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DURABILITY OF SELECTED MALAYSIAN WOOD TREATED WITH DISODIUM OCTABORATE TETRAHYDRATE USED UNDER HAZARD CLASS 2 CONDITION

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Boron-based wood preservative is currently widely used in non-structural products such as furniture and window skirting. Disodium octaborate tetrahydrate (DOT) is a boron-based formulation used as wood preservative. This study evaluated the relative ability of various concentrations of DOT in improving the durability of selected Malaysian timber species (*Hopea* sp., *Irvingia malayana, Cynometra* sp. and *Hevea brasiliensis*) in order to fulfil hazard class 2 (H2) condition. DOT-treated wood were tested in accelerated laboratory tests against subterranean termite (*Coptotermus curvignathus*) for 4 weeks and decay fungi (*Lentinus sajor-caju* and *Coriolus versicolor*) for 16 weeks. The results indicated that DOT improved the durability of all timber species tested against termite and white-rot fungi for use under H2 condition. DOT was easily impregnated into the wood using pressure treatment processes.

Keywords: DOT, boron-based wood preservative, wood durability, wood treatment, termites, fungi

INTRODUCTION

Disodium octaborate tetrahydrate (DOT) ($Na_2O.4B_2O_3.4H_2O$) generally known as Timbor is the most commonly used form of boron preservative. DOT possesses a number of properties that help to make it unique such as it has inorganic salts (non-volatile), near neutral pH, low mammalian toxicity, non-corrosive, high toxicity to insects and fungi, colourless, odourless and compatible with colourants if visual marking is desired. DOT has been considered environmentally acceptable for many years (Thévenon et al. 2010). DOT has high water solubility which allows it to be introduced into wood through conventional methods such as absorption or vacuum pressure treatment (Byrne & Morris 1997). Although boron compounds are easily leachable from wood, the content remaining in the wood is still sufficient to make them effective fungicidal (Obanda et al. 2008).

DOT which is a natural borate compound is very effective against insects and fungi that attack timber in service (Teoh et al. 2011). Borates have been known to be contact toxicants. When treated wood are ingested by wood destroying organisms, these active ingredients will stop food translocation and metabolism in the fungi and insects, causing death. DOT in solution form is normally applied to timber by brushing, spraying, momentary immersion and vacuum pressure treatment. Being a diffusible preservative, DOT will penetrate further into the wood long after the actual treatment process, making the deeper part of wood toxic to wood destroying organisms (Lebow et al. 2010).

Fungus and insects may cause defects in the wood/building structure if they are not controlled. Previously, creosote and chromated copper arsenate (CCA) were the two highly effective, cost-effective and preferred preservatives in protecting wood against both pests compared with copper-based preservatives and organic-based fungicides (Tumen et al. 2013). However, due to environmental concerns over toxic compounds in their formulation the Environmental Protecting Agency in the USA has banned the use of arsenicals in residential structures since 1 January 2004. Other developed countries now have totally banned the use of CCA as wood preservative (Rudi et al. 2012). Hence, environment-friendly wood preservatives should be developed in order to replace these traditional wood preservatives. One of the effective approaches is by testing existing preservatives in the market. DOT may be able to solve this problem as it has been reported to be effective against fungus and insects.

Based on Australian Standard 1604 (2010), hazard class 2 (H2) refers to the hazardous conditions of wood used in buildings and aboveground. This means that the wood (e.g. framing, flooring, structural materials, plywood flooring) used is protected from wetting and is limited to borers and termite attacks. The H2 selection guide is presented in Table 1. When timbers are used in H2 condition, the effects of weather such as sunshine and rain are expected to be minimal. To ease the burden in the demand for hardwood under the H2 class, the use of alternative species should be investigated using wood preservatives such as DOT.

However, very few studies have been done on the treatability of DOT on Malaysian wood and the performance of wood treated with DOT against subterranean termites and fungi. This information is needed in order to diversify the use of non-durable wood species. The objectives of this study were (1) to determine the treatability of four Malaysian timber species (*Hopea* sp., *Irvingia malayana, Cynometra* sp. and *Hevea brasiliensis*) using three different concentrations of DOT and (2) to evaluate the performance of DOT-treated wood blocks exposed to termites and wood decay fungi under laboratory conditions. Results will be compared with those obtained from samples treated with 3% CCA. CCA at 3% is the minimum requirement by Malaysian Standard MS360: 2006 (MS 2006) to attain estimated dry salt retention values of 5.4 kg m^{-3}.

