Twenty-Year Performance of Decking with Two Levels of Preservative Penetration

Paul Ian Morris
Janet Kathleen Ingram

Abstract

In 1991 a field test was established at two locations in Canada to assess the longevity of deck boards that were either untreated or pressure treated with two levels of preservative penetration. These penetration levels were (1) single incised with 80 percent $\geq$ 5 mm and (2) unincised. Minidecks were prepared from each species/treatment variable and visually inspected for decay after 5, 9, 15, and 20 years of exposure. After 9 years the treated boards were virtually free of fungal attack, regardless of the preservative penetration, while decay of the untreated boards was moderate to severe. After 15 years there was still almost no decay in the treated boards, while decay in untreated boards had progressed significantly. At the 20-year inspection all untreated decks, with the exception of western red cedar (*Thuja plicata*), would have had to be replaced due to decay of multiple boards, while all chromated copper arsenate–treated decks remained serviceable regardless of preservative penetration. Based on published work showing how shell treatments with copper-containing preservatives protect decking even with checks penetrating the treated zone, these data are expected to be also relevant to newer preservatives with low levels of mobile copper.

To support moves to modify Canadian wood preservation standards, a field test was established at two locations in Canada to assess the longevity of deck boards of commercial wood species that were either untreated or pressure treated with two levels of preservative penetration. The intent was to determine whether preservative penetration requirements in Canadian standards for residential treated products could be reduced without compromising the service life. The levels of treatment selected were based on a draft standard under discussion at that time. In 1997 the new Canadian Standards Association (CSA) standard was published with a reduced preservative penetration requirement for residential decking (CSA 1997). This standard specified a minimum 5-mm penetration in 16 of 20 core samples rather than the 10 mm previously specified in CSA O80.2 (CSA 1989), and a retention of 6.4 kg/m^3 in a 5-mm assay zone rather than 4.0 kg/m^3 in a 16-mm assay zone. This new standard was based on limited laboratory (Ruddick 1991) and field (Morris and Ingram 1994) test data on wood with thin shell treatment. It was intended that the experiment reported here would either validate or warrant withdrawal of this new standard.

In 2005, the CSA standard was further modified to include a process specification with a gauge retention but no penetration requirement for small dimension products in aboveground low hazard applications, including deck surface boards (CSA 2005). This was based on the early data from the test reported here (Morris and Ingram 2002) and fundamental work demonstrating how thin shell treatments with chromated copper arsenate (CCA) can provide long-term performance. Choi et al. (2002a, 2004) and Morris et al. (2004) showed that low levels of mobile copper could redistribute from treated wood surfaces into checks that opened in service to expose the unpenetrated interior. This mobile copper bound to the untreated surfaces and provided protection against germination of basidiospores, even those of at least one copper-tolerant fungus (Choi et al. 2002b). When the CSA standards were converted to a Use Category system in 2008, a new residential product group was added for structural aboveground uses with a 5-mm penetration requirement (CSA 2008).

This experiment thus contained material that represents aboveground structural wood in CSA O80.1 Residential Product Group C, and aboveground appearance-grade wood

The authors are, respectively, Group Leader—Durability and Protection and Wood Preservation Technologist, FPInnovations, Building Systems, Vancouver, British Columbia, Canada (paul.morris@FPInnovations.ca [corresponding author], janet.Ingram@FPInnovations.ca). This paper was received for publication in January 2013. Article no. 13-00014.

Forest Prod. J. 62(7/8):566–570.

in CSA O80.1 Residential Product Group B (CSA 2008). This article describes the condition of the lumber in this test in terms of decay after 20 years of exposure. Although CCA is no longer registered in Canada and the United States for these residential uses, this article addresses the fundamental issue of whether deep preservative penetration is needed for long-term performance, regarding which there is a lack of data in the literature.

This type of long-term performance data is also very relevant to discussions of life-cycle analysis, where the service life of treated wood products has to be taken into account in determining the overall environmental impact compared with other materials, even though their service life projections may not be supported by hard data (Bolin and Smith 2011).

Materials and Methods

Deck preparation

Boards used in this test came from a large treatability study in which 20 untreated 38 by 140-mm (nominal 2 by 6-in.), 4.8-m-long (16-ft) boards of species typically used for commercial treatment (Table 1) were obtained from 14 treating plants across Canada. Some treating plants supplied more than one species. Each species was obtained from more than one treating plant; thus, material came from multiple geographic sources. Each board had been sawn into two 1.5-m lengths and one 1.8-m length. One of the pieces from each board was incised by that treating plant. The incising patterns varied widely among treating plants; thus, no attempt is made to describe them here.

