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EFFICACY OF COMMONLY USED WOOD PRESERVATIVES AGAINST SUBTERRANEAN TERMITES IN AKUNGBA-AKOKO, ONDO STATE, NIGERIA

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ABSTRACT

The efficacy of three commonly used wood preservatives in Akungba-Akoko, against subterranean termites attack was investigated using three lesser durable wood species. Samples were prepared according to ASTM D3345-17 for durability test. All samples were oven dried for 24 hours at 103±2 ^oC prior to preservative treatments. Treated wood samples were buried half way in the soil and exposed to subterranean termites for 12 weeks at a timber grave yard. Weekly visual rating of the stakes was performed, while a gravimetric weight loss assessment was carried out after the 12 weeks of exposure. Results revealed the presence of two termite species: Macrotermes subhyalinus Rambur and Microtermes spp. within the graveyard. Density of the wood species ranged from 542.28±42.40 Kg/m^3 (P. macrocarpa) to 237.99±6.94 Kg/m^3 (R. heudelotii). Kinematic viscosities (25 ^oC) of the liquid preservatives ranged from 1433.25±30.96 cSt (Timbguard™) to 3909.75±225.76 cSt (Solignum). Preservative absorption capacity ranged from 7.82±2.31 % (P. macrocarpa treated with spent engine oil) to 52.16±9.36 % (R. heudelotii treated with Timbguard™), while preservative retention ranged from 2.57±0.17 Kg/m^3 (R. heudelotii treated with spent engine oil) to 14.42±1.13 Kg/m^3 (A. boonei treated with Timbguard™). All the three preservatives were effective in protecting the three selected wood species with gravimetric weight loss values less than 10 %; establishing their efficacy in protecting wood material against subterranean termites.

Keywords: Wood preservatives, subterranean termites, Preservative efficacy, Wood protection

INTRODUCTION

Throughout the course of history, wood has remained one of the most important renewable natural resources available to mankind, owing to its several plus properties such as excellent strength-to-weight ratio properties, relatively low price and with low tooling cost, all of which render it desirable for a broad variety of applications (Emmanuel and Owoyemi, 2018; González-Laredo *et al.*, 2015; Hingston *et al.*, 2001).

On the other hand, one of the major objections to the use of wood from most tree species for specific purposes such as in outdoor applications is related to their low resistance to the natural processes of degradation (Hill, 2006; Yalinkilic, 1999). Although some indigenous tropical wood species are naturally durable to biodeteriorating agents, however, they are in short supply, leading to the influx of a wide variety of lesser used/durable and fast grown plantation timber species requiring adequate protection (Emmanuel and Owoyemi, 2018).

The occurrence and spread of wood biodeteriorating agents such as termites have led to serious damage to wood products in service as well as other lignocellulosic materials and these have been a serious concern for wood users and foresters. In tropical regions, due to their high diversity, termites cause a very serious damage (Ghaly and Edwards, 2011). They are very prominent and of great economic importance among all wood destroying agents as a result of their destructive nature and wood products in use throughout the world are subject to infestation by insects such as termites

(Owoyemi *et al.*, 2012; Bowyer *et al.* 2003). Previous research has further shown that the subterranean termites attack against buildings mainly occur in areas formerly occupied by one vegetation or the other (Kuswanto; 2015; Mo *et al.*, 2006).
Termites destroy wood by feeding on its structural components; with cellulose being their principal food, thereby reducing its structural ability and appearance. This implies that wood and wood products such as paper, fabrics and wood structures are avidly consumed, and hence, a constant effort is directed towards their control or prevention (Brossard *et al.*, 2007; Peralta *et al.* 2004). Therefore, in outdoor applications, in order to arrest this destructive situation and reduce the loss incurred terms of money and materials, a form of preservative treatment must be given; which are chemical preservatives in most general cases to prevent damage by these aggressive bio-deteriorating agents (Evans, 2002; Schultz and Nicholas, 2002; Craig *et al.*, 2001).

