Oregon State University
Utility Pole Research Cooperative

Department of Wood Science & Engineering
Oregon Wood Innovation Center

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American Transmission Company

Arizona Public Service

Bonneville Power Administration

Brooks Manufacturing Inc.

Copper Care Wood Preservatives Inc.

Dr. Wolman, GMBH

Fortis Alberta

Genics Inc.

Intec Services Inc. (Pole Care Inc.)

ISK Biocides

McFarland Cascade

Nisus

Osmose Utility Services, Inc.

Pacific Gas and Electric

PacifiCorp

Pacific Wood Preserving Companies

Poles, Inc.

Portland General Electric Company

Puget Sound Energy Services

Rio Tinto Minerals

Salt River Project

Snohomish County Public Utility District

Stella-Jones Inc.

The Pentachlorophenol Working Group

Utility Pole Technologies Inc.

Western Wood Preservers Institute

Wood Care Systems

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EXECUTIVE SUMMARY

The UPRC remains active in a wide array of activities that are addressed under six objectives.

Objective I investigates the performance of various internal remedial treatments for arresting internal decay in service. Studies of dazomet applied directly as a powder or contained in paper or plastic tubing showed that the paper tubing had little effect on subsequent release of methyl-isothiocyanate (MITC), while the plastic tubing appeared to delay release, although both resulted in effective levels of chemical in the poles. Investigations of residual dazomet in holes in poles located near the Oregon Coast indicated that some residual dazomet remained in the holes 6 years after treatment, but MITC levels were generally above the threshold for protection against fungal attack. Tests of MITC-FUME where the tubes were either cooled or allowed to heat to the point where the MITC became molten prior to application showed that applying this system in the molten condition had no negative effect on subsequent MITC levels in the wood and, in some cases, resulted in slightly higher loadings. The reasons for this increase are unclear, but the results show that application of this formulation under hotter conditions does not appear to negatively affect the resulting chemical movement.

Trials of fused boron rods and fused boron rods amended with copper continue to show that the boron in both systems have become well distributed in the poles at levels that would be protective against fungal attack. Copper movement has been much more variable and the potential role of this element in rod performance remains uncertain.

The large scale trial of all currently registered internal remedial treatments has shown that MITC levels in metham sodium based systems have all declined below the protective threshold after 54 months. This is consistent with the tendency for this system to provide shorter term protection. MITC levels in daozmet based treatments remain well above the protective threshold, while those in MITC-FUME treated poles remains far above the protective threshold. Similarly, chloropicrin levels in poles receiving this chemical remain far above the threshold.

Boron levels in poles receiving fused boron rods also remain above the protective level 54 months after treatment although the zone of protection does not extend for as great a distance above ground as it does with the volatile internal treatments. There materials are highly dependant on moisture for movement.

Objective II investigates systems for protecting wood in either field drilled bolt holes or other cuts made to preservative treated products. There was no activity under this Objective, although we continue to seek alternative methods for encouraging field treatments of these holes or cuts to reduce the potential for the development of above ground decay.

Objective III investigates a variety of activities intended to improve the performance of poles. This past year we completed two surveys of utilities. The first was a comprehensive survey of practices. The results showed that the pole replacement rate for responding utilities was 0.56 % per year, which was consistent with previous results. Utilities also appeared to purchase cross arms at rates that were proportional to the pole purchase rates suggesting that crossarms provided at least similar service life to that obtained from poles. The survey also indicated that most utilities inspected their poles on an approximately 10 year cycle using excavation coupled with a sound and bore, but there was a wide range in the frequency with which they applied remedial treatments. Finally, most utilities continued to use give-aways for their used poles although many would consider combustion for energy production if it were available. The other survey polled utilities concerning the incidence of wildfires in their system. While some utilities had experienced substantial pole losses, most were not affected by fires and the risk of fires had not adversely affected their purchasing decisions.

Tests of polyurea coated crossarms showed that these barriers continue to perform under tropical conditions although several tests indicated that termites were able to penetrate this barrier when the wood beneath had no preservative treatment. Similar polyurea coating on the tops of poles has provided an excellent barrier against moisture intrusion as a means for limiting internal decay near the pole top.

Concerns about the potential for solvent systems to affect performance of pentachlorophenol against fire and decay fungi have been examined. Fire tests indicated that pole sections treated with penta in either co-solvent/diesel or a biodiesel amended solvent had similar burn characteristics. Similar tests with copper naphthenate treated poles suggested that this treatment experienced slightly more damage than either penta treatment. Stakes treated with penta in either diesel or a biodiesel containing solvent performed similarly in a 4 year field trial near Hilo, Hawaii. These results suggest that the biodiesel solvent evaluated had no negative effect on performance. A larger field trial with more oil combinations is planned to better represent the solvents currently in the marketplace.

A preliminary study of the effects of woodpecker holes on pole flexural properties clearly illustrated the negative effects of the holes on properties. Infrared imaging was also used to investigate the extent of the damage and appeared to be a reasonable method for estimating damage although more work will be needed to better understand how these images might be used by ground personnel to assess to determine the extent of damage prior to climbing.

Preliminary studies have also been undertaken to investigate the potential for using borate pretreatments to reduce the future risk of internal decay in poles. Initial results suggest that some boron is lost during drying and additional boron is lost into the treatment solution (copper naphthenate) during the pressure treating process. The latter boron would likely reach a steady state in the oil over many charges so that boron losses in the retort would be minimal. Further tests are planned and the poles have been installed at our field test site for long term monitoring.

Finally, under **Objective III** we are investigating the potential for using RFID tags for pole inventory. Preliminary trials will begin shortly to test the ability of various tags to withstand the conditions during treatment. Once the most appropriate tagging materials are identified, we will begin larger trials. These tags would be useful for tracking pole inventories in service yards and, if placed above ground, could be used to store information so that field inspectors could instantly determine the prior history of a pole.

Objective IV investigates external groundline decay. While we have a large field trial underway in Arizona, this test will not be evaluated until early next year. We also have a field trial of liners that are designed to limit preservative migration and restrict wood/soil interactions. There were concerns that the barriers would alter wood/moisture relationships and result in moisture accumulation above the groundline that accelerated decay; however, there is no evidence of differences in moisture distribution between lined and non-lined poles. Analyses of soil samples showed that copper levels around the poles were similar for lined and non-lined poles. The results suggest that the soil barrier has little effect on metal losses because most of the contributions come from water running down the pole. The lack of difference reflects that the surface area exposed to run-off is the same for lined and non-lined poles. We will continue to monitor these poles and extend the soil analysis to the penta treated poles in test.

Objective V investigates the performance of copper naphthenate on western wood species. The long term stake test of copper napththenate treated western redcedar continues to show that this system performs well at the specified levels. Field investigations of Douglas-fir poles treated with copper naphthenate in various levels of biodiesel continue in the Puget Sound area. Some evidence of soft rot attack has been found on scattered poles but most of the poles inspected to date appear to be performing well. We will continue to monitor these poles as they age to ensure that the biodiesel does not negatively affect performance.