All the material was shipped to one treating plant in British Columbia where, for most species (Table 1), one incised and one unincised sample from each board were treated using a 2 percent solution of Type C CCA and a treating schedule consisting of 0.5-hour initial vacuum (–77 kPa), 3 hours at 1,035 kPa, and a 1-hour final vacuum (–77 kPa). To determine compliance with the proposed standard under discussion when this test was set up, one core boring was removed from each sample, 250 mm from one end at the center of the heartwood face, halfway between two adjacent incisions. Each core was split, and one half was sprayed with chrome azurol S for measurement of penetration. The other halves of the 20 cores were ground in a Wiley mill to produce wood flour passing a 40-mesh screen. Analytical discs consisting of a mixture of 0.4 g of ovendried wood flour and 0.1 g of cellulose powder were pressed at 132 kPa for 3 minutes and analyzed on a Tracor Northern X-ray spectrometer. Analytical data expressed as weight per weight was converted to weight per volume using the standard density for each species listed in the CSA O80 standards (CSA 1989).

The above approach resulted in a large amount of treated lumber from which a limited number of boards were selected for exposure testing based on preservative penetration criteria. Owing to the variability and unpredictability of the permeability of most Canadian wood species (Cooper and Morris 2007), it is impossible to produce material with a narrow range of preservative penetration any other way. The boards selected for each species came from mixed geographic sources, but they had all been treated at the one treating plant using the same treating schedule. From the available material (except balsam fir [*Abies balsamea*] and red pine [*Pinus resinosa*], where material was limited), 60 samples of lumber, 0.6 m in length were selected for each treatment category for this experiment (Table 1). Seven species were tested with and without incising; four species not normally incised commercially were not tested with incising (Table 1). Conventionally incised boards were selected based on penetration most closely meeting the proposed standard for 80 percent $\geq$ 5 mm. The untreated and unincised-treated boards were end matched to the incised boards wherever possible. With the exception of balsam fir and red pine (Table 1), three decks of 20 boards each were constructed, with duplicates at Vancouver and Ottawa. The mean CCA retention (in a 16-mm assay zone) and penetration of the test boards are given in Table 2.

The decks were constructed using double-dipped, galvanized, twisted shank nails with the experimental boards nailed in two rows of 10 replicates to a 1.22 by 1.22-m frame of incised-treated 2 by 6 boards on edge, with a central support board. The gap between the ends of pairs of deck boards was 20 mm. This test unit was later standardized as American Wood Protection Association (AWPA) E25-08 (AWPA 2008). Ten boards on one side of each treated deck were brush treated with two applications of copper naphthenate (2% copper) field-cut preservative on the cut ends, while the 10 boards on the other side were not field-cut treated, yielding a final replication of 30. Untreated boards were not field-cut treated, yielding a final replication

Table 1.—Common and Latin names, treatments, and replication of wood species at both sites.[a]

		Field-cut treatment				
		Untreated	Unincised treated		Incised treated	
Common name	Latin name	No	Yes	No	Yes	No
Western hemlock	*Tsuga heterophylla* Raf. Sarg.	60	30	30	30	30
Western white spruce	*Picea glauca* Moench, Voss	60	30	30	30	30
Lodgepole pine	*Pinus contorta* Dougl.	60	30	30	30	30
Subalpine fir	*Abies lasiocarpa* Hook, Nutt.	60	30	30	30	30
Eastern white spruce	*Picea glauca* Moench, Voss	60	30	30	30	30
Jack pine	*Pinus banksiana* Lamb.	60	30	30	30	30
Balsam fir	*Abies balsamea* L. Mill.	20	20	20	30	30
Red pine	*Pinus resinosa* Ait.	60[a]	30[a]	30[a]	0	0
Ponderosa pine	*Pinus ponderosa* Laws.	60	30	30	0	0
Southern pine	*Pinus* spp.	60	30	30	0	0
Western red cedar	*Thuja plicata* Donn ex D. Don	60	30	30	0	0

[a] Red pine installed at Vancouver only.

Table 2.—Mean chromated copper arsenate (CCA) retention and penetration, and decay rating after 20 years of exposure.