MATERIALS AND METHODS

Wood preservatives

DOT was used as received (98% DOT87 powder) and different concentrations of preservative were prepared, namely, 5, 7.5 and 10% w/v. CCA (3% w/v) was prepared and used as control.

Sample preparation and treatment process

Four Malaysian wood species were selected for this study, namely, *Hopea* sp. (merawan), *Irvingia malayana* (pauh kijang), *Cynometra* sp. (kekatong) and *Hevea brasiliensis* (rubberwood). The properties of wood species studied are shown in Table 2.

The wood was cut into 19 mm × 19 mm × 19 mm for termite and decay fungi tests and conditioned to a moisture content of about 12% prior to treatment. Wood samples were treated with DOT (5, 7.5 and 10% w/v) according to the method described in MS 544 (MS 2003). Treatments were carried out using Bethel (full-cell pressure) process based on appropriate time–pressure variation of each selected timber species (Table 3). Untreated sample for each timber species and *H. brasiliensis* treated with 3% w/v CCA were used as control. Similar treatment schedule was used to treat *H. brasiliensis* using 3% CCA. Five and 40 replicates for each concentrations were used for termite and decay fungi tests respectively, giving a total of 1275 samples.

Table 1 Hazard class (H2) selection guide

Exposure	Inside, aboveground
Specific service conditions	Protected from wetting, no leaching
Biological hazard	Borers and termites
Typical use	Framing, flooring and similar, used in dry situations

Table 2 Properties of wood tested

Wood species	Strength group[1]	Density (kg m^{-3})
Kekatong (*Cynometra* sp.)	2	880–1155
Pauh kijang (*Irvingia malayana*)	3	930–1250
Merawan (*Hopea* sp.)	4	495–980
Rubberwood (*Hevea brasiliensis*)	5	560–640

[1]As defined in MS 544: Part 2 (MS 2001)

Table 3 Disodium octaborate tetrahydrate treatment schedule

Schedule	Time (min)
Initial vacuum period at -85 kPa	30
Pressure period at 1400 kPa	120
Final vacuum -85 kPa	30

Quality control of treated wood

Determination of DOT retention and penetration in treated wood is important to determine the quality of the treatment process. Retention of DOT in treated wood was identified using spectrophotometric method (MS 2003). Figure 1 shows the sampling technique used prior to DOT retention determination. Shell is the outer part (6 mm) of the sample and core is the centre part (12 mm deep). Penetration test was carried out according to MS 833 (MS 1984).

Bioassay test against termite

Wood samples (19 mm × 19 mm × 19 mm) were conditioned to ensure all solvent had dissipated prior to termite bioassay following the no-choice test procedure of ASTM D3345-17 (ASTM 2017) standard methods with slight modification. Each block was placed in a test bottle with lid and containing 200 g sand, 30 mL deionised water and 1 g of *Coptotermes curvignathus* (subterranean termite). The test bottles were incubated at 22 ± 2 °C and 65 ± 5% relative humidity and examined after 1 and 4 weeks for evidence of tunnelling and termite mortality. After 4 weeks, the blocks were removed from the test bottles, cleaned, dried, re-conditioned and weighed to determine the weight loss. A visual rating of attack was recorded for each block.

Bioassay test against decay fungi

Two types of white-rot fungus, *Trametes versicolor* (culture collection CTB 863A) and *Lentinus sajor-caju* (KUM 70097) were used for this study. *Lentinus sajor-caju* is a local fungus commonly found in Malaysia while *T. versicolor* is a European fungus that is widely used to test decay resistance. Malt (2%) agar was prepared as culture medium and 60 mL was poured into a series of 500-mL squat jars. The jars were covered with lids before being sterilised by autoclaving at 103 kPa steam for 20 min. When cooled the jars were inoculated with the test fungi. All jars were then incubated at 25 °C at 80% relative humidity for 2 weeks and examined for growth of fungus.

The wood samples were dried at 40 °C for 48 hours and then weighed prior to decay fungi test (ASTM 2005). Each 300-mL soda-glass jars were half-filled with 150 mL sterilised forest topsoil wetted to 130% water holding capacity. These jars were sterilised in the autoclave at 122 °C under a steam pressure of 120 KPa for 30 min after which the jars were gradually cooled to room temperature.

