Field Performance of Refractory Softwoods Treated with CA or ACQ after 10 Years of Exposure in Korea and Canada

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Abstract

Korean wood preservation standards require deep penetration, which precludes the use of many refractory species. However, such treatments of refractory species have been shown to be effective in other parts of the world. A field test was therefore initiated to evaluate the performance of western hemlock, a moderately refractory species, and white spruce, a highly refractory species, pressure treated with either copper azole or alkaline copper quaternary under Korean field conditions that included both decay and termite hazards. After 10 years of exposure in a ground proximity and field stake test in Jinju, Korea, the treated materials remained largely sound, while untreated controls failed much earlier, largely due to termite attack. These data suggest that material that does not meet current Korean penetration requirements could still provide effective protection against biodegradation under Korean conditions. Decay was more advanced in matched treated stakes exposed at a test site in Canada than at the site in Korea.

The efficacy of wood preservatives is typically assessed on through-treated materials so that the impact of the preservative on decay resistance can be precisely determined. This includes laboratory tests as well as field tests that use small dimension treatable materials. Such testing can provide useful data to assess performance in treatable species, i.e., wide sapwood pines. However, much of the world's forest resources are resistant to impregnation by wood preservative chemicals (Lehringer et al. 2009, Tarmian et al. 2020, Wood et al. 2020). For such refractory species, it is important to understand how commodity-sized material with incomplete penetration will perform under realistic service conditions. Identification of the conditions that lead to effective performance is needed to define appropriate standards and limits on use.

Most of Canada's forest resources, including spruces, pines, firs, hemlock, Douglas-fir, and larch, are resistant to chemical impregnation (Cooper and Morris 2007). As a result, Canadian standards for preservative-treated wood have focused on developing effective specifications for preservative treatment of refractory species (CSA Group 2008). Four residential product groups have been defined with associated treating requirements to ensure that product performance meets end user expectations. Product Group A includes easily inspected, light-duty, appearance-grade material less than 25 mm thick (e.g., fence boards). Product Group B has similar specifications with dimensions ranging from 25 to 40 mm thick and a maximum width of 150 mm (e.g., deck surface boards). Product Group C includes materials with width greater than 140 mm (e.g., joists). Product Group D includes materials used in ground contact (e.g., fence posts). Groups A and B do not have penetration

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requirements, while Groups C and D require penetrations of 5 to 10 mm for a core to pass, depending on the species and application. Within the use category system, Groups A and B are used in residential UC3.1 applications, Group C in residential UC3.2 applications, and Group D in residential UC4.1 applications (CSA Group 2008).

The North American residential market for treated wood products was developed in the later part of the 20th century with CCA. Following its voluntary withdrawal in 2004, copper azole (CA), alkaline copper quaternary (ACQ), and later micronized copper azole (MCA) became the dominant copper-based preservatives for residential treated wood. Their efficacy as preservative systems has been well documented in many tests (Freeman and McIntyre 2008). Field tests under Canadian conditions have shown that these preservatives can substantially extend the service life of refractory species (Morris et al. 2017, Stirling et al. 2017).

Canadian exporters have expressed interest in supplying lumber to Korean treaters. However, Korean standards currently require deep preservative penetration that Canadian species cannot meet (National Institute of Forest Science 2015, Ra et al. 2017). Despite Canadian field performance data, there was a lack of information on how Canadian species treated with CA or ACQ would perform under Korean conditions. The macroclimate of Korea is similar to parts of Canada, including where Canadian test sites are located in southern Ontario and coastal British Columbia (Morris and Wang 2008, Kim et al. 2011). Nevertheless, significant variations in decay rates with similar climate have been observed (Stirling et al. 2016, Mankowski et al. 2018). In addition, the Canadian sites did not have the Japanese subterranean termite (*Reticulitermes speratus* Kolbe), which is a significant threat in parts of Korea. Laboratory testing of CA and ACQ against *R. speratus* show insignificant mass loss at the commercial retentions (Lee et al. 2015). However, there were no data on field performance against refractory treatments.

