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REEXAMINATION OF THE SOIL BLOCK TEST:

CAN WE OBTAIN COMPARATIVE EFFICACY RESULTS?

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ABSTRACT

So that researchers can run two or more systems side-by-side and rapidly and economically determine which system(s) show promise for further long-term and expensive testing, one of our major efforts is to obtain relative efficacy data from various laboratory and field tests in a comparatively short time period. We reexamined the soil properties necessary to obtain optimal decay in the soil block test and recommend a number of changes to the AWPA E10 and E22 soil block tests. In soil block tests with particulate copper versus amine copper with two copper-tolerant decay fungi, the threshold for amine copper was 0.15 pcf or lower for both fungi. In contrast, wood treated with particulate copper had no or little efficacy against both fungi at the highest retention of 0.30 pcf. Further soil block tests with two copper-tolerant fungi were run using micronized copper quat (MCQ) and amine copper quat (ACQ-type D). With both fungi the thresholds for ACQ was about at or lower than the lowest retention examined, 0.20 pcf, while for MCQ the threshold for both fungi was about 0.30 pcf. The organic co-biocide quat may provide most or all of the protection against the two copper-tolerant fungi for the particulate copper MCQ system. To study a proposed accelerated field ground-contact test, 4x4 timbers treated with the following copper-based systems were purchased; MCQ, ACQ-D, particulate/micronized copper azole (MCA), and amine copper azole (CA-type C). The posts for the accelerated plot, and matched posts for two unaccelerated plots for comparison, were installed at the Dorman Lake research field with untreated, small fungal-infested southern pine sticks placed next to each face at the groundline. Both amine copper systems performed better than the equivalent particulate copper systems, and the ACQ-D posts performed better than CA-C timbers at approximately their UC4A specified retentions. We conclude that the relative efficacies from a soil-block test were comparable to the relative 11-month exposure data from an accelerated 4x4 field test.

INTRODUCTION

Two tests often employed in the development and testing of potential ground-contact preservative systems are the soil block test and the field test. The soil block test, such as the AWPA Standards E10 and E22, is the most widely employed laboratory method to determine biocide efficacy in North America. Only a few studies have examined the soil properties necessary to obtain optimal decay. The most comprehensive is a review by Duncan (1958) who examined 19 soils. However, most of these soils had a silt loam texture and only three had a pH above 6.3 with two of these three having low organic matter of 0.5% or less. Further, Duncan mainly studied the hydrophobic systems of creosote or heavy-oilborne penta, while most of the studies today are concerned with hydrophilic waterborne systems. The results of Duncan's and other studies were employed to specify soil properties in the AWPA E10 and E22 soil block test methods.

In our opinion the soil block test method is not necessarily fully utilized to obtain efficacy data that is relative to field exposure data. We believe that slightly modifying the test protocol for each preservative system(s) examined, such as employing a variable incubation time and inoculation method dependent on the particular preservative might be beneficial.

Proposed preservative systems submitted to an accreditation organization for ground-contact applications require a minimum of three years of outdoor field test data at two geographically-distinct field sites, provided that comprehensive depletion data is also submitted. However, scientific evidence clearly shows that a field exposure time longer than the minimum is necessary to ensure good long-term performance (Lebow et al. 2009, Schultz and Nicholas 2009). Conversely, with the rapid change worldwide caused by some systems being withdrawn from the market for various reasons, realities call for more accelerated field test methods than the current standards such as the AWPA E7 or E8 field tests.

Our overall objective is to develop rapid soil-block and field tests to economically determine which systems have the most promise for further long-term and expensive tests.

To test our proposed soil-block and accelerated field test concepts we chose waterborne copper-based [actually copper(II), hereafter called copper] systems, four of which are currently or were recently widely available for the large residential market. Waterborne copper-based systems replaced the waterborne arsenicals which were voluntarily withdrawn for residential applications in North America in 2004. Two of the systems are formulated with soluble copper stabilized with an amine and an organic co-biocide to control copper-tolerant fungi. The organic co-biocides are a quaternary [quat] ammonium compound (ACQ-D) or the azole(s) tebuconazole with or without co-added propiconazole (CA-C). Two other commercial systems employ solid basic copper carbonate which has been milled down to submicron particles which are then dispersed in water, called micronized, particulate or dispersed copper. Particulate copper systems include those with quat, MCQ, which was widely available up to a year or so ago, and particulate copper with one or two azoles (MCA). The latter system is sometimes formulated with both soluble and particulate copper. The long term performance of the particulate copper preservative systems, in which the copper formulation has been modified from a traditional soluble copper formulation, is unknown with both pro particulate copper [Freeman and McIntyre 2008, McIntyre and Freeman 2008 and 2009, Larkin et al. 2008, Zhang and Ziobro 2009, and McIntyre et al. 2009) or con [Preston et al. 2008, and Schultz and Nicholas 2010] positions being expressed.

