Research article Available online www.ijsrr.org ISSN: 2279–0543

International Journal of Scientific Research and Reviews

Effectiveness of Copper –Chrome - Boron as a Wood Preservative - A Short Review

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ABSTRACT:

Protecting wood from different environmental condition is considered to be a hurdle task. Though the chemical wood preservatives can achieve this goal, it may causes adverse impact to the ecosystem. In this context, the use of inorganic boron along with the combination of copper and chromium as Copper-Chrome-Boron (CCB) gains importance in the wood preservation industry. These review discuss the findings of studies conducted all over the world regarding the effects of CCB treatment on the inherent physical and mechanical properties of wood, resistance to bio deterioration in different environmental conditions and resistance to leaching.

KEY WORDS: Copper-Chrome-Boron, mechanical properties, bio deterioration, leaching.

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INTRODUCTION

Wood is considered to be an important structural material for terrestrial and aquatic applications. When it is used in outdoor applications without any treatments, it will prone to degradation by a wide range of natural causes[1]. Wood can be protected from the attack of fungi, insects, marine borers and other deteriorating organisms by using chemical preservatives[2]. The chemical wood preservatives generally classified into oil born and water born preservatives. Among these, water born fixed type of preservative is preferable for outdoor applications[3]. The water-born fixed type preservatives have a fixative salt, usually sodium or potassium dichromate. These fixatives reduce the leaching of toxic elements like arsenic, fluorides, copper, boron etc from the wood by fixing these elements into the wood. So the water boron preservatives are suitable for marine applications[4].

Copper - chrome –arsenic (CCA) has been widely used in the treatment of wood for decades for indoor and outdoor applications and it is found very effective to protect wood against insects (termites and borers), decay fungi and marine borers. However, environmental concerns about the use of CCA have been raised due to the chance of dispersion of arsenic into the environment and possibility of contamination of soil and groundwater and its risk for humans[5]. The use of CCA has been restricted for outdoor applications in many countries because of the toxicity of arsenic present in the formulation[6]. In 1970s formulations were produced in which arsenic was replaced with less toxic components such as phosphate to give copper-chrome phosphate (CCP), boron (CCB) or fluoride (CCF). Of the three types, CCB is the most acceptable alternative on both environmental[7] and efficacy grounds [8,9].

It has been reported that CCB may be as effective as CCA in sites where temperate climatic conditions with long dry periods are dominant[10]. The restriction of borates to indoor applications has been overcome by the use of more complex formulations where boron is just one active ingredient in a formulation containing two or more e.g., in CCB. Comparison of acute oral LD50 values for boric acid, sodium orthophosphate and arsenic pentoxide indicates that CCB and CCP would be expected to have lower toxicity than CCA, and presumably proportionately less potential for adverse environmental impact. The toxicological studies on mouse showed that boron (LD50 – 1740 mg/kg) in CCB is comparatively less toxic than Arsenic (LD 50-31mg/ kg) in CCA[11].

This review focuses to consolidate the important findings of researchers related to the effectiveness of CCB for indoor and outdoor applications including the marine application. This communication also focused on different views regarding the effect of CCB on the physical and mechanical properties of wood and the leachability of preservative from treated wood.

EFFECT ON THE PHYSICAL AND MECHANICAL PROPERTIES OF WOOD

The chemical wood preservation is extremely important to protect wooden materials from bio-deterioration. In some cases, it will affect the structural properties of wood[5]. The studies conducted by Felipe et al[12] on the effect of CCB treatment on the mechanical properties of Parica Wood (*Schizolobium amazonicum*). The study concluded that the impregnation of CCB in the wood did not change the properties like apparent density, shear strength, hardness, strength and stiffness in compression parallel to the grain. Simsek[13] observed that there is a 4% and 6 % decrease in the compressive stress parallel to grain (CSPG) value of CCB (4%(w/v)) treated Scots pine (*Pinus sylvestris*) and Oriental beech (*Fagus orientalis*) wood panels. The modulus of rupture (MOR) value is also found decrease but which is better than borax and boric acid treated panels. Studies conducted by Rabbi et al[14] found that the impregnation of CCB in mango wood panels by full cell process improves the physical properties of wood. Usta and Hale[15] conducted a study on the effect of thermal treatment of CCB preservatives on the static bending properties of Turkish fir (*Abiesborn mulleriana*). They find out that modulus of elasticity (MOE) and MOR were reduced to a small extent by the full-cell vacuum pressure wood treatment by using 3% of CCB heated at 40 ºC. Shanu et al [16]carried out an experiment to analyse the effects of 8% CCB (chromate-copper-boron) preservative treatment on physical and mechanical properties of *Albizia richardiana* wood using dip treatment. The results showed that the Physical and mechanical properties of the wood improved by treating with CCB preservative.

