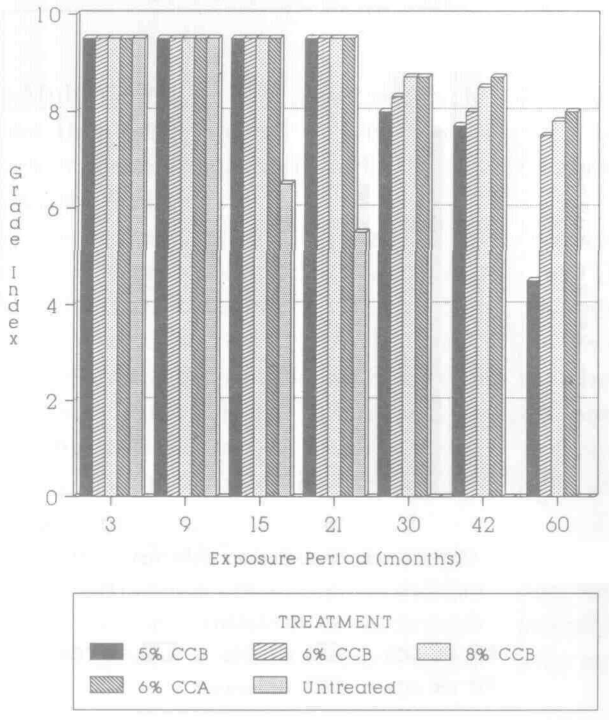

Figure 6. The grade index assessment for kempas (*Koompassia malaccensis*) of 1.5 × 0.25 × 24 *in* size at upper ground after exposure for 60 months

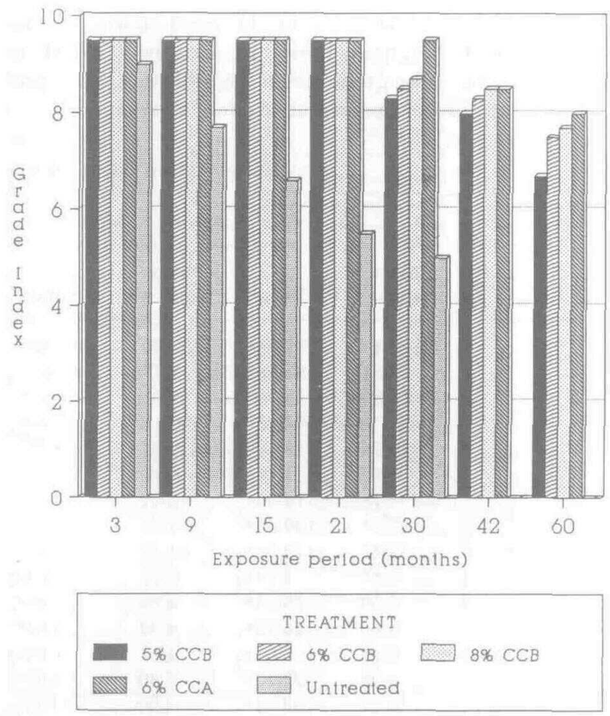

Figure 7. The grade index assessment for kempas (*Koompassia malaccensis*) of 0.75 × 0.75 × 24 *in* size at lower ground after exposure for 60 months