<u>Objectives</u>

<u>Our overall objective in this study was to evaluate a rapid soil block and field test to evaluate the efficacy of new and modified wood preservative systems.</u>

Specific objectives were to:

1. Modify the soil block method and make it "harsher" so that when two or more systems are tested together the relative efficacies can be compared and the qualified results will be

comparable to relatively long-term field tests. The intent is not to use soil block data to predict a system's life for commercially-treated wood, but rather to obtain data so that the relative efficacies of two or more systems can be directly and economically compared and the potential long-term qualified field efficacies determined;

2. As time is an economic consideration when developing new preservative systems, to develop an accelerated ground-contact field test so that the data obtained will allow the relative ground-contact efficacies of two or more systems to be rapidly compared;

3. To determine if the relatively efficacies of the weeks-long soil block and proposed months-long accelerated field tests are comparable for copper based wood preservatives.

EXPERIMENTAL

Effect of Soil Properties on Soil Block Activities

To determine what soil properties are optimal for brown-rot decay on untreated pine sapwood we examined five soils with different soil textures and pHs, and studied the effect of adding hydrated lime to soils with pHs below 5 as specified in the AWPA Standards. The full experimental procedures and soil properties are given in Little et al. 2010.

Soil Block Tests with Amine vs. Particulate Copper

We examined wood treated with particulate copper without a co-biocide or amine solubilized copper without a co-biocide. Two copper tolerant brown-rot fungi were employed, *Postia placenta* and *Antrodia radiculosa*. The soil employed was from Dorman Lake, which we found gave consistently good decay (Little et al. 2010). The feeder strips were inoculated with the particular decay fungus and then incubated for three days to allow the decay fungus to become established before the treated wood wafers were placed on the feeder strips. This method was employed, as opposed to incubating the wood feeder strips until the decay fungus had covered the feeder strips and then placing the treated wood wafers on the mycelium-covered feeder strips, since decay mycelia are extremely acidic and so could cause the particulate copper to quickly become artificially solubilized (McIntyre et al. 2009, Zhang and Ziobro 2009, McIntyre and Freeman 2009, Jin et al. 2010). The AWPA E22 test was employed with a five week incubation period and the extent of decay determined by the strength loss of the wood wafers relative to the strength of matched wafers not exposed to the fungus. The wafer retentions were 0.15, 0.2, 0.25 and 0.3 pcf, copper oxide basis.

Soil Block Tests of MCQ versus ACQ

Soil block tests were run using wood treated with ACQ or MCQ and two copper-tolerant decay fungi, *A. radiculosa* and *P. placenta*. The tests were run as described above, except the incubation time was 9 weeks and the samples were treated to 0.2, 0.25, 0.30 and 0.35 pcf, oxide basis. We typically run this test for about 5 to 6 weeks but employed the longer exposure time to make the test harsher, as discussed above. A few samples were inspected periodically to determine the extent of decay, with the objective to end the test shortly after wood samples from one or both systems had some decay at the lower retentions.

Accelerated Field Ground-Contact Test

We are currently developing an accelerated ground-contact test based on the principal of putting treated wood in outdoor ground-contact next to fungal-infested untreated southern pine "feeder stakes" (Schultz and Nicholas 2010). Thus, this test is somewhat similar to the soil block laboratory test, or the outdoor above-ground American "sandwich" or European "double layer" tests.

The full experimental method for this test is given elsewhere (Schultz and Nicholas 2010). Briefly, we purchased carefully-selected southern pine 4x4s based on the presence of a wide sapwood band, minimal heartwood if any was present, the pith in the center of the timber, and good biocide penetration into the sapwood based on color of a freshly-cut transverse surface. More timbers were rejected than found acceptable. For the accelerated study, six eight-foot 4x4's treated to a labeled UC4A retention with the four waterborne copper-based preservative systems widely available for residential applications were purchased in the winter and spring 2009, and cut into two four-foot lengths. Several small 5 mm thick disks were cut from the center of the post, with the sapwood from the AWPA retention zone of 0 to 1 inch deep sent for analysis to an ISO-certified laboratory. In addition, a 2-3 inch disk was retained. The cut faces were painted with the organic biocide DCOI and the posts placed vertically about 18 inches deep, cut face up, at the Dorman Lake research field near MSU. In addition, two unaccelerated plots were installed at the same time using matched 4x4s at two locations at Dorman Lake. The accelerated posts treated with MCQ had an average total biocide retention of 0.44 pcf [UC4A specified retention is 0.34 pcf], ACQ-D with an average total biocide retention of 0.41 [UC4A retention is 0.40 pcf], MCA with an average total biocide retention of 0.13 pcf [specified UC4A retention is 0.14 or 0.15 pcf], and CA-C with an average total biocide retention of 0.14 pcf [specified UC4A retention is 0.15 pcf]. The MCQ posts on the average were over treated about 30%, with the retentions of the particulate copper quat versus amine copper quat posts having somewhat similar average retentions. Further, the two copper azole systems also had similar average retentions. Thus, the efficacies of the two quat and two azole systems can be directly compared, although the effect of the 30% overtreatment of the MCQ posts needs to be considered.

