Report on the efficacy trials of new pest control products

Report for testing Protecta C60 for Beat (E.A.) Ltd

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1.0 Introduction

Most untreated wood will be attacked by fungi and insects. Wood in its natural state has got an element of natural durability. This natural durability varies from one species to another and even within the same wood - the heartwood and sapwood. The heartwood, due to its extractives, is more endowed with this durability than the sapwood, which has a lot of sugar/starch deposits that make it susceptible to fungal or insect attack (Panshin, A. J and Zeeuw, C. 1980).

Wood is treated by use of chemicals also known as preservatives whose role is to act as a barrier preventing fungi and insects reaching the starch-rich food in the sapwood. Preservatives can be applied by brushing, dipping, sap displacement or pressure impregnation. The Kenya Standard Specification for Preservation of Timber (KS 02-94: 1985 (Confirmed in 1999)) specifies the requirements for preservative treatment of timber; The preservatives, methods of application and suggested average retention levels have all been specified with the object of achieving long service life**.** Preservatives can be classified into three broad categories: water-borne preservatives, oil-borne preservatives, and light organic solvent preservatives (LOSPs). The efficacy trials will be looking at a water-borne preservative, a chromated copper arsenate (CCA).

Objectives

1. To evaluate the efficacy of **Protecta C 60** test chemical as a wood preservative against termites and selected fungi
2. To test **Protecta C 60** against Tanalith C wood preservative as the standard
3. To make recommendation on the suitability of **Protecta C 60** as a wood preservative

2.0 Materials and Methods

2.1 Wood samples

The wood samples measuring 2cm x 2cm x 2cm were sawn from *Eucalyptus grandis* timber. The Eucalyptus species samples were further differentiated by getting samples from the heartwood and sapwood. A total of 168 samples were prepared.

2.2 The treatment of the blocks

One hundred and eight and thirty-six blocks were pressure treated using Protecta C60 and Tanalith C preservatives respectively. The active ingredient(s) for Protecta C60 are copper oxide, chromic acid and arsenic pentoxide while that of Tanalith C are copper sulphate, sodium dichromate and arsenic acid. The treatments were carried out at 3 concentrations (2%, 4% and 6%) in ascending order from the lowest to the highest concentrations (to minimize waste of the test preservatives) using vacuum/pressure treatment plant based at the Timber Treatment International (TTI) Eldoret in accordance to KS 94: 2008 specification for preservation of timber. An initial vacuum of 20mmHg was introduced and held for 5 minutes. Then pressure of 0.7N/mm2 was applied and held for 10 minutes and a final vacuum of 20mmHg was applied and held for 5 minutes. Thus for each concentration, a total of 12 samples were treated while the remaining blocks were untreated (acted as controls of the experiment). Uptake of the preservative was calculated by weighing the wood blocks before and immediately after treatment to the nearest 0.01g. To allow fixation of the preservative in the treated wood samples, the samples were set aside to dry for two weeks.

2.3 Determination of retention

After treatment, the wood blocks were conditioned to allow for distribution of preservative and oven dried to a constant weight. The blocks were then weighed and retention calculated using the following formula;

$$R = \left(\frac{W_2 - W_1}{V}\right)(\text{concentration of preservative})$$

Where

R = Retention (Kg/m^3)

W_1 = Weight of blocks before treatment (Kg)

W_2 = Weight of blocks after treatment (Kg)

V = Volume of blocks (M^3)

2.4 Leaching or weathering process

The wood samples were weighed again to the nearest 0.01g. The leaching process used was in accordance with Section 9.3 of ENV 1250-2: 1994. This protocol gives the laboratory method for measuring losses by leaching into water. The weight of the samples was determined. Three conditioned samples per treatment were placed in a beaker with a ballasting device and a magnetic

stirrer. 250ml of distilled water (the leaching solution) was added. The contents of the beaker were shaken at a frequency of 60 revolutions per minute. The leaching solution was replaced after 24hr for 4 days. The leachate (the sample of water collected for analysis from the beaker) transferred to another vessel and stored in cold storage facilities for analysis for concentrations of copper, chrome and arsenic using an atomic absorption spectroscopy (AAS). The same procedure would be followed for the second, third and fourth immersions (for each set of treated test specimens) ensuring that in between the immersions the leachate would be transferred and kept aside for analysis

At the end of the leaching process, the wood samples were weighed to the nearest 0.01g and set on racks and exposed to the open laboratory room conditions for 3 days and then set in a conditioning chamber maintained at 25°C and 50% relative humidity for 14 days or until the wood samples reached a constant moisture equilibrium when weighed to the nearest 0.01g.

