Protocol Comparison: Laboratory versus Natural Weathering Tests for Performance Evaluation of Coatings on Preservative-Treated Wood

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Abstract

Fourteen stains were tested in the laboratory to compare water uptake and leaching reduction of wood treated with chromated copper arsenate, alkaline copper quat, and copper azole. Based on results of a 2-week test, eight stains were selected to be evaluated over 3 months of accelerated weathering and five stains over 3 years of natural exposure in Toronto, Ontario, Canada. These comparisons were made in order to find a quick and reliable method for replacing natural exposure tests.

Comparison of different weathering techniques showed significant correlations between leaching and water uptake results from laboratory tests and natural weathering. The cumulative percentage of inorganic elements leached from coated samples was highly correlated with the cumulative percentage leached during 3 years of natural weathering. Also, the average moisture content of treated-coated samples after 1 and 3 days of water immersion showed a relatively strong positive correlation with the average moisture content of treated-coated wood samples during wet periods of natural weathering (moisture content above 20%, average of 17 reading times). Thus, this quick laboratory test is a reliable short-term test for evaluating the ability of coatings to reduce leaching and water uptake when applied on preservative-treated wood.

Development of laboratory tests to rapidly obtain comparable results to natural weathering is an essential part of any performance assessment of coatings. To get adequate acceleration and good correlation with natural weathering, artificial weathering tests for coatings should include UV cycles to simulate photo-degradation by sunlight, condensation to simulate moisture absorption, water spray to remove degraded material from the wood surface (Podgorski et al. 2003), and freezing after wet cycles to accelerate development of cracks in coatings and checks in the coated wood specimens (Weldon 2002).

Since sunlight only contains 5 to 7 percent UV light and there is only a small amount of UVB radiation (Sherbondy 1995), to truly simulate the effect of sunlight without resulting in severe polymer damage, accelerated weathering devices should contain UV lamps in the UVA region (400 to 320 nm; Weldon 2002, Brennan and Fedor 2006).

Moisture is another important factor in coating failure studies, particularly when the substrate is wood. Increase in moisture contents (MCs) of coated wood samples in natural weathering is due to condensation, rain, or melting snow or ice (Sherbondy 1995). The stresses caused by development of a moisture gradient between the surface and interior of wood during wetting and drying results in surface checking and sometimes interface failure. In any artificial procedure, it is essential to have different cycles of wet and dry conditions so water can wash off the degraded materials from the surface of coated wood after each UV cycle.

Chromated copper arsenate (CCA)–treated wood is no longer in use for residential applications in North America and has generally been replaced by copper amine preservative systems or micronized copper systems (Freeman and McIntyre 2008). However, CCA decks and fences that were built prior to December 2003 are still in service. The Environmental Protection Agency (EPA) suggested appli-

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cation of semitransparent stains every year to reduce leaching of arsenic and chromium from CCA-treated wood (Health Canada 2005). Copper amine–treated wood (e.g., alkaline copper quat [ACQ] and copper azole [CA]) should also benefit from application of these stains. Even though copper has low toxicity for humans, wood treated with copper amine preservative leaches copper in significant amounts that could cause problems in aquatic environments (Flemming and Trevors 1989).

The principle objectives of this project were to assess the ability of coatings to enhance the serviceability and to reduce wood preservative leaching from wood treated with CCA and copper amine preservative. Developing a short reliable laboratory test as a predictor of natural weathering results will help both preservative and coating industries by reducing the evaluation time as new preservative and coating formulations are developed.

Many studies have used water immersion tests for quick leaching evaluation of treated wood, and exposure times ranging from 14 to 32 days have been used (e.g., Veenin and Veenin 2001, Temiz et al. 2006, Waldron et al. 2006). This article uses the cumulative percentage leached during 3 years of natural weathering to validate data obtained from 2-week water immersion tests and 3 months of accelerated weathering. Also, the average MCs developed during the laboratory tests are compared with those developed after wet periods of natural weathering.

