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Section 1 **Biology**

Evaluating the Effects of Post Dip-Treatment Laser Marking on Resistance to Feeding by Subterranean Termites

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Evaluating the effects of post dip-treatment laser marking on resistance to feeding by subterranean termites

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ABSTRACT

Dip-treatment of wood packing materials is often used instead of pressure treatment mainly because of issues relating to simplicity and cost. Packaging boxes fabricated for the United States Army are required to be dip-treated for at least one minute in an approved preservative solution prior to use. These boxes are expected to have a service life of up to 20 years in a wide variety of environments. Recently, there is interest in using laser markings on these boxes, which can result in a breach of the preservative shell, potentially increasing susceptibility of the wood to termites and decay. Alternatively, thermal modification of the wood by the laser may be sufficient to protect these marked areas. In this study, solid southern pine wood and two types of plywood samples were dip-treated with copper or azole based preservative formulations. Leached and unleached blocks were then evaluated using modified AWPA testing methods to determine if laser marking increased susceptibility to feeding by subterranean termites. Termites preferentially fed within the laser marked areas as compared to non-lasered areas of the block. This suggests that laser marking is a breach of preservative treatment and has the potential to strongly affect the long-term durability of these containment boxes where there is termite pressure. However, when unleached-lasered samples were compared to leached-non-lasered samples, termites showed a stronger preference for feeding on the non-lasered surfaces of leached blocks and the laser marked areas of unleached blocks, indicating that leaching, rather than laser marking, may have more of an effect on termite feeding preference. Results from this study will be used in development of new methods addressing long-term labelling protocols for dip-treated wood packing materials.

Keywords: biodegradation, wood-packing materials, leaching, thermal modification

1. INTRODUCTION

Wooden, wire-bound crates are commonly used by the United States Army, for transportation of materials across the globe. These boxes are expected to have a service life of up to 20 years regardless of geographic location or exposure to environmental factors (e.g. humidity, UV, fungi, insects, water). Normally, wood products designed for outdoor exposure are pressure treated with chemical preservatives. Pressure treatment, however, is time consuming, uses large quantities of liquid chemical and requires access to a wood-treatment facility. An alternative to pressure treatment is dip-treatment, in which wood packing materials are submerged in a chemical preservative for a set amount of time. Dip-treatment does not result in substantial penetration of the preservative into the wood, compared to pressure-treatment, but does result in a protective outer layer that can provide sufficient protection from degradation (De Groot and Stroukoff 1986; Lebow 2010).

Recently, there has been some interest in using laser markings on these dip-treated containment boxes, as these types of markings have the potential to provide a more permanent method for labelling. Since laser marking is typically applied after the boxes are fabricated and dip-treated, there is the potential that the laser will penetrate through the treated surface, exposing the untreated part of the wood. This breach in preservative treatment could increase the susceptibility of these boxes to insect damage and fungal decay. Alternatively, laser marked areas may be sufficiently small that the preservative will leach into these areas after exposure to moisture.

The process of laser marking alone may also have some protective qualities by means of thermally modifying the wood surface. Thermal modification via exposure of wood to high temperatures modifies wood such that it is less likely to be colonized by decay fungi (Esteves and Pereira 2008; Shi et al. 2007). It has also been shown that CO_2 laser treatment produces changes to the wood surface similar to that of heat treated wood (Kubovsky and Kacik 2009).

In this study, we examined the effects of laser marking, post dip-treatment, on susceptibility of three different wood types to feeding by subterranean termites. Different wood types (i.e. solid wood and plywood) were evaluated, as containment boxes are not always fabricated from the same materials.

2. EXPERIMENTAL METHODS

2.1 Test Samples

Three different types of samples were chosen for this assay based on likely use in the field. Sample groups included solid Southern pine wood samples (75 mm x 37 mm x 9 mm), thin-hardwood plywood samples (75 mm x 37 mm x 5 mm) (Fig. 1b) and thick-pine plywood samples (75 mm x 37 mm x 20 mm) (Fig. 1a).

