International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2015): 6.391

Physical Properties and Biological Resistance Capacity of Chemically Treated Bamboo (*B. tulda*) – A Preliminary Study

Runumee D. Borthakur[1], Ellora D. Borah[2]

Rain Forest Research Institute, Deovan, Sotai, Jorhat , P.box No : 136, Assam,India.

Abstract: ***Four years old bamboo (Bambusa tulda) samples were treated with different preservative chemicals and studied the effect on strength properties, physical properties and biodegradation resistance capacity of the treated samples. It was observed that compared to untreated and other simple chemical treatment, the combined treatment of boric acid (BA), copper acetate (CA), zinc chloride ($Zncl_2$), sodium salt of triethelenetetramine dithiocarbamate (triendtc.) followed by kerosene oil showed better performance. Dimensional stability in terms of antishrink efficiency (ASE), weight percent gain (WPG) and bulk coefficient (BC) as well as termite resistance capacity of the treated sample showed better performance compared to untreated sample. The efficacy of the preservative chemicals against termites and fungi was evaluated by burial test. It was observed that the strength properties of the treated bamboo samples in terms of modulus of rupture (MOR) and modulus of elasticity (MOE) was increased as compared to untreated sample.***

Keywords: Preservative, Biodegradation, Dimensional stability, Strength properties.

1. Introduction

Bamboo," the green gold of forest" is the world's fastest growing lignocellulosic bioresources used for innumerable purposes both in the rural and urban sector. The fibrous nature of bamboo makes it one of the most appropriate and versatile raw materials for variety of purposes. A wider acceptance of bamboo for structural and other uses, however, is often hindered by its propensity to biological degradation. In general, bamboo is not durable, average life of untreated bamboos is less than two years (Kumar *et al*. 1994). Though bamboos are endowed with hard and highly refractive outer rind, the presence of rich sources of potential nutrients and lack of toxic extractives which impart natural durability makes it highly biodegradable. Biological organisms recognize the polysaccharide polymers in the cell wall and with the help of specific enzyme systems they have hydrolyze these polymer into digestible units. Termites with their cellulose decomposing bacteria *cellulase*, in their gut can easily digest the cellulosic part of the cell wall and as a result, the strength of lignocellulosic reduces drastically (Stamm, 1964). Again natural weathering factors such as heat, light, oxygen, relative humidity also cause physical as well as chemical changes. Depending on the end-use, the service life of bamboo will vary. Bamboo will last longer, up to 5 years or more when used under cover and out of ground contact, (Liese and kumar, 2003). Generally the attack by biological organisms is severe in tropical regions than in temperate regions. For structural uses, whether indoor or outdoor, whether in tropical or temperate region, bamboo should be treated with preservative chemicals to provide adequate service life.

Post harvest preservative treatments of bamboo have been found to be significantly minimize the loss due to these biodegrading agents and thus enhancing the durability of bamboo or its products. Various inorganic/ organic formulations incorporating copper, arsenic, ammonium, zinc, boron, pentachlorophenol are being used individually or in mixture (Connell, 1991; Dev *et al*, 1997). Bamboo gets poisoned by using these chemicals and protects it from biodegrading agents, resulting in prolonged life of treated bamboo products (Kumar *et al*, 1994, Borthakur and Gogoi 2009). Use of toxic pesticides may have an adverse effect on the quality of life in terms of toxicity to food chain as well as to human and wild life (Rodrigues *et al* 2012). Because of the undesired side effects and long persistence in soil, of late many of these formulations have been removed from the market. In view of this, worldwide search for environmentally benign chemicals is being made to meet the preservative needs (Jain *et al*, 1990; Dev *et al*. 1997). Boron compounds as wood preservatives have several advantages including a broad spectrum activity against insects and fungi, low mammalian toxicity, low volatility and the absence of colour and odor (Yalinkilic *et al*., 1999). Though ecofriendly zinc borate has been discarded as a preservative because of its insolubility in water, it is reported that a suspension of zinc borate controlled mould growth, which might be due to the action of zinc as co biocide and constant release of boric acid through hydrolysis of salts (Lak *et al*, 1993). It has been reported that zinc borate is an environmental friendly preservative to protect wood/bamboo from biodegradation (Dev *et al*. 1997). Similarly transition metal compounds of dithiocarbamate and dithiophosphinates are known antifungal and antibacterial agents and the mode of action being of certain vital enzymes by the sulphur donors, the Cu^{2+} also can inhibit action of several biomolecules (Kalita *et.al*. 2002). Bamboo treated with dithiocarbamate (triendtc.) and kerosene also reported as good inhibitor of termite and fungus (Borthakur and Gogoi 2009). If some new formulations are devised, which may be cost effective, easy to prepare, having low mobility in soil and relatively harmless it would be an ideal inhibitor. Therefore, the present study was undertaken to study the strength property and biodegradation resistance property of bamboo treated with boric acid, copper acetate, zinc chloride, Sodium salt of triethelenetetramine dithiocarbamate (triendtc.) and kerosene and the performance of treated bamboo in natural environmental condition of North-East India.