Materials and Methods

Flat grained sapwood (2 by 14 by 480-cm) boards of southern pine were cut into four equal lengths. Three pieces were treated, each with a different preservative, and one was left as an untreated control sample. Preservatives used were as follows: CCA-C (47.5% CrO_3, 18.5% CuO, 34% As_2O_5), ACQ-C (66.7% CuO, 33.3% quat as alkyl dimethyl benzyl ammonium chloride), and CA-B (96.1% copper, 3.9% tebuconazole). Boards were treated by a full cell process (initial vacuum of 85 kPa, followed by pressure at 1,060 kPa). All samples were targeted to aboveground retention, but the actual retention results were slightly higher when digested samples were analyzed by Inductively Coupled Plasma–Optic Emission Spectrometer (ICP-OES) Optima7300 DV (based on AWPA A7-04; American Wood-Preservers' Association [AWPA] 2006): 5.3 kg/m^3 CCA, 4.9 kg/m^3 ACQ, and 2.0 kg/m^3 CA. Samples were allowed to fix for 1 week at 50°C and 95 percent relative humidity. Smaller specimens were cut from these boards for the different exposure tests described below. At each step the samples were weighed and a small cross section of all boards was cut and placed in an oven (at 105°C) overnight to reach a constant weight in order to determine the MC of the boards. For each type, the MC of the small samples was determined so that the ovendry masses of the larger pieces could be estimated. Then at different intervals, the MC of each sample during exposure was estimated from its current mass and estimated ovendried mass.

Coatings' viscosities were measured at 20°C using a Brookfield viscometer at 20 rpm. Solids contents of coatings were determined based on ASTM D2369 (ASTM International 2010) and specific gravities of coatings were measured by hydrometer (G & W Instruments) at room temperature. Details of the coatings' bases and their measured properties are shown in Table 1; eight coatings (1, 2, 4, 5, 7, 8, 9, and 14) were selected for accelerated

Table 1.—Coating numbers, resin types, bases, and measured properties.[a]

Coating	Resin type	Base	Specific gravity	Viscosity (cP)	Solid content (%wt)
1	Alkyd	Water	1.02	10	17
2	Alkyd-acrylic	Water	1.02	29	27
3	Alkyd	Solvent	0.98	72	47
4	Alkyd-acrylic	Water	1.03	18	28
5	Alkyd	Solvent	0.85	10	38
6	Alkyd	Solvent	0.85	27	35
7	Alkyd	Solvent	0.85	41	31
8	Alkyd	Solvent	0.88	33	45
9	Alkyd	Solvent	0.92	124	46
10	Alkyd-acrylic	Water	1.09	903	27
11	Alkyd	Solvent	0.85	14	26
12	Alkyd	Water	1.01	60	10
13	Alkyd	Solvent	0.95	149	42
14	Polyurethane	Water	1.04	270	29

[a] Eight coatings (1, 2, 4, 5, 7, 8, 9, and 14) were selected for accelerated weathering tests, and five coatings (2, 4, 5, 9, and 14) were chosen for natural weathering exposure.

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Laboratory screening test

Fourteen semitransparent coatings were selected to cover a broad range of resin types, bases, and performance characteristics for deck finishes available in the North American market in 2006 (Table 1). A set of small wood samples (38 by 7 by 45 mm; tangential [T] by radial [R] by longitudinal [L]) was used for 2-week laboratory tests, comparing three preservative treatments plus an untreated control × 14 coatings. All coatings were applied only once following manufacturers' recommendations, except Coating 14 for which two coats were applied (one coat of Step 1 penetrating stain and one coat of Step 2 as UV blocker). Samples were coated on all sides.

Preservative component leaching.—After 48 hours of air drying, two replicate samples were submerged in 75 mL of distilled water for 2 weeks. The water was removed and replaced with fresh water after 1, 3, and 14 days. The collected water was analyzed for inorganic preservative components leaching by ICP-OES Optima 7300 DV. Cumulative leaching losses were determined based on the amounts of preservative components collected in the leachate samples and on the amount originally in the samples, as determined by ICP analysis of digested (AWPA A7-04; AWPA 2006) matched samples.

Water absorption.—Water absorption after 1, 3, and 14 days was determined on the two replicate samples and another replicate sample was kept inside the laboratory, and the same water immersion test was performed 1 year later. At each interval, samples were weighed and their MCs were calculated based on initial estimated ovendry weights calculated at the start of the test according to their initial measured MCs.

Accelerated weathering test

Based on the screening test results and some of the coating properties, such as resin type and coating base

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(water or solvent), eight different penetrating stains, covering a wide range of performance characteristics, were selected for accelerated weathering tests.