Small untreated southern pine sticks were piled in layers at Dorman Lake with local decaying wood material placed between the layers to infest the sticks. The pile was then covered with pine straw. After about two months the pile was uncovered and any heavily-infested sticks were removed and placed next to two of the four faces of each 4x4 at the groundline in the accelerated plot. The pile was then re-assembled with the uninfested southern pine sticks for an additional 3 weeks, at which time most of the sticks had become infested and were placed on the remaining two faces of each 4x4 in the accelerated plot.

After 11 months of exposure the 4x4 posts were inspected by rating each face individually as if it were a 1 inch nominal thick board, using the AWPA E7 rating scale where 10 is no decay, 9.5 indication of decay, 9 slight decay, etc., down to a 0 or failed. The ratings were then averaged for all 12 posts per treatment using both the average ratings of all four faces and the worst face of each post.

RESULTS

Effect of Soil Properties on Soil Block Activities

In this sub-section we only present the proposed test modifications which were arrived at following our study, with the results and conclusions fully discussed in Little et al. (2010). Based on this study we suggested the following changes to the AWPA E10 and E22 standards:

- The AWPA standards specify adding hydrated lime to soil with a pH below 5.0; we found that adding hydrated lime to soils with a pH below 5 greatly reduced the extent of decay and, consequently, this should be eliminated from the standards;
- The AWPA standards specify soil with a pH of 5 to 8; we recommend a pH of 4.5 to 7.5 with additional studies likely necessary;
- The AWPA standards specify soil with a water holding capacity (WHC) of 20 to 40 or 50%; we recommend 20 to 60% WHC;
- The AWPA standards have no mention of organic matter; we recommend a minimum level of 2%;
- The AWPA E10 Standard has two inoculation methods; we suggest adding an optional method to both AWPA Standards of inoculating the feeder strips, waiting three days for the fungus to become initially established and then adding the treated wood. This option should not be employed when testing systems that have a highly leachable biocide such as borates unless the treated wood is pre-leached;
- The AWPA standards specify adding 130% water based on the soil's WHC; we recommend reducing that to 115% for hydrophilic systems or studies with untreated wood; and
- To better understand the influence of soil properties on the soil block test, we recommend that a Round Robin Study be run at one laboratory using two or more decay fungi, employing soils which are used by all laboratories which run soil block decay tests in North America.

Soil Block Tests with Amine vs. Particulate Copper

Pictures of representative particulate copper- or amine copper-treated wafers in the soil block cups for each fungus are shown in Figures 1 to 4, and the average strength relative to the unexposed wafer are given in bar graphs (Figures 5 and 6).

Soil Block Tests of MCQ versus ACQ-D

Figures 7 to 10 show representative pictures of the treated wafers in the soil block cups at the end of the experiment, and Figures 11 and 12 are bar graphs of the results.

Accelerated Field Ground-Contact Test

Figure 13 shows two fungal infested feeder strips adjacent to two faces of a treated 4x4 in the accelerated plot, and figure 14 shows a typical 4x4 treated with MCA after 11 months of accelerated ground contact exposure. The average and worst face ratings for the MCQ, ACQ-D, MCA and CA-C timbers are summarized Figures 15 and 16.

DISCUSSION

Soil Block

While not the original purpose of the soil block study (Little et al. 2010), we wonder if the short-term soil block test was made "harsher" would the results would be more compared to the relatively long-term ground-contact field tests which are run for at least three years? Specifically, the current AWPA E10 and E22 Standards require that untreated wood be run along with the treated wood specimens and that some minimum weight or strength loss must be obtained on these negative controls for the test of be valid. We suggest that in addition to untreated wood, wood treated with a common preservative at some minimal level also be run, and that some specified weight or strength loss be obtained on these positive controls for the test to be valid. This will likely require that the incubation period will need to be lengthened. This is only a suggestion; we hope to hear the opinions of our professional colleagues.

Soil Block Tests with Amine vs. Particulate Copper

Both decay mycelia grew over the top of the wafers treated at all retentions with particulate copper. In contrast, fungal mycelia only grew to a limited extent on the top of wafers treated with the lower retentions of amine soluble copper (Figures 1 to 4). Further, we noticed that with *A. radiculosa* on particulate-treated wood only a narrow band of the most recent mycelia was white with the older mycelia quickly turning yellow; this color change with *A. radiculosa* mycelia has been previously noted to occur as extensive wood decay starts (Tang et al. 2010).