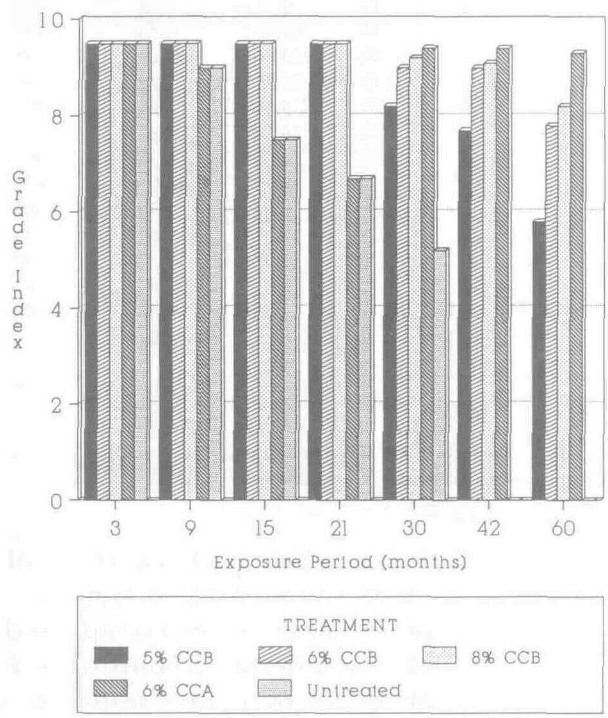

Figure 8. The grade index assessment for kempas (*Koompassia malaccensis*) of 0.75 × 0.75 × 24 *in* size at upper ground after exposure for 60 months

Table 4. Statistical analysis of variance (ANOVA) based on the performance of wood species (SPC), location (LOC), type of wood preservative (CHEM) and exposure time (MON) in terms of the grade index (significance at 5% probability) at different preservative concentrations

		Preservative concentration (% w/w)					
		5		6		8	
Source	DF	Mean Square	F Value	Mean Square	F Value	Mean Square	F Value
SPC	1	1142.45	5217.90*	1053.50	4870.80*	978.75	5001.43*
LOC	1	12.54	57.28*	13.77	63.67*	26.01	132.90*
SIZE	1	25.85	118.06*	32.33	149.48*	21.79	111.33*
CHEM	2	1465.79	6694.68*	1539.16	7116.22*	1582.38	8085.98*
MON	6	529.56	2418.64*	519.61	2402.38*	514.94	2631.32*
SPC*LOC	1	0.27	1.22*ns*	0.19	0.90*ns*	0.10	0.51*ns*
SPC*SIZE	1	4.18	19.09*	13.77	63.67*	0.75	54.94*
SPC*CHEM	2	22.07	100.81*	21.03	97.22*	23.06	117.85*
SPC*MON	6	39.33	179.65*	51.12	236.34*	50.65	258.83*
LOC*SIZE	1	0.37	1.70*ns*	0.22	1.03*ns*	0.20	0.93*ns*
LOC*CHEM	2	5.60	25.58*	4.86	22.45*	0.92	4.72*
LOC*MON	6	5.86	26.76*	4.34	20.04*	2.60	13.30*
SIZE*CHEM	2	0.23	1.06*ns*	0.27	1.24*ns*	0.29	1.47*ns*
SIZE*MON	6	6.08	27.77*	8.40	38.85*	7.27	37.16*
CHEM*MON	12	56.69	258.91*	54.00	249.66*	56.73	289.88*
SPC*LOC*SIZE	1	3.18	14.51*	7.93	36.66*	3.57	18.26*
SPC*LOC*CHEM	2	5.49	25.08*	9.24	42.73*	4.11	20.99*
SPC*LOC*MON	6	5.13	23.43*	7.59	35.09*	3.72	19.00*
SPC*SIZE*CHEM	2	0.11	0.51*ns*	0.39	1.82*ns*	0.08	0.38*ns*
SPC*SIZE*MON	6	4.59	20.98*	5.83	26.93*	3.36	17.19*
SPC*CHEM*MON	12	57.05	260.56*	62.27	287.88*	60.60	309.67*
LOC*SIZE*CHEM	2	5.50	25.11*	7.22	33.36*	1.85	9.46*
LOC*SIZE*MON	6	0.73	3.34*	2.26	10.46*	2.26	11.72*
LOC*CHEM*MON	12	5.88	26.84*	4.47	20.64*	3.96	20.22*
SIZE*CHEM*MON	12	3.21	14.65*	2.18	10.09*	1.84	9.39*
SPC*SIZE*CHEM	2	5.20	23.74*	10.26	47.45*	5.63	38.75*
SPC*LOC*SIZE*MON	6	0.86	3.92*	1.72	7.94*	2.27	11.60*
SPC*SIZE*CHEM*MON	12	3.73	17.05*	1.91	8.83*	2.82	14.44*
LOC*SIZE*CHEM*MON	12	0.79	3.63*	2.33	10.79*	0.75	3.81*
SPC*LOC*CHEM*MON	12	2.04	9.31*	2.34	10.81*	1.70	8.69*
SPC*LOC*SIZE*CHEM*MON	12	0.27	1.22*ns*	0.30	1.39*ns*	0.33	1.68*ns*
ERROR	504	0.219		0.216		0.219	
CORRECTED TOTAL	671						