The use of suitable chemical preservatives substantially extends the useful service life of wood products and structures, thereby, limiting the overhead costs of maintenance and replacement of such products or structures; and providing for a more sustainable and efficient use of timber resources. Existing knowledge have established that some preservatives are more effective than others, with some being more adaptable to certain use requirements (Lebow, 2010). Lebow (2010) also stated that the degree of protection achieved using chemical preservatives depends on the type preservative used as well as proper penetration (absorption) and retention of the chemicals; which are both in turn dependent on the wood species being treated and the treatment process adopted.
On the other hand, it is a common practice amongst contractors and house owners in Nigeria to buy wood and use it directly for construction work without going through the preservative treatment process (Emmanuel and Owoyemi, 2018; Owoyemi and Olaniran, 2014). However, in cases where they adopt preservative treatment, they purchase chemical preservatives based on the merchant's recommendation, without knowing their efficacy (Emmanuel and Owoyemi, 2018).
Consequently, it becomes imperative that common wood preservatives adopted in any locality must go through testing process to ascertain its efficacy as well as level of effectiveness for commonly used wood species before being recommended for use to avoid construction failure.

This study therefore sought to ascertain the efficacy of some commonly used chemical wood preservatives on three commonly used wood species in Akungba-Akoko LGA of Ondo State, Nigeria with a view to providing baseline information and guide to builders, estate developers, and home owners.

MATERIALS AND METHODS

Study Area

This study was carried out at a timber grave yard located within the Adekunle Ajasin University Akungba-Akoko (AAUA), campus in Ondo State, Nigeria. Akungba-Akoko is one of the major towns in Akoko South-West local government Area of Ondo State, Nigeria situated between latitudes 7°21' N and 7°31' N of the equator and longitudes 5°22' E and 5°30' E of Greenwich meridian, and is bounded by Ikare-Akoko to the North, Oba-Akoko to the South, while to the East and West by Iwaro-Oka and Supare-Akoko respectively (Allen, 2012).
The vegetation of the area is of rain forest type, while the climate of the study area is equatorial with two peaks of rainfall and mean annual rainfall of 1500-2000 mm. The first peak comes up between April and July while the second peak falls between late August and October. Also, the relative humidity of 75 - 95% results into severe cold condition in most cases, while the mean annual temperature is in the range of 23-26°C (Olabode, 2014).

Collection and Identification of Termite Species at the Study Site

Termites specimens (workers and soldiers) found at the study site were collected using plastic insect specimen tubes filled with 10 mL of ethanol. The collected specimens were taken to the Center for Termites` Research, Identification and Management, Department of Biology, Federal University of Technology Akure for proper identification.
The identification procedure followed both internal and external morphology assessment of each termite specimen collected from the site. External

morphology for the termite's species identification was carried out after the termites were fixed in dehydrated ethanol series (70 to 100 %), while the internal morphology assessment was carried out after enteric valve armature of the termites were removed, dissected and fixed in alcoholic Bouin's fluid and observed under a scanning electron microscope for verification.

Wood Species Selection and Preparation

Wood species selected for this study include *Alstonia boonei*, *Pterygota macrocarpa* and, *Ricinodendron heudelotii* based on preliminary investigations on the most commonly used species in the locality. Commercial sized boards were purchased from a local sawmill "Kuteyi sawmill" located in Iwaro-Oka Akoko south-west LGA of Ondo State. Samples of green dimensions 35 mm × 35 mm × 450 mm (Tangential × Radial × Longitudinal) were prepared according to ASTM D3345-17 for the durability tests, while smaller test samples (20 mm × 20 mm × 60 mm) were used for basic wood property determination.

Wood conversion processes were carried out at the wood workshop of the Department of Forestry and Wood Technology, Federal University of Technology Akure. All samples were carefully labeled for ease of identification and weighed (T_1) to determine their initial weight prior to oven drying the samples, after which they were oven dried for 24 hours at 103±2 ^oC until a constant weight is attained. The samples were thereafter weighed again (T_2) and their dimensioned obtained prior to preservative treatments and/or tests.

Preservative Selection, Preparation and Treatment Process

Three (3) commonly used chemical preservatives namely: spent automobile engine oil, Solignum, and Timbguard™ were selected based on the findings of the preliminary investigation carried out in the study area.

