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The Role of Moisture Content in Above-ground Leaching

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The role of moisture content in above-ground leaching

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ABSTRACT

This paper reviews previous reports on the moisture content of wood exposed above ground and compares those values to moisture contents obtained using simulated rainfall and immersion methods. Laboratory leaching trials with CCA-treated specimens were also conducted and the results compared to published values for leaching of CCA-treated specimens exposed above ground outdoors. Previous researchers have reported that the moisture content of wood exposed above ground may range from over 80% to minimums of approximately 10%. In most studies, the maximum moisture content fell within 40% to 55% for horizontal specimens and between 30% to 50% for vertical specimens. Minimum moisture contents were generally in the 10% to 15% range. Average moisture contents reported for horizontal exposures ranged from 21% to 26%, while the averages reported for vertical exposure were 19% and 25%. The simulated rainfall method produced a maximum moisture content of 49% in CCA-treated lumber specimens, but did not provide realistic drying between rainfall events. A 14-day continuous immersion with lumber specimens yielded an average final moisture content of 52% in CCA-treated specimens. Both methods produced cumulative copper and chromium leaching values slightly below, and arsenic values slightly above, those reported for wood exposed outdoors. Trials with smaller specimens indicated that immersion and drying schedules could be adapted to create moisture contents similar to those reported in service. Leaching methods could be improved by developing a better understanding of moisture conditions in wood exposed above ground, and of the role of drying cycles in preservative leaching.

Keywords: Above ground, moisture content, leaching, simulated rainfall, immersion

1. INTRODUCTION

There is increasing interest in the development of laboratory methods to estimate environmental release of preservative components from treated wood that is used above ground or above water. Although most preservative-treated wood is not placed in direct contact with soil or water, conventional laboratory leaching methods involve continuous immersion of specimens. In the United States, for example, the American Wood Preservers' Association (AWPA) has two standard laboratory methods to evaluate preservative depletion. AWPA Method E11-06, *Standard Method of Determining the Leachability of Wood Preservatives Immersed in Water*, specifies vacuum impregnation of small cubes with water, followed by continuous immersion for 14 days (AWPA 2006). This test was designed to accelerate leaching and provide rapid results, but in the absence of alternative methods it has also been used by regulatory agencies to estimate leaching and environmental impact. AWPA Method E20-06, *Standard Method for Determining the Leachability of Wood Preservatives in Soil Contact*, involves burying small stakelets in wet soil (AWPA, 2006). While these methods provide a conservative assessment of the ability of a preservative to provide long-term protection in wood used above ground, the relationship between results obtained with these methods and rate of leaching of preservatives from wood exposed above ground is unclear.

Developing a laboratory test to estimate preservative leaching from above-ground uses of treated wood does appear to present greater challenges than that for wood that is continually immersed. An appropriate simulation of the wetting and drying conditions is one of these challenges. While use of simulated rainfall appears to be one valid approach for estimating above-ground leaching, methods involving short immersions have also been proposed (Melcher *et al.* 2004; Schoknecht, 2005; Schoknecht *et al.* 2004).

Regardless of the method used, an important question remains: What is the target water uptake or range of moisture contents that the method should attempt to simulate for above-ground exposures? To answer this question, it is useful to review previous studies that reported the moisture content of pine sapwood exposed outdoors. Many of these studies were conducted to evaluate decay potential while others were designed to evaluate the effect of coatings or pressure treatments on water absorption. Unless otherwise noted, the moisture contents reported here are for control specimens that were not coated or otherwise treated.

In one of the older studies, 25-mm x 102-mm x 914-mm specimens were exposed for 15 months at a 45 degree angle at York, UK (Belford and Nicholson 1969). The upper ends were protected from direct precipitation. Although not stated in the article, it appears that moisture content was determined by weight gain. The authors found the moisture content of untreated radiata pine sapwood was typically above 30%, and was above 50% for 15 continuous weeks of the study. The finding of a continuous moisture content above 50% appears to be unusual in comparison to reports by other researchers (see below), perhaps reflecting the local climatic conditions. In an attempt to develop a detailed profile of moisture content within a deck structure, researchers in North Carolina constructed a Southern Pine decking and railing assembly and fitted various areas with resistance-type moisture sensors (Gaby and Duff 1978). The upper limit of the moisture sensors was 30% MC, and data was truncated at that point. Unfortunately, the authors only report data for 10 days of exposure. They report moisture contents of 10% in the center of horizontal members without checks and over 25% in members with checks. They also found that that the moisture content near the top face of horizontal members was substantially higher than near the bottom face.

In a study intended to evaluate the effect of preservative treatment on water absorption, Edlund and Sundman (1989) exposed pine sapwood specimens (20 x 50 x 500 mm) horizontally or vertically in Stockholm and periodically determined the moisture content by weighing. During the first 12 months, the moisture content of the horizontal pine specimens varied from 12% to over 70% moisture content. During the second year, moisture contents of over 80% were recorded on two occasions. The moisture content of the vertically oriented panels was much lower, exceeding 30% at only one occasion. The moisture content of the CCA-treated specimens was consistently less than the untreated specimens for both vertical and horizontal exposures.