2.5 Exposure of blocks to termites

Sand was collected, washed and then sterilized in a hot plate for 24 hours. This was put in 108 clear plastic test bottles of 300ml, each ⅓ full. 30 ml of distilled water was sprinkled till the sand was wet and kept for two hours. Two blocks of the treated and untreated blocks were put into the sand in each of the bottle and subterranean termites (*Macrotermes natalensis* widely distributed in Kenya) from a single colony were introduced according to a procedure adapted from AWPA E1-97 standard (Standard method laboratory for evaluation to determine resistance to subterranean termites, 1997). The test bottles were then kept in an incubator at temperatures between 25-28°C. Out of the treated wood blocks, the samples that were exposed to termites were 9 at each concentration.

2.5.1 Assessment of termite attack

The blocks were inspected weekly for visual rating and after four weeks for weight loss techniques in the laboratory test. During each inspection, the blocks were removed, cleaned by scrapping soil or sand off the blocks surfaces and intensity of termite attack assessed. The attack was rated visually and weight loss basis as indicated below:

I. Visual rating:

Rating of the damage was as follows;

Table 1: Visual rating for termite attack

Description of attack	Rating	Percentage
Sound	0	(0% attack)
Trace	1	(1-10% attack)
Slight	2	(11-30% attack)
Moderate	3	(31-50% attack)
Severe	4	(51-80% attack)
Fail	5	(81-100% attack)

Exposure of the samples to termites

2.6 Setting up the accelerated decay test (Exposure of blocks to fungi)

The ASTM Standards D 1413-99 was used to set the accelerated decay tests.

The strains used in this study were the brown-rot fungi *Wolfiporia cocos* and white rot fungi *Trametes versicolor*. They were all provided by the pathology laboratory of KEFRI. The fungus *Wolfiporia cocos* is known to be tolerant to copper compounds, whereas the *Trametes versicolor* is prevalent on hardwoods products. These fungi are recommended in the ASTM standards (D1413-99).

2.6.1 Preparation of soil substrate

The soil substrate used had a water holding capacity of 30% (see Section 2.6.2 on how to determine the water holding capacity). All the soil clumps were broken, mixed and sieved through a sieve of 2mm square to get fine moistened soil. Ensure the soil is not so wet when it is sifted that the particles again stick together. The soil was steam sterilised. The culture containers (of capacity 250ml) were also steam sterilised. Once the sterilised containers were cooled, they were half filled with the sterilised soil.

2.6.2 To determine the water holding capacity of soil

The water holding capacity was determined by first filling a small Bucher funnel of approximately 50 mm in diameter and 25 mm in depth and fitted with rapid-filtering paper with sieved soil. The soil was compacted in the funnel then the soil surface was levelled by cutting off excess soil with a spatula at the top of the funnel without further compaction. The filled funnel was placed in a 400cm^3 beaker and retained in an upright position by wedges at the sides of the funnel. Water was added to the beaker to a depth slightly beyond the level of the filter paper. The soil was allowed to wet by capillarity so as to reduce the danger of entrapping air within the column. When the upper soil surface showed signs of wetting more water was added until the water level was approximately the upper surface of the funnel. The beaker was covered and the soil allowed to soak overnight.

The funnel was placed in a suction flask which was connected to the vacuum pump. Full suction was applied for 15 minutes. During suctioning the funnel was covered with a moist cloth on which an inverted cup was placed to prevent evaporation of water from the exposed soil surface. After 15 minutes the funnel was removed from the suction flask, the soil was scraped into a weighed receptacle and weighed to obtain the wet weight W_1. The soil was oven dried for 24 hours at 105±2ºC and re-weighed, W_2. The water holding capacity (soil moisture) was determined based on the oven dry weight of soil:

$$\text{Water holding capacity (WHC), \%} = [(W_1 - W_2)/ W_2] \times 100$$

2.6.3 Preparation of soil culture containers

Plastic containers with holding capacity of 250 g were prepared and surface sterilized using 95% alcohol. The containers were ½ filled with sterile soil. To determine the amount of additional water needed, the

volume of soil that will be used to half-fill a plastic container was weighed W_3. This soil was dried at 105±2ºC over night and reweighed W_4. The amount of water to be added to each culture container with that particular soil was calculated as follows:

Water required g = (WHC x 0.013 x W_4) + W_4 - W_3

2.6.4 Sterilization of treated wood samples and placement in the culture containers

The treated wood samples were sterilized by putting them by retention groups into containers and steamed at 100±2°C for 20 minutes. After cooling, the wood samples were aseptically placed on the soil in the culture containers with soil.

