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Treatability of Underutilized Northeastern Species with CCA and Alternative Wood Preservatives

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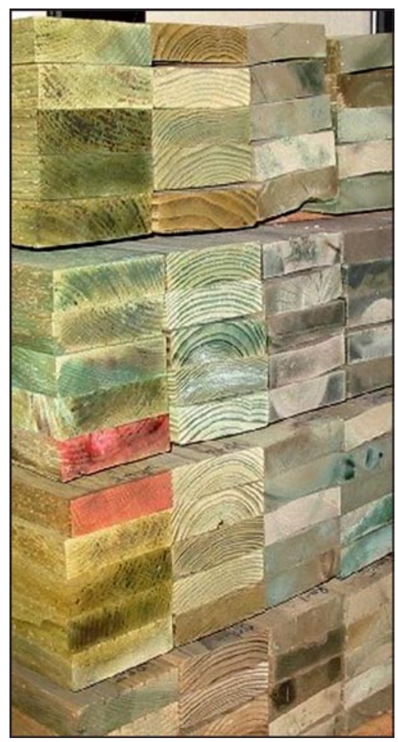

Abstract

Opportunities for use of northeastern species such as balsam fir, eastern spruce, eastern hemlock, and red maple could be improved if these species could be adequately penetrated with preservatives and subsequently shown to be durable in outdoor exposures. In this study, specimens cut from lumber of northeastern species were pressure-treated with either chromated copper arsenate type C (CCA-C), ammoniacal copper citrate (CC), alkaline copper quat type C (ACQ-C), or copper azole type A (CBA-A). Treatability was assessed by measuring retention and penetration of preservative. The results indicate that the arsenic- and chromium-free alternatives to CCA-C can treat northeastern species at least as well as CCA-C and may offer treatability advantages over CCA-C in species such as eastern hemlock and balsam fir. Two species, red maple and eastern spruce, were not adequately treated with any preservative, even after incising. Above-ground and ground-contact durability evaluations with these preservative–wood species combinations are in progress.

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Treatability of Underutilized Northeastern Species with CCA and Alternative Wood Preservatives

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Introduction

Some tree species in the northeastern United States have relatively low commercial lumber value because of trunk size, growth habit, or wood properties. Increasing the value of these species would give forest managers more flexibility in economically managing the forest resource while preserving more traditional commercial species. Adding value to previously underutilized wood species would also create business and employment opportunities in rural communities.

One option for using more northeastern species such as balsam fir, eastern spruce, eastern hemlock, and red maple in durable wood structures is pressure treatment with preservatives. Over 40 pressure-treatment facilities are already located in the Northeast, producing approximately 7 billion (7×10^9) board feet of lumber, timbers, and plywood annually (Mickelwright 1997). Before a wood species can be standardized for treatment with a particular preservative, however, it must be demonstrated that adequate penetration and retention can be achieved through the use of conventional pressure-treatment processes.

Research has been conducted on the treatability of northeastern species with chromated copper arsenate (CCA) and ammoniacal copper arsenate (ACA). Smith (1986) reported on the treatability of eastern white pine, eastern hemlock, Norway spruce, and bigtooth aspen with CCA type C (CCA-C). Preservative uptake was greatest in the white pine, but also appeared promising in incised eastern hemlock. A separate treatability study of Canadian species concluded that eastern white spruce and balsam fir were among the most difficult to treat with CCA-C, although incising did improve treatment (Richards and Inwards 1989). A subsequent study evaluated the treatability of balsam fir, eastern spruce, eastern hemlock, and white pine with both CCA-C and ACA (Gjovik and Schumann 1992). The researchers found that penetration was generally greater with ACA than CCA-C, and that the growth rate of the material (fast or slow) had no significant effect on penetration or retention. In agreement with previous researchers, Gjovik and Schumann found that incising significantly improved treatment. As a result of these studies and further unpublished efforts, eastern hemlock was added to the American Wood-Preservers' Association (AWPA) Book of Standards in 1997, and the incising requirement for eastern white pine was modified for CCA-C (AWPA 1997).

