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Efficacy of Preservative Treatment and Physical Barriers in Preventing Biodeterioration of Rubber Wood under Estuarine Environment

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Abstract

Among the prospective non conventional boat building materials, rubber wood has gained acceptance for being an easily available agricultural by-product. It is highly vulnerable to biodeterioration. The service life of rubber wood under estuarine conditions is estimated to be about six months. Present investigation is focused on the assessment of extent of protection imparted to rubber wood by preservatives like Chromated Copper Arsenate (CCA), dual preservative and physical barriers like paint and Fibreglass Reinforced Plastic (FRP). Eighteen months study showed that untreated rubber wood failed to prevent marine borer attack in six months of exposure to estuarine waters. Among the three retentions of CCA studied, 16 and 29 kg m^{-3} showed susceptibility to attack by *Sphaeroma* spp. and *Teredo* spp. on prolonged exposure. Higher retention of CCA *viz.*, 42 kg m^{-3} and dual treatment imparted higher degree of protection to rubber wood. Physical barriers that were applied on CCA treated panels accorded a 100% protection to rubber wood. Commercially available CCA treated marine grade plywood samples showed moderate attack in twelve months of exposure and failed after eighteen months.

Keywords: Rubber wood, marine borer, CCA, marine plywood, FRP sheathing

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Introduction

CCA has been well recognized for protecting wood against marine borers. In the present scenario of depleting forest resources in India, studies are focused on the use of non-conventional timber species like rubber wood that is easily available as an agricultural by-product. Though rubber wood has mechanical properties comparable to other conventional timbers, it is highly vulnerable to biodegradation (Shukla & Lal, 1985; Gnanaharan & Damodharan, 1992). Preliminary studies revealed that CCA treatment can impart protection to rubber wood under marine conditions than other conventionally used preservatives (Rao et al., 1993; Edwin & Pillai, 2004). According to American Wood Preservers' Association, the retention of preservative for marine application is 40 kg m^{-3} for CCA alone and 16 to 24 kg m^{-3} CCA treated wood followed by creosote to get an ultimate retention of 320 to 400 kg m^{-3} (AWPA, 2003). It was only in the last decade, that the problem of leaching of copper, chromium and arsenic from CCA treated wood on exposure to aquatic environment came into view. In recent years, studies were focused on recommending alternative materials to replace CCA that can impart better protection to wood in aquatic environment and at the same time be able to prevent leaching of CCA components. Eaton & Hale (1993) discussed the use of physical barriers like metal, concrete, plastic and fibreglass as a possible innovation to protect wood in extreme marine conditions. Studies regarding the use of physical barriers like paint, FRP etc to protect CCA treated wood are less reported (Highley, 1999). CCA treated plywood is commercially available as marine grade plywood, which has been extensively used in boat decking.

Objectives of the present study were to: (i) assess the nature and extent of biodeterioration of rubber wood (CCA and dual preservative treated) and

commercially available marine plywood (ii) assess the performance of rubber wood panels protected using physical barriers such as paint and Fibreglass Reinforced Plastic (FRP) in estuarine condition.

Materials and Methods

Rubber wood panels of size 150 x 100 x 25 mm were cut from freshly felled plantation grown trees and immersed in 2% CCA solution to prevent fungal attack. Air seasoning of the panels was carried out for a period of 4 weeks. Panels having below 25% moisture content and devoid of cracks and knots were selected for preservative treatment. Vacuum pressure impregnation of the panels was carried out using 7.5% (w/v) CCA solution as per the conditions detailed in Table 1. To get final retentions of 16, 29 and 42 kg m^{-3}, 200, 100 and 100 panels respectively were treated. Wet weight retention of panels was calculated as per ASTM (1982). Fifty panels treated with CCA at 16 kg m^{-3} retention were further treated with light creosote oil of specific gravity 1.02 - 1.03, sheathed with FRP using chopped strand mat of weight 450 g m^{-2} and polyester resin for reinforcement, and painted with coal tar epoxy finish paint (Asian Paints) with an intermittent drying period of 42h in between. Seasoning of the panels was done at room temperature for four days. Commercially available marine grade plywood samples with CCA retention of 4.05 kg m^{-3} were sized and used for the study.