2.6.5 Selection and preparation of test fungi strains

Three strains of fungi were identified; these were *Trametes versicolor* and *Wolfiporia cocos.* The *Wolfiporia cocos* fungus was selected because it is known to be tolerant to copper compounds. The preservative Protecta C60 is a copper based preservative. The *Trametes versicolor* fungus is a white rot fungus that attacks hardwood products. The cultures containing these fungi were removed from the herbarium culture and left out overnight to attain normal room temperature. After 48 hrs the bottles containing the fungi were taken in the inoculation cabinet for sub-culturing in order to get new and active strains of pathogens. After sub-culturing, the petri dishes containing cultures were then incubated for 2 weeks to allow the fungus to grow in the growth cabinet of 25^{o}C – 30^{o}C.

After incubation, the cultures were taken out (Plate 1and 2); a sterile cock borer (Plate 3) of about 5mm was used to get an inoculum from the petri dishes of a given species of fungi (Plate4).

Plate 1: The sub-cultured *Trametes versicolor* fungus having been incubated for 2 weeks

Plate 2: The sub-cultured *Wolfiporia cocos* (Syn. *Poria cocos*) fungus having been incubated for 2 weeks

Plate 3: Sterilizing the cock borer over a naked flame

Plate 4: Using a cock borer get an inoculum of cultured fungi from the petri dishes

2.6.6 Incubation of test wood blocks

The test wood blocks were weighed before placing them into the culture containers (T_3). During the inoculation process, an inoculum of 5mm from culture plates of a selected fungus was put on the sterilised soil in the culture containers and then a wood block was placed on top of it. (note this was done for all the three fungi). The same procedure of inoculation was done for all concentrations of the test preservative, the standard preservative and controls (one wood block in its own culture container). The culture containers were placed in an incubator set at a temperature of 25^{o}C and kept there for 12 weeks.

2.6.7 Handling of the test wood blocks after exposure to the test fungi

At the end of the 12 weeks the wood blocks were removed from the culture containers. The mycelium was carefully brushed off. Each individual wood block was then weighed to the nearest 0.01 g. The wood blocks were then placed in a conditioning chamber set at 30^{o}C to enable them to attain equilibrium weight. The wood blocks were individually weighed to the nearest 0.01 g (T_4).

The weight loss was calculated from the conditioned weights of the wood block immediately before and after testing as follows:

$$\text{Weight loss, \%} = (100\ (T_3-T_4)/T_3)$$

2.7 Statistical analysis

To evaluate the effect of preservative concentration on the weight loss of the wood blocks for each fungal species, a completely random design was used and then analyzed with the SPSS Statistical Program (Version 17). The variance homogeneity of the variables was verified. The statistical differences were identified using the Tukey test for multiple mean comparisons ($P < 0.05$).

3.0 Results

3.1 Retention of the chemicals

The amount of chemical/preservative absorbed by the wood blocks is the retention which is given as kilograms per cubic metre (Kg/m^3) of wood.

Table 1: Results for amount of retention levels of the chemical in the wood blocks

Chemical	Concentration of chemical	Test material tested	Retention (Kg/m^3)
Protecta C60	2%	Eucalypt heartwood	1.9
		Eucalypt sapwood	2.8
	4%	Eucalypt heartwood	5.3
		Eucalypt sapwood	7.5
	6%	Eucalypt heartwood	4.7
		Eucalypt sapwood	9.7
Tanalith C	2%	Eucalypt heartwood	2.0
		Eucalypt sapwood	2.9
	4%	Eucalypt heartwood	5.7
		Eucalypt sapwood	9.4
	6%	Eucalypt heartwood	6.5
		Eucalypt sapwood	10.6

Generally the sapwood absorbed more preservative than the heartwood. The heartwood is moderately resistant to preservative treatment, and the sapwood is more permeable.

Collection and identification of termites

Termites that were found on the wood blocks were collected for identification. The specimens collected were mainly workers and soldiers.

3.2 Data Analysis

3.2.1 Analysis of the termite tests

The results of the weight losses of wood blocks and termite survival during the termite tests are as follows. [Table 1 (pg 4) was used to rank termite attack]