2. Materials and Methods

The bottom portions of 4 years old bamboo (*Bambusa tulda*) were collected for experiments from the bambusetum of Rain Forest Research Institute, Jorhat, Assam, India. Rectangular strips of approximately 10 x 2.5 x 1.98 cm. (length, breadth, thickness) were prepared from the bamboo for the treatment. They were refluxed with distilled water for three hours so that some of the starch and water soluble contents eluted out. The moisture content of the bamboo was determined by the oven drying method.

The treatment was done as per Bureau of Indian Standards IS: 2380-1977 with the following chemical formulations (5% w/v).

1) Boric acid
2) Copper acetate
3) Zinc chloride
4) Sodium salt of triethelenetetramine dithiocarbamate (triendtc.)

For the treatment, the bamboo samples were oven dried at 105^0 C for 2 hours cooled to room temperature followed by dipping in each of boric acid, copper acetate, zinc chloride and Triendtc. One separate set of samples were treated with (5% each) boric acid followed by copper acetate, zinc chloride and triethylenetetramine dithiocarbamate (Triendtc). After completion of chemical treatments, all the samples were treated with kerosene oil for seven days and air dried.

Evaluation of properties of treated and untreated bamboo

The dimensional parameters such as anti shrink efficiency (ASE),weight percent gain (WPG) bulk coefficient (BC) of the treated and untreated bamboo samples were determined by repeated water soaking method (Rowell and Ellis 1978 ; Deka *et al*, 2003) using the following relations:

***Weight percent gain (WPG)*:**

The WPG or chemical loading was calculated as,

$WPG = (W_t – W_u) \times 100 / W_u$, Where, W_t = OD weight of the treated sample in gm.

W_u = OD weight of the untreated sample in gm.

***Volumetric swelling co-efficient (S) and anti shrink efficiency (ASE)* :**

The anti shrink efficiency (ASE) were calculated following the relations:

$ASE = (S_u – S_t) \times 100 / S_u$

Where, S_u = Volumetric swelling co-efficient based on oven dry volume of the treated sample

S_t = Volumetric swelling co-efficient based on oven dry volume of the treated sample

Bulk co-efficient (BC):

Bulk co-efficient (BC) was calculated as:

$BC = (V_t – V_{u)} \times 100 / V_u$

Where V_u and V_t are oven-drying volumes of untreated and treated samples respectively.

Evaluation of physical and mechanical properties of the bamboo samples

The physical and mechanical properties of the treated and untreated bamboo samples were evaluated by using Universal Testing Machine at NEIST, Jorhat, Assam, India.

Determination of modulus of rupture (MOR)

The MOR of the specimens was reported using the following mathematical expression.

$MOR = 3 PL / 2bd^2$

Where, P = Maximum load applied in kg., L = Length span of the tested specimen in cm.,

b = Width of the specimen in cm, d = Depth of the specimen in cm.

Determination of modulus of elasticity (MOE)

The modulus of elasticity of the test specimen were determined using the relation,

$MOE = P_1 L^3 / 4bd\ ^3Y$.

Where, P_1 = Load in Kg. at proportionality limit, Y = Central deflection at the limit of proportionality load in cm, L = Length span of the test specimen in cm., b = Width of the test specimen in cm. d = Depth of the specimen in cm.

Scanning Electron Micrograph (SEM) study

To study the adherence of chemicals onto bamboo cell wall, the Scanning Electron Micrograph of treated and untreated samples were taken. The observations were made in JEOL, JSM- 35M- 35 CF electron microscope at Indian Institute of Technology, Guwahati, Assam, India.