The studies conducted on the oriental beech (*Fagus Orientalis*) and Calabrian pinewood (*Pinus brutia*) also revealed that the high concentration of boron compounds reduced the static bending properties mainly MOR value compared to the untreated panels[17]. Similar studies conducted with CCA on the mechanical properties of the wood revealed that there is no significant difference in the mechanical properties of treated and untreated samples[18]. Kolman[19] states that the reduction occurs in the mechanical strength properties of CCB treated panels is mainly due to the hydrolysis of wood tissue by the activity of borates. Winandy[20] also states that the acidic nature of wood preservatives decrease the mechanical properties of wood due to the hydrolysis of wood components**.**

RESISTANCE TO BIO DETERIORATION ON TERRESTRIAL ENVIRONMENT

Several workers have studied the performance of CCB against decay compared with CCA preservatives. Wakeling[21] reported that in New Zealand at some sites CCB preservatives (pine sapwood) showed good performance, similar to CCA against wood rot fungus, but the studies revealed that CCB treated panels failed to resist the attack of copper-tolerant brown rot fungi. Similar results have been presented from a comparative study between CCB and CCA preservatives in Malaysia[22]. Hedley[8] showed that CCB preservative formulations performed as well as CCA at sites where soft rot predominated or where no particular decay type was dominant. The susceptibility of CCB treated panels to copper tolerant brown rot fungi have also been reported by Gray and Dickinson[23]; Tamblyn and Levy[24]. Gray and Dickinson[23] concluded that CCB shows better performance than CCA against soft rot decay fungi because greater amounts of copper are absorbed during treatment. Humar et al.[25] carried out the experiments on Norway spruce (*Picea abies*) shown that 5% CCB solution reduced the mass loss of wood over eight weeks of exposure studies under copper tolerant fungi like *Gloeophyllum trabeum*, *Leucogyrophana pinastri* and *Antrodia vaillantii* .

The studies conducted by Selamat et al[22] proved the effectiveness of CCB treatments (5,6 and 8% (m/v)) to increase the durability of non-durable Malaysian timbers like *Koompassia malaccensis* and *shorea robesta* against the attack of termites and other decaying organisms during a year of graveyard test. In the temperate conditions, the service life of CCB treated wooden fence posts is found better even after 18 years of exposure [10]. The Denison single blow impact bending test of these panels shows there was no significant reduction of toughness in any of the zones of these poles.

The resistance of CCB against weathering has been reported since 1974 by sell et al[26]. The anti-weathering properties of CCB treated wood is mainly attributed to the protective effect of Cr-Cu-salt solutions on the wood surface. Yalinkilic et al[27] studied outdoor performances of polyurethane varnish and alkyd-based synthetic varnish coated over chromium-copper-boron (CCB) impregnated Scots pine and chestnut. They reported that CCB pre-impregnation resists weathering of wood. Gerenji et al[28] studied the impact of CCB wood preservative on the corrosion of ST37 steel by using dynamic electrochemical impedance spectroscopy (DEIS), potentiodynamic polarization, and scanning electron microscopy. Results of corrosion tests revealed that CCB displayed inhibitor properties, behaving predominantly as a slightly anodic inhibitor.

RESISTANCE TO BIO DETERIORATION ON AQUATIC ENVIRONMENT

The CCB treated wood panels exposed in the Black Sea, Mediterranean sea and Marmara sea shown to be good condition over a year of exposure, while the untreated panels exposed in all test sites excepts Marmara heavily destroyed by marine borers[29]. The exposure studies carried out in 6 stations around Turkey using 10 % CCB treated panels of around 18 European and 15 African wood species over a year shows the treated panels were remains unattached with borers[30].