Table 2: Results for testing using termites

Chemical / Preservative	Concentration (%)	sample code	Initial wt (g)	Oven dry wt. (g)	Final wt. (g)	Wt. Loss (g)	% loss	Ranking	no. of termites after 28 days
Protecta C60	2	Eucalypt sapwood	5.81	3.94	3.80	0.14	4.3	1 (trace)	0
	2	Eucalypt heartwood	6.14	4.27	4.15	0.12	2.7	1 (trace)	0
	4	Eucalypt sapwood	6.72	3.98	3.89	0.09	2.3	1 (trace)	0
	4	Eucalypt heartwood	6.97	4.36	4.29	0.08	1.71	1 (trace)	0
	6	Eucalypt sapwood	5.64	3.71	3.70	0.01	0.25	1 (trace)	0
	6	Eucalypt heartwood	5.32	3.76	3.76	0.01	0.01	1 (trace)	0
Tanalith C	2	Eucalypt sapwood	5.35	3.87	3.79	0.08	2.0	1 (trace)	0
	2	Eucalypt heartwood	6.10	5.38	5.26	0.12	2.3	1 (trace)	0
	4	Eucalypt sapwood	5.69	3.88	3.75	0.14	3.5	1 (trace)	0
	4	Eucalypt heartwood	6.01	5.03	4.95	0.07	1.4	1 (trace)	0
	6	Eucalypt sapwood	5.84	4.29	4.22	0.06	1.4	1 (trace)	0
	6	Eucalypt heartwood	6.71	5.70	5.65	0.05	0.9	1 (trace)	0
Control samples	0	Eucalypt sapwood	3.35	3.87	2.36	1.50	40.1	3 (moderate)	3.67
	0	Eucalypt heartwood	4.47	3.85	2.44	1.41	37.7	3 (moderate)	1.33

*Each value represents the means of six replications

Termite galleries were evident after 28 days on untreated blocks. The galleries increased with increase in blocks exposure time. This was rated as moderate (3). The termites generally did not get in touch with the treated block samples. The termites in these test bottles had slow movement which indicated the effect of the chemicals. Termite survival rate is not related to weight loss at all (Kartel S. N. & F. Green, 2003).

3.2.1.1 Analysis for Protecta C60 against termites

Analysis for the mean weight losses in the wood blocks treated with the different chemical concentrations of Protecta C60 indicated that wood blocks that had no chemical treatment (control blocks) were noted to have higher weight losses than treated blocks (Table 3).

Table 3: The mean and standard deviation of the chemical concentration of Protecta C60

	N	Mean	Std. Deviation
control	12	1.4583	.12443
2	12	.1288	.04596
4	12	.0845	.06143
6	12	.0103	.00916
Total	48	.4205	.61119

To investigate if the difference was significant a one-way Analysis of Variance (ANOVA) was carried out

Table 4: ANOVA of the chemical concentrations of Protecta C60

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	17.321	3	5.774	1076.546	.000
Within Groups	.236	44	.005		
Total	17.557	47			

From the ANOVA (Table 4) it was noted that the significance value (0.00) is less than 0.05 implying that the means of the concentration of the chemicals applied were statistically different in their effect on the weight loss of the wood blocks. To establish which concentration levels are different in terms of the weight loss on the wood blocks, post hoc tests were conducted.

Table 5: Multiple comparisons between the various chemical concentrations using the Tukey HSD

(I) concentration of chemical	(J) concentration of chemical	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
control	2	1.32958*	.02990	.000	1.2498	1.4094
	4	1.37383*	.02990	.000	1.2940	1.4537
	6	1.44808*	.02990	.000	1.3683	1.5279
2	control	-1.32958*	.02990	.000	-1.4094	-1.2498
	4	.04425	.02990	.458	-.0356	.1241
	6	.11850*	.02990	.001	.0387	.1983
4	control	-1.37383*	.02990	.000	-1.4537	-1.2940
	2	-.04425	.02990	.458	-.1241	.0356
	6	.07425	.02990	.077	-.0056	.1541
6	control	-1.44808*	.02990	.000	-1.5279	-1.3683
	2	-.11850*	.02990	.001	-.1983	-.0387
	4	-.07425	.02990	.077	-.1541	.0056

*. The mean difference is significant at the 0.05 level.

The analysis of multiple comparisons indicates that the control wood blocks (no treatment) were significantly different with all the chemical concentrations. There was also a significant difference between 2% and 6% concentrations of Protecta C60.

3.2.1.2 Analysis for Tanalith C against termites

Analysis for the mean weight losses in the wood blocks treated with the different chemical concentrations of Tanalith C indicated that samples that had no chemical treatment were noted to have higher weight losses than treated blocks (Table 6).

Table 6: The mean and standard deviation of the chemical concentration of Tanalith C

	N	Mean	Std. Deviation
control	12	1.4583	.12443
2	12	.0983	.05237
4	12	.1042	.08028
6	12	.0550	.02714
Total	48	.4290	.60583

To investigate if the difference was significant a one-way Analysis of Variance (ANOVA) was carried out

Table 7: ANOVA of the chemical concentrations of Tanalith C

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	16.971	3	5.657	890.653	.000
Within Groups	.279	44	.006		
Total	17.251	47			

From the ANOVA (Table 7) it was noted that the significance value (0.00) is less than 0.05 implying that the means of the concentration of the chemicals applied were statistically different in their effect on the weight loss of the wood blocks. To establish which concentration levels are different in terms of the weight loss on the wood blocks, post hoc tests were conducted.

