EFFECTS OF GLYCOL ON LEACHABILITY AND EFFICACY OF BORON WOOD PRESERVATIVES[1]

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ABSTRACT

Although boron has many advantages as a wood preservative, this chemical performs poorly in leaching exposures. In this study, we investigated the potential for decreasing the leachability of boron preservatives with polyethylene glycol (PEG). Southern pine (*Pinus* spp.) test samples impregnated with combinations of sodium borate or boric acid and PEG were subjected to both leaching and decay tests. Samples treated sequentially with sodium borate or boric acid and then with PEG-400 or PEG-600 showed a significantly increased resistance to boron leaching. However, decay tests indicated that blocks treated with sodium borate or boric acid and PEG experienced slightly higher weight losses at nearly all retention levels, possibly as a result of PEG depletion. Thus, although the results suggest that bulking agents may enhance the resistance of boron to leaching, the enhanced leach resistance may be a temporary effect.

Keywords: Boron wood preservatives, leaching, polyethylene glycol, fungi.

INTRODUCTION

Boric acid and sodium borate have been used as wood preservatives since the 1930s (Murphy 1990) and are valued for their protective capacity against decay fungi, wood-boring insects, and, at slightly higher retention levels, termites. Boron is also a relatively cost-effective chemical and, more important, has minimal toxicity against non-target organisms (Greaves 1990). In addition, boron-based preservatives are colorless, odorless, noncorrosive, and nonflammable (Hashim et al. 1994; Manning and Artur 1995).

Although boron wood preservatives have many advantages (e.g., Barnes et al. 1989; Laks 1989; Hyde 1994), boron by itself does not adequately protect wood that is in ground contact because of the chemical's susceptibility to leaching (Williams and Amburgey 1987; Nicholas et al. 1990). One option for decreasing the leachability of boron wood preserva-

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TABLE 1. *Boron retentions (kg/m³ BAE) in southern pine blocks treated with boric acid or sodium borate with or without PEG-400 or -600.*

Boron concentration (% BAE)	Process	PEG treatment	Retention (kg/m³ BAE)[a]	
			Boric acid	Sodium borate
0.25	Single	none	0.79 (0.06)	0.77 (0.05)
		PEG-400	0.92 (0.07)	1.13 (0.08)
		PEG-600	1.11 (0.09)	0.90 (0.06)
	Sequential	PEG-400	0.72 (0.09)	0.71 (0.05)
		PEG-600	0.74 (0.08)	0.72 (0.05)
0.05	Single	none	1.66 (0.12)	1.72 (0.13)
		PEG-400	2.06 (0.13)	2.59 (0.15)
		PEG-600	2.36 (0.15)	2.04 (0.12)
	Sequential	PEG-400	1.53 (0.10)	1.55 (0.11)
		PEG-600	1.55 (0.12)	1.59 (0.11)
1.00	Single	none	3.61 (0.21)	3.54 (0.22)
		PEG-400	4.03 (0.22)	4.49 (0.23)
		PEG-600	4.44 (0.21)	4.19 (0.20)
	Sequential	PEG-400	3.32 (0.19)	3.28 (0.18)
		PEG-600	3.37 (0.21)	3.30 (0.17)
2.50	Single	none	9.23 (0.31)	8.87 (0.27)
		PEG-400	12.07 (0.39)	12.63 (0.42)
		PEG-600	12.58 (0.43)	11.01 (0.37)
5.00	Single	none	20.87 (0.56)	19.51 (0.52)
		PEG-400	26.06 (0.63)	26.34 (0.59)
		PEG-600	28.17 (0.81)	24.25 (0.51)
	Sequential	PEG-400	19.13 (0.51)	18.33 (0.53)
		PEG-600	19.39 (0.57)	18.60 (0.56)

[a] Values represent means of 5 replicates per treatment. Values in parentheses represent one standard deviation.

tives is to use mixtures of sodium borate or boric acid and polyethylene glycol (PEG). Polyethylene glycol can almost completely replace water and dimensionally stabilize nonseasoned wood (Goldstein and Loos 1973). The concept of mixing ethylene glycol and borate is not new—monoethylene glycol solutions of borates, brushed or sprayed onto the wood surface, are used commercially for remedial treatments of wood in service (Bech-Andersen 1987; Dickinson 1990; Su and Scheffrahn 1991; Puettmann and Williams 1992; Tokoro and Su 1993a, b)—but little is known about the use of boron/glycol solutions to protect wood in soil contact. The specific objectives of this research were to: (1) determine the leachability of sodium borate/boric acid and PEG mixtures, and (2) evaluate the resistance to wood decay fungi of wood treated with these modified boron preservatives.