Determination of termite resistance capacity: Graveyard Test:

The termite resistance capacities of treated and untreated bamboo samples were determined visually. For this, the treated and untreated test samples were labeled and buried in soil vertically by following completely randomized design in such a way that $1/4^{th}$ of the samples were remaining under soil. Each treatment was replicated five times. Termite activity, fungal infection and other damage caused by the biodeteriorating agents were recorded by visual observation once every two months in the first year and once in six months in the subsequent year. After six months of burial the samples were removed from soil, washed thoroughly with water to remove the debrishes and dried in oven and weighed. Visual decay assessment was recorded as per standard procedure (IS: 4833-1968).While evaluating the results of the visual observation, 5-10 percent of attack is taken as slight (1-1.5 score), 10-25 percent as moderate (2-3score), above 25 percent as bad (3-4.5score) and 50 percent as destroyed (5score). The damage level (in %) in treated and untreated samples were recorded. Observations were continued for a period of three years.

3. Results and Discussion

Table-**1** shows the dimensional variations of bamboo samples treated with different chemicals and their combinations in terms of antishrink efficiency (ASE), bulk coefficient (BC) and weight percent gain (WPG). The bamboo samples treated with BA, CA, $Zncl_2$ followed by Triendtc showed comparatively higher antishrink efficiency (ASE) with increase in bulk coefficient (BC) compared to simple BA,CA and $Zncl_2$ treated bamboo samples. Maximum ASE (48.71%) value at the level of 18.11% WPG shown by the sample treated with boric acid, copper acetate, zinc chloride followed by, triendtc and kerosene. In presence of chemicals, the cell wall of bamboo showed less shrinkage and swelling in contact with moisture than the untreated samples. The presence of kerosene creates a hydrophobic environment inside and on the surface of the samples as well as prevents the leaching of preservatives by moisture penetration. This treatment also showed higher weight percent gain (WPG) value than the other treatments as well as untreated samples.

Table 1: Dimensional characteristic of treated bamboo

S.No	Chemical used	WPG%	BC%	ASE%
1.	Untreated	0	0	0
2.	BA + Kerosene	11.65	4.53	30.67
3.	CA + Kerosene	12.04	4.62	32.14
4.	$Zncl_2$ + Kerosene	14.41	5.25	36.39
5.	BA + CA + $Zncl_2$ + Triendtc +Kerosene	18.11	6.42	48.71

Increase of WPG indicates the presence of added chemicals in to the bamboo samples. The dimensional stability in terms of antishrink efficiency was determined and found to be improved on treatment. However, these samples also exhibits protection from termite compared to simple BA, CA and $Zncl_2$ treatment.

From the measurement of strength (MOR) and stiffness (MOE) of both treated and untreated samples, it was observed that there is increase in the modulus of rupture and modulus of elasticity of the treated samples (**Table 2**). It could be due to the physical bulking of copper acetate, boric acid, zinc chloride, triendtc and kerosene oil. Strength properties of *Gigantochloa scortechinii* bamboo treated with Ammonium Copper –Quaternary (ACQ), Copper Chrome Arsenic (CCA) and Borax Boric Acid (BBA) was evaluated and reported that after the treatment the strength properties of bamboo is increased (Wahab *et al*, 2006) and the strength properties of the treated bamboo dependent on the type of preservative applied, concentration and their retention in the bamboo.

Table 2: Effect of chemical treatment on strength (MOR) and stiffness (MOE) of bamboo

S.No	Chemical used	MOR (N/mm^2)	MOE (N/mm^2)
1.	Untreated	42.70	6520
2.	BA + Kerosene	44.87	7043
3.	CA + Kerosene	45.04	7261
4.	$Zncl_2$ + Kerosene	47.51	7470
5.	BA + CA + $Zncl_2$ +Triendtc +Kerosene	58.06	7853

Colakoglu *et al*. (2003) reported that compression strength of laminated veneer lumber (LVL) treated with boric acid was increased about 1.4% compared to untreated lumber. Figure 1 and 2 shows the bamboo samples before and after the strength property test.

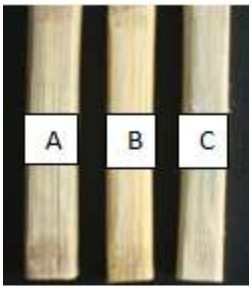

Figure 1: A view of the bamboo sample before MOR test

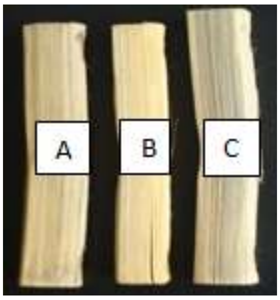

Figure 2: A view of the bamboo sample after MOR test

The incorporation of the preservatives constituent in to the internal configuration of the bamboo samples were studied by scanning electron micrograph (SEM). The penetration of the chemicals resulted in bulking of the cell wall to give dimensionally stabilized bamboo. Increased WPG value proved the incorporation of preservatives inside the bamboo cell wall. The SEM of the untreated sample **(Plate A)** showed a diffused configuration, while the white patches seen in the micrograph (**Plate B**) were the penetration of the chemicals observed on the cell walls of the bamboo.