With both decay fungi only minimal strength loss occurred at the lowest treatment retention with soluble copper. Thus, for amine copper the thresholds for both fungi are 0.15 pcf or lower. In contrast, with *P. placenta* wood treated to the highest level of 0.30 pcf with particulate copper had 100% strength loss, and with *A. radiculosa* the strength loss was 80 to 100% for all retentions. Thus, we conclude that for particulate copper the threshold is greater than 0.30 pcf with copper tolerant fungi. The specified retentions of particulate copper in MCQ and MCA are about 0.22 and 0.17 pcf, oxide basis, for their respective UC4A retentions; both of these copper retentions are below our measured thresholds for particulate copper. Thus, with MCQ or MCA particulate copper systems in ground contact all or most of the protection against copper tolerant fungi will apparently need to be provided by the organic co-biocide.

In an earlier study (Schultz and Nicholas 2009) we found that the control of copper tolerant and other fungi could be greatly improved in long-term field tests with increased levels of soluble copper. The name *copper tolerant* is thus somewhat misleading as increased soluble copper levels will assist in the control these fungi.

Shupe et al. (2010) recently ran AWPA E22 soil block tests with one copper tolerant fungus with micronized copper versus amine copper. They used an incubation time of six weeks and incubated the feeder strips for weeks until the brown rot fungus mycelia had completely covered the feeder strips before placing the treated samples in the decay cup; AWPA Standard E22 requires a minimum incubation of 4 weeks. Our incubation time for the AWPA E22 test was shorter, and we also placed the treated samples on the feeder strips after only three days of incubation due to the highly acidic fungal mycelia solubilizing the particulate copper, as explained earlier. While the decay values from the two studies cannot be directly compared, the relative efficacy results are probably comparable. Shupe and co-workers reported that neither particulate or amine soluble copper performed well, but their data indicates total degradation with particulate copper at all retention levels but a slight protective effect with amine copper at about 0.18 pcf (all retentions are based on oxide basis so that the results can be more readily compared between our and Shupe et al. data) and good protection with 9% weight loss at about 0.25 pcf. [The strength loss data appear sometimes inconsistent in Shupe et al. (2010) with some sets having an average strength gain of 10% or greater after exposure to the decay fungi, so we employed their weight loss data. For comparison of mass loss vs. strength loss of untreated southern pine exposed to a brown rot fungus, samples with a 2.9% mass loss had a 30.3% strength loss (Janzen 2001). In generally, we consider the weight loss threshold to be around 2-3% and the mass loss threshold to be about 10-12% strength loss, values similar to which Janzen (2001) found to be statistically different from matched samples which were not exposed to a brown rot decay fungus.] Further, a dose-response was apparent with amine copper but not particulate copper. Thus, in both our soil block tests with two copper tolerant fungi and Shupe and co-workers studies with one copper tolerant fungus, amine copper had better efficacy against copper tolerant fungi than particulate copper.

Soil Block Tests of MCQ versus ACQ

As can be seen in Figures 7 and 8, with MCQ-treated wood the fungal mycelia covered the wafers even at the higher retention. Further, at the lowest MCQ retention with *A. radiculosa* the fungal mycelia were turning yellow, a sign that significant wood decay was occurring (Tang et al. 2010). In contrast, mycelia only covered the top of wood at the lower levels of ACQ (Figures 9 and 10). The toxic threshold for ACQ with *P. placenta* (Figure 11) is 0.20 pcf or lower, and between 0.20 and 0.25 pcf for *A. radiculosa* (Figure 12). For MCQ, the toxic threshold is about 0.30 pcf for both fungi. The thresholds we found for ACQ with two copper tolerant fungi are about half that of the specified UC4A retention of 0.40 pcf, but the MCQ thresholds' are close to the specified UC4A retention of 0.34 pcf. AWPA Standards E10 and E22 suggest that ground contact field stake retentions should be 1.5 to 2 times greater than the soil block threshold.

Shupe et al. (2010) also ran MCQ and ACQ soil block tests with *P. placenta*. While the data from this and Shupe's studies cannot be directly compared due to experimental differences, the relative efficacies should be comparable. With the two MCQ and two ACQ systems examined by Shupe and co-workers, thresholds based on weight loss were about 0.47 and 0.30 pcf for MCQ [the latter value may be unrealistically low due to a relatively high quat:copper ratio] and 0.30 and 0.28 pcf for ACQ, oxide/total biocide basis. Thus, in both our soil block data with two copper tolerant fungi and Shupe and co-workers with one copper tolerant fungus, ACQ gave better efficacy than MCQ.

Based on our soil block data discussed earlier with particulate versus amine copper, it appears that for MCQ the quat co-biocide may be providing most or all of the protection against the two copper tolerant fungi. It will be necessary to run soil block tests with quat alone to verify this possibility. However, Shupe et al. (2010) ran two MCQ solutions, one of which had a higher quat:copper ratio than the other system [or the MCQ standard]. If particulate copper has no effect with the copper tolerant fungus *P. placenta*, as both we and Shupe and coworkers reported, one can estimate from Shupe et al. data a quat threshold of 0.18 and 0.15 pcf for the two MCQ solutions. As these thresholds are similar, this further suggests that particulate copper provided little or no protection against the copper tolerant fungus examined by Shupe and coworkers.