The types of preservatives used commercially have changed greatly since the research on treatability of northeastern species was conducted. Ammoniacal copper arsenate is no longer used in the United States, and the use of CCA-C has been greatly diminished. For most markets, these preservatives have been replaced with copper-based systems that do not contain arsenic or chromium. Arsenic-free alternatives that have been standardized by the AWPA include alkaline copper quat (ACQ), copper azole (CBA and CA-B), and ammoniacal copper citrate (CC). The chemistry of these newer wood preservatives is substantially different than that of CCA-C, and relatively little research has been published on their ability to penetrate northeastern species. A study evaluating CCA-C and ammoniacal copper quat (ACQ-B) retention (uptake) in red maple reported that uptake was similar in sapwood, but that uptake of CCA-C was greater in heartwood. Preservative penetration was not reported (Smith and others 1996). Since that time ACQ-B has largely been replaced with the amine copper formulations of ACQ (ACQ types C and D). We need to evaluate the ability of these new preservatives to penetrate into more refractory wood species and protect these wood species from decay and insect attack in a range of outdoor exposures. This paper describes research to evaluate the degree of preservative penetration and retention achieved in underutilized northeastern species when pressure-treated with CCA-C and arsenic-free alternative preservatives. An ongoing study is evaluating the durability of the treated wood in above-ground and ground-contact exposure.

Materials and Methods

This research was conducted through the cooperative efforts of the USDA Forest Products Laboratory (FPL); State & Private Forestry; Northeastern Forest Alliance; Vermont Department of Forest, Parks, and Recreation; preservative manufacturers; and cooperating lumber producers in the Northeast. Cooperating mills supplied eastern white pine, eastern spruce, balsam fir, eastern hemlock, and red maple lumber for the study. For comparison, the FPL obtained

Southern Pine lumber. Cooperating preservative manufacturers provided CCA, CC, ACQ, and CBA-A wood preservative formulations for use in the study.

Specimen Preparation

Treatability trials were conducted using standard 38- by 89-mm (nominal 2- by 4-in.) lumber. Both incised and unincised boards were supplied for eastern spruce, balsam fir, eastern hemlock, and red maple species. Incised boards were supplied for eastern white pine only, whereas unincised boards were evaluated for Southern Pine only. The incising density was approximately 3,100 incisions/m^2, with incision length ranging from 12 to 15 mm and incision depth ranging from 5 to 9 mm. Four end-matched specimens 203 mm long were cut from 15 boards of each wood species–incising condition combination. For the Southern Pine lumber, only sapwood samples were used, but the other boards contained a mixture of heartwood and sapwood. The four end-matched specimens were assigned to one of the four types of preservatives. However, the initial treatment charge with CBA-A solution was lost because of equipment malfunction. Those specimens were replaced by cutting another specimen from each original board. Prior to treatment, the specimens were conditioned in a room maintained at 23ºC and 65% relative humidity, and then end-coated with a neoprene rubber sealant to prevent end-grain penetration.

Preservative Formulations

The primary alternatives to CCA-C are ACQ and CBA and CA-B. The CCA-C was also included in this study for comparison. Ammoniacal copper citrate has not been widely used (and was recently withdrawn from AWPA standards) but was included in this study because a previous report (Gjovik and Schumann 1992) indicated that an ammoniacal preservative may penetrate northeastern species more deeply than CCA-C.

Chromated copper arsenate type C (CCA-C)

Actives composition of 47.5% CrO_3, 18.5% copper (expressed as CuO), and 34.0% As_2O5.

Alkaline copper quat type C (ACQ-C)

Actives composition of 66.7% copper (expressed as CuO) and 33.3% alkylbenzyldimethyl ammonium compound. The copper is made soluble in a solution of ethanolamine and water.

Copper azole type A (CBA-A)

Actives composition of 49% Cu, 49% H_3BO3, and 2% tebuconazole. The copper is made soluble in a solution of ethanolamine and water.

Ammoniacal copper citrate (CC)

Actives composition of 66.7% copper (expressed as CuO) and 33.3% citric acid. The copper is made soluble in a solution of ammonia and water.