A ground proximity and a field stake test of refractory species pressure treated with CA and ACQ to Canadian standards was established in Korea in 2010 to test the hypothesis that these treated commodities would effectively resist biodegradation under Korean field conditions (Wang et al. 2014, Ra et al. 2017). Stakes were also installed in a Canadian test site to enable comparison between the rate of biodegradation in ground contact at the sites in Korea and Canada. This article documents the performance of these materials after 10 years of field exposure.

Materials and Methods

Test specimen preparation

The experimental setup has been reported previously by Wang et al. (2014). Briefly, kiln-dried Canadian western hemlock (*Tsuga heterophylla* Raf. Sarg.) and white spruce (*Picea glauca* Moench. Voss) lumber (38 by 89 mm) was selected from commercial mixes of hem-fir and spruce-pine-fir, respectively. These species were chosen to represent a moderately refractory species (hemlock) and a highly refractory species (spruce) (Cooper and Morris 2007). Test lumber was incised and pressure impregnated with either ACQ-D (Timber Specialties Co.) or CA-B (Arch Wood Protection). The treatments targeted CSA O80 series-08 specifications for residential Product Groups C and D (Table 1). For ACQ-D, the target retentions were 4.0 and 6.4 kg/m^3, and for CA-B, the target retentions were 1.7 and 3.3 kg/m^3.

The pressure impregnation cycle consisted of an initial 30-minute vacuum at 75 kPa, followed by a 2-hour press at 1,034 kPa and a final 15-minute vacuum at 75 kPa. All treatments were done at a temperature of 20 $\pm$ 2°C. Test specimens were stickered and air-dried under cover before further processing. Simulated cores were cut from a cross section of each specimen. Preservative penetration was measured by visualization with chrome azurol S as described in AWPA A3-08 (American Wood Protection Association [AWPA] 2008a). Preservative retention was measured in a 0- to 13-mm assay zone by X-ray spectroscopy according to standard AWPA A9-08 (AWPA 2008b). Retention was reported as mass of actives per volume of wood based on theoretical wood density as described in AWPA A9-08.

Field test specimens were cut from treated boards or untreated controls for exposure in either a ground contact field stake test according to AWPA E7-08 (AWPA 2008c) or a ground proximity field test according to AWPA E18-06 (AWPA 2006). A copper naphthenate (2% Cu) field-cut preservative was applied by brush to the cut ends of the treated test specimens. Test specimen allocation is described in Table 2.

Field test sites

The Korean field test site is located near the city of Jinju in the southern part of Korea. It is a cleared piece of land on top of a hill surrounded by bamboo and other vegetation. The soil was noted to be between clay and sandy soil with good natural drainage (Wang et al. 2014). The site experiences hot summers and cold winters with a Scheffer Index of 58 (Kim et al. 2011). It also hosts a population of Japanese subterranean termites (*R. speratus*).

The Canadian test site is in the Petawawa Research Forest near Chalk River, Ontario. The site is surrounded by a mixed coniferous/deciduous forest, and ground cover includes grasses and low shrubs. The soil is a dark brown loam to a depth of 9 cm, changing to a light brown loam that extends to 18 cm. Below this lies coarse sand. The pH is 6.0 at the surface and 5.4 at a depth of 9 cm. The site has mean daily maximum and minimum temperatures of –7.8°C and –18.8°C in January and 25.8°C and 13.8°C in July. The site receives a mean annual precipitation of 822 mm and has a Scheffer Index of 48 (Morris and Wang 2008). There is no termite hazard at the Petawawa site.

Inspection methods

Test materials installed at the Korean site were inspected annually based on the AWPA decay and termite rating scales defined in AWPA E7 and AWPA E18. Test materials installed at the Canadian site were inspected annually for decay based on the AWPA E7 standard. The 9-year rating of the material installed in Canada was missed due to travel restrictions at the time. In the AWPA rating system, 10 represents sound, and 0 represents failure. A combined minimum rating was calculated for materials at the Korean site. This represents the maximum extent of biodegradation regardless of whether it was caused by decay or termite.