The preservative treatment process of the oven dried wood samples of the selected wood species followed a cold-dipping treatment process for 24 hours at room temperature and under atmospheric pressure inside a 25-liter plastic keg with one of its sides cut open. The samples were removed after 24 hours and drained for few hours to remove excess chemicals, after which they were weighed again (T_3) as a measure of the preservative uptake by the samples. Another set of samples of equal replicates were not treated and were used as controls.

Testing Methods

Wood density

Density of the selected wood species used in this study was determined using:

$$\text{Density } (\rho) = \frac{\text{mass of oven dried sample}}{\text{Volume of oven dried sample}} \quad \ldots\ldots (1)$$

Viscosity of preservative chemicals

Viscosity is a measure of a fluid's resistance to flow under an applied force. It describes the internal friction of a moving fluid; i.e. a fluid with large viscosity resists motion more than one with a smaller viscosity and vice versa.

The kinematic viscosity of the selected chemical preservatives in this study was determined using a Brookfield series of Zahn cup (#3). To determine the viscosity of each preservative liquid, the Zahn cup (#3) is dipped into a container bearing the preservative until completely filled and submerged in the preservative. After lifting the cup out of the substance vertically out of the preservative, a timing device was simultaneously started when the top edge of the Zahn cup breaks the surface of the liquid and the timing stopped when the liquid streaming out of cup breaks up, which was recorded correspondingly as the "efflux time". The kinematic viscosity of each preservative was calculated using:

$$V = 11.7\,(t - 7.5) \ldots\ldots\ldots (2)$$

Where:

V = Kinematic viscosity of the preservative in centistokes (cSt)

t = Efflux time recorded for that preservative

Preservative Absorption Capacity

Absorption refers to the amount of chemical preservatives that enters into the wood sample's void space. The preservatives percentage absorption capacity for each of the three wood species used in this study were calculated using:

Absorption (%) = $\frac{T_3 - T_2}{T_2} \times 100$………… (3)

Where:
T_2 = Oven-dry weight of the wood sample prior to preservative treatment
T_3 = Weight of the sample after preservative treatment

Preservative Retention

Retention is the amount of the preservative active ingredient retained in the wood after completion of the treatment cycle.

Preservative retention of treated samples was calculated as follow;

Retention = $\frac{GC}{V} \times 10$ ……… (4)

Where:
G = T_3 - T_2 = initial weight of the wood before treatment subtracted from weight of wood after treatment;
C = grams of preservatives of treating solution; and
V = volume of treated sample in cm^3

Experimental Design

This study was laid out as a Randomized Complete Block Design (RCBD) experiment including 3 wood species and 3 preservative chemicals. Each treatment (i.e. preservative treatment given) was replicated five (5) times for each wood species.

Field (Timber Graveyard) Testing of Wood Samples against Termites

The site for the graveyard was first cleared and cleaned of debris, after which termite activities were stimulated by the introduction of shredded old news print and sprinkling of wood shavings. After one week of observable termite activities, the treated as well as control wood samples were taken to the timber graveyard site and were pegged at a depth of 225 mm into the soil with inter and intra spacing of 1000 mm and 500 mm between each stake (Figure 1) and left for a period of 12 weeks, during which a weekly visual observation of the samples were carried out according to ASTM D2017-05 standard. At the end of the 12 weeks of field testing, the wood samples were withdrawn, oven dried and weighed (T4) to obtain the gravimetric weight loss as a measure of the extent to which the samples were attacked by termites.

Figure 1: Timber graveyard site used for the study

Weekly Visual Assessment of Termite Activities

The weekly visual assessment was carried out for a period of twelve (12) weeks to assess the severity of termite attack on the treated and control wood samples and the rating was done according to ASTM D2017-05 ratings:

10 - (Sound, surface nibbles permitted),
9 - (Light attack),
7 - (Moderate attack with bore holes),
4 - (Heavy attack),
0 - (Failure).