A detailed study conducted in North Carolina (USA) used resistance-type sensors to measure moisture content in Southern Pine deck boards treated with CCA-C (oxide formulation) or CCA-C plus an incorporated water repellent (Zahora 1992). Previous research concluded that a moisture meter correction is not needed for wood treated with the oxide formulation of CCA-C (Richards 1990). No untreated specimens were included in this study, and the moisture content values reported here are for specimens treated with CCA but without the water repellent additive. Sensors were placed at depths of 6, 13, and 19 mm below the surface in boards that were 38 mm thick or 6 and 13 mm below the surface in boards that were 32 mm thick. During a year of exposure, the moisture content of the 38-mm thick specimens varied between 10% and 50%, with the highest moisture contents at the 13 and 19 mm depths (this finding appears to conflict with those of Gaby and Duff (1978), who reported higher moisture contents near the upper surface). Moisture contents were lower in the thinner boards, varying between about 8% to 40%. The authors also noted moisture content tended to be higher in boards with checks. In a subsequent study, Cui and Zahora (2000) report on resistance-type moisture meter readings of both ACQ- and CCA-C-treated boards exposed in Harrisburg, North Carolina, for the period of September through November, 1997. A correction factor was applied to account for the decrease in resistance associated with the ACQ treatment. The moisture content of the ACQ-treated boards varied from 12% to 28%, whereas the CCA-treated boards varied from 9% to 27%. The authors also measured moisture content by weight gain and report that the moisture content of ACQ-treated boards varied between 13% to 41%; moisture content of the CCA-treated boards varied between 11% and 34%. These studies point out that both the type of preservative treatment and the method of measurement can affect moisture content values.

Militz *et al.* (1998) established an outdoor exposure trial to evaluate the moisture content of lap joints for a range of hardwood and softwood species. For comparison, they also exposed pine sapwood specimens (38 x 85 x 300 mm) that were not part of a lap joint. The specimens were exposed horizontally for 19 months in Wageninegen, The Netherlands, with periodic weighing to determine the moisture content. The authors report that pine sapwood moisture content varied from as low as 15% to over 55%.

In an effort to better characterize the moisture content of wood exposed vertically, Rapp *et al.* (2000) suspended 20 x 70 x 100 mm specimens vertically, with exposed end grain, at a site in Hamburg. The specimens were weighed frequently over the course of two years. The untreated pine sapwood moisture content fluctuated between 15% and 45% moisture content, and was above 20% moisture content 219 days, above 25% moisture content 166 days, and above 30% moisture content 104 days of the second year.

In a study of natural durability of European wood species, Lindegaard and Morsing (2003) exposed a variety of wood species horizontally, vertically, and at 45 degrees, for 2.5 years in Denmark. Specimen dimensions were not reported, but from the photographs they appear to be approximately 25 x 75 x 1000 mm. Specimens were periodically weighed to determine moisture content. The moisture content of the Scots pine specimens that were exposed horizontally exceeded 35% (upper range of values not shown) in winter months and dropped to approximately 12% in the summer. The specimens exposed vertically and at 45 degrees appeared to have slightly lower moisture contents, with the maximum value exceeding 35%. Because the authors' primary interest was in tracking moisture contents conducive to decay, values above 35% moisture content were not reported.

As part of an evaluation of accelerated test methods, Saladis and Rapp (2004) exposed pine specimens (25 x 50 x 500 mm) horizontally in Hamburg, Germany, and Girionys, Lithuania. The samples were weighed from March through October, and average moisture content values reported each month. The specimens' average monthly moisture content varied from 17% to 41% in Hamburg to and from 18% to 54% in Girionys. Overall average moisture contents were reported to be between 21% and 23% in Hamburg and 25% and 26% in Girionys.

A recent study conducted in Rotorura, New Zealand, provides applicable data on the moisture content of dimension lumber (45 x 90 mm x 2.5 m) exposed both horizontally and vertically (Hedley *et al.* 2004). In an initial study, radiata pine specimens were exposed horizontally for 55 days in late winter. The moisture content rose to 27% within 6 days, was above 30% after 30 days, and remained above 30% for the remainder of the trial. The maximum moisture content was approximately 43%. A subsequent trial including both horizontal and vertical specimens was conducted for 56 days in late spring. In that trial, the moisture content of the horizontal radiata pine sapwood specimens ranged from approximately 17% to 45%, with an overall average of 25.7%. The moisture content of specimens exposed vertically was lower, ranging from 15% to 30%, with an overall average of 18.6%.

Rydell *et al.* (2005) reports on an exposure of 30- x 50- x 450-mm specimens placed at a 45 degree angle in Uppsala, Sweden (Ellowson *et al.* 2003), with periodic weighing to determine moisture content. The specimen rack included a small overhang to protect the exposed end-grain at the upper end of the specimens. From the graphical data presented, it appears that the moisture content of some specimens exceeded 80% on several occasions, while dropping to a minimum of around 10% on others. The authors report that the untreated Scots pine sapwood had an average moisture content of 25.4% during three years of exposure.

It is evident that evaluations of the moisture content of wood exposed outdoors have produced a relatively wide range of values. Many factors can affect the moisture content of wood exposed outdoors, including local climactic conditions, dimensions of members, degree of checking, orientation (vertical or horizontal) and type of preservative treatment. However, these past studies do provide the general range of moisture contents that might be expected. A few of the values observed are in excess of 80%, but most of the maximums fall within 40% to 55% for horizontal specimens and between 30% to 50% for vertical specimens. Minimum moisture contents generally fall into the 10% to 15% range. Average moisture contents reported for horizontal exposures ranged from 21% to 26%, while the averages reported for vertical exposure were 18.6% and 25.4% (Fig. 1).

