Oregon State University
Utility Pole Research Cooperative

Department of Wood Science & Engineering
Oregon Wood Innovation Center

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ISK Biocides
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Osmose Utility Services Inc.
Pacific Wood Preserving Companies
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Poles, Inc.
Portland General Electric Company
Public Service Company of New Mexico
Puget Sound Energy Services
Salt River Project
Snohomish County Public Utility District
Southern California Edison
Stella-Jones Inc.
The Pentachlorophenol Working Group
Utility Pole Technologies Inc.
Western Wood Preservers Institute

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Executive Summary

We continue to address issues under six Objectives. This past year, we were fortunate to have 3 new members join the coop. Snohomish County Public Utility District joined as a full member, while Poles, Inc. and Stella-Jones Inc. joined as associate members. We appreciate their willingness to support the work, as well as the support and advice of the continuing members.

Objective I addresses the performance of internal remedial treatments including both water and gas diffusible compounds. We continue to evaluate the performance of dazomet in various application systems. Applying dazomet in paper tubes had no noticeable effect on the subsequent release of methylisothiocyanate (MITC), while similar systems in biodegradable plastic tubes initially slowed release. We have also explored the characteristics of residual dazomet in treatment holes. While the residual material in poles in a wetter climate contained little or no dazomet, material from holes in poles in drier climates contained high levels of dazomet. The results suggest that most of the dazomet in holes above the groundline in drier climates is not decomposing. While one could argue that the wood is at a low risk of decay above ground in these locations, it also suggests that utilities in dry climates should revisit their treatment patterns to place more chemical below ground, where it is more likely to become wet enough to decompose into MITC. It also illustrates the importance of the accelerant under these conditions.

We have also explored the potential for using alternative accelerants to encourage dazomet decomposition. This work arose out of the possibility that copper naphthenate, the only accelerant currently listed on the dazomet label, was going to be withdrawn from the market. While that possibility eventually disappeared with the emergence of a new supplier, it highlighted the need for alternative accelerant systems. A number of copper compounds were screened as alternatives including copper hydroxide and oxine copper (copper-8-quinolinolate or copper-8). Copper 8 produced the least improvement in MITC released from dazomet, while a number of other compounds were at least as effective as copper naphthenate. These findings will provide EPA registered alternatives for dazomet decomposition should the need arise.

Field trials with fused borate and fused borate plus copper rods are continuing and show that boron moves well from both rods generally following wetter regimes around the application zone. The copper in the boron/copper rod has moved at very low levels since application. The results indicate that both of the rod types are equally effective at establishing boron levels in wetter areas around the application site.

The large scale field trial of all internal remedial treatments was evaluated 42 months after installation. MITC-FUME treated poles continued to contain extremely high levels of MITC, followed by poles receiving various dazomet systems. MITC levels in poles treated with the various metam sodium systems have declined sharply, which is consistent with previous field data showing that this system tends to provide 3 to 5 years of chemical protection. Boron movement from poles receiving fused borate rods is also consistent with previous results showing that this system does not produce meaningful upward boron movement from the point of application. This trial should provide utilities with comparative data on field performance of all the internal remedial treatments at a single site.

The final activity under Objective I was the installation of a field test of internal treatments in Utah. This test is intended to begin to provide field performance data on internal treatments under drier conditions. This test will be sampled for the first time in October, 2011.

Objective II examines alternative methods for ensuring that field drilled holes in poles are protected. While national standards require that field drilled holes in poles be supplementally protected, this process rarely occurs. The result is internal decay associated with various underbuilt lines. We have explored the performance of bolts covered with a supplemental preservative paste that can diffuse into the wood inside the hole. While our results have been promising, questions have arisen about the potential for corrosion of the bolts. This past summer, we removed bolts from an older trial in which field drilled holes had been treated with boron or fluoride based systems. While some corrosion was present, there was no evidence that corrosion on bolts in holes treated with fluoride or boron were more severe than those found in bolts from non-treated holes. The results indicate that the preservative coated bolts may be a simple method for ensuring compliance with the requirement for treating field drilled holes.

Objective III explores a number of methods for improving the performance of poles through improved specifications. We continue to work on bringing through-boring into the AWPA and ASC standards. The process is complete within the AWPA; however, we still have some additional data to provide to the ASC. We also continue to examine the potential for using coatings on both crossarms and poles to reduce moisture uptake and limit the potential for checking. Field trials in Hawaii indicate that a polyurea coating has performed well in crossarm sections after 18 months of exposure, with no evidence of coating degradation. Exposure of coated samples to termite attack also showed that the termites did not attack the coated chemically treated samples. Additional coated samples treated with borates have been exposed and will be evaluated in 6 months. We recently installed poles with polyurea coated pole tops at our Corvallis test site. These poles will be monitored over time for top condition to determine if this coating is suitable as a pre-installation pole cap. This approach resulted from our previous trial of pole capping, which continues to show that moisture contents in poles with caps remain well below the point where fungi can cause decay. Poles without caps have moisture contents well within the range required for fungal attack. The results illustrate the benefits of water excluding caps.

Trials to evaluate the benefits of end-plating to control checking of crossarms are complete and show that check number and width were markedly greater on arms without end-plates. The results illustrate the benefits of plates to retard check development. The final activity under Objective III was an evaluation of the withdrawal capacity of ground wire fasteners. Increasing theft of ground wire has placed added emphasis on the ability of staples to discourage easy removal of the copper ground wire. Withdrawal resistance was tested on eight different types of ground wire staples driven into pentachlorophenol and ammoniacal copper zinc arsenate treated Douglas-fir pole sections. Treatment type had no noticeable effect on withdrawal resistance, but there were substantial differences in withdrawal resistance among the various staple types. As expected, fastener size had the most noticeable effect. We plan to obtain additional materials to expand this test to provide better guidance to utilities concerning the most appropriate ground wire staple.

Objective IV addresses external groundline preservative treatment performance. We continue to seek clarification for the results from our Georgia Power test and plan to perform a 7 year examination if the participants agree that this will be helpful. In addition, we have included 5 year results from a trial of fluoride/boron and boron pastes and bandages on Douglas-fir, southern pine and western redcedar. Boron from these systems has moved well from the point of application, and fluoride has been found at lower levels that are consistent with the ratio of boron/fluoride in the paste. We will examine these poles at the 7 year point. We have also installed a groundline test on poles in the Phoenix area to develop better data on performance of commercially available systems in drier climates. These poles will be sampled for the first time in February, 2012. We have also installed a series of below ground barriers on poles at our Peavy Arboretum test site to assess both the ability of the barrier to alter wood moisture conditions and to restrict the potential for preservative migration into the surrounding environment. We have completed the background soils analysis, which showed low levels of copper, zinc and arsenic. We will perform the first field assessments this fall. Although we would not routinely recommend these barriers, they may be useful for installations in very sensitive environments.

Finally, we examined the potential for groundline preservative paste components to migrate down the pole with rainfall using a copper/boron based system. Levels of copper and boron in the runoff were both initially high, but declined with repeated rainfalls. The use of tape to seal the bottom of the bandage to restrict downward flow reduced, but did not completely limit the losses. The results suggest that sealing the bottom of a groundline barrier may be useful for restricting loss of chemical. Further tests are planned to determine if restricting losses results in higher chemical levels in the wood.

Objective V examines the performance of copper naphthenate in laboratory and field trials. We continue to evaluate a small scale trial of copper naphthenate treated western redcedar sapwood stakes. The results indicate that copper naphthenate performs well on freshly cut cedar sapwood. These results, along with previous assessments of in-service poles, showed that properly treated copper naphthenate poles are performing well. Last year, we reported on results from laboratory trials of blocks treated with copper naphthenate in mixtures of diesel and biodiesel. The results showed that biodiesel markedly diminished the performance of copper naphthenate. This year, we report on additional trials assessing the effects of stabilizers on performance in these biodiesel/diesel mixtures. These trials were intended to develop data on copper naphthenate systems that had been used commercially to treat Douglas-fir poles. While there were some differences in performance between the tests from the two years, the addition of stabilizers markedly reduced copper naphthenate performance. However, we found no differences in performance of two different copper naphthenate systems. The results indicate that both biodiesel and the stabilizers that are added along with it are detrimental to copper naphthenate performance. Finally, we explored the potential for *Postia placenta*, a common, copper tolerant inhabitant of Douglas-fir heartwood, to move from this material into adjacent copper naphthenate treated sapwood. The results suggested that this fungus did not readily move into the treated sapwood, although we plan some additional tests under different conditions to confirm these results.

Objective VI examines the potential for preservatives to migrate from poles in storage. No tests were performed this past year, but additional trials are planned as materials become available for evaluation.

OBJECTIVE I

DEVELOP SAFER CHEMICALS FOR CONTROLLING INTERNAL DECAY OF WOOD POLES

Remedial treatments continue to play a major role in extending the service life of wood poles. While the first remedial treatments were broadly toxic, volatile chemicals, the treatments have gradually shifted to more controllable treatments. This shift has resulted in the availability of a variety of internal treatments for arresting fungal attack. Some of these treatments are fungitoxic based upon movement of gases through the wood, while others are fungitoxic based upon movement of boron or fluoride in free water. Each system has advantages and disadvantages in terms of safety and efficacy. In this section, we discuss the active field tests of the newer formulations as well as additional work to more completely characterize the performance of several older treatments.

A. Develop Improved Fumigants for Control of Internal Decay

While there are a variety of methods for internal decay control used around the world, fumigants remain the most widely used systems in North America. Initially, two fumigants were registered for wood, metam sodium (32.1% sodium n-methyldithiocarbamate) and chloropicrin (96 % trichloronitromethane) (Table I-1). Of these, chloropicrin was the most effective, but both systems were prone to spills and carried the risk of worker contact. Utility Pole Research Cooperative (UPRC) research identified two alternatives, methylisothiocyanate (MITC) and dazomet. Both chemicals are solid at room temperature, reducing the risk of spills and simplifying cleanup of any spills that occur. MITC was commercialized as MITC-FUME, while dazomet has been labeled as Super-Fume, UltraFume and DuraFume (Table I-1). An important part of the development process for these systems has been continuing performance evaluations to determine when retreatment is necessary and to identify any factors that might affect performance. This past year, we have addressed two critical issues with regard to performance. The first was effectiveness of these treatments in drier climates and the second was to evaluate potential replacement accelerants for dazomet. In addition, we continue to monitor a number of long term field trials.

Table I-1. Characteristics of fumigant internal remedial treatments for wood poles

Trade Name	Active Ingredient	Conc.(%)	Toxicity (LD_{50})	Manufacturer
TimberFume	trichloronitromethane	96	205 mg/kg	Osmose Utilities Services, Inc.
WoodFume ISK Fume SMDC-FUME	sodium n-methyldithiocarbamate	32.1	1700-1800 mg/kg	Osmose Utilities Services, Inc. ISK Biosciences Copper Care Wood Preservatives, Inc
MITC-FUME	methylisothiocyanate	96	305 mg/kg	Osmose Utilities Services. Inc.
Super-Fume UltraFume DuraFume	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiodiazine-2-thione	98-99	320 mg/kg oral 2260 mg/kg dermal	Copper Care Wood Preservatives, Inc Chemical Specialties, Inc. . Osmose Utilities Services. Inc.

1. Performance of Dazomet With or Without Copper Based Accelerants

Date Established:	September 1997
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @ GL (avg., max., min.)	98, 107, 89 cm

Our preliminary field data clearly showed that copper sulfate accelerated the decomposition of dazomet to produce MITC, but this chemical is not generally used by utility personnel. One alternative to copper sulfate is copper naphthenate, which is commonly recommended for treatment of internal field damage to utility poles. There were, however, questions concerning the ability of copper naphthenate, a copper soap, to enhance decomposition in comparison with the copper salt.

Douglas-fir pole sections (283-340 mm in diameter by 3 m long) were pressure treated with pentachlorophenol in P9 Type A oil before being set to a depth of 0.6 m at our field test site. Three steeply sloping holes were drilled into the poles beginning at groundline and moving upward 150 mm and around the pole 120 degrees. Two hundred grams of dazomet was equally distributed among the three holes. One set of three poles received no additional treatment, three poles received 20 g of copper sulfate, and three received 20 g of copper naphthenate (2 % metallic copper) in mineral spirits. The holes were then plugged with tight fitting wood dowels.

The EPA product label for commercially available dazomet-based pole fumigants includes the statement “An accelerant of a 1% solution of copper naphthenate in mineral spirits may be added to treatment holes after [dazomet], and is designed to speed the decomposition and release of active fumigant inside the wood product”. The 20 g of copper sulfate and 20 g of copper naphthenate (2% metallic copper) are contrary to the label and would violate the law if used for commercial applications. At the time this test was established dazomet was not commercially used.

Chemical distribution was assessed annually after treatment by removing increment cores from three equidistant points around each pole at sites 0.3, 1.3, and 2.3 m above the groundline. The outer 25 mm of each core was discarded. The next 25 mm, and the 25 mm section closest to the pith (Figure I-1), of each core were placed into vials containing 5 ml of ethyl acetate, extracted for 48 hours at room temperature, and the resulting extracts were analyzed for residual MITC by gas chromatography using a Shimadzu GC equipped with a flame photometric detector with filters specific for sulfur. MITC levels were determined by comparison with similar analyses of prepared standards. The remainder of each core was then placed on the surface of a 1.5 % malt extract agar petri dish and observed for evidence of fungal growth. Any fungi growing from the cores were examined for characteristics typical of basidiomycetes, a class of fungi containing many important wood decayers.

These poles were not sampled this year.

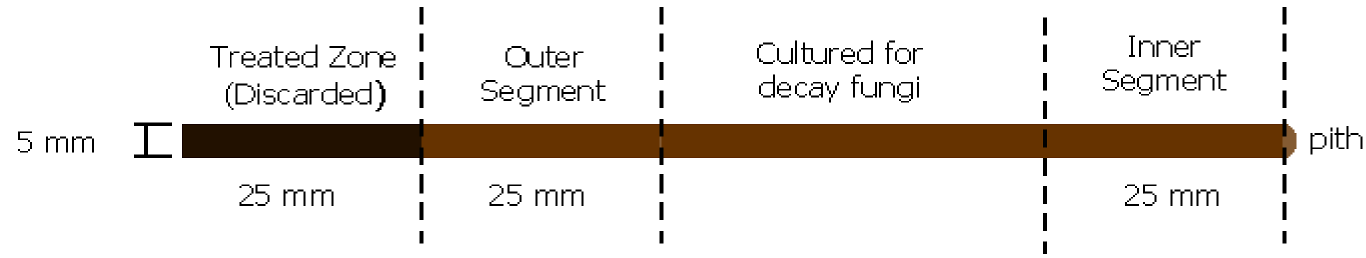


Figure I-1. Representation of increment core showing inner and outer 25 mm segments analyzed for fumigant content. The length of the segment cultured for decay fungi varies in length depending on the size of the pole.

2. Performance of Dazomet in Powdered and Rod Forms in Douglas-fir Pole Sections

Date Established:	March 2000
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @ GL (avg., max., min.)	84, 104, 65 cm

Dazomet was originally supplied in a powdered formulation which was intended for application to agricultural fields where it could be tilled into the soil. Once in contact with the soil, the dazomet would rapidly react to release MITC, killing potential pathogens prior to planting. The drawbacks to the use of powdered formulations for treatment of internal decay in wood poles include the risk of spillage during application, as well as the potential for the presence of chemical dusts that can be inhaled. In our early trials, we produced dazomet pellets by wetting the powder and compressing the mixture into pellets, but these were not commercially available. The desire for improved handling characteristics, however, encouraged the development of a rod form. These rods simplified application, but we wondered whether the decreased wood/chemical contact associated with the rods might reduce dazomet decomposition, thereby slowing fungal control.

Pentachlorophenol treated Douglas-fir pole sections (206-332 mm in diameter by 3 m long) were set to a depth of 0.6 m at the Corvallis test site. Three steeply angled holes were drilled into each pole beginning at groundline and moving upward 150 mm and around 120 degrees. The holes received either 160 g of powdered dazomet, 107 g of dazomet rod plus 100 g of copper naphthenate (2% as Cu), 160 g of dazomet rod alone, 160 g of dazomet rod amended with 100 g of copper naphthenate, 160 g of dazomet rod amended with 100 g of water, or 490 g of metam sodium. Pre-measured aliquots of the amendments were placed into the treatment holes on top of the fumigants. Each treatment was replicated on five poles.

Chemical distribution was assessed 1, 2, 3, 5, 7, 8 and 10 years after treatment by removing increment cores from locations at three equidistant locations around each pole at 0.3, 0.8 or 1.3 m above the groundline. The outer treated zone of each core was discarded, and then the inner and outer 25 mm of the remainder of each core was placed into a tube contained 5 ml of ethyl acetate as previously described. The core was extracted in ethyl acetate for 48 hours at room temperature, then the core was removed to be oven dried and weighed. The ethyl acetate extract was analyzed for residual MITC by gas chromatography as previously described. The remainder of each core was placed on 1.5 % malt extract agar and observed for evidence of fungal growth. Any fungal growth was examined for characteristics typical of basidiomycetes, a class of fungi containing many important wood decayers.

These poles were not sampled in 2011, but will be revisited in 2012 at the 12 year point in the test.

3. Performance of Dazomet in Granular and Tube Formulations

Date Established:	August 2006
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @ GL (avg., max., min.)	89, 97, 81 cm

Dazomet has been successfully applied for over 10 years; however, one concern with this system is the risk of spilling the granules during application. In previous tests, we explored the use of dazomet in pellet form, but this does not appear to be a commercially viable product. As an alternative, dazomet could be placed in degradable tubes that encase the chemical prior to application. The tubes would contain the material prior to application, but could also affect subsequent dazomet decomposition and the release of MITC. In order to investigate this possibility, the following trial was established.

Pentachlorophenol treated Douglas-fir pole sections (2.1 m long by 250-300 mm in diameter) were set to a depth of 0.6 m at the Peavy Arboretum test site. Three 22 mm diameter by 375 to 400 mm long steeply angled holes were drilled into the poles beginning at groundline and moving upward 150 mm and 120 degrees around the pole.

Seventy grams of dazomet was pre-weighed into 125 ml plastic bottles. The content of one bottle was then applied to each of the three holes in each of 10 poles. The holes in 10 additional poles received a 400 to 450 mm long by 19 mm diameter paper tube containing 60 g of dazomet. The tubes were gently rotated as they were inserted to avoid damage to the paper. The holes in one half of the poles treated with either granular or tubular dazomet were then treated with 7 g of 2 % copper naphthenate (as Cu) in mineral spirits (Tenino Copper Naphthenate). As mentioned previously, the addition of copper naphthenate at concentrations higher than 1% is a violation of the product label and not allowed for commercial applications. The holes were plugged with tight fitting plastic plugs. A second set of poles was treated one year later with an improved tube system using these same procedures. The newest tubes were constructed of degradable perforated plastic that should break down over time and not require removal before re-treating the poles.

MITC distribution was assessed 1, 2, 3 and 5 years after treatment by removing increment cores from three locations around the pole 150 mm below groundline, at groundline as well as 300, 450 and 600 mm above groundline. The treated zone of the core was removed and then the inner and outer 25 mm of each core were placed in ethyl acetate, extracted for 48 hours at room temperature and then the extract was removed and analyzed by gas chromatography for MITC. The remainder of each core was placed on 1.5 % malt extract agar and observed for evidence of fungal growth. Any fungal growth was examined for characteristics typical of basidiomycetes, a class of fungi containing many important wood decayers.

MITC levels in poles receiving any of the dazomet treatments were above the 20 ug threshold within one year after treatment between 150 mm below groundline and 450 mm above that zone. MITC levels were slightly more variable 600 mm and 900 mm above groundline (Table I-2, Figures I-2-3). The use of a copper naphthenate accelerant had little effect on total MITC levels found in the wood. This contradicts previous studies showing that the presence of copper enhanced dazomet decomposition to MITC. It is unclear why the copper had so little effect, although moisture levels in the wood may have naturally accelerated decomposition thereby negating the value of the copper. There also appeared to be little difference in MITC levels in poles receiving granular dazomet alone or applied in paper tubes. These results indicate that the paper did not interfere with either dazomet decomposition or subsequent MITC diffusion into the

Table I-2a. MITC levels in Douglas-fir poles 1 to 5 years after application of dazomet as a granular formulation or in paper or plastic tubes as measured 150 mm below to 300 mm above the groundline.

Treatment	Dosage (g/pole)	Supplement	Years after treatment	Residual MITC (ug/g of wood)[a]					
				-150 mm		0 mm		300 mm	
				Inner	Outer	Inner	Outer	Inner	Outer
Granular	210	CuNaph	1	**108** (56)	**53** (87)	**114** (66)	19 (23)	**79** (38)	**45** (56)
			2	**173** (225)	**96** (102)	**131** (158)	**88** (62)	**122** (72)	**56** (40)
			3	**180** (64)	**91** (143)	**132** (56)	**66** (59)	**83** (31)	**60** (42)
			5	**681** (1041)	**78** (78)	**267** (200)	**76** (94)	**112** (48)	**52** (39)
		None	1	**144** (111)	**48** (64)	**108** (49)	15 (24)	**63** (21)	**32** (44)
			2	**189** (241)	**73** (80)	**119** (77)	**49** (49)	**126** (83)	**33** (24)
			3	**232** (145)	**74** (62)	**215** (158)	**85** (100)	**135** (92)	**75** (52)
			5	**477** (521)	**100** (77)	**520** (695)	**97** (79)	**151** (92)	**65** (36)
Paper Tube	180	CuNaph	1	**133** (99)	**66** (97)	**158** (111)	**53** (59)	**81** (40)	**53** (59)
			2	**138** (94)	**103** (106)	**154** (166)	**62** (50)	**135** (93)	**42** (34)
			3	**284** (249)	**137** (93)	**278** (112)	**137** (107)	**101** (38)	**89** (53)
			5	**481** (440)	**155** (133)	**751** (936)	**191** (202)	**141** (38)	**89** (59)
		None	1	**108** (59)	16 (31)	**112** (108)	**21** (32)	**72** (52)	10 (12)
			2	**103** (104)	**55** (47)	**117** (139)	**37** (23)	**122** (84)	**34** (26)
			3	**269** (142)	**53** (36)	**205** (179)	**46** (30)	**100** (50)	**45** (17)
			5	**503** (510)	**107** (51)	**505** (630)	**275** (679)	**134** (49)	**74** (33)
Plastic Tube	103	CuNaph	1	**41** (73)	16 (25)	**51** (49)	19 (19)	**47** (35)	**21** (36)
			2	**104** (53)	**48** (67)	**129** (121)	**97** (158)	**64** (45)	**118** (222)
			4	**162** (109)	**142** (178)	**256** (577)	**65** (63)	**75** (32)	**69** (81)
Control	0	None	1	0 0	1 (5)	8 (31)	0 0	1 (3)	0 0
			2	0 0	0 0	1 (3)	0 0	0 0	0 0
			3	1 (3)	0 0	0 0	0 0	1 (3)	0 0
			5	2 (5)	2 (7)	0 0	0 0	2 (5)	3 (8)

a. Numbers in bold type are above the toxic threshold. Numbers in parentheses represent one standard deviation from the mean of 15 measurements.

Table I-2b. MITC levels in Douglas-fir poles 1 to 5 years after application of dazomet as a granular formulation or in paper or plastic tubes as measured 450 mm to 900 mm above the groundline.

Treatment	Dosage (g/pole)	Supplement	Years after treatment	Residual MITC (ug/g of wood)[a] 450 mm Inner	450 mm Outer	600 mm Inner	600 mm Outer	900 mm Inner	900 mm Outer
Granular	210	CuNaph	1	**47** (27)	**39** (33)	**27** (17)	10 (14)	**21** (34)	1 (3)
			2	**92** (58)	**51** (63)	**109** (103)	**39** (35)	**134** (196)	**64** (69)
			3	**58** (19)	**56** (56)	**45** (15)	**30** (16)	**30** (8)	14 (8)
			5	**74** (32)	**43** (50)	**49** (22)	**24** (16)	**35** (27)	9 (9)
		None	1	**34** (13)	**27** (42)	17 (28)	2 (5)	17 (43)	2 (5)
			2	**94** (115)	**51** (87)	**167** (256)	**35** (40)	**132** (117)	**55** (70)
			3	**87** (31)	**61** (54)	**63** (35)	**35** (29)	**46** (39)	19 (16)
			5	**70** (43)	**45** (58)	**46** (22)	20 (10)	**31** (14)	19 (29)
Paper Tube	180	CuNaph	1	**39** (21)	19 (20)	**22** (13)	5 (7)	12 (25)	2 (4)
			2	**109** (84)	**44** (44)	**118** (112)	**72** (114)	**99** (77)	**54** (41)
			3	**69** (22)	**55** (30)	**44** (14)	**24** (10)	**26** (9)	9 (9)
			5	**81** (31)	**47** (31)	**46** (13)	**29** (19)	**30** (12)	11 (9)
		None	1	**51** (34)	14 (24)	**20** (11)	9 (15)	7 (16)	1 (4)
			2	**108** (163)	**50** (62)	**103** (106)	**48** (69)	**96** (86)	**48** (49)
			3	**61** (20)	**31** (8)	**40** (14)	**21** (7)	**26** (13)	6 (6)
			5	**95** (41)	**53** (31)	**59** (16)	**42** (39)	**40** (29)	14 (8)
Plastic Tube	103	CuNaph	1	**34** (44)	17 (27)	**44** (47)	10 (13)	**74** (153)	**26** (41)
			2	**40** (17)	**32** (24)	**36** (18)	19 (27)	18 (16)	3 (6)
			4	**42** (18)	**30** (43)	**29** (22)	16 (17)	**23** (22)	10 (18)
Control	0	None	1	0 0	0 0	2 (7)	0 0	0 0	0 0
			2	0 0	0 0	1 (3)	0 0	0 0	0 0
			3	2 (3)	0 0	3 (11)	0 0	1 (2)	0 0
			5	2 (5)	0 0	2 (4)	1 (3)	2 (6)	12 (46)

a. Numbers in bold type are above the toxic threshold. Numbers in parentheses represent one standard deviation from the mean of 15 measurements.

surrounding wood.

The use of a plastic tube to contain the dazomet prior to application initially appeared to have a negative effect on MITC levels in the surrounding in wood (Figure I-4). While MITC levels did reach the threshold in the first year, the levels in the -150 mm to +300 mm zone have yet to reach those found in the poles receiving dazomet granules or tubes. This suggests that the plastic tubes may be less useful for this application, although they may have other attributes that make them easier to transport or apply.

Fungal isolation levels tended to be low in all poles in the test (Table I-3). While some decay fungi were isolated from non-dazomet treated poles, the isolations were primarily well above the groundline. Overall levels of non-decay fungi also remain low in the poles receiving dazomet, but did appear to increase sharply in year 5 for the non-fumigated controls. The overall low levels of

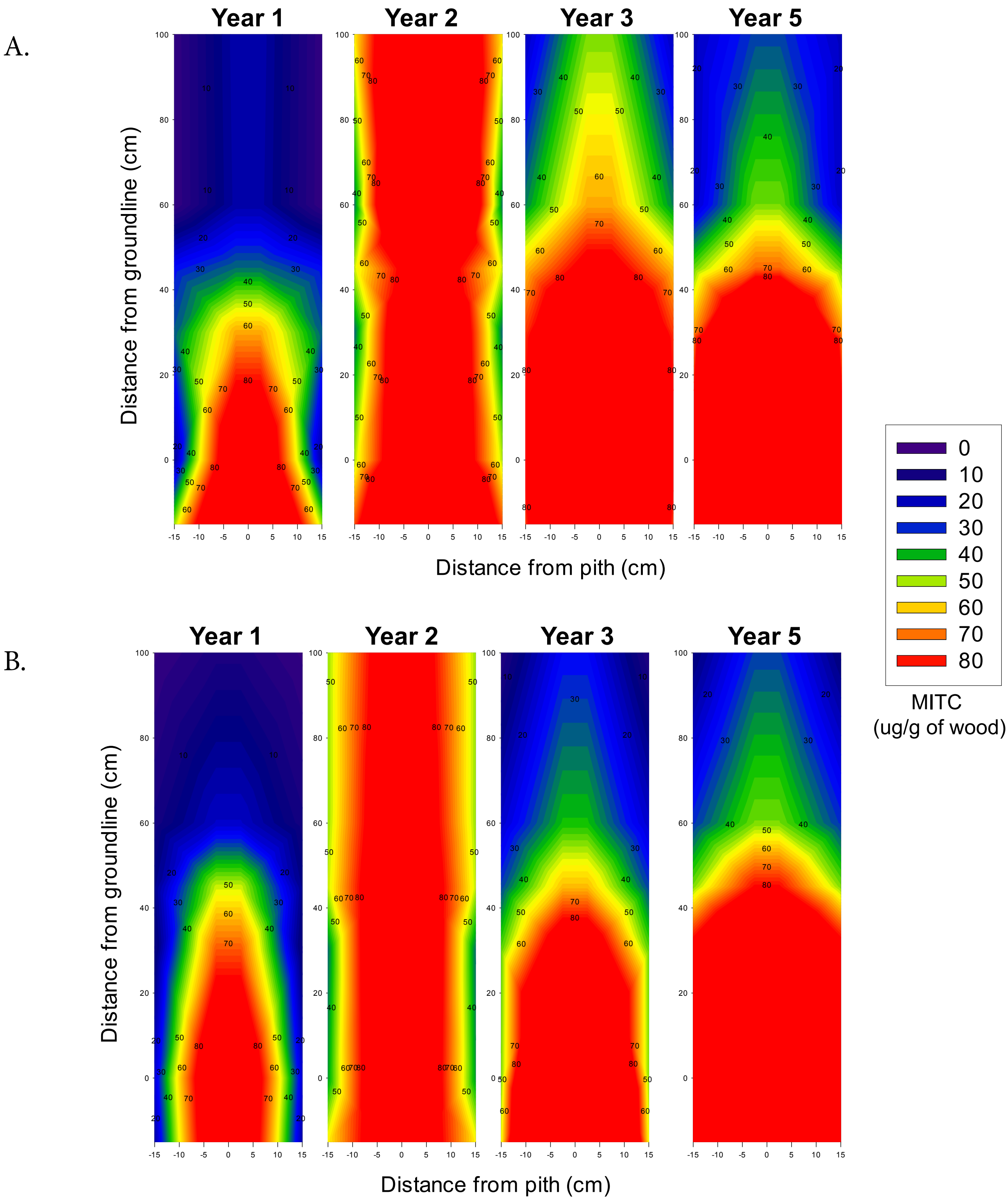


Figure I-2. Maps showing relative levels of MITC in Douglas-fir poles 1 to 5 years after treatment with A. granular dazomet alone or B. the same system in paper tubes.

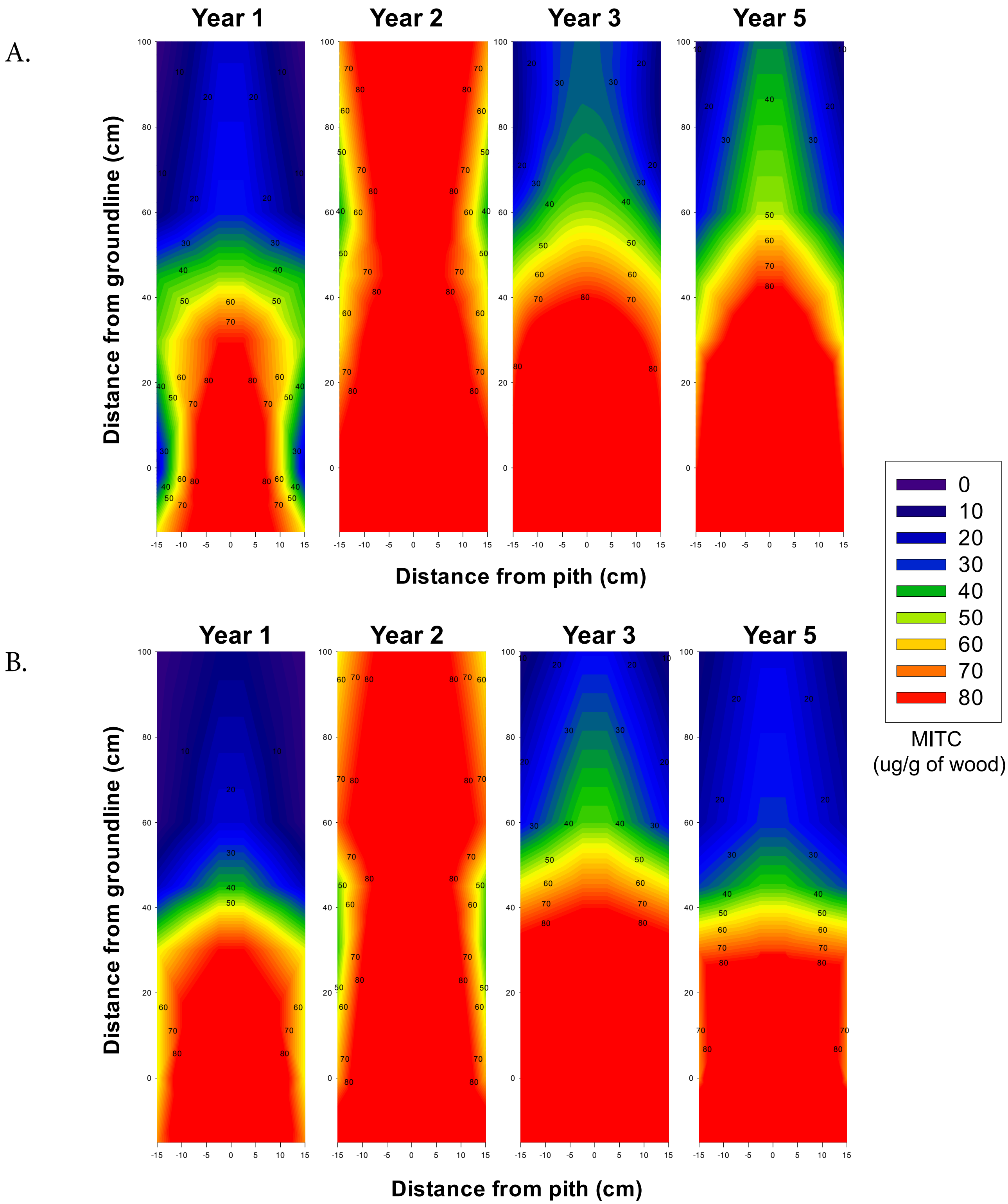


Figure I-3. Maps showing the effects of copper naphthenate addition on relative levels of MITC in Douglas-fir poles 1 to 5 years after treatment with A. granular dazomet alone or B. the same system in paper tubes.

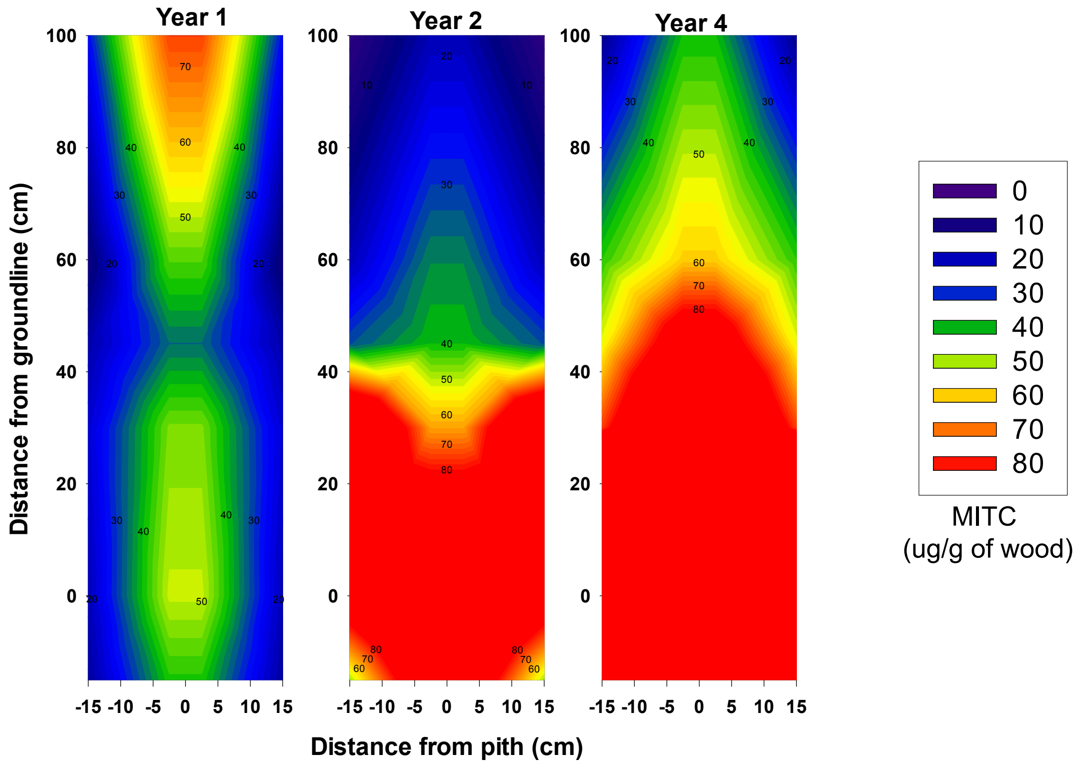


Figure I-4. Maps showing relative levels of MITC in Douglas-fir poles 1 to 4 years after treatment with granular dazomet in plastic tubes.

decay fungi in the poles make it difficult to discern an appreciable difference in performance at the 5 year point.

4. MITC Content of Residual Dazomet in Treatment Holes

Dazomet has been used for internal treatment of decay in wood poles for over a decade. This fumigant decomposes to produce a variety of volatile and non-volatile products, but the most important in terms of fungal control is methylisothiocyanate (MITC) (Forsyth and Morrell, 1992, 1993, 1995). MITC is also a decomposition product of metam sodium and is available in highly concentrated form (sold as MITC-FUME) (Morrell and Corden, 1986; Jin and Morrell, 1997; Morrell, 1996).

One of the more attractive features of dazomet is that the dry powder or granules are relatively stable, only producing MITC in the presence of moisture. This makes it easy to apply and control. While dazomet decomposes in the presence of moisture, the decomposition rate can be slow under some conditions. A number of approaches have been explored for enhancing decomposition (Forsyth and Morrell, 1992). Among the most effective approaches is to add various amounts of copper. Copper sulfate was originally used as the accelerant, but subsequent trials showed that copper naphthenate also accelerated decomposition as did a number of other compounds (Forsyth et al., 1998). Labels for dazomet application to poles include language allowing simultaneous application of copper naphthenate as an accelerant and this has been standard practice

Table I-3. Percentages of increment cores removed from Douglas-fir poles 1 to 5 years after application of dazomet in granular form alone or the same system in plastic or paper tubes that contained either decay or non-decay fungi.

Treatment	Dosage (g/pole)	Supple-ment	Years after treatment	Height above Groundline (cm) -15	0	30	45	60	90
Granular	210	CuNaph	1	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{7}	0 ^{7}	0 ^{0}
			2	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{7}	0 ^{7}	0 ^{0}
			3	0 ^{0}	0 ^{0}	0 ^{20}	0 ^{0}	0 ^{0}	0 ^{13}
			5	0 ^{0}	7 ^{0}	0 ^{0}	0 ^{0}	0 ^{13}	0 ^{0}
		None	1	0 ^{7}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{7}	0 ^{0}
			2	0 ^{0}	0 ^{0}	0 ^{7}	0 ^{7}	0 ^{0}	0 ^{0}
			3	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{7}	0 ^{7}	0 ^{13}
			5	0 ^{13}	0 ^{7}	0 ^{13}	0 ^{13}	0 ^{13}	0 ^{0}
Paper Tube	180	CuNaph	1	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{0}
			2	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{7}
			3	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{13}
			5	0 ^{7}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
		None	1	0 ^{0}	0 ^{13}	0 ^{13}	0 ^{0}	0 ^{7}	0 ^{0}
			2	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
			3	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{7}	0 ^{7}	0 ^{0}
			5	0 ^{0}	0 ^{13}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
Plastic Tube	103	CuNaph	1	0 ^{11}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
			2	0 ^{0}	0 ^{0}	0 ^{6}	0 ^{0}	0 ^{0}	0 ^{6}
			4	0 ^{0}	0 ^{0}	0 ^{0}	11 ^{11}	0 ^{0}	0 ^{0}
Control	0	None	1	0 ^{7}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
			2	0 ^{7}	0 ^{20}	0 ^{13}	0 ^{13}	0 ^{7}	0 ^{0}
			3	0 ^{7}	0 ^{13}	0 ^{13}	0 ^{13}	0 ^{0}	0 ^{13}
			5	0 ^{67}	0 ^{60}	7 ^{60}	0 ^{80}	7 ^{40}	7 ^{53}

among many utilities.

Field trials have shown that dazomet will decompose without an accelerant; however, it takes far longer to reach fungitoxic levels in the wood (Forsyth et al.,1998), and this is likely to be particularly true in poles in drier climates. This makes the use of an accelerant critical where moisture levels are likely to be limiting or, at least, more variable.

While dazomet is widely used across the U.S., one question that has arisen with the use of this chemical is how to retreat poles during regular re-inspection. Many utilities are now approaching the end of their first 10 year inspection cycle and will be revisiting poles that originally received dazomet. In some instances, inspectors are finding considerable quantities of granular material in the original treatment holes, particularly in drier regions. This has raised questions about what, if anything, should be done with this material and, whether additional dazomet should be added to “replenish” the protection. The normal recommendation would be to remove the plugs, check to make sure that any voids have not expanded and add new chemical (Morrell, 1996). There are also concerns about the nature of the residual material, which could be non-decomposed dazomet or, perhaps, decomposition residue such as elemental sulfur. Residual dazomet could be useful because subsequent inspectors could easily add dazomet plus more accelerant to reinitiate decomposition, but the accumulation of decomposition products in the hole might eventually require some type of cleaning or re-boring to create space for new dazomet. The inpact of residual dazomet or its decomposition products or retreatment is under study.

In order to address these issues, the following study was undertaken. Poles that had received dazomet were identified in Oregon and Arizona. The eight Oregon poles had been part of an initial field study established in 1993 evaluating the effect of copper sulfate on dazomet performance. Douglas-fir transmission poles (420 to 510 mm in diameter) in a line located near Corvallis, Oregon were selected for the test. The poles were American National Standard Institute Standard 05.1 Class 1 and 2 twenty-one meter long poles that had been in service for 10-15 years at the time of the test.

Three steeply angled holes (20 mm in diameter by 460 m long) were drilled in each pole beginning at groundline and moving upward at 150 mm increments and around 120 degrees. The poles were treated with either 200 or 400 g of dazomet with or without 1% copper sulfate (w/w). The dosages were premixed and evenly distributed among the three treatment holes. An additional set of poles was treated with 500 ml of 40% sodium n-methyl dithiocarbamate also distributed among three holes at the same locations as those drilled for the dazomet treatments. The treatment holes were plugged with tight-fitting wood dowels.

This test represented a highly controlled study where all the dosages had been weighed and pre-mixed prior to application. The site received an average of 1.4 m of rainfall per year, primarily between October and May, with warm dry summers. Previous studies of other poles in the region indicated that moisture contents within 0.6 m of the groundline are well above the fiber saturation point during the winter. The poles were regularly assessed for MITC content over a 15 year period, at which point there was little evidence of residual MITC in the wood.

The other six poles were located near Phoenix, Arizona and had been commercially treated in 2002 or 2003 with dazomet and presumably copper naphthenate, the most commonly used accelerant. There was little information on the exact amounts applied to each of these poles and no effort was made to determine MITC content in the wood.

Residual dazomet was removed from a treatment hole using a stainless steel spatula. The residual dazomet in the upper 25 mm of each hole was mixed and a subsample was removed. This material was placed in a glass vial and sealed with a Teflon lined cap. The material was returned to the lab at OSU and refrigerated until analyzed.

The dazomet analysis was based on a method by Petanovska-Ilievska and Vodeb (2002) using an acetonitrile/water mixture. The method used in the current study was modified by using a C18 column and adding a small amount of formic acid to the mobile phase.

HPLC Method: A Shimadzu Prominance HPLC equipped with an auto sampler and diode array detector was operated under the following conditions:

Flow rate = 1.0 ml/min

Column: Alltech ODS-3, 150mm by 4.6 mm held at 35°C.

Isocratic elution:

Solvent A = 10% Acetonitrile; 90% of 0.1% v formic Acid

Solvent B = 100% Acetonitrile

1-15 min. 30 % B

15-20 min 90% B

Injection volume: 1 uL

Detector range: 190-400 nm

Dazomet eluted at 3.4 minutes and MITC eluted at 7.3 minutes under these conditions.

Standards: A stock solution of dazomet was prepared by dissolving approximately 50 mg (nearest 0.1 mg) of UltraFume in 20 mL of acetonitrile (ACN). Standards (1, 5, 10, 20 and 50 ug/ml) were prepared by serial dilution of the stock solution in acetonitrile.