Accelerated Field Ground-Contact Test

Based on the relatively short exposure time for this proposed accelerated test, the ACQ-D posts had slightly better [higher] decay ratings than the MCQ posts. If the MCQ posts had been treated to an average retention of 0.34 pcf, the specified UC4A retention, as opposed to being over-treated by about 30%, the average MCQ ratings likely would have been lower and the rating differences greater. Further, the CA-C system performed significantly better than the equivalent MCA system, with the average total biocide retention for each azole system only slightly less than the UC4A specified retention. As can be seen in one of the MCA-treated timbers, Figure 14, significant decay occurred; severe deterioration was observed in many of the MCA-treated posts. Extrapolation of the micronized copper azole soil block mass-loss data of Shupe et al. (2010) gives a threshold value about twice that of the specified UC4A MCA retention. AWPA Standards E10 and E22 suggest that ground contact field stake retentions should be 1.5 to 2 times greater than the soil block threshold. Finally, no dose-response was observed with the MCA-treated posts in the accelerated 4x4 plot. This may indicate that particulate copper, which accounts for about 96% of the total biocide retention by weight (metal basis), was ineffective against copper tolerant fungi – as was also suggested earlier by our and Shupe et al. (2010) soil block data with particulate copper. The above suggest that MCA-treated posts at UC4A retentions in ground contact may perform poorly over the long-term service life expected by consumers if copper tolerant fungi are present.

The ACQ posts performed better than the CA-C posts treated to approximately their respective specified UC4A retentions. This may be due to the higher copper level in ACQ, 0.27 pcf copper oxide basis, versus that in soluble amine copper azole of 0.17 pcf, oxide basis. We found earlier with three other copper-based systems that increased soluble copper retention gave better long-term ground-contact performance at the Dorman Lake research plot where copper-tolerant fungi are present (Schultz and Nicholas 2009).

Overall, the relative efficacy of ACQ was better than that for MCQ in both our and Shupe and co-workers soil block tests with copper tolerant fungi and our short-term accelerated 4x4 field test. Further, Shupe and co-workers (2010) reported soil block data in which amine copper azole performed better than particulate copper azole, and in our accelerated 4x4 field study CA-C performed significantly better than MCA. Thus, it appears that relative soil block efficacies may be correlated to the relative short-term efficacies of our proposed accelerated field test.

CONCLUSIONS

A number of recommended changes were made for the soil properties for the soil block test.

The relative efficacies after 6 weeks (Shupe et al. 2010) or 9 weeks (this paper) of incubation in a soil-block test with copper tolerant fungi for MCQ vs. ACQ, and MCA vs. CA-C data of Shupe and coworkers, are comparable to the relative data from the accelerated 4x4 field test after 11 months of exposure. Our accelerated field test results agree with the ACQ and MCQ results reported by Preston et al. (2008), and short-term results from several accelerated and unaccelerated field tests (Schultz and Nicholas 2010). In contrast, several other publications suggest no efficacy differences between MCQ and ACQ, or particulate copper azole vs. soluble copper azole systems, in soil block and/or field tests (Freeman and McIntyre 2008, McIntyre and Freeman 2008 and 2009, Larkin et al. 2008, Zhang and Ziobro 2009, and McIntyre et al. 2009). Further soil block tests, and longer exposure times of the accelerated and unaccelerated field tests already installed, will provide more definitive data.

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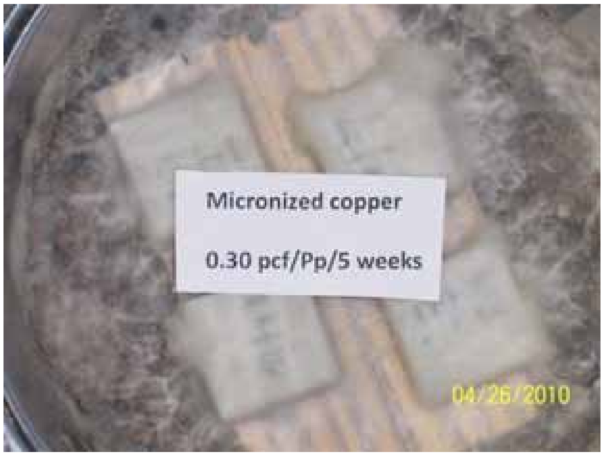


Figure 1 (left) and Figure 2 (right). Notice the heavy mycelia growth of both copper-tolerant fungi on top of the particulate copper-treated wafers even at the highest treatment level of 0.30 pcf. The fungus on the right was a gift from the USDA-Forest Products Laboratory. It was identified as *A. incrassata* when first isolated from the Harrison National Forest near the Gulf Coast of Mississippi and was later re-identified as *Antrodia radiculosa*.

Figure 3 (right) and Figure 4 (left). Notice the minimal fungal mycelia growing on the top of both wafers at the lowest treatment level examined of amine soluble copper of 0.15 pcf, compared to the heavy mycelium at the highest treatment level of 0.30 pcf with particulate copper in Figures 1 and 2.