Objective VI has investigated the potential for preservative migration from poles in storage. This past year, we continued our monitoring of Douglas-fir pole sections treated with copper naphthenate. Copper levels in rainwater runoff have generally been steady although they were elevated in two water collections taken after a long dry period. The remaining analyses suggest that copper losses are primarily a function of water solubility and the amount of rainfall. These results are similar to those found with penta and ACZA and indicate that it would be relatively easy to predict the rates of preservative loss for a given number of stored poles of given dimensions overtime. We will continue to work with these data to develop recommendations for pole storage.

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, metham 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 retreat-

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

<table>
<tr><th>Trade Name</th><th>Active Ingredient</th><th>Conc. (%)</th><th>Toxicity (LD_{50})</th><th>Manufacturer</th></tr>
<tr><td>TimberFume</td><td>trichloronitromethane</td><td>97</td><td>205 mg/kg</td><td>Osmose Utilities Services, Inc.</td></tr>
<tr><td>WoodFume</td><td rowspan="3">sodium n-methyldithiocarbamate</td><td rowspan="3">32.1</td><td rowspan="3">1700-1800 mg/kg</td><td>Osmose Utilities Services, Inc.</td></tr>
<tr><td>ISK Fume</td><td>ISK Biosciences</td></tr>
<tr><td>SMDC-Fume</td><td>Copper Care Wood Preservatives, Inc.</td></tr>
<tr><td>MITC-FUME</td><td>methylisothiocyanate</td><td>96</td><td>305 mg/kg</td><td>Osmose Utilities Services, Inc.</td></tr>
<tr><td>Super-Fume</td><td rowspan="3">Tetrahydro-3,5-dimethyl-2H-1,3,5-thiodiazine-2-thione</td><td rowspan="3">98-99</td><td>320 mg/kg oral</td><td>Pole Care Inc.</td></tr>
<tr><td>UltraFume</td><td rowspan="2">2260 mg/kg dermal</td><td>Copper Care Wood Preservatives, Inc.</td></tr>
<tr><td>DuraFume</td><td>Osmose Utilities Services, Inc.</td></tr>
</table>

ment is necessary and to identify any factors that might affect performance. In 2012, we examined the effectiveness of these treatments in drier climates. In addition, we continue to monitor a number of long term field trials. A listing of active tests under Objective I can be found in Table I-2 and an index to all fumigant and diffusible tests from the inception of the UPRC (1980) to the present can be found in Appendix I.

Table I-2. Active tests under Objective I

Title	Year Started	Treatments	Location	Most Recent Report	Next Sampling
Effect of MITC-FUME Application Temperature on Distribution of MITC in Douglas-fir Pole Sections	2013	MITC-FUME	lab	2013	
MITC Levels in Douglas-fir Poles in a Coastal Environment 6 years After Application of Dazomet	2010	Dazomet	OR	2013	
Ability of Internal Remedial Preservative Systems to Migrate into Distribution Poles in an Arid Climate	2010	Dazomet, MITC-FUME, metham sodium, boron rods	UT	2012	2013
Full Scale Field Trial of All Internal Remedial Treatments	2008	Dazomet (5 products), MITC_FUME, metham sodium (3 products), chloropicrin, boron rods, fluoride rods (2 products)	Corvallis, OR	2013	2015
Performance of dazomet in tube and granular formulations	2006	Dazomet	Corvallis, OR	2013	2016
Performance of copper amended boron rods	2001	Copper/boron rods	Corvallis, OR	2013	2017
Performance of dazomet in rod or powdered formulations	2000	Dazomet	Corvallis, OR	2012	2015
Effect of Boracol and other glycol based materials on movement of boron from fused borate rods	1993	Fused borate rods, Boracol, Boracare, Timbor	Corvallis, OR lab and field	2010	2015
Performance of fused boron rods in above ground exposures in Douglas-fir pole stubs	1993	Fused borate rods	Corvallis, OR	2013	none

1. Performance of Dazomet With or Without Copper Based Accelerants

Our preliminary field data clearly showed that copper sulfate accelerated the decomposition of dazomet to produce MITC, but this chemical is not registered by the EPA for the internal treatment of in-service utility poles. One alternative to copper sulfate is copper naphthenate, which is commonly recommended for treatment of 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 powder, equally distributed among the three holes and three received 20 g of liquid copper naphthenate (2% metallic copper) in mineral spirits, also equally distributed among the three holes. The holes were then plugged with tight fitting wood dowels.

Levels of MITC were above the toxic threshold in the interior of poles near the groundline for all treatments for 8 years. Both copper amendments enhanced decomposition to MITC. The test was sampled for 15 years when MITC levels had fallen below threshold at most locations and were barely above threshold near the groundline of the copper naphthenate treatment. The final report can be found in the 2012 UPRC Annual Report.

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 with moisture 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 ml of metham 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 periodically for 12 years after treatment and remains above threshold in both the inner and outer portions of poles receiving all treatments except metham sodium. The last complete report on this test can be found in the 2012 UPRC Annual Report and the test will next be sampled in 2015.

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 almost 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 rod 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 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 plastic bottles. The content of one bottle was then added to each of the three holes in each of 10 poles. The holes in 10 additional poles each 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 damaging 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). 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 Super-Fume tube system using these same procedures. The newer tubes were constructed of perforated degradable plastic which should break down over time so removal will not be required before re-treating the poles.

MITC distribution was assessed 1, 2, 3, 5 and 7 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 outer 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 (Figure I-1). Any fungal growth was examined for characteristics typical of basidiomycetes, a class of fungi containing many important wood decay fungi.

MITC levels between 150 mm below groundline (GL) and up to 450 mm above in poles receiv-

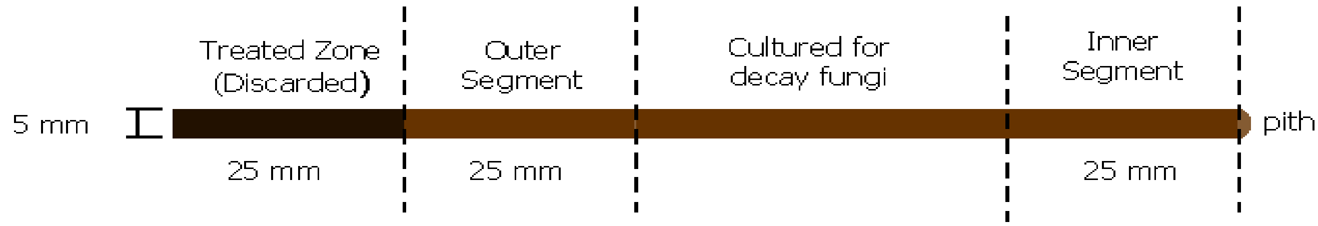


Figure I-1. Representation of increment core showing inner and outer 25 mm segments analyzed for fumigant content. The length of the segment cultured for decay fungi varies in length depending on the size of the pole.

ing granular dazomet alone or with copper naphthenate were above the threshold one year after treatment except at the outer zone at the groundline (Table I-3a and b, Figures I-2 and I-3). MITC levels were also above the threshold in poles receiving dazomet with copper naphthenate in the inner zones 600 and 900 mm above groundline. These results indicated that the dazomet rapidly decomposed to release MITC. MITC levels 150 mm below to 450 mm above groundline in these poles have remained above the threshold for 7 years. MITC levels were highest just below groundline and remain 2 to over 25 times the 20 ug/g of wood threshold. MITC levels at 600 and 900 mm above groundline are above the threshold in both the inner and outer zone at 7 years but were more variable near the pole surface. These results are typical of dazomet performance over time.