Accelerated weathering was conducted on 20 (R) by 140 (T) by 110 (L)–mm samples with the coating applied on all sides. The test included twelve 1-week cycles, according to a modified version of the prEN-927-6 test (European Committee for Standardization 2004). The 1-week testing cycles included 3 days of UVA radiation (340-nm lamp, with intensity of 1.06 mW/cm^2 at 7-cm distance from light source), 1 day of water spray (15 min of water spray every 4 h, providing an average of 37 mm of rain per day) in a conditioning chamber at 35°C and 3 days of freezing at −12°C. Because samples were small and coated on all sides, in order to have a detectable amount of elements in the leachate, three replicates of each coated-treated samples were set in one plastic container (27 by 36 by 23 cm). Samples were placed on plastic mesh secured 6 cm below the top of the container for exposure to the water spray. Leachates were collected and analyzed every week by ICP-OES and the percent leaching losses determined as already described for each interval and totaled over the 3-month test.

To measure the water uptake, samples were weighed twice a week after each UV and rain cycle and their MCs were calculated based on their initial estimated ovendry weight.

Natural weathering test

Among the eight coatings that were used for accelerated weathering, five coatings that covered a range of different resin types, bases, and performance characteristics were selected for natural weathering. Coatings 2, 4, 5, 9, and 14 (Table 1) that were selected for natural weathering tests were applied by brush on the top surface (bark side up) and the end grain of wood samples (2 [R] by 14 [T] by 28 [L] cm, with six to eight annual rings). Three replicates of each treatment (CCA, CA, ACQ, and untreated control) and coating were exposed to natural weathering in Toronto, Ontario, Canada, from May 2006 to May 2009.

The rain water was collected, measured for volume, and analyzed by ICP after 1, 2, and 3 months and every 3 months thereafter to measure the amount of copper, chromium, and arsenic leached from the exposed samples. In addition, samples were weighed every month and their MCs were calculated based on their initial measured MC.

Results and Discussion

Laboratory screening results

Table 2 shows the MCs of screening specimens after 1- and 3-day water immersion tests. The wood MCs and cumulative amounts of components leached after 14 days (expressed as percentage of initial retention) are shown in Table 3.

Analysis of results (two-way analysis of variance [ANOVA]) of percent MCs after 1, 3, and 14 days showed that there were significant differences among different preservative treatment types after 1 day of water immersion. ACQ and CA had significantly higher water uptake than CCA and even untreated wood samples after the 1-day water immersion test. However, when samples were soaked continuously for 2 weeks, the differences among treatments were no longer significant. In contrast, differences among different coatings were significant at all times (ANOVA results). Coatings 4, 9, and 14 had the highest water repellency, and Coatings 1, 5, and 12 were ranked as the three worst coatings with respect to water absorption. After 1 day of water immersion, MCs of samples coated with water-based coatings were similar to those with solvent-based coatings; however, after submersion in water for 2 weeks, the solvent-based coatings had on average lower moisture uptake than water-based coatings. On the other hand, coatings with similar viscosity ranges but different solvent bases (e.g., Coating 1 [alkyd, water-based] and Coating 5 [alkyd, solvent-based]) had similar water uptake. This indicates that viscosity plays a more important role than coating base (water-based or solvent-based) in defining water repellency effect of a coating.

Table 2.—Percent moisture content of screening test samples after 1 and 3 days of water immersion.[a]

Coating	% moisture content after 1 d				% moisture content after 3 d			
	CCA	ACQ	CA	Untreated	CCA	ACQ	CA	Untreated
1-Al (W)	46 (2)	49 (5)	46 (4)	43 (3)	62 (4)	57 (6)	55 (5)	55 (6)
2-Al-Ac (W)	43 (2)	48 (4)	46 (3)	43 (2)	53 (2)	57 (6)	53 (2)	47 (1)
3-Al (S)	37 (4)	43 (6)	44 (6)	39 (8)	49 (6)	51 (3)	52 (5)	44 (6)
4-Al-Ac (W)	27 (3)	36 (3)	33 (2)	44 (4)	42 (3)	50 (4)	47 (1)	49 (3)
5-Al (S)	41 (5)	48 (6)	48 (5)	39 (4)	54 (6)	56 (4)	58 (3)	45 (3)
6-Al (S)	40 (4)	45 (7)	48 (7)	33 (1)	53 (6)	54 (7)	57 (5)	39 (0.5)
7-Al (S)	39 (4)	44 (6)	43 (7)	39 (5)	51 (6)	53 (6)	52 (7)	44 (3)
8-Al (S)	40 (6)	41 (6)	46 (7)	38 (5)	51 (6)	50 (5)	55 (7)	44 (3)
9-Al (S)	27 (3)	32 (3)	36 (10)	29 (5)	40 (4)	44 (1)	46 (8)	41 (7)
10-Al-Ac (W)	40 (5)	42 (6)	40 (2)	43 (1)	51 (7)	52 (4)	48 (1)	48 (2)
11-Al (S)	43 (5)	45 (7)	46 (7)	36 (5)	56 (4)	55 (5)	56 (7)	42 (4)
12-Al (W)	55 (2)	48 (1)	53 (2)	50 (2)	61 (5)	56 (1)	59 (2)	54 (2)
13-Al (S)	28 (3)	38 (6)	35 (6)	33 (5)	43 (6)	51 (5)	45 (4)	40 (2)
14-PU (W)	36 (10)	30 (13)	29 (9)	26 (5)	45 (10)	44 (9)	42 (7)	37 (3)
Uncoated	53 (1)	57 (3)	57 (2)	51 (1)	59 (1)	63 (5)	62 (1)	55 (1)