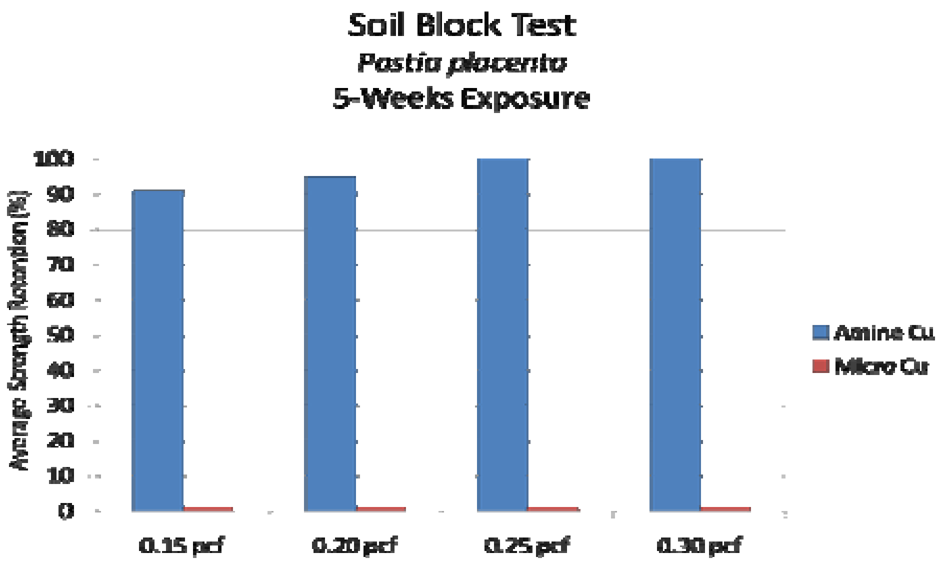


Figure 5. Results from the soil block test with *P. placenta* of amine soluble copper versus particulate copper after five weeks of incubation. The particulate copper-treated wafers had 100% strength loss at all four retentions examined. The toxic threshold for the amine copper is about 0.15 pcf, and that for the particulate copper is greater than 0.30 pcf.

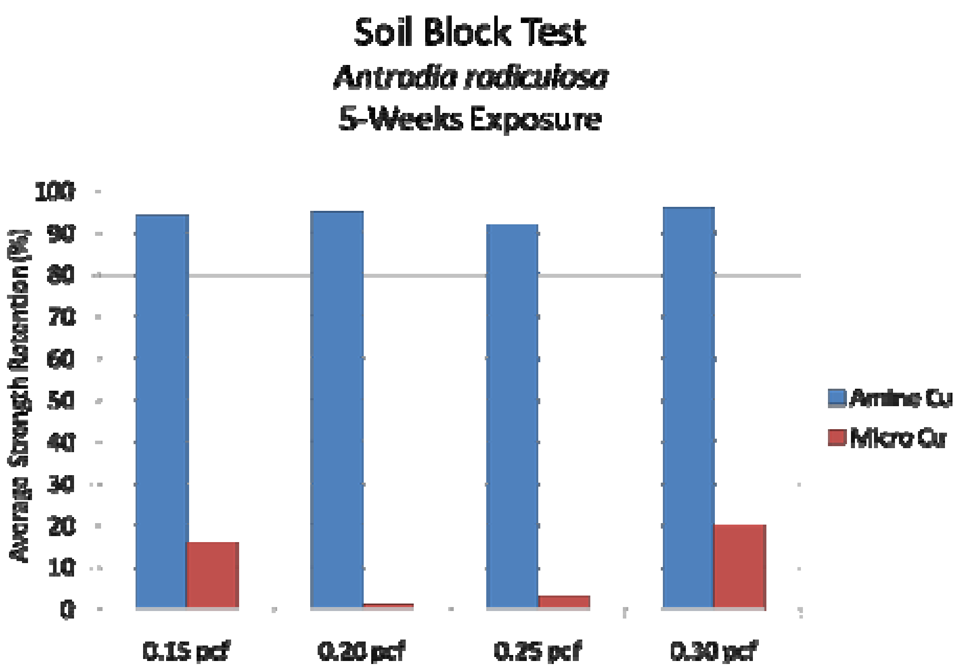
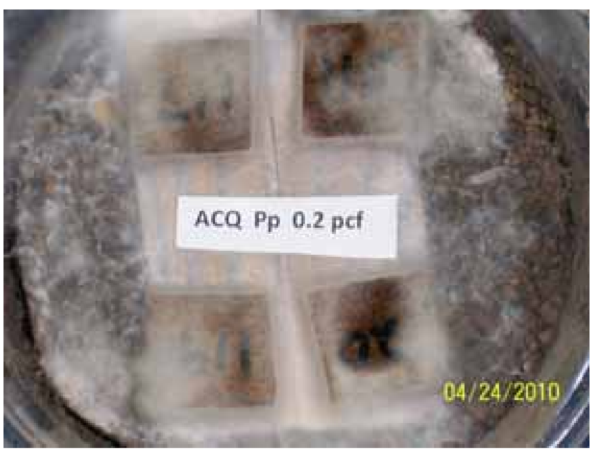
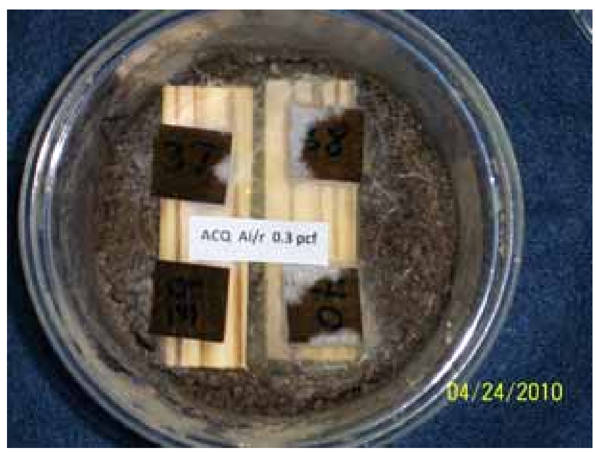