MITC levels 150 mm below GL to 300 mm above GL in poles treated with dazomet applied in paper tubes along with copper naphthenate tended to be similar to those found in poles treated with the granular formulation. MITC levels in poles receiving dazomet in tubes without copper naphthenate were also generally above the threshold except in most outer zones 1 year after treatment. The results suggest that the presence of the cardboard tube had little to no effect on dazomet decomposition to release MITC.

The dazomet in plastic tube treatments were installed approximately one year after the granular and paper tube treatments. MITC levels in these poles have tended to be slightly lower than those found with the other treatments (Figure I-4). The plastic tubes, which contained much smaller doses of dazomet, were also exposed to slightly different rainfall regimes than the other two application methods. It is possible that the plastic limited dazomet decomposition but it is more likely that the lower dose and environmental conditions explain the reduced MITC levels in these poles.

The results are consistent with our previous dazomet trials and suggest that tubes might be an alternative method for applying the granular system. These tests will next be sampled in 2016 at the 10 year point.

4. MITC Levels in Douglas-fir Poles in a Coastal Environment 6 years After Application of Dazomet

Although we have been investigating the performance of dazomet in poles in drier climates for 3 years and have over 15 years of data investigating performance in moist climates, we have relatively little data on the performance of this fumigant in coastal climates.

Table I-3a. MITC levels in Douglas-fir poles 1 to 7 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)	Supple-ment	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)
			7	**525** (1490)	**60** (78)	**50** (57)	**39** (41)	**43** (28)	**38** (22)
		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)
			7	**482** (1377)	**102** (139)	**331** (648)	**75** (96)	**73** (62)	**42** (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)
			7	**1180** (2740)	**97** (105)	**321** (437)	**83** (75)	**56** (35)	**37** (20)
		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)
			7	**101** (141)	**50** (70)	**308** (556)	**72** (66)	**39** (37)	**41** (21)
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)
			6	**69** (60)	**41** (44)	**92** (114)	**31** (25)	**35** (20)	**26** (22)
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)
			7	1 (1)	2 (6)	0 (0)	1 (1)	0 (1)	0 (1)

Numbers in bold are above the toxic threshold of 20 ug/g of wood. Numbers in parentheses represent one standard deviation from the mean of 15 measurements.

Recent reports from cooperators and utility personnel suggested that residual dazomet remained in treatment holes at the end of a normal 10 year maintenance cycle and there were questions about whether to remove this material to apply new chemical, to add new copper naphthenate accelerant or to leave the hole alone and drill new treatment holes. In 2010, we examined residual dazomet removed from treatment holes in poles in Oregon and Arizona. These analyses suggested that color was a good indicator of dazomet condition, with yellower colors indicating more complete breakdown and decreased effectiveness. There is some debate about whether the

Table I-3b. MITC levels in Douglas-fir poles 1 to 7 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)	Supple-ment	Years after treatment	Residual MITC (ug/g of wood)[a]					
				450 mm		600 mm		900 mm	
				Inner	Outer	Inner	Outer	Inner	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)
			7	**52** (38)	**58** (56)	**74** (87)	**122** (142)	**171** (334)	**81** (88)
		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)
			7	**43** (17)	**41** (30)	**35** (30)	**60** (61)	**34** (50)	**79** (109)
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)
			7	**32** (18)	**26** (16)	**32** (42)	**68** (112)	**28** (50)	**52** (94)
		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)
			7	**30** (13)	**36** (15)	**46** (49)	**109** (98)	**51** (44)	**135** (142)
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)
			6	**26** (13)	**23** (23)	**27** (18)	**39** (59)	**28** (45)	**28** (37)
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)
			7	0 (1)	0 (1)	0 (1)	0 0	0 0	0 (1)

Numbers in bold are above the toxic threshold of 20 ug/g of wood. Numbers in parentheses represent one standard deviation from the mean of 15 measurements.

residual is a mixture of dazomet and other materials or some degree of decomposed dazomet. Regardless we now use this simple color change as a rough indicator of dazomet condition. We have recently had inquiries concerning dazomet decomposition in a very wet climate along the southern Oregon coast and report here our preliminary findings.

Nine distribution poles located near Brookings, Oregon were inspected. These poles had received dazomet six years earlier, applied to three steeply angled holes beginning at groundline and moving upward approximately 300 mm and around the pole 120 degrees. Plugs were re-