Note: SPC = species; LOC = location; CHEM = type of preservative; CON = preservative concentration MON = months; *ns* = not significant; * = significant

However, the samples treated with CCA or CCB were significantly protected from termite and soft rot as compared to untreated samples. The difference in performance of CCA and CCB preservatives between kempas and meranti might be due to the reaction of CCA and CCB with the carbohydrates (Pizzi 1990a), wood lignin (Pizzi 1990b) and the salt distribution in the respective wood (Salamah & Zaitun 1991). The amount of lignin and carbohydrates in the respective wood may affect the amount of stable insoluble complexes formed by Cr with lignin (Pizzi

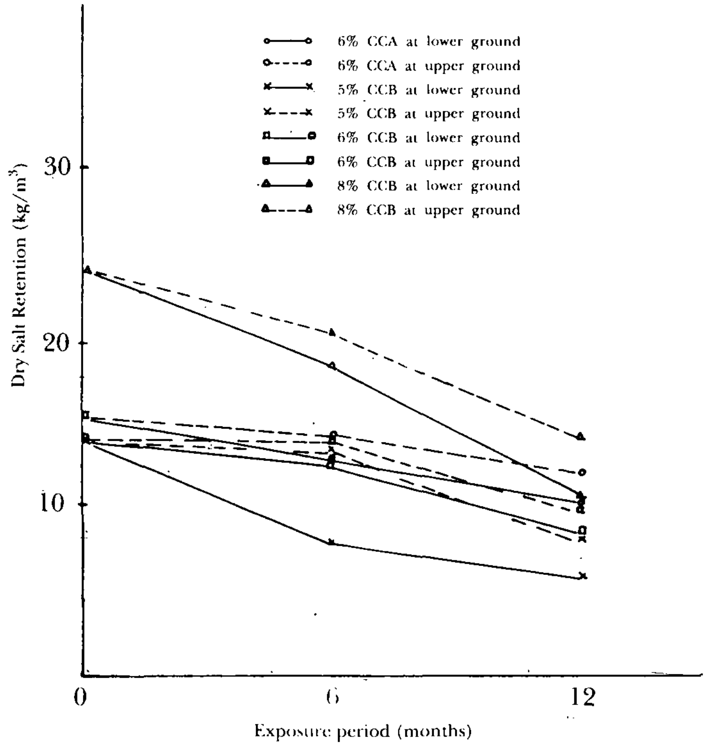

Figure 9. The amount of dry salt retention in CCB and CCA treated kempas at two different test sites for sample size of 0.75 × 0.75 × 24 *in*

