J Wood Sci (2010) 56:166–168
DOI 10.1007/s10086-009-1072-y

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Laboratory evaluation of the termiticidal efficacy of copper HDO

Received: February 2, 2009 / Accepted: August 19, 2009 / Published online: December 4, 2009

Abstract A laboratory no-choice termite bioassay was conducted to evaluate the ability of copper HDO (CX-A or copper xyligen) to protect radiata pine (*Pinus radiata* D. Don) wood samples from attack by two subterranean termite species, *Reticulitermes speratus* and *Coptotermes formosanus*. A series of sapwood samples were pressure treated with either 0.25%, 0.50%, 0.75%, or 1.00% copper HDO solution. Samples treated with equivalent concentrations of a benchmark preservative, CCA-C, were used as treated controls. All samples (including controls) were subjected to an artificial weathering schedule before the bioassay. The samples were exposed to 30-day *R. speratus* tests and 3-week *C. formosanus* tests. Copper HDO was shown to deter termites from significant feeding on the treated wood. At a retention of 5.8 kg/m^3 (treated with 0.75% solution) or higher, the mass loss from termite feeding did not exceed 3% for both the 30-day *R. speratus* tests and the 3-week *C. formosanus* tests. At each of the retentions tested, copper HDO performed comparably with equivalent retentions of CCA-C; however, field data are needed to validate these laboratory results. The preliminary findings are that copper HDO pressure treatment has potential as a viable method of protecting wood from attack by both termite species tested.

Key words Termites · Laboratory evaluation · Copper HDO · *Reticulitermes speratus* · *Coptotermes formosanus*

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Introduction

Copper HDO (CX-A or copper xyligen) is an amine copper-based wood preservative that has been used in Europe for more than 20 years and has recently been standardized by the American Wood Protection Association (AWPA) for aboveground uses.[1] The active ingredients in copper HDO are copper oxide, boric acid, and Cu-HDO [bis-(*N*-cyclohexyl-diazeniumdioxy) copper]. Although Cu-HDO has been used as an active ingredient in waterborne wood preservatives since 1989,[2] little information is available on the termite resistance of wood pressure impregnated with copper HDO. The assessment of wood preservative formulations against subterranean termites is an essential part of their commercial uses. This study was initiated to evaluate the potential of copper HDO for use as a pressure treatment to protect wood against termite attacks. The laboratory results obtained from this study provide useful information on the performance of copper HDO against subterranean termites and the basis for field tests under more realistic conditions.

Materials and methods

Preparation of wood samples

Radiata pine (*Pinus radiata* D. Don) sapwood samples, measuring 20 × 20 mm in cross section by 10 mm in length, were cut from air-dried boards. Before treatment, the samples were conditioned to 12% moisture content. The copper HDO formulation used for this study was composed of 16.3% copper (II) hydroxide carbonate, 5.0% boric acid, and 3.5% Cu-HDO. Chromated copper arsenate (CCA-C) was used as a reference preservative.

The samples were vacuum-pressure treated with copper HDO and CCA-C treating solutions of 0.25%, 0.50%, 0.75%, or 1.00% (w/v) as an active ingredient. The treatment schedule consisted of a 30-min initial vacuum pressure of 0.101 MPa, and then the cylinder was filled with treating solution, followed by a pressure of 1.37 MPa until refusal. No final vacuum was employed. Preservative retention of the treated samples was determined from the solution uptake and the final solution concentration. Just after treatment, all treated samples were wrapped in polyethylene plastic bags and allowed to undergo fixation without drying at 60°C for 72 h, and then air dried.

The weathering of treated samples and untreated controls was conducted according to JIS standard method K 1571.[3] The samples were leached by immersing them into distilled water of tenfold sample volume, while constantly stirring with a magnetic stirrer at 27°C for 8 h, followed by drying in a forced-air oven at 60°C for 16 h. This procedure was repeated on 10 successive days.