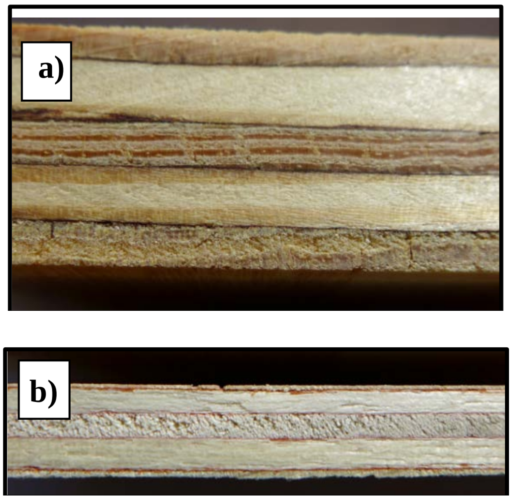

Figure 1: Lateral view of plywood test samples:
(a) 20 mm thick-softwood; (b) 5mm thin-hardwood

2.2 Selection of Preservatives and Dip Treatment

2.2.1 Treatment Chemicals

Six preservatives were chosen for dip treatment (Table 1). All preservatives, with the exception of the azole/imidacloprid preservative (Azl), had been evaluated at two concentrations in previous studies (Lebow et al. 2015), with results indicating that the higher concentration is more effective for most formulations, and thus these concentrations were chosen for the present study. The Azl treatment was found to be highly effective when evaluated at 1.05% in previous termite tests, indicating that a lower concentration should have been evaluated. In this test, Azl was evaluated at 0.5% to better assess the concentration needed for efficacy.

Table 1: Preservatives and active ingredients used for dip-treatments of test specimens

Preservative Abbreviation	Active Ingredients and Concentrations
Cu8	1.8% Cu
CuN	Copper naphthenate (2% Cu)
PCuA-1	Copper azole type 1 (2% Cu)
PCuA-2	Copper azole type 2 (2% Cu)
Azl	Azoles, imidacloprid (0.5% total actives)
Water Control	-

2.2.2 Dip Treatment Methods

Wood samples were placed in 29 cm x 20 cm x 17.5 cm metal-mesh containers and dip treated in the treatment solution on a shaker for 1 minute (Fig. 2a). Samples were then removed, blotted gently to eliminate excess liquid, and weighed. Samples were left to dry in a hood for one week and then conditioned to a uniform moisture content in a 80 °F, 30% RH incubator.

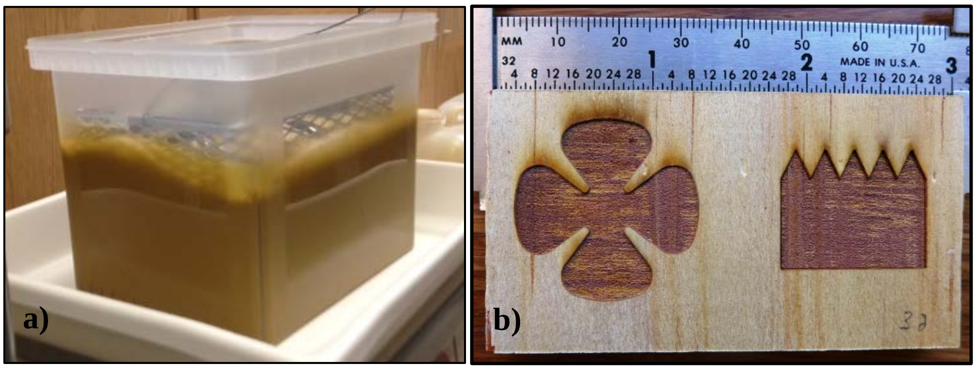

Figure 2: a) Dip-treatment of test samples;
b) Test samples with laser markings (left: interchange; right: clip)

2.3 Laser Marking

Laser-marking was performed on specimens that were already dip-treated with the selected preservative. Laser-marking was conducted by U.S. Army ARDEC personnel using a Universal Laser Systems Model VLS 3.60 CO_2 laser. Two NATO symbols, “interchange” and “clip” were selected as “worst case” examples because of their relatively large surface area. Both symbols were engraved onto a single wide face of the selected specimens (Fig. 2b). The laser was operated at 20-30% power and 100% speed with a resolution of 500 dpi.