Gravimetric Weight Loss Assessment

At the end of the experiment, the wood samples were withdrawn and weighed (T_4), and the gravimetric weight loss due to termite attack was calculated using:

Weight loss (%) = $\frac{T_3 - T_4}{T_3} \times 100$ ……… (5)

Where:

T3 = conditioned weight after treatment

T4 = weight of conditioned wood samples after exposure to termite attack.

Data Analysis

Data obtained were presented using descriptive statistics and data collected on the absorption, retention, and gravimetric weight loss were analyzed using Analysis of Variance (ANOVA) to determine if there exists a significant difference among the species with respect to the aforementioned variables, and where significant differences exists Duncan New Multiple Range Test (DNMRT) was applied as a post hoc test to separate the means.

RESULTS

Termite Identification

The results of termite identification carried out in this study as presented by Figure 2 shows that only two (2) species of termites viz *Microtermes spp*. and *Macrotermes subhylinus* Rambur were identified within the site used for this investigation.

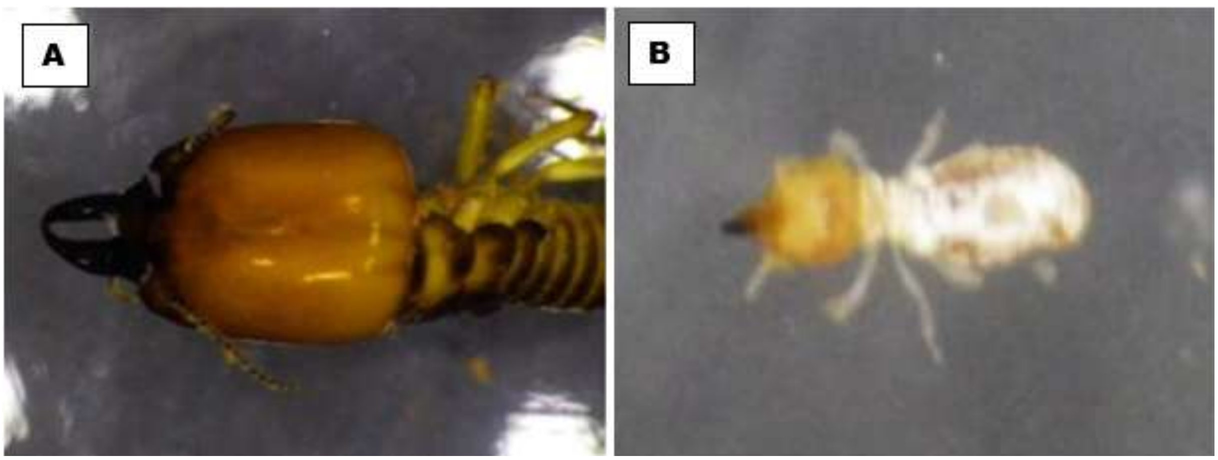

Figure 2: External morphology of identified termite species on the study site.
A: *Macrotermes subhylinus* Rambur;
B: *Microtermes spp*.

Density of Wood Species

The results of this study as shown in Figure 3 revealed that the oven-dry density of *P. macrocarpa* (542.28±42.40 Kg/m^3) and *A. boonei* (461.25±22.51 Kg/m^3) wood used in this study are of medium mean density range, while that of *R. heudelotii* (237.99±6.94 Kg/m^3) is of low-density range.

Viscosity of Chemical Preservatives

The result of the kinematic viscosities (at 25 ^oC) of the liquid preservatives used for this study presented by figure 4 showed that the viscosity for spent engine oil is highest (3909.75±225.76 cSt), followed by Solignum (1749.15±11.7 cSt) and Timbguard™ (237.99±6.94 Kg/m^3). Furthermore, there exists a significant difference in the mean oven-dry densities of the three-wood species. The result showed that there is a significant difference (P < 0.05) in the viscosities of the three selected preservatives.