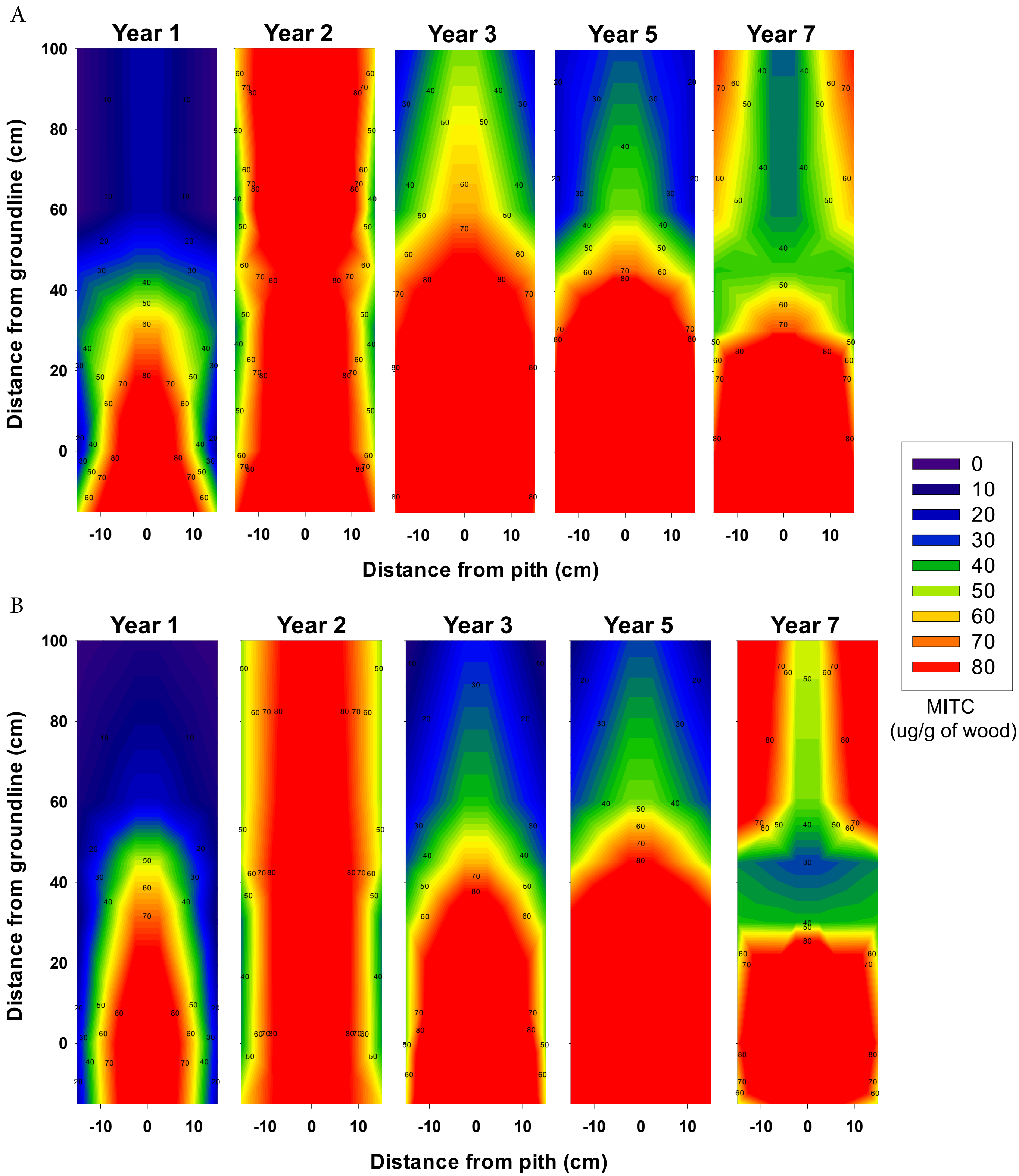


Figure I-2. Maps showing relative levels of MITC in Douglas-fir poles 1 to 7 years after treatment with A. granular dazomet alone or B. the same system in paper tubes.

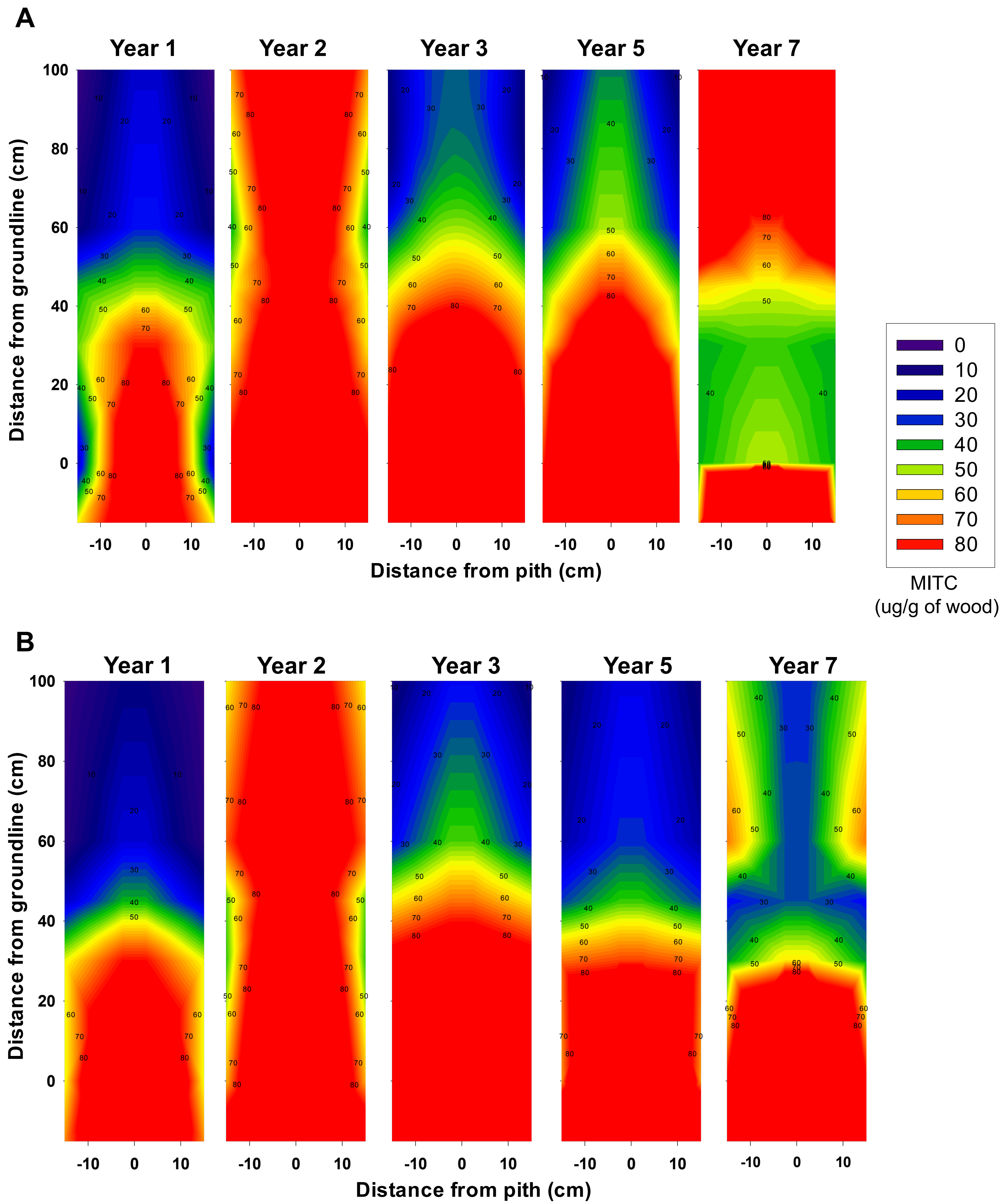


Figure I-2. Maps showing the effects of copper naphthenate addition on relative levels of MITC in Douglas-fir poles 1 to 7 years after treatment with A. granular dazomet alone or B. the same system in paper tubes.