Samples: Between 0.1-0.5 g of the residual material was weighed (nearest 0.1 mg) and dissolved in 20 mL ACN in 20 mL glass vials. The samples collected in Arizona appeared dry while those from Oregon appeared damp with condensation appearing on the sidewalls of the initial collection vials. Photographs were taken of each dazomet sample. Many of the samples contained ACN-insoluble particles that appeared to be soil or wood fibers. Samples were further diluted 1:1000 and filtered through a 0.45 um by 13 mm nylon filter prior to analysis to remove particulate that might contaminate the column.

Method validation and quality control: Dazomet and MITC peaks were identified based on comparison of retention times with known standards. In addition, the absorbance spectra of MITC and dazomet were compared with published absorbance spectra data.

Standards were injected after every 10 samples and the response factor drift was found to be less than 1%.

Dazomet stability in ACN was assessed by analyzing a standard prepared in November of 2010 and comparing these results with those from freshly prepared standards. The response factor of the six month old standard varied by less than 1% from the freshly prepared standards suggesting the dazomet was stable for up to six months. The stability of dazomet in ACN with water or other compounds present has not been evaluated. Therefore, all the samples were freshly prepared prior to HPLC analysis.

Residue Analysis: Dazomet levels in the residues collected from Oregon 17 years after treatment ranged from 0 to 33.5%, with an average residual per hole of 5.6 % dazomet (Table I-4). Only 3 of 13 samples contained no dazomet, suggesting that dazomet remains available for a long period. Photos of the residues removed from the poles show a darkened material that resembled soil (Table I-5). Dazomet content did not appear to vary consistently with height above groundline in

Table I-4. Dazomet content in residues removed from treatment holes 7 to 17 years after application of dazomet powder with or without an accelerant.

Location	Distance Above Groundline (mm)	Residual Dazomet Content (%)	
		Range	Mean (SD)
Oregon	0	1.0 to 14.7	4.3 (5.8)
	150-200	3.5 to 33.5	18.5 (21.2)
	300	0	0
	450	0 to 9.9	3.6 (4.4)
Arizona	0	75.5 to 93.0	84.5 (7.8)
	150-200	13.3 to 93.2	66.4 (32.2)
	300-450	70.8 to 97.0	83.6 (10.7)

these poles. The lack of dazomet in the residue was consistent with separate analyses of wood samples for MITC, the primary decomposition product of dazomet. These results indicated little evidence of MITC suggesting that dazomet was no longer decomposing at a rate sufficient to replenish MITC diffusing from the wood.

Dazomet contents in the residues removed from poles treated in 2002 or 2003 in Arizona were generally much higher in all poles and at all heights (Table I-5). The residue in these poles was generally pale yellow to white and closely resembled the color of the original chemical, although there were exceptions where the residue was slightly darker indicating that color may be a poor indicator of dazomet quality. Some of this color may be caused by intrusion of the oil borne preservative into the treatment hole. Dazomet content of samples removed from the groundline ranged from 76.9 to 93 % (Mean 84.5 +/-7.8%), indicating that very little decomposition had occurred. Dazomet contents in residues from holes 150 to 200 mm above the groundline ranged from 13.3 to 93.2 % (Mean 66.4 +/- 32.2 %), while those 300 to 450 mm above groundline contained 70.8 to 97 % (Mean 83.6 +/-10.7 %) dazomet. Ten of 14 samples contained 80 % or more dazomet, suggesting that the majority of the material originally applied to the poles remained in its original form. These findings would be consistent with the appearance of the residues are are very different from the poles in a wetter climate.

As noted, dazomet has been used for over a decade and is generally applied with an accelerant. The accelerant is presumed to be especially important in drier areas, where pole moisture is likely to be present at lower levels and, perhaps in more variable distribution patterns that might reduce the likelihood that a treatment hole would be in a wet area. The accelerant may help overcome this problem by stimulating dazomet decomposition. Analyses of samples removed from the Arizona poles suggested that the accelerant, if applied, did not appreciably improve decomposition. This suggests a need for a reexamination of using dazomet in dry climates.

The results have a number of implications for current and future dazomet use. The current practice of applying dazomet to holes drilled above the groundline should be reassessed by individual utilities depending on the climatic conditions in their service territory. Utilities in most of the coun-

Table I-5a. Residual dazomet content and appearance of residues removed from Douglas-fir poles in Arizona 6 or 7 years after treatment with dazomet.

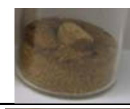
Location and pole #	Treatment Year	Treatment	Ht above GL (mm)	Residual Dazomet (% by weight)	Appearance of residue
Arizona 101	2003	UltraFume	150	13.3	
			300	97.0	
Arizona 102	2003	UltraFume	0	76.9	
			150	59.6	
			300	82.6	
Arizona 103	2003	UltraFume	0	93.0	
Arizona 104	2002	UltraFume	0	89.2	
			200	93.2	
Arizona 105	2002	UltraFume	75	75.5	
			175	83.4	
			400	83.9	
Arizona 106	not recorded	UltraFume	0	87.9	
			150	82.6	
			300	70.8	

Table I-5b. Residual dazomet content and appearance of residues removed from Douglas-fir poles in Oregon 17 years after treatment with dazomet with or without an accelerant.

Location and pole #	Treatment Year	Treatment	Ht above GL (mm)	Residual Dazomet (% by weight)	Appearance of residue
Oregon 12	1993	400g Dazomet +1% $CuSO^4$	0	2.0	
			350	0.0	
Oregon 13	1993	400g Dazomet +1% $CuSO^4$	0	1.1	
			380	0.0	
Oregon 19	1993	400g Dazomet	0	1.0	
			450	2.7	
Oregon 20	1993	400g Dazomet	0	2.8	
			200	33.5	
Oregon 24	1993	200g Dazomet +1% $CuSO^4$	75	3.5	
			450	1.6	
Oregon 25	1993	200g Dazomet +1% $CuSO^4$	300	not enough sample to measure	
			450	0.0	
Oregon 26	1993	200g Dazomet	0	14.7	
Oregon 27	1993	200g Dazomet	450	9.9	

try should not be concerned because the steep slope of the treatment holes drilled above ground ensures that most of the dazomet will be placed in an area where the wood is likely to be wet enough for decomposition to proceed. Utilities in drier regions need to reconsider their application pattern to avoid treatment holes above the groundline and, instead, place their holes beginning at groundline and moving downward. This increases the likelihood that the dazomet will be placed in wetter wood where it will be most effective. This will, however, require some excavation to allow treatment holes to be drilled below groundline and add to the cost of inspection. The alternative would be to drill all the treatment holes as close to the groundline as possible and this might have structural implications, especially in distribution poles where the maximum stresses are at or near the groundline.

When inspectors begin a new treatment cycle, they should examine the residues in treatment holes to determine the degree of decomposition. This need not be done for every pole, but a population of poles should be examined to determine how much, if any, of the original dazomet decomposed.The process should be geared toward adding large amounts of new dazomet or smaller amounts coupled with more accelerant. Residues that appear bright white or yellow to white are likely to contain high levels of non-decomposed dazomet. Adding some additional dazomet along with more accelerant is likely to rei-nitiate the decomposition process and provide renewed MITC generation. However, this premise has not been tested and further trials are planned to more fully understand the long term characteristics of dazomet decomposition in drier climates. Alternately, it may be more practical to use fumigants that are less dependant on moisture for decomposition.

The results also highlight the need for further assessment of dazomet behavior in drier climates to ensure that this chemical is suitable for these environments and is applied in the most effective manner. Questions to answer include:

1. What is the potential for residual dazomet at various exposure periods to further decompose to MITC?
2. How effective are copper based accelerants when applied under currently approved methods in wet and dry exposure conditions (i.e. are accelerants needed in wet climates and are accelerants effective in dry climates)?
3. Can visual inspection of residual dazomet be an effective tool in assessing remaining life cycle?
4. Will adding additional dazomet along with more copper accelerant re-initiate the decomposition process and provide renewed MITC generation?

5. Potential Substitutes for Copper Naphthenate as a Dazomet Accelerant

Dazomet was first evaluated as a potential internal remedial treatment in the late 1970s. This compound decomposes in the presence of moisture to produce methylisothiocyanate (MITC) and a host of other sulfur based compounds. The initial tests of this chemical suggested that the decomposition rate was too slow to be of use and the system was dropped from testing. In the early 1980s, interest was renewed as we searched for more easily handled compounds for internal treatment. Extensive laboratory and field studies showed that dazomet decomposition could be accelerated by the addition of moisture and copper compounds (Forsyth and Morrell, 1992, 1993, 1995, Forsyth et al., 1998). Originally, copper sulfate was tested and proved to be an effective accelerant; however, since this compound was not registered as a pesticide for wood treatment, copper naphthenate was substituted. A number of field trials showed that MITC levels were consistently higher when copper naphthenate was added at the time of treatment and this procedure is a part of the various dazomet labels.

Copper naphthenate has a number of other uses as a wood preservative including initial treatment of wood, treatment of cuts and holes made in treated wood and as an over-the-counter wood preservative for consumer use. Overall, however, copper naphthenate is a relatively minor use preservative. Recently, the primary manufacturer of copper naphthenate (Merichem) announced that it would no longer produce this chemical and that it would cancel its EPA registrations. Although another company (Nisus) subsequently stepped in and announced that they would offer copper naphthenate, the process highlighted the fact that there was no alternative labeled dazomet accelerant for which test data were available. In order to fill this data gap, the following tests were performed.

A test procedure roughly based upon a previous study was used to evaluate the effects of accelerants on dazomet decomposition (Morrell, 1994). Douglas-fir sawdust (0.5 g) was placed into 50 ml glass vials equipped with two-part lids with a PFTE (Teflon) lined septum and 0.25 ml of water was added to half of the vials. The vials were then capped and stored for 2 days at room temperature to allow the wood moisture content to stabilize. Dazomet (0.1 g) was weighed into separate 8 ml vials which were tightly capped until needed. At the start of an experiment, one dazomet vial was emptied into a 50 ml vial and 0.05 mL of a given accelerant was pipetted into the vial, then the vial was sealed and incubated at room temperature for 24 or 48 hours. The potential accelerants assessed were copper sulfate, CuBor, copper-8-quinolinolate, and sodium hydroxide (Table I-6). Controls included no additive as well as copper naphthenate (1% Cu) in

Table I-6. Accelerants evaluated for their ability to enhance decomposition of dazomet to methylisothiocyanate.

Accelerant	Active ingredient	Concentrations tested (% Cu)	Source	EPA registration or CAS #
Copper naphthenate	Copper naphthenate	1	Tenino (Copper Care Wood Preservatives Inc)	EPA# 71992-2-54471
Copper sulfate	Copper sulfate	1	VWR Inc.	CAS# 7758-99-8
CuBor	Copper hydroxide/ boron	1	Copper Care Wood Preservatives Inc.	EPA# 54471-10
Q8 Log Oil	Copper-8-quinolinolate	0.675	CTA Products Group	CAS # 10380-28-6
2% Cu solution	Copper	1 and 2	Osmose Inc.	
Kodiak	Copper hydroxide	1 and 10	ISK Biocides Inc.	CAS# 20427-59-2
Sodium hydroxide	Sodium hydroxide		VWR Inc.	CAS# 1310-73-2

mineral spirits.

After each incubation time, 5 ml of ethyl acetate was added by syringe through the septum (using a second needle to release pressure as the ethyl acetate was added) of each of three vials per treatment. The vials were gently rolled to mix the contents and capture any MITC on the glass walls. The vials were left for 6 hours at room temperature, then 1 ml of the extract was removed and analyzed for MITC content by gas chromatography.

MITC levels tended to vary widely between replicates in a given treatment. This is likely a function of a number of factors including mixing of samples and interactions between wood, moisture and the accelerants. Overall MITC levels also varied between trials and these results are consistent with previous tests using this method. As a result, while the actual MITC levels are presented here, it is more useful to examine the relative differences between treatments to assess accelerant performance.

In the initial trial, MITC levels were relatively low after 24 hours, but rose sharply after an additional 24 hours (Table I-7). The presence of moisture had no effect on MITC levels after 24 hours, and a somewhat variable effect after an additional 24 hours of incubation.

MITC levels were lower after 24 hours in both the dry and wet wood samples with no accelerant, no wood, or those amended with copper-8. The copper-8 amended samples contained the lowest MITC levels in dry and wet wood after 24 hours, and magnitude of the standard deviations suggests that these levels did not differ markedly from those for the controls. MITC levels in the presence of copper-8 did increase in both dry and wet wood after 48 hours, but the levels were still lower than those for the other accelerants tested. The reduced effect of copper-8 compared with either of the other copper accelerants may occur because the coordination between the copper and the quinolines makes the copper less available for interaction with dazomet. The other possible alternative copper compounds tested appeared to produce MITC release rates that were similar to those produced by copper naphthenate in both wet and dry wood. The CuBor contains both copper hydroxide and boron although it appears that the presence of the boron did not improve dazomet decomposition compared to the copper naphthenate.

One problem with the initial trial was a tendency for the dazomet granules to fall to the bottom of the tube and out of contact with the wood. This reduced the potential interactions between the wood, any moisture present and the dazomet. This is important since a high percentage of the dazomet applied to a treatment hole is likely to be in contact with the wood surrounding the hole, creating more opportunity for interactions that enhance decomposition. Dazomet interaction with the wood in the second trial was improved by using smaller wood particles that were less likely to allow the dazomet to fall to the bottom of the vial. At the same time, the amount of accelerant added to the mixture was doubled to 0.1 ml to increase the potential for interaction. All of the other treatments and procedures in this trial were the same, except that a copper hydroxide solution (Kodiak) was added to the second test.

MITC levels in the second trial were much higher than those found earlier (Table I-8). This could reflect the change in wood particle size or the addition of twice as much accelerant. The addition of copper-8 produced slight improvements in MITC levels in both wet and dry wood, but neither

Table I-7 Effect of various accelerants on decomposition of dazomet to MITC in the presence of Douglas-fir sawdust either used dry or at 50 % moisture content.

Accelerant	Cu conc. (%)	Total MITC (ug)[a]			
		dry sawdust		wet sawdust	
		24 hours	48 hours	24 hours	48 hours
CuNaph	1	88 (7)	750 (87)	89 (8)	800 (150)
Cu8	0.0675	34 (29)	350 (50)	51 (2)	483 (29)
CuBor	1	103 (16)	1217 (275)	68 (7)	750 (132)
wood + dazomet control	0	58 (8)	0 0	58 (8)	200 (180)
no dazomet	0	0 (0)		0 (0)	
dazomet alone	0	46			

a. Numbers in parentheses represent one standard deviation from the mean of three replicates.

Table I-8 Effect of various accelerants on decomposition of dazomet to MITC in the presence of wet or dry Douglas-fir heartwood.

Accelerant	Cu conc. (%)	Total MITC (ug)[a]			
		dry sawdust		wet sawdust	
		24 hours	48 hours	24 hours	48 hours
CuNaph	1	944 (119)	693 (23)	979 (56)	755 (196)
Cu8	0.675	648 (123)	257 (37)	636 (114)	265 (65)
CuBor	1	1032 (68)	957 (9)	1064 (55)	1080 (66)
Kodiak	10	1110 (28)	1568 (178)	1138 (46)	2747 (533)
none	0	443 (245)	148 (14)	471 (206)	153 (4)

a. Numbers in parentheses represent one standard deviation from the mean of three replicates.

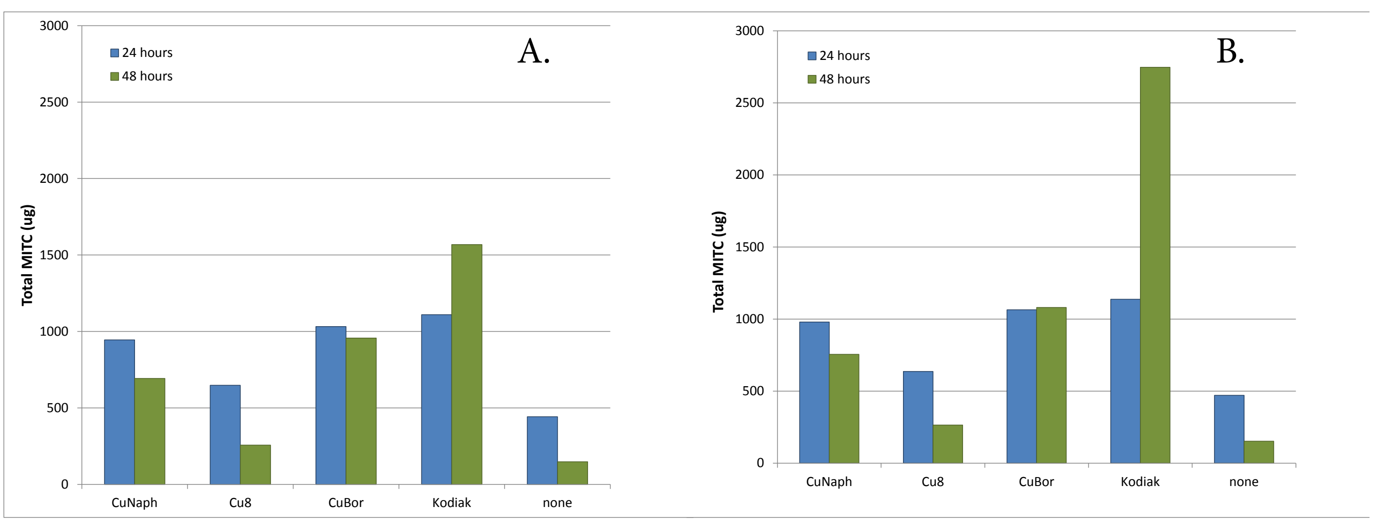


Figure I-5. Effect of accelerants and moisture content on release of MITC from dazomet mixed with Douglas-fir heartwood A. dry and B. at 50% MC and incubated at room temperature for 24 or 48 hours.

of these levels approached those found when copper naphthenate, CuBor or the Kodiak copper compounds were added to the mixture (Figure I-5). Moisture content again had little effect on release rate, which is surprising given the previous findings with dazomet. It is possible that the moisture level chosen (50 %) was not sufficient to produce a noticeable effect on decomposition.

One concern with this trial was that there might be variations in MITC level based upon when a sample was analyzed after collection. Since it takes several hours to process the collected samples, this could introduce error into the system if all the replicates from a given treatment were analyzed sequentially instead of being spaced across the entire analysis time. In order to assess this potential problem, samples from this experiment were ordered so that all the replicate # 1 samples were analyzed followed by the replicate # 2 samples and finally, the third replicates. The results were then plotted by replicate. There was an upward trend with time of analysis with the control, Kodiak, 1% CuNaph, and CuBor treatments in the 24 hour dry treatment and a slightly lower upward trend in the 24 hour wet samples (Figure I-6). The effect disappeared in the 48 hour samples from the dry vials except for the Kodiak accelerant. The effect was more variable in the wet samples at 48 hours, with upward trends on the 1% CuNaph and copper-8 and more variable

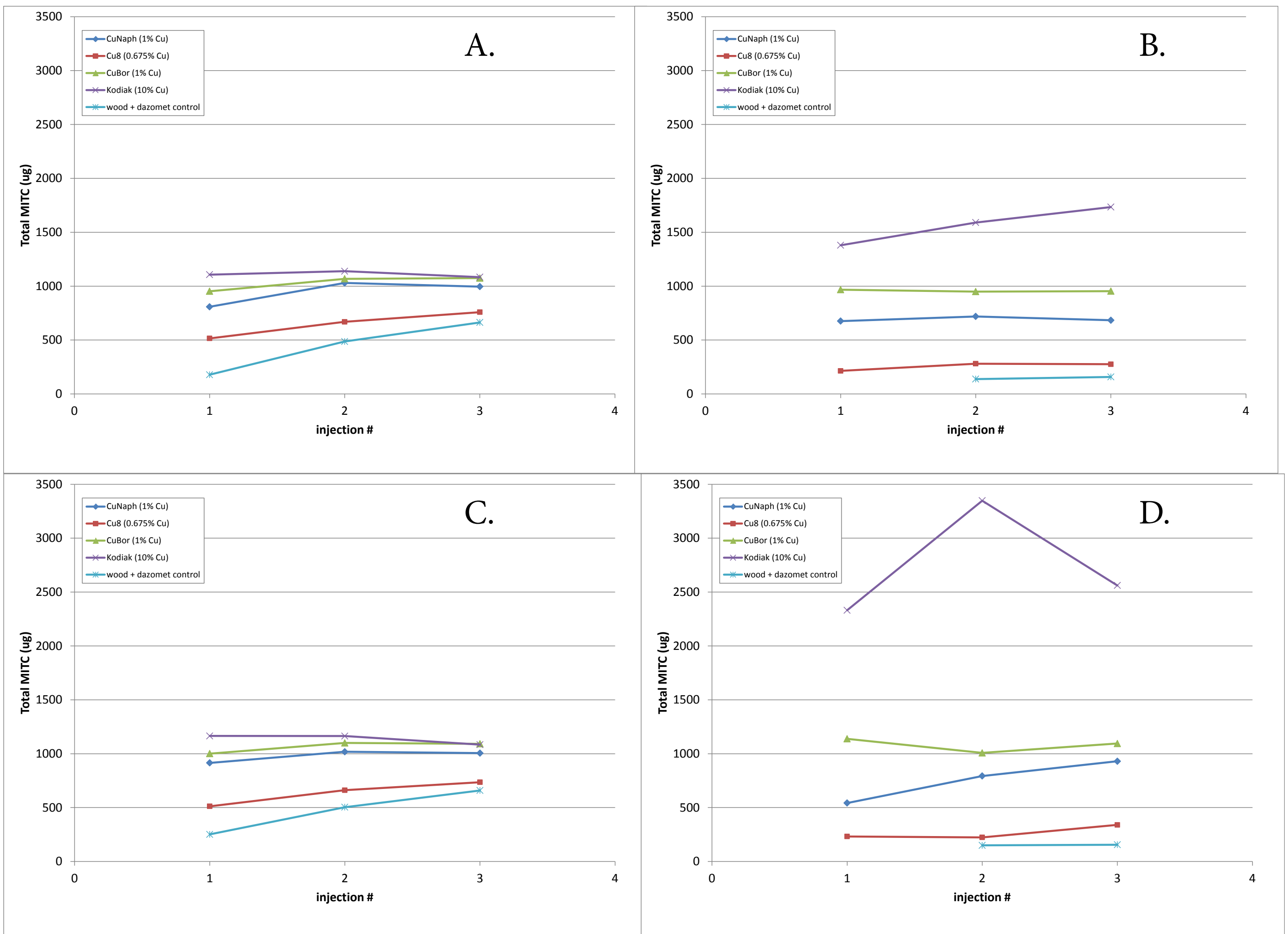


Figure I-6. MITC levels in replicate ethyl acetate extracts from vials containing dry A. 24 hour and B. 48 hour or wet C. 24 hour and D. 48 hour Douglas-fir sawdust with dazomet, and with or without an accelerant. The three injections were approximately 60 minutes apart.

effects on the other treatments. The results indicate that prolonged storage and concentrating analysis of a given treatment (i.e. analyzing them all at the same time) may bias the results using these procedures.

The final trial included all of the potential accelerants plus two new materials, a proprietary Cu solution and sodium hydroxide. The sodium hydroxide was included to determine if raising the wood pH might stimulate additional breakdown. All the remaining compounds were evaluated at 1% Cu but the proprietary Cu solution was also evaluated as supplied (2% Cu). Because of a sampling failure, only the 48 hour results were usable. All of the copper based accelerants except copper-8 were associated with marked increases in MITC levels after 48 hours of incubation (Table I-9, Figure I-7). The concentrated copper hydroxide (Kodiak) produced the highest MITC levels in wet wood; however, the increase in MITC level was not proportional to the 10-fold increase in copper. The addition of sodium hydroxide produced only a slight increase in MITC level that would not be worth the added chemical costs. The copper compounds, with the exception of copper-8, all uniformly increased the decomposition rate of dazomet to MITC. These results are promising because all of these compounds already have existing EPA registrations for application to wood making it much easier to obtain registrations for this application. Although the issue with copper naphthenate was resolved by the agreement by Nisus to begin offering this product, the results indicate that there are a number of alternatives that could be substituted for this compound with little or no loss in effectiveness if copper naphthenate becomes unavailable.

Table I-9 Effect of various accelerants on decomposition of dazomet to MITC in the presence of wet or dry Douglas-fir heartwood.

accelerant	Total MITC (ug)[a]		
	% Cu	dry	wet
1% CuNaph	1	520 (72)	566 (32)
50% CuBor	1	561 (51)	530 (98)
10% kodiak	1	503 (60)	528 (43)
50% Prop. Cu	1	521 (34)	571 (31)
CuSO4	1	506 (33)	477 (52)
100% Cu8	0.625	198 (19)	208 (14)
100% kodiak	10	618 (86)	976 (62)
100% Prop. Cu	2	617 (65)	739 (8)
NaOH	0	234 (19)	254 (43)
wood + dazomet control	0	174 (1)	182 (13)
no dazomet	0	1 (0)	0 (0)

a. Numbers in parentheses represent one standard deviation from the mean of three replicates.

B. Performance of Water Diffusible Preservatives as Internal Treatments

While fumigants have long been an important tool for utilities seeking to prolong the service lives of wood poles by limiting the extent of internal decay, some users have expressed concern about the risk of these chemicals. Water diffusible preservatives such as boron and fluoride have been developed as potentially less toxic alternatives to fumigants. (Table I-10) Boron has a long history of use as an initial treatment of freshly sawn lumber to prevent infestations by various species of powder post beetles in both Europe and New Zealand (Becker, 1976, Cockcroft and Levy, 1973; Dickenson et al., 1988; Dietz and Schmidt, 1988, Dirol, 1988, Edlund et al., 1983; Ruddick and Kundzewicz, 1992, Smith and Williams, 1967; Williams and Amburgey, 1987). This chemical has also been used more recently for treatment of lumber in Hawaii to limit attack by the Formosan subterranean termite. Boron is attractive as a preservative because it has exceptionally low toxicity to non-target organisms, especially humans, and because it has the ability to diffuse through wet wood. In principle, a decaying utility pole should be wet, particularly near the groundline and this moisture can provide the vehicle for boron to move from the point of application to wherever decay is occurring. Boron is available for remedial treatments in a number of forms, but the most

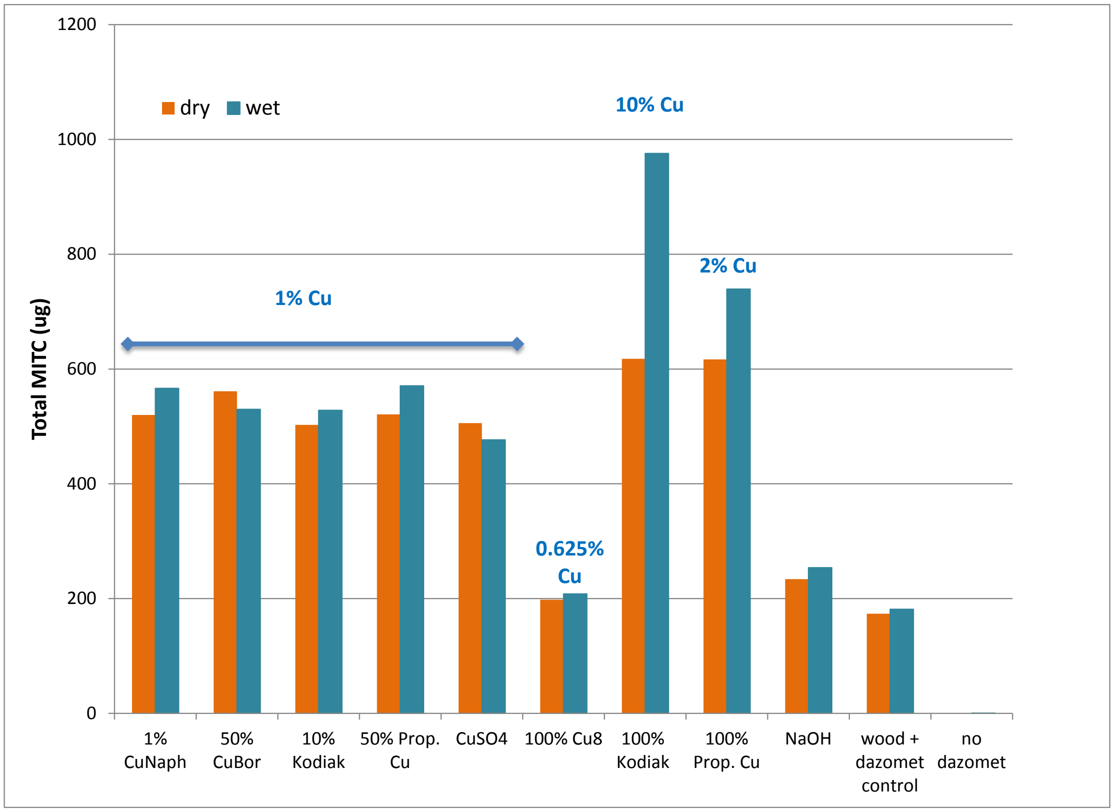


Figure I-7. Effect of accelerants on dazomet decomposition to MITC in the presence of ground Douglas-fir wood and water.

Table I-10. Characteristics of diffusible internal remedial treatments for wood poles

Trade Name	Active Ingredient	Conc. (%)	Toxicity (LD_{50})	Manufacturer
Impel Rods Bor8-Rods	boron	100	>2000 mg/kg	Pole Care Inc. Osmose Utilities Services, Inc.
Pole Saver Rods	boron/fluoride	58/24	>2000 mg/kg	Preschem Ltd.
Flurods	fluoride	98	105 mg/kg	Osmose Utilities Services, Inc.
Cobra-Rods	boron/copper	97/3	10000 mg/kg oral 5000 mg/kg dermal	Genics Inc.

popular are fused borate rods which come as either pure boron or boron plus copper (Morrell et al., 1992, 1995; Morrell and Schneider, 1995; Schneider et al., 1993). These rods are produced by heating boron to its molten state, then pouring the molten boron into a mold. The cooled boron rods are easily handled and applied. In theory, the boron is released as the rods come in contact with water.

Fluoride has also been used in a variety of preservative formulations going back to the 1930's when fluor-chrome-arsenic-phenol was employed as an initial treatment. Fluoride, in rod form, has long been used to treat the area under tie plates in railroad tracks and has been used as a dip-diffusion treatment in Europe. Fluoride can be corrosive to metals, although this should not be a problem in the groundline area. It might be advisable to avoid application near iron bases attachments. Sodium fluoride is also formed into rods for application, although fluoride rods are less dense than boron rods.

Both of these chemicals have been available for remedial treatments for several decades, but widespread use of these systems has only occurred in the last decade and most of this application has occurred in Europe.

1. Performance of Copper Amended Fused Boron Rods

Date Established:	November 2001
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta and Douglas-fir creosote
Circumference @ GL (avg., max., min.)	78, 102, 66 cm

The ability of boron and copper to move from fused rods was assessed by drilling holes perpendicular to the grain in pentachlorophenol treated Douglas-fir poles beginning at the groundline and then moving upward 150 mm and either 90 or 120 degrees around the pole. The poles were treated with either 4 or 8 copper/boron rods or 4 boron rods. The holes were then plugged with tight fitting plastic plugs. Chemical movement was assessed 1, 2, 3, 5, 7 and 9 years after treatment by removing increment cores from locations 150 mm below groundline as well as at groundline, and 300 or 900 mm above this zone. The outer, 25 mm of treated shell was discarded, and the core was divided into inner and outer halves. The cores from a given zone on each set of poles were combined and then ground to pass a 20 mesh screen. This ground wood was hot water extracted prior to being analyzed according to procedures described in American Wood Protection Standard A2 Method 16, the Azomethine-H assay (AWPA, 2004). The results were expressed on a kg of boric acid equivalent (BAE)/cubic meter of wood basis. Previous studies in our laboratory indicate that the threshold for protection of Douglas-fir heartwood against internal decay is approximately 0.5 kg/m^3 BAE (Freitag and Morrell 2005).

Boron levels in pole sections were below the protective threshold level 1 year after treatment, but then gradually increased over the threshold in the next 2 years (Figures I-8 & I-9). Treatment levels appeared to drop slightly between 5 and 7 years after treatment, although they remained above the threshold in many cases. Boron levels tended to be highest at groundline and 150 mm below that zone, reflecting the tendency for the wood to be wetter in these regions. Moisture is

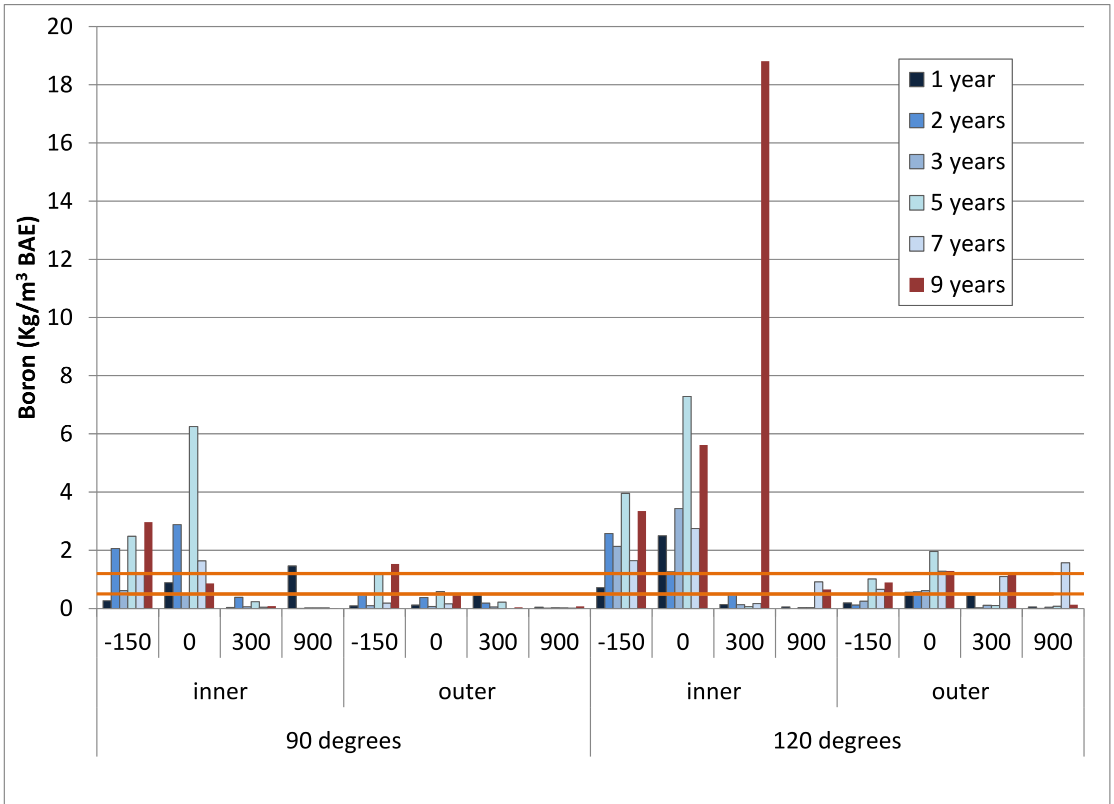


Figure I-8. Boron levels at selected locations above or below groundline in Douglas-fir poles 9 years after treatment with 4 boron/copper rods.

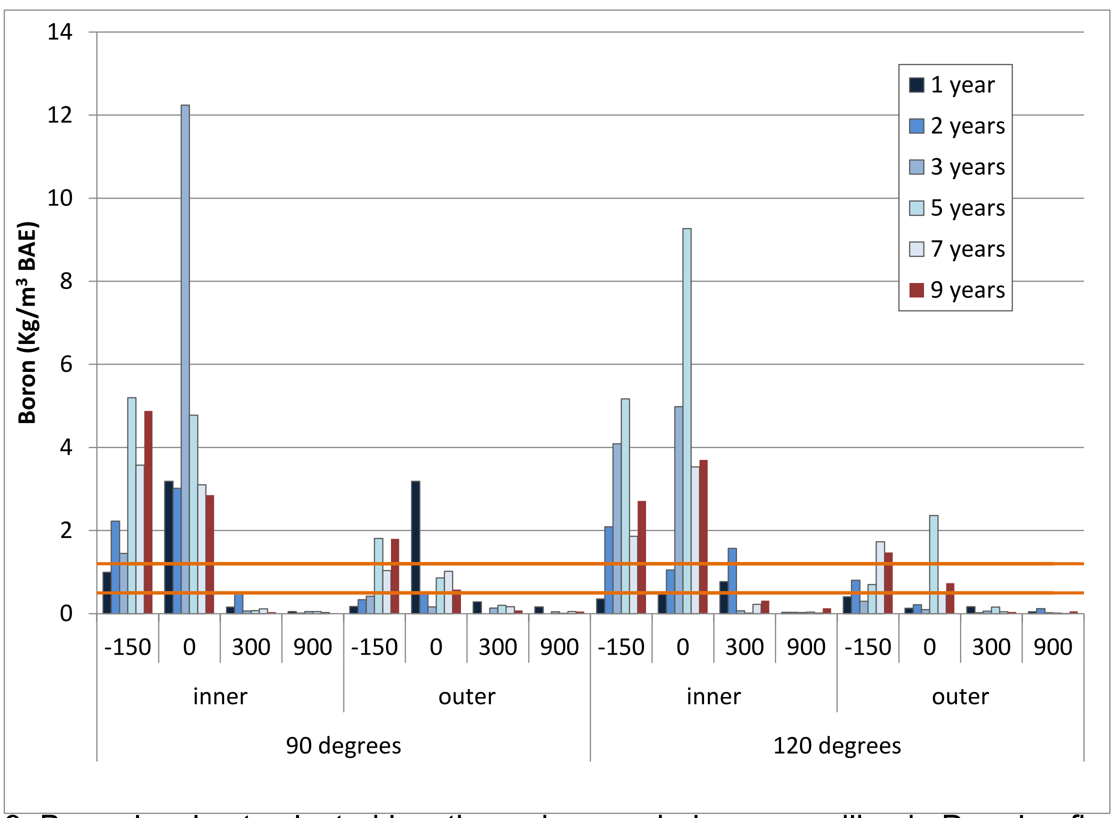


Figure I-9. Boron levels at selected locations above or below groundline in Douglas-fir poles 9 years after treatment with 4 boron rods.

obviously critical for boron movement. Boron levels also tended to be higher in the inner zones of increment cores, reflecting the positioning of the rods further inward in the treatment holes. Boron levels tended to be below the threshold 300 or 900 mm above groundline, reflecting the lower moisture regimes present in these zones. Boron levels in poles sampled 9 years after treatment rose sharply at a number of locations. In previous boron rod studies, we could equate these rises in boron level to an exceptionally wet year. Rainfall levels were normal for the year but the pattern did differ with rain continuing well into the end of June. Normally, rainfall would taper off sharply at the end of April and the wood would begin to dry. The prolonged wet period may have enhanced boron movement, although it is difficult to see how this would make a difference so far into the test when the rods have largely disintegrated.

Boron levels in poles receiving fused borate and fused borate plus copper rods appeared to be equally effective at establishing threshold levels in the application zone, suggesting that the copper in the latter system had little influence on either initial boron diffusion or subsequent retention in the wood.

Increasing the rod dosage from 4 to 8 rods per pole had only a slight effect on borate levels in the wood (Figure I-10). While boron levels in the wood did not double with the higher dosage, they did increase somewhat in the inner zone. More importantly, they appeared to be slightly more stable in terms of levels over time. Boron levels in the outer zone tended to be low over the entire test period. While there was some indication that boron levels might be slightly higher in the

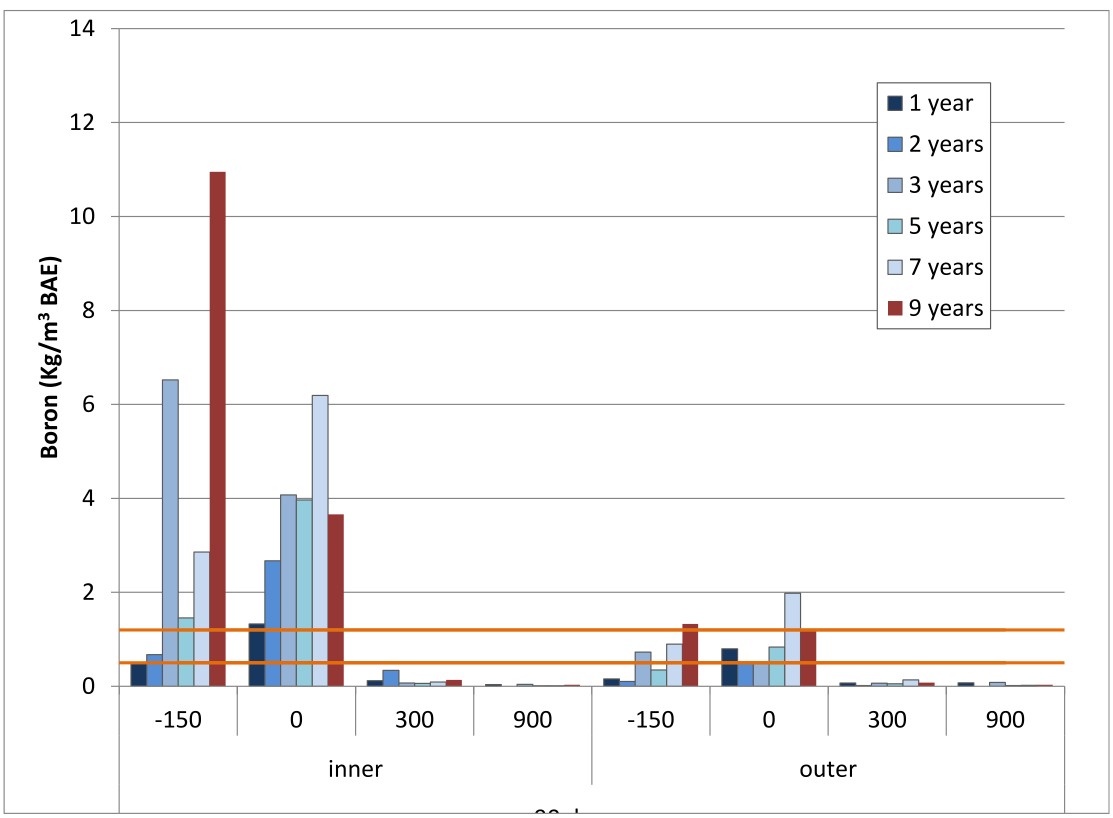


Figure I-10. Boron levels at selected locations above or below groundline in Douglas-fir poles 9 years after treatment with 8 boron/copper rods.

outer zones for poles receiving the higher dosage, these differences were slight and probably not meaningful in terms of wood protection.

Copper levels have been well below the protective threshold throughout the test. No copper was detected 7 years after treatment, while slight amounts were detected in year 9 in several locations. As with the boron data, this may reflect the wetter spring conditions at the test site (Figure I-11). While these levels have increased, they are still well below those required to provide any substantive wood protection. There are no established threshold levels for copper plus boron.

Culturing of increment cores removed from the poles revealed the presence of some decay fungi in the poles, especially at groundline (Table I-11). Some decay fungi were isolated 300 or 900 mm above groundline, however, the overall low levels of boron in these zones suggest that the rod application would have little or no effect on fungal colonization at these distances above the groundline. Fungal isolations near groundline tended to be more prevalent in poles receiving 4 fused borate rods using either the 90 or 120 degree spacing, although the isolation levels were very low (10 % of cores sampled). No decay fungi were isolated at or below the groundline for poles treated with either 4 or 8 fused borate/ copper rods. Given the very low levels of copper associated with these treatments, it is unclear why there is any substantial difference in isolation frequency. Further assessment will be needed to determine if copper enhances performance as boron levels decline.

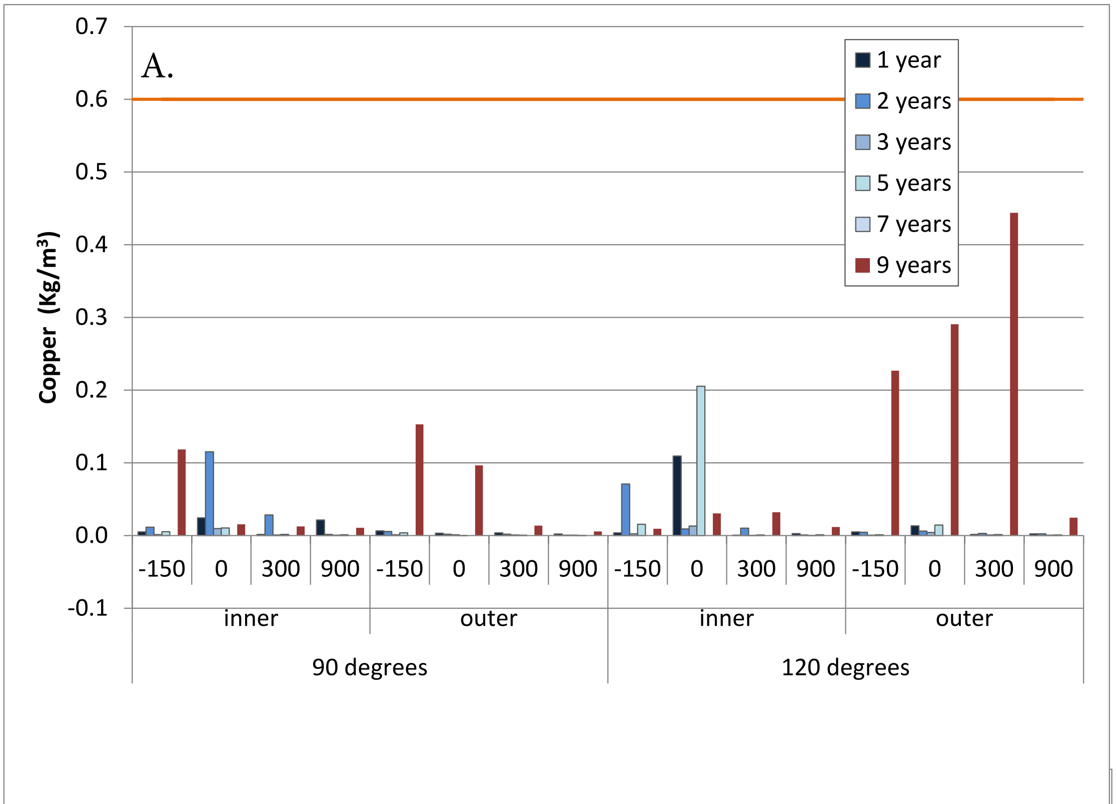
The results indicate that the boron from fused borate and fused borate plus copper rods is diffusing into Douglas-fir heartwood at rates capable of protecting against fungal attack. While there are some slight differences in chemical levels and in the presence of decay fungi, the results suggest that the systems provide similar protection.