Table 1.—Preservative retention and penetration of test materials (from Wang et al. 2014).[a]

Test	Species	Preservative	Minimum retention requirements of CSA O80 (kg/m^3)	Average retention ± SD (kg/m^3)	Percentage of samples with penetration ≥8 mm	Percentage of samples with penetration ≥5 mm
Ground contact (AWPA E7)	Spruce	CA	3.3	2.8 ± 1.3	31	46
	Hemlock			2.8 ± 0.6	92	92
	Spruce	ACQ	6.4	5.9 ± 2.5	23	69
	Hemlock			6.9 ± 0.6	100	100
Ground proximity (AWPA E18)	Spruce	CA	1.7	1.7 ± 0.5	NA	85
	Hemlock			1.8 ± 0.2	NA	100
	Spruce	ACQ	4.0	4.2 ± 1.6	NA	69
	Hemlock			4.0 ± 0.9	NA	100

[a] AWPA = American Wood Protection Association; CA = copper azole; ACQ = alkaline copper quaternary.

Table 2.—Experimental design and test specimen allocation.

Species	Treatment	Number of test specimens		
		E18 Korea	E7 Korea	E7 Canada
Western hemlock	ACQ	13	13	10
	CA	13	13	10
	Untreated	10	10	10
White spruce	ACQ	13	13	10
	CA	10	13	10
	Untreated	10	10	10

[a] ACQ = alkaline copper quaternary; CA = copper azole.

Results and Discussion

The ground proximity test in Korea showed steady attack by both decay and termites in the untreated controls (Figs. 1 through 3). Almost all untreated controls, except for one hemlock specimen, had failed after 10 years in test. In contrast, the treated materials showed little evidence of decay or termite attack after 10 years of exposure at the Korean site. These data show that hemlock and spruce treated to the Product Group C specifications with CA or ACQ remain sound after 10 years despite the exposure conditions of the ground proximity test being more favorable for decay than typical UC3.2 applications due to the close proximity to the ground and the slow-drying, humid environment created by the shade cloth. These findings are in agreement with previous above ground or ground proximity field tests of refractory species. An exposed ground proximity test of ACQ-treated lodgepole pine and Pacific silver fir glulam in British Columbia, Canada, found minimal decay after 10 years, while controls were heavily decayed (Stirling et al. 2022). Above ground decking tests in Madison, Wisconsin, that included refractory species treated with ACQ and CA showed no decay in treated material after 10 years of exposure, while untreated controls were moderately decayed (Lebow and Halverson 2015). A commercial CA treatment included as a reference product in ground proximity tests in Hilo, Hawaii, also showed resistance to decay and Formosan subterranean termites after 6 years of exposure (Konkler et al. 2020). In a ground proximity test in New Zealand, low retention treatments of radiata pine with ACQ had largely failed after 10 years of exposure (Singh and Page 2020). This difference in performance affirms the critical role that preservative retention plays in product performance.

