

Threshold Determination for Chromated Copper Arsenate and Creosote Oil for Termiticidal Treatment of *Gmelina arborea* Wood

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ABSTRACT

The threshold point of Chromated Copper Arsenate (CCA) and Creosote Oil preservatives for the treatment of *Gmelina arborea* wood against subterranean termites was investigated. Wood samples from 15 years old *Gmelina arborea* trees were cold-dipped with CCA at 4%, 3% and 2% concentration levels while Creosote oil was used undiluted as well as at 1:1 and 1:3 Creosote oil - kerosene mixtures. The treated samples and control were exposed to termite attack at the timber grave yard, Federal University of Technology, Akure, Nigeria for 36 months. The result revealed the efficacy of CCA in the protection of *Gmelina* wood at the three concentration levels for the 36-month period with samples maintaining an ASTM mean visual rating of 10 (sound) at 2, 3 and 4% CCA treatment levels. Creosote Oil provided protection for only 12 months period as it recorded heavy attack and failure at the end of 30 months thereby suggesting a post-treatment schedule every 12 months for the undiluted Creosote oil in order to sustain protection of the wood. It could be concluded that 3% concentration level is the threshold value for CCA wood treatment while creosote oil could only be used undiluted for 12 months, its dilution with solvent reduced its potency.

Keywords: *Gmelina arborea*; Chromated Copper Arsenate; Creosote Oil; threshold; subterranean termites; timber grave yard

INTRODUCTION

Wood is a material that is in high demand in the construction industry because of its versatility and ease of fabrication. It is a common practice among wood users to buy any chemical found in the market for treating wood prior to use for building and construction without knowing the active ingredients of the chemical and the best concentration level suited for termites. This could be attributed to ignorance, coupled with the fact that most wood users do not really see preservation as an essential part of wood utilization process. This has led to flooding of the market with various types of chemicals under various trade names. The result is the wood treatment failure being experienced today. According to a report on failure of termites' protection for wood structures in Florida, 61 % and 9% of pre-construction and post-construction treatments for wood, respectively failed (AWCA, 1995). These failures have been identified as chemical barrier failures. It has been estimated that the worldwide cost of treating building timbers damaged by termites annually is in the order of US\$200 million (Edward and Mill, 1986).

The only solution lies in using the appropriate preservative with the right formulation and absorption which could protect the wood as well as adopting the appropriate treatment method that will ensure deeper penetration to provide enough 'envelope' covering for the wood (Owoyemi and Kayode, 2008; Olaniran *et al.*, 2010). According to Fahlstrom (2003), wood that has withstood the destructive attacks of fungi for 15 to 25 years does not suddenly fail overnight because of the

presence of fungi and insect, but could be due to reduction in preservative concentration below the threshold point. Draft Indian Standard (2006) defined threshold retention as the minimum amount of preservative that is effective in preventing decay fungi and insect attacks under a particular condition. Fahlstrom (2003) described threshold concentration as the minimum chemical amount impregnated into wood which will completely inhibit the attack of bio-deterioration agent under a specific test conditions. The minimum retention of preservative (threshold value) that prevents growth of decay fungi is determined in standardized laboratory and field tests. This threshold value is an expression of point of failure or the limit of protection offered by any preservative.

Chromated Copper Arsenate (CCA) is a water-borne preservative used for the long-term protection of wood against attack by fungi, insects and marine borers. It is a mixture of copper, chromium, and arsenic formulated as oxides or salts. The chromium acts as a chemical fixing agent and has little or no preserving properties; it helps the other chemicals to fix in the timber, binding them through chemical complexes to the wood's cellulose and lignin. The copper acts primarily to protect the wood against decay fungi and bacteria, while the arsenic is the main insecticidal component (Vergara *et al.*, 2013). CCA is generally accepted as a very effective preservative treatment for certain wood species. Kenneth (1998), reported that CCA treatment provides very good protection against termites at retention as low as 1.6 kg/m³. Best protection has been achieved with carefully balanced mixtures of copper and chromium salts, sometimes with addition of arsenic, the latter enhancing the toxicity

against insects. CCA-treated wood is used primarily for construction timbers, utility and construction poles, marine timbers and pilings, fence posts and wood foundation lumber (Cooper, 1991).