Figure 6. Results from the soil block test with *A. radiculosa* of amine soluble copper versus particulate copper after 5 weeks of incubation. The toxic threshold of the particulate copper is greater than 0.30 pcf, and that for the amine copper is less than or equal to 0.15 pcf.

Figures 7 (left) and 8 (right). Pictures show wood treated with MCQ to 0.30 pcf after 9 weeks of incubation to two copper-tolerant fungi. Note the relative heavy fungal mycelia growth on the tops of the treated wafers.





Figures 9 (left) and 10 (right). Pictures show wood treated with ACQ to 0.20 pcf with *P. placenta* (Figure 9) or 0.30 pcf with *A. radiculosa* (Figure 10) after 9 weeks of incubation. Note the difference in mycelia growth on the top of the ACQ-treated wafers compared to that for the MCQ-treated wafers in Figures 7 and 8 above.

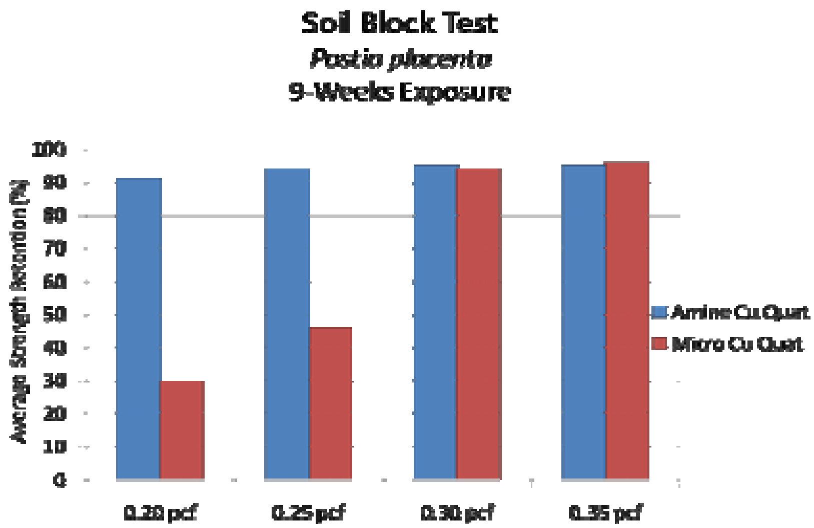


Figure 11. Soil block results after 9 weeks of incubation for ACQ versus MCQ with *P. placenta*. The toxic threshold for MCQ is about 0.30 pcf, and that for ACQ is 0.20 pcf or less.

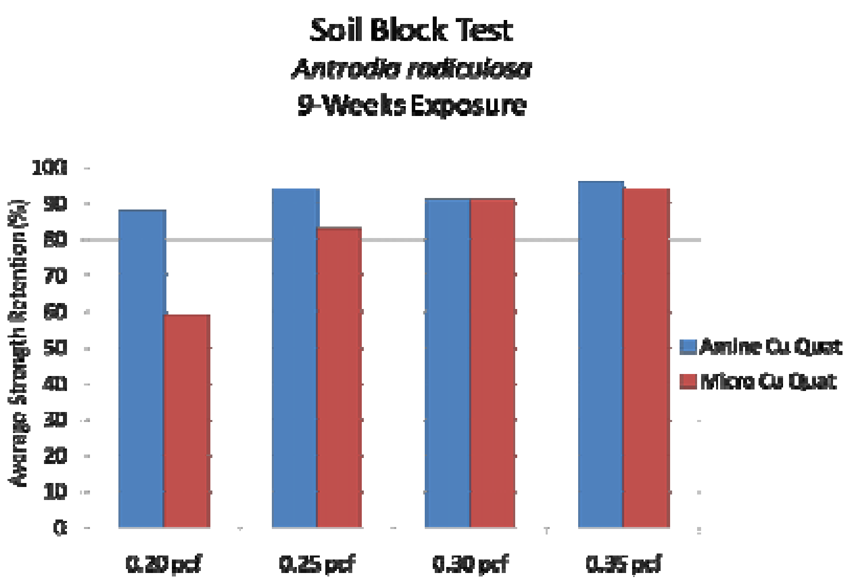


Figure 12. Soil block results afer 9 weeks of incubation for ACQ versus MCQ with *A. radiculosa*. The toxic threshold for MCQ is about 0.30 pcf, and that for ACQ is about 0.20 pcf.