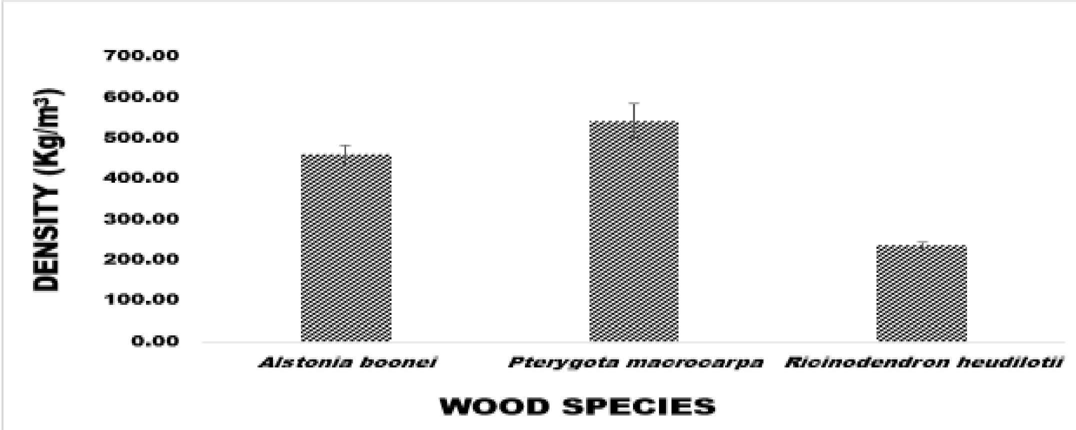

Figure 3: Oven-dry densities of the wood species used for this study

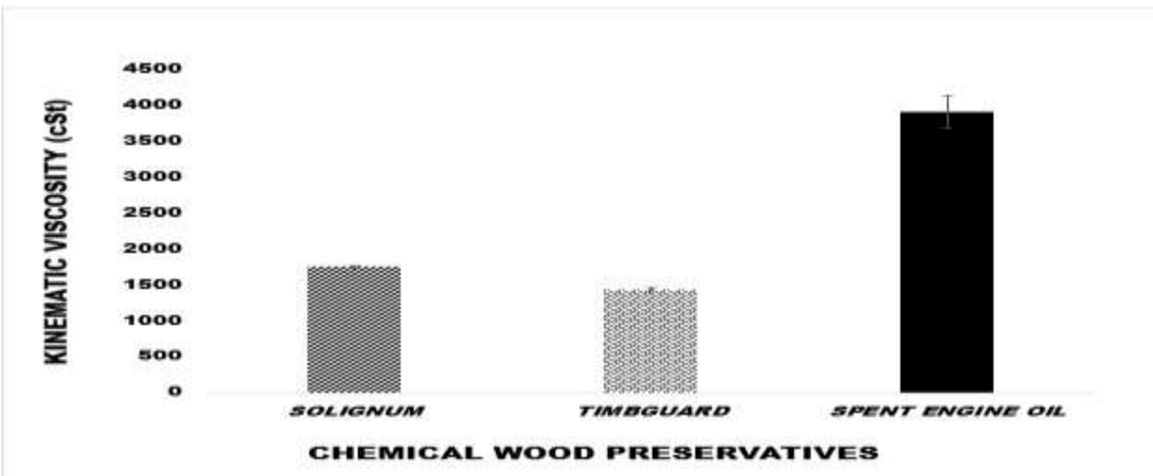

Figure 4: Kinematic viscosities (at 25 ^{o}C) of the chemical wood preservatives used for this study

Chemical Preservative Absorption and Retention

With respect to the absorption capacity of the wood species for the preservatives used in this study, an inverse trend is observed between the density of the wood species and their absorption capacity for the preservatives. Table 1 shows that *R. heudelotii* has the highest mean absorption value (28.45±18.15 %), followed by *A. boonei* (25.56±18.45 %), while *P. macrocarpa* **s**pecies has the least mean preservative absorption value (15.07±8.92 %) recorded.

On the other hand, Table 1 also show that the retention of the chemical preservatives on the wood samples varied with species. This time, *A. boonei* has the highest mean retention value (7.78±5.15 Kg/m^3), followed by *P. macrocarpa* (5.95±3.23 Kg/m^3), while *R. heudelotii* has the least mean preservative retention value (5.39±3.15 Kg/m^3) of the three selected wood species.