Termite feeding tests

Reticulitermes speratus *tests*

Five replicates of each treated samples and untreated controls were exposed to subterranean termites (*Reticulitermes speratus* Kolbe) collected from fallen pine tree trunks on the Uji campus of Kyoto University (Uji, Japan). The test containers were a series of 9-cm diameter by 5.5-cm-tall plastic jars, each containing 10 g coarse vermiculite and 17 ml distilled water. One wood sample was placed on the surface of the damp vermiculite, and 200 undifferentiated workers were introduced to each jar. The test containers were kept at 28°C and >85% relative humidity in a dark room for 30 days. At the end of the test period, the wood samples were cleaned, dried at 60°C and weighed, and then the mass loss of the samples was calculated.

Coptotermes formosanus *tests*

Five replicates of each treated samples and untreated controls were exposed to subterranean termites (*Coptotermes formosanus* Shiraki) from a laboratory colony according to the JIS K 1571.[3] The wood samples were exposed to termites kept in containers made of acrylic tube sections (80 mm in diameter and 60 mm in length) that were sealed at one end with 5-mm thick hard plaster. In addition, 2-cm square sections of plastic mesh were placed on the bottoms of the containers, and the wood samples were placed on the plastic mesh. A total of 150 workers and 15 soldiers from the *C. formosanus* species were introduced in each container. The containers were held in acrylic boxes that were lined with moistened cotton wool to provide a water source that could penetrate through the plaster. The test containers were maintained in a dark room at 28°C and at >85% relative humidity for 3 weeks. At the end of the test period, the wood samples were washed, dried at 60°C and weighed, and then the mass loss of the samples was calculated. In addition, the number of live termites (workers and soldiers) was counted to assess percent mortality, another indication of the efficacy of the preservative system.

Results and discussion

Reticulitermes speratus tests

Summary data on the mass loss (wood consumption) of preservative treated samples and untreated controls caused by no-choice *R. speratus* feeding tests are given in Table 1. The results indicate that untreated controls were attacked substantially more than treated samples at the lowest retention of both preservatives, indicating the satisfactory conditions under which the termite tests were conducted in this study. Termite feeding on the treated samples was relatively well correlated with retention in both preservatives; that is, the amount of termite attack decreased sharply with increasing retention.

As has been used in the JIS standard method K 1571[3] for *C. formosanus* tests, the arbitrary value of 3% mean mass loss was used to determine the protection threshold in this study. Thus, any treatment for which less than 3% mean mass loss was shown was deemed successful in protecting test samples from termite attack. On the basis of this criterion, copper HDO and CCA-C at the retention of 3.8 kg/m^3 or lower failed to protect test samples against termite attack. Accordingly, it could be summarized that copper HDO retentions of 5.8 kg/m^3 or higher and CCA-C retentions of

Table 1. Mass loss of the preservative-treated and control test specimens after 30 days of exposure to *Reticulitermes speratus*[a]

Treatment	Treatment concentration (%)	Retention (kg/m^3)	Mass loss (%)
Untreated			25.3 (1.20) A[b]
Copper HDO	0.25	2.0 (0.04)	6.1 (0.94) B
	0.50	3.8 (0.11)	3.6 (0.60) C
	0.75	5.8 (0.33)	2.7 (0.58) CD
	1.00	7.4 (0.41)	1.6 (0.14) D
CCA-C	0.25	1.9 (0.07)	5.9 (0.62) B
	0.50	3.8 (0.11)	3.4 (0.85) C
	0.75	5.7 (0.40)	2.8 (0.51) CD
	1.00	7.7 (0.21)	1.7 (0.23) D

[a] Each value represents the mean of five samples, and the values in parentheses represent one standard deviation

[b] Mean mass loss with the same letter are not significantly different from each other (statistical significance was $P < 0.05$) using Duncan's multiple range test

Table 2. Mass loss and termite mortality from the preservative-treated and control test specimens of no-choice tests following 3 weeks of exposure to *Coptotermes formosanus*[a]