Figure 13. Picture of a treated southern pine 4x4 at ground level in the accelerated plot at Dorman Lake plot with a fungal-infested feeder strip showing on the right face and a second feeder strip barely visible on the left face.   The feeder strips are untreated southern pine sticks which were infested at Dorman Lake by being layered with various local decaying woody material and when decay was apparent were placed next to all four faces of the 4x4s in the accelerated plot.

Figure 14. A typical MCA-treated 4x4 post after 11 months of exposure in the accelerated plot. Note the extensive decay on the top face, and the decay on the next face.   All four faces are rated separately, and then the average of all four faces or the rating of the worse face were reported.

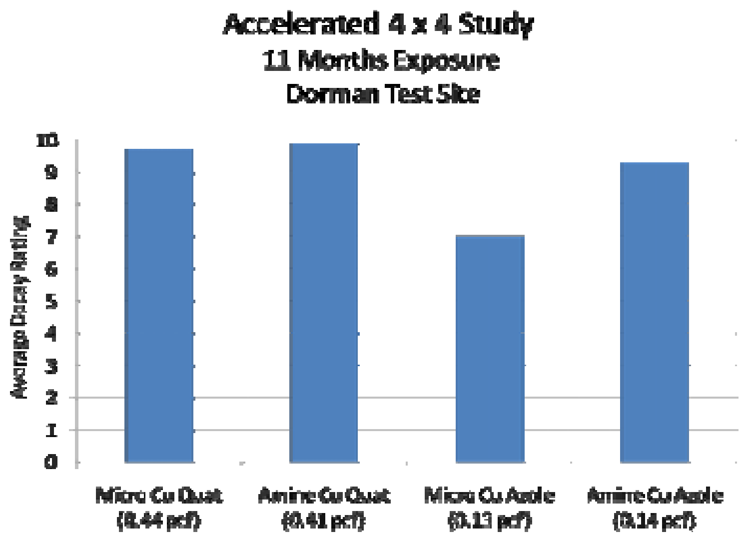


Figure 15. The average ratings for all four treatments examined in the accelerated post study, based on the average ratings of all four faces of each post. The average retention of the posts with each treatment are given in parenthesis. The MCA ratings are significantly lower than the ratings for the other three copper-based systems. With the particulate versus amine copper/quat systems, and also the particulate versus amine copper/azole systems, the amine soluble copper systems performed better than the equivalent particulate system. The MCQ timbers were treated to 0.44 pcf, with the specified UC4A retention for MCQ being 0.34 pcf. Thus, if the MCQ timbers had been to closer to the specified retention, as were the ACQ timbers, the differences in the ratings between ACQ and MCQ would likely have been even greater.

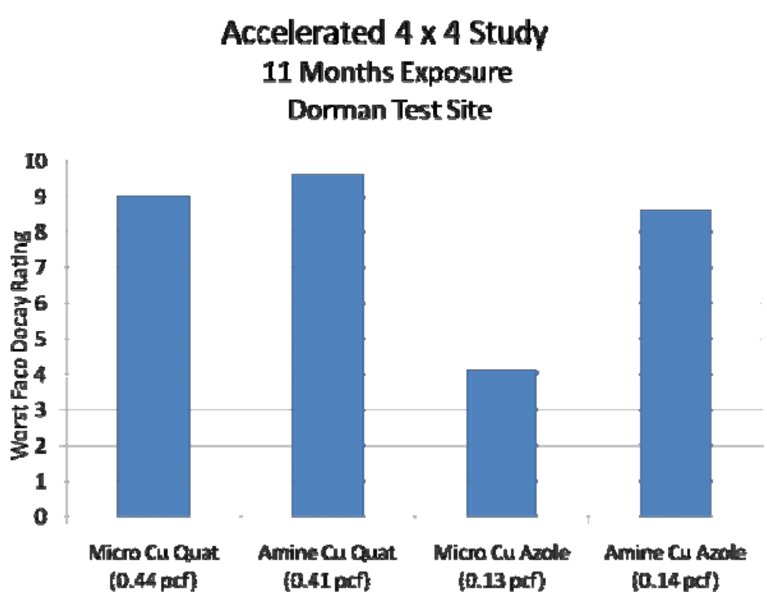


Figure 16. Similar bar graph as above, but based on the worst face of each post examined.