[a] Values are means (standard deviations) of three replicates. CCA = chromated copper arsenate; ACQ = alkaline copper quat; CA = copper azole; Al = alkyd; Al-Ac = alkyd-acrylic; W = water-based; S = solvent-based; PU = polyurethane. Eight coatings (1, 2, 4, 5, 7, 8, 9, and 14) were selected for accelerated weathering tests, and five coatings (2, 4, 5, 9, and 14) were chosen for natural weathering exposure.

Table 3.—Specimen moisture contents (three replicates) and cumulative preservative component leached (average of two replicates) of screening samples after 2 weeks.[a]

| | % moisture content after 14 d, mean (SD) | | | | Cumulative % leached after 14 d | | | | |
| | | | | | CCA | | | ACQ | CA |
Coating	CCA	ACQ	CA	Untreated	As	Cu	Cr	Cu	Cu
1-Al (W)	62 (4)	57 (6)	55 (5)	55 (6)	2.1	4.0	0.9	7.0	8.6
2-Al-Ac (W)	53 (2)	57 (6)	53 (2)	47 (1)	1.4	4.6	0.6	6.5	7.9
3-Al (S)	49 (6)	51 (3)	52 (5)	44 (6)	1.7	6.2	0.8	5.5	7.7
4-Al-Ac (W)	42 (3)	50 (4)	47 (1)	49 (3)	0.4	2.1	0.3	4.9	5.6
5-Al (S)	54 (6)	56 (4)	58 (3)	45 (3)	2.4	6.3	1.1	8.4	10.9
6-Al (S)	53 (6)	54 (7)	57 (5)	39 (1)	2.0	6.2	0.8	6.9	9.2
7-Al (S)	51 (6)	53 (6)	52 (7)	44 (3)	1.2	4.3	0.6	7.3	8.2
8-Al (S)	51 (6)	50 (5)	55 (7)	44 (3)	2.0	7.3	0.8	6.6	8.6
9-Al (S)	40 (4)	44 (1)	46 (8)	41 (7)	0.4	3.1	0.2	3.1	4.3
10-Al-Ac (W)	51 (7)	52 (4)	48 (1)	48 (2)	0.6	3.2	0.7	6.6	8.9
11-Al (S)	56 (4)	55 (5)	56 (7)	42 (4)	1.9	6.8	0.9	8.7	9.6
12-Al (W)	61 (5)	56 (1)	59 (2)	54 (2)	1.3	6.2	0.9	11.1	11.9
13-Al (S)	43 (6)	51 (5)	45 (4)	40 (2)	0.4	2.0	0.2	5.9	6.6
14-PU (W)	45 (10)	44 (9)	42 (7)	37 (3)	0.2	1.7	0.2	4.1	3.5
Uncoated	59 (1)	63 (5)	62 (1)	55 (1)	2.6	6.9	1.1	12.1	14.6

[a] CCA = chromated copper arsenate; ACQ = alkaline copper quat; CA = copper azole; Al = alkyd; Al-Ac = alkyd-acrylic; W = water-based; S = solvent-based; PU = polyurethane. Eight coatings (1, 2, 4, 5, 7, 8, 9, and 14) were selected for accelerated weathering tests, and five coatings (2, 4, 5, 9, and 14) were chosen for natural weathering exposure.