Species	Treatment	Mean (SD) retention (kg/m³)[a]	Penetration (mm) Mean (SD)	Penetration (mm) % ≥5	Decay rating Vancouver Untreated cut ends	Decay rating Vancouver Field-cut treated	Decay rating Ottawa Untreated cut ends	Decay rating Ottawa Field-cut treated
Western hemlock (WH)	Untreated	0.0 (0.0)	0.0 (0.0)	NA	5.3	NA	4.6	NA
	Unincised	2.8 (0.4)	3.4 (3.3)	9	9.8	9.6	10	10
	Incised	4.3 (1.1)	7.0 (1.8)	87	10	10	10	10
Western spruce (WS)	Untreated	0.0 (0.0)	0.0 (0.0)	NA	3.9	NA	4.2	NA
	Unincised	1.5 (0.4)	2.4 (2.9)	27	9.5	9.9	9.8	10
	Incised	2.5 (0.7)	6.4 2.0)	90	10	9.8	10	10
Lodgepole pine (LPP)	Untreated	0.0 (0.0)	0.0 (0.0)	NA	5.3	NA	5.4	NA
	Unincised	2.8 (1.3)	5.3 (4.7)	35	9.9	9.9	10	10
	Incised	3.0 (1.1)	6.8 (2.1)	87	9.9	10	10	10
Subalpine fir (AF)	Untreated	0.0 (0.0)	0.0 (0.0)	NA	7.4	NA	8.5	NA
	Unincised	1.4 (0.2)	3.2 (3.4)	20	9.5	9.6	10	10
	Incised	2.0 (0.5)	6.2 (3.0)	75	9.9	9.9	10	10
Eastern spruce (ES)	Untreated	0.0 (0.0)	0.0 (0.0)	NA	4.5	NA	7.2	NA
	Unincised	0.8 (0.2)	2.1 (1.4)	7	10	9.8	10	10
	Incised	2.0 (0.5)	5.9 (1.4)	7	10	9.9	10	10
Jack pine (JP)	Untreated	0.0 (0.0)	0.0 (0.0)	NA	7.3	NA	6.7	NA
	Unincised	2.2 (0.4)	5.3 (4.4)	45	9.9	10	10	10
	Incised	3.6 (0.9)	6.8 (1.7)	98	10	9.9	10	10
Balsam fir (BF)	Untreated	0.0 (0.0)	0.0 (0.0)	NA	5.5	NA	3.8	NA
	Unincised	1.4 (0.1)	3.5 (3.9)	22	9.4	9.5	10	10
	Incised	2.0 (0.6)	6.2 (3.4)	65	9.9	9.8	10	10
Red pine (RP)	Untreated	0.0 (0.0)	0.0 (0.0)	NA	6.1	NA	NA	NA
	Unincised	1.5 (0.1)	5.6 (4.7)	42	9.8	9.8	10	10
Ponderosa pine (PP)	Untreated	0.0 (0.0)	0.0 (0.0)	NA	3.6	NA	4.0	NA
	Unincised	7.9 (0.1)	11.3 (5.9)	78	9.9	9.9	10	10
Southern pine (SP)	Untreated	0.0 (0.0)	0.0 (0.0)	NA	1.8	NA	0.7	NA
	Unincised	11.6 (0.5)	16.0 (0.0)	100	10	9.9	10	10
Western red cedar (WRC)	Untreated	0.0 (0.0)	0.0 (0.0)	NA	8.2	NA	10	NA
	Unincised	1.1 (0.0)	1.2 (0.6)	0	9.9	9.8	10	10

[a] Retention was in a 16-mm assay zone.

of 60 (Table 1). The decks were mounted on 150-mm-tall concrete blocks in fenced areas adjacent to FPInnovations' Vancouver and Ottawa laboratories in the summer of 1991. The Ottawa decks were moved to the grounds of the Central Experimental Farm in Ottawa in 1994.

Using Scheffer's (1971) climate index, the value calculated for Vancouver was 50, while that for Ottawa was 48, based on recent climate data (Morris and Wang 2008).

Inspection of test material

After 20 years of exposure, each board was assessed for decay. The inspection method involved gentle probing of checks and end grain with a metal spatula for signs of softening or cavities. Particular attention was paid to areas of high moisture content, areas of discoloration, areas with collapse visible on the surface, and areas sounding hollow or dull when tapped with the blunt end of the spatula. Basidiomycete sporophores were noted on the ends and undersides of some untreated deck members. The overwhelming majority of these were visually identified as *Gloeophyllum sepiarium* (Wulf. ex Fr.) Karst. Each deck board was rated at each inspection using the old AWPA system (Table 3) for consistency, even though a new more detailed rating system has been introduced (AWPA 2008). Comparisons among sets of samples were made using Student's *t* test in Excel with untransformed data.