Rao and Balaji[31] reported that CCB treated structures showed an excellent resistance against bio-deterioration and the service life is 7 to 8 times compared to controls in marine conditions.

Marine exposure trials were conducted on *Albizia lebbeck* and Tetrameles *nudiflora* timbers after pressure impregnation with two common wood preservatives viz. CCA(5%) and CCB (5%) shows both the preservatives increase the service life of the wood compared to control panels[32]. Tarakanadha[33] carried out a study to find out the impact of wood preservatives on the settlement and growth of marine fouling organisms in *Bombax ceiba* at Krishnapatnam coast. The panels were pressure treated with copper chrome arsenic (CCA), copper chrome boric acid (CCB), ammoniacal copper zinc arsenate (ACZA), ammoniacal copper quaternary (ACQ). The results showed that a greater variety of fouling assemblages were on control, CCB and CCA treated panels compared to ACZA, CC and ACQ treated panels. CCA treated panels had heavier settlement of barnacles followed by oysters and bryozoans, while CCB treated panels had heavier settlement of oysters followed by barnacles and bryozoans. This study also shown that all treated panels were resist to bio deterioration while the untreated panels were completely degraded after 6 months of exposure.

Muslich and Hadjib[34] reported that the suitable preservative treatment could increase the durability of low value timbers available in Thailand for marine applications. They compared the durability of CCB(3%) treated and plastic impregnated panels of plantation crop timbers (*Paraserianthes falcataria, Agathis sp, Pinus merkusii, Hevea brasilliensis*) with the conventionally used forest timbers (*Tectona grandis, Instia biyuga, Vitex pubescens*, and *Eusideroxylon zwageriI*) as untreated control for marine applications. The exposure studies were carried out in the waters of Rambut Island. After 6 and 12 months of exposure, the results showed that CCB preserved timber were more durable than plastic impregnated timber and untreated timber. Wood samples were mostly attacked by marine borer organisms from the family of Pholadidae and Teredinidae. The experiment results revealed the possibility of using those plantation forest timber species for marine construction purposes. Another study conducted by Muslich[35] on the 16 wood species seen in Thailand also reported that the CCB (3%) treated panels resist the marine borer attack. Muslich and Rulliaty[36] conducted the similar study on 25 locally available wood species from Java. Most of the specimens treated with CCB were resistant to marine borers.

LEACHING OF BORON FROM THE CCB TREATED WOOD

The magnitude of boron leached from CCB treated wood is higher than that of copper and chromium[37,38]. Previous studies show that while fixing boron may reduce leaching, it may lock the boron resulting in loss of biological efficacy[39]. Ana and Jose[40] evaluated the leaching of copper, chromium and boron from 1.6% of CCB (Cu 9.7%; Cr, 15.9%; B, 0.36%) treated panels by using the laboratory assay and atmospheric exposure studies conducted based on the Spanish weathering conditions for one year. According to the results the total emissions of Cu and Cr obtained in a laboratory assay were lower than those for panels under field conditions. However, the percentage of boron leached from wood was found to be higher in laboratory than in field assays. The initial rate of leaching of boron is found to be higher than other metals in both experiments.

CONCLUSION

Copper –Chrome-Boron is considered to be more eco-friendlier wood preservative than Copper-Chrome-Arsenic. It is found to be effective on both terrestrial and aquatic applications. This review article is focussed to consolidate the important studies conducted all over the world on the effectiveness of CCB treatment. In this review we have discussed different aspects of CCB preservative treatment includes its effectiveness to increase the durability of wood in different environmental conditions, effects on the inherent physical and mechanical properties of wood and the leach ability of metal components from the treated wood. This review is believed to be useful for the researchers, students and common people for getting a better understanding of this preservative.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the support from the Coconut Development Board (CDB) for funding this study. They also thank, Director CIFT for the facilities provided and for his kind encouragement and guidance during the course of the study.