2.4 Leaching

Prior to testing, all unmarked specimens and a subset of laser-marked specimens were placed on racks and leached for 20 hours in a rainfall simulator by spraying specimens with a total of 200 mm of rainfall at a rate of 10 mm/hr. Rainfall was applied in repeating intervals of 1 hr rainfall/ 5 hours off (total of 200 mm).

2.5 Termite Test Methods

2.5.1 Experimental Design and Test Arena

Termite testing was conducted following the American Wood Protection Association Standard E1-15 method for a two-choice test procedure (AWPA 2015). Equivalent test specimens with and without laser marking were presented in the same testing arena so that termite attack could be compared directly (Fig. 3a). All test blocks were autoclaved prior to being placed in sterile plastic chambers, containing 100g sand and 18 mL DI water (Fig. 3b). One gram (~300 termites) of freshly collected eastern subterranean termites (*Reticulitermes flavipes* (Kollar), Janesville, WI) was then added to each test chamber and maintained in an incubator at 80°F and 80% RH. Test specimens were exposed to termite feeding for 4-weeks (solid wood samples) or 6-weeks (plywood samples). After the test, blocks were removed, brushed free of debris, dried in a hood and re-conditioned to a uniform moisture content at 80% RH before final weights were obtained. Termites from each container were separated into dishes and weighed to determine mortality.