Creosote is the oldest and most widely used wood preservative oil in the market and has been in use for more than 150 years. In the past, creosote was produced by the high-temperature distillation of bituminous coal tar, but is currently produced from the dissolution of chemicals like pentachlorophenol and copper naphthenate in oil (James, 2002). Creosoted wood provides a high calorific value and does not leave any toxic residues (EPA 2007, CBPD 2008). Creosote is toxic to fungi and insects, it is relatively insoluble in water, and is generally low cost. It is used where wood is in contact with the ground or in buildings that have a high decay hazard such as railway sleepers, fence posts and battens. It is also effective in marine structures. According to Barnes and Murphy (1995), creosote is described as traditional organic biocides, and that despite the extreme environmental pressures it faced, there appears to be no viable direct replacement for it in its special uses. The preservative is relatively cheap and available in Nigerian markets. In order to ensure adequate protection of *Gmelina arborea* wood used outdoors, there is the need to determine the concentration level of preservative required to prolong its shelf life.

MATERIALS AND METHODS

The study area

The materials for this work were rectangular wood samples obtained from a 15-year old plantation of *Gmelina arborea* at the Federal University of Technology, Akure (FUTA),

$$\text{Retention in kg/m}^3 = 10 \times \left(\frac{GC}{V} \right)$$

(1)

Where G = (T₂ – T₁) Treated weight -- Initial weight; C = Weight of preservative in 100 g of treating solution (g)
V = Volume of sample in cm³.

The treated wood samples were conditioned in the laboratory at room temperature for 24 hours after which they were weighed and recorded as T₃, which is the weight after conditioning. This weight (T₃) was used to calculate the weight loss (%) after the field test. The field exposure test was carried out at the Timber graveyard at FUTA. Termites' baits of *Gmelina arborea* wood off-cuts were randomly

$$\text{Weight loss \%} = 100 \times \left(\frac{T_3 - T_4}{T_3} \right)$$

(2)

Where: T₃ = conditioned weight after preservation treatment; T₄ = Weight after exposure to termites' attack.

The experimental design was 2 × 3 × 5 factorial experiment in Complete Randomized Design (CRD). Data obtained from the estimation of weight loss was subjected to Analysis of Variance (ANOVA) to determine the significant differences between the varying preservative concentrations. Duncan

Nigeria. The University, which lies within the tropical rainforest zone of Nigeria, is located on Latitude 7.2971727°N and Longitude 5.1460648°E. The mean annual temperature is 26°C, while the elevation is 350 m above sea level and the relative humidity ranges from 85 to 100% during the rainy season and about 60% during the dry period.

Sample preparation and treatment

The preparation and impregnation of the test wood samples were done according to the American Society for Testing Materials (1974) (ANSI/ASTM D1413-1974/10 - reapproved, 1980) standard. Thirty-five (35) rectangular wood samples, each measuring 35 x 35 x 450 mm, were obtained from the 15- year old *Gmelina arborea* trees. The samples were weighed and the weights were recorded as T₁. The samples were then marked with waterproof ink and dried in an oven for 24 hours at 105°C until constant weights were attained and the weights were recorded as T₂. The samples were then divided into 3 sets of 15, 15 and 5 samples. The first set of 15 samples was further divided into three groups of five in each group (A, B and C) which were cold dipped by immersion in an open tank containing CCA at 2 %, 3 % and 4 % concentration levels respectively. The second set of 15 samples was also cold dipped by immersion into undiluted Creosote as well as Creosote/kerosene mixtures (1:1 Creosote - kerosene mixture and 1:3 Creosote - kerosene mixture) for 24 hours while the third set consisting of 5 samples was left untreated to serve as the control.

The retention, which is the weight of active ingredients of preservatives left in the wood, was calculated using the ANSI/ASTM D1413-74 (1974) standard as follows (equation 1):

scattered on the ground for one week to induce and initiate termites' activities before the stakes were pegged at 225 mm below the ground level for 36 months. Stakes were removed after 12, 24 and 36 months of exposure and weighed to obtain the weight loss due to termites' attack. Weight loss was calculated as follows (Equation 2):

Multiple Range Test was used to separate treatment means found to differ significantly.