Results and Discussion

No substantial decay (rating of 7 or below) was found at Ottawa in incised-treated boards of any species (Table 2). The overwhelming majority of incised-treated specimens in Vancouver were also free of confirmed decay, with a few rated 9 for suspicion of decay, unconfirmed.

The unincised-treated samples were generally sound with a few exceptions. In Ottawa, one western spruce (*Picea glauca*) board without field-cut treatment contained moderate decay, rated 7. In Vancouver, one western spruce board without field-cut treatment, two subalpine fir (*Abies lasiocarpa*) boards, one with field-cut treatment and one without, one balsam fir field-cut treated board, and one ponderosa pine (*Pinus ponderosa*) board without field-cut treatment were rated 7.

There was a statistically significant difference (using a *t* test at 95% confidence) between unincised and incised samples for uncoated eastern spruce (*Picea glauca*), western

Table 3.—Old American Wood Protection Association (AWPA) system for rating decay.

Rating	Condition of the board
10	No attack
9	Suspicion of, or superficial, decay
7	Evident but moderate decay
4	Severe decay
0	Failure due to decay

spruce, and balsam fir and end-coated eastern spruce. There was no difference between incised and unincised in any other species with or without field-cut treatment. The unincised boards were selected to have less than 5-mm penetration and generally failed to meet the retention requirement of 2.0 kg/m^3 of CCA in a 16-mm analysis zone (approximately comparable to 6.4 kg/m^3 in a 5-mm assay zone), while the incised groups passed this standard (Table 2). The 16-mm assay zone was originally used to give comparable loadings to gauge retentions. The 2008 CSA standard for residential decking did not list CCA, but it specified a gauge retention of 2.0 kg/m^3 for alkaline copper quat.

Although there was very little decay present in treated boards, the majority of the confirmed decay (rating of 7) was in boards without field-cut treatment. However, there was no statistically significant difference between boards with and without field-cut treatment of any species ($P < 0.05$). While the lack of field-cut treatment on nominal 2-inch material can be ameliorated by mobile copper (Choi et al. 2004), the same may not be true in all circumstances, particularly for larger dimensions. Application of field-cut preservative is therefore always recommended.

Decay in untreated samples of all species progressed substantially in the years between evaluations. Figures 1 and 2 illustrate the pattern of decay in untreated decks using the mean ratings of the 60 replicate boards at Vancouver and Ottawa, respectively. By the inspection at 15 years of exposure, none of the species were completely free of attack, and untreated decks of most species at both locations, except western red cedar (*Thuja plicata*) and subalpine fir, would have required replacement as a consequence of decay. Subalpine fir is not normally considered a durable species. At 20 years only the western red cedar would not have needed replacement at either site.

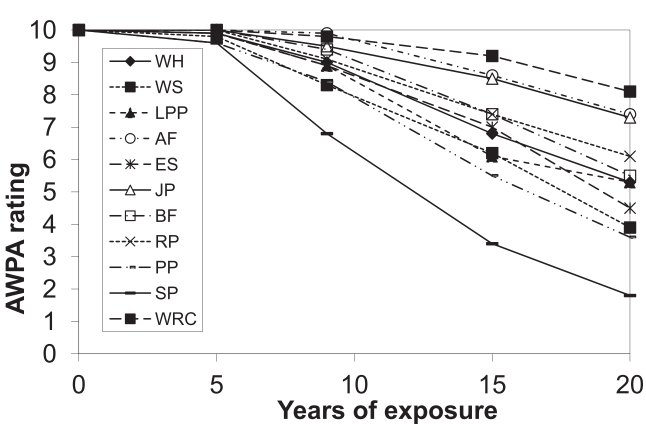

Figure 1.—Performance of untreated decks in Vancouver over 20 years of exposure. Abbreviations are defined in Table 2.