Table 3 represents the cumulative amounts of components leached, expressed as percentage of initial retention, after 14 days of water immersion. Based on the results of the two-way ANOVA test of screening samples, water-based coatings were significantly more efficient in reducing arsenic and copper leaching from CCA-treated wood than solvent-based coatings tested in this study (Fig. 1), as was also observed in the natural weathering results (Nejad and Cooper 2010). There was a strong positive correlation between MCs of samples after 14 days and cumulative percentage leached of all components. Correlation was the highest for CA-treated wood ($R^2 = 0.85$) and the lowest for copper from CCA-treated wood ($R^2 = 0.52$), with all the correlations being highly significant at a 95 percent confidence level.

Accelerated weathering results

Figure 2 illustrates the MC changes of treated and untreated uncoated wood samples during 12-week accelerated cycles. During wet periods there were significant differences among MCs of treated samples, but after each dry cycle (3 d UV) all samples reached similar MCs. Copper amine–treated wood samples (ACQ and CA) had on average 50 percent higher water absorption than CCA-treated wood samples (Fig. 2). There was no significant difference between MCs of CCA and untreated wood samples. The average MCs of all coated and uncoated samples following the wetting cycles are presented in Figure 3. All coated samples showed trends similar to those of uncoated samples as shown in Figure 2, but overall with lower moisture uptake (Fig. 3). CA-treated samples (coated and uncoated) had on average 32 percent MC, which was significantly higher than for ACQ-treated samples (29%).

Both coatings and treatments had significant effects on moisture absorption of wood samples, and there was a significant interaction effect between coatings and treatments ($\alpha = 0.05$). For instance, although most coatings had better water repellency performance on CCA and uncoated wood in comparison with copper amine–treated woods, Coating 9 (alkyd, solvent-based) performed well on all treatments. In general, water-based coatings evaluated in accelerated tests showed higher water absorption than solvent-based coatings, similar to laboratory screening data.

Cumulative percentages leached from samples after 12 cycles of accelerated weathering are shown in Table 4. All coated samples had lower preservative component leaching than uncoated ones. Similar to the screening results, Coatings 4, 9, and 14 performed better in terms of leaching reduction and Coating 9 performed the best for water repellency. Also, there were very strong positive correla-
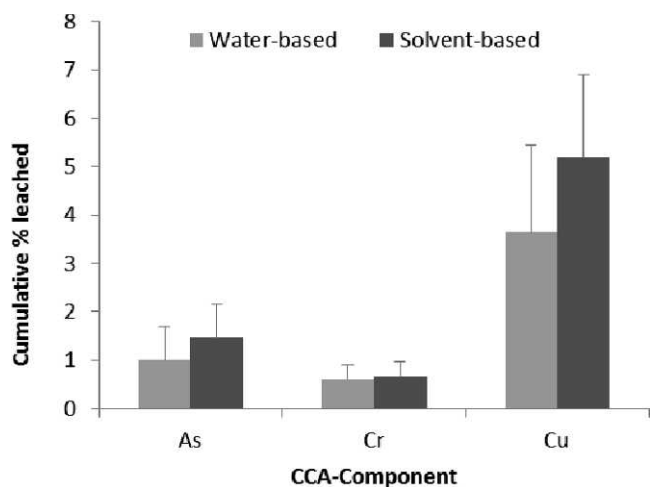