RESULTS

The results of CCA and creosote preservative retention by *Gmelina arborea* wood presented in Table 1 shows that CCA had a mean retention value of 1.8 kg/m³, 1.35 kg/m³ and 0.9 kg/m³ for 4%, 3%, and 2% concentration levels, respectively while Creosote oil had mean retentions of 2.9 kg/m³, 1.45

kg/m³ and 0.96 kg/m³ for undiluted, 1:1 creosote - kerosene and 1:3 creosote -kerosene mixtures, respectively. Retention, which is the weight of active ingredients left in the wood after treatment revealed the effect of different retention levels of CCA and Creosote oil on the resistance of *G. arborea* wood to termites' attack.

Table 1: Weight loss of *Gmelina arborea* treated with CCA and Creosote oil at 12, 24 & 36 months of exposure to termites' attack.

Preservative	Treatment Conc.	Retention kg/m ³	Weight loss (%) at 12 months	Weight loss (%) at 24 months	Weight loss (%) at 36 months
CCA	4%	1.8	3.39 ± 0.56 ^a	4.50 ± 1.68 ^a	5.50 ± 2.06 ^a
	3%	1.35	5.16 ± 0.29 ^b	5.80 ± 0.75 ^b	6.50 ± 0.84 ^b
	2%	0.9	7.27 ± 0.34 ^c	7.83 ± 0.76 ^c	8.40 ± 0.76 ^c
Creosote oil	Undiluted	2.9	12.40 ± 3.09 ^a	33.30 ± 6.93 ^a	54.20 ± 6.93 ^a
	1:1	1.45	14.68 ± 6.10 ^b	39.80 ± 13.65 ^{ab}	65.00 ± 13.65 ^{ab}
	1:3	0.96	24.19 ± 9.34 ^c	50.10 ± 20.88 ^{bc}	76.00 ± 20.88 ^{bc}
	Control	-	56.45 ± 19.12 ^d	71.50 ± 54.14 ^d	86.70 ± 65.63 ^d

Values are means of five replicates ± standard deviation; *Means with different superscripts vertically are significantly different (p<0.05)

The results of the 36 months' field exposure test to termites' attack at the timber grave yard revealed that in the first 12 months, *Gmelina arborea* wood treated with CCA at the various concentration levels of 4%, 3% and 2% had mean weight loss of 3.39%, 5.16%, and 7.27%, respectively. *Gmelina* wood stakes treated with Creosote oil at undiluted, 1:1 creosote - kerosene and 1:3 creosote - kerosene mixtures had mean weight loss of 12.40%, 14.68%, and 24.19%, respectively. During the first 12 months, there was a significant difference in the level of protection provided by CCA and Creosote preservatives at the varying concentrations (Table 1). At 24 months of field exposure, only the concentrations (4%, 3% and 2%) of CCA preservative were effective in protecting the *Gmelina* wood stakes while there

was no significant difference in the level of protection provided by undiluted Creosote and Creosote/kerosene mixtures (Table 1). At 36 months of exposure, there were significant differences in the protective effects of the different concentrations of CCA preservative, at 4 %, 3 % and 2 % with mean weight loss of 5.50%, 6.50%, and 8.40%, respectively. On the other hand, undiluted Creosote and Creosote mixtures with kerosene had no significant effect in the weight loss of *Gmelina* stakes at the end of 36 months (Tables 1). The Effect of time on the exposure of *Gmelina* stakes treated with CCA and CREO presented in Figures 1 and 2 revealed that at different concentration, CCA performed better than CREO.

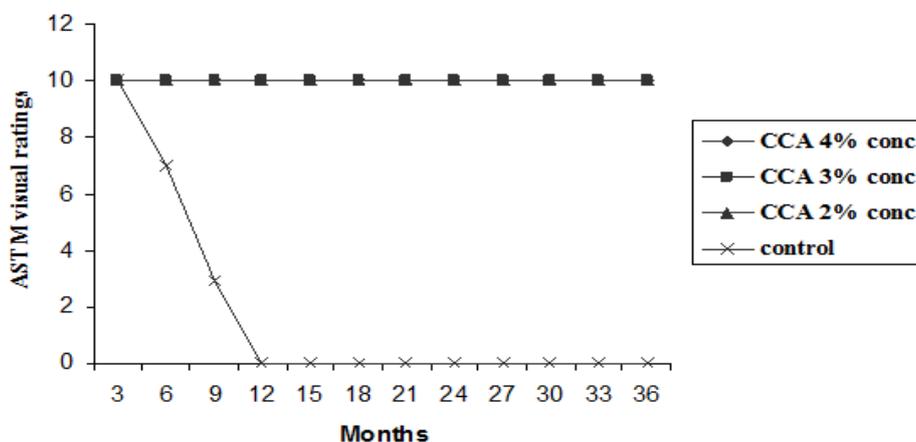


Figure 1: Effect of time on the exposure of *Gmelina* stakes treated with CCA.