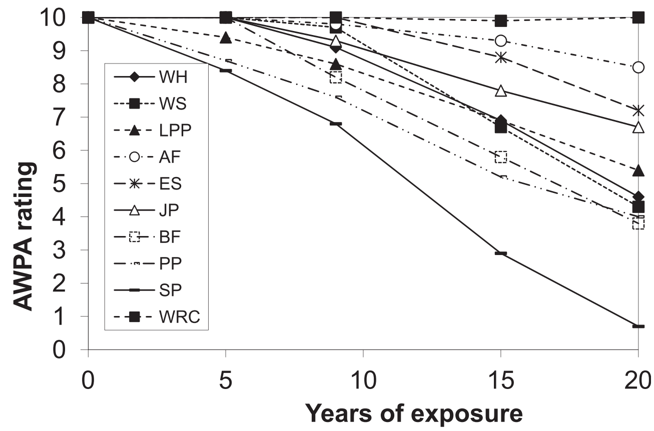

Figure 2.—Performance of untreated decks in Ottawa over 20 years of exposure. Abbreviations are defined in Table 2.

The condition of most species was similar at the two locations, likely due to the similar aboveground decay potential as indicated by the similar Scheffer index values (Morris and Wang 2011). The only substantially lower decay rating in Vancouver compared with Ottawa was for untreated western red cedar (statistically significantly different at 95% confidence using a *t* test), which may be due to a greater prevalence in the British Columbia air spora of fungi adapted to decay this species.

There were several minor issues with this test method, which have been resolved by the revision of AWPA E25 in 2012. There was inadequate support in the center of the deck. The central support has therefore been twinned. The four boards at the edges of the deck were impossible to break (rating 0) even when badly decayed because of support from the underlying frame. Thin nontest edge boards have been added to the deck design. The opposing ends of the two rows of boards were difficult to inspect at 20 mm apart, but did not really represent typical butt joints. Inert cross pieces have been added to create butt joints without allowing direct spread of decay fungi from one replicate to another. Some nail popping occurred. Screws are now specified instead of twisted shank nails. Also, as a result of this work, an automatic rating of no higher than 8 on the new AWPA rating scale was applied when basidiomycete sporophores were observed (AWPA 2008).

These results confirm the predictive findings of the accelerated tests of Dost (1988), indicating that refractory species with limited CCA penetration can perform well in service. Although CCA is no longer registered in the United States or Canada for most residential applications, these results are expected to be relevant to thin shell treatments with newer copper-based preservative systems. This is because the long-term performance of CCA shell treatments has now been explained by mobile copper adsorbing to exposed untreated wood in checks preventing spore germination (Choi et al. 2002a, 2004; Morris et al. 2004). Wood-rotting basidiomycetes tolerant to copper, when in mycelium form and producing oxalic acid, have been found to have non–copper-tolerant spores (Choi et al. 2002b, Woo and Morris 2010) because the spores do not produce oxalic acid. If it had been mobile arsenic that provided the protection effect, there would have been much greater cause for concern regarding the long-term performance of arsenic-free, copper-based preservatives as thin shell treatments in

Canadian wood species. The newer copper-based preservatives have similar or more mobile copper than CCA. Chung and Ruddick (2004) demonstrated more copper mobility in copper-amine–based preservatives than in CCA, while Stirling and Morris (2010) and Stirling et al. (2012) found similar mobility in a micronized copper–based preservative. The amounts of copper deposited in checks opening in micronized copper quaternary–treated wood were sufficient to prevent germination of basidiospores (Stirling et al. 2012). These results collectively suggest that Canadian species with thin shell treatments of the micronized copper–based preservatives in aboveground residential applications, where spore germination is the primary mode of infection (Fougerousse 1984), should provide similar service lives to the CCA-treated decking reported here.

Conclusions

After 20 years of exposure aboveground, deck boards treated with CCA by typical commercial processes remained in very good condition in terms of decay, irrespective of whether they were incised or end coated.

Most of the untreated decks, with the exception of western red cedar, failed between 9 and 15 years of service, and would have been replaced by the majority of homeowners as a consequence of decay.

The least well-treated decks (eastern spruce) and the worst performing treated decks (balsam fir) contained less decay than untreated western red cedar after 20 years of exposure.

Acknowledgments

The operation and maintenance of FPInnovations' field test sites is supported by the Canadian Forest Service under the contribution agreement existing between the government of Canada and FPInnovations. The authors would like to acknowledge Wood Preservation Canada for permission to publish data generated under contract.

Literature Cited

American Wood Protection Association (AWPA). 2008. Standard field test for evaluation of wood preservatives to be used above ground (UC3B): Decking method. E-25-08. AWPA, Birmingham, Alabama. 3 pp.