Racks carrying experimental panels were immersed in the test site located at North Oil Tanker Berth, which is a part of Cochin backwater system in June 2005. Six replicates of selected panels were tied using polyethylene ropes on two different iron racks according to the statistically acceptable randomized design. Racks were immersed 1 m below the water level. Six panels each were returned every six months to the laboratory for analysis after washing with sea water. Fouling organisms were scraped off from the panels and dominant foulers and wood borers were noted.

Visual observations: Panels were visually examined for the presence of borer attack. The number and diameter of borer holes on each type of the panel were enumerated. The destroyed superficial area was traced on to a transparent graph sheet and estimated. The panels with no signs of attack was rated as 0, with galleries covering not more than 10% of total surface area rated as 1, more than 10% of coverage was rated as 2, the panels with severe attack with substantially reduced cross- sectional dimensions was rated as 3 and the panels with more than half of the total area of the panel lost was rated as 4.

X - ray radiographic analysis: Internal damage of the panels was assessed by X-ray analysis according to BS EN 275:1992 as suggested by Eaton (1985). Panels were radiographed using X-ray (45kV, 20 mA) for 15 sec with a distance of 76 cm between panels and 60 MA Elpro X-ray machine. Darker regions in the X-ray radiograph represent tunnels in the surrounding wood matrix. Length and diameter of the tunnels were measured and the area/volume was calculated. Panels were graded for molluscan attack according to area of the tunnels. Panels without any attack was rated as 0, the panels with not more than 15% area deteriorated was rated as 1, the panels with not more than 25% of area deteriorated was rated as 2, panels with 25% to 50% area deteriorated rated as 3 and panels with more than 50% of the area deteriorated rated as 4. For each of the panels, total area and volume destroyed was calculated from the data and reported as percentage area and percentage volume of the panel destroyed. Statistical significance ($p<0.05$) of the data was assessed using SPSS version 12.0.1. (SPSS Inc.).

Hydrographical conditions prevailing in the test site was monitored fortnightly throughout the period of study. Atmospheric temperature and water temperature were measured using centigrade thermometer corrected to ± 0.1°C. Water samples were brought to the laboratory and were analyzed for dissolved oxygen, salinity, pH and turbidity as per standard methods (Strickland & Parsons, 1965).

Results and Discussion

Major macrofoulers observed included barnacles, hydroids, mussels, and polychaete worms. Major wood boring organisms observed included, *Sphaeroma* spp., *Teredo* spp. and *Martesia* spp.

Hydrographical data collected during the study showed considerable difference between pre-monsoon, monsoon and post-monsoon periods. Study was initiated during onset of monsoon in June and as southwest monsoon and northeast monsoon intensified, salinity at the site reduced gradually. Maximum salinity observed was 29.14 ppt and minimum was 0.39 ppt. During monsoon, heavy wave action and churning up of sediments increased

turbidity of water to 32 NTU and reduced the amount of dissolved oxygen to 4.6 mg l^{-1}. Crustacean wood borers were present on all the panels irrespective of the preservative in use and seasonal changes. It was the only species observed during monsoon season when there was a sudden drop in salinity, which may be due to the fact that it breeds throughout the year and can tolerate wide ranges of salinity and temperature (Pillai, 1961; Cheriyan, 1964). Although the *Sphaeroma* spp. was known to be euryhaline, less number of organisms was observed during the monsoon.

Results of visual observation of the panels are summarized in Table 2. Untreated rubber wood samples failed between 6 – 12 months and marine plywood panels in 18 months. Treated panels of 16 kg m^{-3} retention showed severe attack after 18 months while panels with a higher retention 29 kg m^{-3} showed trace attack. Panels treated with CCA to retention of 42 kg m^{-3} were free of attack even after 18 months of exposure. Dual treated, painted and FRP sheathed rubber wood panels provided 100% protection during the entire period of estuarine exposure. Untreated rubber wood panel showed 4.5 times increase in number of borer holes when samples were removed after 6 and 12 months. On retrieval after 6 months, 22 borer holes were observed in the untreated rubber wood panel. After 18 months, untreated panels were completely destroyed making it difficult to count and measure the dimensions of borer holes. In marine plywood panels, there was no significant increase in damage during initial 6 and 12 months while panels were completely destroyed in 18 months. For CCA 16 kg m^{-3}, there were no significant changes in 6 and 12 months but borer holes significantly increased showing localized damage removing a part of the panel in 18 months. No borer attack was observed on dual treated, painted and FRP sheathed panels.