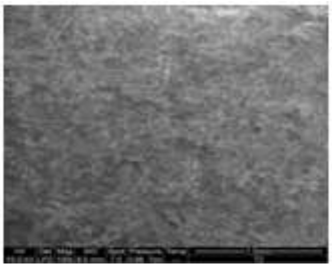

Plate A: SEM of untreated bamboo

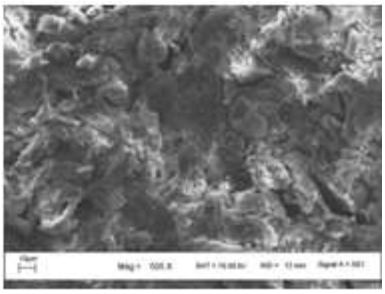

Plate B: SEM of treated bamboo

After one year of graveyard (Fig -3) test it was observed that compared to untreated samples, the samples treated with only boric acid, copper acetate and zinc chloride was slightly damaged by termite. On the other hand, the samples treated with BA, CA, $Zncl_2$ and triendtc combination showed good biodegradation inhibition .The bio-resisting property of this treatment may be due to the antibacterial and antifungal activity of the boric acid, copper acetate and dithiocarbamate. The antifungal, antibacterial and insecticidal activity of dimethyldithiocarbamate of copper has been patented in U.S. as wood preservative (Batterrshell *et al*., 1998). Boric acid has been reported as stomach poison for insects (Yamaguchi, 2003). Similarly transition metal compounds of dithiocarbamate and dithiophosphinates are known antifungal and antibacterial agents and the mode of action being of certain vital enzymes by the sulphur donors, the Cu^{2+} also can inhibit action of several biomolecules (Kalita *et al*.,2002). Dithiocompounds also inhibit the enzyme *actycholinesterase* (Gruzdyev *et al.*, 1980).

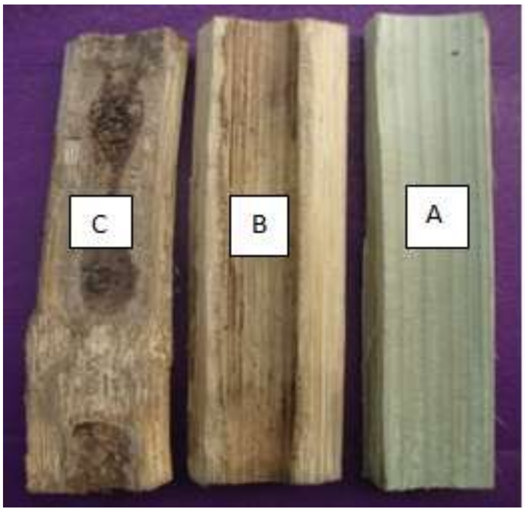

Figure 4: A view of the treated and untreated sample after one year of graveyard test

The experiment showed that the presence of sulphur compounds like dithiocarbamate derivatives in presence of boric acid, copper acetate and zinc chloride inhibits the vital activity of microorganism and fungus by blocking the activity of *cellulase*. Further petroleum oil like kerosene has low toxicity to warm blooded animals but prevents metabolism in egg or insect body. The oil can easily penetrate through the wax scale and cuticles, can cause coagulation of the cytoplasma and inhibit the course of enzyme process (Gruzdyev *et al.,* 1980).The presence of boric acid and copper acetate hydrolyze to give slightly acidic medium due to presence of acetic acid. However, the presence of boric acid and copper dithiocarbamate, there is a substantial decrease of *cellulase* activity as seen from the amount of glucose released.

4. Conclusion

From the present studies, it may be concluded that treatment of bamboo samples with boric acid followed by copper acetate, zinc chloride, triethylenetetramine dithiocarbamate, and kerosene can be used for achieving dimensional stability and prevent biodegradation. The treated sample showed better resistance to fungal and termite attack due to cellulose inhibiting effect of copper dithiocarbamate. The strength and stiffness properties of bamboo can also be improved by this treatment. Compared to other chemical methods of treatment of bamboo, the present method appears to be better in the sense that the chemicals are cost effective, can be handle and applied easily and less toxic at low concentration and at the same time give very good results.