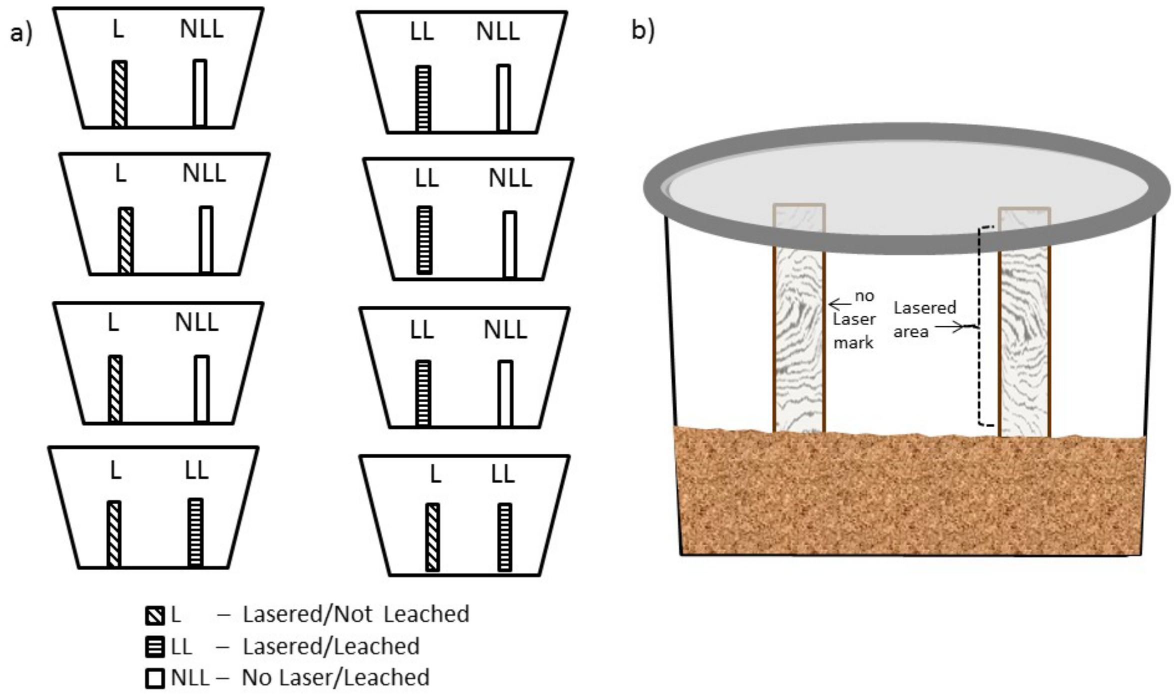

Figure 3: a) assignment of test sample pairs (8 testing arenas/preservative); b) test set-up

2.5.1 Data Analysis

Termite test blocks were evaluated by the percent of surface attack rather than by weight loss since the large size of the specimens and toxicity of the preservatives resulted in relatively low weight loss values. This was done by photographing all six sides of each specimen after termite exposure and using ImageJ (Rasband 1997) to calculate the surface area of termite feeding on each surface and to compare feeding inside and outside of the laser marking.

3. RESULTS AND DISCUSSION

3.1 Effect of Laser Marking on the Extent of Termite Attack

As preservatives for this study were chosen based on already observed efficacy against termites, weight loss of the treated blocks was low for all preservatives tested (~0-2%) and resulted in high levels of termite mortality. Therefore, weight loss was not informative in overall experimental analysis. Calculations of mortality were also difficult in that a few of the control groups died in the plywood samples, likely from the toxicity of the adhesive used. In addition, unlike no-choice assays, when presented with two test samples in an arena, termites will preferentially choose between the samples, while also being influenced by the other block in the test chamber. Data analysis was therefore conducted in a paired manner to account for this effect.

Overall, three main questions were targeted by the termite feeding assay:

1. Is there a difference in termite feeding preference between leached and un-leached laser marked samples?

2. Does laser marking increase the percent surface attacked compared to the non-laser marked samples, particularly in the non-lasered areas of the block?

3. Are unleached, lasered samples more susceptible to termite feeding than the non-lasered, leached samples?

4. Are there any major differences between the three types of wood samples used?

3.1.1 Termite Feeding Preference between Leached and Un-Leached, Lasered Blocks

Laser-leached and laser-unleached blocks were examined by calculating the ratio between the percent of feeding within the lasered area, compared to percent feeding outside of the lasered area. Since all blocks in this test were lasered, results below show the effect of leaching on termite preference for feeding within the laser marked area of the block compared to the non-lasered areas (Fig. 4).