2. Performance of Fused Borate Rods in Internal Groundline Treatments of Douglas-fir Poles

Thirty pentachlorophenol treated Douglas-fir poles (283-364 mm in diameter by 2 m long) were set to a depth of 0.6 m at the Peavy Arboretum test site. Three 22.5 mm diameter holes were drilled perpendicular to the grain beginning at groundline and moving around the pole 120 degrees and upward 150 mm. Each hole received either 1 or 2 boron rods (180 or 360 g of rod, respectively). The holes were then plugged with tight fitting wooden dowels. Each treatment was replicated on 10 poles.

The poles were sampled 1, 3, 4, 5, 7, 10, 12 and 15 years after treatment by removing increment cores from sites located 15 cm below groundline as well as 7.5, 22.5, 45, and 60 cm above the groundline. The cores were divided into inner and outer segments which were ground to pass a 20 mesh screen, then extracted and analyzed for boron using the Azomethine H method. Boron levels were expressed on a kg/m^3 of boron as boric acid equivalent (BAE). Previous studies in our laboratory indicate that the threshold for protection of Douglas-fir heartwood against internal decay is approximately 0.5 kg/m^3 BAE.

Boron levels remained above threshold at groundline for the entire 15 year sampling period. This



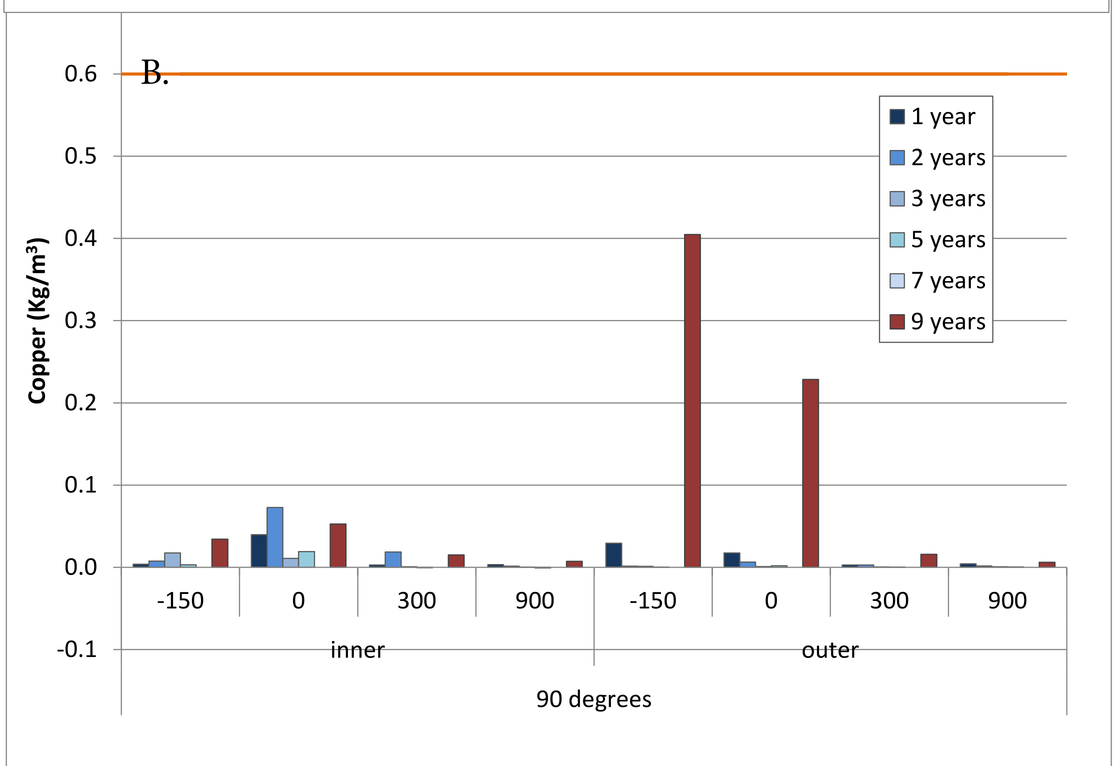


Figure I-11. Copper levels at selected locations above or below groundline in Douglas-fir poles 9 years after treatment with A. 4 or B. 8 boron/copper rods.

Table I-11. Fungi ($\text{decay}^{\text{non-decay}}$) isolated from Douglas-fir poles 1 to 9 years after treatment with fused boron or copper/boron rods applied in varying dosages and patterns.

Treatment	Rod Spacing	Year Sampled	Isolation Frequency (%)			
			-150 mm	0 mm	300 mm	900 mm
4 copper/boron rods	90°	1	0^{7}	0^{10}	0^{20}	0^{7}
		2	0^{33}	0^{20}	0^{10}	7^{0}
		3	0^{27}	0^{10}	0^{0}	7^{13}
		5	0^{33}	0^{30}	20^{0}	7^{13}
		7	0^{44}	0^{14}	20^{20}	0^{11}
		9	0^{38}	0^{0}	0^{25}	0^{14}
4 copper/boron rods	120°	1	0^{40}	0^{0}	0^{0}	0^{13}
		2	0^{33}	0^{20}	0^{0}	0^{0}
		3	0^{47}	0^{30}	0^{0}	7^{7}
		5	0^{40}	0^{10}	0^{10}	0^{0}
		7	0^{9}	0^{14}	0^{13}	29^{0}
		9	0^{13}	0^{25}	0^{0}	31^{19}
4 boron rods	90°	1	0^{7}	0^{10}	0^{0}	0^{0}
		2	0^{20}	10^{10}	0^{0}	7^{0}
		3	0^{40}	10^{50}	0^{0}	13^{7}
		5	7^{27}	10^{20}	10^{0}	13^{0}
		7	10^{40}	0^{33}	0^{0}	0^{0}
		9	0^{14}	0^{0}	0^{18}	0^{0}
4 boron rods	120°	1	0^{0}	0^{0}	0^{0}	0^{20}
		2	0^{20}	10^{10}	0^{0}	7^{0}
		3	0^{40}	10^{50}	0^{0}	13^{7}
		5	0^{47}	10^{30}	0^{10}	7^{0}
		7	0^{0}	0^{50}	0^{0}	0^{0}
		9	0^{0}	0^{0}	0^{0}	7^{0}
8 copper/boron rods	90°	1	0^{0}	0^{0}	0^{0}	0^{7}
		2	0^{0}	0^{0}	0^{20}	0^{7}
		3	0^{27}	0^{10}	0^{0}	0^{0}
		5	0^{33}	0^{0}	0^{0}	13^{33}
		7	0^{0}	0^{0}	0^{0}	0^{0}
		9	0^{25}	0^{0}	0^{0}	0^{7}

test is now completed and showed that boron remained in the poles at protective levels for 10 or more years, although it did require slightly longer times to reach effective levels in the wood after application.

3. Effect of Glycol on Movement of Boron from Fused Boron Rods

Date Established:	March 1995
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @ GL (avg., max., min.)	87, 99, 81 cm

While boron has been found to move with moisture through most pole species (Dickinson et al., 1988; Dietz and Schmidt, 1988; Dirol, 1988; Edlund et al., 1983; Ruddick and Kundzewicz, 1992), our initial field tests showed slower movement in the first year after application. One remedy to the initial slow movement that has been used in Europe has been the addition of glycol to the treatment holes. Glycol is believed to stimulate movement through dry wood that would normally not support diffusion (Edlund et al., 1983).

Pentachlorophenol treated Douglas-fir pole sections (259 to 315 mm in diameter by 2.1 m long) were set to a depth of 0.6 m in the ground at the Peavy Arboretum test site. The pole test site receives an average yearly precipitation of 1050 mm with 81% falling between October and March.

Four 19 mm diameter holes were drilled at a 45 $^{\circ}$ downward sloping angle in each pole, beginning 75 mm above the groundline, then moving 90 degrees around and up to 230, 300, and 450 mm above the groundline. An equal amount of boron (227 g BAE) was added to each pole, but was delivered in different combinations of boron, water, or glycol . The boron rods were 100 mm long by 12.7 mm in diameter and weighed 24.4 g each. An equal weight of boron rod composed of one whole rod and a portion of another, were placed in each hole followed by the appropriate liquid supplement or were left dry. The holes were then plugged with tight fitting wooden dowels. Each treatment was replicated on five poles.

The pole sections were sampled 1, 2, 3, 5, 7, 10, 12 and 15 years after treatment by removing two increment cores 180 degrees apart from 300 mm below the groundline, and cores from three equidistant locations around the pole 150 and 300 mm above the groundline. The treated portion of the cores was discarded, then the remainder of each core was divided into zones corresponding to 0-50 (O), 51-100 (M), and 101-150 (I) mm from the edge of the treated zone. The zones from the same depth and height from a given treatment were combined and ground to pass a 20 mesh screen. The resulting sawdust was then extracted and analyzed using the Azomethine-H method.

The results indicate that adding glycol or water based boron to boron rods at the time of treatment resulted in much more rapid boron movement, thereby increasing the rate of fungal control. The additives also appeared to enhance boron longevity in the poles, providing an enhanced protective period in comparison to treatments with rods only.

As a result, supplemental applications in conjunction with boron rods should especially be considered where these formulations are being applied to actively decaying wood where considerable additional damage might occur while the boron diffuses from the rods into the surrounding wood.

This test was last sampled in 2010 and will be revisited in 2015.

4. Performance of Fluoride/Boron Rods in Douglas-fir Poles

Date Established:	August 1993
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @ GL (avg., max., min.)	80, 88, 74 cm

Fluoride/boron rods are used in Australia for remedial treatment of internal decay in Eucalyptus poles. Although not labeled for wood treatment in the U.S, these rods have potential for use in this country. The rods contain 24.3 % sodium fluoride and 58.2 % sodium octaborate tetrahydrate (Preschem, Ltd). The rods have a chalk-like appearance. In theory, the fluoride/boron mixture should take advantage of the properties of both chemicals which have relatively low toxicity and can move with moisture through the wood.

Pentachlorophenol treated Douglas-fir poles (235-275 mm in diameter by 3.6 m long) were set to a depth of 0.6 m and a series of three steeply sloping holes were drilled into each pole, beginning at groundline and moving upward 150 mm and around the pole 90 or 120 degrees. A total of 70.5 or 141 g of boron/fluoride rod (3 or 6 rods per pole) was equally distributed among the three holes which were plugged with tight fitting wooden dowels. Each treatment was replicated on five poles.

Chemical movement has assessed 1, 2, 3, 5, 7, 10, 12 and 15 years after treatment. The test was discontinued in 2008, but it showed that the boron moved well from these rods, while the fluoride movement was more variable. This likely reflected the lower levels of fluoride in the system. The results suggested that higher dosages of fluoride would be needed to produce toxic levels in the poles.

5. Performance of Sodium Fluoride Rods as Internal Treatments in Douglas-fir Poles

Date Established:	May 1995
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @ GL (avg., max., min.)	97, 97, 81 cm

Fluoride has a long history of use as a water diffusible wood preservative and was long an important component in Fluor-Chrome-Arsenic-Phenol as well as in many external preservative pastes (Becker, 1976). Like boron, fluoride has the ability to move with moisture, but a number of studies have suggested that it tends to remain at low levels in wood even under elevated leaching conditions. Fluoride has also long been used in rod form for protecting the areas under tie plates on railway sleepers (ties) from decay. These rods may also have some application for internal decay control in poles.

Fifteen pentachlorophenol treated Douglas-fir pole sections (259-307 mm in diameter by 2.4 m long) were set in the ground to a depth of 0.6 m at the Peavy Arboretum test site. Three 19 mm diameter by 200 mm long holes were drilled beginning at groundline and moving around the pole 120 degrees and upward 150 mm. Each hole received either one or two sodium fluoride rods. The holes were then plugged with tight fitting wooden dowels. Eight poles were treated with one rod per hole and seven poles were treated with two rods per hole. After 3 years, five of the poles were destructively sampled. The remaining five poles from each treatment will be sampled in subsequent years. They were not sampled this year.

C. Full Scale Field Trial of All Internal Remedial Treatments

Date Established:	March 2008
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @ GL (avg., max., min.)	102, 117, 86 cm

Over the past 3 decades, we have established numerous field trials to assess the efficacy of internal remedial treatments. Initially, these tests were primarily designed to assess liquid fumigants, but over time, we have also established a variety of tests of solid fumigants and water diffusible pastes and rods. The methodologies in these tests have often varied in terms of treatment pattern as well as the sampling patterns employed to assess chemical movement. While these differences seem minor, they can make it difficult to compare data from different trials.

We addressed this issue by establishing a single large scale test of all the EPA registered internal remedial treatments at our Corvallis test site (Table I-12).

Pentachlorophenol treated Douglas-fir pole stubs (280-300 mm in diameter by 2.1 m long) were set to a depth of 0.6 m. Three (for poles treated with diffusible rods) and four (for poles treated with fumigants) steeply sloping treatment holes (19 mm x 350 mm long) were drilled into the poles beginning at groundline and moving upward 150 mm and around the pole 120 degrees. The various remedial treatments were added to the holes at the recommended dosage for a pole of this diameter. The treatment holes were then plugged with removable plastic plugs. Copper naphthenate (2% Cu) was added to all dazomet treatments. The accelerant was poured onto the top of the dazomet in the treatment holes until the visible fumigant appeared to be saturated. No attempt was made to quantify the amount of copper naphthenate added to each treatment hole.

Chemical movement in the poles was assessed 18, 30 and 42 months after treatment by removing increment cores from three equidistant sites beginning 150 mm below ground, then 0, 300, 450, 600 mm above groundline. An additional height of 900 mm above groundline was sampled for the fumigant treated poles. The outer, preservative-treated shell was removed, and then the outer and inner 25 mm of each core was retained for chemical analysis using a method appropri-

Table I-12. Remedial treatments evaluated in Douglas-fir poles at the Peavy Arboretum test site.				
Product Name	Dosage/ pole	CuNaph (2% as Cu)	Common name	Active Ingredient
DuraFume	280 g	+	dazomet	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione
Super-Fume	280 g	+	dazomet	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione
UltraFume	280 g	+	dazomet	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione
Basamid	280 g	+	dazomet	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione
Basamid rods	264 g	+	dazomet	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione
MITC-FUME	120 g	-	methylisothiocya-nate	methylisothiocyanate
WoodFume	475 ml	-	metam sodium	Sodium N-methyldithiocarbamate
SMDC-Fume	475 ml	-	metam sodium	Sodium N-methyldithiocarbamate
Pol Fume	475 ml	-	metam sodium	Sodium N-methyldithiocarbamate
Chloropicrin	475 ml	-	chloropicrin	trichloronitromethane
Impel rods	238 g (345 g BAE)	-	boron rod	Anhydrous disodium octaborate
FLURODS	180 g	-	fluoride rod	sodium fluoride
PoleSaver rods	134 g	-	fluoride rod	disodium octaborate tetrahydrate, sodium fluoride

ate for the treatment. The fumigants were analyzed by gas chromatography. Chloropicrin was detected using an electron capture detector while the MITC based systems were analyzed using a flame-photometric detector. The remainder of each core was plated on malt extract agar and observed for fungal growth. Boron based systems were analyzed using the Azomethine-H method; while fluoride based systems were analyzed using neutron activation analysis.

In order to simplify the discussion, we will discuss the results by chemical using the thresholds for chemical protection for each system. As noted earlier, the threshold for protection against fungal attack is 20 ug/oven dried g of wood for fumigant based systems, both MITC and chloropicrin, 0.5 kg/m^3 of wood for internal decay control for boron and 0.10 kg/m^3 for fluoride (as fluoride) (Freitag and Morrell 2005).

Generally, no MITC was detected in any of the non-treated poles over the first 30 months of testing; however, this past year, we detected low levels of MITC in some poles (Table I-13). We believe this chemical contamination occurred due to inadvertent transfer during handling. All of the values were well below the threshold for fungal protection.

MITC levels in dazomet plus copper naphthenate treated poles were 10 to 15 times the threshold in the inner zones150 mm below groundline 18 months after treatment (Table I-13; Figure

Table I-13. Residual MITC levels in Douglas-fir poles 18-42 months after application of selected remedial treatments.

Treatment	Cu Naph	months after treatment	Height above groundline (mm)					
			-150		0		300	
			inner	outer	inner	outer	inner	outer
Control	-	18	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
		30	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
		42	11 (16)	5 (8)	8 (13)	4 (6)	5 (8)	4 (7)
Dazomet	+	18	**337** (266)	**158** (196)	**289** (322)	**102** (105)	**163** (112)	**151** (119)
		30	**253** (257)	**78** (73)	**366** (278)	**78** (60)	**201** (139)	**109** (77)
		42	**270** (297)	**165** (146)	**299** (281)	**196** (176)	**181** (212)	**121** (69)
Dazomet rods	+	18	**283** (260)	**181** (347)	**254** (166)	**51** (73)	**159** (66)	**95** (115)
		30	**348** (292)	**149** (169)	**391** (394)	**115** (122)	**220** (90)	**134** (201)
		42	**315** (198)	**171** (145)	**691** (1128)	**176** (129)	**253** (139)	**118** (74)
DuraFume	+	18	**255** (164)	**126** (118)	**160** (87)	**83** (95)	**131** (81)	**82** (79)
		30	**297** (232)	**106** (88)	**333** (359)	**79** (55)	**212** (201)	**72** (44)
		42	**256** (199)	**152** (171)	**243** (150)	**143** (117)	**329** (536)	**87** (43)
MITC-FUME	-	18	**1868** (1682)	**207** (219)	**24710** (88693)	**560** (1335)	**2085** (1906)	**372** (430)
		30	**1773** (1871)	**565** (435)	**2328** (1945)	**535** (461)	**1318** (1176)	**412** (323)
		42	**1210** (1243)	**712** (1569)	**794** (617)	**334** (187)	**491** (311)	**246** (136)
Pol Fume	-	18	**132** (74)	**63** (56)	**661** (1539)	**69** (36)	**149** (104)	**120** (168)
		30	**53** (30)	**47** (49)	**52** (36)	**40** (37)	**50** (23)	**47** (24)
		42	**38** (28)	**21** (14)	**27** (17)	**24** (21)	**34** (24)	16 (7)
SMDC-Fume	-	18	**152** (75)	**74** (55)	**168** (132)	**50** (22)	**135** (75)	**90** (77)
		30	**76** (50)	**48** (27)	**75** (41)	**40** (19)	**64** (28)	**45** (24)
		42	**39** (28)	20 (9)	**36** (21)	**20** (10)	**25** (8)	14 (3)
Super-Fume Tubes	+	18	**173** (152)	**50** (77)	**121** (85)	**46** (46)	**91** (72)	**54** (47)
		30	**138** (160)	**42** (42)	**135** (104)	**58** (73)	**83** (40)	**38** (26)
		42	**132** (150)	**72** (60)	**157** (244)	**50** (38)	**68** (23)	**39** (26)
UltraFume	+	18	**174** (92)	**239** (324)	**175** (115)	**136** (183)	**168** (83)	**151** (208)
		30	**229** (188)	**318** (821)	**300** (198)	**136** (162)	**195** (85)	**170** (204)
		42	**246** (267)	**206** (163)	**283** (236)	**194** (187)	**246** (152)	**166** (105)
WoodFume	-	18	**187** (125)	**91** (120)	**157** (106)	**74** (54)	**156** (107)	**103** (99)
		30	**68** (52)	**38** (32)	**75** (61)	**45** (45)	**57** (40)	**37** (24)
		42	**53** (24)	20 (22)	**33** (21)	17 (19)	**24** (21)	15 (16)
Chloropicrin	-	18	**37096** (134096)	**6052** (11848)	**16347** (24851)	**18001** (25506)	**22498** (27167)	**12951** (16512)
		30	**12749** (22396)	**4900** (8571)	**1149** (2837)	**1071** (1895)	**6516** (6511)	**1585** (1853)
		42	**14515** (16483)	**6638** (8019)	**10407** (8273)	**2758** (4865)	**7436** (6102)	**9203** (10330)

a. Numbers in parentheses represent one standard deviation around the mean of 15 replicates. Numbers in bold type are above the toxic threshold.

I-12). As we have seen in previous studies, MITC levels tended to be lower in the outer zones at the same distance above groundline. Chemical levels were slightly lower but still 5 to10 times above threshold at groundline and 5 to 8 times threshold 300, 450, and 600 mm above that level. MITC levels were 2 times the threshold in the inner zone 1 m above groundline, but just below threshold in the outer zone. The results indicate that the dazomet/copper naphthenate treatment is performing well in this test. MITC levels at 30 and 42 months were similar to those found at 18 months although there was some variation in levels at particular locations. Overall, however, the MITC distribution appeared to be similar at the two later time points and indicates that the treatment is continuing to produce MITC at levels well above those required for protection (Figure I-12).

Table I-13 continued. Residual MITC levels in Douglas-fir poles 18-42 months after application of selected remedial treatments.

Treatment	Cu Naph	months after treatment	Height above groundline (mm)					
			450		600		1000	
			inner	outer	inner	outer	inner	outer
Control	-	18	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
		30	0 (0)	0 (0)	0 (0)	0 (0)	1 (4)	0 (0)
		42	8 (13)	5 (8)	5 (8)	5 (7)	7 (10)	5 (7)
Dazomet	+	18	**148** (112)	**167** (205)	**107** (99)	**123** (206)	**47** (30)	19 (12)
		30	**165** (102)	**93** (55)	**142** (110)	**106** (95)	**75** (38)	**48** (46)
		42	**128** (66)	**125** (108)	**114** (58)	**106** (103)	**99** (63)	**96** (144)
Dazomet rods	+	18	**147** (55)	**118** (168)	**97** (53)	**53** (69)	**49** (36)	9 (21)
		30	**153** (55)	**84** (64)	**114** (52)	**72** (82)	**79** (37)	**29** (23)
		42	**170** (53)	**118** (98)	**138** (79)	**85** (71)	**77** (32)	**35** (21)
DuraFume	+	18	**132** (59)	**105** (109)	**99** (86)	**90** (134)	**45** (22)	**27** (37)
		30	**120** (73)	**57** (37)	**92** (51)	**49** (23)	**58** (34)	**32** (18)
		42	**111** (52)	**88** (73)	**76** (38)	**56** (44)	**46** (26)	**36** (29)
MITC-FUME	-	18	**1574** (2239)	**360** (332)	**840** (673)	**283** (214)	**848** (764)	**235** (208)
		30	**882** (932)	**292** (236)	**904** (1066)	**330** (279)	**662** (589)	**261** (250)
		42	**389** (281)	**184** (107)	**350** (284)	**189** (106)	**369** (250)	**165** (117)
Pol Fume	-	18	**136** (76)	**123** (111)	**118** (61)	**78** (58)	**65** (29)	**35** (26)
		30	**51** (26)	**39** (20)	**53** (26)	**45** (23)	**41** (22)	**23** (19)
		42	**25** (18)	15 (7)	**24** (17)	16 (8)	**20** (9)	14 (7)
SMDC-Fume	-	18	**144** (112)	**71** (52)	**114** (89)	**61** (47)	**72** (51)	**24** (23)
		30	**56** (26)	**37** (19)	**49** (20)	**31** (16)	**52** (37)	**25** (15)
		42	**26** (12)	13 (4)	**24** (10)	13 (5)	**27** (15)	13 (13)
Super-Fume Tubes	+	18	**60** (22)	**60** (44)	**39** (17)	**38** (30)	**35** (72)	16 (19)
		30	**54** (21)	**31** (15)	**37** (19)	**24** (22)	**25** (10)	12 (11)
		42	**53** (33)	**40** (32)	**44** (21)	**23** (10)	**24** (13)	11 (8)
UltraFume	+	18	**112** (51)	**113** (134)	**98** (72)	**77** (65)	**59** (69)	**26** (20)
		30	**156** (79)	**103** (112)	**127** (74)	**87** (64)	**76** (47)	**39** (24)
		42	**150** (63)	**125** (81)	**143** (57)	**175** (187)	**78** (47)	**82** (80)
WoodFume	-	18	**127** (79)	**85** (112)	**129** (62)	**100** (112)	**95** (48)	**46** (60)
		30	**53** (34)	**35** (21)	**48** (25)	**33** (26)	**55** (28)	**32** (30)
		42	20 (15)	14 (16)	**25** (24)	13 (13)	**26** (17)	12 (12)
Chloropicrin	-	18	**9263** (14788)	**6772** (13209)	**3429** (6239)	**606** (853)	**795** (780)	**86** (181)
		30	**424** (1009)	**2307** (5072)	**3582** (4241)	**1129** (1819)	**3691** (11390)	**278** (339)
		42	**3463** (3691)	**3135** (2518)	**3916** (3752)	**1492** (1755)	**3743** (4902)	**702** (1217)

a. Numbers in parentheses represent one standard deviation around the mean of 15 replicates. Numbers in bold type are above the toxic threshold.

MITC levels in the DuraFume plus copper naphthenate treated pole sections followed trends that were similar to the other two dazomet treatments although the MITC levels were somewhat lower 18 months after treatment (Figure I-12). MITC levels at this time were 6 to 12 times threshold 150 mm below groundline, then 4 to 8 times threshold at groundline, 300 mm and 450 mm above that level. MITC levels 30 or 42 months after treatment had increased to levels similar to those found with the other two dazomet treatments suggesting that there was little difference in MITC levels among the three treatments.

MITC levels in poles treated 18 months earlier with UltraFume plus copper naphthenate were 8 to 11 times threshold 150 mm below groundline and declined only slightly at groundline and 300 mm above that zone (Figure I-12). MITC levels were 3 to 5 times threshold 450 and 600 mm above groundline and 1-2 times threshold 900 m above groundline. MITC levels from UltraFume were

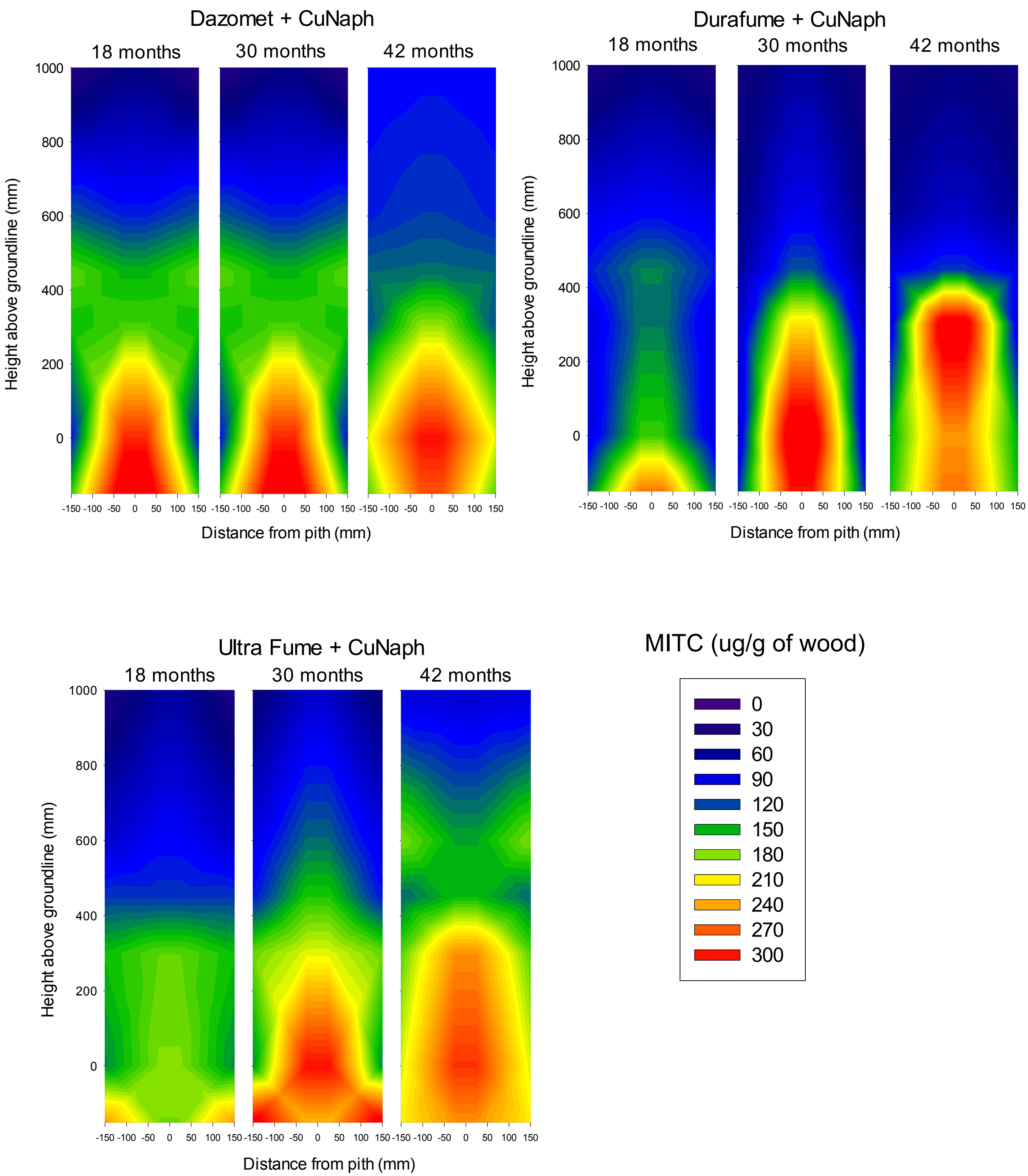


Figure I-12. Distribution of MITC in Douglas-fir poles sections 18 to 42 months after treatment with dazomet plus copper naphthenate, DuraFume plus copper naphthenate or UltraFume plus copper naphthenate.

slightly lower than those for the other two dazomet-based systems, although the levels were still well above the threshold for protection. MITC levels in poles 30 months after treatment had risen considerably and were similar to those found with the other dazomet based treatments. MITC levels after 42 months were similar to those found at 30 months and consistent with the levels found in the other dazomet-based treatments. It is unclear why this system had slightly lower MITC levels at the first sampling point although there are some slight differences in formulation density that might affect decomposition. Over time; however, this treatment seems to be performing similarly to the other dazomet systems.

MITC levels in the dazomet rod/copper naphthenate treatment were 9 to14 times threshold 150 mm below groundline and then declined to 4 to 8 times higher than threshold at groundline at the18 month sampling (Figure I-13). MITC levels declined slightly further above ground, ranging from 2 to 7 times threshold at the 300, 450 and 600 mm levels. MITC levels were above threshold in the inner zone 900 mm above groundline but below on the outer. As with the granular dazomet, the system appears to be well distributed through the test poles at fungitoxic levels. Chemical levels at 30 and 42 months were higher than those found at 18 months, suggesting that the rod formulation had no long-term negative effect on release rate.

MITC levels in poles treated 18 months earlier with Super-Fume in tubes plus copper naphthenate were 2 to 8 times threshold 150 mm below groundline, and 4 to 6 times threshold at groundline and 300 or 450 mm above those levels (Figure I-13). MITC levels were slightly less than two times threshold 600 mm and in the inner zone 1 m above groundline. While the treatment resulted in fungitoxic levels of MITC 150 mm below to 600 mm above groundline, the overall levels present were lower than those found with granular and rod formulations of the same chemical. MITC levels at 30 and 42 months remained lower in comparison with those found with the other dazomet based systems. In our previous trials, we found relatively little effect of the tube on dazomet decomposition as measured by MITC level; however, the tube did appear to have a consistent negative effect on performance in this test. Although the MITC levels remain well above the threshold, they are much lower than those found with the other systems. This suggests that the tube might improve handling safety during application; however, these potential benefits are out-weighed by the negative effects on MITC release rate.

MITC levels in MITC-FUME treated poles were 90 times the threshold in the inner zone 150 mm below groundline and 10 times that level in the outer zone 18 months after treatment (Figure I-14). The elevated MITC levels in the inner zone continued through groundline to 900 mm above groundline. Levels in the outer zones at these same heights were also elevated, ranging from12 to 28 times the threshold value. The extremely high MITC levels in these poles reflect the application of pure MITC. In the case of both dazomet and sodium n-methyldithiocarbamate, the chemicals must decompose to release MITC. In this case, the MITC sublimes directly from a solid to a gas and can move rapidly into the wood. The results indicate that the MITC-FUME has produced exceptional levels of protection at all sampling locations18 months after treatment. Although MITC levels 30 months after treatment had declined they were still 5 to 6 times those found with dazomet based treatments near the groundline zone and averaged 40 times the threshold. Clearly, MITC-FUME delivers a substantial pulse of chemical to the treated zone that should be capable of eliminating virtually all fungi present. Levels continue to decline 42 months after treatment; however, the chemical levels remain nearly 60 times the threshold in the inner zone 150

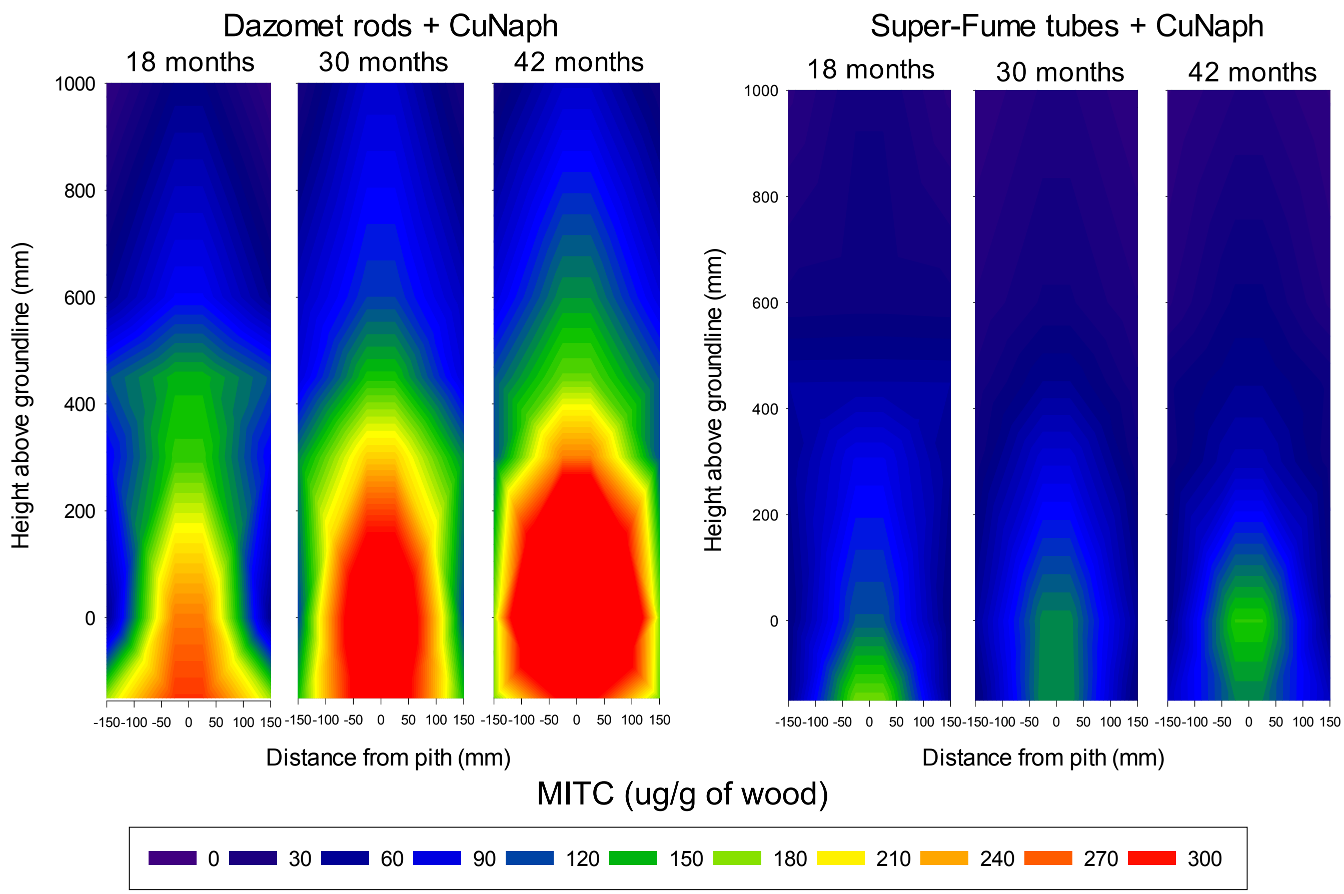


Figure I-13. Distribution of MITC in Douglas-fir poles sections 18 to 42 months after treatment with dazomet rods plus copper naphthenate or Super-Fume tubes plus copper naphthenate.

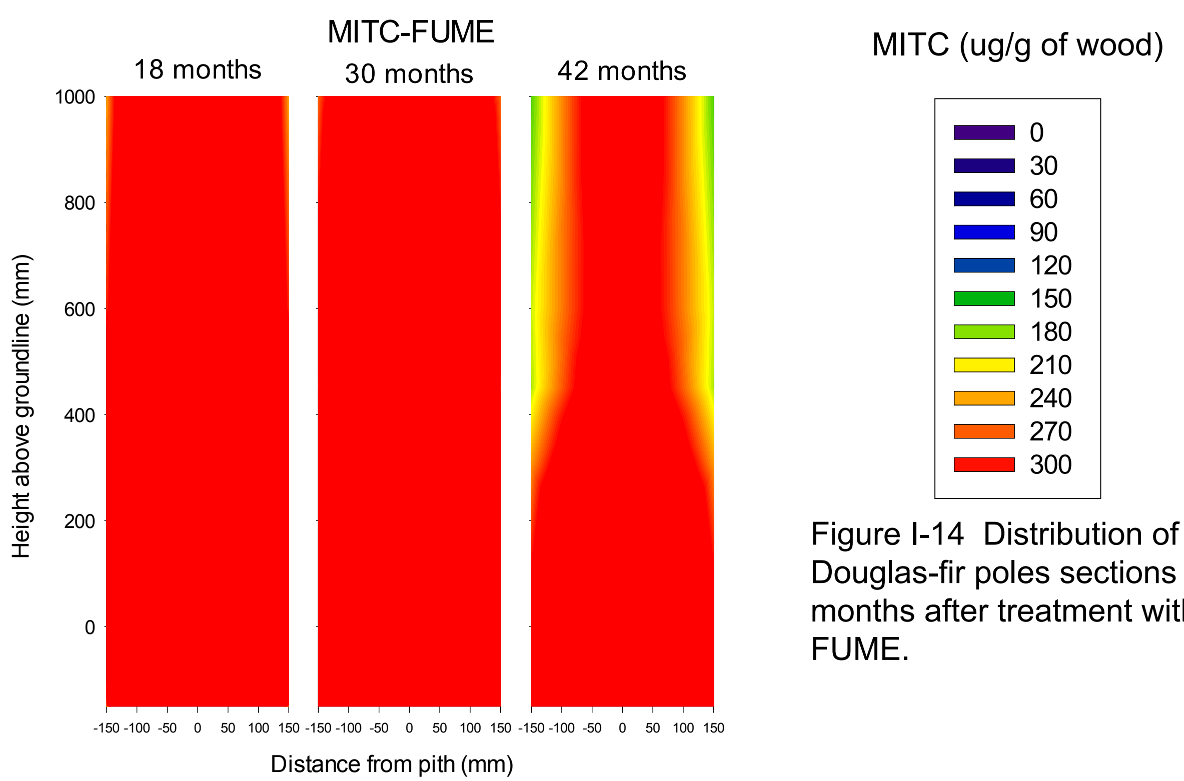


Figure I-14 Distribution of MITC in Douglas-fir poles sections 18 to 42 months after treatment with MITC-FUME.

mm below ground and nearly 40 times the threshold in the same zone at groundline. The MITC in MITC-FUME has clearly moved into the wood at extremely high levels and is still 8 times the threshold almost 1 m above groundline at this point. This system clearly provides a rapid, large dose of chemical to arrest any fungi present in the pole.

Pol-Fume, SMDC-Fume and WoodFume all contain sodium n-methyldithiocarbamate as the active ingredient and must decompose in the wood to release MITC. Previous studies have shown that the rate of decomposition is relatively low; however, these products have some attractive features including low cost and lack of strong volatile odors.

MITC levels in poles treated 18 months earlier with Pol-Fume were 3 to 7 times threshold 150 mm below groundline, while levels were 3 to 25 times threshold at groundline (Figure I-15). Chemical levels were 5 to 7 times threshold 300 and 450 mm above groundline and 1 to 5 times threshold between 600 mm and 900 mm. Protective levels were found at all sampling locations. MITC levels in these same poles had declined substantially 30 months after treatment, although chemical levels remained above the threshold for fungal protection 900 mm above the groundline. MITC levels 42 months after treatment continued to exhibit a progressive decline. MITC levels in the groundline and below ranged from 1 to less than 2 times threshold, indicating that the protective effect of this chemical was being lost at a fairly rapid rate. The steep decline in MITC levels is characteristic of metam sodium treatment.

MITC levels in SMDC-Fume treated poles and poles treated with WoodFume followed trends that were very similar to those found for Pol-Fume, with protective levels at all heights 18 months after treatment and a sharp decline 30 months after treatment (Figure I-15). These results indicate that metam sodium-based treatments provide a relatively quick, large pulse of MITC followed by a fairly sharp decline in residual protection. This behavior is consistent with the tendency for decay fungi to begin to re-colonize metam sodium treated poles 5 to 7 years after treatment, although these fungi do not appear to be causing substantial decay at this time. The relatively ephemeral nature of metam sodium should be considered whenever utilities are contemplating extending their inspection/remedial treatment program. While this treatment has been shown to provide protection for the recommended 10 year inspection and retreatment cycle, this does not mean that MITC levels in the wood remain above the protective level for the entire cycle. Instead, this protective period is based upon the fact that the treatment eliminates established decay fungi and sufficient MITC remains in the wood to prevent re-infestation for 3 to 5 years. At that time, fungi can reinvade the wood; however, this process has to occur in the same manner it originally occurred. This means that fungal spores or hyphae must enter the untreated portions of the pole through checks and other defects. This process is slower than if the fungi in the soil could directly invade the wood and provides an additional period of protection. Prolonging the treatment cycle increases the likelihood that decay fungi will find the checks and begin to degrade the wood.