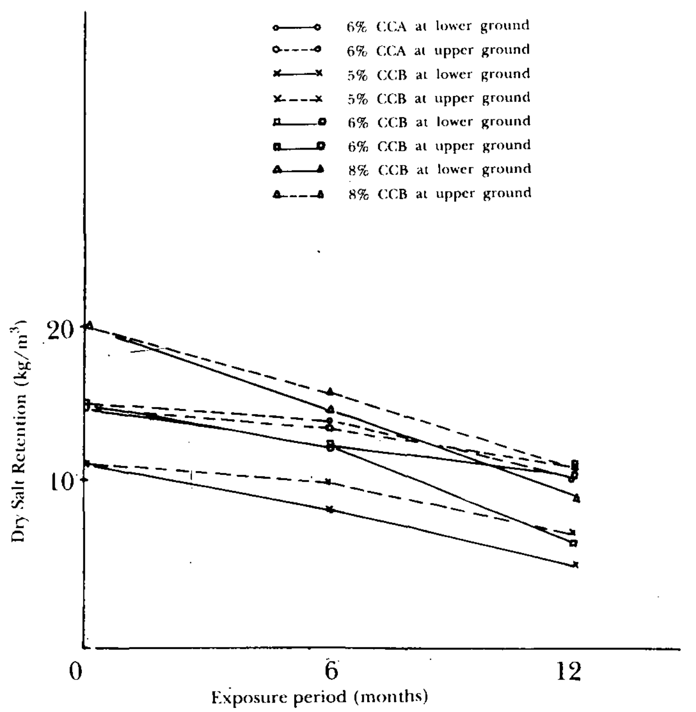

Figure 10. The amount of dry salt retention in CCB and CCA treated kempas at two different test sites for sample size of 0.75 × 0.75 × 24 *in*

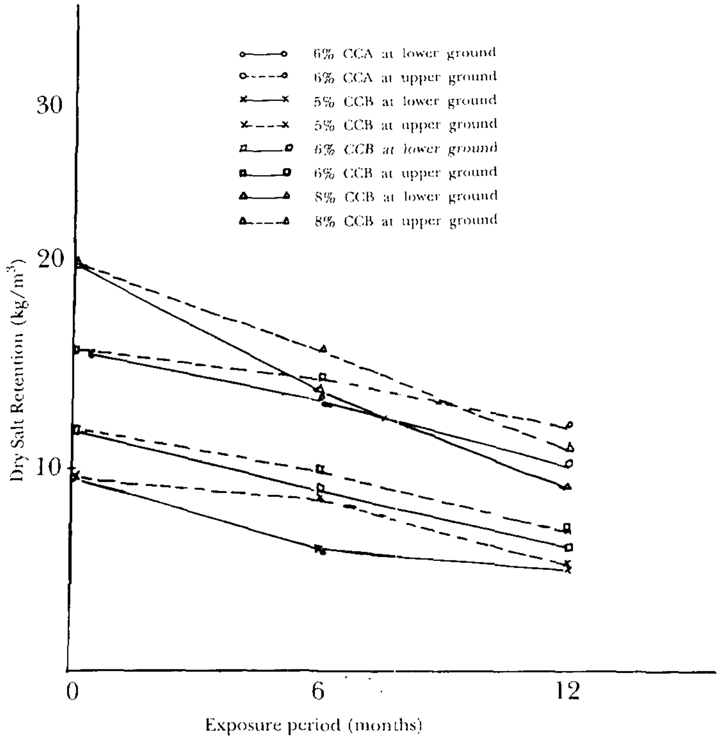

Figure 11. The amount of dry salt retention in CCB and CCA treated meranti tembaga at two different test sites for sample size of $0.75 \times 0.75 \times 24$ *in*

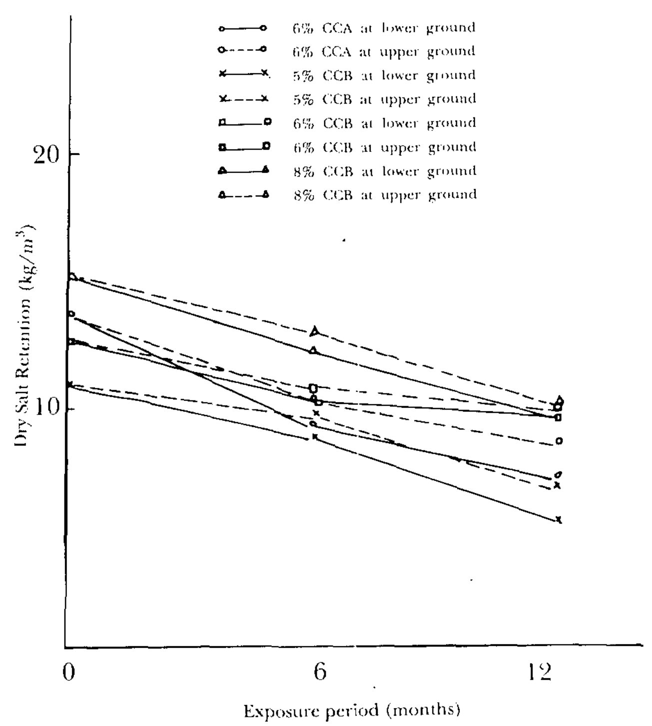

Figure 12. The amount of dry salt retention in CCB and CCA treated meranti tembaga at two different test sites for sample size of $0.75 \times 0.75 \times 24$ *in*