Once again, Timbguard™ is the most retained while the spent engine oil was the least retained of all preservatives irrespective of the wood species and this can be attributed to their viscosity, which aids its easy flow and penetration into the inner crevices of the wood structure at higher rates, and hence, the higher retention values observed.

Visual Ratings of Treated Wood Samples

The visual assessment results from this study indicates that all three commonly used preservatives investigated were effective in preventing and/or limiting termite attack on the wood of the three selected wood species compared to their untreated counterparts (Figures 5**A** through **C**). However, the extent of the protection varied among species and with the preservatives. With respect to the wood species, *Alstonia boonei* performed best while wood samples treated with Timbguard™ has the best performance of the three preservatives investigated.

Table 1: Absorption and Retention Mean values of wood species treated with selected wood preservatives

Wood species	Preservative	Absorption (%)	Retention (kg/m^3)
Alstonia boonei	Solignum	17.75±1.69^b	6.30±0.59^b
	Timbguard™	49.95±4.93^a	14.42±1.13^a
	Spent engine oil	8.98±0.85^c	2.62±0.29^c
	Average	**25.56±18.45^i**	**7.78±5.15^i**
Pterygota macrocarpa	Solignum	12.42±8.06^b	5.36±2.58^b
	Timbguard™	24.97±3.37^a	9.53±1.30^a
	Spent engine oil	7.82±2.31^c	2.95±0.64^c
	Average	**15.07±8.92^j**	**5.95±3.23^j**
Ricinodendron heudelotii	Solignum	18.03±2.36^b	4.47±1.82^b
	Timbguard™	52.16±9.36^a	9.14±1.70^a
	Spent engine oil	15.17±1.05^c	2.57±0.17^c
	Average	**28.45±18.15^i**	**5.39±3.15^j**

Values are mean±SD; values in the same column with the same superscript are not significantly different from each other for each species