REFERENCES

1. Ibach RE. Wood handbook: wood as an engineering material. Madison, WI: USDA Forest Service, Forest Products Laboratory. General technical report FPL; GTR-113.199; 14.1-14.27.
2. Kartal SN, Yoshimura T and Imamura Y. Decay and termite resistance of boron-treated and chemically modified wood by in situ co-polymerization of allyl glycidyl ether (AGE) with methyl methacrylate (MMA). Int. Biodeterior. Biodegrad. 2004; 53: 111–117.
3. Findlay WPK. Preservation of timber in the tropics. Martinus Nijhoff/Dr W. Junk Publishers, Dordrecht, The Netherlands. 1985.
4. Is 401. Preservation of Timber-Code of Practise (Fourth Revision).2001.
5. Pinheiro RV. Influência da preservação contra a demanda biológica em propriedades de resistência e de elasticidade da madeira. Tese (doutorado), Universidade de São Paulo, São Carlos, São Paulo. 2001;187,.
6. Nordstrom DK, Worldwide occurrences of arsenic in ground water. Science.2002; 296: 2143–2146.
7. Tillott RJ and Coggins CR. Non-arsenical Wood Preservatives - A Review of Per- formance and Properties. Annual Record British Wood Preserving Association 1981; 32-48.

8. Hedley ME, Relative performance of copper chrome boron (CCB) and copper chrome arsenate (CCA) in ground contact. International Research Group on Wood Preservation Document No. IRG/WP 92-3694,1992.
9. Hedley ME. Relative performance of Copper-Chrome-Arsenate and Copper-Chrome-Boron in field stake tests. Report prepared for Koppers- Hickson Wood Protection (NZ) Ltd. NZ FRI Wood Processing Division Project Code 4517 38.1995.
10. Kakaras JA, Goroyias GJ, Papadopoulos AN and Hale MD. Observation on the performance of CCB and creosote treated fence posts after 18 years of exposure in Greece. International Research Group on Wood Preservation. Document No. IRG/WP 02-30288. 2002.
11. Hedley, M.D., An assessment of risks associated with use of CCA-treated timber in sensitive environments and options for its substitution with alternative timber materials. Conservation Advisory Science Notes No. 154. 1997.
12. Felipe HI, Fabiane SF, Luciano DV et al. Physical and Mechanical Properties of Paricá Wood Species Treated with CCB Preservative. Int. J. Mater. Eng., 2013; 3(4): 82–86.
13. Simsek H, Baysal E, Yilmaz M and Culha F. Some Mechanical Properties of Wood Impregnated With Environmentally-Friendly Boron and Copper Based Chemicals. 2013; 58(3): 495–504.
14. Rabbi F, Islam M and Rahman, ANMM. Wood Preservation : Improvement of Mechanical Properties by Vacuum Pressure Process. Int. J. Eng. Appl. Sci. 2015; 2(4): 75–79.
15. Usta I and Hale M. Effects of concentration and temperature of CCA and CCB on wood strength of Turkish fir (Abies bornmulleriana). IRG/WP 09-40450.2009.
16. Shanu, S, Das A, Rahman M and Ashaduzzaman M. Effect of Chromate-Copper-Boron preservative treatment on physical and mechanical properties of Raj koroi (*Albizia richardiana*) wood. Bangladesh J. Sci. Ind. Res. 2015; 50(3): 189-192.
17. Toker H, Baysal E, Simsek H et al. Effects of Some Environmentally-Friendly Fire-Retardant Boron Compounds on Modulus of Rupture and Modulus of Elasticity of Wood. Wood Res. 2009; 54: 77–88.
18. Yildiz UC, Temiz A, Gezer ED and Yildiz S. Effects of the wood preservatives on mechanical properties of yellow pine (*Pinus sylvestris L.*) wood. Build. Environ. 2004; 39(9): 1071–1075.
19. Kollmann F, Cote WA. Principles of wood science and technology. Solid wood. Springer-Verlag. 1968; 149–151.
20. Winandy JE, Green F and Keefe D. Treatability problems - Relationships between anatomy, chemical composition and treatability. Int. Res. Gr. Wood Prot. 32nd Annu. Meet. 2001.