Bolin, C. A. and S. T. Smith. 2011. Life cycle assessment of ACQ-treated lumber with comparison to wood plastic composite decking. *J. Cleaner Prod*. 19:620–629.

Canadian Standards Association (CSA). 1989. Preservative treatment of lumber, timber, bridge ties and mine ties by pressure processes. CAN/CSA O80.2-M89. CSA, Rexdale, Ontario, Canada.

Canadian Standards Association (CSA). 1997. Preservative treatment of decking lumber with waterborne preservatives by pressure processes. CSA O80.32. CSA, Rexdale, Ontario, Canada.

Canadian Standards Association (CSA). 2005. Preservative treatment of wood products for light-duty above-ground residential uses by pressure processes. CSA O80.36-05. CSA, Etobicoke, Ontario, Canada.

Canadian Standards Association (CSA). 2008. Wood preservation. CSA O80 Series-08. CSA, Etobicoke, Ontario, Canada.

Choi, S. M., J. N. R. Ruddick, and P. I. Morris. 2002a. Should preservatives be partly mobile? *Proc. Can. Wood Preserv. Assoc*. 23:170–181.

Choi, S. M., J. N. R. Ruddick, and P. I. Morris. 2002b. The copper tolerance of mycelium vs. spores for two brown rot fungi. International Research Group on Wood Preservation IRG/WP/10422. IRG Secretariat, Stockholm. 5 pp.

Choi, S. M., J. N. R. Ruddick, and P. I. Morris. 2004. Chemical redistribution in CCA-treated decking. *Forest Prod. J*. 54(3):33–37.

Chung, P. and J. N. R. Ruddick. 2004. Leaching of copper from ACQ treated wood exposed above ground. International Research Group on Wood Preservation IRG/WP/04-50219. IRG Secretariat, Stockholm. 10 pp.

Cooper, P. and P. I. Morris. 2007. Challenges in treating Canadian species. *Proc. Can. Wood Preserv. Assoc*. 28:9–20.

Dost, W. A. 1988. Performance of different qualities of durable lumber in exposure as wood decking exposed as decking in California—A progress report. *Proc. Am. Wood Preserv. Assoc*. 84:71–72.

Fougerousse, M. E. 1984. Some considerations of fungal testing of treated wood with particular interest to basidiomycetes fungi. *Proc. Am. Wood Preserv. Assoc*. 80:59–66.

Morris, P. I. and J. K. Ingram. 1994. Performance of decking after 9–13 years' exposure. Report to the Canadian Forest Service. Forintek Canada Corp., Vancouver, British Columbia, Canada. 9 pp.

Morris, P. I. and J. K. Ingram. 2002. Field testing of wood preservatives in Canada. XI. Nine-year inspection of the CITW decking test. *Proc. Can. Wood Preserv. Assoc*. 23:156–169.

Morris, P. I., J. K. Ingram, J. N. R. Ruddick, and S. M. Choi. 2004. Protection of untreated wood by adjacent CCA-treated wood. *Forest Prod. J*. 54(3):29–32.

Morris, P. I. and J. Wang. 2008. A new decay hazard map for North America using the Scheffer index. International Research Group on Wood Protection IRG/WP 08-10672. IRG Secretariat, Stockholm. 13 pp.

Morris, P. I. and J. Wang. 2011. Scheffer index as preferred method to define decay risk zones for above ground wood in building codes. *Int. Wood Prod. J*. 2(2):67–70.

Ruddick, J. N. R. 1991. The influence of CCA penetration in sawnwood on its performance against decay fungi. *Forest Prod. J*. 41(11/12):19–24.

Scheffer, T. C. 1971. A climate index for estimating potential decay in wood structure above ground. *Forest Prod. J*. 21(10):29–31.

Stirling, R., J. Drummond, and P. I. Morris 2012. Inhibition of basidiospore germination by copper from MCQ, ACQ and CCA leachates. International Research Group on Wood Protection IRG/WP 12-310778. IRG Secretariat, Stockholm. 10 pp.

Stirling, R. and P. I. Morris 2010. Mobility of copper from MCQ in shell-treated wood exposed above ground. International Research Group on Wood Protection IRG/WP 10-30534. IRG Secretariat, Stockholm. 8 pp.

Woo, C. S. and P. I. Morris 2010. Sensitivity to copper of basidiospores from copper tolerant fungi: *Fomitopsis palustris* and *Oligoporus placentus*. International Research Group on Wood Protection IRG/WP 10-10707. IRG Secretariat, Stockholm. 9 pp.