Treatment Process and Evaluation

All the treatments were conducted at room temperature. A treatment solution of 1% actives was used for CCA-C, CC, and ACQ-C, whereas a concentration of 0.74% was used for CBA-A. An initial vacuum of −75 kPa (25 inHg) was maintained for 30 min, the treatment solution was introduced, and the pressure was maintained at 1.03 MPa (150 lb/in^2) for 2 h. The success of the treatments was evaluated by measuring preservative penetration and retention. Retention was determined by weighing each specimen before and after treatment to determine solution uptake and then adjusting for solution concentration. Penetration was determined by allowing the specimens to air-dry and then cutting them in half to expose a fresh cross section. The cross section was sprayed with chrome azurol–S copper indicator solution prepared in accordance with AWPA Standard C31–02 (AWPA 2005). Penetration measurements similar to those determined commercially (by removal of increment cores) were obtained by measuring penetration at the midpoint of both narrow faces of each specimen (AWPA Standard M2–01, AWPA 2005). The two measurements from each specimen were averaged to obtain a single penetration value.

Statistical Analysis

A statistical analysis of variance was conducted on average preservative penetration using the SAS (SAS Institute Inc., Cary, North Carolina) general linear model (GLM) procedure in conjunction with a Tukey studentized range test. Type of preservative, wood species, and incising (incised or unincised) were considered as independent variables.

Results and Discussion

Alternative preservatives generally penetrated the northeastern species at least as well as CCA-C (Table 1), and penetration by ACQ-C and CC was generally greater than that of CCA-C. All the alternative preservatives achieved greater average penetration than CCA-C in unincised Southern Pine, and as expected, penetration was greater in Southern Pine than in the northeastern species evaluated. However, variability was high between replicates, and the unincised specimens showed no significant difference in penetration between any of the preservatives at the 95% confidence level. Of the northeastern species evaluated, penetration was greatest in eastern white pine and least in eastern spruce. With incising, however, penetration of ACQ-C in eastern hemlock was nearly as great as that in eastern white pine. The benefits of incising northeastern species were reported in earlier studies (Gjovik and Schumann 1992; Smith 1986; Richards and Inwards 1989). With the exception of red maple, incising increased penetration in other species as well. The increase in penetration with incising was not always statistically significant. Significant interaction between wood species and incising (incised versus unincised) prevented generalizations about the relative ability of the four preservatives to penetrate incised specimens. Incising

Table 1—Summary of penetration and retention for wood species–preservative combinations

			Penetration (mm)		Retention (kg/m^3)[a]	
Preservative	Wood species	Incised	Average	Standard deviation	Average	Standard deviation
CBA-A[b]	Balsam fir	No	6	7	2.98	1.28
	Balsam fir	Yes	12	6	4.07	1.27
	Eastern hemlock	No	11	9	3.65	1.09
	Eastern hemlock	Yes	22	11	5.17	0.91
	Eastern spruce	No	3	3	1.42	1.04
	Eastern spruce	Yes	4	4	2.27	0.80
	Red maple	No	8	9	2.87	1.94
	Red maple	Yes	7	6	3.21	1.57
	Southern Pine[c]	No	38	8	6.09	0.27
	Eastern white pine	Yes	25	12	5.43	0.91
ACQ-C[d]	Balsam fir	No	16	14	4.06	1.69
	Balsam fir	Yes	22	13	5.26	1.44
	Eastern hemlock	No	20	14	4.86	1.28
	Eastern hemlock	Yes	29	12	6.01	0.84
	Eastern spruce	No	4	5	1.63	1.02
	Eastern spruce	Yes	5	4	2.38	0.98
	Red maple	No	11	13	2.80	1.68
	Red maple	Yes	12	12	3.38	1.83
	Southern Pine	No	40	0	6.24	0.29
	Eastern white pine	Yes	35	10	5.94	0.77
CCA-C[e]	Balsam fir	No	7	11	2.99	2.10
	Balsam fir	Yes	12	9	4.08	1.22
	Eastern hemlock	No	13	14	3.45	2.03
	Eastern hemlock	Yes	20	13	5.25	1.18
	Eastern spruce	No	3	4	1.49	0.98
	Eastern spruce	Yes	6	3	2.63	0.86
	Red maple	No	7	7	2.34	1.47
	Red maple	Yes	10	13	3.32	1.33
	Southern Pine	No	31	17	5.04	2.12
	Eastern white pine	Yes	30	11	5.54	0.81
CC[f]	Balsam fir	No	12	13	3.30	1.36
	Balsam fir	Yes	18	10	4.23	1.29
	Eastern hemlock	No	13	10	3.54	1.42
	Eastern hemlock	Yes	23	12	4.91	1.15
	Eastern spruce	No	4	3	1.39	0.68
	Eastern spruce	Yes	10	3	2.28	0.66
	Red maple	No	13	15	2.56	1.66
	Red maple	Yes	11	7	2.98	1.11
	Southern Pine	No	39	7	5.19	1.77
	Eastern white pine	Yes	32	11	5.02	1.06