1979, 1982; Hon & Chang 1985). Statistical analysis based on various CCB preservative concentrations shows no significant difference in treatment at concentrations of 8, 6 and 5% m/v up to 21 months exposure for kempas and up to 3 months exposure for meranti tembaga against wood destroying agents. The effect of preservative concentration was detected to be highly significant only after 21 months exposure for kempas and 3 months for meranti. Samples treated with concentration 8% m/v show no significant difference to samples with concentration 6% m/v. However, samples treated with concentrations 8 and 6% m/v were significantly better protected that those treated with concentration 5% m/v.

The result from this study shows that the sample size at 0.75 × 0.75 × 24 *in* was not significantly different from that at 1.5 × 0.25 × 24 *in* based on the grade index. However, the latter sample size caused easy mechanical damage to the samples during the test, especially for meranti tembaga.

Assessment at various months after exposure at the test plots shows that the grade index of samples significantly decreased as the number of months increased. It means that the samples were more susceptible toward termite or/with fungus when the samples were left longer in the ground. One reason might be due to the leachability of the respective salt in the treated wood (Tables 5 and 6). Three types of subterranean termites were found as the major destroying agents at the plots during the 60 months exposure period, *i.e. Macrotermes maccensis, Coptotermes curvignathus* and *Odontotermes sp.*. Only one type of decay fungus was found on the wood during that period, that is soft rot. However, the type of soft rot attacking the wood was not identified. Both termites and soft rot were found in all samples. Nearly 80% of the wood deterioration was due to termite attack and 20% from soft rot.

There are many types of complexes that can be formed between any individual salt or salts in CCA and CCB with the wood components or extractives. These reactions are still under study by many scientists interested in wood preservation. The individual salt of copper, chromium, arsenic and boron in the treated wood has a tendency to leach out after exposure of the wood to water or rain for a certain period. However, the rate of leaching for boron from the treated wood is much higher than that of the other three chemicals as shown in Tables 5 and 6.

Conclusion

CCA and CCB preservatives gave almost the same degree of protection at 6% of solution strength. The similarity in performance of the two preservatives is interesting, particularly in view of the more severe loss of boron from the CCB treated timber than arsenic from the CCA treated timber.

In this study the most important factors influencing the severity of attack were the site conditions and type of timber. There are many factors which contribute to the performance of treated woods in ground contact such as timber permeability and the distribution of preservative within the wood structure. Further study is recommended for preservative distribution in the wood structure after treatment and the effect of extractives on the preservative fixation.

Table 5. The percentage of individual compounds in treated meranti tembaga stakes at 0, 6 and 12 months exposed in the test plots

				CONTROL			6 MONTHS			12 MONTHS		
Location	Size	Preservative	% m/v	Cu salt	Cr salt	As/B salt	Cu salt	Cr salt	As/B salt	Cu salt	Cr salt	As/B salt
LG	A	CCB	5	0.77	1.30	0.51	0.61	0.81	0.25	0.57	0.68	0.13
			6	0.86	1.68	0.49	0.69	1.22	0.37	0.52	0.84	0.20
			8	1.98	2.33	1.39	1.05	2.47	0.36	0.98	1.39	0.20
		CCA	6	0.72	1.82	1.01	0.51	1.53	0.97	0.38	1.23	0.57
UG	A	CCB	5	0.77	1.30	0.51	0.71	1.24	0.31	0.29	0.87	0.09
			6	0.86	1.68	0.49	0.81	1.44	0.28	0.49	1.15	0.17
			8	1.98	2.33	1.39	1.48	2.07	0.90	0.94	1.78	0.35
		CCA	6	0.72	1.82	1.01	0.57	1.61	1.00	0.45	1.31	0.96
LG	B	CCB	5	0.86	1.13	0.32	0.68	0.99	0.19	0.43	0.72	0.01
			6	1.11	1.52	0.45	0.72	1.12	0.26	0.58	0.93	0.14
			8	1.24	1.89	0.52	1.12	1.45	0.36	0.94	1.14	0.26
		CCA	6	0.63	1.36	0.97	0.52	1.12	0.78	0.43	0.96	0.87
UG	B	CCB	5	0.86	1.13	0.32	0.77	1.01	0.29	0.54	0.83	0.06
			6	1.11	1.52	0.45	0.83	1.27	0.17	0.76	0.97	0.17
			8	1.24	1.89	0.52	1.17	1.58	0.40	0.98	1.33	0.13
		CCA	6	0.63	1.36	0.97	0.40	1.23	0.91	0.26	1.06	0.90