Chloropicrin levels in poles treated with this fumigant were several orders of magnitude greater than the threshold in the groundline region and still well above the threshold well above the zone 18 months after treatment (Table I-13, Figure I-16). Chloropicrin levels were much lower 30 months after treatment but were still 600 times the threshold in the inner zone 150 mm below groundline and almost 60 times the threshold in the same zone at groundline. The 42 months analyses are in process and will be included in the final report for this year. The extremely high

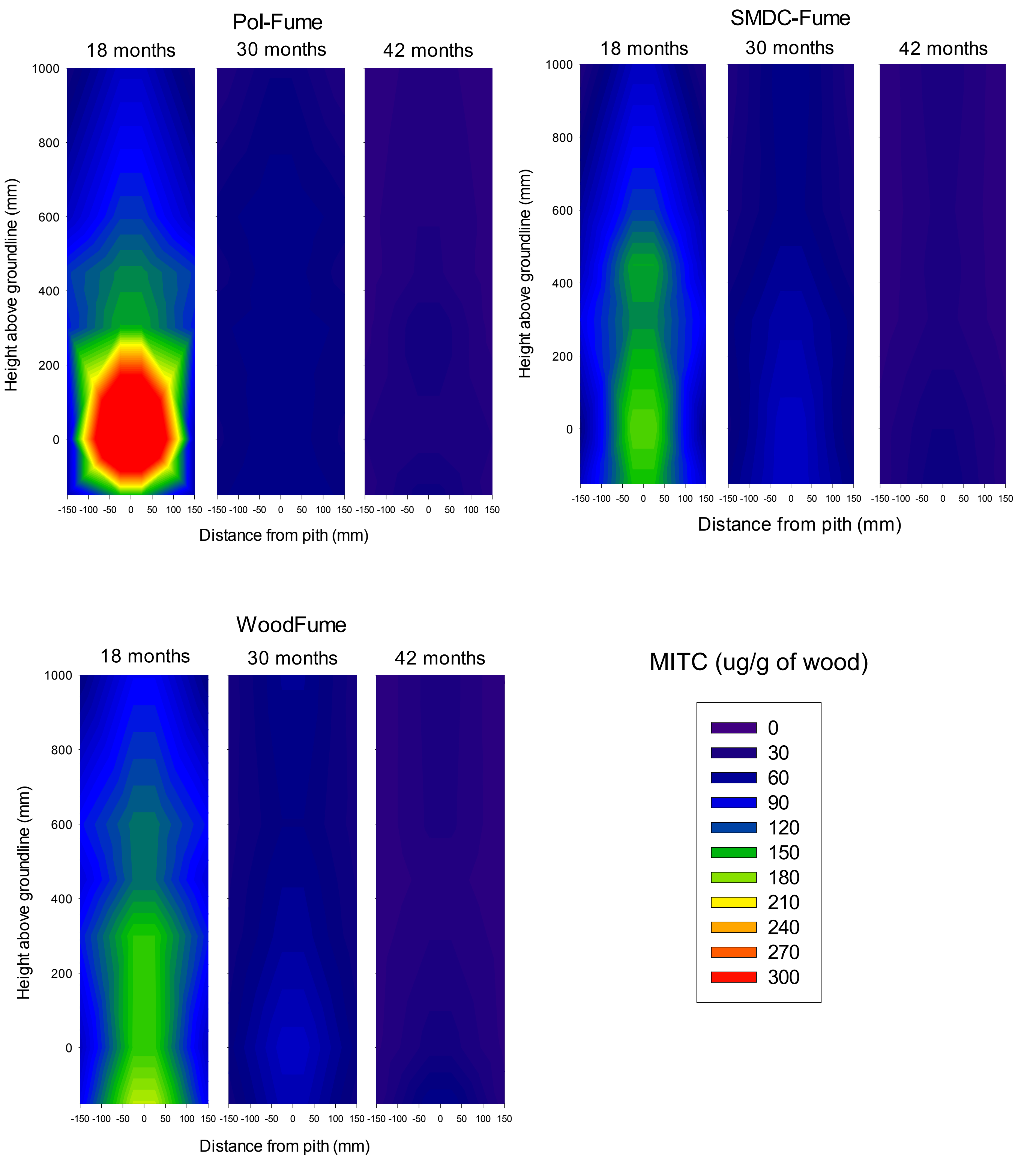


Figure I-15. Distribution of MITC in Douglas-fir poles sections 18 to 42 months after treatment with Pol-Fume, SMDC-Fume, or WoodFume.

chemical levels associated with this treatment are consistent with previous tests and illustrate why this chemical is effective in poles for many years. Previous studies have found chloropicrin to be present at fungitoxic levels up to 20 years after treatment. Unfortunately, handling aspects

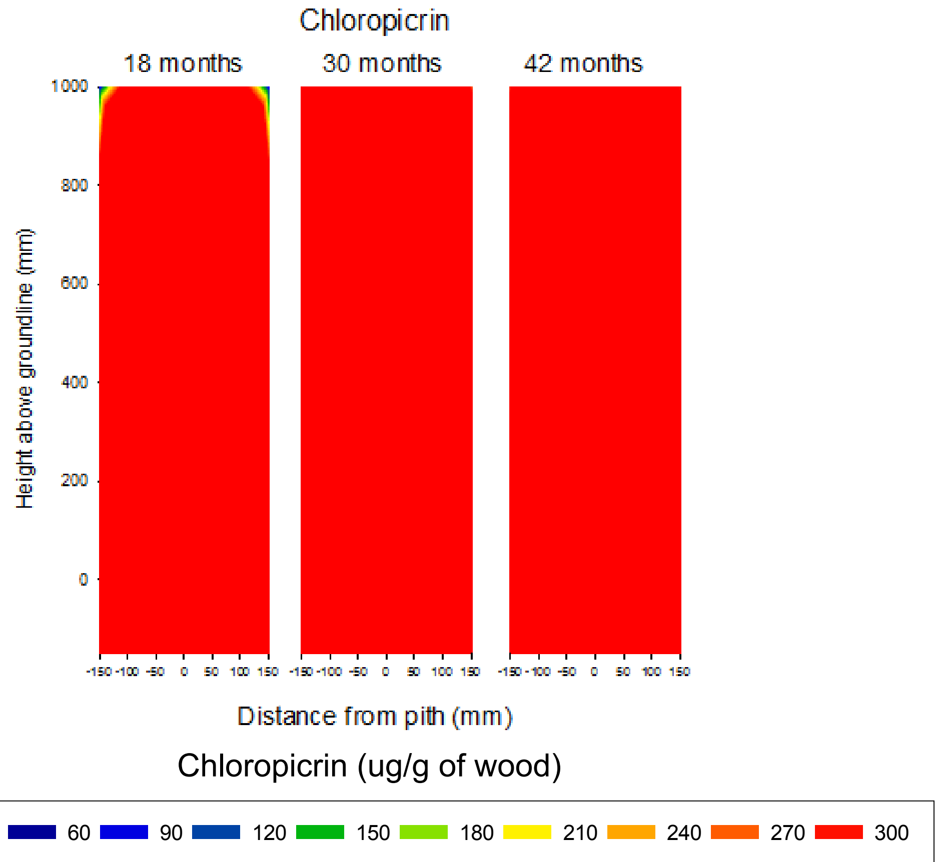


Figure I-16 Distribution of chloropicrin in Douglas-fir poles sections 18 to 30 months after treatment.

and labeling requirements limit the use of this chemical to transmission poles in remote locations, but the results illustrate why chloropicrin remains desirable to use in these locations.

Sampling of poles treated with boron-based systems was limited to 150 mm below to 600 mm above the groundline because these systems are less likely to migrate for long distances upward early in the test. Boron levels in both Impel and Pol Saver rod treated poles were at background levels 450 and 600 mm above groundline at both sampling times.

Boron levels were at or above threshold in the inner zones 150 mm below and at groundline for the Impel rod treated poles, but below that level in the outer zone (Table I-14). Boron levels were above threshold in the outer zones of the same poles 300 mm above groundline (Figure I-17). In general, boron is not widely distributed in these poles beyond the groundline at levels that would confer protection. These results are typical for water-based systems, which require longer time periods to become effective. Achieving protective levels closer to the pole surface required 30 to 42 months and this would be the primary drawback of water diffusible systems. However, they do show that boron levels from these rods can reach protective levels within 18 months in the pole interior.

Boron levels in poles treated with Pol Saver rods were above threshold levels in the inner zones 150 mm below and at groundline as well as in the outer zone at groundline 18 months after treatment (Table I-14; Figure I-17). Boron levels remained elevated in these same zones 30 and 42 months after treatment suggesting that the treatment was providing groundline protection. The test site is extremely wet and it was interesting to note that boron levels in the outer zone 150 mm below groundline remained below the threshold until the 42 month point. This suggests that the

Table I-14. Boron levels at various distances above and below the groundline in Douglas-fir poles 18 to 42 months after application of Impel or Pol Saver rods.

Treatment	months after treatment	Height above groundline (mm)[a]					
		-150		0		300	
		inner	outer	inner	outer	inner	outer
Control	18	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	30	0.07 (0.02)	0.07 (0.02)	0.07 (0.02)	0.06 (0.00)	0.08 (0.03)	0.08 (0.04)
	42	0.18 (0.24)	0.19 (0.23)	0.21 (0.28)	0.18 (0.25)	0.21 (0.27)	0.20 (0.28)
Impel rods	18	**2.59** (1.44)	0.37 (0.35)	**7.68** (10.11)	0.16 (0.20)	0.02 (0.03)	**0.97** (2.17)
	30	**6.67** (8.01)	0.39 (0.40)	**1.30** (0.47)	**2.14** (3.60)	0.16 (0.13)	0.15 (0.14)
	42	**5.49** (5.77)	**0.98** (0.88)	**6.30** (7.76)	**3.09** (3.91)	**0.53** (0.74)	**0.72** (1.25)
Pol Saver rods	18	**0.84** (0.11)	0.14 (0.24)	**7.50** (4.55)	**0.61** (0.74)	0.00 (0.00)	0.04 (0.08)
	30	**1.54** (1.98)	0.31 (0.18)	**4.44** (4.86)	**1.28** (0.57)	0.18 (0.01)	0.18 (0.11)
	42	**1.24** (0.79)	**1.02** (0.49)	**1.73** (1.10)	**1.03** (0.31)	0.13 (0.09)	0.16 (0.09)

Treatment	months after treatment	Height above groundline (mm)[a]			
		450		600	
		inner	outer	inner	outer
Control	18	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	30	0.10 (0.03)	0.06 (0.01)	0.08 (0.00)	0.07 (0.02)
	42	0.19 (0.29)	0.21 (0.26)	0.21 (0.23)	0.08 (0.02)
Impel rods	18	0.02 (0.03)	0.02 (0.03)	0.02 (0.04)	0.00 (0.01)
	30	0.07 (0.04)	0.10 (0.09)	0.07 (0.03)	0.05 (0.02)
	42	0.09 (0.09)	0.17 (0.18)	0.07 (0.02)	0.08 (0.03)
Pol Saver rods	18	0.02 (0.04)	0.06 (0.06)	0.02 (0.03)	0.03 (0.04)
	30	0.12 (0.01)	0.09 (0.03)	0.09 (0.03)	0.07 (0.03)
	42	0.11 (0.05)	0.11 (0.06)	0.13 (0.01)	0.11 (0.03)

a. Numbers in parentheses represent one standard deviation around the mean of 3 (control and Pol Saver) or 5 (Impel rods) replicates. Numbers in bold type are above the toxic threshold.

higher moisture levels at this site may negate the effects of boron near the surface below ground. However, boron levels inside the wood do appear to be at effective levels below ground.

Fluoride levels in poles 18 months after treatment with FLUROD were well above the threshold in the inner and outer sampling zones at groundline and 150 mm below groundline, indicating that the fluoride had rapidly moved from the rods into the surrounding wood (Table I-15). Fluoride

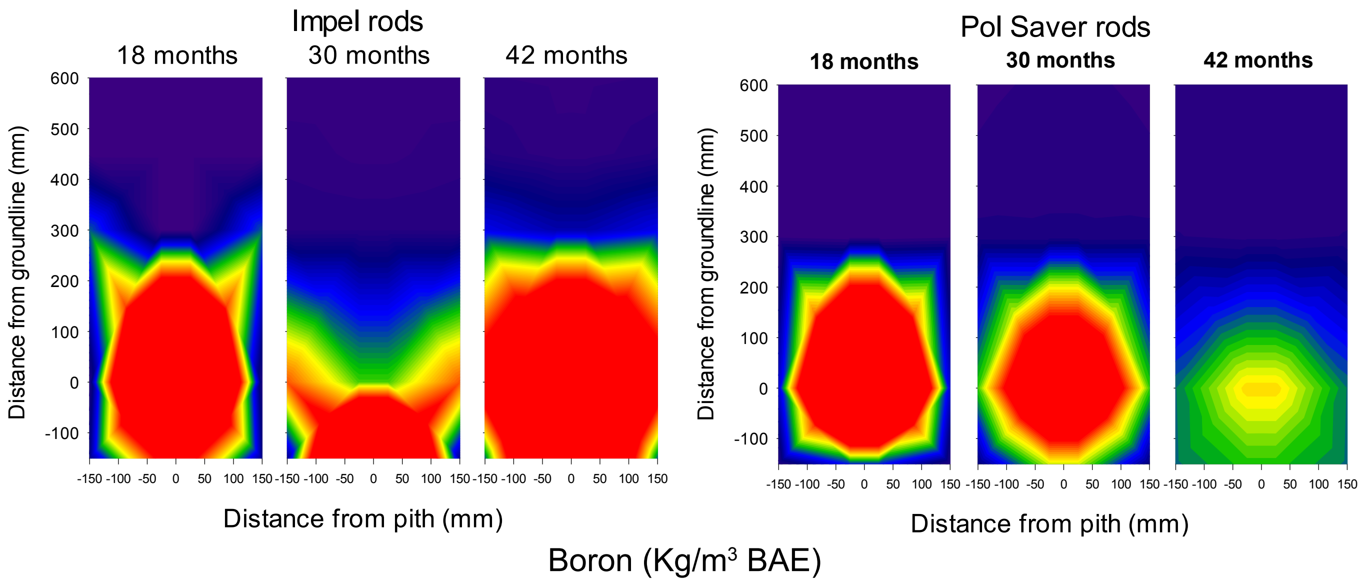


Figure I-17. Boron distribution in Douglas-fir poles 18 to 42 months after application of Impel or Pol Saver rods.

was at background levels 300 mm above groundline indicating that little fluoride moved upward from the point of application. Fluoride levels declined markedly in the inner zone 150 mm below groundline 30 months after treatment, but remained the same in the outer zone. Fluoride levels increased markedly in the inner zone at groundline at the same sample time, but remained relatively unchanged in the outer zone. The results indicate that fluoride has moved well into the wood in the treatment zone of the poles.

Fluoride analyses are only available from the 30 month sampling for poles treated with Pol Saver Rods. These results indicate that fluoride was present at protective levels in the inner zones 150 mm below groundline as well as in both the inner and outer zones at groundline (Table I-16). Fluoride levels 150 mm below groundline were much lower than those found with the FLURODS,

Table I-15. Residual fluoride levels in Douglas-fir pole sections 18 and 30 months after application of FLUROD or Pol Saver rods.

Treatment	Year	Height above groundline (mm)[a]					
		-150		0		300	
		inner	outer	inner	outer	inner	outer
FluRod	18	**1.011**	**0.123**	**0.363**	**0.390**	0.052	0.024
	30	**0.385**	**0.149**	**0.914**	**0.313**	-0.014	0.035
	42						
Pol Saver rods	18						
	30	**0.113**	0.049	**0.633**	**0.196**	-0.007	-0.009
	42						

a. Numbers in bold type are above the toxic threshold.

while those at groundline were only slight lower. As with the FLUROD treatment, there was no evidence of fluoride movement 300 mm above groundline.

The results indicate that the fluoride based systems are moving into the poles at levels capable of providing fungal protection within the groundline and, with one system, slightly below that zone.

Fungal isolations remain low in all fumigant treatments, but non-decay fungi were more frequently isolated from poles treated with diffusibles (Table I-16). The poles treated with Impel rods were found to harbor decay fungi 42 months after treatment. The isolations were all from above 300 mm above the groundline where boron levels were just above threshold (300 mm) or far below (450 and 600 mm). The percentages reported in Table I-16 represent just four isolations of decay fungi, but these came from three of the five poles treated with Impel rods. Decay fungi have been isolated from a third to a half of cores taken below 600 mm above groundline in non-treated control poles.

D. Ability of Internal Remedial Preservative Systems to Migrate into Distribution Poles in an Arid Climate

The majority of internal remedial treatment trials established by the UPRC have been established in areas with mild, wet climates. Although these materials are used extensively in dry, cold climates we do not have data on their movement and effectiveness under these conditions.

We recently established a field trial of selected EPA registered internal remedial treatments on in-service distribution poles in the Rocky Mountain Power service district south of Salt Lake City, Utah to examine this issue.

Distribution poles that had not previously received an internal remedial treatment were selected for the test. The poles were treated with oil-based preservatives. Poles were randomly allocated to a given treatment and each treatment was replicated on six poles (Table I-17).

The treatments were:

Dazomet with accelerant (2% elemental copper)
Dazomet w/o accelerant
MITC-FUME
Metam sodium
Fused boron rods with accelerant (water)
Fused boron rods w/o accelerant
Non-treated control

Three steeply sloping treatment holes (19 mm x 350 mm long or 250 mm long for rods, 380 mm for fumigants) were drilled into the poles beginning at groundline and moving upward 150 mm and around the pole 120 degrees. The metam sodium treated poles received four holes/pole. The various remedial treatments were added to the holes at the recommended dosage for a pole of this diameter, along with any recommended additive, and then the holes were plugged with plastic plugs. The non-treated control poles were not drilled.

Table I-16. Isolation frequencies of decay and $^{non-decay}$ fungi from pentachlorophenol treated Douglas-fir poles 18 to 42 months after treatment with selected internal remedial treatments

Treatment	Cu Naph	months after treatment	Height above groundline (mm)					
			-150	0	300	450	600	1000
Fumigant Control	-	18	33 ^{17}	17 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
		30	33 ^{50}	33 ^{50}	17 ^{17}	0 ^{17}	0 ^{17}	0 ^{0}
		42	50 ^{50}	50 ^{50}	50 ^{50}	33 ^{50}	33 ^{17}	0 ^{50}
Dazomet	+	18	0 ^{7}	0 ^{0}	7 ^{13}	0 ^{7}	0 ^{7}	0 ^{7}
		30	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{0}
		42	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
Dazomet rods	+	18	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{7}
		30	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
		42	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
DuraFume	+	18	0 ^{7}	0 ^{7}	0 ^{0}	0 ^{0}	0 ^{7}	0 ^{7}
		30	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
		42	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{0}
MITC-FUME	-	18	0 ^{0}	0 ^{13}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
		30	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
		42	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
Pol Fume	-	18	0 ^{0}	0 ^{7}	0 ^{7}	0 ^{13}	0 ^{0}	0 ^{20}
		30	0 ^{0}	0 ^{13}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{7}
		42	7 ^{7}	0 ^{0}	7 ^{7}	0 ^{7}	7 ^{7}	0 ^{0}
SMDC-Fume	-	18	0 ^{0}	0 ^{13}	0 ^{7}	0 ^{7}	0 ^{13}	0 ^{7}
		30	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
		42	0 ^{0}	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{0}	0 ^{0}
Super-Fume Tubes	+	18	0 ^{0}	0 ^{0}	0 ^{13}	0 ^{7}	0 ^{0}	0 ^{7}
		30	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
		42	0 ^{7}	0 ^{0}	0 ^{7}	0 ^{7}	0 ^{7}	0 ^{0}
UltraFume	+	18	0 ^{0}	0 ^{0}	0 ^{20}	0 ^{7}	0 ^{7}	0 ^{0}
		30	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{7}
		42	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
WoodFume	-	18	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{20}	0 ^{7}
		30	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
		42	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{20}	0 ^{7}	0 ^{0}
Chloropicrin		18	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
		30	0 ^{7}	7 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	7 ^{0}
		42	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
Diffusible Control		18	0 ^{0}	14 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	
		30	22 ^{56}	33 ^{11}	0 ^{22}	0 ^{0}	0 ^{22}	
		42	33 ^{67}	33 ^{67}	33 ^{33}	22 ^{44}	0 ^{44}	
Impel rods		18	0 ^{7}	0 ^{8}	0 ^{18}	0 ^{8}	0 ^{7}	
		30	7 ^{47}	0 ^{7}	0 ^{27}	7 ^{33}	0 ^{47}	
		42	0 ^{67}	0 ^{27}	7 ^{60}	13 ^{60}	7 ^{60}	
Pol Saver rods		18	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	
		30	0 ^{67}	0 ^{0}	0 ^{33}	0 ^{44}	0 ^{44}	
		42	0 ^{78}	0 ^{56}	0 ^{78}	0 ^{78}	0 ^{78}	
FLUROD		18	0 ^{0}	0 ^{0}	0 ^{20}	0 ^{40}	0 ^{13}	
		30	0 ^{13}	0 ^{0}	0 ^{47}	0 ^{60}	0 ^{60}	
		42	0 ^{20}	0 ^{20}	0 ^{33}	0 ^{20}	0 ^{53}	

Table I-17. Characteristics of poles in the Rocky Mountain Power system treated with selected internal remedial treatments.

OSU Pole #	RMP Pole #	Species	Primary Treatment	YI	Class	Length	Treatment
325	301800	cedar	creosote	1999	4	40	boron + water
339	184005	cedar	penta	2005	4	40	boron + water
330	302900	Douglas-fir	penta	1996	4	35	boron + water
304	195502	L. pine	penta	1971	4	35	boron + water
311	192501	L. pine	penta	1980	4	35	boron + water
318	191501	L. pine	penta	1983	5	35	boron + water
335	199312	cedar	penta	2007	3	40	control
342	195900	cedar	penta	2002	4	45	control
333	197501	Douglas-fir	cellon (penta)	1981	4	40	control
307	194508	L. pine	penta	1971	5	35	control
314	192530	L. pine	penta	1980	4	35	control
321	197504	L. pine	penta	1981	5	40	control
322	301701	cedar	creosote	1999	4	40	dazomet
336	197705	cedar	penta	1999	4	40	dazomet
331	303900	Douglas-fir	cellon (penta)	1996	5	35	dazomet
301	196502	L. pine	penta	1981	5	40	dazomet
308	193501	L. pine	penta	1981	5	35	dazomet
315	191505	L. pine	penta	1981	4	40	dazomet
324	301702	cedar	creosote	1999	5	30	dazomet + Cu
329	301906	Douglas-fir	penta	1999	4	30	dazomet + Cu
338	197700	Douglas-fir	penta	2008	4	35	dazomet + Cu
303	195501	L. pine	penta	1971	4	35	dazomet + Cu
310	193500	L. pine	penta	1980	5	35	dazomet + Cu
317	191503	L. pine	penta	1983	4	35	dazomet + Cu

Table I-17 continued. Characteristics of poles in the Rocky Mountain Power system treated with selected internal remedial treatments.

OSU Pole #	RMP Pole #	Species	Primary Treatment	YI	Class	Length	Treatment
327	301902	Douglas-fir	cellon (penta)	1984	5	35	impel rods
302	195500	L. pine	penta	1971	4	35	impel rods
309	193502	L. pine	penta	1981	5	35	impel rods
316	191504	L. pine	penta	1983	5	35	impel rods
334	199406	cedar	penta	2005	4	40	metam sodium
341	194901	cedar	penta	2002	4	45	metam sodium
332	194406	Douglas-fir	penta	2000	5	30	metam sodium
306	194501	L. pine	penta	1981	5	40	metam sodium
313	192531	L. pine	penta	1981	5	35	metam sodium
320	191600	L. pine	penta	1983	4	40	metam sodium
328	301905	cedar	creosote	1999	5	30	MITC-FUME
340	186200	cedar	penta	2006	4	35	MITC-FUME
326	301930	Douglas-fir	penta	1995	4	35	MITC-FUME
305	195503	L. pine	penta	1984	4	40	MITC-FUME
312	192500	L. pine	penta	1981	5	35	MITC-FUME
319	191500	L. pine	penta	1983	5	40	MITC-FUME

Chemical movement in the poles will be assessed 1, 2, 3, and 5 years after treatment by removing increment cores from three equidistant sites beginning 150 mm below ground, then 0, 300, 450, 600 mm above groundline. An additional height of 900 mm above groundline will be sampled for the fumigant treated poles. The outer, preservative-treated shell will be removed, and then the outer and inner 25 mm of each core will be retained for chemical analysis using a method that is appropriate for the treatment. The remainder of each core will be plated on malt extract agar and observed for fungal growth. The first sampling will take place in October 2011.

E. Effect of Remedial Internal Treatments on Drywood Termites

Over the past 3 decades, fumigants have been extensively studied for their ability to control internal fungal decay in utility poles, but there has been little study on their efficacy against various wood inhabiting insects. Early field trials by the Bonneville Power Administration noted that subterranean termites were killed by internal application of chloropicrin or metam sodium, however, the chemicals were applied directly to the infested area and the observations were anecdotal, rather than the result of systematic attempts to use fumigants to control insects. In field trials in New York on CCA -treated Douglas-fir poles, gelatin encapsulated methylisothiocyanate and Vorlex treatments were found to have little effect on carpenter ants. The ants tended to move up and away from the treatment zone, but were otherwise unaffected by the treatment. Carpenter ants pose a special challenge for utilities because they inhabit, but do not consume, wood.

As a result, carpenter ants are often less affected by preservative treatments than insects that consume wood. Ants are also fairly mobile in terms of colony location, making it less likely that a fixed treatment at groundline will eliminate a colony.

Unlike carpenter ants, termites are more confined in their nests but there may be differences in susceptibility within termite groups. For example, subterranean termites excavate tunnels through an area of soil and then move upward whenever they contact suitable woody biomass. Thus, most of the colony is probably not present in the utility pole, but is instead spread across the area. Fumigant treatment is likely to kill any workers in close proximity to the treatment, but most other workers and the queen are less likely to be affected. Other workers are also likely to seal off the treated area. As a result, the infestation may be controlled for a time, but workers will later re-explore the pole as the chemical levels decline. Thus, internal treatments may be only temporarily effective against these termites.

The group that is most likely to be affected by internal treatments is the drywood termite (Kalotermidae). These insects inhabit dry wood (<12 % moisture content) in the desert U.S. southwest, although they are reported to range from Oregon to California (McKern et al., 2007). Drywood termites are commonly found in dead branches in trees and utility poles provide a similar habitat. These insects are difficult to detect until the damage is severe and their presence high up the pole makes detection difficult.

As noted, there is little data on the ability of internal remedial treatments to affect drywood termites. This past year, we initiated controlled laboratory trials to assess the ability of methylisothiocyanate (MITC) to affect drywood termites. The procedures were a modification of those described by Indrayani et al. (2007)

Douglas-fir sapwood blocks (30 by 30 by 50 mm long) with 10 mm diameter and 40 mm deep holes drilled through one end grain were conditioned to stable moisture contents, then 18 *Incisitermes minor* pseudergates were added to each hole. The holes were then covered with a stainless steel mesh screen and the blocks were incubated over salt solutions designed to produce wood at 12% moisture content (Figure I-18). Each block was placed in an individual jar.

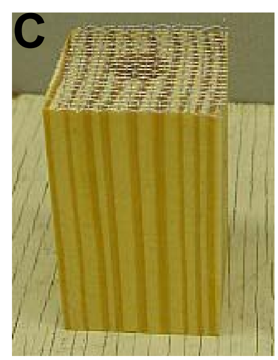


Figure I-18. A. Jars containing blocks with termites and vials into which methyisothiocyanate was placed. B. A jar with a block and vial placed over a salt solution. C. A blocks and metal screen.

The blocks were incubated for 8 weeks to allow the termites to become conditioned and begin to feed on the wood. Three chambers were left as controls, then the remainder received measured amounts of MITC that, based upon previous studies, should produce MITC levels in the wood of 5, 10, 20 or 100 ug/oven-dried g of wood (Zahora and Morrell, 1989).

Following the addition of the fumigant the blocks were then incubated at 32 C with minimal air-exchange designed to allow the workers to survive but to minimize MITC loss. After four weeks the infested blocks were opened, and the workers removed and counted to determine how many died during exposure. The blocks were then extracted in ethyl acetate and the extract analyzed for MITC. The blocks were then reconditioned to the original moisture content to determine wood weight loss caused by termite exposure. The results provide some guidance concerning the levels of chemical necessary in wood to arrest drywood termite attack. These levels are then compared with previous assessments of MITC levels in poles associated with metam sodium, dazomet and MITC-FUME treatments to determine if toxic levels were achieved.

It was difficult to produce an environment that allowed MITC to diffuse at low levels through the wood in the same manner as it would in pole. In nearly all cases, the termite workers failed to survive the test exposure, even in blocks which were not exposed to MITC. In a field exposure, the workers would be able to avoid higher levels of fumigant, while they had no opportunity to do so in this test configuration. We will continue to seek methods for assessing the efficacy of the internal treatments against termites.

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OBJECTIVE II

IDENTIFY CHEMICALS FOR PROTECTING EXPOSED WOOD SURFACES IN POLES

Preservative treatment prior to installation provides an excellent barrier against fungal, insect, and marine borer attack, but this barrier only remains effective only as long as it is intact. Deep checks that form after treatment, field drilling holes after treatment for attachments such as guy wires and communications equipment, cutting poles to height after setting and heavy handling of poles that result in fractures or shelling between the treated and non-treated zones can all expose non-treated wood to possible biological attack. The Standards of the American Wood Protection Association currently recommend that all field damage to treated wood be supplementally protected with solutions of copper naphthenate. While this treatment will never be as good as the initial pressure treatment, it provides a thin barrier that can be effective above the ground. Despite their merits, these recommendations are often ignored by field crews who dislike the oily nature of the treatment and know that it is highly unlikely that anyone will later check to confirm that the treatment has been properly applied.

In 1980, The Coop initiated a series of trials to assess the efficacy of various field treatments for protecting field drilled bolt holes, for protecting non-treated western redcedar sapwood and for protecting non-treated Douglas-fir timbers above the groundline. Many of these trials have been completed and have led to further tests to assess the levels of decay present in above-ground zones of poles in this region and to develop more accelerated test methods for assessing chemical efficacy. Despite the length of time that this Objective has been underway, above-ground decay and its prevention continues to be a problem facing many utilities as they find increasing restrictions on chemical usage. The problem of above-ground decay facilitated by field drilling promises to grow in importance as utilities find a diverse array of entities operating under the energized phases of their poles with cable, telecommunications and other services that require field drilling for attachments. Developing effective, easily applied treatments for the damage done as these systems are attached can lead to substantial long term cost savings and is the primary focus of this Objective.

A. Evaluate Treatments for Protecting Field Drilled Bolt Holes

While most utility specifications call for supplemental treatment whenever a hole or cut penetrates beyond the depth of the original preservative treatment, it is virtually impossible to verify that a treatment has been applied without physically removing the bolt and inspecting the exposed surface. Most line personnel realize that this is highly unlikely to happen, providing little or no motivation for following the specification.

Given the low probability of specification compliance, it might be more fruitful to identify systems that ensure protection of field damage with little or no effort by line personnel. One possibility for this approach is to produce bolts and fasteners that already contain the treatment on the threaded surface. Once the “treated” bolt is installed, natural moisture in the wood will help release the chemicals so that they can be present to inhibit the germination of spores or growth of hyphal fragments of any invading decay fungi.

The efficacy of these treatments was evaluated using both field and laboratory tests. In the initial laboratory tests, bolts were coated with either copper naphthenate (Cop-R-Nap) or copper naphthenate plus boron (CuRap 20) pastes and installed in Douglas-fir pole sections which were stored for one or two weeks at 32 C. The poles were then split through the bolt hole and the degree of chemical movement was assessed using specific chemical indicators (AWPA, 2006 a-c). Penetration was measured as average distance up or down from the bolt.

Copper penetration longitudinally away from the bolt holes has been limited over the 8 year field test (Tables II-1, 2). Average copper penetration for the COP-R-PLASTIC treated rods was 2.7 mm after 6 years, while that around the CuRap 20 treated bolts was 3.8 mm. The copper in both systems was not designed to be mobile and these results reflect that limited ability to migrate.

Fluoride and boron would both be expected to migrate for longer distances away from the original treatment site. Both move well with moisture and the bolt holes should be avenues for moisture movement into the wood during our wet winters. Longitudinal movement of both fluoride and boron appeared to be limited over the 8 year test period. Although maximum penetration was up to 120 mm from the rods, mean fluoride and boron penetration were only 22.0 and 11.7 mm, respectively (Tables II-1, 2). The results were variable, but one explanation may be that moisture movement may be restricted around each of the relatively tight fitting bolts.

As utilities continue to use internal and external treatments to protect the groundline zone, slow development of decay above the ground may threaten the long term gains provided by groundline treatments. Treated fasteners could be used to limit the potential for above ground decay, allowing utilities to continue to gain the benefits afforded by aggressive groundline maintenance.

One question that arose from this work was the potential for the treatments to accelerate metal corrosion. While boron is not known to be highly corrosive, the additives in the pastes may increase the risk of wood/metal interactions. While we have destructively sampled all the pieces in

Table II-1. Penetration of copper around chemically treated threaded galvanized bolts inserted into Douglas-fir poles sections and exposed in the field for 1 to 8 years.

Treatment	Diffusion	Degree of Chemical Movement (mm)[a]					
		Copper					
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 6	Yr 8
Cop-R-Plastic	Average	<1	2.3 (1.3)	3.0 (0.8	2.3 (1.0)	2.3 (0.5)	2.7 (0.5
	Maximum	29.8 (28.8)	237.5 (64.0)	50.5 (47.5)	8.8 (3.2)	7.0 (5.6)	42.5 (32.9)
CuRap 20	Average	3.0 (1.2)	2.3 (0.5)	<1	1.0 (0.8)	8.3 (11.8)	3.8 (1.7)
	Maximum	20.5 (9.7)	110.3 (98.3)	51.3 (52.5)	7.3 (9.0)	18.0 (19.8)	21.8 (9.8)

Table II-2. Penetration of boron or fluoride around chemically treated threaded galvanized bolts inserted into Douglas-fir poles sections and exposed in the field for 1 to 8 years.

Treatment	Diffusion	Degree of Chemical Movement (mm)[a]					
		Boron/Fluoride					
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 6	Yr 8
Cop-R-Plastic	Average	<1	2.0 (2.8)	2.0 (1.8)	7.0 (4.7)	7.3 (3.1)	22.0 (18.9)
	Maximum	117.5 (138.7)	107.5 (73.7)	15.3 (16.9)	28.3 (18.0)	15.5 (5.4)	119.7 (33.9)
CuRap 20	Average	3.3 (0.5)	6.3 (3.4)	2.8 (2.2)	20.3 (16.1)	12.5 (6.7)	11.7 (8.7)
	Maximum	49.8 (10.5)	45.8 (28.5)	49.5 (55.1)	118.8 (69.4)	30.0 (29.5)	48.8 (47.5)

this test, we do still have bolts in test that were inserted in holes receiving similar treatments.

In 1979, a series of lightly pentachlorophenol treated Douglas-fir poles (200-250 mm in diameter by 4.5 m long) were installed at the Peavy Arboretum test site. A series of eight 25 mm diameter holes were drilled perpendicular to the grain beginning 600 mm above the groundline and extending upwards at 450 mm intervals to within 450 mm of the top. The holes were offset at 90 degrees from those above and below. The holes were then assigned to be treated with 10 % pentachlorophenol in diesel oil, powdered disodium octaborate tetrahydrate, powdered ammonium bifluoride, or 40 % boron in ethylene glycol (Boracol). Additional holes were left without chemical treatment to serve as controls. Bolts were inserted into each treatment hole. Half of the holes on each pole were given metal gain-plates on both sides and half were given plastic gain-plates.

The presence of decay fungi in the wood around the holes was monitored over a 20 year period to assess the efficacy of each supplemental treatment. Boron and ammonium bifluoride provided the best protection over the test period (Morrell et al., 1990). While these results were interesting and illustrated the benefits of supplemental surface treatments with diffusibles, the inability to convince line personnel to utilize these treatments renders the results moot. However, hardware in the treated poles can be used to assess the long term impact of supplemental treatment on connector corrosion.

This past year, we removed bolts from poles treated with each of the treatments and examined them for evidence of corrosion in comparison with non-treated controls. While there was evidence of slight corrosion on all of the bolts removed from the poles, there was no evidence that corrosion was any greater on any given treatment (Figure II-1 to II-4). The levels of chemical applied at the time of treatment were relatively small and all of the chemicals tested were water diffusible. Thus, it is likely that most of the chemical had diffused away from the initial treatment site and into the surrounding wood before it had a chance to induce measureable corrosion. The results, coupled with the excellent performance of the paste-coated rods in the more recent trials illustrate the potential for using relatively light treatments to protect wood out of soil contact for long periods of time and highlight the benefits of further development of treated connectors for use by contractors working on poles.

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American Wood Protection Association. 2006c. AWPA Standard A3 Standard methods for determining penetration of preservatives and fire retardants. Method 7. Method for determining penetration of fluoride in wood. AWPA Book of Standards, AWPA, Selma, Alabama.

Morrell, J.J., M.A. Newbill, and R. D. Graham. 1990. Evaluation of remedial treatments for protecting field-drilled bolt holes. Forest Products Journal 40(11/12):49-50.

Figure II-1. Condition of nuts, bolts and gain plates removed from field drilled bolt holes 32 years after treatment of the exposed non-treated wood with ammonium bifluoride prior to bolt insertion.

Figure II-2. Condition of nuts, bolts and gain plates removed from field drilled bolt holes 32 years after treatment of the exposed non-treated wood with boron (Polybor) prior to bolt insertion.

Figure II-3. Condition of nuts, bolts and gain plates removed from field drilled bolts holes 32 years after treatment of the exposed non-treated wood with Boracol prior to bolt insertion.

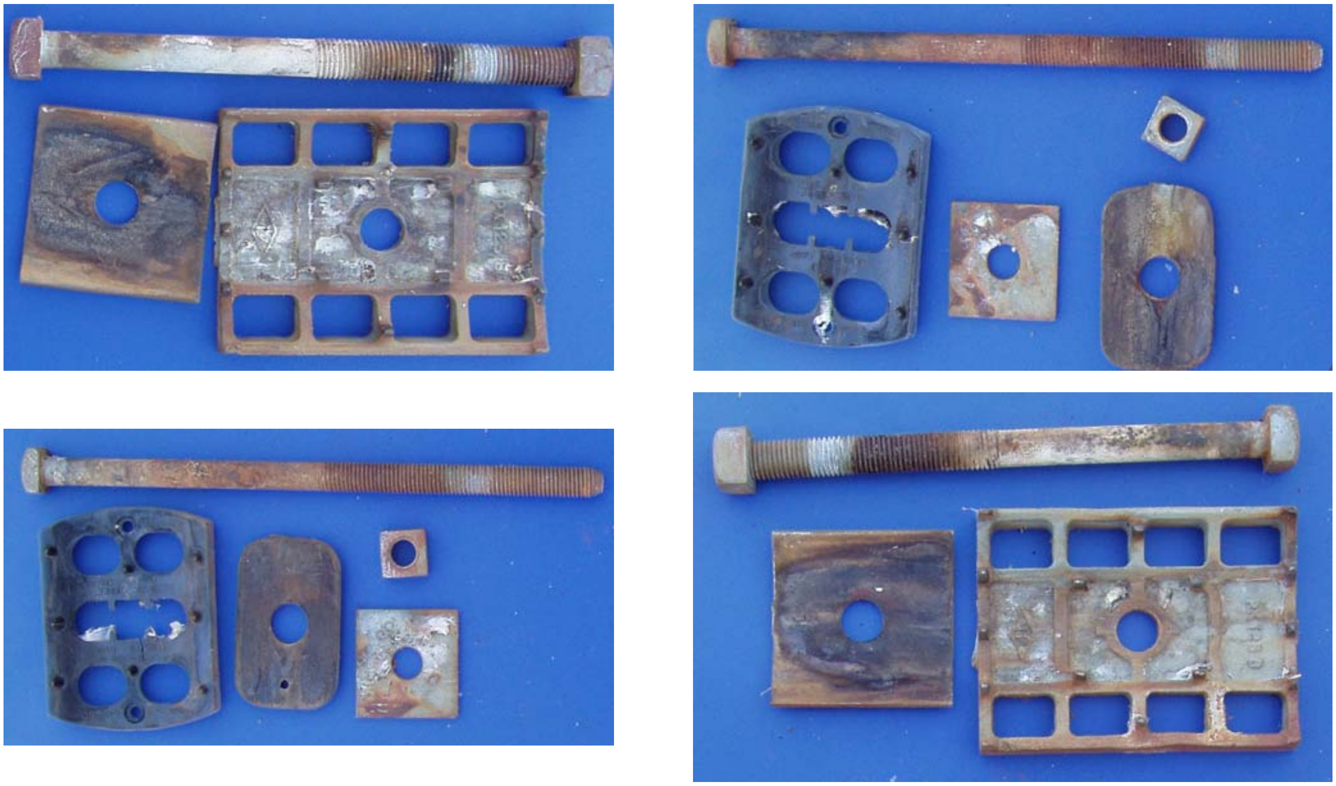

Figure II-4. Condition of nuts, bolts and gain plates removed from field drilled bolts holes after 32 years when no supplemental treatment was applied.

OBJECTIVE III

EVALUATE PROPERTIES AND DEVELOP IMPROVED SPECIFICATIONS FOR WOOD POLES

A well treated pole will provide exceptional performance under most conditions, but even a properly treated structure can experience decay in service. While most of our efforts have concentrated on developing systems for arresting in-service decay, developing methods for preventing this damage through improved initial specifications and identifying better methods for assessing in-service poles would produce even greater investment savings for utilities. The goals of Objective III are to develop new initial treatment methods, explore the potential for new species, assess various inspection tools and explore methods for producing more durable wood poles.

A. Effects of Through-Boring on Preservative Treatment and Strength of Douglas-fir Poles

The proposed through-boring standard is under consideration by the ASC 05 committee; however, we still need to provide more detailed information on specific poles. We will complete those analyses in the next 6 months.

B. Update on Coated Crossarm Sections Exposed in Hilo, Hawaii

Preservative treated Douglas-fir performs extremely well when exposed above the ground out of soil contact, such as when used as a crossarm to support overhead electrical lines in a distribution system. Douglas-fir contains a high percentage of difficult to treat heartwood and it is generally not feasible to completely penetrate this material with preservative. However, checks that open beyond the depth of the original preservative treatment can permit the entry of moisture as well as fungi and insects that can result in deterioration and premature failure. In previous studies, we found that horizontally exposed crossarms developed deep checks on the upper surfaces that allowed water to pool and fungi to invade the untreated wood. Arms exposed at an angle in a wishbone configuration did not experience these deep checks and tended to provide better performance. We attributed this to the ability of the arms to shed water and avoid pooling of water in the checks.

While the wishbone configuration is attractive in some applications, it is not suitable for all poles. An alternative approach to limiting checking and subsequent moisture entry into arms is to coat the exterior of the arm to retard moisture entry and presumably limit entry by fungi and insects. Polyurea coatings have been employed for protecting a variety of surfaces and appear to have potential as wood coatings in non-soil contact. In this report, we summarize field exposures of Douglas-fir samples coated with polyurea and exposed for 18 months near Hilo, Hawaii.

Decay Tests: Douglas-fir crossarm sections were either left non-treated or pressure treated to the AWPA Use Category requirement with pentachlorophenol in P9 Type A oil. One half of the arms from each group (non-treated or treated) were then coated with polyurea. The arms were then shipped to Hilo, Hawaii, where they were exposed on test racks 450 mm above the ground (Fig-

Figure III-1. Examples of Douglas-fir crossarm sections with and without polyurea coating immediately after exposure near Hilo, Hawaii.

ure III-1). The site receives approximately 5 m of rainfall per year and the temperature remains a relatively constant 24-28 C. The site has a severe biological hazard (280 on the Scheffer Climate Index Scale- which normally runs from 0 (low decay risk) to 100 (high decay risk) within the continental U.S.) and a severe UV exposure. Non-treated wood normally fails within 2 years at this site, compared to 4 to 5 years in western Oregon.

Assessment for the first 2 years was primarily visual and consisted of examining coating condition on the upper (exposed) and lower surfaces. Additional coated samples were exposed in June of 2011 (Figure III-2).

Termite Tests: Ideally, the polyurea would provide protection against termites without the addition of a preservative. The potential effectiveness of the polyurea as a barrier was assessed using 125 mm long Douglas-fir blocks that had been cut from boards (50 by 100 mm) that had either been left without treatment or had been treated with pentachlorophenol as describe above. Half of the sections were then coated with polyurea. The samples were evaluated for resistance to the Formosan termite (*Coptotermes formosanus)* at a test site located in Hilo.

In the termite tests, hollow concrete blocks were laid directly on the soil in a 1 m square in an area with known attack by *C. formosanus*. This species is considered to a very aggressive wood destroyer and is found in the southern U.S. as well as in Hawaii and the tip of Southern California. Materials resistant to this species would be expected to be resistant to most North American termites.

A series of 19 mm by 19 mm southern pine sapwood stakes were driven into the ground in the concrete block openings to provide avenues for termite workers to explore upward. A sheet of 6 mm thick southern pine plywood was then placed on top of the concrete blocks. The test pieces

Figure III-2. Polyurea coated Douglas-fir crossarm sections exposed in June 2011.

were arranged on the array so that every piece was surrounded by southern pine sapwood sticks. This allowed foraging termite workers to explore throughout the array and to be able to choose to attack specific wood samples while avoiding those that might be repellant (Figure III-3). The entire assembly was covered to prevent overhead wetting. This arrangement posed little or no

Figure III-3. Example of a termite array containing non-coated and polyurea coated Douglas-fir lumber sections at the time of exposure.

risk of chemical leaching.

The degree of termite damage was visually assessed 6 months after exposure using the following scale

10	no attack, some slight grazing allowed
9.5	slight grazing
9.0	termite attack but little penetration
8.0	termite penetration
7.0	substantial termite attack
4.0	termite attack renders sample barely serviceable
0	sample destroyed

In June of 2011, additional samples were exposed using the same procedures except that one half of the samples were left without treatment and the other half were dipped in disodium octaborate tetrahydrate (borate) to explore the potential for using boron as a wood treatment under the polyurea coated materials. These samples will be inspected in November 2011.

Non-coated, non-treated wood was destroyed by Formosan termite attack 6 months after installation as was the non-treated feeder stock placed around the array (Table III-1). These results indicate that conditions were suitable for aggressive termite attack. Interestingly, coated, but non-treated blocks were also completely destroyed at the 6 month point. The coatings surrounding the non-treated blocks, however, were largely intact, except for entry holes along the end-grain (Figure III-4). The ability of the termites to locate non-treated wood beneath the coating also

Table III-1. Effect of a polyurea coating on degree of damage experienced by penta-treated and non-treated Douglas-fir lumber.