[a]Expressed as acti□ of CBA-A normalized to a 1.0% solution concentration for comparison to other preservatives.
[b]Copper azole type A.
[c]Southern yellow pine.
[d]Alkaline copper quat type C.
[e]Chromated copper arsenate type C.
[f]Ammoniacal copper citrate.

appeared to offer the most significant increases in penetration for CC, CBA-A, and CCA, and the least improvement for ACQ-C. In the two most refractory species (red maple and eastern spruce), average penetration of the ammonia-based CC was greater than that of ACQ-C or the other preservatives, and penetration of CC was greater than CCA-C for all species. This agrees with earlier reports that another ammonia-based preservative, ACA, achieved better penetration of eastern spruce, balsam fir, and eastern hemlock than did CCA-C (Gjovik and Schumann 1992), and ACQ solutions containing ammonia offered improved penetration of some western species (Morris and others 2002).

Minimum penetration required by AWPA standards for refractory species is typically 10 mm (AWPA 2005). In most cases, at least 80% of the boards sampled in a charge would be required to meet or exceed this minimum. In this study, none of the northeastern species–preservative combinations met this requirement without incising (Fig. 1). Interestingly, the CCA-treated Southern Pine also failed this requirement (note that the minimum sapwood penetration of Southern Pine required by AWPA standards is actually 63 mm or 85% of the sapwood depth). After incising, penetration equaled or exceeded 10 mm in over 80% of the specimens for all the eastern hemlock treatments except CCA-C. Both ACQ-C and CC also met this requirement in balsam fir specimens. Penetration in incised eastern white pine exceeded 10 mm in all the specimens for all preservatives, supporting earlier research reporting ready treatability of this species (Gjovik and Schumann 1992; Smith 1986).

This research shows that relative penetration of preservatives is species-dependent. Average penetration of CC in incised eastern spruce was twice that of any other preservative, but CC penetration was less than that of ACQ-C in balsam fir and eastern hemlock. Average penetration of CBA-A was slightly greater than that of CCA-C in Southern Pine, but less than that of CCA-C for incised white pine. Some of these preservative–wood species interactions are possibly anomalies of this particular study, but a similar effect was noted in a study of the treatability of spruce–pine–fir (SPF) species with CCA-C and borate preservatives (Lebow and others 2005). In that study, lodgepole pine and Engelmann spruce were among the most treatable species with CCA-C but ranked toward the bottom in treatability with borate solutions. Balsam fir, in contrast, treated poorly with CCA-C but relatively well with borate solutions.

Trends in preservative retention generally mirrored trends in penetration, but differences between preservatives are somewhat less apparent. The CC retention in incised eastern spruce was no greater than that of other preservatives, even though CC penetration appeared to be greater than for other preservatives. The CC retention was proportionally lower than penetration for other species as well. The retentions achieved in this study are somewhat arbitrary and reflect the solution concentration used. Higher retentions could have been achieved by increasing the solution concentration.

Conclusions

Results indicate that the arsenic- and chromium-free alternatives to CCA-C evaluated in this study have the capacity to treat northeastern species at least as well as CCA-C. Some of the CCA-C alternatives, such as ACQ-C and CC, may offer advantages in improved treatment of these species. Eastern white pine, balsam fir, and eastern hemlock all appear to be treatable with ACQ-C, although incising may be necessary for eastern hemlock and balsam fir. Treatment of eastern spruce and red maple was not promising for any of the preservatives evaluated, even after incising. Treatability with a preservative does not necessarily ensure durability because fixation and microdistribution of a preservative may vary. Ground-contact and above-ground durability evaluations with these preservative–wood species combinations are in progress.

