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# EFFECT OF MICROWAVE HEATING ON pH AND DURABILITY OF *EUCALYPTUS TERETICORNIS* WOOD

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Microwave treatment increases treatability of wood. In the present study, *Eucalyptus tereticornis* wood was exposed to microwave radiation with 2450 MHz frequency for 3 and 5 min at four different microwave intensity treatments. The pH, retention of preservative and durability against termite of microwave-treated and control specimens were tested. Results revealed that the pH of wood decreased and retention of preservative in wood increased with increasing microwave treatment times and intensity but resistance against termite was not affected. Microwave pre-treatment can be useful to improve retention of preservative and to reduce the pH of wood.

Keywords: Microwave intensity, preservative, retention, treatment, termite

## INTRODUCTION

*Eucalyptus tereticornis* is an important plantation species in India and is the first eucalyptus exported from Australia. The wood is widely used among others for construction, bridges, poles, piles, posts, boats, hardboard and particle board (Brink 2008).The wood is moderately durable in exterior conditions and has good weathering and wearing properties. The pH of wood is one of the key chemical properties which affect a number of processes related to its utilisation. For example, excessive acidic wood can produce corrosion of fasteners and nails used in wooden construction, affect the fixation of preservative salts in wood preservation and increase the consumption of Kraft liquor in wood pulping (Sinthole 2005, Hernandez 2013). The wood pH and buffering capacity affect curing properties of the resins during manufacturing of wood composite (Bulian & Graystone 2009).

The average chemical composition of oven-dried *E. tereticornis* wood is 45–48% cellulose, 11–23% pentosans, 22–30% lignin and 0.5–1.3% ash (Brink 2008).The reactive hydroxyl groups of the carbohydrates are responsible for many physical and chemical properties of wood. In wood modification, basic chemistry of the cell wall polymers is altered. This can change important properties of the wood including durability, dimensional stability, hardness and UV-stability (Homan & Jorissen 2004).

Microwave radiation is an innovative method to increase permeability of wood and thus improve its preservative penetration (Torgovnikov & Vinden 2009, Dashti et al. 2012b).Microwave modification of wood structure can increase the wood permeability, the rate of drying in hardwoods, improve drying quality and even produce new composite products and open new opportunities for increasing timber durability by impregnation with preservatives (Torgovnikov & Vinden 2009). However, effect of microwave treatment on pH of wood and durability against termite has not been reported so far.

Pre-steamed sapwood specimens had approximately 4% decrease in the amount of holocellulose compared with corresponding control specimens (Dashti et al. 2012a). This change in chemical composition may be considered as the root of the change in the diffusion coefficient (Zhang & Cai 2008).In the present study, microwave treatment was carried out to evaluate its effect on pH of wood and its durability against termite.

## MATERIALS AND METHODS

### Preparation of wood specimens

Freshly felled logs of *E. tereticornis* (~10 to 12 years old) with 90 cm girth were procured for the

experiment from the Forest Research Institute, Dehradun (30° 19' N, 78° 4' E). The logs were sawn into planks of 6.35 cm thickness with full log width and length. Wood planks were converted into longitudinal specimens of size 3.8 cm (width) × 3.8 cm (thickness) × 15 cm (length). Straight grained and defect free specimens were submerged in fresh water to maintain their green condition prior to microwave treatment.

## Microwave treatment

Microwave oven with maximum output power of 900W at frequency 2450 MHz was used for the experiment. Treatments were carried out at various intensities and times, namely, intensity: 95.57 (T-1), 111.50 (T-2), 127.42 (T-3), 143.35 (T-4) W $cm^{-2}$ and untreated (C-1) as well as time: 3 (A) and 5 (B) min. Six replicates for each treatment were carried out, total 162 specimens (54 for pH analysis and 108 for termite mound test). After microwave treatment, the specimens were examined for checks and cracks compared with control specimens.

## Wood pH

Treated wood for the pH analysis and control specimens were converted into chips. The pH of the wood samples was determined using hot water extraction method (Sinthole 2005).