Figure 1.—Comparing effect of water-based coating with solvent-based coating in reducing chromated copper arsenate (CCA) component leaching during the 2-week laboratory test. As = arsenic; Cr = chromium; Cu = copper.
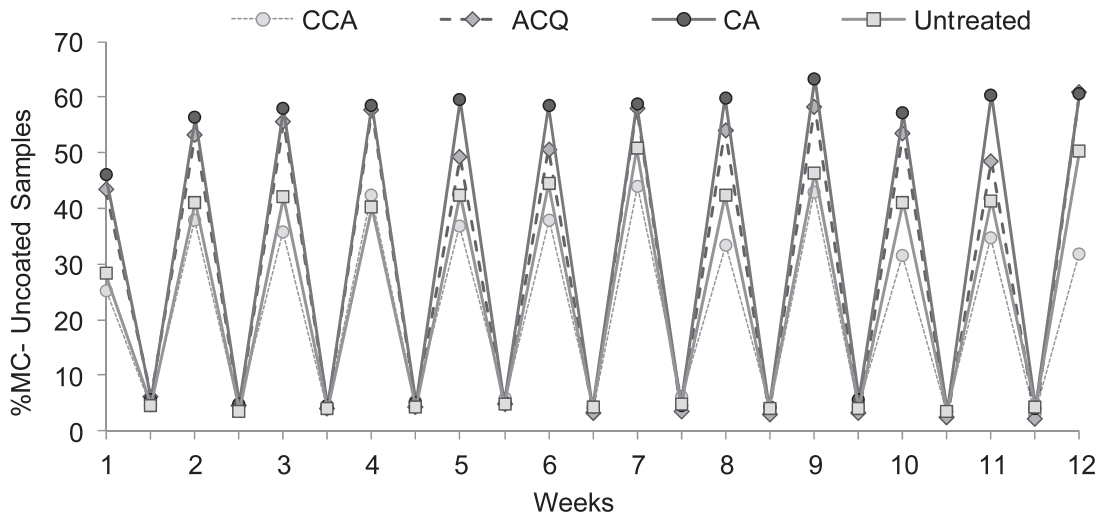
Figure 2.—Average moisture content (MC) of uncoated, but different treated wood samples during 12 weeks of artificial weathering. CCA = chromated copper arsenate; ACQ = alkaline copper quat; CA = copper azole.
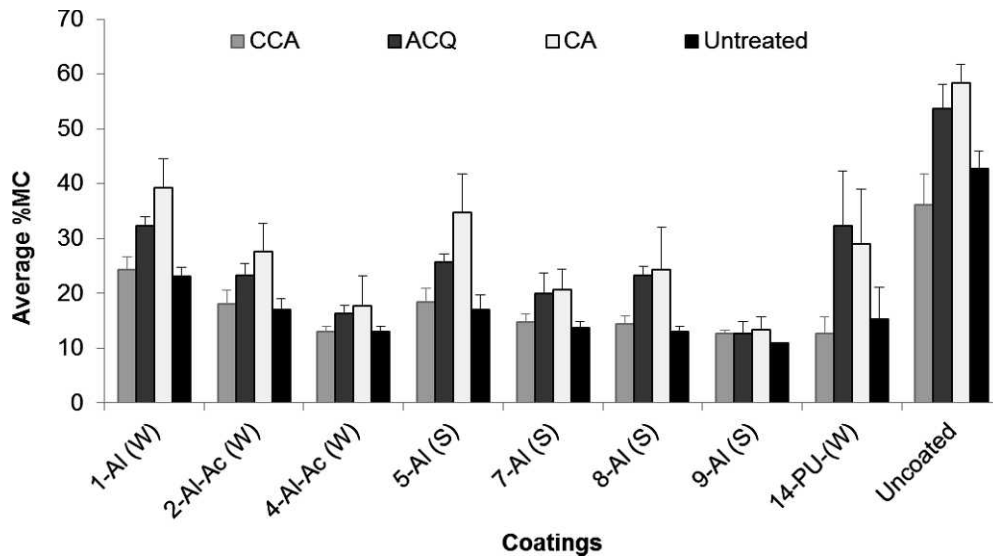

Figure 3.—Average percent moisture content (MC) of samples following the wet cycle during 12 weeks of accelerated weathering. CCA = chromated copper arsenate; ACQ = alkaline copper quat; CA = copper azole. See the tables for explanation of the coatings.

Table 4.—Cumulative percentage leached after 3 months of accelerated weathering.[a]

	Cumulative % leached				
	CCA			ACQ	CA
Coating	As	Cu	Cr	Cu	Cu
1-Alkyd (W)	0.12	1.7	0.07	2.4	3.1
2-Alkyd-acrylic (W)	0.08	1.0	0.03	1.1	1.4
4-Alkyd-acrylic (W)	0.04	0.3	0.01	0.7	0.5
5-Alkyd (S)	0.06	0.6	0.04	3.6	3.6
7-Alkyd (S)	0.06	0.7	0.03	1.5	1.2
8-Alkyd (S)	0.06	0.4	0.03	1.7	1.6
9-Alkyd (S)	0.02	0.1	0.01	0.5	0.5
14-PU (W)	0.03	0.1	0.01	0.6	0.4
Uncoated	0.25	1.8	0.2	8.9	9.9

[a] CCA = chromated copper arsenate; ACQ = alkaline copper quat; CA = copper azole; As = arsenic; Cu = copper; Cr = chromium; W = water-based; S = solvent-based; PU = polyurethane.

tions between average MCs of samples during 12 weeks (wet periods) and cumulative percentages leached in accelerated weathering tests. Correlation between water uptake and leaching was the highest for arsenic from CCA-treated wood ($R^2 = 0.96$) and the lowest for copper from ACQ-treated wood ($R^2 = 0.76$); all the correlations were highly significant at the 95 percent confidence level. Overall, Coatings 5 and 1 were the worst and Coating 9 was the best in both leaching reduction and water repellency. Coating 14, which showed high water repellency in the 2-week laboratory test, lost its effectiveness especially on ACQ- and CA-treated wood during accelerated weathering with UV cycles.