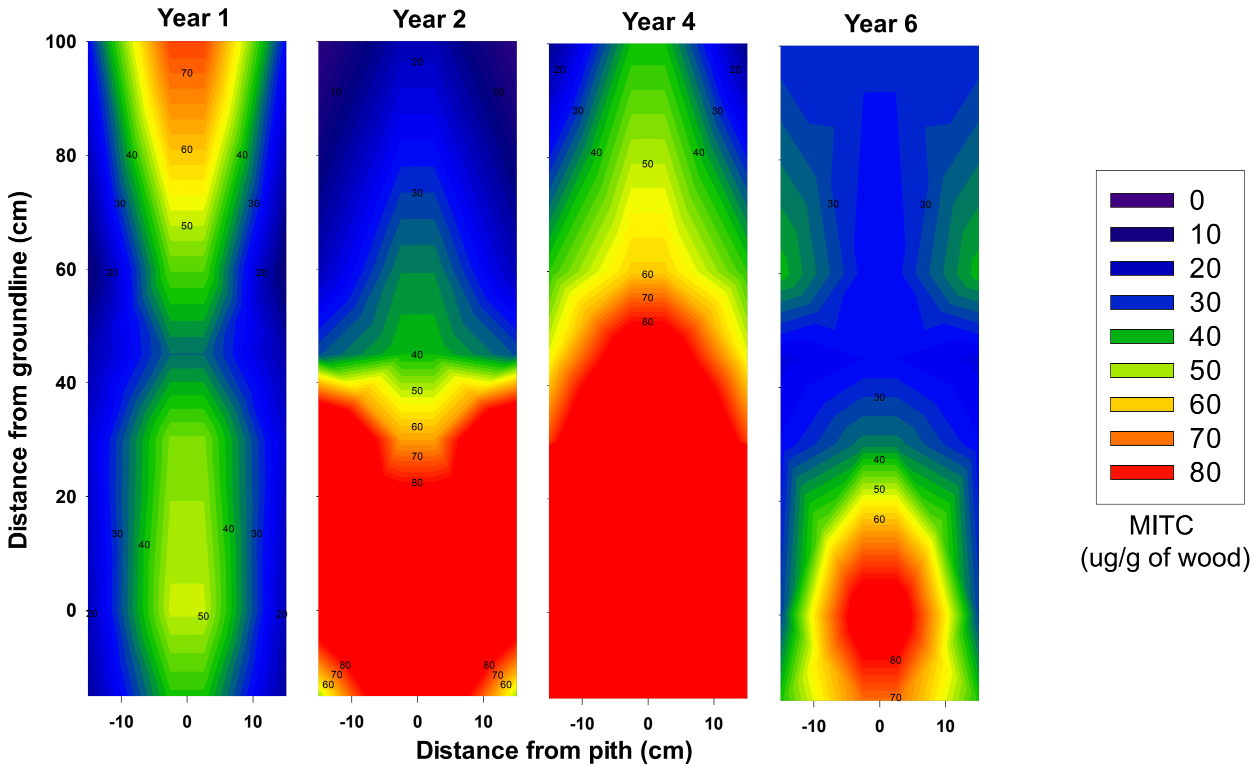


Figure I-4. Maps showing relative levels of MITC in Douglas-fir poles 1 to 6 years after treatment with granular dazomet in plastic tubes.

moved from the fumigant-treatment holes and the holes were probed with a metal shim to determine the relative depth of residual dazomet. A small amount of the material in each treatment hole was removed with a stainless steel spatula and placed in a Teflon cap-sealed borosilicate vial. These samples will be examined for the degree of dazomet decomposition at a later date.

In general, the condition of the dazomet in many treatment holes could be described as a 40-50 mm long plug of nearly solidified dazomet-containing copper naphthenate on top of crystalline dazomet. However, this was not always the case. Many treatment holes at groundline were free of residual dazomet. In one instance, dazomet was virtually absent from holes in one pole and completely filled the holes in another pole located 6 m away. Holes in poles immediately adjacent to Brookings Harbor tended to have little residual chemical near groundline, reflecting the wetter conditions nearest the coast.

In addition to examining the condition of residual dazomet in treatment holes, increment cores were removed from each pole at groundline and 300 mm and 600-900 mm above groundline. The outer and inner 25 mm of each core was removed and placed, individually, into 5 ml of ethyl acetate in a Teflon cap-sealed glass vial. The cores were extracted for 48 hours at room temperature, then the core was removed, oven dried and weighed. A subsample of the ethyl acetate was analyzed for methylisothiocyanate (MITC) using a Shimadzu Gas Chromatograph equipped with a flame photometric detector with filters specific for sulfur. The levels of MITC were quantified by comparison with GC analyses of standard solutions. A target MITC level of 20 ug/g of wood was used as the fungicidal threshold.

After the fumigant samples were removed from each core and placed into ethyl acetate, the remainder of each core was processed for cultural analysis. Each core segment was placed into a plastic drinking straw; the straw was stapled shut and then the cores were returned to the lab. Once there, each core segment was removed, flamed briefly to kill contaminants on the wood surface and then placed on 1.5% malt extract agar in plastic petri dishes. The plates were observed for evidence of fungal growth over a 30 day period and any growth was examined for characteristics typical of basidiomycetes, a class of fungi containing many important wood decayers. This analysis is still underway, but will provide an additional measure of MITC effectiveness.

MITC was detected in all nine poles, although the levels varied widely from a low of 3.8 ug to a high of 839 ug per g of wood (Table 1-4). MITC levels were above the threshold in 35 of 48 samples and were within 4 ug of the threshold in five others. MITC levels tended to be highest at groundline and 300 mm above groundline, which corresponds to the original treatment zone. MITC levels tended to be higher in the inner zone of the poles reflecting the tendency for the treatment to move toward the bottom of the treatment holes and the pole center. MITC levels in one pole (F4387) were much lower than those found in the other eight poles sampled.

Table I-4. MITC levels in increment cores removed from selected locations on Douglas-fir poles in the Coos-Curry Electric system 6 years after treatment with dazomet.

Pole #	MITC Content (ug/oven dry g wood)[a]					
	Groundline		300 mm		600 mm	
	inner	outer	inner	outer	inner	outer
2678	-	-	**210**	**60.6**	**87**	22.9
7841	**44.6**	11	**37.4**	**22.8**	**84.6**	5.4
8902	**602.8**	**57.5**	**839.5**	13.6	**25.9**	**269.1**
C3182	**486.2**	**148**	**186.9**	**105.6**	**131.8**	**31.9**
F0258	**65.8**	**88.5**	**80.6**	18.1	**83.3**	15
F0261	**69.3**	**20.8**	**102.5**	17.9	**56.2**	**23.8**
F4382	**106.2**	**48.8**	**71.8**	16.5	**60.3**	8.1
F4387	7.3	18.8	18.5	3.8	**34.5**	5.5
R96	**141.6**	**75.4**	-	-	-	-

aValues in bold are above the 20 ug/g of wood threshold for fungal protection.

The results indicate that MITC is present at effective levels in the original treatment zone of distribution poles sampled along the southern Oregon coast 6 years after treatment, although the dazomet has presumably decomposed. Although residual dazomet provides a reservoir for continued decomposition it also poses a challenge when re-treating since the inspector must decide if the remaining material is still active or merely decomposed material. Residual dazomet color does appear to be a useful indicator of the remaining effectiveness with more yellow residues indicative of less residual dazomet.