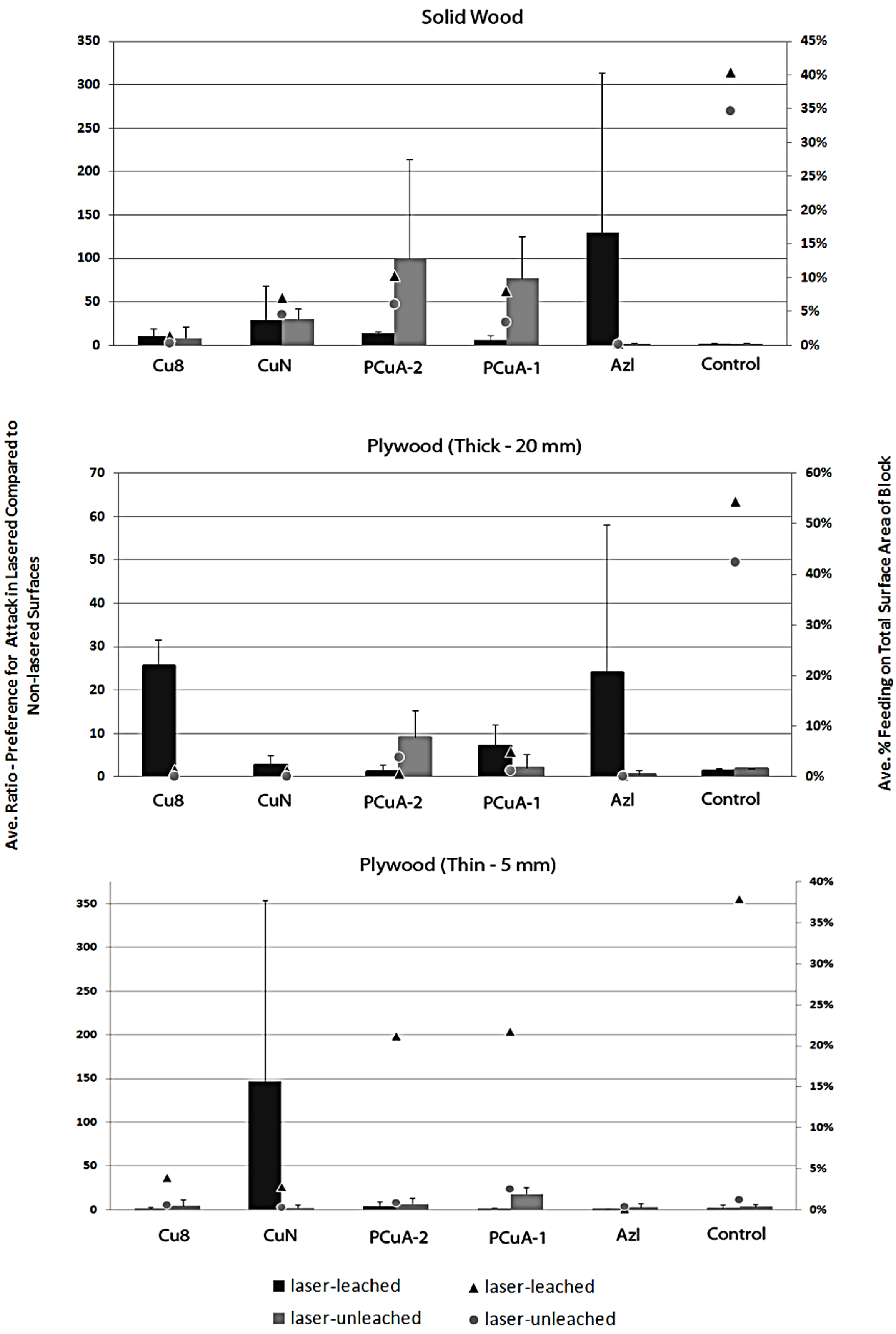

Figure 4: Termite preference for feeding in lasered areas of leached and unleached, treated blocks. Bars show preference for termite feeding within laser markings as compared to non-lasered areas of the same blocks (primary y-axis); markers (squares and circles) show total percent surface area with termite feeding for leached and unleached samples (secondary y-axis). Error bars represent standard deviation.

Solid wood specimens treated with PCuA-2 and PCuA-1 showed higher levels of feeding within the laser-marked area for unleached blocks, compared to leached specimens. Examination of total surface feeding in these groups indicated that the termites were able to feed on a greater surface area of the test specimens in leached vs. unleached blocks, resulting in the increased preference for feeding within the lasered areas of the unleached specimens. This was also observed for the PCuA-2 treated, thick (20 mm) pine plywood specimens. In contrast, the higher toxicity Cu8, CuN and Azl treatments prevented even small amounts of feeding on unleached specimens, but did show a preference for feeding in the lasered area in leached specimens. Overall, the total surface area fed on by termites was higher in leached blocks than in unleached specimens, even within the control groups. In both leached and unleached groups, termites displayed some preference for feeding within the laser marking, but these preferences were strongly influenced by treatment and leaching.

3.1.2 Percent Surface Attack on Lasered and Non-Lasered Test Blocks

In many of the treatments, termites seemed to preferentially target the laser-marked areas of the test blocks for feeding (Fig. 5). This preference for feeding within laser-markings as opposed to the surrounding areas of the block was examined by quantitatively comparing the average percent surface attack on the lasered and non-lasered surfaces of leached, laser marked and non-laser marked specimens.