How do these observations on the moisture content of wood exposed outdoors compare to our current standard or proposed leaching methods? It is apparent that the methods such as AWPA E11, which specify vacuum impregnation with leaching water, achieve and maintain moisture contents in excess of 100%. It is less clear what range of moisture contents is achieved with simulated rainfall or immersion methods. To address this question, we measured the moisture content of lumber specimens exposed using a simulated rainfall method that has been used to estimate leaching from wood exposed above ground (Lebow *et al*. 2003, Lebow *et al.* 2004), as well as by total immersion. The results of those moisture content assessments are compared to their associated leaching rates and to previous reports of leaching from wood exposed to natural weathering. The moisture content of smaller specimens exposed by immersion and drying was also evaluated.

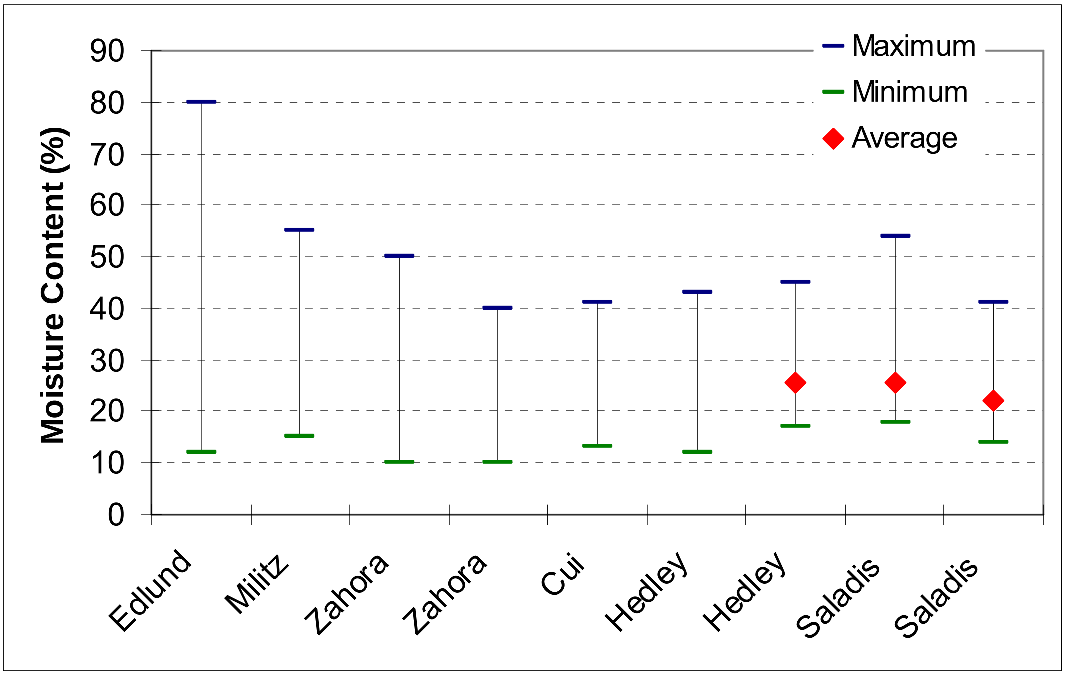

Figure 1a. Range of moisture contents reported by various authors for pine sapwood exposed horizontally. Values are for untreated wood with the exception of Zahora (CCA-treated) and Cui (ACQ-treated). In most cases, maximum and minimum values were estimated from graphical data, while average values are those reported by the authors (Edlund and Sundman 1989, Militz *et al.* 1998, Zahora 1992, Cui and Zahora 2000, Hedley *et al.* 2004, Saladis and Rapp 2004).

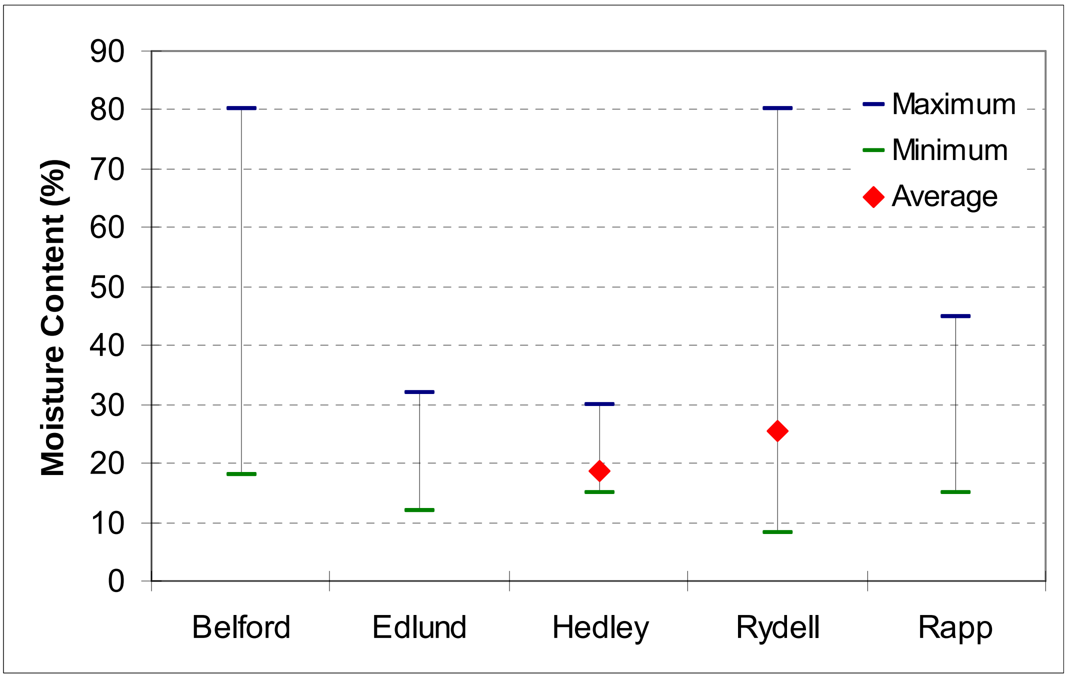

Figure 1b. Range of moisture contents reported by various authors for untreated pine sapwood exposed vertically or at a 45 degree angle (Belford and Nicholson 1969, Edlund and Sundman 1989, Hedley *et al.* 2004, Rapp *et al.* 2000, Rydell *et al.* 2005). Maximum and minimum values were estimated from graphical data, whereas average values are those reported by the authors.