Treatment	Treatment concentration (%)	Retention (kg/m^3)	Mass loss (%)	Termite mortality (%)	
				Worker	Soldier
Untreated		–	20.5 (0.52) A[b]	16	4
Copper HDO	0.25	1.9 (0.09)	4.2 (0.41) B	40	100
	0.50	3.8 (0.11)	3.1 (0.33) C	56	100
	0.75	5.8 (0.38)	2.4 (0.11) CD	66	100
	1.00	7.6 (0.33)	1.3 (0.18) E	68	100
CCA-C	0.25	1.9 (0.09)	3.9 (0.78) B	100	100
	0.50	3.8 (0.10)	2.8 (0.20) CD	100	100
	0.75	5.8 (0.37)	2.3 (0.37) D	100	100
	1.00	7.6 (0.23)	1.2 (0.10) E	100	100

[a] Each value represents the mean of five samples, and the values in parentheses represent one standard deviation
[b] Mean mass losses with the same letter are not significantly different from each other (statistical significance was $P < 0.05$) using Duncan's multiple range test

5.7 kg/m^3 or higher were successful in protecting test samples against *R. speratus* attack. According to the statistical analysis, termite feeding on copper HDO treated samples did not differ significantly from the CCA-C treated samples at each of retentions tested. This result suggests that copper HDO has performed comparably with equivalent retentions of CCA-C for protecting samples against *R. speratus* attack.

Coptotermes formosanus tests

The results of no-choice *C. formosanus* feeding tests for the copper HDO- and CCA-C treated samples are summarized in Table 2. As was the case for the *R. speratus* tests, the untreated controls showed a significantly higher mass loss than samples treated at the lowest retention of both preservatives. Further, the mass loss caused by termite attack decreased with increasing preservative retention.

According to JIS standard method K 1571,[3] any treatment for which more than a 3% mean mass loss was recorded was considered to be unsuccessful in protecting test samples against termite attack. Using this criterion, copper HDO at 2.0 kg/m^3 and 3.8 kg/m^3 as well as CCA-C at 1.9 kg/m^3 failed to protect significant termite attack. Therefore, it could be summarized that copper HDO treatment at 5.8 kg/m^3 or higher and CCA-C treatment at 3.8 kg/m^3 or higher was successful in protecting test samples from *C. formosanus* attack. Although samples treated with copper HDO were slightly more attacked when compared to samples treated with equivalent retentions of CCA-C, the statistical analysis showed that there was no significant difference between treatments for the amount of attack sustained to samples at each of the retentions tested. These results suggests that the performance of copper HDO against termite attack is equivalent to CCA-C when protecting samples against *C. formosanus* as observed in the *R. speratus* tests. The fact that the mass losses observed by *C. formosanus* are slightly smaller than those found for *R. speratus* might be explained by the difference in the number of workers and the exposure period applied for either of the termite tests.

The mortality rate of termites forced to feed on copper HDO-treated samples was 40%–68% and was retention-dependent. In contrast, CCA-C treatment was very effective against termite attack, killing all workers and soldiers within 1 week of exposure. These results indicate that copper HDO possesses insecticidal properties. However, the repellent and/or antifeedant properties of copper HDO against termites might be more important in protecting samples from termite attack compared to insecticidal properties.

Conclusions

The results of this laboratory evaluation demonstrate that copper HDO is toxic to termites and, at the appropriate retention, will deter both the termite species tested from feeding on the treated wood. At each of the retentions tested, copper HDO performed comparably with equivalent retentions of CCA-C for protecting samples against both termite species. Weathered pine samples treated with copper HDO at 5.8 kg/m^3 (treated with 0.75% solution) or higher sustained a mean mass loss less than 3% from termite feeding for both the 30-day *R. speratus* tests and 3-week *C. formosanus* tests. This result is comparable to the minimum concentration of 1.0% for copper HDO, which has been recommended for aboveground uses by the manufacturer.[4] However, field studies are needed to test the applicability of these laboratory results, and to refine the threshold retention required for protection from termite attack.

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