References

[1] Battershell, R.D.; Jacobson, B.M.; Abraham, A.C.; Pereira, B.M. and Kempf, J.V. (1998). *United States Patent No*. 5731036. March 24.
[2] Borthakur R.D. and P.K. Gogoi (2009): Studies on dimensional stability and termite resistance capacity of bamboo *(B.balcooa*) after treatment with chemicals and plant extracts. *Indian Forester*. 135 (9), pp 1217 -1231.
[3] Colakoglu,G.,Colak,S., Aydin,I.,Yildiz,U.C. and Yildiz,S. (2003): Effect of boric acid treatment on mechanical properties of laminated beech lumber. Silva Fennica 37(4), pp 505 -510
[4] ConnellM. (1991) : Industrial wood preservatives- The history, development, use ,advantages and future trends. In R Thompson (Ed), The chemistry of wood preservation. The Royal Society of Chemistry, Cambridge, pp 16 – 33.
[5] Deka, M. and Saikia C.N. (2003): Studies on dimensional stability, thermal degradation and termite resistance properties of bamboo (*Bambusa tulda Roxb*.) treated with thermosetting resins.
[6] Journal Bamboo and Rattan, 2 (1),pp 29-41.
[7] Dev,I.; Bagga, J.K.; Misra, S.C. and Kumar, S(1997),: Termite resistance and permanency tests on Zinc-Borate- An environmental friendly preservative. Journal of Timber Development Association (India), XLIII (2), pp 10-15.
[8] Gruzdyev,G.S.;Zinchenko,V.A.;Kalinin,V.A.andSlovtsov,R.I.(1980): Means for controlling plant pests. *In* G.S.Gruzdyev,(*Ed*) The Chemical Protection of Plants. Mir Publishers, Moscow. Pp 236 -239.
[9] Indian Standard Institution (1977): Method of Test for wood particle boards and boards from other lignocellulosic materials. IS: 2380, Manak Bhavan, New Delhi.
[10] Jain, J.K.; Dobriyal, P.B.; Thapa, R.S. and Kumar, S (1990): Antitermite efficacy test on chlorinated phenolic compounds. J.Timb. Dev. Assoc. (India), 36 (1*)*
[11] Kalita,D.K.;Das,D.K.and Gogoi, P.K. (2002): Synthesis, characterization and antibacterial activity of 2-methylpiperazinedithiocarbamatesof Ru(III),Rh(III), Pd(II),Os(II) and Pt(II). Proceedings of National Academy of Science, India. 72(A), Pp 7 -13.
[12] Kumar, S., Shukla K.S., Dev I. and Dobriyal P.B. (1994): Bamboo preservation handbook. Indian council of forestry research and education, DehraDun
[13] Lak, P.E.; Park, C.G. and Richter, D.L. (1993): Anti sap stain efficacy of borates against Aureo basidium pullulans. Forest product journal 43(1) pp 33-34.
[14] Liese, W. and Kumar, S. (2003): Bamboo preservation compendium. Technical report No.1 INBAR tech. Report No. 22. pp 105.
[15] Logan,J.W.M. and Buckley, D.S. (1991): Subterranean termite control in buildings. *In* R Thompson (*Ed*), *The chemistry of wood preservation.* The Royal Society of Chemistry, Cambridge, pp 294 – 305.
[16] Rowell,R.M. and W.D. Ellis, 1978. Determination of dimensional stabilization of wood using water soaks method. Wood Fiber Sci., 10, pp 104-111.

[17] Stamm, A.J. (1964): Sorption of water vapour by cellulosic materials. *In* wood and cellulosic sci. Ronald Press, New York., pp 312 – 342.

[18] Wahab,R; Moktar,J.;Sudin,M and Hasim,W Samsi (2006): Strength properties of preservative treated Gigantochloa scortechinii after vacuum imoregnation process. International Journal of Agricultural Research,1, pp 8-13.

[19] Yamaguchi,H. (2003): Silicic acid boric acid complexes as wood preservatives. Wood Sci. Technol. 37, pp 287 – 297.

[20] Yalincilic,M.K.; Gezer,E.D.;Tkahashi,M.;Demirci,Z.; IIhan,R.,and Immamura,Y. (1999): Boron addition to non or low formaldehyde cross linking reagents to enhanced biologicalresistance and dimensional stability of wood. Holzals Roh-und werkstoff 57,351 – 357.