## Preservative treatment

Microwave-treated and control (C) specimens were subjected to preservative treatment by full cell method of impregnation using pressure 689.47 kPa for 1 hour in water soluble 4% acid copper chromate preservative. Controls (C-1) were maintained without preservative treatment and were used as reference samples for conducting termite mound test.

After treatment, excess preservative was blotted out using filter paper and specimens were weighed immediately to determine the preservative uptake and retention according to the standard (IS 401 2001). Treated specimens were allowed to dry for 21 days for proper distribution and fixation of preservative and conditioning of specimens. The amount of preservative solution absorbed by specimen (retention value, R, in kg $m^{-3}$) was calculated as:

$$R = \frac{G \times C \times 10}{V}$$

where G = weight (g) of the preservative solution absorbed by the block (final weight of block after absorption – initial weight of block), C = weight (g) of the preservative in 100 g of treating solution and V = volume of the test block ($cm^3$).

## Termite mound test

Microwave and microwave-cum-preservative treated including controls (without any treatment) were converted into test blocks of size 100 mm × 25 mm × 6 mm. The termite mound test of the wood samples was performed according to Shukla (1977) (Table 1).

## Statistical analysis

Statistical analysis was conducted using SPSS 16 version. Retention of preservative by *E. tereticornis* at different intensities and times of microwave treatments were compared using variance analysis (ANOVA) and the Duncan homogeneity test at 95% confidence interval.

**Table 1** Classification of wood into various resistance classes on the basis of wood consumed by termites (Shukla 1977)

| Numerical rating | Symbol | Condition of sample |
|---|---|---|
| 0 | N | No attack, sample free from termite attack |
| 0.5 | VSw | Trace attack, termite attack area less than 5% of the surface |
| 1.0 | Sw | Light attack, 5–20% |
| 2.0 | Mw | Moderate attack, 20–35% |
| 3.0 | Bw | Heavy attack, 35–50% |
| 5.0 | Dw | Very heavy attack, >50% |

## RESULTS AND DISCUSSIONS

There were no checks or cracks on treated *E. tereticornis* wood samples at lower microwave intensity of 95.57 W $cm^{-2}$ for 3 min but at higher intensity and time, checks or cracks were observed in the wood samples (Figure 1). Development of checks or cracks is desirable up to a certain extent as it can improve treatability of wood (Poonia et al. 2015) as shown in Figure 2.

### pH analysis of wood

The results of pH analysis of *E. tereticornis* wood after microwave treatment at different intensities and times are shown in Table 2. The pH of control was 3.9 whereas, with the increased treatment time and intensity, the pH of *E. tereticornis* wood slightly decreased. When wood becomes acidic, wood durability is improved against biodegradable agencies such as insects, pests and fungi (Bahmani et al. 2016, Kaur et al. 2016). The results showed insignificant differences between T-1A (3.7), T-2A (3.7) and T-3A (3.6) treatments. This showed that microwave treatment was insignificant at lower intensity and time. The effect of microwave treatment on pH of wood at higher intensity and time exhibited significantly different pH compared with control (T-1B (3.5), T-2B (3.4), T-4A (3.4), T-3B (3.2) and T-4B (3.2)) but the values were insignificant between them. Similar results of pH reduction were reported by Niemz et al. (2010) in thermally modified wood of softwood and hardwood species. These changes in pH may be related to changes in the distribution of salts, extractives, acidic groups