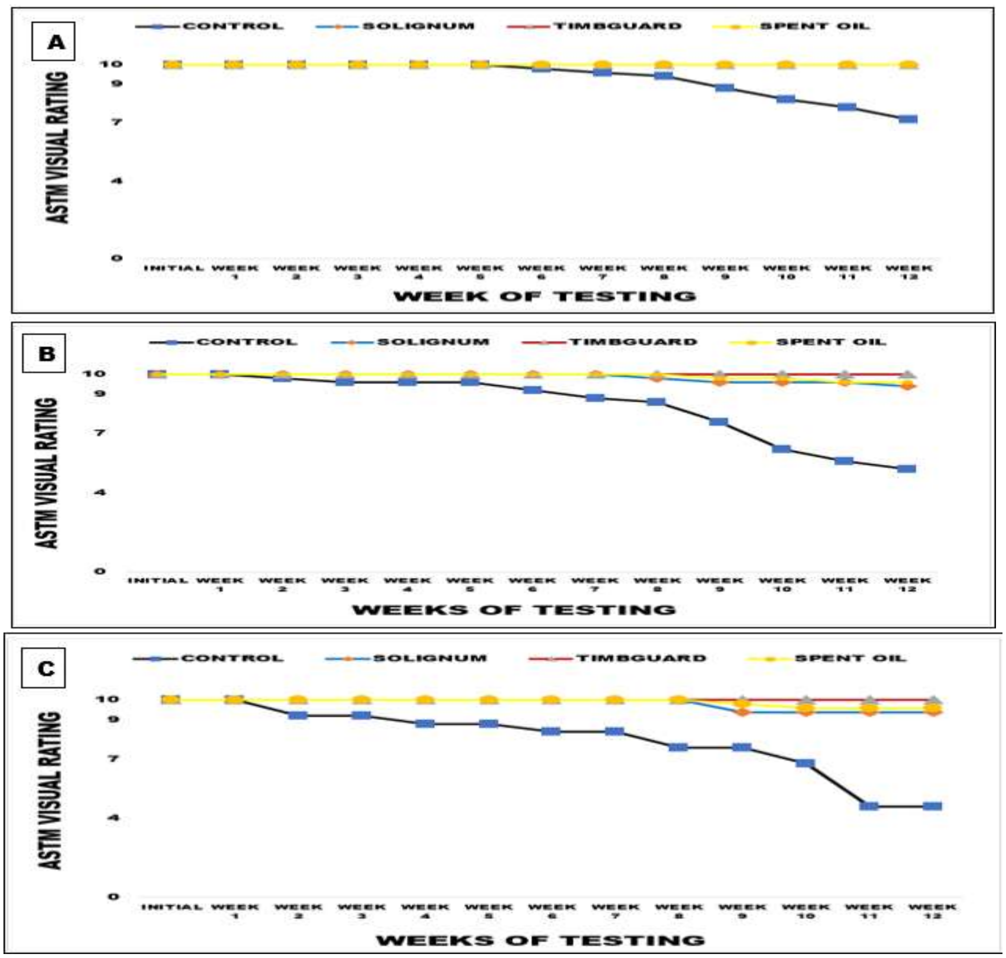

Figure 5: Visual ratings of wood samples treated with the wood preservatives;
A: *A. boonei*;
B: *R. heudelotii*;
C: *P. macrocarpa*

Gravimetric Weight Loss of Treated Wood Samples

The result of the gravimetric weight loss (Figure 6) of the wood species used in this study revealed that all the chemical preservatives were able to protect the wood species for the period of 12 weeks' exposure to termite as against the untreated samples, which is an indication that all wood structures from these species must be treated to extend their useful service life.

The result of this study further revealed that wood treated with Timbguard™ recorded the lowest mean weight loss value. However, wood samples treated with all other preservatives recorded significantly lower weight loss values compared to their controls.

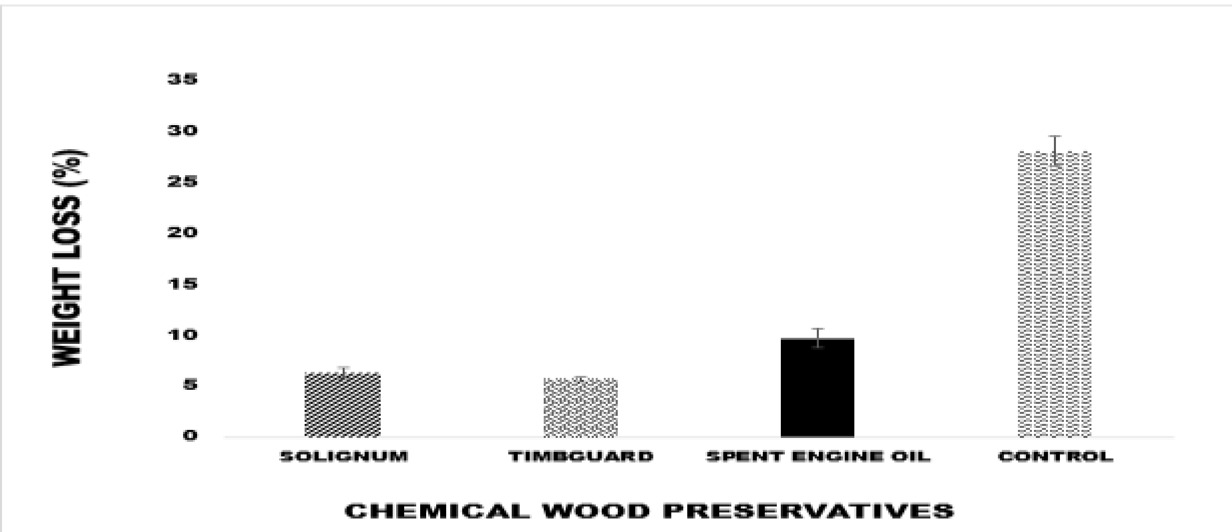

Figure 6: Gravimetric weight loss of the wood samples treated with the different preservatives on treatment basis

DISCUSSION

Wood Density and Preservative Treatment

Wood density results of the three species used for this study corroborates the assumptions of the authors in the selection of these wood species that they are of medium to small density range, judging from their known history of susceptibility to termite attack. It is a common knowledge that the higher the density of a wood, the greater its resistance to biodeteriorating agents (Andres *et al.*, 2015; Taylor *et al.*, 2002). Therefore, a selection of the high-density wood species would have obscured the results of the real efficacy of the selected preservative chemicals under investigation.