Note: A = 0.75 x 0.75 x 24 *in*   Cu salt = $Cu_2SO_4.5H_2O$
B = 1.5 x 0.25 x 24 *in*   Cu salt = $K_2Cr_2O_7$
LG = Lower ground   As salt = $As_2O_5.2H_2O$

Table 6. The percentage of individual compounds in treated meranti tembaga stakes at 0, 6 and 12 months exposed in the test plots

				CONTROL			6 MONTHS			12 MONTHS		
Location	Size	Preservative	% m/v	Cu salt	Cr salt	As/B salt	Cu salt	Cr salt	As/B salt	Cu salt	Cr salt	As/B salt
LG	A	CCB	5	0.65	1.04	0.13	0.31	0.64	0.10	0.30	0.42	0.05
		CCB	6	0.70	1.16	0.10	0.53	0.87	0.07	0.41	0.57	0.08
		CCB	8	1.14	1.42	0.28	1.95	1.12	0.13	0.47	1.68	0.11
		CCA	6	0.45	0.72	0.68	0.37	0.68	0.49	0.33	1.52	0.39
UG	A	CCB	5	0.65	1.04	0.13	0.59	1.08	0.09	0.48	0.53	0.07
		CCB	6	0.70	1.16	0.10	0.68	0.99	0.07	0.52	1.65	0.05
		CCB	8	1.14	1.42	0.28	1.01	1.21	0.19	0.63	1.98	0.08
		CCA	6	0.45	0.72	0.68	0.47	0.68	0.56	0.41	1.57	0.48
LG	B	CCB	5	0.53	0.62	0.21	0.43	0.51	0.10	0.20	0.37	0.07
		CCB	6	0.77	0.84	0.27	0.69	0.73	0.15	0.33	0.44	0.08
		CCB	8	0.98	1.18	0.18	0.70	1.02	0.12	0.37	0.69	0.09
		CCA	6	0.49	0.69	0.57	0.44	0.68	0.43	0.33	0.56	0.38
UG	B	CCB	5	0.53	0.62	0.21	0.47	0.57	0.19	0.37	0.43	0.08
		CCB	6	0.77	0.84	0.27	0.70	0.90	0.16	0.44	0.71	0.12
		CCB	8	0.98	1.18	0.18	0.81	1.04	0.07	0.49	0.82	0.07
		CCA	6	0.49	0.69	0.57	0.42	0.60	0.22	0.33	0.53	0.46

Note: A = 0.75 x 0.75 x 24 *in* — Cu salt = $Cu_2SO_4.5H_2O$
B = 1.5 x 0.25 x 24 *in* — Cu salt = $K_2Cr_2O_7$
LG = Lower ground — As salt = $As_2O_5.2H_2O$
UG = Upper ground — B salt = H_3BO_3

Based on this study, CCB preservative was found to be effective for wood protection under Malaysian conditions. However, the treated wood can be used only for indoor application which is protected against rain. This is due to the boron in CCB preservative that is largely unfixed in the wood and will leach out when the timber is exposed to rain and ground contact. The actual concentration of wood preservative that should be used in the treatment solution would have to be determined and approved by the relevant authorities.

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