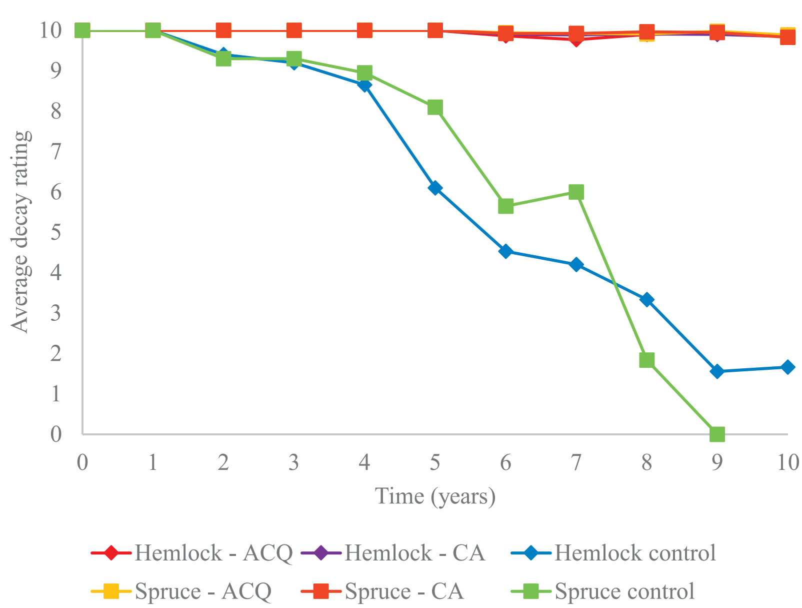

Figure 1.—Average decay ratings of white spruce and western hemlock specimens untreated or treated with ACQ or CA-B in a ground proximity test in Jinju, Korea. ACQ = alkaline copper quaternary; CA-B = copper azole, Type B.

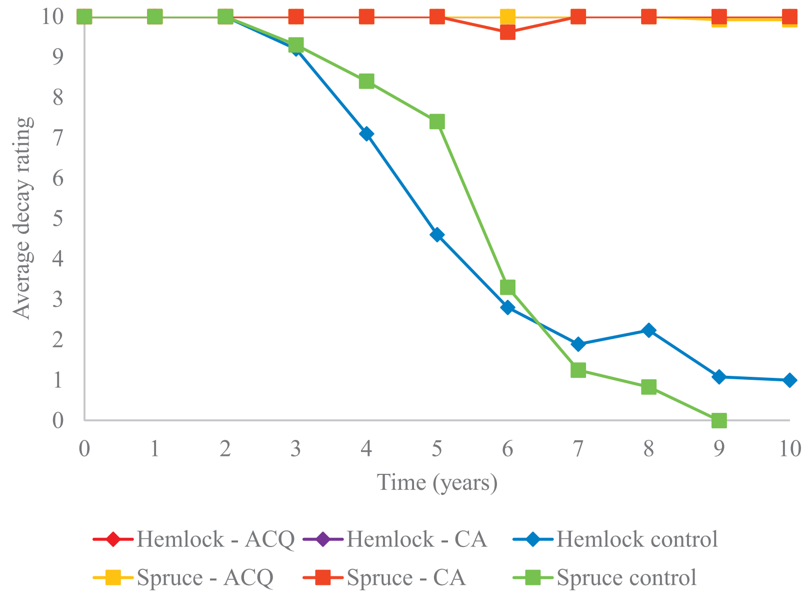

Figure 2.—Average termite ratings of white spruce and western hemlock specimens untreated or treated with ACQ or CA-B in a ground proximity test in Jinju, Korea. ACQ = alkaline copper quaternary; CA-B = copper azole, Type B.

The field stake test in Korea showed rapid degradation of untreated controls (Figs. 4 through 6). This was the result primarily of termite attack. Additional controls added during the experiment confirmed continued high termite activity (data not shown). The number of stakes available to evaluate for decay was reduced by failure due to termites at previous inspections. However, in surviving stakes, decay also progressed steadily. Since it was possible to rate stakes only for decay that had not failed due to termites, no decay ratings are reported after Year 2 for spruce and Year 7 for hemlock. The treated material resisted all termite attack. This is consistent with data from laboratory tests that indicated that CA- and ACQ-treated wood resisted attack by *R. speratus* (Lee et al. 2015). Suspicion of decay or early-stage decay was observed in some spruce stakes treated with either CA or ACQ after 10 years in test. The treated hemlock stakes remained sound. This difference between the performance of treated spruce and treated hemlock is likely due to the greater preservative penetration in the hemlock stakes. These data show that hemlock and spruce treated close to Canadian Product Group D specifications for CA and ACQ remain close to sound after 10 years of exposure at the Korean site. These findings are similar to previous ground contact field tests of refractory species pressure treated with CA or ACQ. A ground contact field test of glulam treated with ACQ found early stage of decay in treated material after 10 years of exposure at a Canadian test site (Stirling et al. 2022).