5. Effect of MITC-FUME Application Temperature on Distribution of MITC in Douglas-fir Pole Sections

MITC-FUME is a crystalline solid at room temperature but becomes molten as temperatures exceed approximately 31 C. The application recommendations for this system in hotter climates suggest that MITC-FUME application tubes be kept on ice in a cooler prior to application, primarily to reduce the risk of spills and worker contact, but also to limit the potential for the molten MITC-FUME to pour out of the tube as it is applied to the wood. As we have discovered over the past few years, most recommendations for fumigant treatment were developed based upon tests in cooler, wetter climates and there are few data on the effects of recommended practices on performance under warmer conditions. In this report, we examined the effects of temperature at the time of application on subsequent distribution of MITC in Douglas-fir pole stubs.

Douglas-fir pole sections (200-250 mm diameter by 600 mm long) were kiln-dried to a target moisture content of 12% then end-coated with a single layer of latex paint to minimize moisture movement. The goal was to produce poles with moisture contents similar to those present in a drier climate. A single hole was drilled at a steep sloping angle starting approximately 200 mm from the top (Figure I-5). The poles were then placed in the kiln and maintained at 40 C for 7 days, to simulate a pole to be fumigant-treated in a hot, dry climate. Tubes of MITC-FUME that had either been stored on ice (5 C) or maintained in a water bath at 40 C, were uncapped and placed in each hole, open side down. The tubes had been weighed prior to application to track MITC-FUME loss. The holes were quickly plugged with removable plastic plugs and the poles were left in the kiln for an additional 5 days without heating before being moved to a room maintained at 32 C and 30% relatively humidity. Six poles were treated with heated MITC-FUME and six with cooled material.

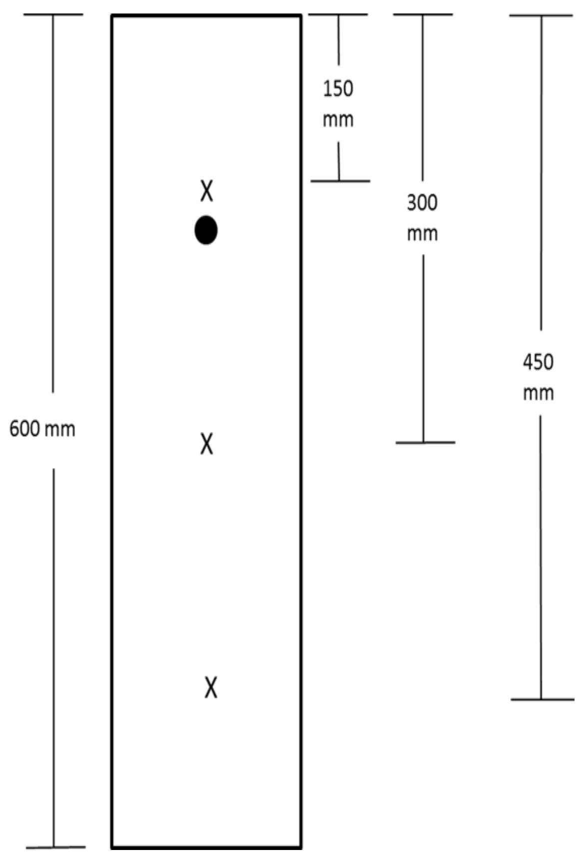


Figure I-5. Locations of the treatment hole (circle) and increment core sampling sites (X) on Douglas-fir pole sections receiving either solid or molten MITC-FUME.

The tubes were removed from the poles after 4 weeks and weighed to determine MITC-FUME loss. Only six of the tubes could be removed, two from the 40 C tubes and four from the 5 C tubes. All tubes were empty after 28 days, indicating that the chemical had rapidly moved out of the tubes, regardless of the initial application temperature. Rapid movement from the tubes is consistent with MITC-FUME behavior in earlier tests where tubes in poles stored at 32 C rapidly lost chemical (Figure I-6).

MITC levels in the poles were assessed 4 and 12 weeks after application by removing increment cores from sites located 150 mm, 300 and 450 mm from the top of the pole sections (Figure I-5). The cores were divided into thirds (outer, middle and inner) and each core segment was placed into 5 ml of ethyl acetate and extracted for a minimum of 48 hours. The resulting extract was analyzed by gas chromatography for MITC content. Each core was oven dried and weighed so that MITC content could be expressed on an oven dry basis of wood.

MITC levels in the poles were extremely high, reflecting the rapid movement of chemical from the tubes and there were tremendous variations in levels by position (Table I-5). There was a consistent gradient in MITC levels from the outer to inner core segments which is consistent with previous tests and reflects the tendency of the steeply sloping hole to direct chemical downward toward the pole center. This effect might be expected to be greater on poles receiving molten MITC-FUME, but the trend was observed on both treatments.

The concern with application of molten MITC-FUME was that chemical would be lost from the poles; however, MITC levels in poles receiving molten MITC-FUME were consistently higher than those found in poles receiving the cooled material and these differences were present at both sampling times. The only time when MITC levels in poles receiving solid MITC-FUME were higher was at 12 weeks in the inner zone 300 mm from the pole top. It is unclear why MITC levels would be higher with molten MITC-FUME since all of the MITC-FUME had moved out of the tubes in both treatments and should have been in the wood. MITC has a strong affinity for wood and should be rapidly sorbed as it exits the tube. The molten MITC-FUME would have been rapidly absorbed by the wood to some extent and would then volatilize to begin diffusing through the pole section. The material applied at 5 C would have done much the same once the warm wood surrounding the tube heated the MITC-FUME above 31 C. Aluminum is an excellent conductor and the tubes should have warmed rapidly, creating only a small time difference between the two treatments in terms of when molten MITC-FUME would have moved out of the tubes. The results suggest that the more rapid movement associated with molten MITC-FUME produced better MITC distribution.

At the very least, the results indicate that application of MITC-FUME to poles at elevated temperatures is not detrimental to subsequent MITC movement. We have retained these pole sections and will sample them again to determine if the two application methods have an effect on longer term MITC distribution.

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 associated with these chemicals. Water diffusible preservatives such as boron and fluoride have been developed as potentially less toxic alternatives to fumigants (Table I-6).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; Dickinson 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).