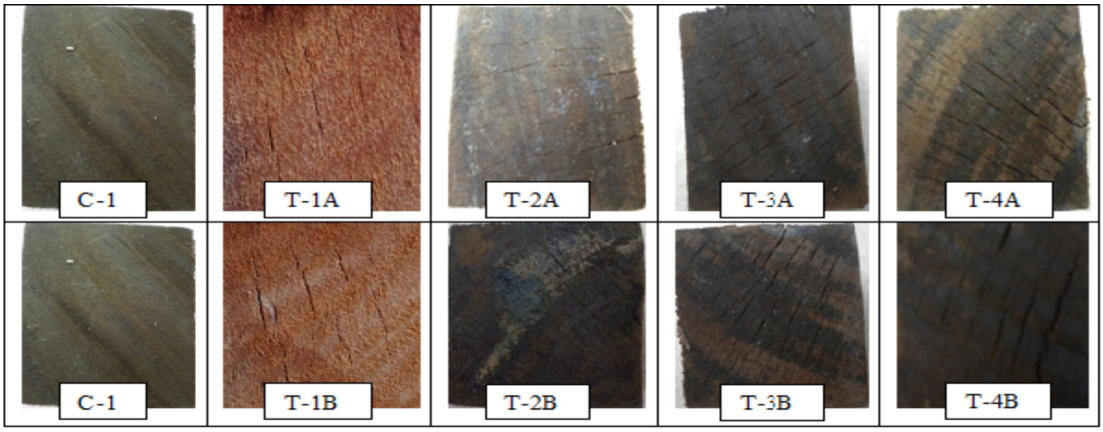


**Figure 1** Checks and cracks developed during microwave treatment (intensity: 95.57 (T-1), 111.50 (T-2), 127.42 (T-3), 143.35 (T-4) W $cm^{-2}$ and time: 3 (A) and 5 (B) min) in *Eucalyptus tereticornis* wood specimens compared with control (C-1)

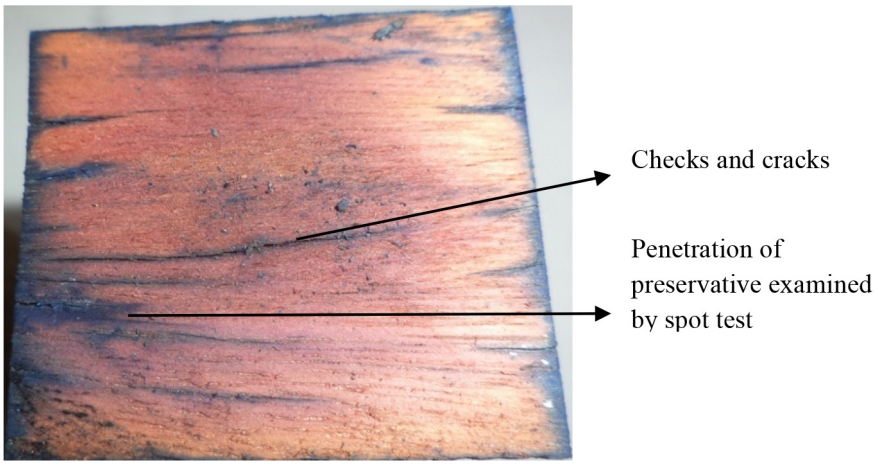


**Figure 2** Effect of checks and cracks on treatability of *Eucalyptus tereticornis* wood

in hemicelluloses and soluble and insoluble organic acids, as these substances appear to be responsible for the acidity of wood (Packman 1960, Hernandez 2013). The decrease in pH is caused by the production of organic acids during thermal treatment mainly by the degradation of hemicelluloses in which acetyl groups split off (Nuopponen et al. 2004). Phenolic carboxylic acid and 4-O-methyl-glucuronic and galacturonic acids which are produced as the result of hydrolysis of wood also add to the acidity (Windeisen et al. 2007).

## Retention of preservative

Mean retention of preservative is shown in Table 2. Control specimens (without microwave treatment) exhibited minimum retention value (2.03 kg $m^{-3}$), whereas microwave-treated specimens at different intensities and times exhibited almost 3.78 fold increase in retention level (2.14 to 9.72 kg $m^{-3}$). Retention of acid copper chromate preservative increased with increase in microwave intensity and time and was maximum (9.72 kg $m^{-3}$) in T-4B, i.e. specimens subjected to microwave intensity of 143.35 W $cm^{-2}$ for 5 min) whereas lowest (2.14 kg $m^{-3}$) in T-1A (95.57 W $cm^{-2}$ intensity for 3 min). The higher the microwave intensity and exposure time, the higher the retention of preservative. Improvement in impregnation properties following acid copper chromate and microwave pretreatment was also reported by Treu and Gjolsjo (2008) for Norway spruce (*Picea abies*) and Hong et al. (2005) for larch (*Larix olgensis*).