2. EXPERIMENTAL METHODS

2.1. Simulated Rainfall

Moisture content and leaching trials were conducted using a rainfall simulator and 38- x 140- x 254-mm specimens cut from Southern Pine sapwood lumber. A previously constructed device was used to spray deionized water onto the wide faces of the specimens. Ten air-atomizing, wide-angle, round spray nozzles were supported on a 1.2- by 2.4-m wire grid at a height of 1 m above the specimens. Each nozzle was supplied with air and water through a flexible hose. The rate of rainfall was controlled by adjusting the ratio of air to water pressure supplied to the nozzles. Air pressure was regulated at 345 kPa and water pressure at 221 kPa. This pressure combination produced a spray of fine droplets at a rate of 3.0 mm/h. Specimens were laid horizontally, with the wide face turned up, in trays 280 mm long by 150 mm wide by 114 mm deep; the specimens were supported 20 mm above the bottom of the trays so that they did not contact standing water. Hoses attached to the bottom of the trays drained water run-off into 19-L low density polyethylene collection containers below the platform. A more detailed explanation of the simulated rainfall apparatus can be found in Lebow *et al.* 2003. The specimens were sprayed for 10.5 hours/day for 4 days per week (Monday through Thursday) for a total of 42 hours per week. Between rainfall events, the specimens were left within their trays and allowed to air-dry, but the Plexiglas enclosure surrounding the specimens minimized air flow. The water was not re-used or re-circulated.

2.1.1 Moisture Content Trial

The moisture content evaluation was conducted for 2 weeks. Five Southern Pine sapwood specimens (initial moisture content in the range of 7% to 9% moisture content) were placed into the artificial rainfall apparatus. The specimens were weighed immediately before each 10.5-hour rainfall event, at evenly spaced times within each rainfall event, and immediately after the rainfall event. Average moisture content was calculated using a time-weighted mean based on linear interpolation between recorded measurements.

2.1.2. Leaching Trial

Southern Pine sapwood specimens (five replicates) were end-sealed and pressure-treated with a 1% solution of CCA-C, weighed, and then wrapped in plastic for one week. They were then allowed to equilibrate in a room maintained at ambient conditions (6% to 9% equilibrium moisture content) prior to leaching. The leaching test was conducted as described in Section 2.1 for a total of 6 weeks. This pattern produced an average of 756 mm of rainfall. All water draining off the specimens during the course of a week was collected, weighed, acidified with nitric acid, and sub-sampled for ICP analysis.

2.2. Leaching from Immersed Lumber Specimens

For comparison to the simulated rainfall trials, end-sealed Southern Pine sapwood specimens (38 x 140 x 254 mm) were conditioned to ambient room conditions (6% to 9% moisture content). Five replicates were pressure-treated with a 1% solution of CCA-C, weighed, and then wrapped in plastic for one week. They were then allowed to equilibrate at ambient conditions (6% to 9% equilibrium moisture content) prior to leaching. The leaching regimen was similar that specified by AWPA Standard E11, except that the specimens were not vacuum-impregnated with water at the start of the test. Each specimen was immersed in approximately 3500 mls of water (weighed to the nearest 0.1 g). The water was sampled and replaced after intervals of 6, 24, and 48 hours, and subsequently at 48-hour intervals for a period of up to 2 weeks. Specimens were weighed at the conclusion of the trial to allow calculation of final moisture content.

2.3. Immersion Trials with Small Specimens

Moisture content trials were also conducted with smaller specimens as described by Melcher *et al.* 2004; Schoknecht 2005; and Schoknecht *et al.* 2004. The relatively thin, flat specimens (10 x 50 x 150 mm) allow rapid water uptake, as well as rapid drying. For immersion, the specimens were placed in shallow trays with glass weights to prevent the specimens from floating. A plastic mesh was placed under the specimens and between the specimens and the glass weights to allow water access to all surfaces of the specimens. The specimens were weighed immediately before and after each immersion, and then periodically during drying. Extra specimens were oven-dried to determine the average initial moisture content (7% to 8%), and to allow calculation of the oven-dry weight of the immersed specimens. Since moisture content profiles were based on unequal time intervals, average moisture content was calculated using a time-weighted mean. For ease of calculation, this was based on linear interpolation between recorded measurements.