MATERIALS AND METHODS

Test samples

Southern pine (*Pinus* spp.) sapwood, free of defects or fungal colonization, was cut into 19-mm cubes, oven-dried (105 ± 3°C) for 12 h, and then weighed (nearest 0.01 g) prior to use. For the decay resistance tests; feeder strips were cut from quarter-sawn southern pine sapwood (3 × 28 × 34 mm long). The brown-rot decay fungi used in this experiment, *Neolentinus lepideus* (Fr:Fr.) (Redhead & Ginns) (Madison-534) and *Postia placenta* (Fr.) (M. Larsen & Lombard) (Madison-698), were obtained from the USDA, Forest Service, Forest Products Laboratory in Madison, WI.

Treatment solutions

Five concentrations (0.25, 0.50, 1.00, 2.50, and 5.00% BAE) each of sodium borate and

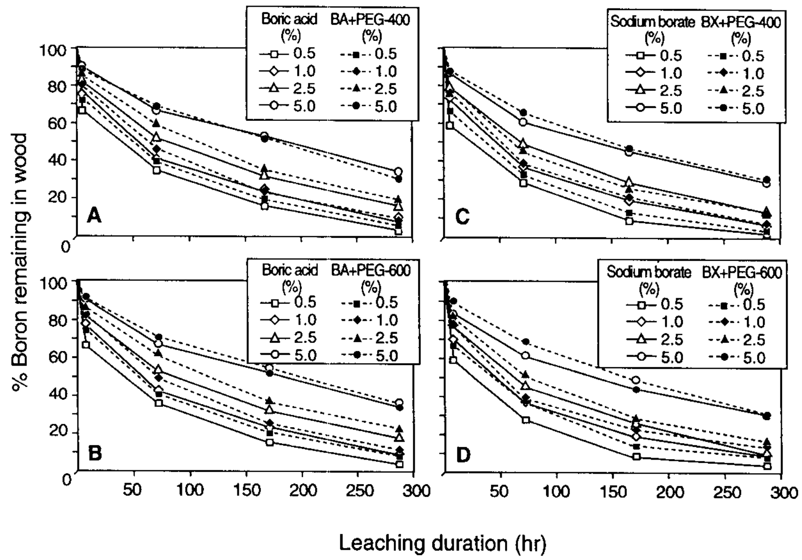

FIG. 1. Residual boron in southern pine blocks treated with boric acid (A, B) or sodium borate (C, D) with (simultaneously) or without PEG-400 (A, C) or PEG-600 (B, D) and exposed in a 288-h leaching test.

boric acid, with and without 10% PEG-400 or 10% PEG-600, were prepared. Boron-free solutions of 10% PEG-400 and 600 were also prepared.

Boron retention tests

Test samples were treated by drawing a 10-cm Hg vacuum over the blocks for 30 min and

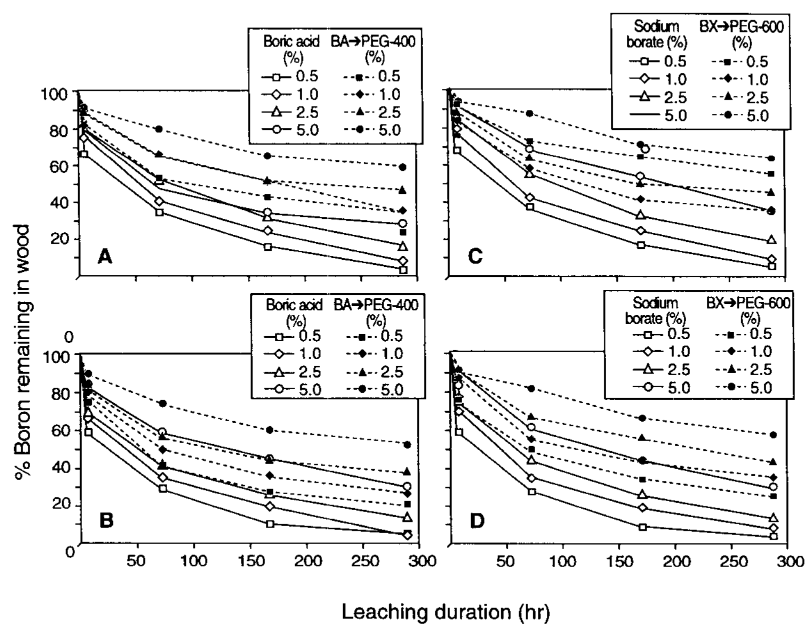

FIG. 2. Residual boron in southern pine blocks treated with boric acid (A, B) or sodium borate (C, D) with (sequentially) or without PEG-400 (A, C) or PEG-600 (B, D) and exposed in a 288-h leaching test.