Table 8: Multiple comparisons between the various chemical concentrations using the Tukey HSD

(I) concentration of chemical	(J) concentration of chemical	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
control	2	1.36000*	.03254	.000	1.2731	1.4469
	4	1.35417*	.03254	.000	1.2673	1.4410
	6	1.40333*	.03254	.000	1.3165	1.4902
2	control	-1.36000*	.03254	.000	-1.4469	-1.2731
	4	-.00583	.03254	.998	-.0927	.0810
	6	.04333	.03254	.548	-.0435	.1302
4	control	-1.35417*	.03254	.000	-1.4410	-1.2673
	2	.00583	.03254	.998	-.0810	.0927
	6	.04917	.03254	.440	-.0377	.1360
6	control	-1.40333*	.03254	.000	-1.4902	-1.3165
	2	-.04333	.03254	.548	-.1302	.0435
	4	-.04917	.03254	.440	-.1360	.0377

*. The mean difference is significant at the 0.05 level.

The analysis of multiple comparisons indicates that the control wood blocks (no treatment) were significantly different with all the chemical concentrations.

3.2.1.3 Compare the two chemicals (Protecta C60 and Tanalith C) against termites

Table 9: Comparison of the mean weight loss after exposure to termites against each chemical

Name of chemical	Mean weight loss	N	Std. Deviation
Protecta C60	.4205	48	.61119
Tanalith C	.4290	48	.60583
Total	.4247	96	.60532

The Tanalith C gave a slightly higher mean of weight loss than with Protecta C60. To assess if the difference was significant a one-way ANOVA was carried out.

Table 10: ANOVA of the chemicals against termite attack

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.002	1	.002	.005	.946
Within Groups	34.808	94	.370		
Total	34.809	95			

The significance level is 0.946 which is greater than 0.05. This implies that there was no significant difference between the Protecta C60 and the Tanalith C in terms of their effectiveness on weight loss of the wood sample as regards termite attack.

Table 11: Performance of the chemicals at various concentrations

concentration of chemical	Mean weight loss	N	Std. Deviation
control	1.4583	24	.12169
2	.1135	24	.05063
4	.0943	24	.07062
6	.0326	24	.03024
Total	.4247	96	.60532

The control samples had the highest mean weight loss while the samples that had 6% chemical applied had least mean weight loss. To assess if the difference was significant a one-way ANOVA was carried out.

Table 12: ANOVA of the chemical concentrations

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	34.274	3	11.425	1963.388	.000
Within Groups	.535	92	.006		
Total	34.809	95			

The significance value (0.00) is less than 0.05 implying that the means of the concentration of the chemicals applied were statistically different in their effect on the weight loss of the sample material. To establish which concentration levels are different in terms of the weight loss on the sample material, post hoc tests were conducted.

Table 13: Multiple comparisons between the various chemical concentrations using the Tukey HSD

(I) concentration of chemical	(J) concentration of chemical	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
control	2	1.34479*	.02202	.000	1.2872	1.4024
	4	1.36400*	.02202	.000	1.3064	1.4216
	6	1.42571*	.02202	.000	1.3681	1.4833
2	control	-1.34479*	.02202	.000	-1.4024	-1.2872
	4	.01921	.02202	.819	-.0384	.0768
	6	.08092*	.02202	.002	.0233	.1385
4	control	-1.36400*	.02202	.000	-1.4216	-1.3064
	2	-.01921	.02202	.819	-.0768	.0384
	6	.06171*	.02202	.031	.0041	.1193
6	control	-1.42571*	.02202	.000	-1.4833	-1.3681
	2	-.08092*	.02202	.002	-.1385	-.0233
	4	-.06171*	.02202	.031	-.1193	-.0041

*. The mean difference is significant at the 0.05 level.

The significance values of the comparison between the control and the chemical concentration levels of 2%, 4% and 6% levels were less than 0.05. This means that the chemical concentration levels and the control are significantly different from the control on their effect on the weight loss of the sample material. There is also significant difference between the concentration level 6% with all the concentration levels.