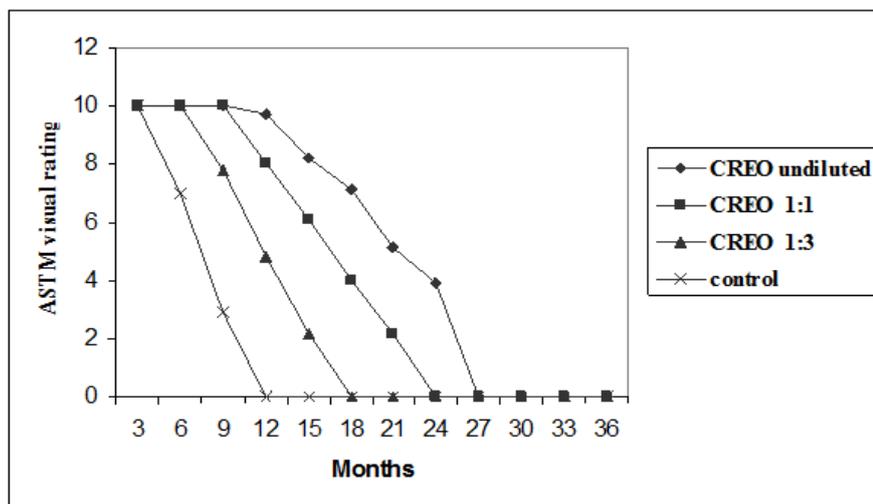


Figure 2: Effect of time on the exposure of Gmelina stakes treated with CREO

DISCUSSION

The service life of wood is extended when it is chemically treated with wood-preserving compounds. Failure due to decay infestation or insect attack starts because the natural resistance of the wood or the preservative has been leached or reduced to a point just below the retention or threshold concentration (Sónia *et al.*, 2012). Threshold value therefore is the minimum amount of chemical that if impregnated into wood will inhibit the attack of specific bio-deteriorating agent on wood under specified test conditions (Indian Standard, 2006). The level of protection provided by CCA at 4%, 3%, and 2% concentrations was significantly different and proved effective for treating Gmelina wood for the 36 months of exposure. Jeanette (2002) asserted that no other wood preservative agent has had such a long history of excellent performance as CCA, which is supported by the results of this study which revealed the longer lasting effect of CCA over Creosote oil. All CCA concentration levels used in this study were effective in the protection of *Gmelina* wood against termites, thus it will be economically expedient if the lowest concentration level is used as the minimum threshold value of CCA for Gmelina wood. However, Fahlstrom (2003) asserted that, for practical purposes, it will be advisable to go somewhat above the minimum threshold to allow for some future decrease within a desirable life extension. Consequently, 3% concentration level will be the ideal CCA preservative threshold level for Creosote oil was also adequate for the preservation of the *Gmelina arborea* wood but the effect of the preservative could not last longer than 12 months period. However, with the undiluted Creosote failing after 12 months of treatment, a post-treatment schedule should be adopted for Creosote oil treated wood every eleventh month to ensure further protection from termites' attack. This will ensure continuous protection of *G. arborea* wood in service, prevent chemical barrier failure and extend its service life. Creosote oil (sometimes called solignum in Nigerian local market) is readily available in the market and the most sought for because it is relatively cheap and available and may be diluted with kerosene to get a cheaper preservative (Willeitner, 1977).

CONCLUSION AND RECOMMENDATIONS

The effectiveness of any wood preservative treatment depends not only on the active ingredients of the preservative itself, but also on the method of application and net volume uptake. Results from this study showed that the resistance *Gmelina arborea* wood to termite attack was enhanced through the application of preservative treatments. *Gmelina arborea* treated with CCA at 4%, 3% and 2% concentration was resistant to subterranean termite attacks for up 36 months. Though undiluted creosote oil protected *Gmelina arborea* wood, the protection only lasted for only 12 months, while creosote/kerosene mixtures were effective for shorter period of time. The threshold points established for CCA and Creosote are 3% concentration and undiluted concentration levels, respectively. A post-treatment schedule is however necessary for undiluted Creosote oil after 12 months to ensure longer lasting protection.

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