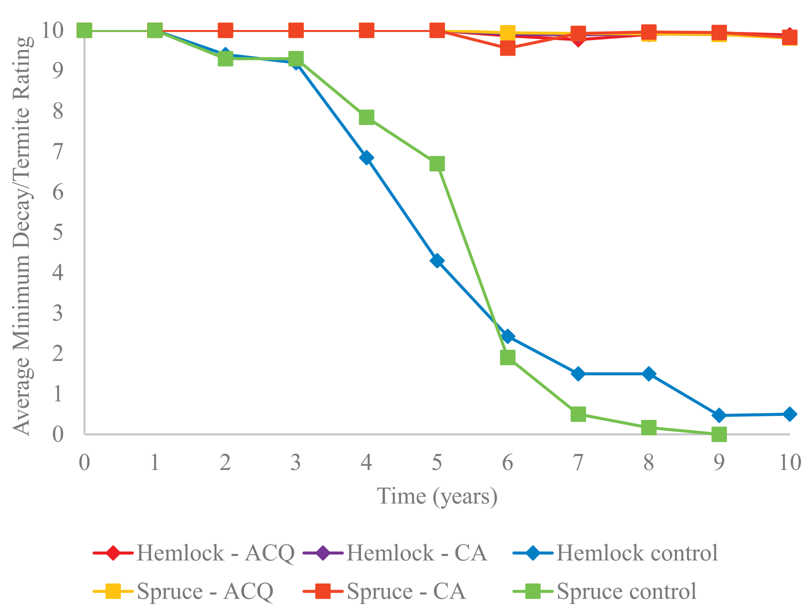

Figure 3.—Average lowest (decay/termite) ratings of white spruce and western hemlock specimens untreated or treated with ACQ or CA-B in a ground proximity test in Jinju, Korea. ACQ = alkaline copper quaternary; CA-B = copper azole, Type B.

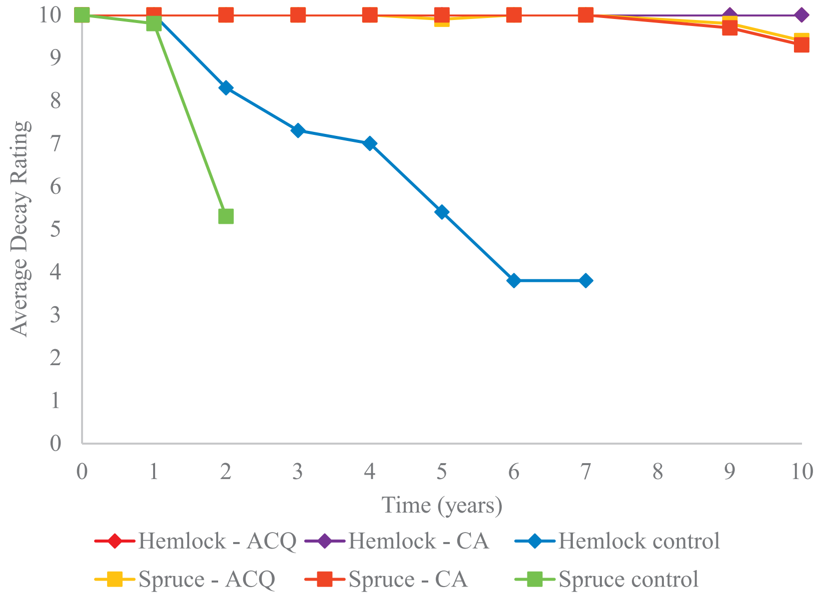

Figure 4.—Average AWPA decay ratings of white spruce and western hemlock stakes untreated or treated with ACQ or CA-B in a ground contact stake test in Jinju, Korea. AWPA = American Wood Protection Association; ACQ = alkaline copper quaternary; CA-B = copper azole, Type B.

Several refractory species pressure treated with CA or ACQ were reported to perform well against decay and subterranean termites after 12 years of exposure at a test site in Mississippi (Lebow et al. 2018).