3.2.2 Results for the accelerated decay tests

Weight loss resulting from fungal attack is the method most frequently used to determine the effectiveness of a preservative treatment to protect wood from decay. Decay resistance can be expressed as either weight loss or residual weight according to ASTM D 2017-81 shown as follows:

Table 14: Decay resistance expressed as either weight loss or residual weight

Average weight loss (%)	Average residual weight (%)	Indicated class of resistance to a specified test fungus
0 – 10	90 – 100	Highly resistant (HR)
11 – 24	76 – 89	Resistant (R)
25 – 44	56 – 75	Moderately resistant (MR)
45 or above	55 or less	Slightly resistant or non- resistant (NR)

Table 15: The mean percentage weight loss of the wood blocks and their performance rating

Chemical	Concentration of chemical	Fungus exposed	Test material tested	Mean % weight loss	Rating
Protecta C60	2%	*Trametes versicolor*	Eucalypt heartwood	5.3	HR
			Eucalypt sapwood	5.1	HR
		Wolfiporia cocos	Eucalypt heartwood	7.9	HR
			Eucalypt sapwood	5.3	HR
	4%	*Trametes versicolor*	Eucalypt heartwood	5.0	HR
			Eucalypt sapwood	4.7	HR
		Wolfiporia cocos	Eucalypt heartwood	5.5	HR
			Eucalypt sapwood	5.8	HR
	6%	*Trametes versicolor*	Eucalypt heartwood	5.2	HR
			Eucalypt sapwood	5.8	HR
		Wolfiporia cocos	Eucalypt heartwood	5.7	HR
			Eucalypt sapwood	5.6	HR
Tanalith C	2%	*Trametes versicolor*	Eucalypt heartwood	4.0	HR
			Eucalypt sapwood	9.9	HR
		Wolfiporia cocos	Eucalypt heartwood	8.9	HR
			Eucalypt sapwood	9.0	HR
	4%	*Trametes versicolor*	Eucalypt heartwood	5.0	HR
			Eucalypt sapwood	5.2	HR
		Wolfiporia cocos	Eucalypt heartwood	12.0	R
			Eucalypt sapwood	6.7	HR
	6%	*Trametes versicolor*	Eucalypt heartwood	5.5	HR
			Eucalypt sapwood	5.5	HR
		Wolfiporia cocos	Eucalypt heartwood	4.4	HR
			Eucalypt sapwood	4.7	HR
	Control	*Trametes versicolor*	Eucalypt heartwood	11.4	R
			Eucalypt sapwood	11.6	R
		Wolfiporia cocos	Eucalypt heartwood	13.0	R
			Eucalypt sapwood	11.8	R

The results of the ranking fungal attack (Table 15) shows generally the chemical treatments made the wood blocks highly resistant to fungal attack. However, the control blocks were rated resistant with weight loss ranging between 11- 24%.

3.2.2.1 Analysis for Protecta C60 against fungi

Analysis for the mean weight losses in the wood blocks treated with the different chemical concentrations of Protecta C60 indicated that samples that had no chemical treatment were noted to have higher weight losses than treated blocks (Table 16).

Table 16: Performance of the Protecta C60 at various concentrations against selected fungi

	N	Mean	Std. Deviation
control	12	.5042	.12894
2% concentration of chemical	12	.2592	.11123
4% concentration of chemical	12	.2133	.04812
6% concentration of chemical	12	.2267	.02741
Total	48	.3008	.14786

The mean weight loss from the control wood blocks was higher than that obtained by the treated blocks. To investigate if the difference was significant, a one-way Analysis of Variance (ANOVA) was carried out

Table 17: ANOVA of the chemical concentrations of Protecta C60

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.675	3	.225	28.062	.000
Within Groups	.353	44	.008		
Total	1.028	47			

The significance value (0.00) is less than 0.05 implying that the means of the concentration of the chemicals applied were statistically different in their effect on the weight loss of the sample material. To establish which concentration levels are different in terms of the weight loss on the sample material, post hoc tests were conducted

Table 18: Multiple comparisons between the various chemical concentrations using the Tukey HSD

(I) concentration of the chemical applied	(J) concentration of the chemical applied	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
control	2% concentration of chemical	.24500*	.03655	.000	.1474	.3426
	4% concentration of chemical	.29083*	.03655	.000	.1932	.3884
	6% concentration of chemical	.27750*	.03655	.000	.1799	.3751
2% concentration of chemical	control	-.24500*	.03655	.000	-.3426	-.1474
	4% concentration of chemical	.04583	.03655	.597	-.0518	.1434
	6% concentration of chemical	.03250	.03655	.810	-.0651	.1301
4% concentration of chemical	control	-.29083*	.03655	.000	-.3884	-.1932
	2% concentration of chemical	-.04583	.03655	.597	-.1434	.0518
	6% concentration of chemical	-.01333	.03655	.983	-.1109	.0843
6% concentration of chemical	control	-.27750*	.03655	.000	-.3751	-.1799
	2% concentration of chemical	-.03250	.03655	.810	-.1301	.0651
	4% concentration of chemical	.01333	.03655	.983	-.0843	.1109

*. The mean difference is significant at the 0.05 level.