TABLE 2. *Weight losses in southern pine blocks treated with combinations of boron and PEG exposed to* Neolentinus lepideus *in a soil block test.*

	Treatment solution		Wood weight loss (%)[a]	
Boron compound	Boron concentration (%BAE)	PEG	Combined treatment	Sequential treatment
None	–	–	44.8 (2.9)	– –
Boric acid	0.25	–	8.9 (0.5)	– –
		400	9.9 (0.7)	13.3 (0.7)
		600	8.4 (0.4)	14.3 (0.6)
	0.50	–	4.4 (0.4)	– –
		400	7.6 (0.5)	5.0 (0.5)
		600	6.4 (0.3)	4.6 (0.4)
	1.00	–	3.3 (0.4)	– –
		400	3.7 (0.5)	3.4 (0.2)
		600	3.1 (0.2)	2.9 (0.3)
	2.50	–	3.7 (0.4)	– –
		400	4.0 (0.3)	2.9 (0.2)
		600	3.4 (0.3)	2.3 (0.2)
	5.00	–	4.2 (0.3)	– –
		400	4.4 (0.2)	3.5 (0.2)
		600	4.0 (0.3)	3.2 (0.3)
Sodium borate	0.25	–	11.4 (0.6)	– –
		400	12.7 (0.6)	13.0 (0.7)
		600	14.1 (0.6)	15.0 (0.7)
	0.50	–	5.0 (0.4)	– –
		400	7.1 (0.5)	5.4 (0.5)
		600	7.7 (0.4)	5.8 (0.5)
	1.00	–	4.1 (0.4)	– –
		400	4.2 (0.3)	3.4 (0.3)
		600	4.9 (0.3)	3.5 (0.4)
	2.50	–	3.9 (0.3)	– –
		400	3.4 (0.3)	2.8 (0.2)
		600	3.7 (0.2)	2.4 (0.3)
	5.00	–	4.2 (0.4)	– –
		400	4.6 (0.4)	3.8 (0.3)
		600	4.3 (0.3)	3.3 (0.4)

[a] Values represent means of 5 replicates per treatment. Values in parentheses represent one standard deviation.

then flooding the treatment solution onto the wood. Some blocks were treated with combined boron/PEG solutions in a single process while others were first impregnated with boric acid or sodium borate solutions, then impregnated with 10% PEG-400 or PEG-600 in a sequential process. The wood samples were kept in the treatment solution for 30 min before the vacuum was released. The wood samples were then removed from the treatment solution, wiped lightly to remove solution from the wood surface, and weighed (nearest 0.01 g) to determine gross retentions for each block.

Leaching tests

Leachability was assessed according to American Wood-Preserver's Association Standard M 11-87 (AWPA 1996). Eighteen blocks per treatment were air-dried, then immersed in beakers of distilled water over which a vacuum was applied for 20 min. After the vacuum was released, the wood blocks were kept in the deionized water for an additional 20 min, then lightly wiped and placed into a beaker containing 300 ml deionized water. The water was changed after 6, 24, and 48 h, and thereafter at 48-h intervals, over a total of 14 days.

TABLE 3. *Weight losses in southern pine blocks treated with combinations of boron and PEG and exposed to* Postia placenta *in a soil block test.*

Boron compound	Treatment solution: Boron concentration (%BAE)	Treatment solution: PEG	Wood weight loss (%)[a]: Combined treatment	Wood weight loss (%)[a]: Sequential treatment
None	–	–	47.1 (3.1)	– –
Boric acid	0.25	–	7.1 (0.5)	– –
		400	7.4 (0.6)	6.2 (0.7)
		600	7.3 (0.5)	7.3 (0.3)
	0.50	–	2.9 (0.4)	– –
		400	3.1 (0.4)	3.6 (0.4)
		600	3.2 (0.3)	3.9 (0.4)
	1.00	–	3.2 (0.2)	– –
		400	3.3 (0.3)	3.3 (0.3)
		600	3.3 (0.3)	3.5 (0.2)
	2.50	–	3.4 (0.3)	– –
		400	3.5 (0.3)	3.4 (0.4)
		600	3.6 (0.4)	3.7 (0.4)

[a] Values represent means of 5 replicates per treatment. Values in parentheses represent one standard deviation.

At each water change, two blocks were removed for quantitative boron analysis. To perform this analysis, test blocks were ground to pass a 30-mesh screen and the resulting material was dried at 50°C for 12 h. One-gram samples were ashed at 500°C for 16 h, then 3–10 drops of 6 N HCl (hydrochloric acid) were added to the crucibles to dissolve the ash. The acidified residue was washed into a beaker with 70-ml deionized water, stirred for a few minutes, and then filtered through Whatman #4 (very fast) filter paper. The precipitate on the filter paper was washed four times with 10-ml portions of hot deionized water (70–80°C). The effluent was diluted to 250 ml in a volumetric flask and analyzed for boron with the Azomethine-H method (Docks 1990).