Natural weathering results

Table 5 summarizes the average MCs of natural weathering samples during wet periods (MC above 20%) and cumulative percentages leached after 3 years of

Table 5.—*Percent moisture content of samples in wet periods and cumulative percentage leached during 3 years of natural weathering.*[a]

| | % moisture content | | | | Cumulative % leached | | | | |
| | | | | | CCA | | | ACQ | CA |
Coating	CCA	ACQ	CA	Untreated	As	Cu	Cr	Cu	Cu
2-Al-Ac (W)	27 (2)	34 (4)	37 (5)	27 (4)	1.4 (0.1)	1.5 (0.2)	0.2 (0.02)	6.0 (1.4)	5.7 (1.2)
4-Al-Ac (W)	24 (2)	31 (3)	36 (4)	27 (4)	1.0 (0.1)	1.1 (0.2)	0.2 (0.01)	4.7 (1.0)	4.1 (0.1)
5-Al (S)	22 (0.5)	33 (3)	36 (1)	24 (0.3)	1.5 (0.2)	1.8 (0.2)	0.3 (0.02)	4.4 (0.6)	5.4 (1.2)
9-Al (S)	22 (0.5)	30 (1)	31 (2)	29 (1)	1.1 (0.2)	1.5 (0.2)	0.2 (0.02)	3.5 (0.1)	3.3 (0.6)
14-PU (W)	25 (0.1)	32 (1)	35 (2)	30 (2)	1.3 (0.2)	0.7 (0.2)	0.1 (0.01)	3.6 (0.4)	4.8 (0.7)
Uncoated	28 (1)	36 (2)	39 (1)	36 (3)	2.3 (0.2)	2.4 (0.1)	0.4 (0.03)	11.2 (2.4)	11.6 (3.1)

[a] Values are means (standard deviations). CCA = chromated copper arsenate; ACQ = alkaline copper quat; CA = copper azole; Al = alkyd; Al-Ac = alkyd-acrylic; W = water-based; S = solvent-based; PU = polyurethane.

exposure. There was a strong correlation between average MCs of ACQ- and CA-treated wood samples during wet periods and the cumulative percentages leached in 3 years, but no significant correlation between water uptake and leaching for CCA components.

Protocol comparison

Leaching.—Generally, the natural weathering performance of stains could be predicted by both short-term laboratory studies and by accelerated weathering exposures. There were high correlations between cumulative percentages of preservative components leached from screening and accelerated weathering and cumulative amounts leached after 3 years of natural weathering (Table 6).

Results of both screening and accelerated test methods were highly correlated to natural weathering, and it is more convenient to perform a 2-week laboratory test for prediction of coating performance under long-term natural exposure than the accelerated weathering test. Therefore, we recommend this short-term test for predicting the ability of a new coating formulation to resist preservative component leaching. However, from the slopes of the regressions lines (Table 6) it can be seen that the amount leached in laboratory tests cannot be directly used for prediction purposes. For example, the amount of arsenic leached from

Table 6.—*Correlation between laboratory leaching results and natural weathering results for cumulative percentage of preservative components leached.*

| Component[a] | Natural weathering | | |
	R^2	P	Regression line
Screening			
CCA-As	0.72	0.032	$y_{As-CCA} = 0.48x + 0.93$
CCA-Cu	0.86	0.008	$y_{Cu-CCA} = 0.25x + 0.61$
CCA-Cr	0.71	0.037	$y_{Cr-CCA} = 0.21x + 0.09$
ACQ-Cu	0.90	0.004	$y_{Cu-ACQ} = 1.15x - 1.98$
CA-Cu	0.96	0.001	$y_{Cu-CA} = 0.92x - 0.46$
Accelerated			
CCA-As	0.92	0.002	$y_{As-CCA} = 4.96x + 1.02$
CCA-Cu	0.71	0.035	$y_{Cu-CCA} = 0.73x + 1.04$
CCA-Cr	0.94	0.001	$y_{Cr-CCA} = 1.22x + 0.16$
ACQ-Cu	0.86	0.005	$y_{Cu-ACQ} = 0.79x + 3.51$
CA-Cu	0.94	0.009	$y_{Cu-CA} = 0.76x + 3.73$

[a] CCA = chromated copper arsenate; ACQ = alkaline copper quat; CA = copper azole; As = arsenic; Cu = copper; Cr = chromium.

screening samples in 2 weeks was twice as high as the amount leached during 3 years of natural exposure. For copper leaching from ACQ and CA, the slopes were close to 1 indicating that the 2-week water immersion results (laboratory) corresponded more closely to copper leaching from copper amine preservatives after extended natural weathering.