Preservative Treatment	Average Termite Rating[1]			
	Non-Coated		Coated	
	6 months	12 months	6 months	12 months
Non-treated	0	-	0	-
Penta-treated	10	10	10	10

[1]Values represent means of 10 replicates per treatment

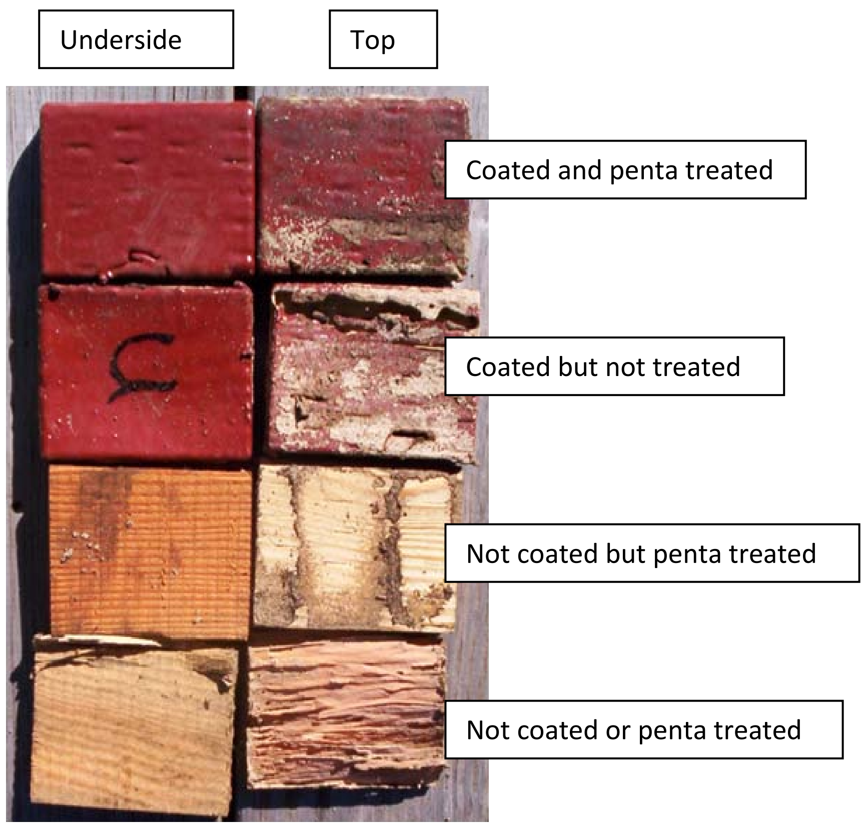

Figure III-4. Examples of undersides (top) and upper surfaces of coated and non-coated Douglas-fir lumber with and without penta treatment.

illustrates the aggressive nature of these insects. The test configuration is designed to limit the potential for moisture entry that might result in leaching of extractives from the wood that could be attractive to foraging workers. The results suggest that the attack was initiated by volatiles moving through the coatings from the wood and into the covered chamber. These also indicate that barriers alone are insufficient to limit attack by this insect.

Penta treated wood in the arrays was free of termite attack at the 6 month time point regardless of whether it was coated or not, although the surfaces were heavily mudded by the workers. This lack of damage reflects the exceptional performance of penta as a wood preservative. The arrays were reset with fresh non-treated feeder material after the first evaluation and then evaluated after an additional 6 months of exposure. Once again, the feeder material was completely destroyed and the samples were heavily mudded by the termites. However, there was no evidence of attack on any of the coated or non-coated, treated samples. The samples were reset with additional feeder material and will be evaluated in another 6 months at the same time the borate-treated samples are evaluated.

Coated and non-coated samples have been exposed above the ground for over 18 months at the termite-free site (Figure III-5 & 6). While the coated samples have weathered on the upper surfaces, the coatings show no signs of failure or of losing their flexibility. At least one of the non-coated, non-treated samples had a fungal fruiting body, suggesting that the wood was beginning to decay internally. The remaining samples showed no evidence of degradation beyond the weathering normally associated with the site.

These samples will be inspected at 24 months. At some point, samples will be removed and returned to Corvallis to assess the coating integrity. At present, however, the coatings appear to be holding up well under the harsh UV exposure with no evidence of cracking or other defects that

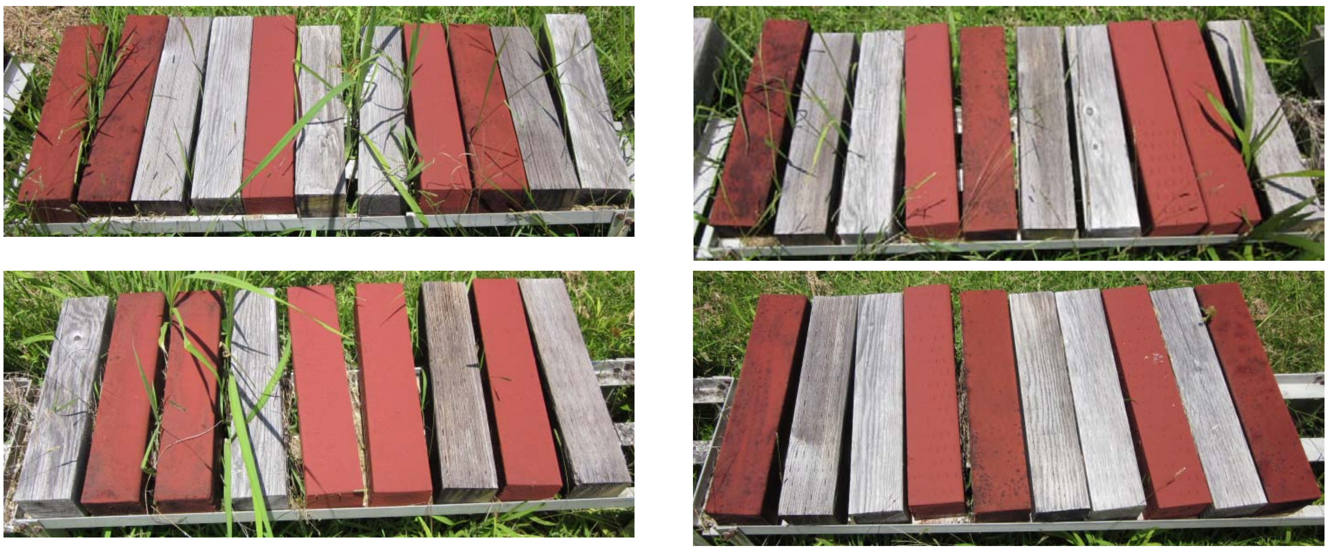

Figure III-5. Examples of the upper (UV exposed) surfaces of coated and non- coated Douglas-fir crossarm sections 18 months after installation at Hilo, Hawaii.

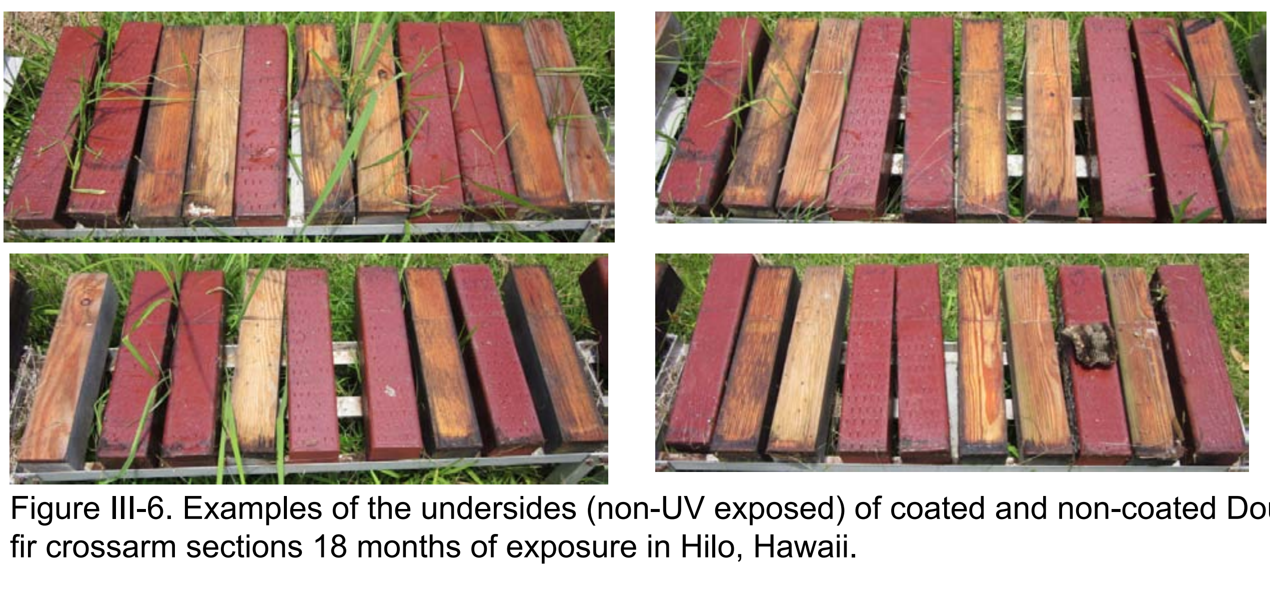

Figure III-6. Examples of the undersides (non-UV exposed) of coated and non-coated Douglas-fir crossarm sections 18 months of exposure in Hilo, Hawaii.

could lead to coating failure and moisture ingress.

C. Performance of Fire Retardants on Douglas-fir poles

Transmission, and to a lesser extent distribution, lines often pass through forested areas. Vegetation control to limit the potential for trees contacting the lines is an important and expensive component of right-of-way maintenance. Despite these practices, poles in areas with heavy vegetation may still be vulnerable to rangeland or forest fires. There are a number of possible methods for limiting the risk of fires on poles. In the past, metal barriers were placed around poles in high hazard areas; however, this practice reduced pole service life because the barriers trapped moisture on the pole surface.

As an alternative, poles can be periodically treated with fire retardants. Some of these materials are designed for short term protection and must be applied immediately prior to a fire, while others are longer lasting and provide 1 to 3 years of protection. While these fire retardant treatments have been available for decades, there is little published information on their efficacy or their longevity. Over the past five years, we have evaluated a number of field-applied fire retardants and found them to remain effective. No fire tests were conducted this past year although we continue to seek other candidate materials.

D. Effect of End Plates on Checking of Douglas-fir Crossarms

The environmental conditions in a crossarm present a much lower risk of decay than would be found at groundline; however, the arms are subjected to much wider fluctuations in wood moisture content than poles. Arms expand as they wet and then shrink when they dry. This repeated cyclic moisture behavior can lead to mechanical damage and the development of deep checks. These checks can lead to splits that cause bolts and other hardware to loosen and fail. The incidence of splits in crossarms is generally low, but the cost of repairs can be significant. Thus, the development of methods for limiting splitting in crossarms would be economical in many utility systems.

Figure III-7. Example of an end-plate on a penta treated Douglas-fir crossarm.

One approach to limiting splitting is end-plating. End-plates have long been used to limit splitting of railroad ties and many rail lines routinely plate all ties. End-plates might provide similar benefits for crossarms; however, there is little data on the merits of these plates for this application. In order to develop this data, the following test was established.

Thirteen pentachlorophenol treated Douglas-fir crossarm sections (87.5 mm by 112.5 mm by 1.2 m) long were end-plated on both ends then cut in half to leave one plated end and one non-plated end on each arm (Figure III-7). The objective was to compare checking with and without plates on comparable wood samples. The plates were developed by Brooks Manufacturing (Bellingham, WA). The arms were initially examined for the presence of checks. The arms were then immersed in water for 30 days before being removed and assessed for check development. The total number of checks longer than 2.5 cm on each face was recorded, and the width of the widest check on each face was measured. The arm sections were air dried and measurements were made again. The arms were then returned to the dipping tank for an additional 30 days before the cycle was repeated. The arms were air-dried in the first cycle and kiln-dried for the remaining 12 cycles.

The differences in degree of checking between the arms were slight for the first few drying cycles and checking was actually slightly greater in end-plated arms early in the test (Table III-2). Continued moisture cycling, however, has gradually shown that check width and frequency have both become larger on the arm end without the end-plate. Check width appears to have reached a maximum between 12 and 13 wet/dry cycles, while the frequency of checking has continued to slowly increase on the plated ends of the arms. The results suggest that both the frequency and size of checks can be limited by end-plating. These results parallel those found with end-plating on railway sleepers. In the case of the sleepers, the need for anti-splitting devices is much greater because of the tendency of many hardwood species to split as they season; however, the principle is the same. These plates would be especially useful in very dry areas or in those subjected to extreme wet/dry cycles. In both cases, the build-up of internal stress can lead to deep check development that can compromise crossarm connectors.

Table III-2. Number and width of checks in crossarms with or without end-plates after repeated wet/dry cycles.

Cycle	Average Number of Checks				Widest Check			
	Wetting Cycle		Drying Cycle		Wetting Cycle		Drying Cycle	
	No End Plate	End Plate	No End Plate	End Plate	No End Plate	End Plate	No End Plate	End Plate
1	2.32	0.36	0.48	0.12	1.00	1.50	0.81	0.81
2	0.20	0.08	1.00	0.52	0.31	1.00	1.10	1.40
3	0.00	0.08	0.24	0.16	0.00	1.10	1.00	1.30
4	0.04	0.08	1.00	0.96	0.64	1.50	1.20	1.10
5	0.04	0.08	0.56	0.80	0.70	1.80	3.00	1.50
6	1.92	0.32	2.00	0.36	0.81	0.89	2.50	2.00
7	1.40	0.52	2.24	2.00	0.71	1.40	3.60	2.10
8	0.96	0.12	2.00	1.44	1.90	1.90	7.00	2.20
9	0.92	0.52	3.08	2.24	3.00	1.20	6.60	3.40
10	1.52	1.05	3.84	2.20	4.00	1.10	5.90	2.60
11	0.84	0.40	3.40	2.32	2.11	1.19	6.98	2.98
12	3.16	1.40	3.60	2.36	1.15	0.81	7.90	2.20
13	1.24	0.60	3.48	2.80	1.13	0.83	9.20	3.70

E. Assessing Internal Condition of the Above-Ground Regions of Douglas-fir Poles

The susceptibility of Douglas-fir to internal decay at groundline is well documented and can be easily rectified by through-boring (Graham, 1980, Morrell and Schneider, 1994, Newbill, *et al.*, 1999, Newbill, 1997, Rhatigan and Morrell, 2003). This practice has improved the protection of the critical groundline zone of Douglas-fir poles, extending the service life of these poles by several decades (Mankowski, *et al* 2002). In many locations, however, Douglas-fir poles can also develop internal decay well above the groundline. This is particularly true in areas which experience wind-driven rainfall such as those regions along the Oregon and Washington coasts. The extent of this damage and the ability to accurately assess the impact on pole properties varies. Several years ago, we initiated a cooperative inspection program with Portland General Electric (PGE), inspecting poles in a number of lines across their service territory.

The results indicated that above-ground decay was an issue in older poles, particularly in areas of the Coast Range of Western Oregon, where wind driven rain tends to be most prevalent. These findings led PGE to institute system-wide climbing inspection of their older transmission lines. While these inspections have identified a number of poles in need of replacement, one problem with the inspection process is the subjectivity of the process. Line personnel climb the pole, sounding with a hammer as they move upward. Any suspect areas are then more closely assessed by drilling. Although the process is fairly subjective, there is an ability to calculate residual section modulus using residual shell depths as measured in the inspection holes. Ideally, however, the use of some form of non-destructive testing could be used to delineate any internal damage so that more precise engineering calculations could be made. These types of devices would also create a record of internal condition that could be used in subsequent inspections to track the progress of any internal defects.

Unfortunately, there are few non-destructive inspection devices capable of developing the kind of internal pole condition information needed to accurately assess remaining pole strength. Recently, however, we identified a device from New Zealand that has some potential for this application. The preliminary assessment was promising, but we are still waiting for the manufacturer to modify the device based upon line personnel suggestions. Then we will further evaluate the accuracy of the instrument.

F. Effect of Capping on Pole Moisture Content

We have long advocated for the tops of utility poles to be protected with a water shedding cap. While the original preservative treatment does afford some protection, checks that develop on the exposed end-grain can allow moisture to penetrate beyond the original depth of treatment. We have observed extensive top decay in older (>50 to 60 years old) Douglas-fir distribution poles which might ultimately reduce the service life of the pole. Capping can prevent this damage, but there is relatively little data on the ability of these devices to limit moisture entry.

Ten Douglas-fir poles that had been removed from service were cut into 2.5 m lengths and set in the ground to a depth of 0.6 m. The poles were cut so that the top was at least 150 mm away from any pre-existing bolt hole. The original bolt holes on the pole sections were then plugged with tight fitting wood or plastic plugs to retard moisture entry.

Five of the poles were left without caps while the remainder received Osmose pole caps. Initial moisture contents were determined by removing increment cores 150 mm below the top of each pole (Figure III-8). The outer treated zone was discarded, and then the inner and outer 25 mm of

Figure III-8. Example of a capped pole (Osmose Pole Topper)used to assess the effects of capping on wood moisture content.

the remainder of the core were weighed, oven-dried and re-weighed to determine wood moisture content.

The effect of the caps on moisture content was assessed 4 months after treatment at the end of our rainy season. Increment cores were removed from just beneath the pole cap or at an equivalent location on the non-capped poles. The cores were processed as described above. Moisture contents at the start of the test were 20 and 28 % for the inner zones while they were 17 and 19 % for the outer 25 mm of non-capped and capped poles, respectively, (Table III-3). The elevated levels in the inner zones of the capped poles were due to one very wet pole. Moisture contents at the 4 month point had declined in both the inner and outer zones of the capped poles, even though sampling took place during our winter rainy season. Moisture contents in the non-capped pole sections rose to 25.2 % and 19.1 % in the inner and outer zones, respectively. While the increases were not major, they did show that the non-capped poles were wetter. We have continued to monitor moisture levels periodically over the 40 month exposure. Moisture contents in the non-capped poles tend to cycle up and down with the wet and dry seasons typical of the test site (Table III-3).

Moisture contents in non-capped pole sections 12 months after installation were 37.5 % in the inner zone and 25.6 % in the outer zone, while those in the same zones in capped poles averaged 14.2 % and 16.4 %, respectively. Moisture contents in capped poles have continued to remain at low levels after 40 months. The levels are within the expected equilibrium moisture content for wood exposed outdoors and far below those required for active fungal decay. Moisture contents in poles without caps continue to cycle with season. Moisture contents in the inner zones of non-capped poles were 99% 40 months after installation, well above the point where fungal decay would begin in the outer zone. While these poles dried somewhat in the summer, the elevated moisture levels will eventually allow decay fungi to become established, ultimately leading to top decay.

Table III-3. Wood moisture contents 0 to 40 months after installation of water shedding caps to Douglas-fir pole sections.

Exposure	Sampling	Control		Pole Cap	
(mo)	Month	inner	outer	inner	outer
0	February	20.1	16.8	28.4	19.7
4	June	25.2	18.9	19.0	18.3
12	February	37.5	26.1	14.2	16.4
28	June	60.7	27.4	15.5	15.9
32	October	29.3	17.4	13.6	13.5
40	June	99.3	35.5	13.6	16.1

Clearly, capping has a marked effect on moisture content. Over time, we would expect the lower moisture content to reduce the risk of both preservative depletion and internal decay development. We will continue monitoring these pole sections over the coming seasons to establish internal moisture trends associated with the caps.

G. Evaluation of Polyurea Coating as a Method for Controlling Moisture Levels in Douglas-fir pole Tops

The polyurea barriers have proven to be durable on crossarms in sub-tropical exposures at Hilo, Hawaii. We wondered if these materials would also be effective for protecting the tops of newly installed poles. To investigate this possibility, six pentachlorophenol treated Douglas-fir pole sections (3 m long) were coated with polyurea from the tip to approximately 0.9 m below that zone. The poles were set to a depth of 0.6 m at a test site on the OSU campus. Increment cores were removed from the zone below the coated surface and divided into inner and outer 25 mm sections as described above. Each core section was weighed immediately after removal from the pole, then oven-dried and re-weighed. The difference was used to determine installation moisture content (Table III-4).

Table III-4. Moisture contents in polyurea capped Douglas-fir poles immediately after installation as determined by oven drying increments cores removed from the poles.

Pole #	Moisture content (%)	
	inner	outer
491	25.9	16.0
492	20.3	16.0
493	20.3	16.4
494	23.8	21.6
495	20.5	17.4
496	31.8	26.7

Moisture contents at the time of installation ranged from 16.0 to 31.8%. The averages for the inner and outer zones were 23.8% and 19.0% respectively. These poles were installed in the spring of 2011 and will be periodically sampled to assess the effect of the coating on internal moisture by removing increment cores in the same manner. The surface coating will also be monitored for evidence of adhesion with the wood as well as the development of any surface degradation.

H. Ability of Ground Wire Staples to Resist Withdrawal

Staples are commonly used to hold ground wires to poles. For many years, there was relatively little concern about these staples. Recently, however, thieves have targeted copper ground wires and the ability of these staples to provide maximum resistance to withdrawal has taken on added importance. Among the Advisory Committee recommendations last year, was a request to evaluate the performance of these staples. Co-op members were requested to supply 200 of the staples used in their systems. Douglas-fir pole sections treated with either pentachlorophenol (penta) in P9 Type A oil or with ammoniacal copper zinc arsenate (ACZA) were used in the evaluation. The penta poles were freshly treated to the ground contact retention (9.6 kg/m^3), while the ACZA poles had originally been treated to the same retention but had been weathered for 5 years as part of our work under Objective VI.

A total of eight staple types were received from cooperators. The staples varied widely in dimensions and materials (Table III-5, Figure III-9). The staples were driven to a set depth (12 mm above the wood surface) using a hydraulic press on a Tinius Olsen testing machine (Figure III-10). Thirty-two staples from each source were driven into pole sections from each treatment group. The staples were driven in a line at 150 mm intervals along the pole length and each line was separated by 150 mm around the pole (Figure III-12). Large checks and knots were avoided

Table III-5. Characteristics of ground wire staples tested for withdrawal resistance.

Staple #	Supplier	Size (in)	Force (pounds)					
			ACZA wood			Penta wood		
			Min.	Max.	Average (std)	Min.	Max.	Average (std)
1	McClean Power Systems	2 x 5/8 x 0.168	310	671	493 (106)	248	508	384 (73)
2	Unknown	1 1/2 x 1/2 x 0.06	100	309	240 (52)	71	319	216 (77)
3	Hughes Supply	2 x 1/2 x 0.162	321	905	614 (135)	332	870	604 (141)
4	Hughes Supply	2 x 5/8 x 0.162	316	874	582 (140)	204	728	499 (119)
5	Hughes Supply	1 3/4 x 3/8 x 0.148	178	610	413 (115)	167	704	354 (116)
6	Lawson Hardware Mfg. Inc.	1 3/4 x 3/8 x 0.148	237	520	382 (82)	184	457	335 (87)
7	Lawson Hardware Mfg. Inc.	2 x 1/2 x 0.162	264	768	563 (143)	307	773	528 (122)
8	Unknown	3 x 2 x 0.25	484	2103	1486 (364)	604	1493	1039 (170)

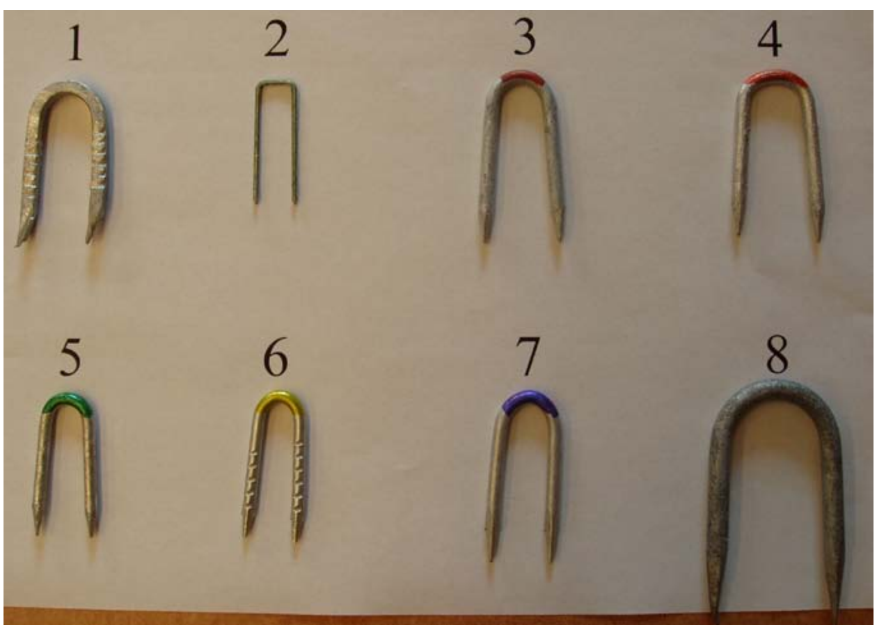

Figure III-9. Examples of ground wire staple types evaluated for withdrawal resistance from penta and ACZA treated Douglas-fir poles.

when inserting the staples.

Once the staples were set, they were withdrawn using a specially constructed jig (Figure III-13) that withdrew the staples at a set rate (6 mm/min) while measuring the load required to achieve withdrawal.

The wire staples provide the lowest withdrawal resistance while the largest staples provided almost six times more withdrawal resistance (Table III-5). Withdrawal resistance values were

Figure III-10. Example of a ground wire staple being driven into a Douglas-fir pole section.

Figure III-11. Example of a pole containing rows of ground wire staples driven into the surface.

similar for most of the other fasteners tested. In terms of the effect of dimensions on withdrawal, fasteners 1, 3, 4, and 7 were fairly close in size and had similar values. Wood treatment did not appear to affect withdrawal resistance for a given fastener. While one might expect that the oil in the penta treated poles would lubricate the staple, making withdrawal easier, this was not the case and there was little difference in withdrawal between the two treatments (Figures III-13 and 14). Fastener withdrawal resistance is a function of both fastener dimension and the depth to which the fastener is driven. Manufacturers also incorporate various surface features that are intended to increase the pressure exerted by the wood on the fastener.

Figure III-12. Example of a ground wire staple being mechanically withdrawn from a pole section.

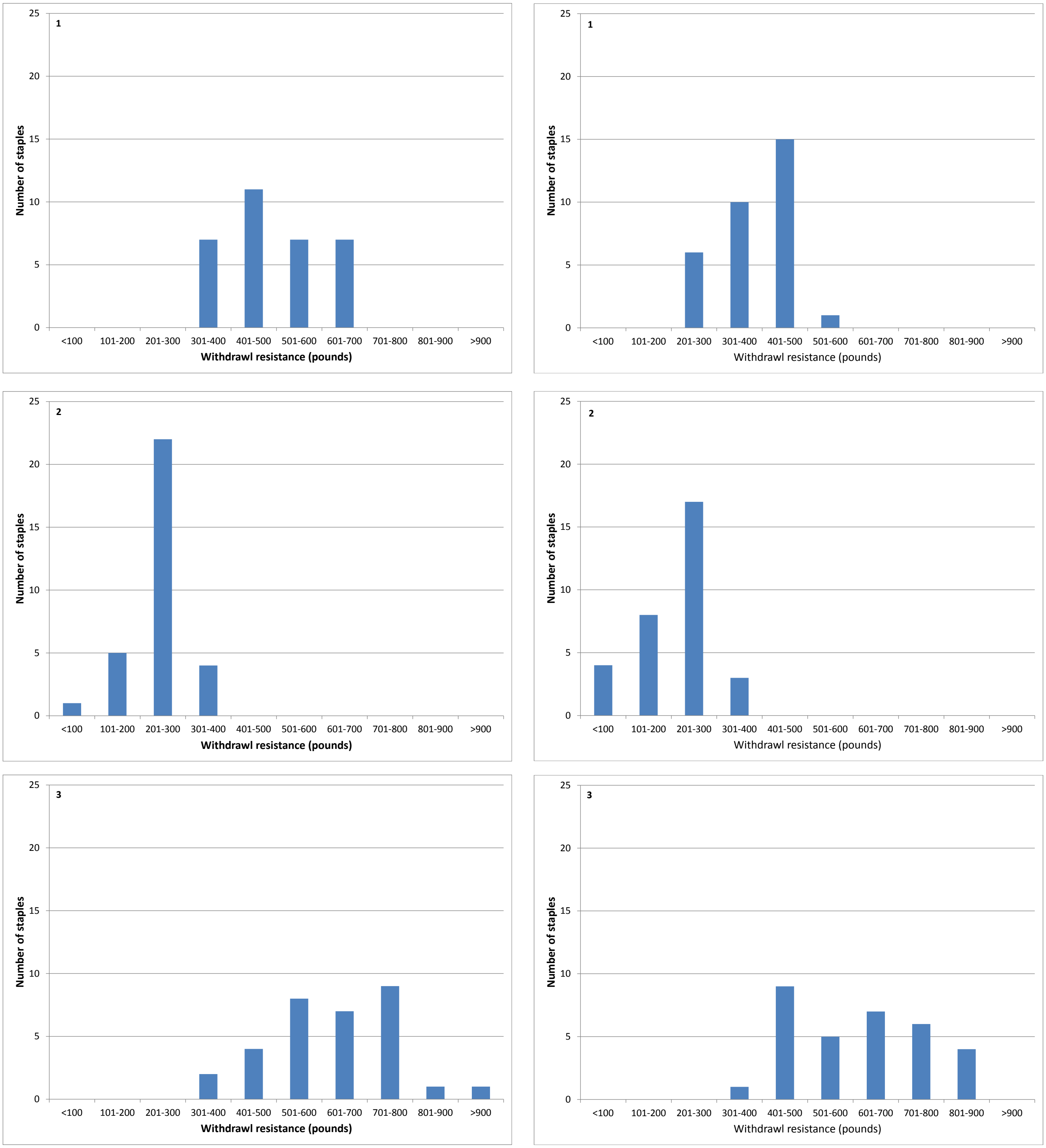

Figure III-13. Histograms showing relative distribution of force required to withdraw ground wire staples from ACZA (left) or penta (right) treated Douglas-fir poles. Thirty-two staples of each type were tested for each pole treatment.

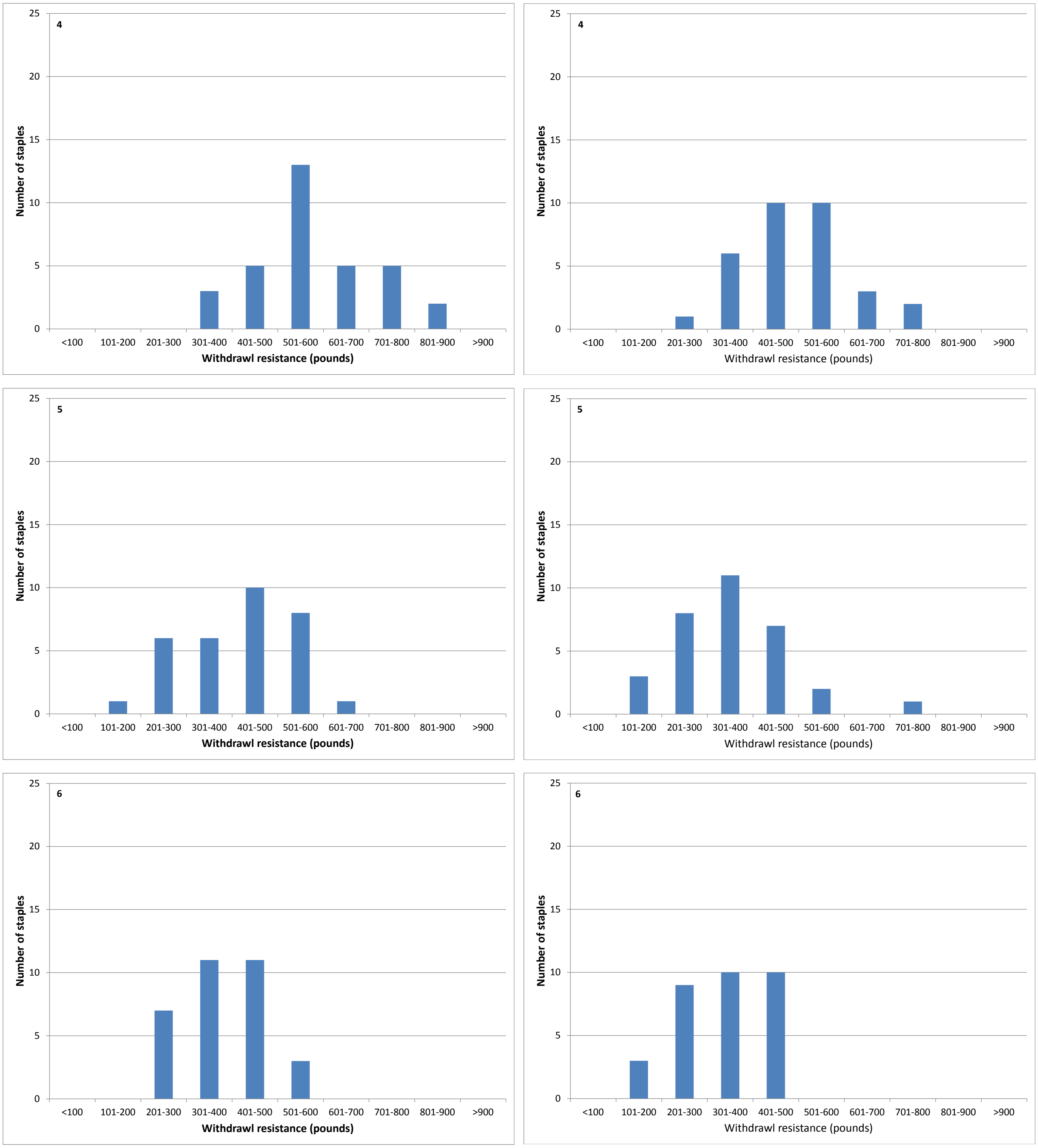

Figure III-13 continued. Histograms showing relative distribution of force required to withdraw ground wire staples from ACZA (left) or penta (right) treated Douglas-fir poles. Thirty-two staples of each type were tested for each pole treatment.

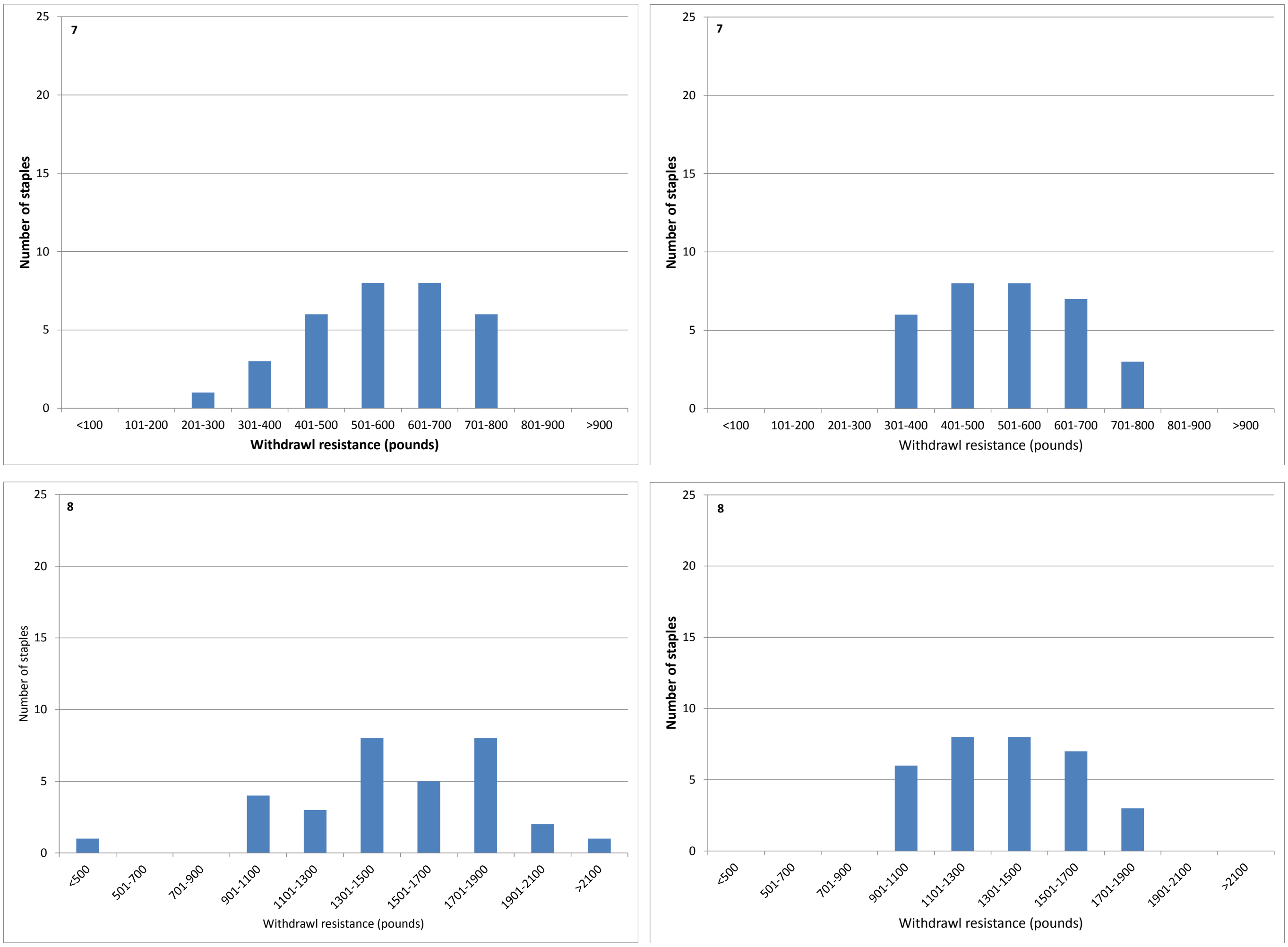

Figure III-13 continued. Histograms showing relative distribution of force required to withdraw ground wire staples from ACZA (left) or penta (right) treated Douglas-fir poles. Thirty-two staples of each type were tested for each pole treatment.

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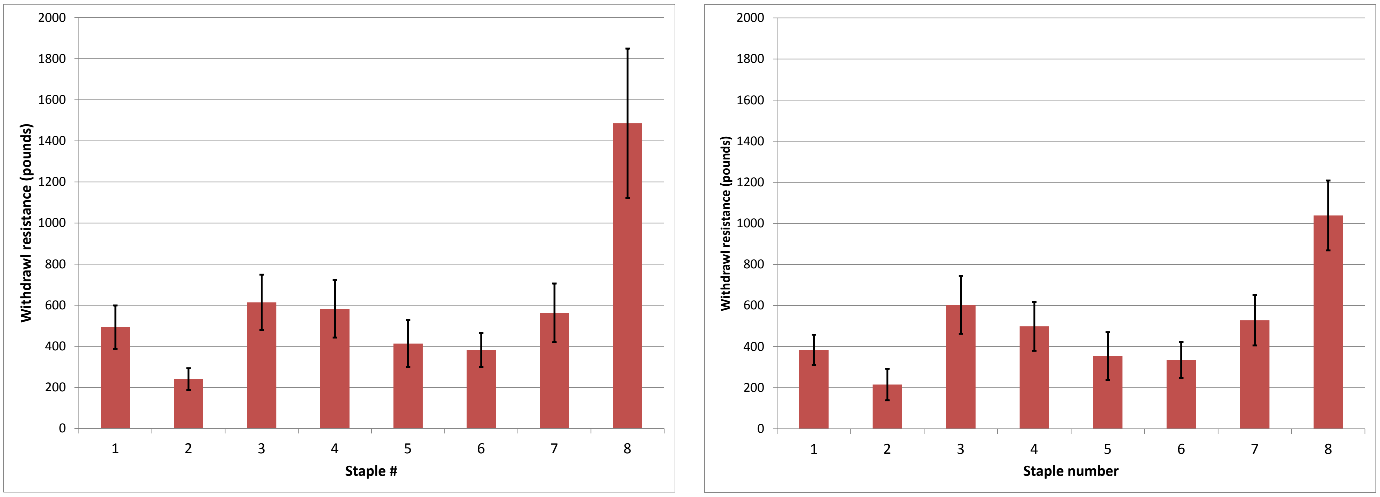

Figure III-14 Average force required to withdraw ground wire staples from ACZA (left) or penta (right) treated Douglas-fir poles. The error bars represent one standard deviation from the mean of thirty-two staples for each pole treatment.

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OBJECTIVE IV

PERFORMANCE OF EXTERNAL GROUNDLINE PRESERVATIVE SYSTEMS

While preservative treatment provides excellent long term protection against fungal attack in a variety of environments, there are a number of service applications where the treatment eventually loses its effectiveness. Soft rot fungi can then decay the wood surface, gradually reducing the effective circumference of the pole until replacement is necessary. In these instances, pole service life can be markedly extended by periodic below ground application of external preservative pastes that eliminate fungi in the wood near the surface and provide a protective barrier against re-invasion by fungi in the surrounding soil.

For many years, the pastes used for this purpose incorporated a diverse mixture of chemicals including pentachlorophenol, potassium dichromate, creosote, fluoride and an array of insecticides. The re-examination of pesticide registrations by the U.S. Environmental Protection Agency in the 1980s resulted in several of these components being listed as restricted use pesticides. This action, in turn, encouraged utilities and chemical suppliers to examine alternative preservatives for this application. While these chemicals had prior applications as wood preservatives, there was little data on their efficacy as preservative pastes and this lack of data led to the establishment of this Objective. The primary goals of this Objective are to assess the laboratory and field performance of external preservative systems for protecting the below ground portions of wood poles.

A. Performance of External Preservative Systems on Douglas-fir, Western redcedar, and Ponderosa Pine Poles in California

The field test in California is now completed. The final results were provided in the 2002 annual report.

B. Performance of Selected Supplemental Groundline Preservatives in Douglas-fir-Poles Exposed Near Corvallis, Oregon

The pole sections in the field test of copper/boron and copper/boron/fluorides had declined to the point where they could no longer be sampled and this test was terminated in 2003.

C. Performance of External Treatments for Limiting Groundline Decay in Southern Pine Poles near Beacon, New York

This test is completed. The final results from this test were presented in the 2009 Annual Report.

D. Performance of External Treatments for Limiting Groundline Decay on Southern Pine Poles in Southern Georgia

Over the past two decades, the UPRC has established a series of tests to evaluate the performance of external supplemental preservative systems on utility poles. Initially, tests were established on non-treated Douglas-fir pole sections. The tests were established on non-treated wood because the absence of prior treatment limited the potential for interference from existing preservatives, and the use of non-decayed wood eliminated the variation in degree of decay that might be found in existing utility poles. Later, we established tests on western redcedar, western pine and Douglas-fir poles in the Pacific Gas and Electric system near Merced, CA. The poles in this test had existing surface decay and were sorted into treatment groups on the basis of residual preservative retentions. Within several years, we also established similar trials in western redcedar and southern pine poles in Binghamton, New York and southern pine poles near Beacon, New York. In the Beacon test, we altered our sampling strategies in consultation with our cooperators and attempted to better control application rates. The chemical systems evaluated in these trials have varied over the years as a result of corporate changes in formulation and cooperator interest. One other drawback of these tests is that none have been performed under truly high decay hazards. In this section, we describe procedures used to establish a test of currently registered formulations in the Georgia Power system.

Southern pine poles that had been in service for at least 10 years were selected for the test. The poles were treated with oil-based treatments (CCA would interfere with analysis of copper containing systems) and, ideally, would not have been subjected to prior supplemental surface treatment. Unfortunately, we could not locate poles in the Southern Company system that had not been previously treated below ground. All of the poles in this test had previously been treated with OsmoPlastic in 1980 and/or 1994. While the oilborne components in this formulation will not interfere with future analysis, this system contains fluoride. This necessitated some prior sampling of poles to assess residual fluoride levels for the poles that were to be treated with the two fluoride containing Osmose formulations. We recognize that it would have been better to have poles that had not received prior treatment; however, this was not possible within the system. Prior treatment can have a number of potential effects. Obviously, residual fluoride can increase the amounts of fluoride found in the test poles; however, we hope to be able to factor this chemical loading out using our pre-treatment sampling. The presence of residual chemical may have other effects on diffusion of newly applied chemicals (potentially both positive and negative); however, this subject has received little attention and we have no data supporting the premise of synergy.

Fluoride levels in poles receiving either COP-R-PLASTIC or PoleWrap averaged 1.18 and 0.96 kg/m^3, respectively, in the outer 25 mm prior to treatment (Table IV-1). These levels are well above the internal threshold for fluoride (0.67 kg/m^3), but still below the level we have traditionally

Table IV-1. Fluoride levels in poles prior to treatment.

Proposed Treatment	Distance from Surface (mm)	Fluoride Level (kg/m^3)[1]
COP-R-PLASTIC	0-25	1.18 (1.77)
	25-50	0.46 (0.35)
	50-75	0.53 (0.36)
Pole Wrap	0-25	0.96 (0.89)
	25-50	0.54 (0.25)
	50-75	0.62 (0.28)

1. Numbers in parenthses represent one standard deviation around the mean of 10 measurements.

used for performance of fluoride based materials in soil contact (2.24 kg/m^3). Fluoride levels further inward ranged from 0.46 to 0.62 kg/m^3. These levels are at or just below the internal threshold. It is clear that we will have to use caution in interpreting the results from these tests. On the positive side, however, the results suggest that some re-examination of the retreatment cycle might be advisable to determine if the period between treatments might be extended.