X-ray radiographs revealed the presence of long tunnel like burrows deep into the wood (Fig.1). These tunnels were lined with calcareous shell

Table 1. Conditions of vacuum - pressure impregnation

Retention (kg m^{-3})		Initial vacuum (cm of Hg)	Time (min)	Pressure (k Pa)	Time (min)	Final vacuum (cm of Hg)	Time (min)
CCA	16	56	30	172.37	90	38	15
	29	56	30	448.16	30	38	15
	42	56	30	517.11	15	38	15
Creosote	150	56	30	344.74	45	38	15

Table 2. Rating system for attack by Teredinids, other molluscs and crustaceans after exposure periods of 6, 12 and 18 months in estuary

Type of panel	Rating for attack of crustaceans (for 6, 12 and 18 months)			Rating for attack of molluscs (for 6, 12 and 18 months)		
	6	12	18	6	12	18
Rubber wood (Untreated)	1	1	4	2	4	4
CCA 16 kg m^{-3}	0	1	2	0	1	3
CCA 29 kg m^{-3}	1	0	1	0	0	1
CCA 42 kg m^{-3}	0	0	0	0	0	0
Dual (CCA 16 kg m^{-3} + Creosote 150 kg m^{-3})	0	0	0	0	0	0
Paint	0	0	1	0	0	0
FRP	0	0	0	0	0	0
Marine plywood	1	1	1	2	2	4

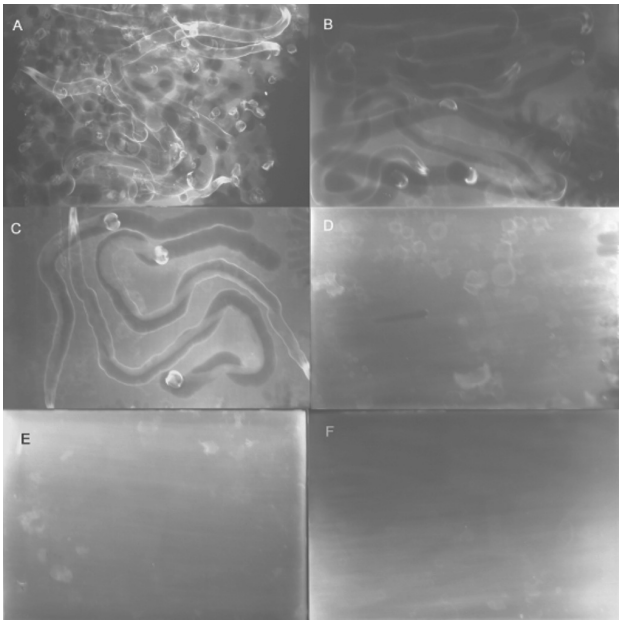

Fig 1. X-ray radiograph of estuarine exposed rubber wood samples for 18 months showing attack by *Teredo* spp. and *Sphaeroma* spp. A: untreated rubber wood, B: Marine plywood, C: CCA treated to 16 kg m^{-3}, D: CCA treated to 29 kg m^{-3}, E: CCA treated to 42 kg m^{-3}, F: Dual treated

characteristic to *Teredo* spp. that appeared darker than the surrounding wood. After an exposure period of six months, tunnel like burrows with an average diameter of 9 mm was observed on untreated and marine plywood panels. Three such long burrows of length 122, 86 and 70 mm were observed in the untreated panels while two such burrows of length 61 mm and 200 mm were observed in marine plywood. Untreated panels retrieved after 18 months were completely infested with *Teredo* spp. making it impossible to measure the area destroyed using X-ray radiograph. After twelve months, X-ray radiographs of panels of 16 kg m^{-3} CCA retention revealed two burrows of length 47 mm and 26 mm with an average diameter of 4 mm although no signs of borer attack was shown externally. CCA 29 kg m^{-3}, CCA 42 kg m^{-3}, dual treated panels, FRP and paint coated panels were without any internal tunnels.