Water uptake.—There were significant correlations ($P < 0.005$) between average MCs of ACQ-treated ($R^2 = 0.86$) and CA-treated ($R^2 = 0.70$) samples in accelerated weathering and average of MCs of samples during wet periods in 3 years of natural weathering (MC above 20%, average of 17 collection times), but not for CCA-treated samples. Also, measuring changes in MCs of coated-treated and untreated wood samples during 12 weeks after dry and wet cycles was very helpful in predicting ranking of coating performance in service. However, it is always preferable to look for a reliable test that is quicker, easier, and less labor intensive, that has no energy consumption, and that can be performed with the least laboratory equipment.

The best correlation of the 2-week laboratory test and natural weathering data was found based on the average MCs of
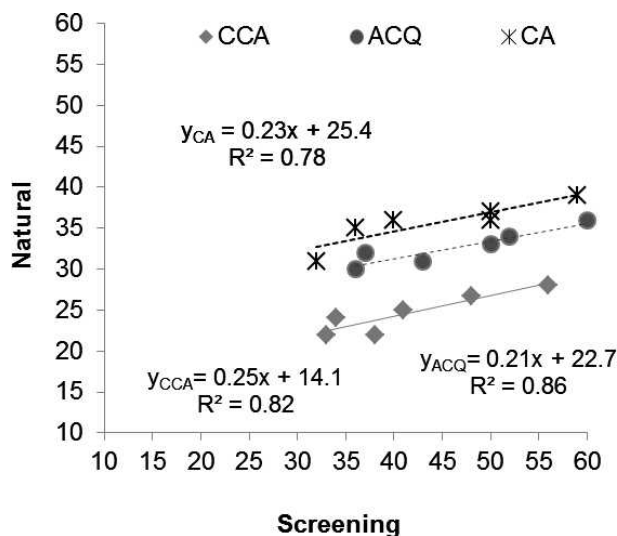
Figure 4.—*Correlation between average moisture content (MC) of screening (2-wk laboratory test after 1 and 3 days) and natural weathering (3 y, average of 17 MC measurements during wet periods). CCA = chromated copper arsenate; ACQ = alkaline copper quat; CA = copper azole.*

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samples after 1 and 3 days of water immersion. The highest R^2 value was 0.86 for ACQ-treated wood samples as shown in Figure 4. The correlation between MCs of the 2-week laboratory test with natural weathering for coated untreated wood samples was not statistically significant (data not shown). This could be due to treatments playing a significant role in water uptake of coated samples. During natural weathering, untreated wood samples had higher UV degradation (color change) and checking, especially compared with ACQ-treated wood samples. Unfortunately, neither of the accelerated tests enhanced the weathering degradation seen in untreated wood in natural weathering. Another important point that could help while testing coating performance in the laboratory is to ensure that coatings are already cured completely. For instance, alkyd-based coatings take a few months of air drying to completely cure; their water repellency should be tested after the cure process is complete. Looking closely at data obtained from the laboratory test in comparison with natural weathering revealed that the highest deviations were related to alkyd samples that were tested after 48 hours of air drying in the laboratory and to Coating 14 (polyurethane, water-based) samples that performed very well during the first 2 years, after which surface erosion of the coating caused a significant increase both in leaching and water-uptake results.

Conclusions

A 2-week water immersion screening test of coated CCA-, ACQ-, and CA-treated and of untreated wood samples proved to be a useful method for assessment of coating efficiency to reduce leaching and water uptake under natural weathering exposure. Results of both 3 months of accelerated weathering and the screening tests showed strong positive correlations between average MC of samples during wet periods and cumulative percentage of preservative components leached from treated woods. However, for natural exposure, only the cumulative amounts leached from ACQ- and CA-treated wood samples were related to the average MCs of samples during wet periods over the 3-year exposure. Based on screening test results and confirmed by natural weathering, water-based coatings are more effective in reducing CCA component leaching than are solvent-based coatings.

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