Poles in the test were allocated to a given treatment and each treatment was replicated on a minimum of ten poles. An additional ten poles were included as non-treated controls.

The treatments in this test were:

CuBor (paste and bandage)
CuRap 20 (paste and bandage)
Cobra Wrap
COP-R-PLASTIC
PoleWrap (Bandage)

Each pole was excavated to a depth of 450 mm (18 inches) and any weakened wood was scraped away. The residual circumference of the pole was measured at groundline then the chemical was applied according to the manufacturer's label recommendations. In most cases, only one application rate, 1.6 mm, (1/16 inch) is allowed, but CuBor allowed for 1/16 to 1/2 inch (1.6 to 13 mm) paste thickness. After a consultation among the participants at the time the test was planned, it was agreed that all pastes would be applied at a single thickness. Since all of the other pastes could only be applied at 1.6 mm thickness, CuBor was applied at this thickness as well. While the same overall volume of paste was delivered to each pole (assuming similar circumference), density and copper content differences among the formulations created some variations in total copper applied. This can be best illustrated using the circumference of a Class 4 forty foot long pole and a 450 mm deep application zone. A 1.6 mm thick application rate delivers 0.87 kg of COP-R-PLASTIC paste per pole, compared with 0.78 and 0.79 kg/pole for the CuRap 20 and CuBor treatments, respectively (Table VI-2) As a result, total copper levels delivered per pole for CuRap 20 and CuBor would be 89.6 and 85.1% of those delivered in an equivalent COP-R-PLASTIC treatment. This might have some effect on ultimate chemical movement, although the results with these and many prior tests suggest that other factors such as copper mobility and adhesion to the wood surface probably play a much greater role in the ability of copper to migrate into the wood.

Table IV-2. Material properties of the three copper-based pastes tested in the Georgia field trial and the effects of density on total copper delivered to a Class 4 forty foot pole with each formulation using a 1.6 mm thick layer of each paste.

Paste Product	Density (kg/liter)	Application Rate (kg/pole)	Metallic Cu (kg/pole)
CuBor	1.20	0.74	0.0148
CuRap 20	1.26	0.78	0.0156
COP-R-PLASTIC	1.41	0.87	0.0174

Application rates on a given pole were determined by weighing the container and brush applicator before and after treatment. The difference represented the amount of chemical applied to a pole. Treated areas were then covered with the outer barriers recommended by the manufacturer and the soil was replaced around the pole.

Chemical movement from the pastes into the wood was assessed in five poles per treatment 1, 2, 3 and 5 years after treatment by removing increment cores from approximately 150 mm below the groundline. A small patch of the exterior bandage and any adhering paste was scraped away, and then increment cores were removed from the exposed wood on one side of the pole. The cores were cut into two different patterns. Chemicals containing copper-based biocides were segmented into zones corresponding to 0-6, 6-13 and 13-25 mm from the wood surface. Wood from a given zone from each pole was combined and then ground to pass a 20 mesh screen. Copper was assayed by x-ray fluorescence spectroscopy (XRF). Initially, we used a dilution method for copper analysis. A re-analysis of these results suggested that dilution considerably under-estimated copper levels. As a result, all of the retained samples were analyzed by extraction and ion coupled plasma spectroscopy to determine copper content. Unfortunately we cannot locate the residual sawdust for years 1 or 2. As a result, we have elected to present the test data on two graphs showing years 1 and 2 or 3 and 5. Comparisons between XRF and ICP data for the diluted year 3 samples indicate that the XRF values are low. If the volume of sawdust is sufficient for analysis, the XRF and ICP analyses are very similar. The samples from year 5 for all poles of the same treatment were combined to provide more material for analysis and copper was measured by XRF. The Year 5 data were presented in the 2010 Annual Report.

This study was scheduled for completion in 2009 with the Year 5 field sampling. Questions about the validity of the data arose because some samples from the non-treated poles contained relatively high levels of copper and boron. It appeared that in two instances treated poles were sampled instead of control poles. All of the groundline wraps and pastes in this study were providing protection 5 years after application, and the Advisory Committee decided against an additional sampling at 7 years to confirm these results.

E. Develop Thresholds for Commonly Used External Preservative Systems

Over the past decade, we have assessed the ability of a variety of external preservative pastes and bandages to move into treated and non-treated wood. While these tests have produced data showing that the systems can move into the wood, one of the short-comings of this data is the difficulty in determining just how much chemical is required to confer protection.

This is a particularly difficult topic to study because of the groundline environment. In most cases, the wood still has some level of initial preservative treatment present and the goal is to supplement that chemical loading. At the same time, the soil environment harbors fairly aggressive microorganisms and the wood may already be colonized by fungi. Finally, most of the previous data on fungal thresholds has been developed for traditional wood decay fungi, while surface decay below ground is dominated by soft rot fungi. Soft rot fungi tend to be more chemically tolerant and their location within the wood cell wall makes them potentially less susceptible to chemical action. Finally, a number of these systems contain both water diffusible and oil soluble components which move at different rates into the wood.

In previous tests, we have attempted to develop threshold data on diffusible systems using blocks treated with various combinations of preservatives and then exposed in soil burial soft rot tests. These tests have produced extremely variable results, most probably because the chemicals tended to move from the wood during the tests. While this would also happen in wood in service, the changing chemical environment during the test made it difficult to develop reasonable threshold estimates.

We continue to seek alternative methods for assessing thresholds on mobile chemicals in soil contact.

F. Performance of Boron/Fluoride Pastes and Bandages on Douglas-fir, Western redcedar, and Southern Pine poles

Preservative treatments provide an excellent barrier against fungal attack in soil contact, but over time, the effectiveness of these treatments declines to the point where external decay can develop. In high value applications, this damage is often arrested by excavating to a depth of 300 to 450 mm around a structure, scraping away any soil/damaged wood, and applying a supplemental preservative. The treatment is covered with a plastic barrier and the hole is back-filled. Supplemental systems often contain several components including some that coat the surface to prevent renewed attack and others that diffuse inward from the surface to arrest growth of fungi already present in the wood (Love et al., 2004).

Most external preservative systems used in North America contain copper as the surface barrier and either boron or fluoride as the diffusible component. These systems have generally provided excellent protection and are widely used to enhance the performance of western redcedar, oil-treated southern pine, Douglas-fir poles treated with pentachlorophenol in liquefied petroleum gas, or any pole that is set into concrete. Globally, however, there is a shift away from heavy metal based preservatives and this move is likely to affect North American utilities as well. One possible alternative treatment is the boron/fluoride system currently used in Australia and South Africa. This system is applied in self contained bandages that are easy to handle and apply or as pastes.

While these preservatives are used in a wide array of formulations worldwide, the precise levels of chemical required for protection are difficult to determine.

Water diffusible fungicides such as boron and fluoride are excellent candidates for limiting fungal attack in the heartwood of species that are resistant to conventional preservative treatment (Becker, 1976, 1973; Cockcroft and Levy, 1973). Boron and fluoride are two examples of water diffusible compounds that are primarily employed where their ability to diffuse through water in wood can be used to deliver chemicals into wood that normally resists traditional preservative treatment using pressure processes. Boron has long been used in dip/diffusion processes for treatment of building framing to prevent beetle attack, while fluoride has been used to treat wooden windows and door frames (Becker, 1976). In addition, both chemicals are used for remedial treatment of wood that is decaying in service (deJonge, 1986; Dickinson et al., 1988; Dietz and Schmidt, 1988; Morrell and Schneider, 1995, Panek et al., 1961; Sheard, 1990). These compounds, applied as either rods placed into holes drilled into the structure or paste applied to the surface, can move with moisture to the point where decay is occurring. Assessing the movement of either compound into the wood is relatively simple and can be accomplished using either chemical indicators or chemical extraction and analysis of the extracts. While chemical quantification is relatively simple, determining how much of each compound is required for protection against fungal attack is a much greater challenge.

The simplest way to assess toxicity is to expose fungi to the toxicant in agar or other growth media (Richards, 1924); however, this approach is extremely artificial and does not account for the potential interactions between the wood and the toxicant. The alternative is to treat wood blocks to selected retentions with the toxicant, then expose these blocks to fungal attack. The resulting weight losses are plotted against chemical loading and the point where weight losses are no longer considered to be of fungal origin is considered to be the threshold. The soil and agar block tests are the two most common methods for accelerated decay tests. These methods work reasonably well for chemicals that are relatively immobile in wood and that are intended for protecting wood in direct soil contact; however, they become more problematic with chemicals that remain mobile and are primarily used for protecting the interior of a wood product.

The estimated thresholds for wood protection determined using wood block exposures range widely for both boron and fluoride (Table IV-3). The wide range of values reflects, in part, the array of conditions under which the tests were performed as well as differences between the woods and fungal isolates tested. For example, thresholds are likely to be much higher if the tests allowed chemical leaching to occur. While this factor would be important in applications where the chemically treated wood is directly exposed to soil or liquid water, boron and fluoride are used in rod forms that are intended for internal application. The risk of leaching is minimal under these conditions, making a leaching exposure threshold value suspect. The target chemical levels in wood become important when considering re-treatment cycles. Remedial treatments are generally reapplied at regular intervals to provide continued supplemental protection to the wood, but the point at which re-application is necessary can be difficult to determine. Refining the re-treatment cycles can produce considerable cost savings for electrical utilities if it allowed them to safely delay treatments. One approach for determining re-treatment time has been to chemically analyze the wood to assess residual chemical levels, then reapply once the levels decline below a given level. Determining the reapplication level, however, is difficult without more precise data on the threshold required for protection against fungal attack.

There are, however, only limited data on the effectiveness of these systems on U.S pole species. In this report, we describe 5 year field trial results of boron and fluoride-based bandages and pastes on non-treated Douglas-fir, western redcedar and southern pine pole sections.

Douglas-fir (*Pseudotsuga menziesii*), southern pine (*Pinus* sp.) and western redcedar (*Thuja plicata*) pole sections (250-300 mm in diameter by 2.1 m long) were set to a depth of 0.6 m in the ground at a field test site near Corvallis, Oregon. The site has a Mediterranean climate with cool, moist winters and mild dry summers. The site receives an average of 40 inches of rainfall per year, nearly all of which falls in the winter months. The site has a Scheffer Climate index for above-ground decay of approximately 45 where 0 represents a very low risk of decay and 100 a severe risk (Scheffer, 1971).

Table IV-3. Thresholds for fluoride and boric acid against selected decay fungi as predicted in previous studies.

Fungus	Boron (kg/m3 BAE)	Fluoride (kg/m^3)	Source
G. trabeum	0.5 to 0.7		Becker, 1959
	1		Findlay, 1953
	1.6 to 2.4	1.13-1.36	Baechler and Roth,1956
	1.6 to 2.4	1.18-1.36	Fahlstrom, 1964
	<3.1		Ruddick et al., 1992
	2.9		Wiliams and Amburgey, 1987
	4.7		Roff, 1969
G. saepiarium	2.2		Edlund et al., 1983
P. placenta	0.4 to 0.8	1.13-1.31	Baechler and Roth, 1956
	1.0 to 1.4	1.31-1.45	Fahlstrom, 1964
	< 3.1		Ruddick et al., 1992
	4.3		Roff, 1969
N. lepideus	0.3		Findlay, 1953
	0.5 to 1.4		Becker, 1959
	1.0 to 1.4	0.63-0.95	Baechler and Roth, 1956
	1.6 to 2.4	0.86-1.08	Fahlstrom, 1964
T. versicolor	0.6	6.06-10.22	Baechler and Roth, 1956
	2.2 to 3.6	6.10-10.22	Fahlstrom, 1964
	4.7		Roff, 1969
C. puteana	0.5 to 0.7		Becker, 1959
	1.0 to 1.4	1.08-1.22	Fahlstrom, 1964
	3.9		Roff, 1969

The poles were allocated to seven treatment groups. Because of limited pole availability, treatment groups varied between two and five poles. The pole sections were treated with Bioguard Paste, Bioguard bandage, a degradable bandage or Bioguard Boron Paste (boron alone) (Table IV-4). The tops of bandages on all but one set of Bioguard Paste treated southern pine poles were wrapped with duct tape to reduce moisture intrusion between the bandage and the wood. The tape was applied either just at groundline or 100 mm above the groundline, depending on the height of the bandage. Two southern pine, two Douglas-fir and two western redcedar poles did not receive any treatment and served as non-treated controls.

Chemical movement in the poles was determined 1, 2, 3 and 5 years after treatment by removing

Table IV-4. Characteristics of boron/fluoride pastes and bandages used to treat Douglas-fir, southern pine and western redcedar pole sections in 2006.

Treatment	Active Ingredients	% Active
Bioguard Paste	boric acid	30-40
	sodium fluoride	10-25
Bioguard Bandage	disodium octaborate tetrahydrate	30-60
	sodium fluoride	10-30
Bioguard Boron Paste	disodium octaborate tetrahydrate	0-10
	boric acid	40-60

eight increment cores from a site 150 mm below the groundline on one side of each pole section. The cores were divided into zones corresponding to 0-12, 12-25, 25-50, and 50-75 mm from the wood surface. Wood from a given zone for a single treatment from each pole was combined, and then ground to pass a 20 mesh screen. The resulting sawdust was then divided into two samples.

One set of samples was hot water extracted and analyzed for boron content according to American Wood Preservers' Association Standard A2 Method 16, the Azomethine H method (AWPA, 2004b). Boron levels in the samples were determined by comparison with standards containing known amounts of boron. For comparison purposes, boron was considered to be at an effective level for internal decay control when present at 0.03 pounds per cubic foot (pcf) (0.5 kg/m^3) BAE (boric acid equivalent) or greater (Table IV-3). The threshold for protection in external applications is believed to be approximately 0.14 pcf (2.24 kg/m^3), although this figure is probably a bit high because of the difficulty in estimated loadings needed for a mobile chemical.

Fluoride in the wood was analyzed using a method described by Chen et al. (2003) in which the ground wood was extracted in 0.1 m $HClO_4$ for 3 hours at 176°F, then the supernatant was analyzed for fluoride using a specific ion electrode according to procedures described in AWPA Standard A2 Method 7 (AWPA, 2004a). Fluoride levels were quantified by comparison with similar tests on prepared standards and were expressed on a kg of fluoride per unit volume of wood using the assumed density values listed in AWPA Standard A12 (AWPA, 2004c).

Fluoride thresholds have received less study, but appear to be equal to or lower than those for boron for internal decay control (Tables IV-5 & 6). Our laboratory data suggests a threshold between 0.00626 and 0.0125 pcf (0.1 and 0.2 kg/m^3) for this application. External fluoride thresholds appear to vary more widely, but are probably similar to those for boron. There is no established threshold for the combination of boron and fluoride.

Background levels of fluoride and boron in the poles were negligible at each sampling point (Tables IV-5 & 6). As expected, both fluoride and boron levels in poles receiving either pastes or bandages were highest near the surface and declined sharply with distance inward. Chemical levels also tended to be consistently higher deeper in the wood with southern pine poles, reflecting the deeper sapwood associated with this species. Boron and fluoride levels generally declined between 1 and 2 years, although levels remained above threshold in the wood. The major exception to the decline was the Bioguard Boron Paste treatment, where loadings increased up to 50 mm from the surface.

Fluoride data are only available for 2 years. The additional data from the 3 and 5 year samples

Table IV-5. Fluoride content at selected distances inward from the surfaces of poles treated with various external preservative systems.

Treatment	Wood Species	Reps	Fluoride (kg/m^3)[a]							
			0-12 mm		12-25 mm		25-50 mm		50-75 mm	
			1 year	2 years	1 year	2 years	1 year	2 years	1 year	2 years
Degradable Bandage	DF	3	0.15 (0.06)	0.07 (0.01)	0.04 (0.03)	0.04 (0.02)	0.02 (0.01)	0.01 (0.00)	0.01 (0.01)	0.01 (0.00)
Bioguard Bandage	DF	5	**0.93** (0.69)	0.37 (0.31)	0.42 (0.34)	0.25 (0.20)	0.06 (0.03)	0.11 (0.08)	0.01 (0.00)	0.01 (0.01)
	SYP	3	**1.25** (0.38)	**0.70** (0.20)	0.56 (0.28)	**0.69** (0.08)	**0.88** (0.32)	**0.69** (0.15)	0.43 (0.25)	0.42 (0.16)
	WRC	5	**0.94** (0.72)	**0.69** (0.35)	0.25 (0.13)	0.32 (0.20)	0.03 (0.05)	0.03 (0.04)	0.01 (0.00)	0.01 (0.01)
Bioguard Paste, taped 10 cm above GL	DF	5	**2.61** (0.47)	**2.02** (0.83)	0.30 (0.20)	0.55 (0.11)	0.08 (0.10)	0.10 (0.07)	0.01 (0.01)	0.05 (0.04)
	SYP	4	**3.56** (1.43)	**1.98** (1.15)	**2.55** (0.98)	**1.58** (0.85)	**1.65** (0.78)	**1.46** (0.76)	**0.75** (0.70)	**1.06** (0.63)
	WRC	5	**1.46** (0.66)	**1.26** (0.85)	0.36 (0.12)	0.41 (0.17)	0.03 (0.02)	0.05 (0.04)	0.01 (0.00)	0.01 (0.01)
Bioguard Paste, taped at GL	DF	5	**3.27** (1.20)	**2.58** (0.39)	0.55 (0.58)	0.40 (0.14)	0.08 (0.06)	0.06 (0.05)	0.04 (0.03)	0.24 (0.48)
	SYP	4	**2.99** (0.91)	**0.99** (0.63)	**2.49** (0.83)	**0.79** (0.36)	**1.92** (0.36)	**0.82** (0.39)	**1.31** (0.14)	0.66 (0.39)
	WRC	5	**1.55** (0.73)	**1.22** (0.89)	0.36 (0.26)	0.42 (0.20)	0.13 (0.21)	0.07 (0.05)	0.01 (0.02)	0.03 (0.04)
Bioguard Paste, not taped	SYP	4	**1.69** (0.80)	**0.98** (0.83)	**1.25** (0.56)	**0.74** (0.11)	**1.16** (0.32)	**0.86** (0.07)	**0.87** (0.19)	**0.82** (0.04)
Non-treated Control	DF	2	0.02 (0.01)	0.01 (0.01)	0.00 (0.00)	0.00 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.00 (0.00)
	SYP	2	0.02 (0.00)	0.02 (0.01)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.00 (0.00)
	WRC	2	0.02 (0.02)	0.01 (0.01)	0.01 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)

a. Numbers in parentheses represent one standard deviation. Numbers in bold are above 0.6 kg/m^3 fluoride.

Table IV-6. Boric acid equivalent (BAE) at selected distances inward from the surfaces of poles treated with various external preservative systems.

Treatment	Wood Species	Reps	BAE (kg/m^3)[a]				
			year	0-12 mm	12-25 mm	25-50 mm	50-75 mm
Degradable Bandage	DF	3	1	0.58 (0.16)	0.30 (0.09)	0.12 (0.06)	0.05 (0.06)
			2	0.17 (0.07)	0.09 (0.07)	0.09 (0.04)	0.04 (0.03)
			3	0.26 (0.09)	0.23 (0.19)	0.12 (0.03)	0.13 (0.10)
			5	0.03 (0.04)	0.03 (0.04)	0.05 (0.00)	0.03 (0.03)
Bioguard Bandage	DF	5	1	**6.10** (6.96)	**1.44** (1.46)	0.20 (0.15)	0.04 (0.06)
			2	**3.97** (2.08)	**1.69** (1.43)	0.63 (0.32)	0.14 (0.13)
			3	**4.58** (3.15)	**2.07** (1.05)	**0.78** (0.46)	0.11 (0.09)
			5	**1.70** (1.11)	**0.91** (0.59)	0.60 (0.35)	0.24 (0.13)
	SYP	3	1	**5.86** (0.96)	**3.65** (0.28)	**2.05** (0.36)	**1.06** (0.37)
			2	**4.74** (0.56)	**4.61** (2.28)	**1.83** (0.23)	**1.86** (1.12)
			3	**2.89** (1.75)	**1.49** (1.10)	**0.87** (0.53)	0.67 (0.44)
			5	**2.23** (0.96)	**0.99** (0.42)	0.42 (0.20)	0.20 (0.05)
	WRC	5	1	**6.63** (6.69)	**1.56** (0.92)	0.23 (0.30)	0.08 (0.02)
			2	**6.37** (2.44)	**2.94** (2.06)	0.39 (0.36)	0.07 (0.06)
			3	**4.25** (2.25)	**2.02** (1.54)	0.59 (0.44)	0.12 (0.11)
			5	**3.15** (2.47)	**1.40** (0.94)	0.45 (0.08)	0.36 (0.49)
Bioguard Paste, taped 10 cm above GL	DF	5	1	**14.95** (3.27)	**1.32** (0.88)	0.43 (0.65)	0.09 (0.09)
			2	**9.50** (8.07)	**1.91** (0.82)	0.41 (0.34)	**0.75** (0.85)
			3	**1.74** (0.89)	**1.18** (0.61)	**0.76** (0.30)	0.14 (0.13)
			5	**3.64** (3.97)	**2.41** (2.30)	**1.19** (0.70)	0.28 (0.21)
	SYP	4	1	**13.60** (11.80)	**8.84** (7.84)	**4.16** (3.98)	**1.20** (1.63)
			2	**11.14** (6.94)	**8.85** (6.25)	**5.42** (4.95)	**2.00** (2.41)
			3	**4.38** (2.96)	**3.12** (1.97)	**2.56** (1.61)	**2.06** (1.40)
			5	0.19 (0.30)	0.17 (0.30)	0.07 (0.14)	0.08 (0.11)
	WRC	5	1	**14.80** (9.73)	**2.98** (1.23)	0.36 (0.15)	0.07 (0.05)
			2	**12.48** (12.58)	**2.89** (1.29)	0.53 (0.26)	0.10 (0.05)
			3	**2.83** (2.15)	**2.13** (1.75)	0.63 (0.47)	0.25 (0.22)
			5	**0.87** (1.04)	**0.96** (0.88)	**0.68** (0.45)	0.32 (0.44)
Bioguard Paste, taped at GL	DF	5	1	**21.35** (7.61)	**2.88** (2.95)	0.46 (0.35)	0.19 (0.19)
			2	**18.72** (2.00)	**2.31** (0.84)	0.30 (0.22)	**0.97** (2.00)
			3	**3.96** (2.39)	**2.43** (1.44)	**0.70** (0.57)	0.61 (0.70)
			5	**1.95** (1.63)	**1.34** (1.03)	**0.69** (0.47)	0.48 (0.30)
	SYP	4	1	**14.39** (5.85)	**10.97** (4.31)	**6.52** (2.21)	**3.32** (2.00)
			2	**2.80** (2.55)	**1.94** (1.84)	**1.69** (1.62)	**1.56** (1.50)
			3	**1.16** (1.29)	**0.92** (1.03)	**1.01** (0.92)	**1.18** (0.93)
			5	0.08 (0.07)	0.07 (0.04)	0.04 (0.04)	0.08 (0.01)
	WRC	5	1	**11.13** (10.11)	**2.01** (1.36)	**1.18** (1.89)	0.10 (0.05)
			2	**10.13** (10.56)	**3.25** (2.18)	**0.70** (0.39)	0.28 (0.24)
			3	**4.11** (4.36)	**3.42** (3.11)	**1.35** (1.31)	0.13 (0.07)
			5	**1.11** (1.40)	**1.32** (0.95)	**1.22** (0.36)	0.31 (0.11)
Bioguard Paste, not taped	SYP	4	1	**4.16** (3.16)	**3.48** (2.46)	**2.56** (1.47)	**1.99** (0.76)
			2	**3.53** (0.97)	**2.44** (0.66)	**2.17** (0.59)	**2.15** (0.52)
			3	**1.46** (0.89)	**1.14** (0.71)	**1.07** (0.56)	**1.11** (0.60)
			5	0.09 (0.08)	0.05 (0.03)	0.04 (0.04)	0.12 (0.10)

Table IV-6. Boric acid equivalent (BAE) at selected distances inward from the surfaces of poles treated with various external preservative systems.

Treatment	Wood Species	Reps	BAE (kg/m^3)[a]								
			year	0-12 mm		12-25 mm		25-50 mm		50-75 mm	
Bioguard Paste, not taped	SYP	4	1	**4.16**	(3.16)	**3.48**	(2.46)	**2.56**	(1.47)	**1.99**	(0.76)
			2	**3.53**	(0.97)	**2.44**	(0.66)	**2.17**	(0.59)	**2.15**	(0.52)
			3	**1.46**	(0.89)	**1.14**	(0.71)	**1.07**	(0.56)	**1.11**	(0.60)
			5	0.09	(0.08)	0.05	(0.03)	0.04	(0.04)	0.12	(0.10)
Bioguard Boron Paste	DF	3	1	**4.94**	(2.91)	**1.10**	(0.37)	0.07	(0.10)	0.01	(0.01)
			2	**18.25**	(6.99)	**4.80**	(3.16)	**1.57**	(1.93)	0.56	(0.86)
			3	**10.46**	(0.76)	**5.90**	(0.88)	**1.87**	(0.45)	0.46	(0.34)
			5	**6.17**	(7.14)	**3.75**	(2.82)	**2.61**	(1.27)	**1.30**	(1.49)
Non-treated Control	DF	2	1	0.01	(0.01)	0.00	(0.00)	0.02	(0.01)	0.00	(0.00)
			2	0.00		0.00		0.03		0.01	
			3	0.08	(0.06)	0.00	(0.00)	0.03	(0.05)	0.04	(0.05)
			5	b	b	b	b	b	b	b	b
	SYP	2	1	0.00	0.00	0.00	0.00	0.00	(0.00)	0.01	(0.01)
			2	0.05	(0.03)	0.15	(0.12)	0.02	(0.03)	0.05	(0.00)
			3	0.17	(0.05)	0.06	(0.03)	0.07	(0.02)	0.06	(0.00)
			5	0.05	(0.07)	0.01	(0.01)	0.06	(0.04)	0.09	(0.06)
	WRC	2	1	0.00	0.00	0.03	(0.05)	0.02	(0.03)	0.04	(0.05)
			2	0.18	(0.09)	0.17	(0.20)	0.08	(0.08)	0.19	(0.19)
			3	0.10	(0.01)	0.07	(0.00)	0.07	(0.03)	0.09	(0.01)
			5	0.00		0.00		0.00		0.00	

a. Numbers in parentheses represent one standard deviation. Numbers in bold are above the toxic threhold of 0.67 Kg/m^3 BAE.
b. The control pole stubs were too degraded to sample.

will be reported in subsequent annual reports. Fluoride loadings tended to be much lower than those for boron, regardless of wood species or the use of a bandage or a paste at each time point (Table IV-5). This is likely a function of the ratio of components in the system. Fluoride levels tended to be highest with the paste, suggesting that the more intimate contact created when the paste is brushed on the surface improves initial uptake. Fluoride concentrations were highest at the surface at each time point, and then declined by 50% or more in the 12 to 25 mm zone except with southern pine, where the decline with distance from the surface was much slower. In general, however, fluoride concentrations beyond the outer 12 mm were similar for the paste and bandage systems, indicating that the primary initial benefit of the paste was a higher surface loading of chemical. One might expect this initial loading to translate into higher fluoride concentrations deeper in the wood over time, but further sampling will be required to confirm this premise.

Taping the top of the bandage appeared to markedly increase subsequent levels of fluoride found near the surface, with taped poles containing nearly twice as much fluoride as non-taped poles in each year. Fluoride concentrations were minimal for the degradable bandage. Although this system was evaluated only on Douglas-fir, the fluoride levels were only 1/6 those found with the Bioguard bandage, suggesting that the degradable bandage system was not suitable for groundline treatment.

Boron loadings tended to be much higher than those found for fluoride in the same poles, reflecting the higher concentration of this component employed in the system (Table IV-6). Boron loadings in the outer 12 mm of all three pole species were well above the minimum threshold for both the Bioguard bandage and both paste systems over the first 2 years in test. As with fluoride, boron loadings in the outer 12 mm were much higher in the paste treatment, compared with the bandage system. Boron levels in the outer zone were similar with wood species for the bandage, but varied more widely with the paste. As with fluoride, boron levels declined with distance from the surface, but were near the threshold 25 to 50 mm from the surface for bandage-treated southern pine and 50 to 75 mm from the surface for pine poles treated with the Bioguard paste and wrapped at groundline. Boron levels in Douglas-fir and western redcedar poles tended to be below the threshold 25 to 50 mm below the surface, reflecting the much shallower sapwood in these species.

The absence of tape at the top of the bandages had a profound effect on boron level in the wood. Poles without the tape around the top of the bandage contained nearly 50 % less boron in the outer 12 mm than did taped poles 2 years after treatment. Boron levels in the Bioguard Boron paste system were much lower than those found with the Bioguard paste and similar to those found with the Bioguard bandage one year after treatment but increased dramatically in the second year. Boron levels declined markedly in all treatments at the 3 year point and continued to decline until the 5 year point. While levels remained well above the threshold in all species at the 3 year point, boron levels were below the threshold for the southern pine poles treated with Bioguard paste but were still above that level for the Bioguard bandage at 5 years.

Southern pine tends to have much more permeable sapwood than the other two species and this may have encouraged more rapid migration from the wood. As with all external treatments, declining chemical concentrations do not necessarily equate to immediate biological attack. Instead, fungi must gradually re-colonize the substrate. As a result, there is a lag between declining chemical concentration and the initiation of renewed surface attack.

The results indicate that both boron and fluoride moved into the wood at rates that would be effective against decay fungi. Boron in the paste system has moved into the wood at slightly higher levels than the bandages over 5 years, suggesting that the ability to place the paste directly on the wood surface, including any surface checks, has advantages in terms of maximizing chemical delivery. It is also interesting to note that boron levels in poles treated using the bandage tended to remain at higher levels at the 5 year point. It is possible that the bandage material retarded chemical loss. If so, it might also slow the rate of microbial attack once boron loadings decline to levels below the threshold.

Although the benefits of pastes vs. bandages must be weighed against ease of application, the tendency for most external groundline preservatives used in North America to be applied by contractor crews probably makes ease of application and any benefits of ease of application less critical to a utility than it might be if a utility crew performed the work.

G. Performance of External Groundline Treatments in Drier Climates

External groundline preservatives are applied throughout the United States and we have established field trials in Oregon, California, Georgia and New York to assess the effectiveness of these systems under a range of environmental conditions. One area where we have neglected to collect field performance data is in drier climates. Conditions in these areas differ markedly from those in wetter climates. While soil moisture content near the surface may be low, subsurface moisture contents can be very conducive to decay. Soil conditions may also differ with a tendency toward more alkaline conditions in some areas. These characteristics may alter the performance of supplemental groundline treatments.

In order to assess this possibility, western pine, southern pine, western redcedar and Douglas-fir poles in both the Salt River Project and Arizona Public Service systems were selected for study. The pole population consisted of poles treated with creosote or pentachlorophenol in AWPA Solvent Types A, B, and D. Solvent Types B and D are both volatile systems that evaporate from the wood after treatment, leaving a clean and dry surface, while Solvent P9 Type A remains in the pole. There has been a long history of performance issues related to the use of Solvent Types B and D. The absence of residual solvent tends to render penta less effective against soft rot fungi and these poles tend to experience substantial surface degradation in relatively short times after installation. While neither Solvent Types B nor D is still being used to treat poles, many utilities have hundreds of thousands of poles in service that were initially treated with these systems.

Each of the seven treatments (Table IV-7) was applied to an equal number of poles of each species/solvent combination when possible. The exception was Bioguard Tri-Bor paste, which was applied only to Douglas-fir poles treated with pentachlorophenol in Solvent P9 type A. The area around each pole was excavated to a depth of 450 to 600 mm, and then any decayed surface wood was removed. The pole circumference was measured to ensure that the pole retained sufficient section area to be retained in the system. Small pieces of surface wood were then removed from the poles and placed in plastic bags for later culturing. These samples were placed on malt extract agar in petri dishes and any fungi growing from the wood were examined microscopically. The goal was to characterize the surface flora present at the time of treatment and compare the flora over the next few years.

The systems were all supplied in paste form. The circumference of each pole to be treated was measured at groundline and the amount of paste to be applied to each pole was calculated using the actual product unit weight and recommended paste thickness (Table IV-8). The bucket containing the paste was weighed and then the paste was applied to the pole from 75 mm above groundline to a depth of 460 mm below groundline using the calculated paste dosage. The bucket was reweighed and the difference between initial and final weight was used to ensure that the calculated paste coverage per unit area was achieved.

The pastes were then covered with the barrier recommended for each system and the soil was replaced around the pole.

The degree of chemical migration will be assessed 1, 2, 3 and 5 years after treatment by excavating on one side of each pole, removing a small section of external barrier (100 by100 mm) 150 mm below the groundline and scraping away any excess paste. We will remove two 12 mm deep sections of shavings using a 38 mm diameter Forstner bit. A portion of the shavings will be placed on malt extract agar in Petri plates to determine if soft rot fungi are present and the remainder of the sample will be ground to pass a 20 mesh screen. One half will be analyzed for copper while the other will be analyzed for any organic preservative present in the system. An

Table IV-7 Characteristics of poles receiving external preservative treatments in the Phoenix, Arizona area.

OSU Pole #	Species	Primary Treatment	YI	Class/ Length	Treatment	Fungal isolations[b] (before treatment)
401	SP	penta	1997	1/40	Osmose EP[a]	Non-decay
402	WP	gas	1986	5/40	MP400-EXT	
403	WP	gas	1985	5/40	Bioguard	
404	DF	gas	1983	5/40	CuBor	
405	WP	gas	1983	5/40	Osmose EP	Soft rot
406	WP	gas		5/40	Control	
407	WP	gas	1983	5/40	COP-R-PLASTIC II	
408	WP	gas	1972	5/40	CuBor	Soft rot
409	WP	gas	1984	5/40	CuRap 20	
410	WP	gas	1981	5/40	CuRap 20	
411	WP	gas	1981	5/40	MP400-EXT	
412	WP	gas	1972	5/40	Osmose EP	Soft rot
413	WP	gas	1972	5/40	COP-R-PLASTIC II	
414	WP	gas	1972	5/40	Bioguard	Soft rot
415	WP	gas	1983	5/40	CuRap 20	
416	WP	gas	1983	5/40	CuRap 20	
417	WP	gas	1984	5/40	CuBor	Decay
418	WP	gas	1984	5/40	COP-R-PLASTIC II	
419	DF	gas	1984	5/40	Bioguard	
420	DF	gas	1962	5/35	MP400-EXT	mold
421	DF	creosote	1962	5/35	Osmose EP	Soft rot
422	WP	gas	1984	5/40	CuBor	
423	WP	gas	1984	5/40	COP-R-PLASTIC II	
424	WP	gas	1984	5/40	Bioguard	
425	DF	creosote	1962	5/35	CuRap 20	Decay and mold
426	DF	creosote	1962	5/35	COP-R-PLASTIC II	Decay and mold
427	DF	creosote	1962	5/35	MP400-EXT	Soft rot
428	DF	creosote	1962	5/35	Control	
429	WRC	creosote		4/35	Bioguard	
430	WRC	creosote		4/35	CuBor	mold
431	WRC	penta	1987	5/40	Control	Non-decay
432	WRC	penta	1987	5/40	Osmose EP	
433	WRC	penta	1987	5/40	MP400-EXT	Decay and soft rot
434	WP	creosote	1989	5/40	Osmose EP	mold
435	WP	gas	1986	5/40	MP400-EXT	
436	WP	gas	1986	5/40	COP-R-PLASTIC II	

a.EP = Experimental Paste. b. Type of rot has not yet been confirmed.

Table IV-7 continued. Characteristics of poles receiving external preservative treatments in the Phoenix, Arizona area.

OSU Pole #	Species	Primary Treatment	YI	Class/ Length	Treatment	Fungal isolations[b] (before treatment)
437	WP	gas	1986	5/40	CuBor	
438	DF	gas	1986	5/40	CuRap 20	
439	DF	penta	1992	4/40	Bioguard	
440	DF	creosote	1992	4/40	Control	
441	DF	gas	1986		Control	
442	WP	gas	1986	5/40	Control	
443	DF	penta	2006	1/45	MP400-EXT	
444	DF	penta	2002	3/45	CuBor	
445	DF	penta	2002	3/45	COP-R-PLASTIC II	
446	DF	penta	2001	3/45	Bioguard	
447	DF	penta	2002	4/40	Osmose EP	
448	DF	penta	2002	4/40	CuRap 20	
449	DF	penta	2002	4/40	MP400-EXT	
450	DF	penta	2002	4/40	CuBor	
451	DF	penta	2001	4/40	COP-R-PLASTIC II	
452	DF	penta	2001	4/40	Bioguard	
453	DF	penta	2000	4/40	Osmose EP	
454	DF	penta	1999	3/45	Control	
455	DF	penta	1999	3/45	CuRap 20	
456	DF	penta	1999	3/45	MP400-EXT	Soft rot
457	DF	penta	1999	3/45	Control	
458	DF	penta	1999	3/45	CuBor	
459	DF	penta	1999	3/45	COP-R-PLASTIC II	
460	DF	penta	1999	3/45	Bioguard	
461	DF	penta	1999	3/45	Osmose EP	
462	DF	penta	1999	3/45	CuRap 20	
463	DF	penta	1999	3/40	MP400-EXT	
464	DF	penta	2001	4/40	Control	
465	DF	penta	2001	4/40	CuBor	
466	DF	penta	1998	1/45	COP-R-PLASTIC II	
467	DF	penta	1998	1/40	Bioguard	
468	DF	penta	1998	4/40	Osmose EP	
469	DF	penta		4/40	Control	Soft rot
470	DF	penta	2002	1/40	CuRap 20	
471	DF	penta	2002	4/40	MP400-EXT	
472	DF	penta	2002	3/45	Control	

a.EP = Experimental Paste. b. Type of rot has not yet been confirmed.

Table IV-7 continued. Characteristics of poles receiving external preservative treatments in the Phoenix, Arizona area.

OSU Pole #	Species	Primary Treatment	YI	Class/ Length	Treatment	Fungal isolations[b] (before treatment)
473	DF	penta	2002	3/45	CuBor	
474	DF	penta	2002	3/45	COP-R-PLASTIC II	
475	DF	penta	2002	3/45	Bioguard	
476	DF	penta	2002	3/45	Osmose EP	
477	DF	penta	2000	3/45	CuRap 20	
478	DF	penta	2002	3/45	MP400-EXT	
479	DF	penta	2004	3/45	CuBor	
480	DF	penta	2001	3/45	COP-R-PLASTIC II	
481	DF	penta	2006	3/45	Bioguard	
482	DF	penta			Control	
483	DF	penta			Osmose EP	
484	DF	penta	2002	3/40	CuRap 20	
485	DF	penta	2002	4/40	Bioguard Tri-Bor EP	
486	DF	penta	2007	4/40	Bioguard Tri-Bor EP	
487	DF	penta	2008	4/40	Bioguard Tri-Bor EP	
488	DF	penta	2009	4/40	Bioguard Tri-Bor EP	
489	DF	penta	2007	4/40	Bioguard Tri-Bor EP	
490	DF	penta	2005	4/40	Bioguard Tri-Bor EP	
491	DF	penta	2004	3/45	Bioguard Tri-Bor EP	
492	DF	penta	2008	2/50	Bioguard Tri-Bor EP	
493	DF	penta	2008	2/50	Bioguard Tri-Bor EP	
494	DF	penta	2007	3/45	Bioguard Tri-Bor EP	
495	DF	penta			Bioguard Tri-Bor EP	
496	DF	penta	2006	3/45	Bioguard Tri-Bor EP	

a.EP = Experimental Paste. b. Type of rot has not yet been confirmed.

additional six increment cores will be removed from the exposed zone. The cores will be segmented into zones corresponding to 0-6, 6-13, 13-25, 25-50 and 50-75 mm from the surface. The wood from a given zone on an individual pole will be combined and ground to pass a 20 mesh screen. It may be necessary to combine the wood from the outer 0 to 6 mm zone from all poles of a treatment to accumulate a sufficient quantity of material for analysis. The resulting wood samples will be analyzed for residual chemical using the most appropriate method. Boron will be analyzed by the Azomethine-H method while copper will be analyzed by x-ray fluorescence spectroscopy unless we find that the active ingredient levels are below the threshold for detection. In that case, copper will be analyzed by ICP. At the start, we will analyze both cores and the shavings for copper until we can establish whether the two sampling methods produce similar values. Bifenthrin will be analyzed by extraction and gas chromatography, while tebuconazole will

Table IV-8. Material properties of the pastes tested in the Arizona field trial.

Paste	lb/gal	Active Ingredient	% Active
CuBor	10.1	copper hydroxide (2% metallic Cu)	3.1
		sodium tetraborate decahydrate	43.5
CuRap 20	10.1	copper naphthenate (2% metallic Cu)	18.2
		sodium tetraborate decahydrate	40.0
COP-R-PLASTIC II	12.4	sodium fluoride	44.4
		copper naphthenate (2% metallic Cu)	17.7
MP400-EXT	10.6	sodium tetraborate decahydrate	43.7
		copper-8 quinolinolate	0.3
		tebuconazole	0.2
		bifenthrin	0.04
Osmose experimental paste	10.8	unknown	
Bioguard	11.0	boric acid	30-40
		sodium fluoride	10-25
Bioguard Tri-Bor experimental paste	11.0	boric acid	30-50
		Borax 5 mol (Neobor)	7-15
		Boroguard ZB (zinc borate hydrate)	7-15

be analyzed by extraction and high performance liquid chromatography.

The results will be summarized and compared with the reported threshold for each component. These poles will be sampled early in 2012.

H. Effects of Pasture Wrap on Preservative Migration from Externally Treated Poles

One of the questions that arose in our groundline treatment trial in Georgia was the role of pasture wrap on external preservative treatments. Pasture wrap is applied to the top of external preservative bandages to limit the potential for animals coming into contact with the preservative paste; however, the wrap may also alter the ability of rainfall runoff to move down the pole and through the paste. Some poles in the Georgia trial had received pasture wrap while others had not and there was some concern that this might affect performance. In order to test this potential, pentachlorophenol treated Douglas-fir posts (150 mm in diameter by 2.4 m long) were attached to an external framework so that rainfall could strike the pole surfaces and run down the surfaces where it could be collected. Two posts were left without treatment to serve as controls, and six posts were treated with a preservative paste containing an amine-based copper naphthenate and boron. The posts were then wrapped with a plasticized paper barrier. Three of the treated posts then received pasture wrap applied around the top of the barrier. Polyvinylchloride (PVC) tubes (150 mm diameter) were fitted around each post from the butt to a point 450 mm above the butt. Plastic funnels were attached to the base of these PVC tubes and the PVC tubes were filled with coarse sand. The funnels were connected to 12 L containers that captured all water running down the poles and through the sand (Figure IV-1). Water was collected at each rainfall event and weighed to determine total rainfall. A subsample of this water was then analyzed for copper and boron.

In the first tests, we used traditional wraps with and without pasture wrap. The pasture wrap had no noticeable effect on the rates of boron or copper levels in the runoff and indicated that these wraps would not have altered the results from our groundline field test in Georgia. Following that test, however, we wondered if there might be better ways to limit preservative migration downward from the pastes. Toward that end, we applied a different copper boron paste formulation to a new set of penta treated poles along with the traditional coated paper barrier and then wrapped the bottoms of the paper covering the wraps on one half of the posts with duct tape. Water was collected after each rainfall as described previously and these samples were analyzed by ICP for boron and copper.

Both copper and boron were detected at very low levels in the runoff even from poles with no groundline paste application. These levels; however, were far below those found in runoff from poles receiving groundline wraps. Cumulative boron levels in runoff from poles treated with the copper/boron paste rose steadily over time, but the levels were particularly high early in the process. Copper levels followed similar trends (Figures IV-2 & 3). These results were consistent with previous tests. The addition of the duct tape barrier around the bottom of the wrap reduced, but did not prevent migration of either boron or copper (Figures IV 4 & 5). While the tape did provide a reasonable seal around the barrier, moisture was clearly capable of moving through the tape and the other portions of the barrier to facilitate downward copper and boron migration. Despite the apparent lack of success, the tape did reduce metal levels in the runoff by almost

Figure IV-1. Post sections treated with groundline paste showing the plastic containment tubes and the containers used to capture runoff.