3. RESULTS AND DISCUSSION

3.1. Moisture Content

The pattern of moisture content developed during the simulated rainfall regimen is shown in Fig. 2. Because of the large specimen sizes, the moisture content increased slowly and also decreased slowly during periods between rainfall events. The maximum average moisture content reached during the two weeks of this evaluation was only 34%, but based on the pattern of weight gain and loss it is probable that the average moisture content will continue to increase with time. At the conclusion of the 6-week leaching trial, the CCA-treated specimens were weighed and found to have an average final moisture content of approximately 49%. It appears that the simulated rainfall method can obtain moisture contents at or above those reported for wood exposed outdoors. However, as conducted in this study, the simulated rainfall regimen did not replicate the drying conditions and minimum moisture contents reported for wood exposed outdoors. Although a small amount of checking was noted in some of the specimens following the three-day drying intervals, greater checking would be expected to develop if the specimens had been dried to the 10% to 15% minimum moisture contents for wood exposed outdoors. Longer drying intervals or accelerated drying techniques would be needed to obtain lower moisture contents using this simulated rainfall method.

Because they gain and lose water quickly relative to their size, the smaller 10- x 50- x 150-mm species allow more flexibility in obtaining moisture content profiles similar to those reported for outdoor exposure. Average moisture contents in the 40% to 45% range were obtained after only 2 hours of continuous immersion, although slightly lower moisture contents were typically observed for the initial immersion of each specimen. However, the thin specimens also dried rapidly after immersion, and in initial trials this resulted in a lower than desired average moisture content. This rapid drying can be prevented by placing the specimens into a closed container after immersion, creating a period for water to diffuse within the wood. Trials with a range of immersion scenarios revealed that maximum, minimum, and average moisture conditions similar to those reported for wood exposed horizontally in service can be accomplished with a relatively simple combination of immersion, diffusion, and drying periods. A hypothetical example of such a scenario is shown in Fig. 3. In this scenario, the specimens are immersed for 2 hours, covered for 22 hours to prevent drying, and then uncovered to allow drying at ambient conditions for another 24 hours. Specimens could then be immersed on Monday, Wednesday, and Friday of each week. For convenience, on the third immersion day of the week (Friday) the diffusion period could be shortened to 6 hours so that no activity would be required over the weekend. These changes would increase the maximum moisture content to approximately 40% and the average moisture content to approximately 24%. Other target moisture contents can be achieved by adjusting the length of the immersion and moisture diffusion periods.

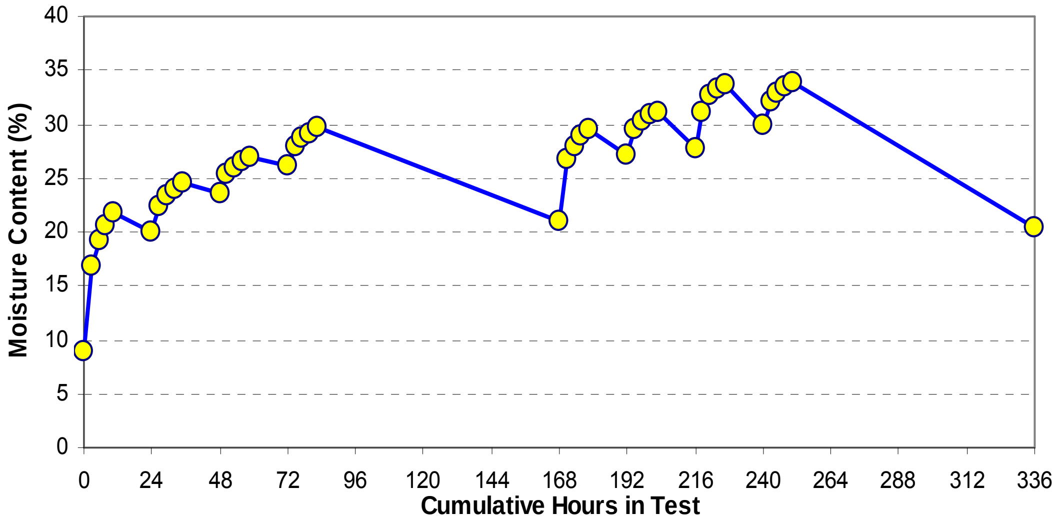

Figure 2. Moisture content of untreated 38 x 140 x 254 mm pine sapwood specimens during exposure to 2 weeks of simulated rainfall.