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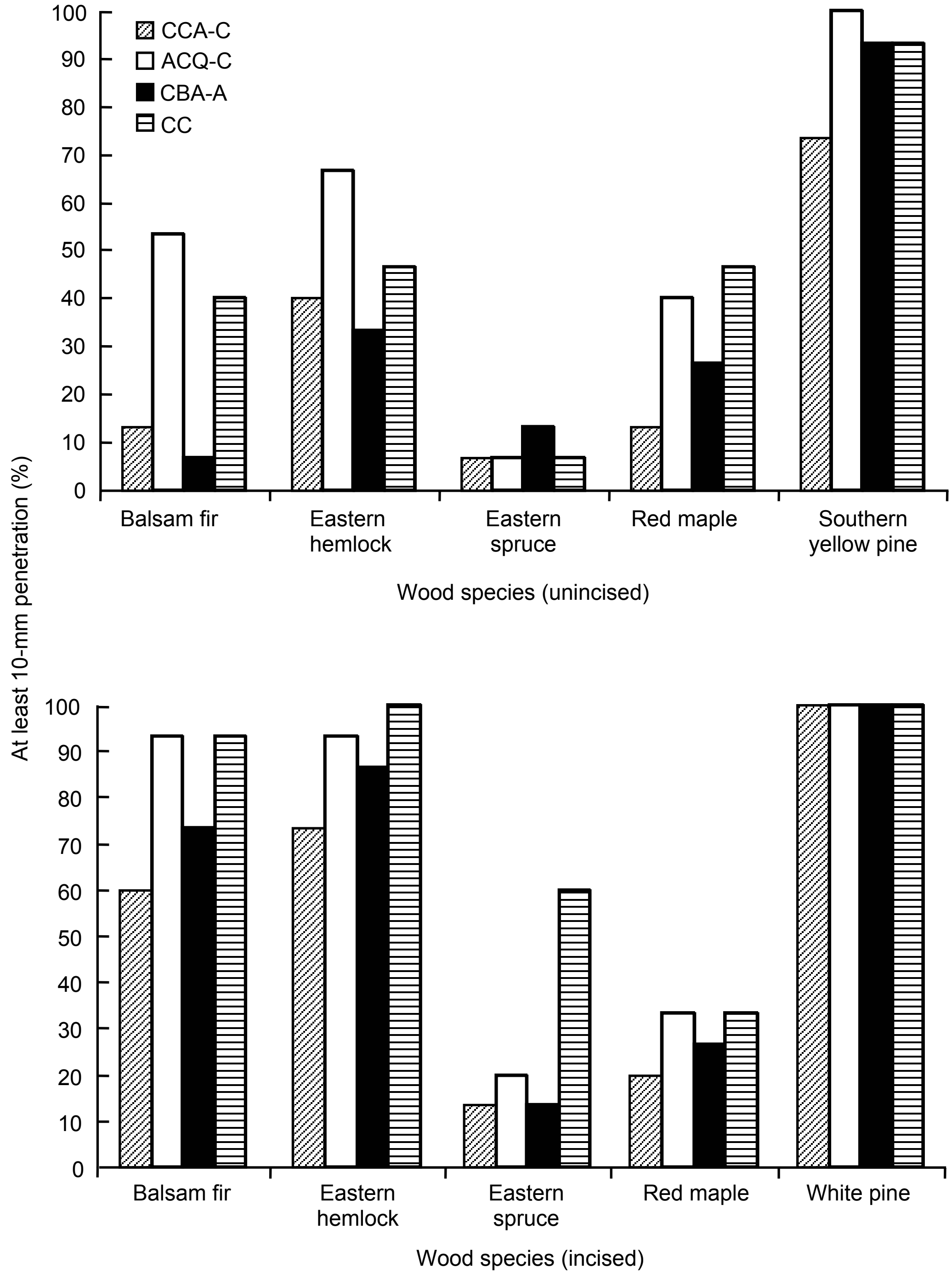

Figure 1—Percentage of unincised (top) and incised (bottom) specimens with at least 10-mm penetration on narrow faces (CCA-C, chromated copper arsenate type C; ACQ-C, alkaline copper quat type C; CBA-A, copper azole type A; CC, ammoniacal copper citrate).