The matched stakes installed at the Canadian test site in Petawawa, Ontario, were subjected only to a decay hazard. Untreated controls decayed steadily, and all had failed after 8 years (Fig. 7). The rapid termite attack of the untreated stakes in the Korean test site makes comparison of decay rate difficult, though the available data suggest that it is somewhat similar at both sites. In contrast to the Korean site, moderate to advanced decay was observed in treated spruce stakes in Petawawa. Early stages of decay were also observed in treated hemlock stakes. The Petawawa site is known to contain copper-tolerant, soil-inhabiting, strand-forming, wood-rotting basidiomycete fungi, which may explain the higher degree of decay in treated samples. Previous work has shown that a range of site factors can lead to very different rates of biodegradation. For example, Mankowski et al. (2018) reported greater decay in treated spruce stakes in Wisconsin than in Mississippi. This would not be predicted based on climate data but instead may be explained by soil characteristics, ground cover, differences in fungal community, and microclimate.

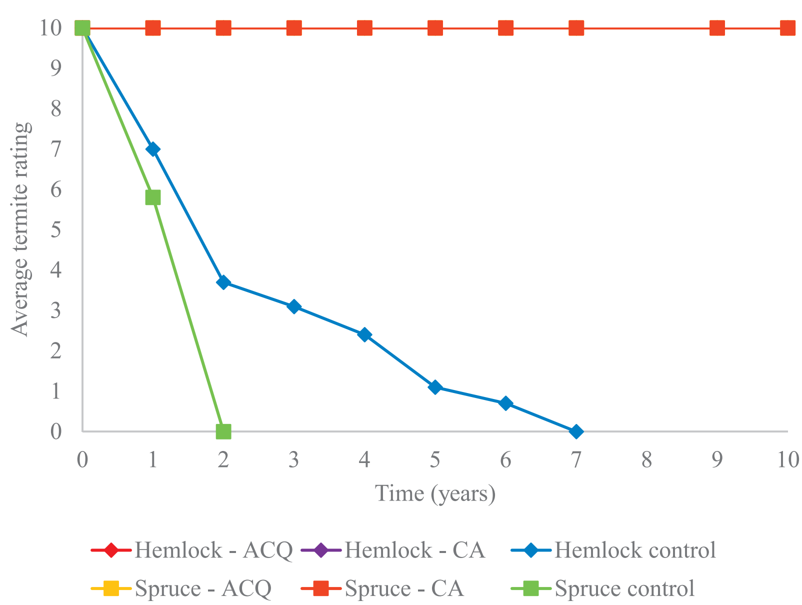

Figure 5.—Average AWPA termite ratings of white spruce and western hemlock stakes untreated or treated with ACQ or CA-B in a ground contact stake test in Jinju, Korea. AWPA = American Wood Protection Association; ACQ = alkaline copper quaternary; CA-B = copper azole, Type B.