Percentage area and volume of panels deteriorated during 6, 12 and 18 months of immersion in the field are given in the Table 3. During 6, 12 and 18 months of exposure, damage in total superficial area observed was 1.78 ± 0.96 cm^2, 14.35 ± 2.04 cm^2 and 300 ± 20.15 cm^2 and total volume destroyed was 80.16 ± 10.20 cm^3, 330.79 ± 15.25 cm^3 and 375 ± 23.57 cm^3 respectively. Marine plywood panels showed destruction in total area of 1.22 ± 0.12 cm^2, 3.24 ± 1.20cm^2 and 4.25 ± 0.56 cm^2 with a corresponding loss in volume of 80.2 ± 9.86 cm^3, 42.8 ± 6.24 cm^3 and 248.3 ± 15.74 cm^3 after 6, 12 & 18 months respectively. After 18 months of exposure in the field, the area of the panel destroyed was 18.84 ± 3.25 cm^2, 5.8 ± 1.02 cm^2 for CCA 16 kg m^{-3} and CCA

Table 3. Percentage area and volume of the panels deteriorated during 6, 12 and 18 months of immersion in the field

Panel Type	Six months		Twelve months		Eighteen months	
	% area destroyed	% volume destroyed	% area destroyed	% volume destroyed	% area destroyed	% volume destroyed
Untreated	0.42	21.38	*3.38	**88.21	*70.58	**100000
CCA (16 kg m^{-3})	0	0	0	2.45	*4.43	**81.6
CCA (29 kg m^{-3})	0.369	0.502	0	0	1.36	1.2
CCA (42 kg m^{-3})	0	0	0	0	0	0
Dual (CCA 16 kg m^{-3} + Creosote 150 kg m^{-3})	0	0	0	0	0	0
FRP	0	0	0	0	0	0
Paint	0	0	0	0	0	0
Marine plywood	0.287	**22.21	0.76	**11.41	1.0	**66.23

*Showing significantly increased value for % area destruction when compared to the value for untreated rubber wood in six months ($p<0.05$)

**Showing significantly increased value for % volume destruction when compared to the value for untreated rubber wood in six months ($p<0.05$)

29 kg m^{-3} with a corresponding loss in volume of 81.6 ± 8.10 cm^3 and 1.2 ± 0.06 cm^3 respectively. None of the panels treated with CCA to a retention of 42 kg m^{-3} and dual preservative showed deterioration. FRP sheathing and paint coating accorded a 100% protection to the underlying rubber wood panel.

Earlier studies conducted have shown that rubber wood without any treatment gets completely destroyed after an exposure period of six months (Rao et al., 1993; Edwin & Pillai 2004). In the present investigation, the total volume of the untreated rubber wood deteriorated was 21% within six months and 88% within one year. Cheriyan & Cherian (1983), Krishnan et al. (1983), Sreenivasan & Vallabhan (1988) reported that CCA is very effective in preventing the attack of woodborers and can increase durability of less durable varieties of wood. On prolonged exposure, CCA treated panels of lower retention showed damage. This may be explained as crustacean wood borers are tolerant to copper treated timber and thereby lower retentions of CCA are non-resistant to the attack of wood borers (Barnacle et al., 1983; Cookson & Barnacle 1987; Rao et al., 1993; Cragg et al., 1999; Oevering, 2001; Kuppusamy et al., 2004).

Dual preservative treatment is known to prevent woodborers effectively (Richards, 1983; Johnson & Gutzmer, 1984; Edwin et al., 1993; Iblach, 2005). In the present investigation, dual treatment was found to be efficient in preventing both crustacean and molluscan woodborers. According to Edwin & Pillai (2004), dual treated rubber wood prevented borer attack for more than a year. Catamarans, made out of logs of *Albizia chinensis* and *Bombax ceiba* treated with CCA to retentions *viz.,* 16 kg m^{-3} and 32 kg m^{-3} resisted borer attacks for about 24 years (IWST, 1997). Two fishing canoes made of rubber wood treated with CCA and creosote are under experimental operation along the Kerala coast (Edwin et al., 2005).

From the investigation carried out in Cochin estuarine system, it can be concluded that the service life of rubber wood can be increased by CCA treatment. But on prolonged exposure for 12 to 18 months, the CCA treated panels *viz*., at retention levels of 16 kg m^{-3} and 29 kg m^{-3} showed susceptibility to borer attack especially due to *Teredo* spp. Higher retention *viz*., 42 kg m^{-3} of CCA preservative in wood imparted higher degree of protection. Dual treated panels performed equally well as CCA treated panels of 42 kg m^{-3} retention. Physical barriers that were applied on CCA treated rubber wood panels accorded a 100% protection against woodborers. In the present scenario of effective utilization of low cost non durable wood species this study is crucial and decisive.

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