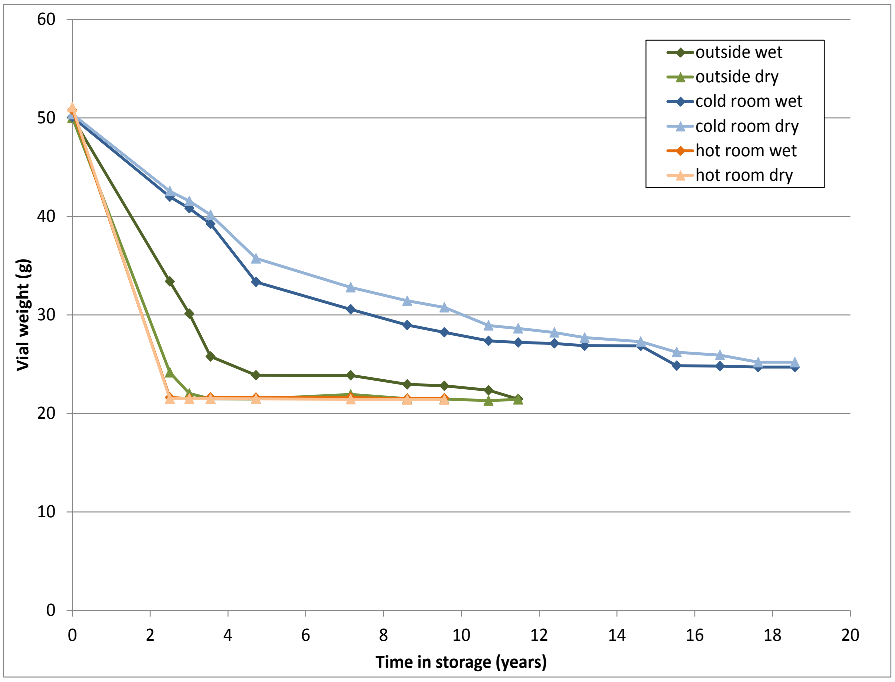


Figure I-6. MITC content in MITC-FUME tubes in poles stored outside, at 32 C and at 5 C

Table I-5. Effect of MITC-FUME state (molten or solid) on subsequent MITC levels in Douglas-fir pole sections 4 or 12 weeks after treatment.

Distance From Top (mm)	Segment	Weeks	Vial Storage Condition	
			40 C	5 C
150	inner	4	1116.2 (669.3)	747.4 (569.3)
		12	785.6 (421.8)	557.9 (278.1)
	middle	4	790.3 (428.1)	465.1 (345.7)
		12	540.8 (192.1)	346.9 (184.6)
	outer	4	251.5 (90.1)	140.2 (116.3)
		12	233.6 (75.6)	107.3 (56.6)
300	inner	4	1165.8 (344.7)	927.0 (830.9)
		12	766.4 (604.8)	1270.6 (953.1)
	middle	4	929.7 (250.9)	392.2 (211.1)
		12	705.6 (173.8)	506.6 (370.9)
	outer	4	398.1 (117.7)	148.7 (125.1)
		12	308.8 (92.2)	137.7 (95.3)
450	inner	4	633.1 (289.3)	171.0 (148.7)
		12	683.6 (65.1)	389.1 (300.0)
	middle	4	456.4 (193.7)	159.6 (107.0)
		12	615.2 (452.9)	287.3 (362.2)
	outer	4	169.9 (83.2)	37.4 (32.2)
		12	127.9 (42.0)	51.9 (41.4)

Numbers in parentheses represent one standard deviation from the mean of 15 measurements.

Table I-6 Characteristics of diffusible internal remedial treatments for wood poles.

Trade Name	Active Ingredient	Conc. (%)	Toxicity (LD_{50})	Manufacturer
Impel Rods Bor8-Rods	boron	96-100	>2000 mg/kg	Pole Care Inc. Wood Care Systems
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	95.3/2.9	10000 mg/kg oral 5000 mg/kg dermal	Genics Inc.

This chemical has also been widely used 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 popular are fused borate rods which come as pure boron or as 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 based attachments. Sodium fluoride is also formed into rods for application, although fluoride rods are less dense than boron rods, which limits the amount of chemical that can be applied to a treatment hole.

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 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, 9 and 11 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 A65, the Azomethine-H assay (AWPA, 2012). 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-7, I-8). This test was initiated at the start of our rainy season. Previous tests show the moisture contents in poles at this site are well above levels required for boron diffusion over the winter. 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 pole to be wetter in these regions. Moisture is 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, and the limited ability of boron to diffuse upwards.

Boron levels in poles sampled 9 years after treatment rose sharply at a number of locations in the pole. 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 had largely disintegrated.

Boron levels in the poles 11 years after treatment were above the threshold at groundline and 150 mm below that level in the inner zones for poles treated with the boron alone and the boron

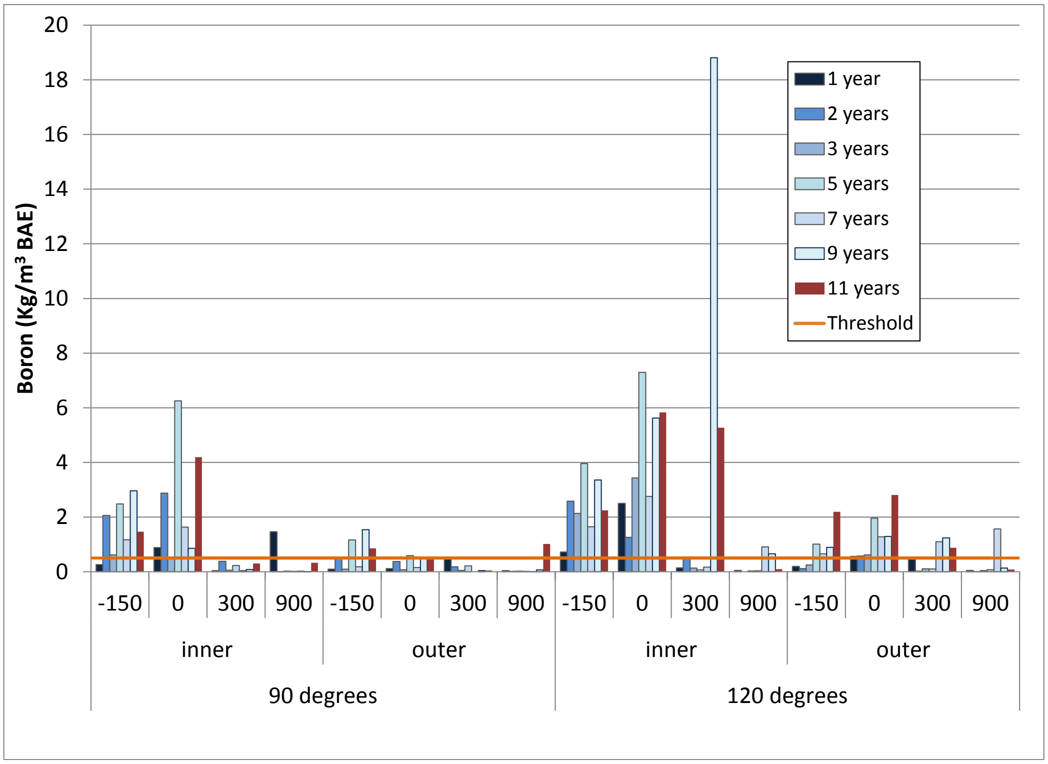


Figure I-7. Boron levels at selected locations above or below groundline in Douglas-fir poles one to 11 years after treatment with 4 boron/copper rods.