Figure 5: Specimens showing preferential feeding within laser-marked areas on solid pine test blocks (note: little feeding on blocks treated with Azl; laser markings on untreated, control specimens are no longer visible)

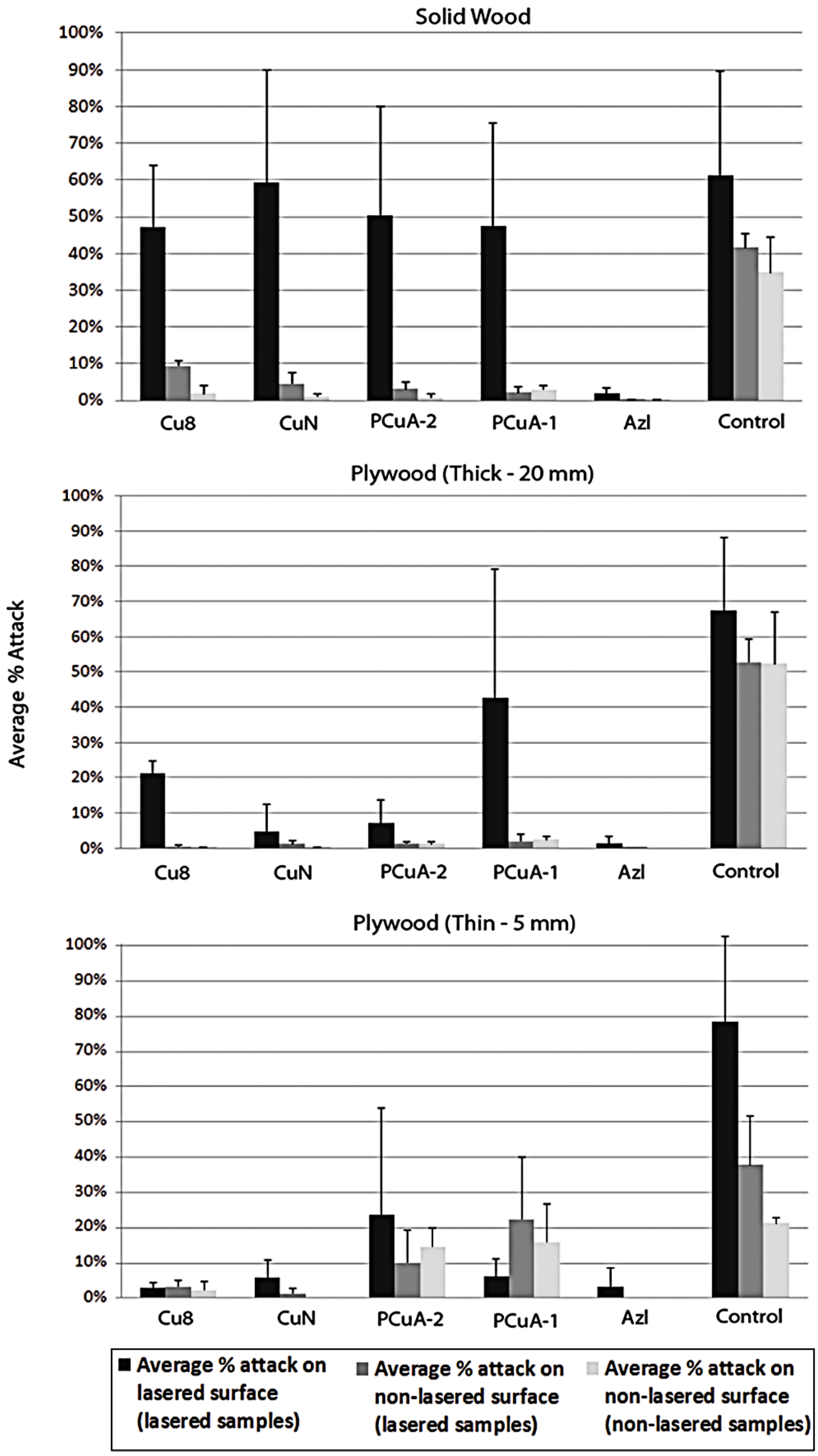

Figure 6: Termite surface attack in lasered vs. non-lasered, leached blocks.
Error bars represent standard deviation.