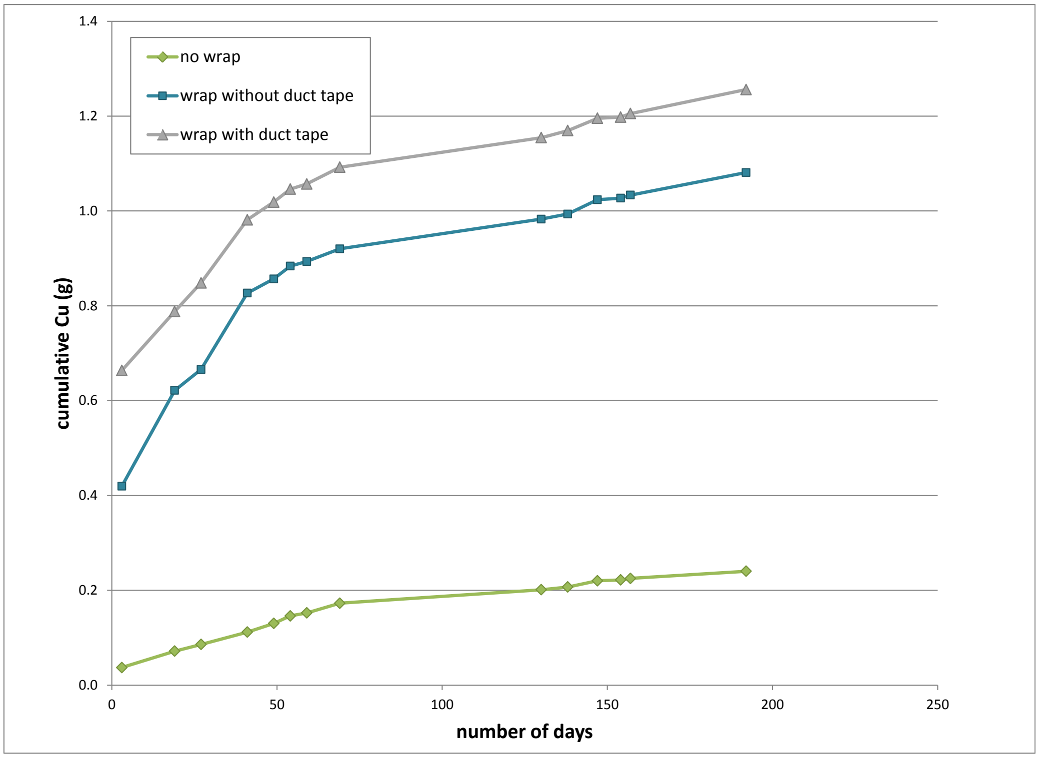

Figure IV-2. Cumulative copper levels in rainwater runoff from the butts of pentachlorophenol treated Douglas-fir pole sections treated with a copper naphthenate/boron paste with or without a duct tape seal at the bottom of the wrap.

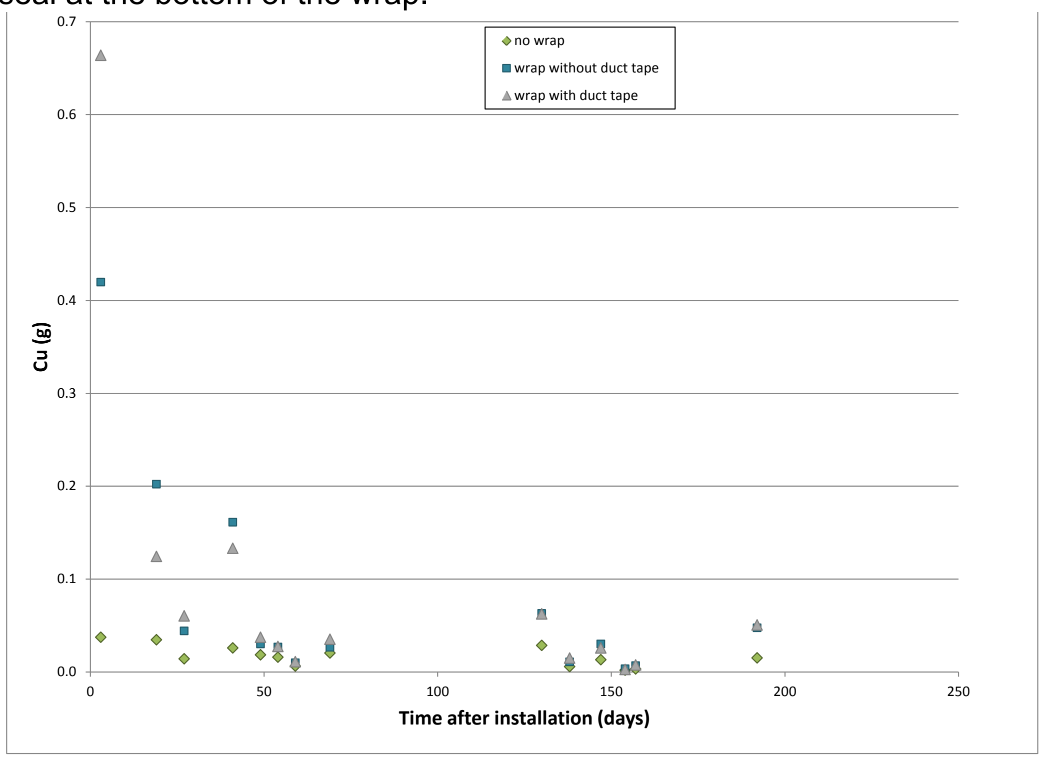

Figure IV-3. Copper levels at each time point in rainwater runoff from the butts of pentachlorophenol treated Douglas-fir pole sections treated with a copper naphthenate/boron paste with or without a duct tape seal at the bottom of the wrap.

1/3 early in the rainfall exposure test and by approximately 20 % later on. The rate of reduction of boron in the runoff was nearly 50 % early on and approximately 30 % at the end of the test. It is unclear whether these reduced runoff rates would translate into improved chemical loadings within the wood. The posts will be sampled when the test is concluded to determine if boron or copper retentions are higher in posts with the duct tape seal.

I. Effect of External Barriers on Pole Performance

Preservative treatment is a remarkably effective barrier against biological attack, but these same chemicals can be susceptible to migration into the surrounding soil. A number of studies documenting the levels of chemical migration have shown that the migration occurs for only a short distance around a treated structure and that the levels present do not pose a hazard in terms of environmental impact or disposal. Despite these data, some utilities have explored the use of external barriers to contain any migrating preservative. These barriers, while not necessary in terms of environmental issues, may have a secondary benefit in terms of both retaining the original chemical and limiting the entry of moisture and fungi.

The potential for barriers to limit moisture uptake in poles was assessed in a trial where pole sections with two different barriers were installed in either soil or water. The poles were maintained indoors and were not subjected to overhead watering. The results showed that considerable moisture wicked up poles in this exposure and moisture contents at groundline were suitable for decay development, even with the barriers. As might be expected, poles immersed in water wetted more quickly than those in wet soil; however, all poles were generally wet enough for decay to occur within 2 years of installation. These poles have subsequently been moved to our field test site and set so that the tops of the barriers extend 150 mm above the soil level. These pole sections were then sampled for wood moisture content at groundline, 150 mm above the groundline and 300 mm above groundline immediately after installation and 2 years after installation as described above.

In 2007, an additional set of penta-treated Douglas-fir pole stubs were encased in the newest generation of Biotrans liner and set into the ground at our Peavy Arboretum research site (Figure IV-6). The poles were each sampled prior to installation to determine chemical penetration and retention and baseline moisture content. Five poles received a Biotrans liner that extended 150 mm above groundline; five received a Biotrans liner that extended 300 mm above groundline and eleven poles were left without liners.

Six, 12 and 18 months after installation the poles

Figure IV-6. A Biotrans liner.

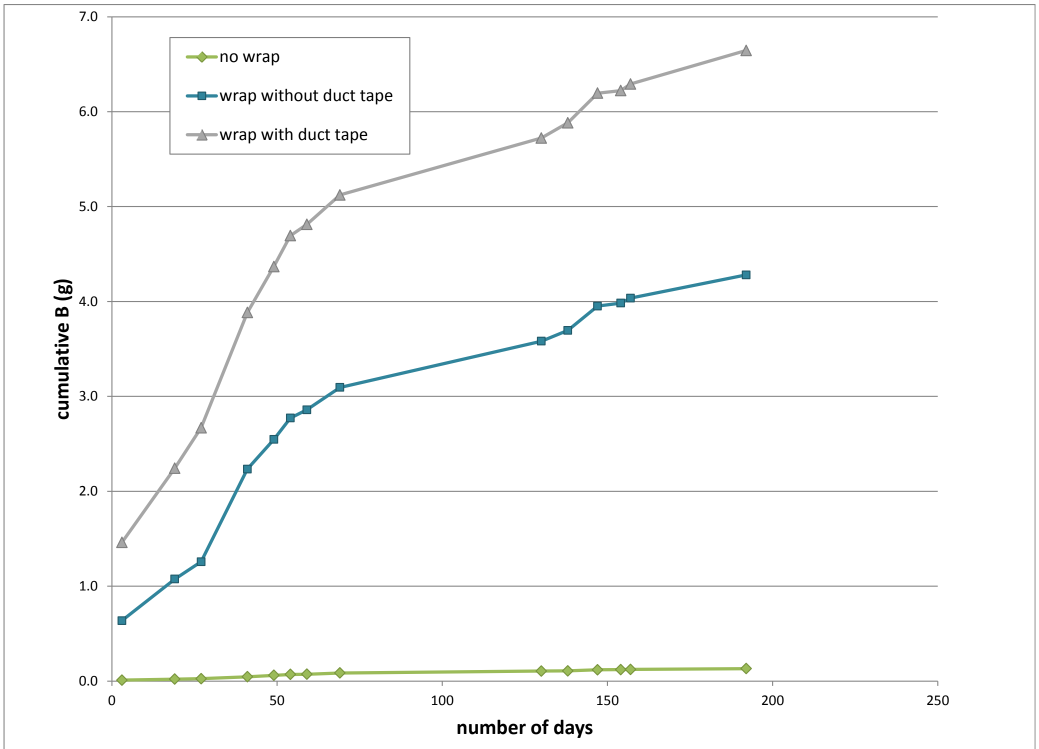

Figure IV-4. Cumulative boron levels in rainwater runoff from the butts of pentachlorophenol treated Douglas-fir pole sections treated with a copper naphthenate/boron paste with or without a duct tape seal at the top of the wrap.

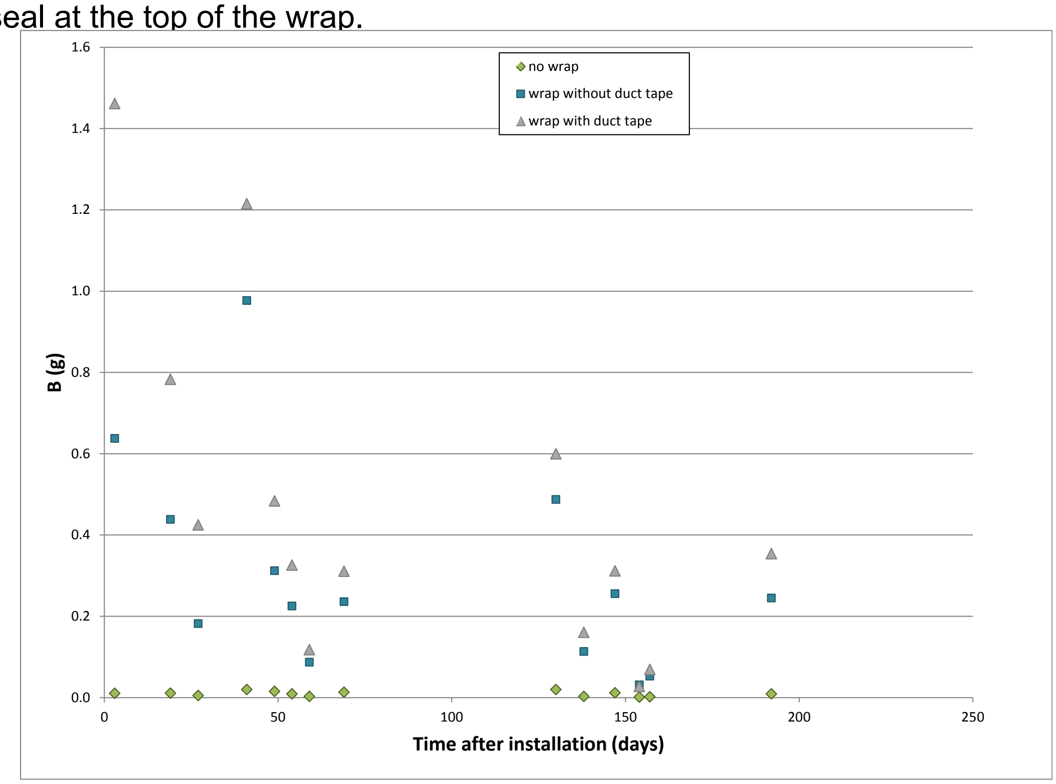

Figure IV-5. Boron levels at each time point in rainwater runoff from the butts of pentachlorophenol treated Douglas-fir pole sections treated with a copper naphthenate/boron paste with or without a duct tape seal at the bottom of the wrap.

were sampled by removing six increment cores from a single location 150 mm below groundline. Penetration was measured on each core, and then the cores were cut into zones corresponding to 0-13, 13-25, 25-50, and 50-75 mm from the wood surface. Each segment was placed into an individual tared vial, capped tightly and returned to the lab. The cores were weighed, oven-dried, and then weighed again. The difference between initial and oven-dry weight was used to determine moisture content. The sampling holes were plugged and any damage to the external coating was repaired to limit the potential for moisture to move into the wood through the sample holes.

Sampling of these poles 6 months after installation revealed that moisture contents 150 mm above the groundline were similar although the moisture levels in poles without a liner were slightly lower. Moisture contents 6 months after installation were elevated in the outer zone (0-13 mm from the surface) and declined with distance inward (Table IV-9). There appeared to be little difference in above ground moisture content between poles with and without barriers. The 6 month sampling coincided with the middle of our rainy season when wood moisture content would be expected to be elevated. Sampling 12 months after setting revealed moisture contents that were uniformly low in the poles without a barrier, while those with barriers remained at or above 45 % moisture content in the outer 13 mm. These results suggest that the barrier limited drying. While this does not necessarily mean that barriers will affect the rate of decay, it does mean that conditions suitable for decay extend further upward from the groundline than they do in poles without barriers and inspectors would need to alter their inspection procedures to ensure that they detect decay in these structures.

Moisture contents 18 months after setting once again rose to levels above the fiber saturation

Table IV-9. Wood moisture contents at selected distances from the surface of poles with and without a field barrier.

Treatment	Exposure Period (Mo)	Wood Moisture Content (%)[1]			
		0-13 mm	13-25 mm	25-50 mm	50-75 mm
Biotrans Liner 150 mm above groundline	0	39.5 (10.0)	35.1 (7.4)	34.0 (11.8)	33.5 (10.5)
	6 (wet)	57.8 (19.0)	48.1 (10.5)	37.6 (2.6)	37.7 (5.5)
	12 (dry)	48.7 (13.9)	35.6 (10.3)	35.7 (14.6)	34.6 (16.1)
	18 (wet)	48.8 (11.9)	40.6 (11.2)	34.7 (5.3)	31.6 (4.7)
Biotrans Liner 300 mm above groundline	0	38.5 (7.7)	32.2 (3.9)	32.2 (8.1)	40.3 (24.3)
	6 (wet)	67.1 (18.3)	49.5 (5.7)	38.8 (3.0)	35.5 (3.2)
	12 (dry)	45.1 (20.7)	34.6 (9.8)	33.3 (7.0)	33.1(6.7)
	18 (wet)	60.0 (14.6)	40.1 (6.3)	37.4 (5.0)	36.5 (5.6)
Non-lined	0	34.4 (3.5)	28.9 (2.7)	27.2 (3.2)	29.1 (3.30
	6 (wet)	54.3 (14.9)	47.1 (7.4)	42.1 (7.9)	43.7 (10.8)
	12 (dry)	20.2 (4.9)	28.7 (15.7)	28.8 (8.3)	29.5 (4.3)
	18 (wet)	47.3 (15.0)	34.7 (6.1)	31.5 (3.6)	31.7 (5.4)

1. Numbers in parentheses represent one standard deviation from the mean of 15 measurements for wrapped poles or 33 measurements for non-wrapped poles.

point in the non-barrier treated poles, but changed little in the barrier protected poles. These results indicate that poles without barriers experience much greater seasonal fluctuations in moisture content although all of the moisture contents measured were near or above the point where fungal attack can begin. One interesting finding was that the moisture contents in barrier treated poles have not tended to increase over time. In our original assessment, one possible development was for moisture to continue to move down checks and into the below ground portions of the poles. This would result in an ever increasing moisture content that might produce very high moisture contents that could limit oxygen and thereby inhibit decay. This has not, to date, occurred.

These poles will be sampled at the end of the summer of 2011.

J. Establish a Field Trial of Current Liner Systems

Liner systems have been employed for over a decade wherever utilities have concerns about the potential risk of preservative migration from treated wood. While these systems have been reported to improve overall treatment performance, there is little data on the effects of these systems on preservative migration. In the fall of 2010 we installed a field test of poles with and without liners to address the following objectives:

-To assess the ability of external barriers to retard preservative migration from poles in soil contact.
-To determine the impact of external barriers on wood moisture contents above and below the barrier over time.

Douglas-fir pole sections (250-300 mm in diameter by 3.1 m long) were treated to 9.6 kg/m^3 with pentachlorophenol and southern pine pole sections of the same dimensions were treated with CCA to a retention of 9.6 kg/m^3 or penta to a retention of 7.2 kg/m^3. The pole sections were sampled using an increment borer prior to use to determine initial preservative penetration and a sufficient number of cores were removed to determine retention per pole section. The pole sections were set to a depth of 0.9 m with or without field liners. Poles with liners were set so that the liner was 150 mm above the groundline. One set of poles will be used for monitoring potential migration of preservative components into the surrounding soil, and the other set will be used for measuring wood moisture content above and below the barrier.

Soil samples were collected prior to pole installation from 20 random locations at the test site using a trowel. A small pit was dug at each sampling location and soil was removed from depths of 0 to 25 mm, 25 to 50 mm, 50 to 75 mm and 75 to 150 mm below the ground level. The soil was air dried, screened through a #6 brass sieve and then divided into two samples. The first was analyzed for copper, chrome and arsenic by ICP (Table IV-10). The remaining sample will be analyzed by solvent extraction and, after cleaning up, analysis by GC-MS for penta. These results will be used to establish baseline levels of preservative in the soil for comparison to soil samples removed in subsequent years .

At annual intervals after installation, cores will be removed from the soil beginning immediately adjacent to the poles, as well as 150 and 300 mm away. A minimum of three poles with, and

Table IV-10. Metal levels in soil samples removed from the Peavy Arboretum test site prior to installation of CCA and penta treated poles with or without external field liners.

Sample Depth (mm)	Cu (ppm)	As (ppm)	Zn (ppm)
0-25	4.7	0.5	2.8
25-50	3.0	0.4	1.3
50-75	2.8	0.4	1.0
75-150	2.5	0.4	0.6

three poles without, field liners will be sampled per treatment/species combination. The soil cores will be divided into zones as described above and then analyzed for the appropriate preservative. We would expect to move the sampling further outward if we detect increased chemical levels at the initial sampling sites.

Background metal levels in soil samples taken prior to setting the poles tended to be very low. Copper levels ranged from 2.4 to 4.7 ppm, zinc levels ranged from 0.6 to 2.8 ppm and arsenic levels ranged from 0.4 to 0.5 ppm. Metal levels were highest near the soil surface and probably reflect rainwater inputs. While there are older ammoniacal copper, zinc and chromated copper arsenate treated posts uphill from the trial site, they are nearly 50 m away. Previous sampling of soil around in-service utility poles in a number of locations indicates that metal levels fall to background levels within 300 mm of the pole. The baseline levels in this test are consistent with background levels found at other sites. We will sample the soil around these poles at the 1 year point in October 2011 and the results will be reported in the next annual report.

Wood moisture content was assessed at the time of installation and will again be assessed at the beginning of the rainy season over a 3 year period. At each time point, increment cores will be removed from three locations around each of four poles per treatment/species combination beginning 150 mm below groundline, then moving upward to groundline, and 300 and 900 mm above groundline. Each increment core will be divided into zones corresponding to 0 to 25 mm, 25 to 75 mm and 75 mm to the pith. Each core section will be placed into a tared glass vial which will be sealed and returned to the lab where the cores will be weighed, oven dried and reweighed to determine wood moisture content. The sampling holes will be plugged with tub-caulking to retard moisture entry and the liner will be repaired. The results will be used to develop moisture content profiles over time for the wrapped and non-wrapped poles.

These poles will be assessed in the fall of 2011 and the results will be included in subsequent reports.

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OBJECTIVE V

PERFORMANCE OF COPPER NAPHTHENATE TREATED WESTERN WOOD SPECIES

Copper naphthenate has been available as a wood preservative since the 1940's, but the real commercial use of this system has only occurred in the last decade, as utilities sought less restrictively labeled chemicals. Copper naphthenate is currently listed as a non-restricted use pesticide, meaning that applicators do not require special licensing to apply this chemical. This has little bearing on the use of preservative treated wood, since there are no restrictions on who can use any of the preservative treated wood products currently on the market (although there are recommended practices for the use of each product); however, some users have sought to soften their environmental image by shifting to alternative preservatives such as copper naphthenate.

A. Performance of Copper Naphthenate Treated Western Redcedar Stakes in Soil Contact

Copper naphthenate has provided reasonable protection in a variety of field stake tests, but there is relatively little long term data on western wood species. To help develop this information, we established the following test.

Western redcedar sapwood stakes (12.5 by 25 by 150 mm long) were cut from either freshly sawn lumber or from the outer surfaces of the above ground zones of utility poles that had been in service for approximately 15 years. The latter poles were butt-treated, but had not received any supplemental treatment to the above ground portion of the pole.

The stakes were conditioned to 13% moisture content, then weighed prior to pressure treatment with copper naphthenate diluted in diesel oil to produce target retentions of 0.8, 1.6, 2.4, 3.2, and 4.0 kg/m^3. Each retention was replicated on ten freshly sawn and ten weathered stakes. In addition, sets of ten freshly sawn and weathered stakes were each treated with diesel oil alone or left without treatment to serve as controls.

The stakes were then exposed in a fungus cellar maintained at 30 C and approximately 90% relative humidity. Soil moisture was allowed to cycle between wet and dry conditions to avoid favoring soft rot attack (which tends to dominate in soils that are maintained at high moisture levels). The condition of each stake was visually assessed annually using a scale from 10 (completely sound) to 0 (completely destroyed).

Three years ago, we replaced the decay chambers, which had degraded to the point where they did not tightly seal. This often resulted in drier conditions that were less conducive to decay. The new chambers created much more suitable decay conditions and this was evidenced by subsequent drops in ratings for all treatments.

Freshly sawn stakes continue to outperform weathered stakes at all retention levels. (Figures V-1, 2). All of the freshly sawn stakes treated with copper naphthenate to retentions of 4.0 kg/

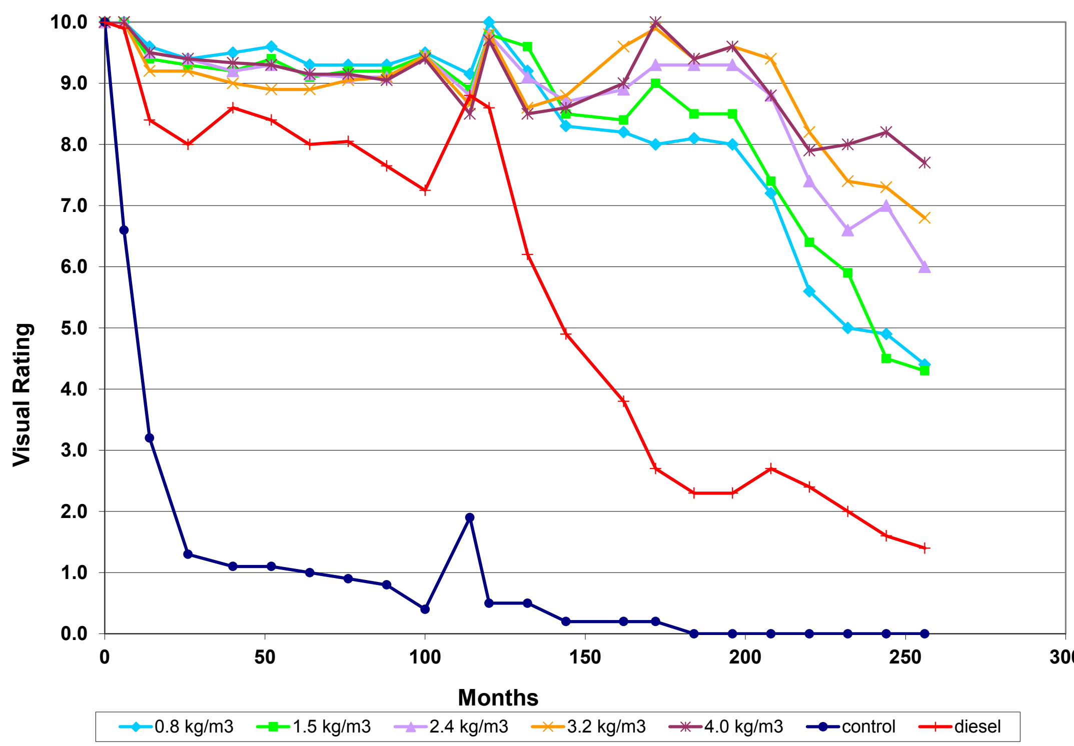


Figure V-1. Condition of freshly sawn western redcedar sapwood stakes treated with selected retentions of copper naphthenate in diesel oil and exposed in a soil bed for 256 months.

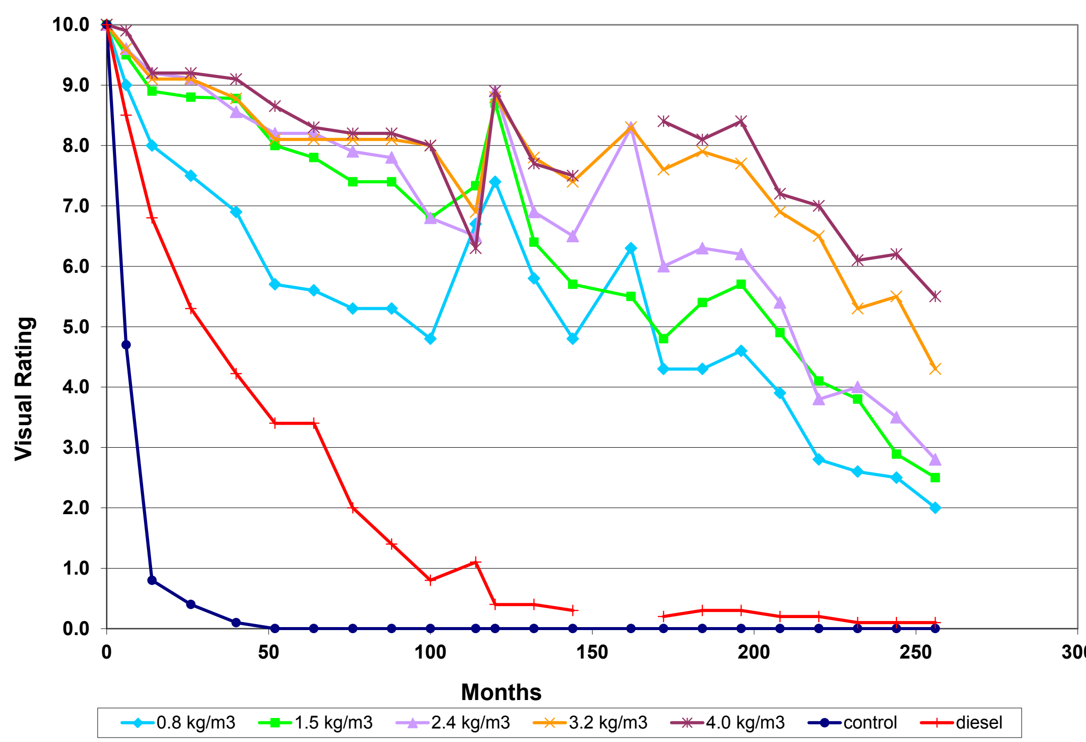


Figure V-2. Condition of weathered western redcedar sapwood stakes treated with selected retentions of copper naphthenate in diesel oil and exposed in a soil bed for 256 months.

m^3 continue to provide excellent protection after 256 months, while the conditions of the stakes treated to the two lower retentions continued to decline this past year. Stakes treated to the two lowest retentions have declined below a 5.0 rating suggesting that decay has significantly degraded the wood. Ratings for the intermediate retention were just above 6.0, indicating that the treatment had also begun to lose some of its efficacy.

Weathered stakes tended to exhibit much greater degrees of damage at a given treatment level. Weathered stakes treated to the three lowest retentions had ratings below 3.0 indicating that they were no longer serviceable (Figure V-2). The stakes treated to these three retentions continued to experience declining ratings. The conditions of stakes treated to the two higher retentions also declined in the past year. Ratings for the highest retention were below 6, while those for the next highest retention were approaching 4. Clearly, prior surface degradation from both microbial activity and UV light tended to sharply reduce the performance of the weathered material.

Weathered wood was originally included in this test because the cooperating utility had planned to remove poles from service for retreatment and reuse in other parts of the system. While this process remains possible, it is clear that the performance characteristics of the weathered retreated material will differ substantially from that of freshly sawn material. The effects of these differences on overall performance may be minimal since, even if the outer, weathered wood were to degrade over time, this zone is relatively shallow on cedar and would not markedly affect overall pole properties.

The copper naphthenate should continue to protect the weathered cedar sapwood above ground; allowing utility personnel to continue to safely climb these poles, and any slight decrease in above ground protection would probably take decades to emerge. As a result, retreatment of cedar still appears to be a feasible method for avoiding pole disposal and maximizing the value of the original pole investment.

A more reasonable approach; however, might be to remove the weathered wood and then treat the poles. This process would be very similar to that which is already used for removing sapwood on freshly peeled poles to produce a so-called “redbird” pole. Since the weathered wood is already physically degraded, it likely contributes relatively little to the overall material properties and its treatment serves little practical purpose. The removal of this more permeable, but weaker wood, would effectively reduce the pole class, but might result in a better performing pole. The resulting treatment on shaved poles might be shallower, but the non-treated wood beneath would be durable heartwood.

The results with freshly sawn and treated western redcedar clearly show good performance of this system and these results were consistent with field performance of this preservative on western species. We continue to seek copper naphthenate treated Douglas-fir poles located in the Northwest so that we can better assess field performance of this system.

B. Performance of Copper Naphthenate Treated Douglas-fir Poles in Western Oregon

No additional copper naphthenate treated poles were examined this past year. We will continue to seek out older poles treated with this chemical in order to develop a more complete performance data-base.

C. Effect of Biodiesel Co-Solvents on Performance of Copper Naphthenate

Introduction

Last year, we reported on laboratory trials to assess the effects of biodiesel on copper naphthenate performance against decay fungi. The effects of soy, canola and recycled cooking oil-based biodiesels was assessed using the American Wood Protection Association E10 soil block method. These tests showed that the addition of biodiesel as a co-solvent had no effect on one decay fungus, *Gloeophyllum trabeum*, but it had a profound negative effect on blocks exposed to *Postia placenta*. This fungus is copper tolerant, but the presence of biodiesel seemed to magnify this effect and, in many cases, we could not determine a threshold for fungal protection. There was considerable discussion at the annual meeting about these results and it became apparent that poles were being treated with copper naphthenate using various levels of biodiesel along with selected anti-oxidants.

We also became aware that two different copper naphthenate formulations had been employed, one the traditional hydrate system and the other a newer carbonate system. Although there was a suggestion that the carbonate system would perform better in the presence of biodiesel, there were no data to support this claim. Finally, given that the fungus employed in our tests is also among the most common inhabitant of Douglas-fir heartwood in in-service poles, we were concerned that this fungus might be able to grow into the heartwood and then progress from there into the copper naphthenate treated sapwood. In essence, this would produce sapwood surface decay from the inside out and would be extremely difficult to detect in service. The additional questions were addressed under the following objectives.

Objectives

1. Investigate the effects of biodiesel as a co-solvent on the performance of carbonate and hydrate copper naphthenate.
2. Assess the effects of biodiesel stabilizers on the performance of copper naphthenate.
3. Examine the potential for *Postia placenta* in Douglas-fir heartwood to colonize and degrade copper naphthenate treated sapwood.

All tests for the first two objectives were performed according to American Wood Protection Association Standard E10 using southern pine sapwood (most likely *Pinus taeda* L.).

<u>Wood Treatment</u>

Soil Block Tests: Defect free, southern pine sapwood lumber was cut into 19 mm cubes and the cubes were sorted by weight to avoid excessively dense or light samples. The blocks were oven dried (50 C) for 24 hours, then weighed (nearest 0.001g). The blocks were then segregated into groups of 36 for treatment.

The blocks for a given treatment were placed in mesh bags that were then placed into containers to which treatment solution was added to a level sufficient to cover the blocks throughout the treatment process. The treatment solutions were diluted in toluene so that they delivered approximately 112 kg/m^3 of solvent/co-solvent to the blocks. This is consistent with the amount of solvent typically impregnated into Douglas-fir poles. Failure to use toluene as a diluent would have produced excessively high solvent loadings that would have affected the test outcome. The containers were then placed into a pressure treatment vessel which was closed and subjected to a 30 minute vacuum (625 mm Hg) followed by a 30 minute pressure period at 880 KPa. The pressure was released, the solution was drained and the blocks were allowed to dry on the surface before being weighed. The difference between the oven dry and the post-treatment weight was used to calculate net uptake.

These procedures were used to prepare blocks treated to copper naphthenate target retentions of 0.4, 1.2, and 2.4 kg/m^3 (as Cu) using #2 diesel alone or amended with 10, 20, or 30 % soy based bioidiesel. An additional treatment used 98 % soy based biodiesel, but was only tested against *P. placenta*. Copper naphthenate produced using the traditional hydration method as well as one produced using a modified method (carbonate) were evaluated. Additional blocks were treated with toluene or water.

The effects of biodiesel stabilizers on copper naphthenate performance was evaluated using a single target retention (1.28 kg/m^3 as Cu) of either hydrate or carbonate based copper naphthenate in a solvent mixture containing #2 diesel amended with 30 % soy biodiesel. The stabilizers examined were Biostable at 1000, 1500, or 2000 ppm, Biostable at 1000, 1500 or 2000 ppm plus 250 ppm TBHQ tertiary butylhydroquinone (TBHQ), TBHQ alone at 125, 250 or 500 ppm, and propyl gallate at 250, 500, or 1000 ppm. The stabilizer concentrations evaluated were based upon actual use concentrations employed to treat Douglas-fir poles and were only tested with the source copper naphthenate used in actual practice.

Sapwood decay test: Douglas-fir sapwood blocks (15 X 25 X 50 mm long)(*Pseudotsuga menziesii* (Mirb.) Franco) for evaluating the potential for *P. placenta* invasion from Douglas-fir heartwood were prepared by oven drying (50 C) and weighing each block, then treating to target retentions of 0.2, 0.4 or 0.8 kg/m^3 (as Cu) using #2 diesel amended with 30 % soy based biodiesel. Additional blocks were impregnated with either toluene or water to serve as controls.

Both types of blocks were then wrapped in aluminum foil and stored for 7 days before being air-dried and then oven dried (50 C). The blocks were then weighed. One half of the blocks in each treatment were then subjected to a weathering procedure as described in AWPA Standard E10. Briefly, the blocks were submerged in water for 2 hours at room temperature (20-23 C), then placed in an oven maintained at 50 C for 14 days. The blocks were then weighed.

<u>Fungal Exposure</u>

Soil Block Tests: Weathered and non-weathered blocks for soil block exposures were briefly soaked in distilled water, placed in plastic bags and subjected to 2.5 mrad of ionizing radiation from a cobalt-60 source. The blocks were then exposed to one of two fungi, *G. trabeum* (Pers ex Fr) Murrill (Isolate Madison 617) or *P. placenta* (Fries) M. Larsen et Lombard (Isolate Madison 698). Both fungi are common brown rot fungi, with the former exhibiting tolerance to organic preservatives and the latter exhibiting tolerance to copper based biocides (DaCosta and Kerruish, 1964; Zabel, 1954).

Decay chambers for assessing the effects of copper naphthenate source (hydrate or carbonate) and stabilizers consisted of 454 ml glass french squares that were half filled with a moist forest loam. A western hemlock (*Tsuga heterophylla (Raf.) Sarg)* sapwood feeder strip (3 by 28 by 34 mm) was placed on the soil surface, then the jars were loosely capped and autoclaved for 45 minutes at 121 C. After cooling, small agar plugs cut from the actively growing edge of a culture of the test fungus were placed on the feeder strips, then the jars were loosely capped and incubated at 28 C until the fungus had covered the feeder strip. Two sterile test blocks from a given treatment were then added to each jar. The jars were loosely capped and incubated at 28 C for 12 weeks. Each variable was evaluated on 6 blocks per fungus/treatment combination.

At the end of the incubation period, the blocks were removed from the bottles, scraped clean of adhering mycelium and weighed. The difference between initial oven-dry weight and final weight was used to calculate moisture content which served to confirm that moisture conditions were suitable for fungal decay. The blocks were then oven dried and weighed. These weights, along with the original oven dry weights were used to calculate mass loss. The resulting weight losses were averaged for each treatment/fungus exposure group.

Sapwood Decay Test: Assessing the potential for *P. placenta* to move from Douglas-fir heartwood into adjacent copper naphthenate treated sapwood required a slightly different approach. Non-treated Douglas-fir heartwood blocks (15 X 25 X 50 mm long) were oven dried (103 C), weighed and then vacuum soaked with water. Vermiculite (400 g) along with 15 heartwood blocks and 1 liter of 0.5 % malt extract was added to an autoclavable plastic bag equipped with a breathable patch that allowed air-exchange but limited the potential for microbial contamination. The bags were loosely sealed and autoclaved (121 C) for 45 minutes. After cooling, 120 ml of a liquid inoculum containing hyphae of *P. placenta* was added, then the bags were sealed and incubated at 28 C for 11 weeks.

The fungal inoculum used to inoculate the vermiculite-filled bags was prepared by inoculating 0.5 % malt extract with agar plugs cut from the actively growing edges of cultures of *P. placenta*. The malt extract was incubated for 2 weeks, then the hyphae were collected by pouring the liquid through a sterile Buchner funnel without filter paper. The hyphae were rinsed several times with sterile distilled water to remove excess nutrients, then backwashed into a blender jar and blended at full speed for about 10 sec. The inoculated blocks in the vermiculite-filled bags were periodically examined to assess the degree of fungal colonization. Once colonization had proceeded to an acceptable level, one fungal colonized heartwood block was affixed to a similarly sized sapwood block treated to a given level with copper naphthenate so that the wide faces were touching. The two blocks were then wrapped in a piece of sterilized plastic film held in place with a sterile rubber band (Figure V-3). The assembled blocks were then placed into sterilized wide mouth glass jars (500 ml) filled halfway with vermiculite moistened to 300 % moisture content (Figure V-4). The jars were sealed and incubated at 28 C for 20 weeks. The degree of fungal colonization was periodically assessed by removing non-treated sapwood assemblies, scraping the surfaces clean of fungal mycelium, and oven drying (50 C) prior to weighing. Weight loss was used as the measure of fungal damage.

These procedures differed from the soil block tests in a number of ways. First, they used Douglas-fir sapwood in place of southern pine sapwood. While sapwoods are generally similar in the

Figure V-3. Examples of Douglas-fir block assemblies used to evaluate the potential for *P. placenta* to move from the heartwood to copper naphthenate treated sapwood where A) 2 blocks wrapped in plastic, B) the blocks outside the wrap and C) the sapwood/heartwood (left/right) blocks side by side.

Figure V-4. Decay assemblies in glass jars used to assess the potential for *P. placenta* to move from the inoculated Douglas-fir heartwood to copper naphthenate treated Douglas-fir sapwood

susceptibility to decay, they can differ in their treatability. Southern pine sapwood is typically more permeable than Douglas-fir. While this might not affect overall retentions in the blocks, it might affect the distribution of preservative and this could, ultimately affect performance. In addition, the blocks did not receive any exogenous nutrients or moisture nor were they in a location that would have allowed them to obtain nutrients from the soil (such as might happen with fungal translocation of nutrients in soil block tests).

This approach was taken in light of the environment inside a through-bored copper naphthenate treated Douglas-fir pole. *P placenta* is unlikely to be present in the through-bored groundline zone of a pole because the treated heartwood is a potent barrier to colonization. Thus, *P. placenta* is more likely to be present in heartwood above the through-bored zone where the fungus would have little or no access to soil associated nutrients that might stimulate fungal growth and decay.

These procedures were designed to mimic this environment.

Soil Block Tests: Weight losses for non-treated, non-weathered controls exposed to *G. trabeum* averaged 59.5 % and 51.9 % for blocks treated with either toluene or water, respectively, while they averaged 50.8 and 46.9 % when treated with the same solvents and exposed to *P. placenta* (Table V-1). Weight losses were similar for weathered materials treated with the same solvents and exposed to these fungi. These data indicate that conditions were suitable for aggressive fungal attack.

The weight losses found in the current test were also compared with those from 2010 (Table V-2). In general, the degree of fungal attack on copper naphthenate treated samples was lower in the most recent test, although the trends showing a biodiesel effect on copper naphthenate performance were still present. The soil block test is a biological procedure and it is not surprising to see differences emerge between individual trials run over time. These differences can often arise due to variations in fungal activity, but they may also reflect more subtle differences. For example, the # 2 diesel source might have varied (the soy employed in these trials was the original material used last year). This makes it important to examine trends rather than comparing specific weight losses between different tests.

Weight losses for blocks exposed to *G. trabeum* tended to decline sharply with increasing copper retention, regardless of copper naphthenate source or the presence of soy based biodiesel (Table V-1, Figures V-5 and 6). These results are similar to those found last year and are consistent with the fact that this fungus is not known to be tolerant to copper based biocides.
Weight losses for blocks exposed to *P. placenta* did show a trend to increasing weight losses with higher levels of biodiesel for all three retentions tested (Table V-1, Figures V-7 and 8). This effect was more subtle for non-weathered material, but was still apparent at the lower retentions. Exposure of weathered blocks to *P. placenta* showed a clear effect of increasing biodiesel level. While all treatments (diesel alone plus the biodiesel treatments) provided minimal protection at 0.4 kg/m^3, increasing copper retentions tended to perform better in diesel alone.

Addition of soy-based biodiesel tended to reduce performance at 1.2 and 2.4 kg/m^3. The effect was most noticeable when the solvent was virtually all biodiesel (98 %), but there was a steady trend upward in weight loss at lower biodiesel concentrations. It was also clear that there was some variation in these data. For example, weight losses were higher for the 1.2 kg/m^3 copper naphthenate treated blocks in # 2 diesel than they were when 10 % biodiesel was added. However, the overall trend showed a steady decline in performance with increasing biodiesel level.