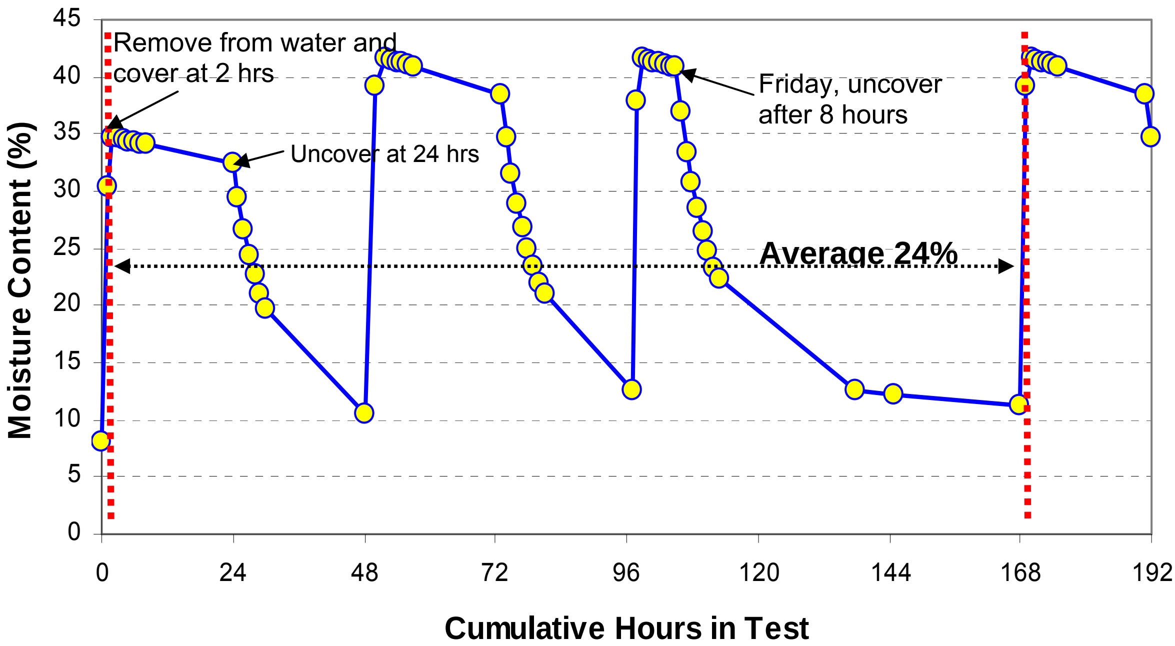

Figure 3. Moisture content profile in 10 x 50 x 150 mm samples using a hypothetical schedule with a 2 hour immersion followed by a diffusion period before drying.

3.2. Leaching Results

The amounts of copper, chromium, and arsenic lost from the CCA-C treated specimens using the simulated rainfall and continuous immersion methods are shown in Fig. 4. Leaching from the immersed samples was generally greater at equivalent exposure times, although the difference between the two methods was not as great as might be expected for copper and chromium release. If leaching from the simulated rainfall specimens was attributed to only the surface area of the top and two sides, the amount of copper and chromium leaching would be roughly equivalent at equivalent time points, and the total amount leached would be appear to be slightly greater for the artificial rainfall method. Interestingly, the final moisture content of the specimens at the conclusion of leaching was also roughly equivalent to 49% for the simulated rainfall method and 52% for the immersed specimens. This finding suggests continuous immersions may have value in estimating release from wood used above-ground if the conditions of the test are adjusted to obtain similar moisture contents. However, a comparison of the arsenic leaching between the two methods indicates substantially greater release from the immersed specimens when compared at equivalent time points and at the conclusion of the tests. It also appears that the trend of copper release from the immersed specimens differs from that of arsenic and chromium and also differs between the two test methods. The relatively high arsenic release noted in this study (as compared to copper) is probably a reflection of the low (1%) concentration of the treatment solution.

One approach to evaluating these methods is by comparison to data on leaching from wood exposed outdoors. Several authors have reported on leaching of CCA (or CCB) from specimens exposed horizontally above ground for extended intervals. In a study conducted in western Oregon (USA), 28- x 140- x 140-mm CCA-treated western hemlock specimens released at total of 37.8 ug/cm^2 copper, 11.9 ug/cm^2 chromium, and 70.5 ug/cm^2 arsenic after exposure to 747 mm of rainfall (Lebow *et al.* 2000). More recently, Taylor and Cooper (2005) exposed 38- x 137- x 200-mm Southern Pine specimens to 685 mm of precipitation in Toronto, Canada. The specimens released a total of 43.8 ug/cm^2 copper, 11.6 ug/cm^2 chromium and 89 ug/cm^2 arsenic. Both of these studies used end-sealed specimens, and the surface area has been adjusted in this paper so that all leaching is considered to be from the top and two sides. Kennedy and Collins (2001) assembled test decks from 22- x 90- x 300-mm radiata pine specimens that had been CCA treated using either a full cell or modified full cell process. The specimens were selectively end-sealed to obtain 8.8 unsealed ends per square meter of deck, and exposed to approximately 600 mm of rainfall in Brisbane. For this paper, we averaged the results of the two treatment methods, yielding total releases of 12.7 ug/cm^2 copper, 16.0 ug/cm^2 chromium, and 51.9 ug/cm^2 arsenic. In the most recent study, Garcia-Valcarcel and Tadeo (2006) exposed 15- x 80- x 500-mm CCB-treated specimens to 500 mm of rainfall at test site in Madrid. They reported a cumulative copper release of 22.7 ug/cm^2 and a cumulative chromium release of 20 ug/cm^2.

In Fig. 5, we have plotted the results of the previously reported outdoor leaching studies along with the laboratory leaching tests conducted as part of this report. The results of the laboratory-simulated rainfall method have been adjusted to limit the leaching surface area to the top and two sides of each specimen. The relation of immersion leaching to volume of rainfall is unknown, and is shown as a line on the graph. There is substantial variation in the amounts of copper, chromium, and arsenic reported to leach in outdoor exposures, although this is not surprising given the range of exposure locations and conditions. The amounts of copper and chromium leached by simulated rainfall appear to be slightly below those reported for outdoor exposures, while that of arsenic is slightly above those reported for outdoor exposures.