Results for lasered samples showed a distinct preference for feeding within the lasered area over the non-lasered area, particularly in the solid wood group (Fig. 6). This suggests that the lasering does represent a breach of preservative treatment that is targeted by the termites. When comparing feeding on the non-lasered surfaces in lasered and non-lasered samples, results showed minor differences, particularly in Cu8 and CuN treated solid wood blocks. This could indicate that the laser marking on these specimens increased the termites' ability to feed on the non-lasered surfaces compared to specimens with no laser markings. Laser markings in all other treatment and specimen types did not appear to increase termite feeding to the rest of the block, although higher numbers of termites and longer exposure times might be necessary to see these differences.

3.1.3 Termite Feeding Preference between Unleached-Lasered Blocks and Non-Lasered-Leached Blocks

Unleached-lasered samples were compared to leached-non-lasered samples by again comparing the average percent surface attack on the lasered and non-lasered surfaces. Results showed, for unleached blocks, that termites preferentially feed within the lasered surface rather than on the non-lasered areas (Fig. 7). This is seen in CuN, PCuA-2 and PCuA-1 for solid wood, PCuA-2 and PCuA-1 for thick (20 mm) plywood, and Cu8 and PCuA-1 and PCuA-2 in thin (5 mm) plywood. In the solid wood samples, the total area of termite feeding was slightly higher in CuN and PCuA-2 lasered, unleached blocks compared to non-lasered, leached blocks. All other groups, however, showed slightly higher feeding in leached samples, regardless of laser treatment.