The role of weathering in the biodiesel effect is especially important given the relatively minor weathering to which the blocks were exposed. The AWPA E10 procedures for oil-borne treatments calls for soaking the blocks in water for 2 hours, followed by oven drying for 14 days at 50 C. While it is unlikely that poles in service would be exposed to 50 C in the soil contact zone, they are very likely to be exposed to water in wetlands or other low-lying, poorly drained areas for long periods of time. Thus, any biodiesel effects on copper naphthenate mobility

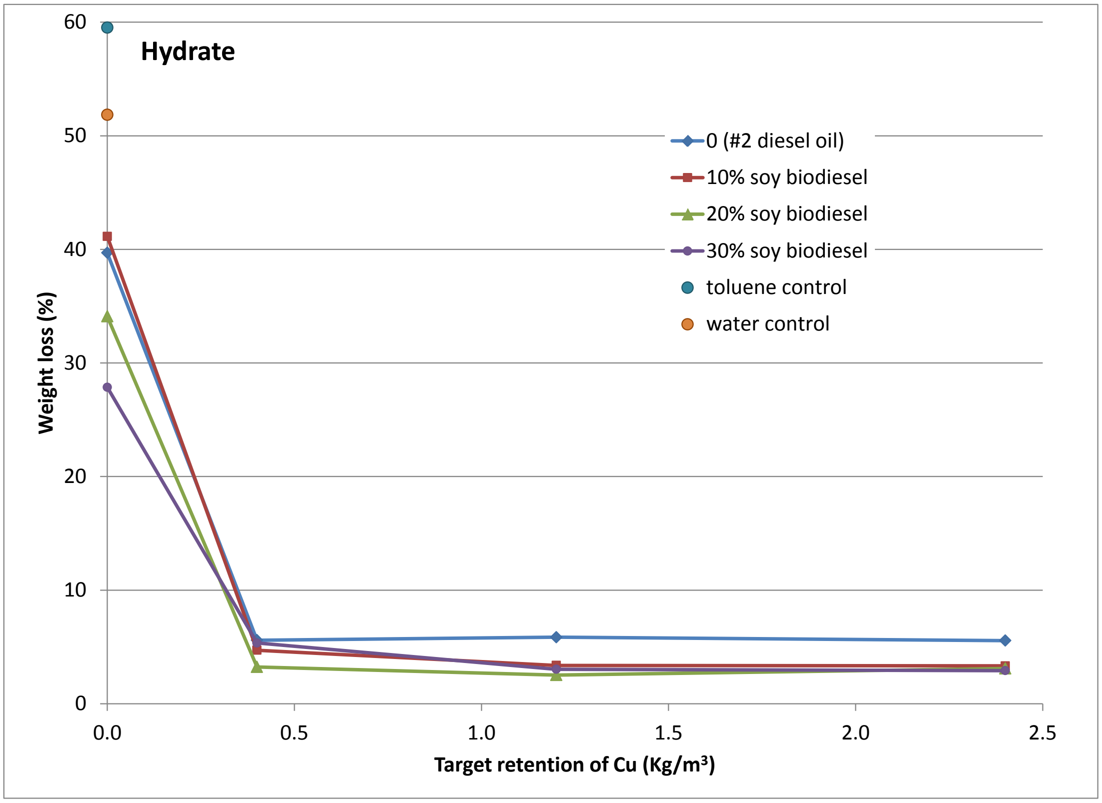
Table V-1. Effect of biodiesel as a cosolvent on weight losses of southern pine blocks treated with copper naphthenate from two sources following 12 weeks of exposure to *G. trabeum* or *P. placenta* in an AWPA E10 soil block test.[a]

Fungus	Copper napthe-nate	% soy bio oil	Target retentions (Kg/m^3)															
			0		0.4		1.2		2.4		0		0.4		1.2		2.4	
			Not weathered								Weathered							
G. trabeum	carbonate	0	39.7	(3.9)	6.7	(0.8)	5.4	(1.2)	5.4	(0.8)	48.0	(6.6)	3.6	(0.9)	1.9	(0.2)	2.2	(0.6)
		10	41.1	(4.2)	4.6	(0.8)	3.3	(0.4)	3.9	(0.8)	47.6	(4.1)	2.5	(0.4)	2.3	(0.4)	1.7	(0.3)
		20	34.1	(5.2)	4.4	(1.5)	3.5	(0.6)	4.3	(0.6)	38.1	(6.9)	3.0	(0.4)	2.0	(0.3)	2.1	(0.4)
		30	27.9	(6.6)	4.9	(1.2)	2.9	(0.2)	2.1	(0.6)	36.0	(5.1)	2.9	(1.2)	1.7	(0.3)	1.6	(0.5)
	hydrate	0			5.6	(0.5)	5.8	(1.2)	5.6	(1.5)			2.4	(0.3)	0.9	(0.4)	2.1	(0.5)
		10			4.7	(0.5)	3.4	(0.6)	3.3	(2.9)			2.7	(0.8)	2.2	(0.2)	2.1	(0.5)
		20			3.2	(0.5)	2.5	(0.4)	3.1	(0.5)			3.0	(0.8)	1.6	(0.3)	1.4	(0.3)
		30			5.3	(1.0)	3.0	(0.6)	2.9	(0.7)			2.8	(0.7)	1.7	(0.5)	1.8	(0.4)
	toluene	0	59.5	(5.5)							55.7	(9.6)						
	water	0	51.9	(11.8)							52.8	(5.3)						
P. placenta	carbonate	0	33.8	(2.4)	12.2	(7.5)	4.6	(0.7)	4.0	(1.7)	48.3	(3.8)	23.3	(9.5)	1.3	(0.3)	1.5	(0.7)
		10	32.6	(4.4)	15.3	(5.0)	3.6	(0.4)	2.7	(0.7)	41.2	(2.6)	19.5	(4.1)	9.7	(7.7)	1.6	(0.4)
		20	32.2	(6.9)	15.4	(4.3)	6.8	(3.4)	4.6	(0.8)	42.0	(5.0)	23.0	(6.4)	18.4	(8.5)	4.7	(3.1)
		30	37.9	(8.8)	21.1	(4.6)	12.7	(3.3)	7.8	(5.3)	32.2	(13.7)	25.2	(11.4)	26.1	(5.6)	11.2	(9.9)
		98	21.4	(4.7)	22.8	(9.1)	8.2	(4.8)	11.0	(6.9)	35.2	(9.6)	22.1	(8.1)	16.1	(4.3)	18.1	(6.9)
	hydrate	0			23.5	(14.3)	4.3	(1.4)	4.9	(1.2)			21.8	(11.0)	9.2	(8.1)	2.4	(1.7)
		10			13.0	(5.1)	3.7	(1.4)	3.2	(0.3)			27.9	(4.2)	1.8	(0.8)	1.6	(0.7)
		20			11.9	(6.1)	3.3	(1.2)	3.8	(2.4)			24.1	(4.6)	16.7	(6.0)	1.9	(0.6)
		30			20.1	(10.2)	6.6	(2.4)	6.3	(4.5)			26.1	(10.9)	17.1	(2.3)	3.0	(1.1)
		98			24.6	(2.4)	13.7	(4.4)	8.0	(1.2)			32.5	(4.2)	28.8	(4.2)	15.7	(7.1)
	toluene		50.8	(7.3)							47.4	(8.3)						
	water		46.9	(6.2)							50.6	(4.8)						

a. Numbers in parentheses represent one standard deviation from the mean of six replicates.

Table V-2. Comparison between wood weight losses produced by *G. trabeum* or *P. placenta* on southern pine sapwood blocks treated with copper naphthenate in # 2 diesel with or without a biodiesel cosolvent as determined by exposure in an AWPA E10 soil block test.

Fungus	Bio oil	% soy bio oil	Target retentions (Kg/m3)															
			0		0.4		1.2		2.4		0		0.4		1.2		2.4	
			Not weathered								Weathered							
			2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010
G. trabeum	soy	0	39.7	31.1	5.6	8.1	5.8	7.5	5.6	7.4	48.0	49.7	2.4	5.2	0.9	2.5	2.1	2.0
		10	41.1	35.0	4.7	7.4	3.4	6.2	3.3	5.5	47.6	43.0	2.7	5.2	2.2	2.5	2.1	2.3
		20	34.1	32.9	3.2	8.8	2.5	4.8	3.1	5.3	38.1	37.7	3.0	5.8	1.6	2.7	1.4	2.1
		30	27.9	33.5	5.3	8.3	3.0	5.9	2.9	5.0	36.0	33.5	2.8	5.5	1.7	3.5	1.8	2.7
	toluene	0	59.5	60.4							55.7	49.5						
	water	0	51.9	53.6							52.8	49.0						
P. placenta	soy	0	33.8	38.8	23.5	14.8	4.3	7.6	4.9	7.5	48.3	47.6	21.8	27.5	9.2	22.1	2.4	6.4
		10	32.6	41.8	13.0	20.1	3.7	7.4	3.2	6.1	41.2	43.2	27.9	31.3	1.8	24.9	1.6	7.6
		20	32.2	39.2	11.9	21.5	3.3	11.3	3.8	7.1	42.0	46.8	24.1	31.4	16.7	21.5	1.9	11.4
		30	37.9	40.0	20.1	27.7	6.6	22.3	6.3	10.8	32.2	41.8	26.1	24.6	17.1	26.7	3.0	21.0
	toluene	0	50.8	47.1							47.4	49.6						
	water	0	46.9	51.1							50.6	50.7						



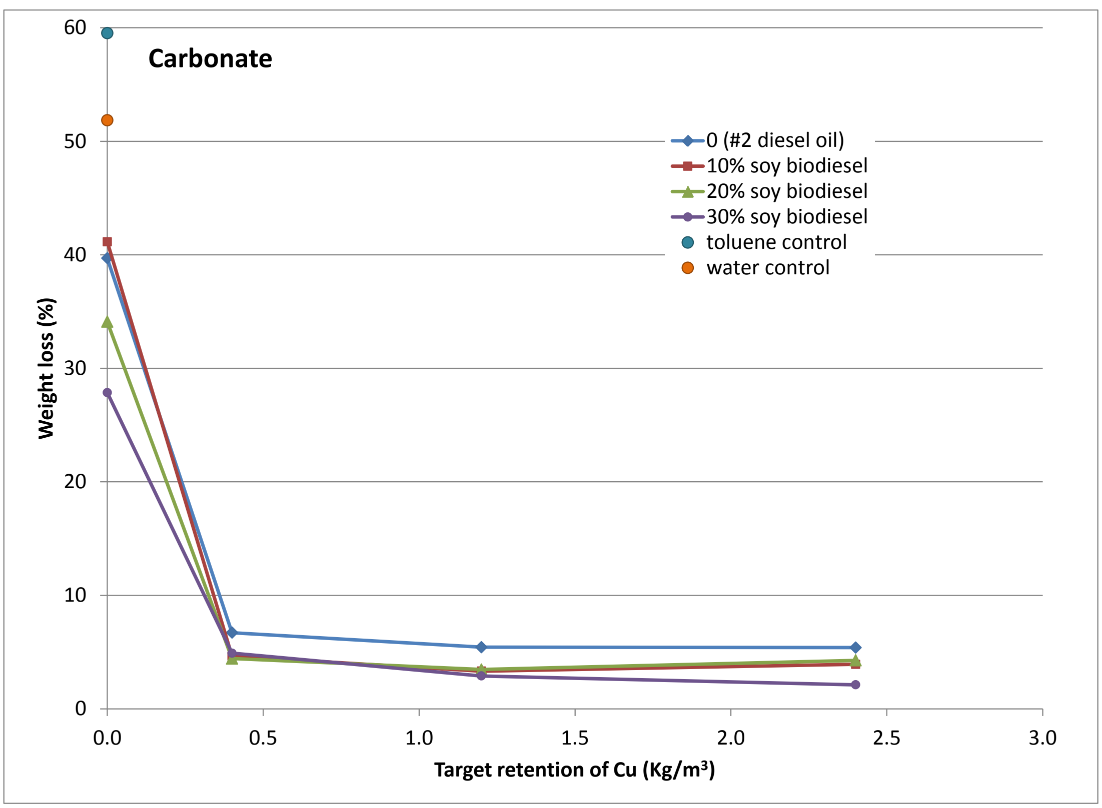
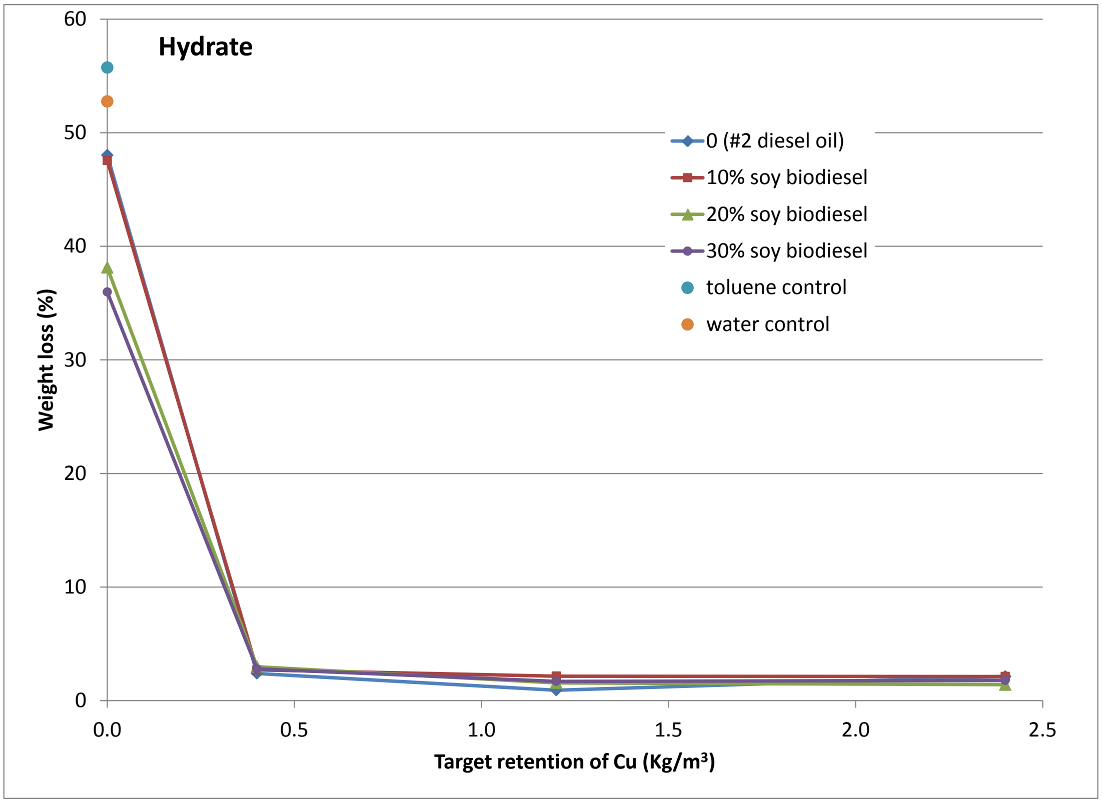


Figure V-5. Effect of copper naphthenate source (hydrate or carbonate) and the presence of different levels of a soy-based biodiesel co-solvent on resistance of non-weathered southern pine sapwood blocks exposed to *G. trabeum* in an AWPA E10 soil block test.



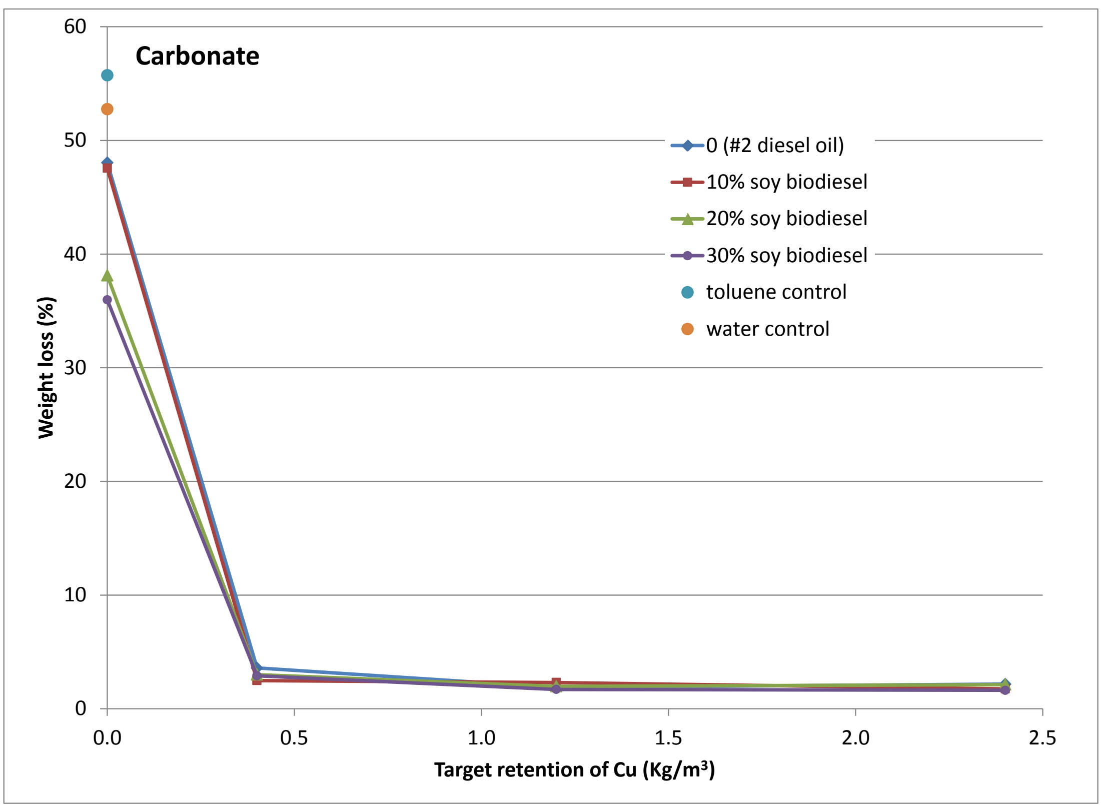


Figure V-6. Effect of copper naphthenate source (hydrate or carbonate) and the presence of different levels of a soy-based biodiesel co-solvent on resistance of weathered southern pine sapwood blocks exposed to *G. trabeum* in an AWPA E10 soil block test.

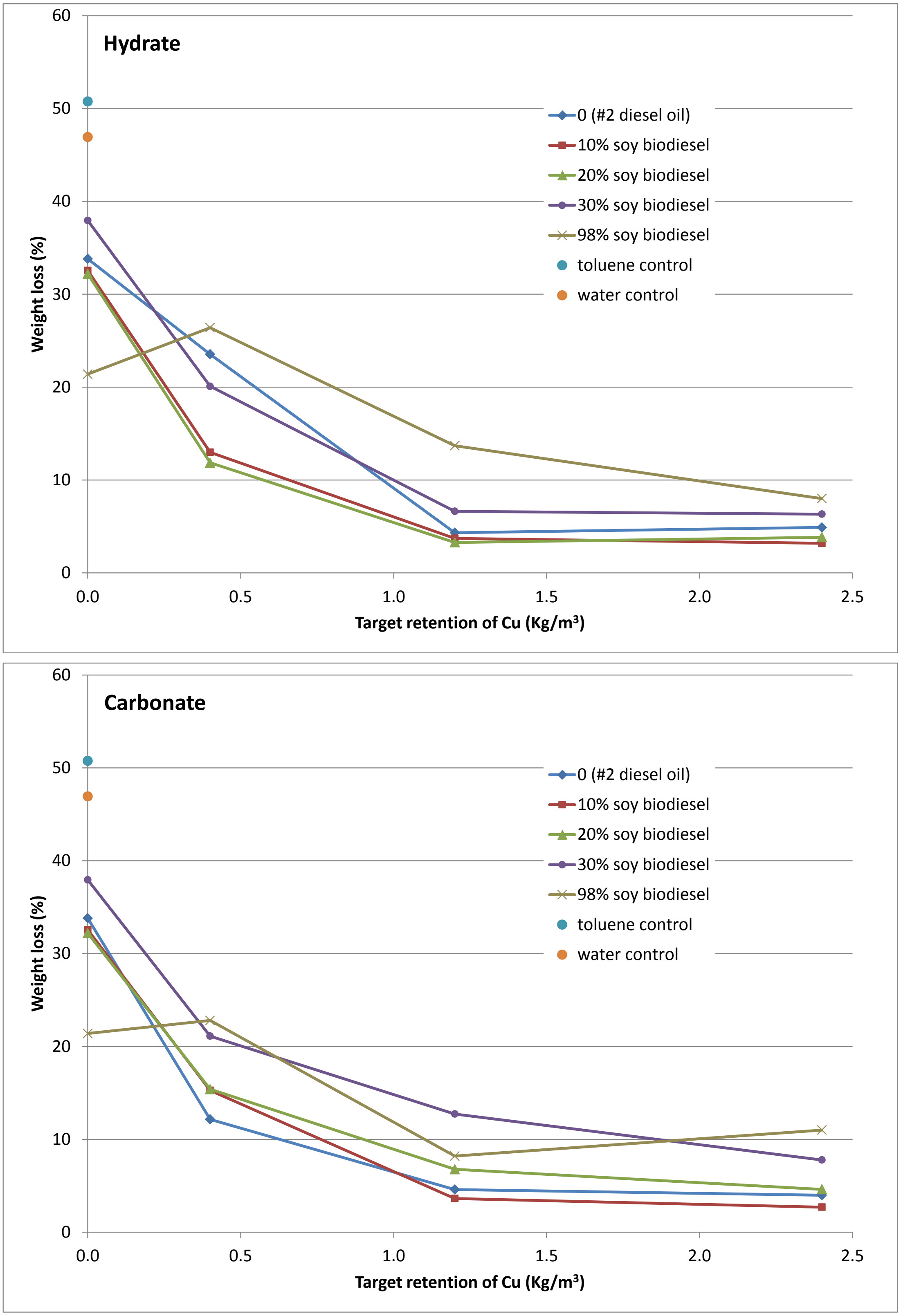


Figure V-7. Effect of copper naphthenate source and the presence of different levels of a soy-based biodiesel co-solvent on resistance of non-weathered southern pine sapwood blocks exposed to *P. placenta* in an AWPA E10 soil block test.

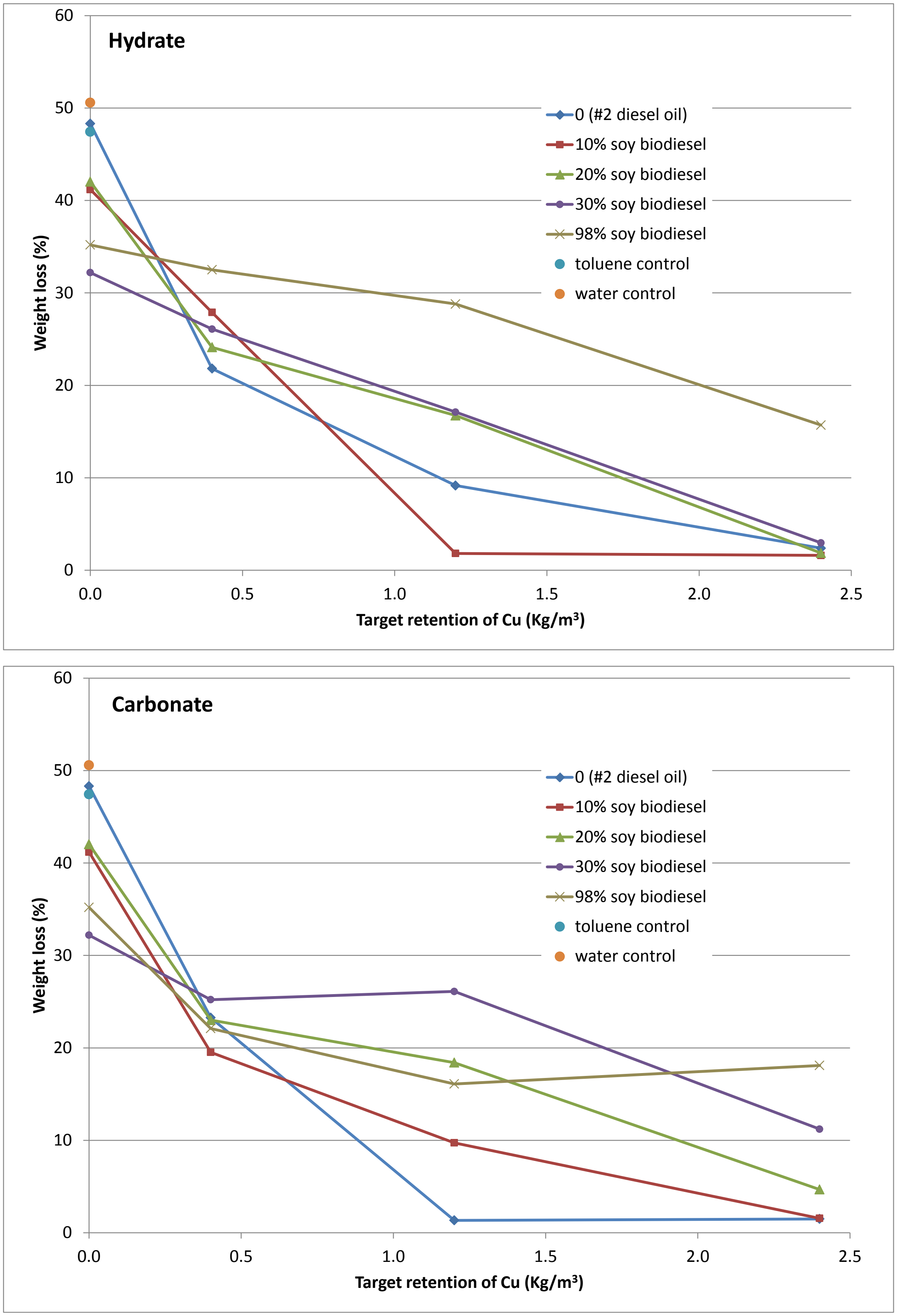


Figure V-8. Effect of copper naphthenate source (hydrate or carbonate) and the presence of different levels of a soy-based biodiesel co-solvent on resistance of weathered southern pine sapwood blocks exposed to *P. placenta* in an AWPA E10 soil block test.

would dramatically affect long term performance.

The original intent of this portion of the test was to determine if there were differences in performance with biodiesel co-solvents and copper naphthenate source. While there were slight differences in performance with individual treatments, there were no consistent differences that would suggest a formulation effect. This is critical for utilities who have already employed these poles in their systems because it means that they do not have to worry whether a specific pole was treated with hydrate or carbonate based copper naphthenate.

During discussion with the manufacturers, we became aware that stabilizers were often added to the treatment solutions in combination with the biodiesel. These stabilizers were not a part of the original trial and were evaluated in this follow-up study to ensure that they did not negatively affect copper naphthenate performance. Because the primary focus of this study was the stabilizers, the only retention evaluated corresponded to the middle retention specified in the AWPA Standards for southern pine. Although both copper naphthenate systems were evaluated, the test was not fully replicated across all stabilizers and copper naphthenate sources because not all stabilizers were used with both systems.

As with the original tests, the presence of stabilizers had little or no effect on copper naphthenate performance against *G. trabeum* regardless of copper naphthenate formulation, although weight loses were slightly higher in weathered materials (Table V-3, Figure V-9). It is difficult to determine if these higher weight losses are of biological origin because there was little evidence of fungal growth on these blocks. It is possible; however, that the additives altered the preservative or the diesel solvent making them more susceptible to leaching.

The addition of stabilizers to copper naphthenate in #2 diesel/30 % soy based biodiesel had a consistently negative effect on performance against *P. placenta*. With the exception of the lower two levels of propyl gallate in the carbonate based copper naphthenate, the presence of a stabilizer produced much higher weight losses. This effect was exacerbated by weathering, suggesting that the biodiesel and the stabilizers render the fungicide either less effective or more mobile.

Blocks exposed to *P. placenta* tended to be heavily bleached suggesting that the copper was either leached from the wood into the surrounding soil or was immobilized as copper oxalate. The latter explanation is more likely since copper tolerant brown rot fungi are known to over-produce oxalic acid which then sequesters available copper. Copper oxalate has much lower activity against fungi, reducing the effectiveness of the original treatment. The stabilizers appear to magnify this effect. Given the magnitude of the weight losses experienced in weathered blocks, it is difficult to determine which stabilizer was most detrimental. The results indicate that the stabilizer further magnifies the negative effects of biodiesel on copper naphthenate performance.

While the effects of biodiesel and the stabilizers on copper naphthenate performance are readily apparent, the causes remain unknown. We have sent weathered and non-weathered blocks to other cooperators for chemical analysis to determine the nature of the change. We hope to report on these data in future UPRC annual reports.

At present, however, the results confirm our previous findings that copper naphthenate is espe-

Table V-3. Effect of stabilizer presence and level on performance of southern pine sapwood blocks treated with copper naphthenate in #2 diesel amended with 30 % soy-based biodiesel as determined using an AWPA E10 soil block test with *G. trabeum* and *P. placenta*.

Fungus	Stabilizer	Stabilizer conc. (ppm)	non-weathered				weathered			
			carbonate		hydrate		carbonate		hydrate	
G. trabeum	None	0	2.9	(0.2)	3.0	(0.6)	1.7	(0.3)	1.6	(0.5)
	Biostable	1000			2.0	(5.2)			6.8	(1.3)
		1500			1.8	(1.3)			4.7	(16.0)
		2000			1.8	(1.1)			7.0	(1.5)
	Biostable plus 250 ppm TBHQ	1000			2.6	(7.7)			7.8	(1.0)
		1500			2.0	(1.2)			1.7	(23.2)
		2000			2.7	(0.9)			7.5	(2.0)
	Propyl Gallate	250	1.6	(0.4)			6.2	(0.6)		
		500	1.9	(0.4)			6.5	(0.9)		
		1000	1.5	(0.4)			7.0	(1.0)		
	TBHQ	125			2.0	(0.9)			6.8	(1.3)
		250			2.0	(0.4)			6.3	(1.0)
		500			1.6	(0.7)			7.2	(1.1)
P. placenta	None	0	12.7	(3.3)	6.6	(2.4)	18.4	(8.5)	16.7	(6.0)
	Biostable	1000			12.2	(1.4)			32.0	(9.1)
		1500			21.2	(10.3)			40.3	(8.7)
		2000			27.6	(8.7)			40.4	(12.8)
	Biostable plus 250 ppm TBHQ	1000			8.3	(14.4)			44.8	(5.7)
		1500			25.1	(5.9)			34.3	(13.1)
		2000			30.0	(6.5)			40.7	(7.1)
	Propyl Gallate	250	11.0	(3.9)			31.5	(7.1)		
		500	9.1	(2.9)			32.7	(4.9)		
		1000	20.4	(5.6)			27.6	(3.6)		
	TBHQ	125			12.1	(6.9)			25.5	(7.8)
		250			7.8	(3.0)			19.9	(7.4)
		500			10.6	(4.6)			30.0	(10.0)

cially sensitive to the presence of biodiesel, although there appeared to be little consistent difference in performance with the two different copper naphthenate formulations.

Sapwood Decay Tests: The final phase of the current work was to assess the potential for *P. placenta* to grow from heartwood into adjacent copper naphthenate treated sapwood. The heartwood blocks used as feeder material to bring the test fungus into contact with the treated sapwood were heavily decayed, indicating that the fungus was capable of substantial decay. Weight

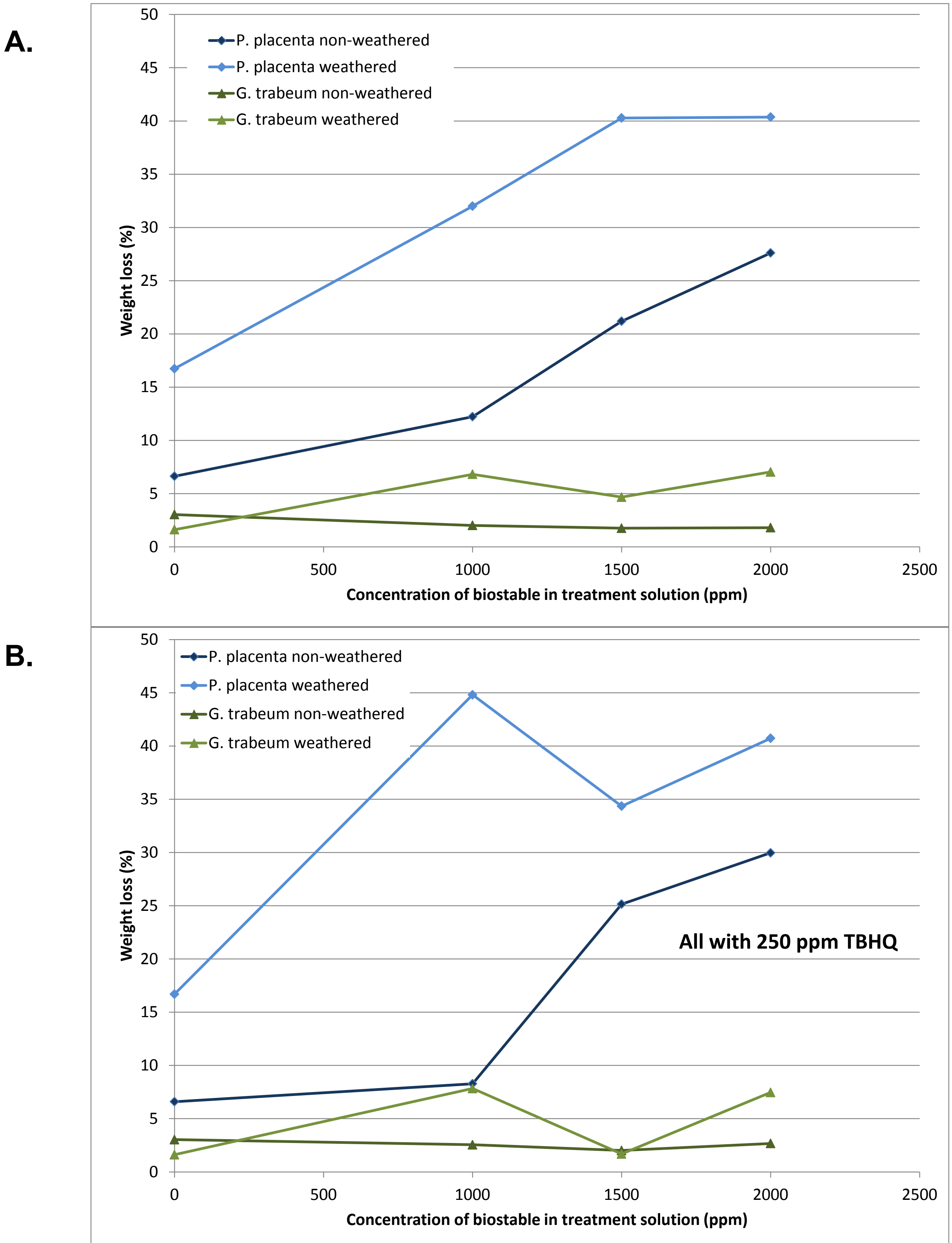
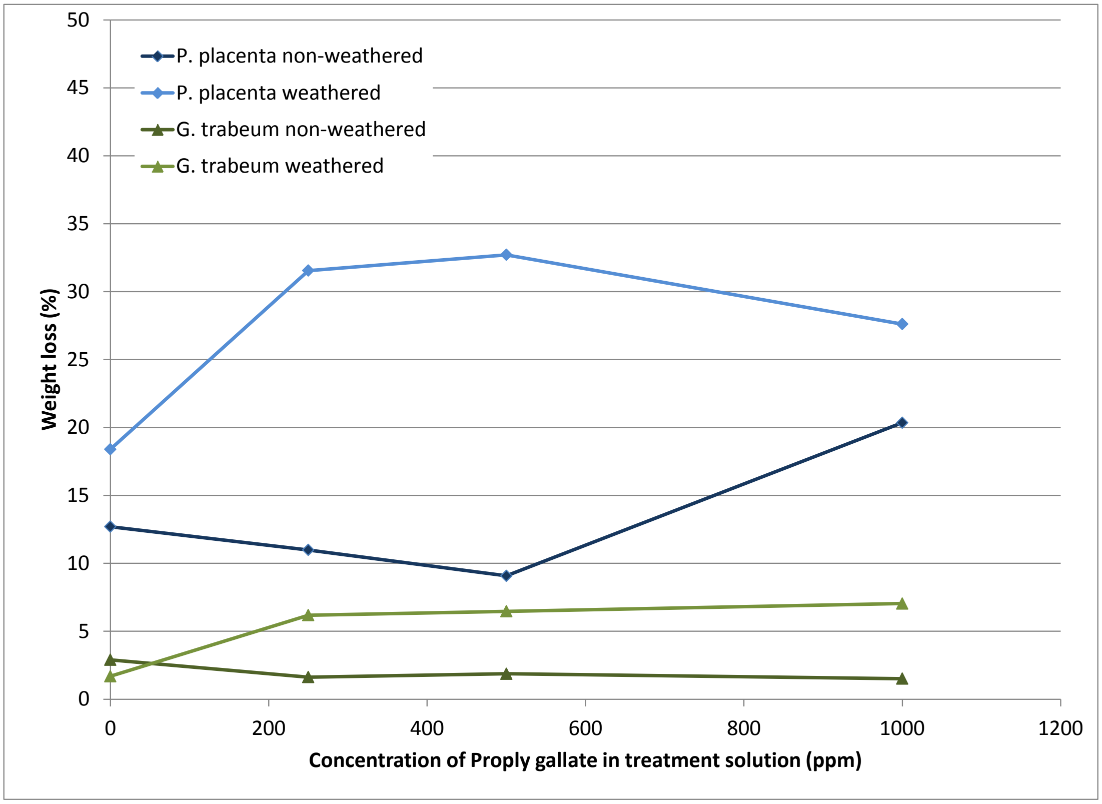


Figure V-9. Effect of biostabilizers A. biostable and B. biostable with 250 ppm TBHQ on performance of copper naphthenate solubilized in #2 diesel amended with 30 % soy-based biodiesel.

C.



D.

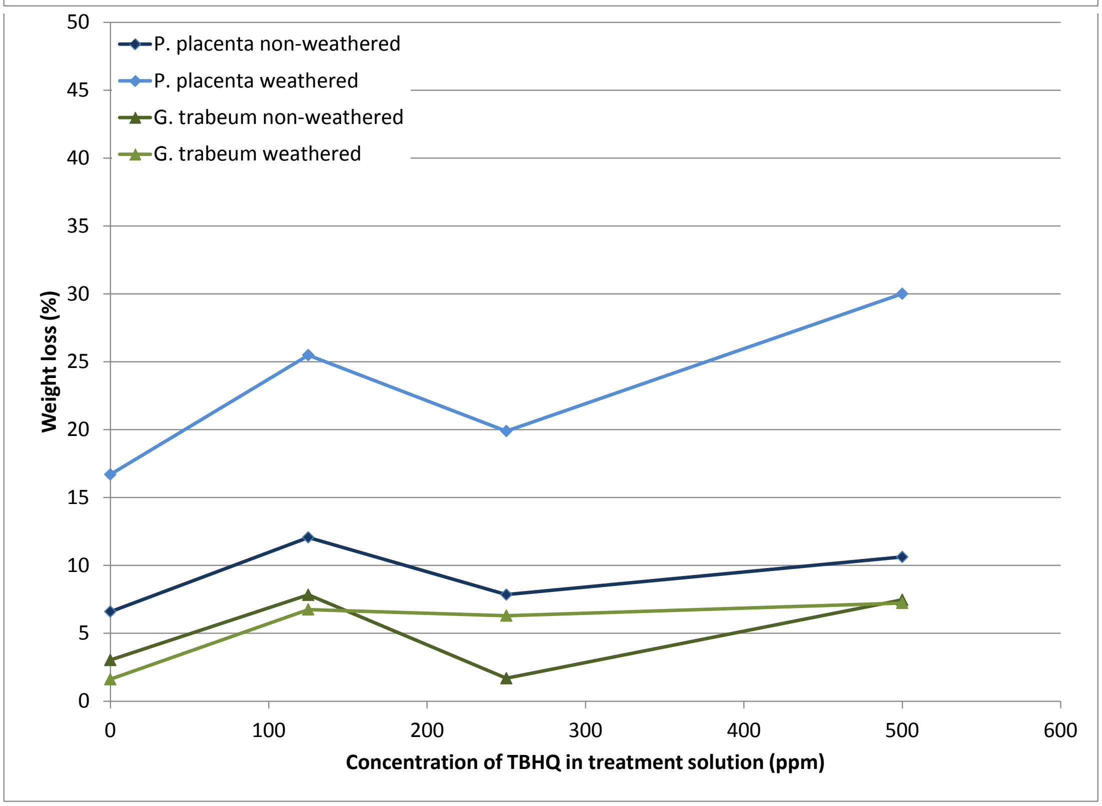


Figure V-9. cont.. Effect of biostabilizers C. propyl gallate and D.TBHQ on performance of copper naphthenate solubilized in #2 diesel amended with 30 % soy-based biodiesel.

losses for water or toluene impregnated Douglas-fir sapwood blocks were 22.6 and 17.5 %, respectively, after the 20 week exposure period (Table V-4). While these weight losses were lower than those found in the southern pine sapwood blocks exposed in a traditional soil block test, the lack of soil contact and the block configuration likely limited fungal activity. This test configuration was specifically designed to simulate an above-ground internal decay condition where moisture content was potentially lower and there was no source of exogenous nutrients. These conditions would be expected to result in reduced weight losses.

Table V-4. Weight loss of copper naphthenate treated Douglas-fir sapwood blocks after 20 weeks in contact with heartwood blocks infested with *P. placenta*.

solvent	not weathered				weathered			
	0	0.2	0.4	0.8	0	0.2	0.4	0.8
#2 diesel	13.56 (3.19)	8.84 (3.87)	5.18 (1.82)	4.33 (1.32)	21.01 (4.96)	8.77 (1.95)	8.58 (2.44)	8.15 (4.41)
30% soy boidiesel	9.67 (3.44)	8.23 (3.14)	3.19 (0.85)	3.30 (0.57)	11.77 (2.64)	8.98 (2.41)	7.52 (1.68)	6.49 (1.59)
toluene	17.46 (7.22)							
water	22.64 (6.11)							

Weight losses in non-weathered blocks treated with #2 diesel alone or amended with 30 % soy-based biodiesel were lower than those for the non-treated control, showing the benefits of residual solvent in the blocks. Weight losses for weathered blocks treated with the same solvents were more variable, with weight losses being lower in the biodiesel amended solvent. Weight losses declined in the copper naphthenate treated blocks, even at the lowest level tested for both non-weathered and weathered blocks (Figure V-10). There also appeared to be no evidence of decay on the treated samples. These results indicate that the fungus was unable to move from the heartwood to colonize and degrade the treated sapwood.

These results suggest that, while *P. placenta* may still colonize Douglas-fir heartwood in copper naphthenate treated poles in service, it is unlikely to move from that position outward to degrade the treated sapwood shell. This is extremely important, because this ability would position the fungus to colonize the heartwood where it might not be detected, and move outward to degrade critical portions of the pole at locations where it might be very difficult to detect using conventional inspection methods. These results indicate that this is unlikely to occur.

The addition of biodiesel as a co-solvent for odor reduction negatively affected the performance of both hydrate and carbonate based copper naphthenate. The use of stabilizers in biodiesel amended solvents further reduced the efficacy of copper naphthenate. The findings reinforce previous tests and suggest that particular vigilance should be paid to poles treated with copper naphthenate in biodiesel amended solvents to detect the onset of any early decay.

On the positive side, it would appear that *P. placenta* established in the heartwood is not able to move from this wood into adjacent copper naphthenate treated sapwood. This finding is important because this fungus is among the most common causes of internal decay in Douglas-fir utility poles. These results indicate that no special arrangements will need to be taken to limit the colonization by this fungus.

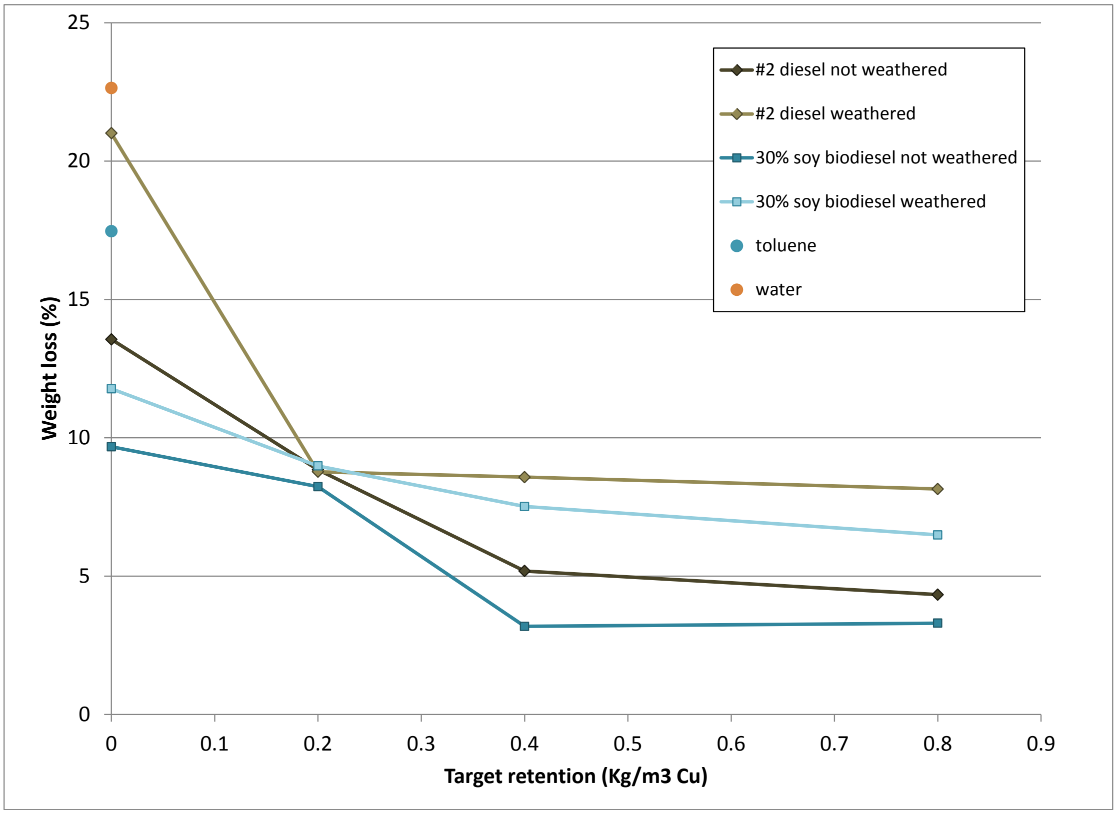


Figure V-10. Weight losses in Douglas-fir sapwood samples treated with copper naphthenate in #2 diesel alone or amended with 30 % biodiesel and exposed to *P. placenta* colonized Douglas-fir heartwood blocks for 20 weeks at room temperature.

OBJECTIVE VI

ASSESS THE POTENTIAL ENVIRONMENTAL IMPACTS OF WOOD POLES

Preservative treated wood poles clearly provide excellent service under a diverse array of conditions, but the increasing sensitivity of the general public to all things chemical has raised a number of questions concerning the preservatives used for poles. While there are no data indicating that preservative treated wood poles pose a risk to the environments in which they are used, it is important to continue to develop exposure data wherever possible. The goal of this objective is to examine usage patterns for preservative treated wood (specifically poles) and to develop exposure data that can be employed by utilities to both assess their use patterns and to answer questions that might arise from either regulators or the general public. More recently, we have explored methods for capturing chemical components in runoff from stored poles as a means of mitigating any potential risks associated with pole storage.

Although this remains an important issue, no additional tests were performed this past year. We will seek additional materials, particularly those prepared using Best Management Practices for further evaluation.