The significance values of the comparison between the control and the chemical concentration levels of 2%, 4% and 6% levels were less than 0.05. This means that the chemical concentration levels and the control are significantly different. However, the different chemical concentration levels are not statistically significant from each other in their effect on the weight loss of the sample material.

To investigate the effect of Protecta C60 on the selected the fungi ANOVA was carried out after computing the mean weight loss for each fungus (Table 19)

Table 19: Effect of Protecta C60 on the test fungus

	N	Mean	Std. Deviation
trametes	24	.2908	.15592
poria	24	.3108	.14197
Total	48	.3008	.14786

Table 20: ANOVA for effect of Protecta C60 on the test fungus

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.005	1	.005	.216	.644
Within Groups	1.023	46	.022		
Total	1.028	47			

The significance value (0.644) is greater than 0.05 implying that the means of the weight loss against the two fungi is not significantly different.

To investigate the effect of Protecta C60 on the selected wood block sections (heartwood or sapwood) an ANOVA (Table 22) was carried out after computing the mean weight loss for different wood sections (Table 21)

Table 21: The effect of the weight loss on the selected wood block sections of either heartwood or sapwood

	N	Mean	Std. Deviation
eucalypt heartwood	24	.3104	.15014
eucalypt sapwood	24	.2913	.14813
Total	48	.3008	.14786

Table 22: ANOVA for effect of Protecta C60 on selected wood block sections of either heartwood or sapwood

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.004	1	.004	.198	.658
Within Groups	1.023	46	.022		
Total	1.028	47			

The significance value (0.658) is greater than 0.05 implying that the means of the weight loss against the two wood sections is not significantly different.

3.2.2.2 Analysis for Tanalith C against fungi

Analysis for the mean weight losses in the wood blocks treated with the different chemical concentrations of **Tanalith C** indicated that samples that had no chemical treatment were noted to have higher weight losses than treated blocks (Table 23).

Table 23: Performance of the Tanalith C at various concentrations against selected fungi

	N	Mean	Std. Deviation	Maximum
control	12	.5042	.12894	.71
2% concentration of chemical	12	.3267	.14896	.58
4% concentration of chemical	12	.2975	.23814	.86
6% concentration of chemical	12	.2125	.08946	.45
Total	48	.3352	.18906	.86

To investigate if the difference was significant a one-way Analysis of Variance (ANOVA) was carried out

Table 24: ANOVA of the chemical concentrations of Tanalith C

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.541	3	.180	6.970	.001
Within Groups	1.139	44	.026		
Total	1.680	47			

The significance value (0.00) is less than 0.05 implying that the means of the concentration of the chemicals applied were statistically different in their effect on the weight loss of the sample material. To establish which concentration levels are different in terms of the weight loss on the sample material, post hoc tests were conducted

Table 25: Multiple comparisons between the various chemical concentrations using the Tukey HSD

(I) concentration of the chemical applied	(J) concentration of the chemical applied	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
control	2% concentration of chemical	.17750*	.06568	.046	.0021	.3529
	4% concentration of chemical	.20667*	.06568	.015	.0313	.3820
	6% concentration of chemical	.29167*	.06568	.000	.1163	.4670
2% concentration of chemical	control	-.17750*	.06568	.046	-.3529	-.0021
	4% concentration of chemical	.02917	.06568	.970	-.1462	.2045
	6% concentration of chemical	.11417	.06568	.317	-.0612	.2895
4% concentration of chemical	control	-.20667*	.06568	.015	-.3820	-.0313
	2% concentration of chemical	-.02917	.06568	.970	-.2045	.1462
	6% concentration of chemical	.08500	.06568	.571	-.0904	.2604
6% concentration of chemical	control	-.29167*	.06568	.000	-.4670	-.1163
	2% concentration of chemical	-.11417	.06568	.317	-.2895	.0612
	4% concentration of chemical	-.08500	.06568	.571	-.2604	.0904

*. The mean difference is significant at the 0.05 level.

The significance values of the comparison between the control and the chemical concentration levels of 2%, 4% and 6% levels were less than 0.05. This means that the chemical concentration levels and the control are significantly different from the control on their effect on the weight loss of the wood blocks. However, the different chemical concentration levels are not statistically significant from each other in their effect on the weight loss of the wood blocks.

Table 26: Effect of Tanalith C on the test fungus

	N	Mean	Std. Deviation
trametes	24	.3096	.17758
poria	24	.3608	.20035
Total	48	.3352	.18906

Table 27: ANOVA of Tanalith C on the test fungus

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.032	1	.032	.880	.353
Within Groups	1.648	46	.036		
Total	1.680	47			

The significance value (0.658) is greater than 0.05 implying that the means of the weight loss against the two wood sections is not significantly different.