Wood sample (19 mm × 19 mm × 19 mm) was assigned to each jar which was already inoculated with fungus and incubated at 25 °C (dark) and 75% relative humidity for 16 weeks. At the end of the 16 weeks, the treated and untreated (control) wood samples were removed from the jars and fungal mycelium was brushed off. The samples were dried overnight at the 40 °C and weight loss was calculated. Based on the weight loss percentage the wood samples were assigned to the various resistance classes stipulated in Table 4.

RESULTS AND DISCUSSIONS

Retention level of DOT

Retention levels of DOT in treated wood samples are given in Table 5. The active ingredient in borate-based wood preservative compounds, including crystallised borates, i.e. boron trioxide, can be expressed as boric acid equivalent. *Cynometra* sp. had higher retention values followed by *I. malayana, Hopea* sp. and *H. brasiliensis*. The highest percentage (42.53%) of retention was recorded in the shell samples of *Cynometra* sp. treated with 10% DOT while the lowest (1.40%) retention was in *Hopea* sp. core samples treated with 5.0% DOT (Table 5). The percentage of retention in the shell was higher than in the

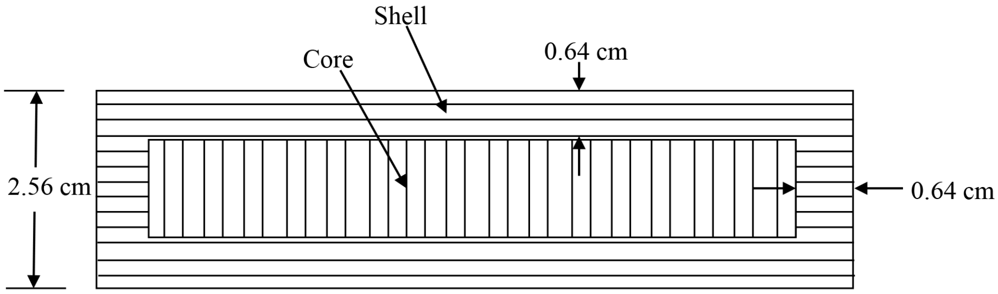

Figure 1 Sample for DOT retention determination test

Table 4 Classification of decay test resistance*

Decay rating	Mean % weight loss
Very resistant	Nil/negligible
Resistant	< 6
Moderately resistant	6–10
Non-resistant	10–30
Perishable	> 30

*Based on ASTM D2017 (ASTM 2005)

Table 5 Retention of disodium octaborate tetrahydrate (DOT) in wood samples

DOT (% w/v)	Sampling	Wood species/% BAE (w/w)			
		Hopea sp.	*Irvingia malayana*	*Cynometra* sp.	*Hevea brasiliensis*
5.0	Shell	19.824	15.217	27.045	11.872
5.0	Core	1.395	5.755	8.925	5.449
7.5	Shell	23.858	26.435	31.721	16.339
7.5	Core	3.813	17.102	11.287	7.517
10.0	Shell	24.986	41.931	42.533	24.498
10.0	Core	5.214	23.135	16.206	17.220

Mean of five replicates for each species; BAE = boric acid equivalent

core for all samples and DOT concentrations due to insufficient pressure level and short treatment period. By increasing pressure and duration of copper naphthenate treatment on hardwood, variability of retention between core and shell could be reduced (Hunt & Garratt 1967).

Termite resistance

The resistance of DOT-treated wood against termite is summarised in Figure 2. Consumption of wood specimens by termites was determined based on weight loss. There was no significant difference ($p < 0.5$) of weight loss when the three species (*Hopea* sp., *I. malayana, Cynometra* sp.) were treated with different concentrations of DOT. Highest weight loss was seen in control *H. brasiliensis* (without DOT), followed by 5, 7.5 and 10% DOT-treated *H. brasiliensis*. The least weight loss (1.6%) was observed in *Hopea* sp. and *I. malayana* treated using 10% DOT. Generally, all wood samples (except *H. brasiliensis* which was heavily attacked) were observed to be slightly attacked by termite when exposed for 4 weeks. Only *H. brasiliensis* test block treated

