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SHORT NOTICE

DETERMINATION OF BORON GIVEN TO WOOD CALCULATED BY SOME EXPRESSION TYPES

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ABSTRACT

In this study, boron amount of in wood given by impregnation was evaluated as based on oven dried weight of wood, solution uptake of treatment and actual boron detected by ion chromatograph in order to make a base for further evaluations. Wood specimens were prepared from Japanese cedar (*Cryptomeria Japonica* Don.) and impregnated as three concentration levels of boric acid 0.25, 1.00, and 4.70 % aqueous solutions. Boron given to wood was calculated by different types of the expressions.

KEY WORDS: Boric acid, wood, impregnation, oven dried weight, solution uptake, ion chromatograph

INTRODUCTION

Boron containing chemicals such as boric acid and borax have been using extensively in wood impregnation as individual chemicals or some mixtures with other chemicals such as CCB (cupper-chromate-boron) in order to protect it against deteriorating agents and fire. They are known as diffusible preservatives and their low mammalian toxicity increased their popularity for the last years in particular (Chen et al. 1997, Murphy 1990, Drysdale 1994).

Threshold levels of boron against microorganisms and insects were extensively studied by many researchers (Grace et al. 1992, Tamashiro et al. 1991, Lloyd 1993, Drysdale 1994). In those studies and others related to fire resistance of wood revealed that very low loading of

boron (0.10-0.50 %) was generally effective against fungi while more loading over 1.00 % is necessary for insecticidal activity. As for fire retardancy, high boron should be given to wood for a required protection level and also boric acid and borax are suggested to be used together (LeVan and Tran 1990).

Boron given to wood is reported by many expressions such as retention, loading, weight gain and calculations based on volume and/or weight of the wood to be treated. Although, weight gain and loading terms are generally preferred for wood modifying chemicals, it can also be used for boron treatment since every chemical resulted in some changes in physical, chemical, mechanical, and biological wood properties. Thus, it is necessary to understand the expressions of boron content given to wood by any type of treatment. Similar comparisons of treatment efficacy for CCA (cupper, chromate, arsenic) was reported by Smith et al. (1996) and it is stated that treatment efficacy need to be referenced to both concentration of copper in the treating solution and the actual concentration of copper in the wood.

MATERIALS AND METHODS

Japanese cedar (*Cryptomeria Japonica* Don.) wood was used as 2 cm (tangential) x 2 cm (radial) x 1 cm (longitudinal) diameters and were impregnated into wood as three concentration levels of boric acid 0.25, 1.00, and 4.70 % aqueous solution in a treatment chamber by applying 30 min vacuum of specimens at 760 $mmHg^{-1}$ followed by leaving in the treatment solution for 30 min for diffusion. Boron given to wood was calculated by different types of the expressions and evaluated in comparison with the boron detected boron content in wood by Ion Chromatograph after hot water extraction.

Boron given to wood is expressed by following calculation types:

Retention values based on solution uptake

Retention of boric acid as kg/m^3 and percentage was calculated from solution uptake of wood based on initial and final weights according to the formulas,

$$\text{Retention } (kg/m^3) = \frac{G \times C}{V} \times 10$$

Where G is the amount of solution absorbed by wood = $T_2 - T_1$; where T_2 is weight of wood after impregnation and T_1 is weight of wood before impregnation, C is solution concentration as percentage, and V is the volume of the specimen as cm^3,

$$\text{Retention } (\%) = \frac{G \times C}{W_0} \times 100$$

W_0 is calculated oven dried weight of the specimens from specific gravity value.

Weight gain values based on oven dried weights

Weight gain of wood due to chemical load was calculated from the following equations:

$$WG\ (kg/m^3) = \frac{W_{02} - W_{01}}{V} \times 10$$

$$WG\ (\%) = \frac{W_{02} - W_{01}}{W_{01}} \times 100$$

Where W_{02} is final oven dried weight of a wood specimen after impregnation and W_{01} is the initial oven dried weight of a wood specimen before impregnation.

ppm boron detected from wood after hot water extraction

Treated specimens were grounded to pass 50 mesh and 2g milled wood was taken from each treated wood for hot water extraction by 3 h. Detected boron was converted to ppm by using formula given by Selemat et al. (1989):

$$\%\ BAE\ in\ treated\ wood\ (w/w) = \frac{(ppmB) \times (61.84/10.81) \times f \times 100}{Oven\ dry\ weight \times 10}$$

Where ppmB is the calculation of boron from chromatograph analysis and f is the dilution factor.

Additionally all the obtained and calculated loadings were expressed as BAE and B_2O_3 levels in order to understand the differences among the given terms.

BAE levels

In addition to above expressions some kg/m^3 and percentage values of boron was converted to boric acid equivalent and B_20_3 in order to make comparison of all obtained results to better the differences or similarities of given terms. Because, beyond classic retention or weight gain expressions especially for boron treatments irrespective of the boron compound concentration of treating solution and net dry salt given to wood is also expressed as boric acid equivalent (BAE). In case of concentration of borate solution was taken as a base, following equation gives the net dry salt retention of boron compounds as BAE (Borax, Technical Service Bulletin 107A):

$$Retention = \frac{Av \times C}{100}\ (kg/m^3)\ BAE$$

Where Av is net volumetric absorption of treating solution (litres/m^3 of treated timber), C is the

concentration of borate solution (BAE % w/v); concentration of borate solution in BAE percentages as w/v is calculated from the formula:

$$\text{BAE w/v \%} = \text{Solution concentration (\%)} \times \frac{\text{Molecular weight of elemental boron}}{\text{Molecular weight of boron compound}}$$

The molecular weight of elemental boron is 10.8 and for H_3BO_3 molecular weight of the compound is 61.8, so that solution concentration is multiplied with 0.175 constant value for calculation of BAE of the solution as percentage of w/v.