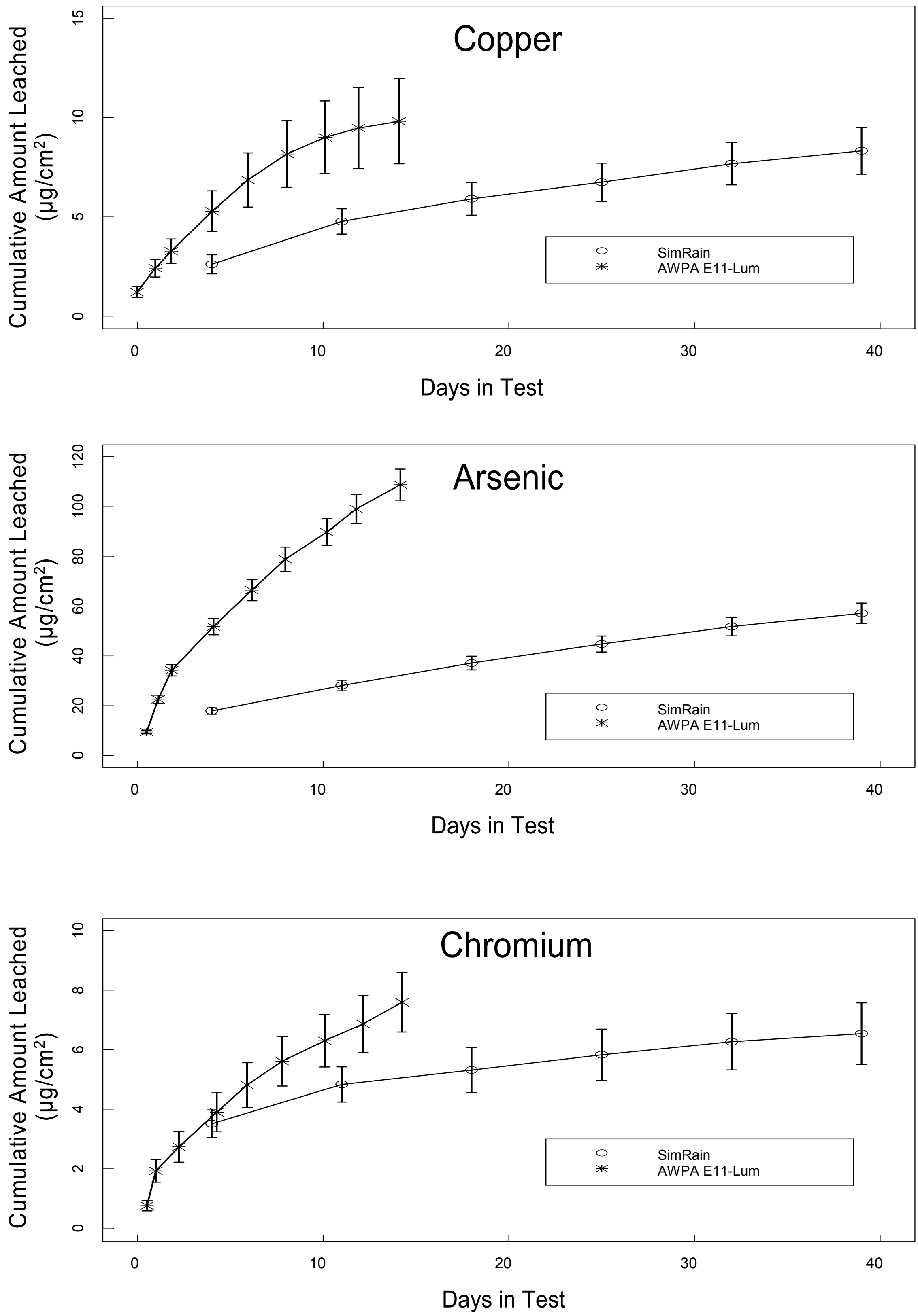

Figure 4. Cumulative release (ug/cm^2) from lumber specimens exposed to artificial rainfall or continuous immersion. Bottom surface is included in area of rainfall specimens. Bars show plus or minus one standard error.