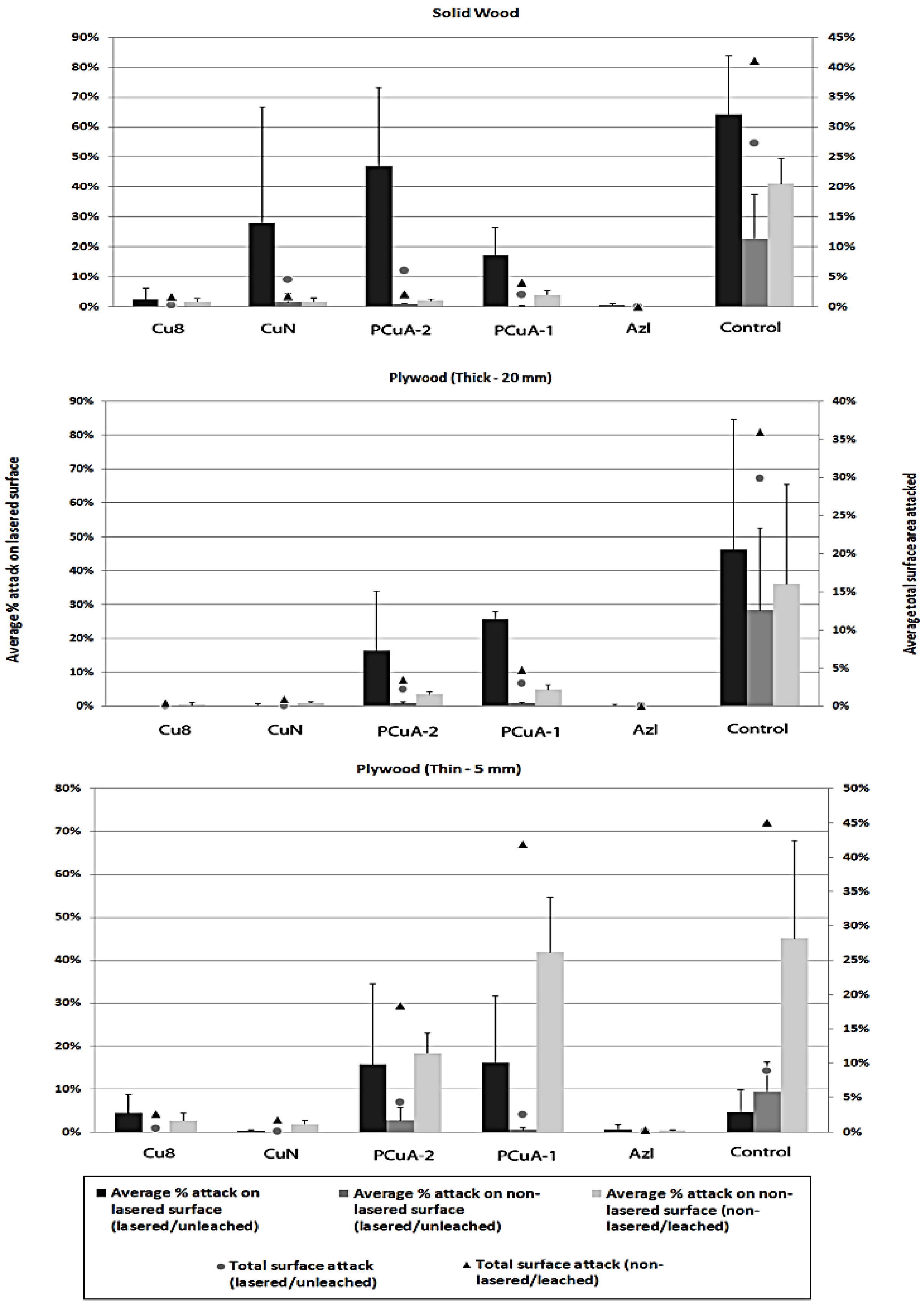

Figure 7: Termite surface attack in lasered-unleached vs. non-lasered-leached blocks. Error bars represent standard deviation.

3.1.4 Differences in Termite Feeding between the Solid Wood and Plywood Samples

There were some interesting differences not only in termite feeding preferences between the three wood sample types tested, but also in the overall durability of the wood blocks. Untreated, thin plywood control samples, made up of all hardwood plys, showed that termites fed more on leached blocks compared to their unleached counterparts. Although not tested directly, the toxicity of the adhesives used to fabricate these blocks may have been reduced with leaching, allowing for increased termite activity. Once termites were able to start feeding on the thin, plywood blocks, many of the plys began pulling apart, which was not a concern at the onset of the study, but would significantly affect long-term durability in a field setting.

4. CONCLUSIONS

- All preservatives chosen resulted in complete to nearly complete termite mortality and resulted in negligible mass loss to the test specimens overall.
- Low levels of termite feeding in some of the plywood controls (i.e. thin hardwood blocks) suggests at least some toxicity of the adhesive used to make the boards that strongly influenced termite feeding.
- In treated samples, particularly those that were unleached, termites preferentially fed within the laser marked area as opposed to feeding on the non-lasered areas of the block, suggesting that laser marking is a breach of preservative that does increase termite susceptibility.
- Major differences were seen between leached and unleached samples, indicating that leaching likely has a stronger effect, at least initially, on termite feeding preference than does laser-marking.

In general, termites did preferentially feed within the laser-marked areas, although this did not appear to result in greater overall damage to the test wood blocks. It is possible, however, that termite damage could extend to a greater degree from the laser-marked area under “real world” conditions, especially if the mark was placed on a relatively large piece of solid wood close to the ground, such as a pallet block or stringer. In contrast, laser-marks are less likely to lead to significant damage if placed farther from the ground on thinner material, such as the plywood sides of a containment box. This study indicates the need for development of new methods addressing long-term labelling protocols for dip-treated wood packing materials.

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