B_2O_3 levels

In addition to BAE levels of the boron, H_3BO_3 retention in wood is also possible to express as boric oxide since boron ion is present in wood with oxygen bonds as trihedral or tetrahedral system. Boric acid also can be viewed as a hydrated of boric oxide (Smith 1986). Hence, it is supposed to dehydrate as;

$$2H_3BO_3 \longrightarrow 3H_2O + B2O$$

Mw: 123.6652 Mw: 696196

Thus, B_2O_3 % is found as 69.6196/123.6652 x 100= 56.2968

Where 123.6652 are molecular weight of 2 mol H_3BO_3 and 69.6196 is that of boric oxide.

RESULTS AND DISCUSSIONS

Retention of boric acid as kg/m^3 and percentage; weight gain of wood due to chemical load; ppm boron detected from wood after hot water extraction; and kg/m^3 and percentage values of boron was converted to boric acid equivalent (BAE); and B_20_3 are given in Tab. 1 to 5, respectively.

Since oven dried weight of wood is not necessary and in most cases impossible, retention values of the chemicals generally used for the timber at industrial scale treatments are calculated by using solution uptake levels and concentration of the solution. In first case in which boron amounts calculated by the oven dried weight differences bases, extractives, and easily leachable substances of wood by acidic solutions is not considered while in the second case in which the retention based on initial weight of wood and solution uptake together with solution strength, all the chemicals considered to have been solved in water and well distributed in both solution given in wood and remained at outside of the wood. In both cases, exact boron given in the wood is doubtful and need further evaluations as detecting boron in wood or controlling the boron content in the impregnation solution during and after treatment.

Tab. 1: Retention levels of boric acid in Japanese cedar wood determined by solution uptake of the specimens

Treatment code*	H_3BO_3 conc. (%)	pH of fresh solution	Retention level	
			Kg/m^3 Mean ± SD**	% Mean ± SD
A	0.25	6.09	2.19 ± 0.03	0.88 ± 0.06
B	1.00	5.27	8.77 ± 0.16	3.54 ± 0.30
C	4.70	3.71	41.24 ± 0.75	16.96 ± 1.49

*Each reading is average of 50 specimens
** Standard deviation

Tab. 2: Weight gain levels of Japanese cedar wood specimens treated with boric acid

Treatment code*	H_3BO_3 conc. (%)	pH of fresh solution	WG level	
			Kg/m^3 Mean ± SD**	% Mean ± SD
A	0.25	6.09	1.21 ± 0.46	0.50 ± 0.19
B	1.00	5.27	3.31 ± 0.38	1.49 ± 0.21
C	4.70	3.71	25.11 ± 0.50	10.26 ± 0.59

* Each reading is average of 50 specimens
** Standard deviation

Tab. 3: IC results of detected boron from specimens after being treated H_3BO_3

Treatment code*	Detected boron (ppm) Mean ± SD**	BAE	
		w/v	w/w
A	1221.9 ± 6.3	0.213	0.349
B	5731.7 ± 11.2	1.002	1.639
C	15654.2 ± 39.6	2.736	4.477

*Each reading is average of 3 injections sampled from hot water extraction of 10 grounded specimens
** Standard deviation

Tab. 4: Calculated BAE % w/v retentions of boric acid in Japanese cedar wood

Treatment code	H_3BO_3 conc. BAE % w/v	Retention level	
		Kg/m^3 BAE	% w/v BAE
A	0.044	0.386	0.008
B	0.17	1.492	0.030
C	0.82	7.195	0.144

Tab. 5: Retention levels of boric acid as B_2O_3 percentages based on the oven dry weights of specimens before and after treatment

Treatment code	H_3BO_3 conc. B_2O_3 %	Retention level	
		Kg/m_3 B_2O_3	% B_2O_3 w/w
A	0.11	0.551	0.228
B	0.45	1.507	0.678
C	2.14	11.431	4.671

Here B_2O_3 % retention levels seem interestingly very close to actual percent concentration of treatment solutions.

CONCLUSSIONS

Boron given to wood was calculated some expression types such as over dried weight of wood, solution uptake of treatment and actual boron detected by Ion Chromatograph. Three concentration levels of boric (0.25%, 1%, and 4.70%) were used.

In most cases, since oven dried weight of wood is not necessary and impossible, retention values of the boron in wood after impregnation are calculated other expression types.

In diffusion impregnation treatments of timber, it is nesessary to use concentrated solutions of borate (20-40 % w/v) and alternatively to obtain similar levels of preservative retention, concentrations of solutions used in pressure impregnation processes are considerably lower than those in diffusion treatments, typically being in the range of 1-2 % w/v (Borax, Technical Service Bulletin 107A). Irrespective of the boron compound actually used, it is conventional to expresss both the concentration of treating solution and the net dry salt retention obtained in the timber in terms of BAE (Borax, Technical Service Bulletin 107A).

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