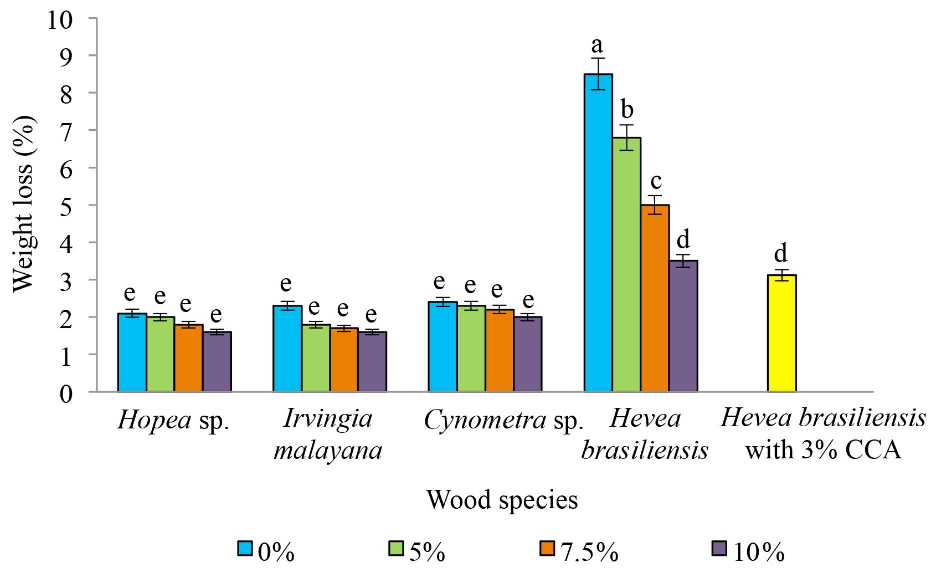

Figure 2 Average percentage weight loss of treated wood species with different concentrations of DOT against *C. curvignathus* after 4 weeks exposure

with various concentrations of DOT showed significant difference in weight loss. The results from this study are accordance with Grace (1991) who reported that all *C. formosanus* died within 15 days in dust treated with boric acid powder. Ayrilmis et al. (2005) observed greatest mortality of *C. formosanus* in test blocks of oriented strand boards treated with single DOT and boric acid than those treated with melamin phosphate after two weeks of exposure. DOT is a successful commercial treatment for structural lumber as it acts as poison to termites (Grace 2002).

Decay resistance

Figures 3 and 4 show the mean weight loss of untreated, DOT-treated wood and *H. brasiliensis* treated with 3% CCA after 16 weeks of exposure to white-rot fungi *L. sajor-caju* and *T. versicolor*. There was significant effect of DOT concentration on the durability of DOT-treated *Hopea* sp., *I. malayana, Cynometra* sp. and *H. brasiliensis*. DOT wood preservative at 5, 7.5 and 10% concentration, even though susceptible to *L. sajor-caju,* showed better performance in terms of weight loss compared with untreated blocks. This was the case with wood species tested. The average weight loss was reduced as the concentration of DOT increased from 5 to 7.5 and 10% concentration for all wood samples tested. Almost similar performance was also observed when these samples were exposed to *C. versicolor* fungus.

Generally, the higher the concentration of wood preservative the lower the weight loss of wood species. *Cynometra* sp., being naturally durable in the SG2 group, displayed the least weight loss compared with other wood species with weight loss in the range of less than 15% when exposed to the two types of fungi. *Hopea* sp. and *I. malayana* displayed similar behaviour. However, DOT concentration of more than 10% was required for all three timber species in order to get the same performance as 3% CCA treated blocks. Effectiveness of boric acid as a fungicide depends on two factors, i.e the type of wooden material and the strain of fungus.

An obvious improvement was observed in *H. brasiliensis* samples where significant reduction in weight loss was observed with the application of DOT. This was because DOT was evenly distributed across the surface of *H. brasiliensis.* Different types of wood have different levels of chemical absorption during treatment (Salamah & Zaiton 1991). The authors also found that the ratio of chemicals tested in the various depths of wood can vary from one timber to another. Selecting *H. brasiliensis* as a test wood species, and based on the performance when exposed to *L. sajor-caju*, a minimum concentration of 5% DOT wood preservative can be recommended for protection of wood against fungal decay.