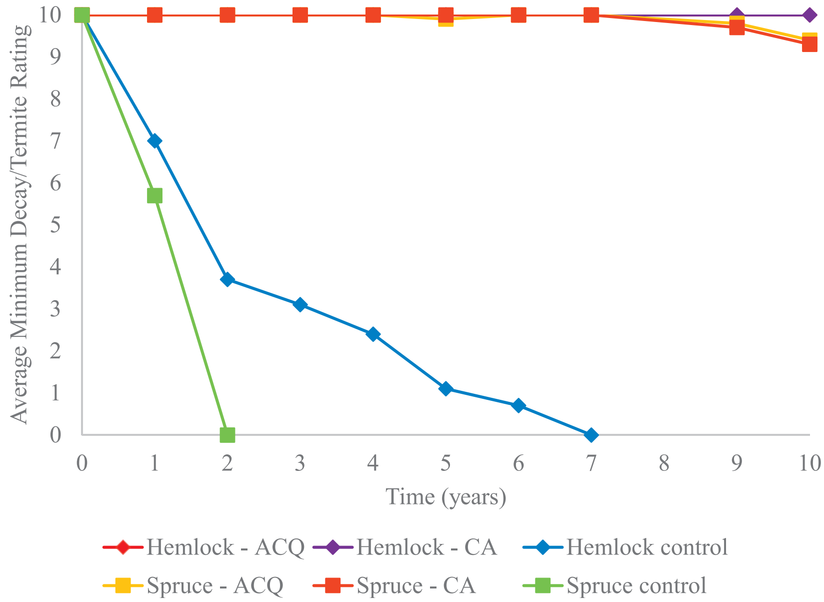

Figure 6.—Average lowest (decay/termite) ratings of white spruce and western hemlock stakes untreated or treated with ACQ or CA-B in a ground contact stake test in Jinju, Korea. ACQ = alkaline copper quaternary; CA-B = copper azole, Type B.

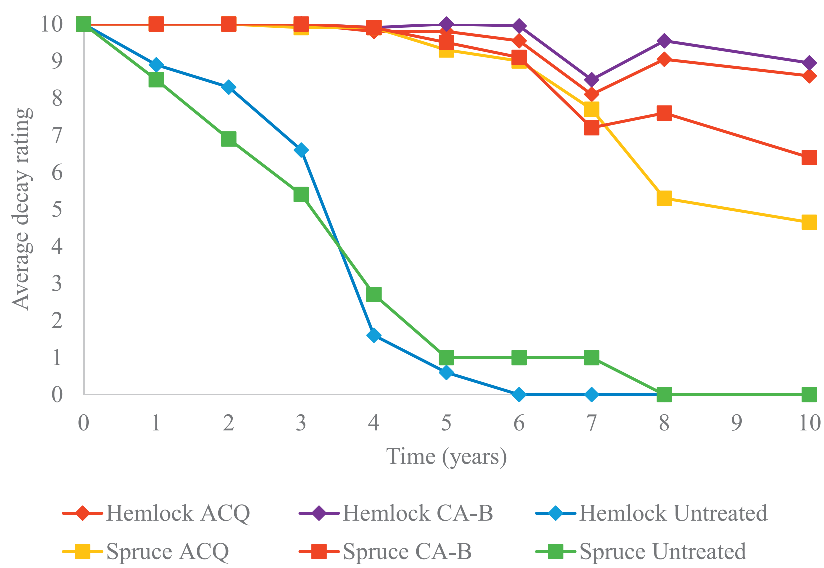

Figure 7.—Average decay ratings of white spruce and western hemlock specimens untreated or treated with ACQ or CA-B in a ground contact stake test in Petawawa, Canada. ACQ = alkaline copper quaternary; CA-B = copper azole, Type B.

Morris et al. (2017) reported 10-year performance of CA- and ACQ-treated Pacific silver fir (*Abies amabalis*) and white spruce. At comparable retentions, the CA- and ACQ-treated stakes exposed in the Canadian test sites at Maple Ridge and Kincardine had similar levels of decay to the material installed in Korea and less decay than the material installed in Petawawa. This provides further evidence of how aggressive the Petawawa site is for ground contact decay. It also suggests that data from Maple Ridge and Kincardine may be comparable to data from Jinju, Korea.

MCA is now widely used for treating residential wood products in North America. Stirling et al. (2017) reported that Pacific silver fir and white spruce stakes treated with MCA to standardized retentions were resistant to decay at the Maple Ridge and Kincardine sites after 6 years of exposure. While not evaluated in Jinju, the similar decay rates observed in Maple Ridge and Kincardine suggest that MCA may also be an effective treatment for spruce-pine-fir and hem-fir in Korea.

Conclusion

Spruce and hemlock pressure impregnated with CA or ACQ resisted decay and termite attack after 10 years of exposure in a ground proximity and field stake test in Jinju, Korea. Termites were very active at the Korean site, resulting in rapid failure of untreated controls in both ground contact and ground proximity tests. In contrast, the preserved wood specimens were almost entirely free of termite damage. Decay was more advanced in matched CA- and ACQ-treated material exposed in Petawawa, Canada, than in Jinju, Korea, after 10 years of exposure. These data suggest that pressure treatment of refractory species with CA or ACQ may provide long-term protection against biodegradation under Korean conditions.

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