Table 28: The effect of the weight loss on the selected wood block sections of either heartwood or sapwood

	N	Mean	Std. Deviation
eucalypt heartwood	24	.3454	.21871
eucalypt sapwood	24	.3250	.15809
Total	48	.3352	.18906

Table 29: ANOVA of the weight loss on the selected wood block sections of either heartwood or sapwood

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.005	1	.005	.137	.713
Within Groups	1.675	46	.036		
Total	1.680	47			

The significance value (0.713) is greater than 0.05 implying that the means of the weight loss against the two wood sections is not significantly different.

3.2.2.3 Compare the two chemicals (Protecta C60 and Tanalith C) against fungi

Table 30: Comparison of the performance of the chemicals applied against selected fungi

Name of chemical applied	Mean weight loss	N	Std. Deviation
protecta C60	.3008	48	.14786
tanalith C	.3352	48	.18906
Total	.3180	96	.16970

The highest mean of weight loss was with Tanalith C. To assess if the difference was significant a one-way ANOVA was carried out.

Table 31: ANOVA of the chemicals against fungal attack

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.028	1	.028	.985	.324
Within Groups	2.708	94	.029		
Total	2.736	95			

The significance level is 0.324 which is greater than 0.05. This implies that there was no significant difference between the Protecta C60 and the Tanalith C in terms of their effectiveness on weight loss of the wood sample.

Table 32: Performance of the chemicals at various concentrations against fungal attack

Concentration of the chemical applied	Mean	N	Std. Deviation
control	.5042	24	.12611
2% concentration of chemical	.2929	24	.13311
4% concentration of chemical	.2554	24	.17343
6% concentration of chemical	.2196	24	.06511
Total	.3180	96	.16970

The control samples had the highest weight loss mean while the samples that had 6% chemical applied had least weight loss mean. To assess if the difference was significant a one-way ANOVA was carried out.

Table 33: ANOVA of the chemical concentrations against fungal attack

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.173	3	.391	23.028	.000
Within Groups	1.563	92	.017		
Total	2.736	95			

The significance value (0.00) is less than 0.05 implying that the means of the concentration of the chemicals applied were statistically different in their effect on the weight loss of the sample material. To establish which concentration levels are different in terms of the weight loss on the sample material, post hoc tests were conducted.

Table 34: Multiple comparisons between the various chemical concentrations using the Tukey HSD

(I) concentration of the chemical applied	(J) concentration of the chemical applied	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
control	2% concentration of chemical	.2113*	.03599	.000	.1168	.3057
	4% concentration of chemical	.2488*	.03599	.000	.1543	.3432
	6% concentration of chemical	.2846*	.03599	.000	.1901	.3790
2% concentration of chemical	control	-.2113*	.03599	.000	-.3057	-.1168
	4% concentration of chemical	.0375	.03599	.725	-.0569	.1319
	6% concentration of chemical	.0733	.03599	.183	-.0211	.1678
4% concentration of chemical	control	-.2488*	.03599	.000	-.3432	-.1543
	2% concentration of chemical	-.0375	.03599	.725	-.1319	.0569
	6% concentration of chemical	.0358	.03599	.752	-.0586	.1303
6% concentration of chemical	control	-.2846*	.03599	.000	-.3790	-.1901
	2% concentration of chemical	-.0733	.03599	.183	-.1678	.0211
	4% concentration of chemical	-.0358	.03599	.752	-.1303	.0586

Based on observed means.
The error term is Mean Square (Error) = .016.

*. The mean difference is significant at the .05 level.

The significance values of the comparison between the control and the chemical concentration levels of 2%, 4% and 6% levels were less than 0.05. This means that the chemical concentration levels and the control are significantly different from the control on their effect on the weight loss of the wood block. However, the different chemical concentration levels are not statistically significant from each other in their effect on the weight loss of the sample material.

4.0 Conclusions

The test chemical Protecta C60 compared well with the Tanalith C chemical for both tests of resistance against termites and selected fungi. There was no significant difference between the Protecta C60 and the Tanalith C in terms of their effectiveness on weight loss of the wood sample as regards termite attack and fungal attack.

The three concentrations for each of the chemicals were also not significant different with the termite tests. The chemical deterred the termites and any weight loss was not significant. However, for the fungal tests generally there was significant difference between the concentrations at 2% and 6% for Protecta C60. For Tanalith C, the chemical concentrations were not significant different.

Protecta C60 is suitable to be used as a wood preservative against subterranean termites and fungal attack. It is recommended at least 4% concentration to be used for Protecta C60 to have full protection against termites and fungi.

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