21. Wakeling, R. N., A comparison of the soft rot, white rot and brown rot in CCA, CCP, CCB, TCMTB and benzalkonium chloride treated *Pinus radiata* IURFO stakes after 9-15 years' exposure in five test sites in New Zealand, International Research Group of Wood Preservation Document. No. IRG/WP/1485. 1991.
22. Selamat S, Said Z and Ahmad F. Effectiveness of Copper-Chrome-Boron As Wood. J. Trop. For. Sci. 6(2); 1993: 98–115.
23. Gray SM and Dickinson DJ. CCA modifications and their effect on soft rot in hardwoods. International Research Group on Wood Preservation. Doc. No. IRG/WP/3201. 1982.
24. Tamblyn N and Levy C. Decay resistance of stakes treated with preservatives. Journal of the Institute of Wood Science.1981; 9(2):55- 61.
25. Humar M, Šentjurc M, Amartey SA and Pohleven F. Influence of acidification of CCB (Cu/Cr/B) impregnated wood on fungal copper tolerance. Chemosphere, 2005; 58: 743–749.
26. Sell J, Muster WJ, Wälchli O. Investigations on weathered wood surfaces. Part V: The efficiency of Cr-Cu-B- salt- solutions for surface treatment. Holz als Roh-und Werkstoff. 1974; 32(2): 45-51.
27. Yalinkilic MK, Imamura Y, Takahashi M and Yalinkilic AC. In situ polymerization of vinyl monomers during compressive deformation of wood treated with boric acid to delay boron leaching. For. Prod. J. 1999; 49: 43–51.
28. Gerengi H, Tascioglu C, Akcay C and Kurtay M. Impact of copper chrome boron (CCB) wood preservative on the corrosion of St37 steel. Ind. Eng. Chem. Res., 2014; 53: 19192–19198.
29. Bobat A. Utilisation and resistant period of treated wood material in mine and undersea. PhD Thesis. Black Sea Technical University, Graduate School of Natural and Applied Sciences, Department of Forest Industrial Engineering, Trabzon. 1996.
30. Sen S, Sivrikaya H and Yalçin M. Natural durability of heartwoods from European and tropical Africa trees exposed to marine conditions. 2009; 8(18): 4425–4432.
31. Rao, K. S., and M. Balaji., Treated catamarans: A boon to fishermen. IWST Technical Bulletin, published by IWST Extension support division. 1997; 1-10.
32. Rao MV, Aggarwal PK. Marine exposure trials on two treated timbers used for fabricating catamarans. J. Indian Acad. Wood Sci., 2011; 8(2): 193–197.
33. Tarakanadha B, Aggarwal PK, Prasad NR, Rao KS. Performance of Different Wood Protection Methods in Tropical Marine Waters, Krishnapatnam Harbour, India. J. Ind. Acad. Wood Sci. 2007; 17(6): 343-349.

34. Muslich M and Hadjib N. The Possibility of Using Timber From Plantation Forest Treated with Plastic and CCB for Marine Construction. Indonesian Journal of Forestry Research. 2008; 5(1): 65-72.
35. Muslich M. The CCB Treatment of Sixteen Indonesian Wood Species Against Marine Borers. Indonesian journal of Forestry Research. 2006; 30(1): 41-53.
36. Muslich M and Rulliaty S. Durabilty of 25 Local Specific Wood Species From Java Preserved With CCB Against Marine Borers. Journal of Forestry Research, 2010; 7(2): 144–154.
37. Peylo A and Willeitner H. The Problem of Reducing the Leach ability of Boron by Water Repellents. Holzforschung. 1995; 49: 211–216.
38. Peylo A and Willeitner H. Leaching of boron-more than 3 years of field exposure. The International Research Group on Wood Preservation. IRG/WP 97-30143. 1997.
39. loyd, JD, Dickinson DJ, Murphy RJ. The Probable Mechanisms of Action of Boric Acid and Borates as Wood Preservatives. International Research Group on Wood Preservation IRG/WP 1450. 1990.
40. Garcia-Valcarcel, AI and Tadeo JL. Leaching of copper, chromium, and boron from treated timber during aboveground exposure. Environ. Toxicol. Chem. 2006; 25(9): 2342–2348.