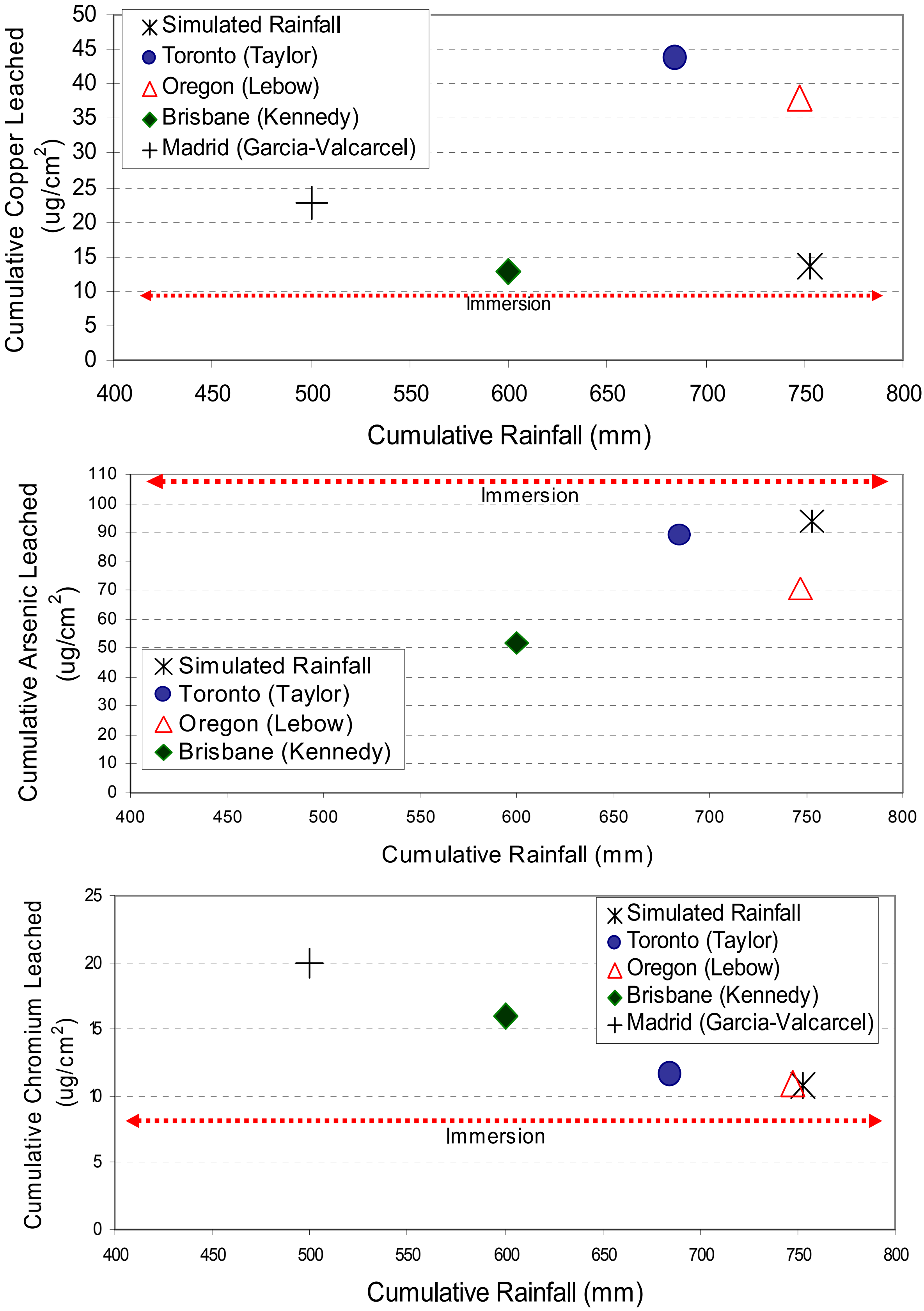

Figure 5. Amount leached as a function of rainfall for four outdoor locations and the simulated rainfall trial conducted in this study. Cumulative leaching from the immersion trial is shown as a dashed line because the relationship to volume of rainfall is not known. Sources: Garcia-Valcarcel and Tadeo, 2006; Kennedy and Collins, 2001; Lebow, et al, 2000; Taylor and Cooper, 2005.

It is possible that leaching may have been greater from the simulated rainfall specimens if they had been allowed to dry to a lower moisture content and experience a greater degree of check development. Because time is required for mobilized preservative components to diffuse through the wood to the surface, the lower leaching from simulated rainfall may also result from the compressed time frame. Although the volume of rainfall was similar to a year of exposure, the length of time for diffusion of mobilized components through the wood is probably shorter than that of a specimen exposed outdoors for a year. The specimens subjected to continuous immersion also experienced a very compressed time frame. A compressed time frame is, of course, the goal of accelerated testing, but the application of accelerated leaching results for estimation of in-service leaching is far from obvious, and this is especially true when small specimens are used. In an effort to overcome this problem, Waldron *et al.* (2005) have proposed a modeling approach to leaching estimation based on a preservative's availability and diffusion coefficients. Once certain preservative-specific parameters are determined, leaching can be estimated as a function of product dimensions and the length of time that the wood is wet.

Regardless of the approach used, improved estimation of leaching from wood above ground requires a better understanding of the moisture-content profiles for wood that is exposed both horizontally and vertically. Further research may be needed to develop better data on the moisture content of wood exposed in a range of climates, as there is relatively little data on moisture contents of larger-dimension (38-mm thickness or greater) wood exposed horizontally. Fortunately, this type of data is also of great interest to researchers studying biodeterioration and may become more readily available in the future. The role of drying and check development in leaching is largely unquantified and may warrant further consideration. Previous researchers reported that the inclusion of drying intervals in immersion schedules did not increase release of copper, chromium, or boron from CCB-treated wood if rainwater or deionized water was used as the leaching media (Garcia-Valcarcel *et al.* 2004). However, drying periods did increase leaching when soil water was used as the leaching media. The authors did not report whether the specimens developed checks during drying intervals, but it is likely that checking would have been limited in the relatively small (15- x 25- x 50-mm) specimens used in that study.

4. CONCLUSIONS

Previous researchers have reported that the moisture content of wood exposed above ground may range from as high as 80% to as low as 10%. In most studies, the maximum moisture content fell within 40% to 55% for horizontal specimens and between 30% to 50% for vertical specimens. Minimum moisture contents were generally in the 10% to 15% range. Average moisture contents reported for horizontal exposures ranged from 21% to 26%, while the averages reported for vertical exposure were 18.6% and 25.4%. The simulated rainfall method produced maximum moisture contents similar to those reported for wood exposed outdoors, but the large specimens were slow to absorb moisture during rainfall events and slower to dry between events. As a result, the extent of drying between rain events was less than that reported in outdoor exposures. The lumber specimens that were continually immersed obtained maximum moisture contents similar to those exposed to artificial rainfall but did so in less than half the time. Both methods produced total copper and chromium leaching slightly below that reported for wood exposed outdoors, while the arsenic release from the samples was roughly equivalent to or greater than that of wood exposed outdoors. However, it should be noted that these findings may be specific to CCA. Because smaller specimens rapidly gain water during immersions and loose water during drying, it is relatively simple to create accelerated immersion/diffusion/drying regimens that produce a range of moisture contents similar to those reported for wood exposed outdoors, but the relationship of leaching results obtained by this method to that from product-sized material needs further clarification. Further research is needed to better characterize the range of moisture contents experienced by wood exposed outdoors so that models or methods can be developed to more closely simulate those conditions.

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