Consistently, the preservative absorption capacities were in the order Timbguard™ > Solignum > Spent engine oil for the three wood species, with the Timbguard™ being the most absorbed. This implies that the viscosity of the wood preservatives played a key role in their absorption by the wood species. Therefore, it can be asserted that the resistance to flow of the preservatives was in accordance with their kinematic viscosities, as preservative chemicals with higher viscosity are known to resist flow through the treated wood samples more than those with lower viscosity values (Owoyemi, 2010)**.**

More so, Desch (1981) reported that the anatomical structure of wood exhibits a lot of influence on the absorption capacity for preservatives, therefore, it can be inferred that the low density *R. heudelotii* has large pores which enhances the easy penetration of fluid, while *Pterygota macrocarpa* and *Alstonia boonei* both of medium density range has smaller pore sizes compared to the *R. heudelotii*, hence, their lower absorption capacities. However, the differences in their absorption capacities could be attributed to the presence of extractives or other factors related to the complex microporous structure of wood.

On the other hand, the retention of the chemical preservatives, which is the weight of the active ingredients left in the wood after solvent evaporation, is in consonance with the findings of Schultz *et al.* (2007) that the wood material exhibits variation in retention of chemical preservatives with respect to species. This variation in retention may occur due to variation in the anatomical structure of wood species as well as their density (Ogbogu,1996; Mcquire, 1974). More so, the difference in anatomical structure of wood has a lot of influence on the absorption and retention of wood preservatives (Janfa *et al.*, 2015) which is an indication according to Olaniran *et al*. (2010), that the higher the density of the wood species the lower the rate of absorption and vice versa.

Efficacy of Preservative Treatments Against Termite Attack

The relative variation in resistance of the wood samples to termite attack may be attributed to the variation in the absorption and retention of the preservatives (Owoyemi, 2010), as the Timbguard™ preservative was the most absorbed while *Alstonia boonei* has the highest retention of the preservatives used. Also, studies have proved that treatment factors such as viscosity and temperature of the treating solution, treatment methods (i.e. soaking method, vacuum and/ or pressure regimes etc.) and their durations are some of the parameters that influence wood treatability (Oteng – Amoako, 2006; Islam *et al.*, 2008).

The presence of *Macrotermes subhylinus* Rambur species have been reported by Owoyemi *et al.* (2017) to be associated with aggressive foraging activities with a corresponding high termite attack rate. Therefore, this explains the consistent aggressive attack experienced by the untreated wood samples of the three species throughout the period of the study period.

On the other hand, gravimetric weight loss results of treated wood samples, reveals that while Timbguard™ is the most effective of the investigated preservatives the other preservatives i.e. Solignum and spent engine oil are also efficacious in the preservation of wood against termite attack. Hence, where cost is a consideration, the spent engine oil can serve as a suitable wood preservative against attack by subterranean termites, since the spent engine oil is regarded as a waste product of automobile engines.

CONCLUSION

From the results of this study, it can be concluded that preservative uptake depends on the density of the wood material and viscosity of the preservative chemical. Also, the treated wood samples exhibited higher resistance to attack by subterranean termites after twelve weeks of field test, irrespective of the wood species; indicating that all three preservatives were efficacious in protecting the wood species from subterranean termite attack.

However, Timbguard™ was found to be the most effective amongst the three as measured by the ASTM D2017-05 visual ratings and the gravimetric weight loss after 12 weeks of field. Therefore, where the cost of procurement is of consequence, the spent engine oil becomes a worthy and effective alternative to protect large wooden members of structures such as the roof structure of buildings etc. in Akungba-Akoko from subterranean termite's attack. Since they are sourced at no cost from local automobile mechanic shops.

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