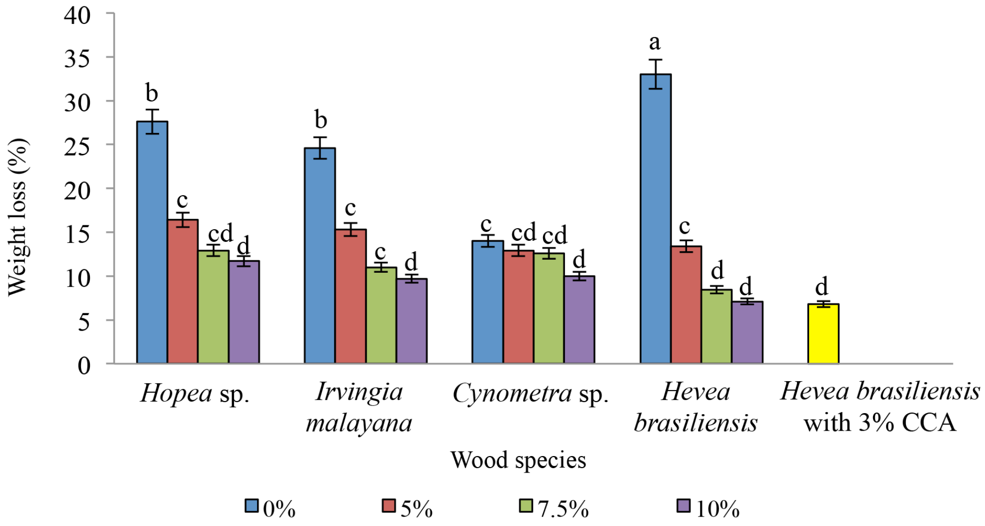

Figure 3 Weight loss of four untreated and DOT-treated Malaysian timbers and *H. brasiliensis* treated with 3% chromated copper arsenate (CCA) samples against white-rot *Lentinus sajor-caju*

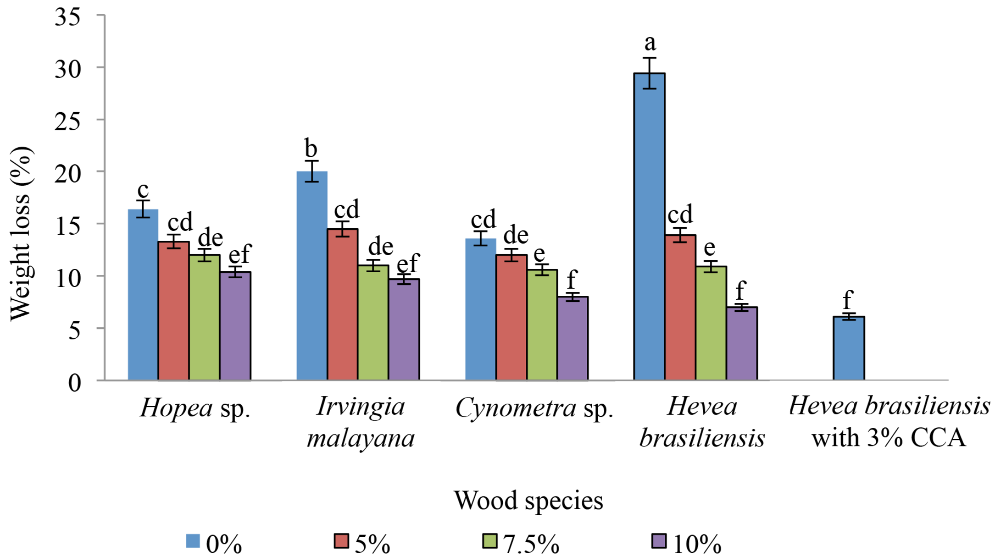

Figure 4 Weight loss of four untreated and DOT-treated Malaysian timbers and *H. brasiliensis* treated with 3% chromated copper arsenate (CCA) samples against white-rot *Trametes versicolor*

CONCLUSIONS

The results of this study indicated that higher concentration of DOT provided better protection against termite and decay fungi. Three of the DOT concentrations (5, 7.5 and 10%) provided protection greater than that of 3% CCA. *Hopea* sp., *I. malayana, Cynometra* sp. and *H. brasiliensis* were easily impregnated with 5, 7.5 and 10% aqueous solution of DOT using pressure treatment process.

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