**Table 2** Effect of microwave treatment on pH of wood, retention of preservative and its performance in termite mound test

| Treatment | pH | Retention (kg $m^{-3}$) | Average numerical rating | | Final condition of the sample |
|---|---|---|---|---|---|
| | | | First season | Second season | |
| Control (C-1) | 3.9 a | - | N (0.16) | Sw (1.05) | Light attack |
| T-1A | 3.7 a | - | N (0.10) | Sw (1.02) | Light attack |
| T-1B | 3.5 b | - | N (0.10) | Sw (1.00) | Light attack |
| T-2A | 3.7 a | - | N (0.12) | Sw (1.04) | Light attack |
| T-2B | 3.4 b | - | N (0.13) | Sw (1.10) | Light attack |
| T-3A | 3.6 a | - | N (0.20) | Sw (1.05) | Light attack |
| T-3B | 3.2 b | - | N (0.23) | Sw (1.00) | Light attack |
| T-4A | 3.4 b | - | N (0.12) | Sw (1.02) | Light attack |
| T-4B | 3.2 b | - | N (0.12) | Sw (0.90) | Light attack |
| Control (C) + ACC | | 2.03 c | N (0) | N (0) | No attack |
| T-1A+ ACC | | 2.14 c | N (0) | N (0) | No attack |
| T-1B+ ACC | | 4.64 e | N (0) | N (0) | No attack |
| T-2A+ ACC | | 3.41 d | N (0) | N (0) | No attack |
| T-2B+ ACC | | 5.03 f | N (0) | N (0) | No attack |
| T-3A+ ACC | | 4.34 e | N (0) | N (0) | No attack |
| T-3B+ ACC | | 7.34 g | N (0) | N (0) | No attack |
| T-4A+ ACC | | 5.04 f | N (0) | N (0) | No attack |
| T-4B+ ACC | | 9.72 h | N (0) | N (0) | No attack |

Mean square errors of pH and retention are 0.21 and 0.58 at ($p \leq 0.05$) level respectively; different letters in the same column denote significantly different groups, values in parentheses indicate mean numerical rating values; ACC = acid copper chromate; intensity: 95.57 (T-1), 111.50 (T-2), 127.42 (T-3), 143.35 (T-4) W $cm^{-2}$ and untreated (C-1), time: 3 (A) and 5 (B) min

### Termite mound test

The performance of microwave and acid copper chromate-treated *E.tereticornis* specimens in termite mound test are shown in Table 2. Control and microwave-treated specimens were normal in first season and were lightly attacked by termite, with scores between 0.5 and 1.0. This was equivalent to 5–20% destruction of specimens found in second season. The specimens subjected to acid copper chromate (ACC) preservative treatment followed by microwave treatment exhibited normal status in second consecutive season of exposure. Higher protection was achieved when wood was treated with microwave prior to treatment acid copper chromate. Controls and microwave-treated specimens were not resistant against termites. Microwave treatment followed by 4% acid copper chromate treatment at 689.47 kPa for 1 hour exhibited complete protection against termite. Hence it can be recommended for application. In previous studies, heat treatment of wood has been reported ineffective against termite attack (Metsa-Kortelainen et al. 2011, Duarte et al. 2012). Preservatives such as alkaline copper quaternary, chromated copper arsenat and creosote have significant roles in protection of wood against termite compared with untreated wood (Kumar & Dev 1993, Dev et al. 1997).

## CONCLUSIONS

The study concludes that the *E. tereticornis* wood treated with microwave at different intensities and times did not impart durability against termite but showed significant improvement in retention of preservative and reduced the pH of wood. Results also showed significantly higher protection against termite when microwave treatment was combined with acid copper chromate preservative. Thus, it is recommended that microwave followed by preservative treatments be opted for refractory wood species.

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