Laboratory fungal decay resistance tests

Decay resistance was assessed using American Society for Testing and Materials Standard D 1413-88 (ASTM 1988), with *N. lepideus* and *P. placenta* as the test fungi. Briefly described, 454-ml French squares were half-filled with forest soil and a feeder strip was added. The jars were capped and autoclaved at 103.4 kPA for 35 min on each of two consecutive days to ensure sterility (Amburgey 1976). After cooling, the feeder strip was inoculated with an agar disc cut from the actual growing edge of the test fungus, and the bottles were incubated at 25°C and 80% relative humidity until the wood strip was covered by mycelium. The test blocks for this analysis were autoclaved for 30 min at 100 ± 2°C before being added to the jars. The jars were then incubated at 25°C for 12 wk. After the incubation period, the blocks were removed and conditioned at 25 ± 2°C and relative humidity of 65–70% for 2 wk. Changes between initial and final conditioned weight served as a measure of fungal attack.

RESULTS AND DISCUSSION

Boron retention tests

Adding PEG-400 or PEG-600 to treatment solutions increased boric acid and sodium borate retention (Table 1). Similar results have been reported for PEG and CCA (chromated copper arsenate) (Trumble and Messina 1986). Obtaining adequate boron loadings is generally not a problem when pressure-treating pine species (Hunt and Garrett 1967), but the PEG could allow the use of more dilute treatment solutions for this purpose. When wood blocks were treated sequentially, first with sodium borate or boric acid and then with PEG-400 or 600, boron preservative retention in all cases was lower than that of wood blocks treated with boron and no glycol solution (Table 1). This result may reflect depletion of surface boron into the glycol solution during the second treatment. Delaying the second treatment to allow borate diffusion into the wood might reduce surface losses, but this process would increase the logistical complexity of the treatment.

Leaching tests

When incorporated into either boric acid or sodium borate treatment solution, PEG-600 and PEG-400 had little or no effect on the resistance of boron to leaching (Fig. 1). This result agrees with that of Trumble and Messina (1986), who found that PEG in CCA had no effect on CCA leaching. After 288 h of leaching, the boron content in blocks treated with 5% boric acid + PEG-600, the boron content decreased by 65%, and in blocks treated with 5% sodium borate + PEG-600 the boron content decreased by 70%. These decreases differed little from those for the boron-alone 5% treatments. The lack of leach resistance is consistent with the solubility of both components, and indicates that supplemental PEG has little effect on boron leach resistance. In blocks treated with 0.5% boric acid or sodium borate, little boron remained after 288 h of leaching regardless of PEG addition.

Blocks that were first treated with boric acid or sodium borate solutions, then air-dried and treated with 10% PEG-400 or PEG-600, showed less leaching than blocks treated with a combined solution (compare Figs. 1 and 2). The reasons for this effect are not clear, but it may reflect a tendency for the second treatment to solubilize and carry boron deeper into the block where it would be less susceptible to leaching. While sequential treatments would probably increase treatment costs beyond an economical level, there may be other methods for applying low-cost bulking agents to the wood surface to retard boron loss. The addition of PEG did not completely inhibit boron loss, a finding that suggests that PEG might only be useful for enhancing aboveground performance of boron treated wood.

Fungal decay resistance tests

Weight losses due to fungal attack were generally low for all boron treatments (Tables 2 and 3). Weight losses followed a dose response relationship at lower retentions, but leveled off at higher retentions. The occurrence of weight loss at higher retentions probably reflects boron or PEG leaching rather than fungal-associated weight loss. Weight losses caused by *N. lepideus* were slightly higher for blocks treated with 0.25% BAE sodium borate than for blocks treated with 0.25% BAE boric acid in the combined boron/PEG treatment but not in the sequential treatment. The reasons for this variation are unclear.

Weight losses differed little between samples treated with boric acid or sodium borate alone and those amended with PEG. Similarly, there was little or no difference in weight losses when blocks were treated sequentially with boron and PEG versus those treated with a combined PEG/boron solution. PEG is relatively non-fungitoxic and the soil block tests reflect this characteristic. The results indicate that PEG will not enhance the biological activity of boron in the wood.

CONCLUSIONS

Treatment with boron/PEG solutions did not enhance decay resistance in comparison with boron solutions without PEG, but did enhance boron uptake. Sequential treatment with boron compounds followed by PEG appears to reduce the susceptibility of boron to leaching. The results suggest that glycol application may be useful for retaining boron in wood.

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