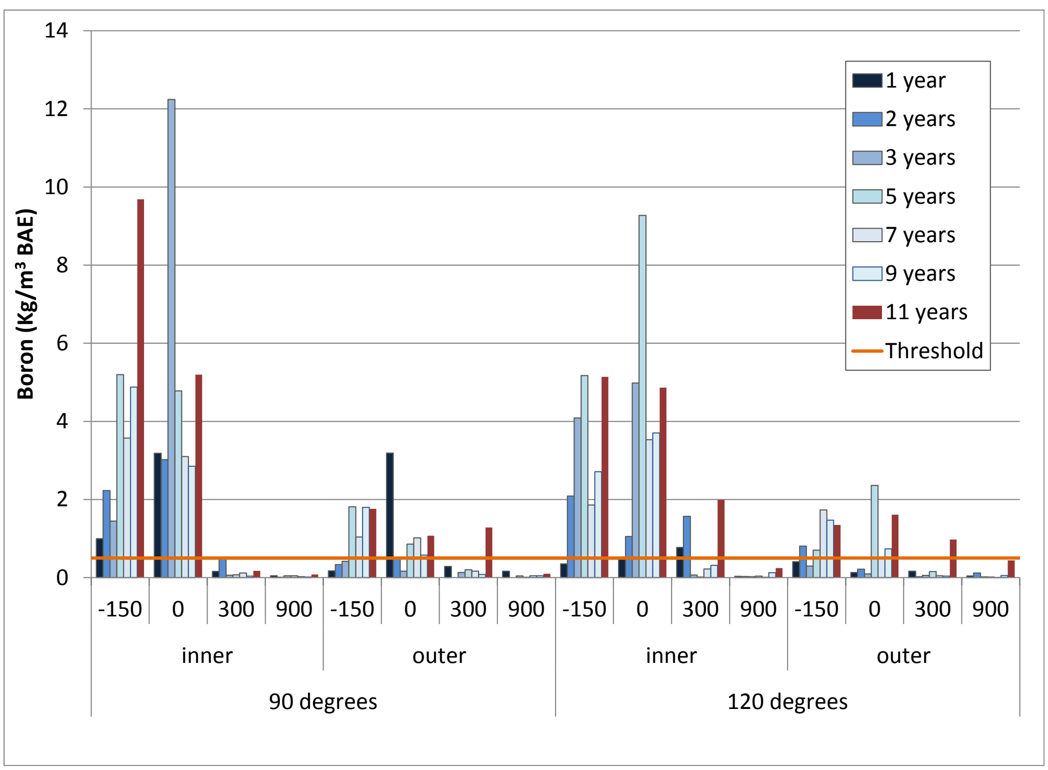


Figure I-8. Boron levels at selected locations above or below groundline in Douglas-fir poles one to 11 years after treatment with 4 boron rods. The elevated values at 300 mm in the inner zone of poles treated using a 120 degree spacing likely reflect one very high value from a sample removed immediately adjacent to the original treatment hole.

plus copper rods. There appeared to be no consistent differences in boron levels between the two systems. Boron levels in the outer zones tended to be more variable, although they were over the threshold in some instances. As with all internally applied remedial treatments, the sloping application holes and the area occupied by the plug would tend to enhance chemical movement toward the pole center.

Fused borate and fused borate plus copper rods appeared to be equally effective at establishing threshold levels of boron 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 and the increases were not proportional to the increased chemical applied (Figure I-9). Boron levels appeared to be slightly more stable over time but those 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 outer zones for poles receiving the higher dosage, these differences were slight and probably not meaningful in terms of wood protection. As noted above, the sloping holes will tend to move chemical inward, but the higher dosages have the potential to place the rods immediately adjacent to wood in the outer zone and this should result in higher boron levels. It is unclear why this did not occur although it could reflect varying moisture regimes closer to the surface that would be less suited for boron diffusion.

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 years 9 and 11 in several locations. As with the boron data, this may reflect the wetter conditions at the test site (Figure

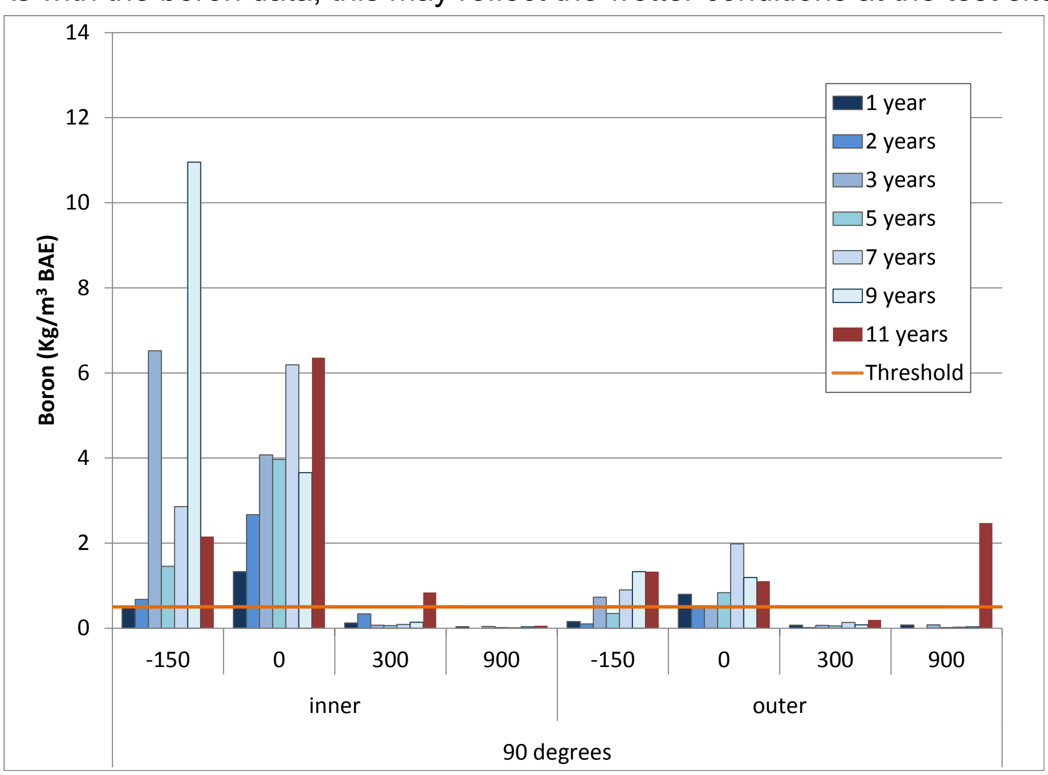
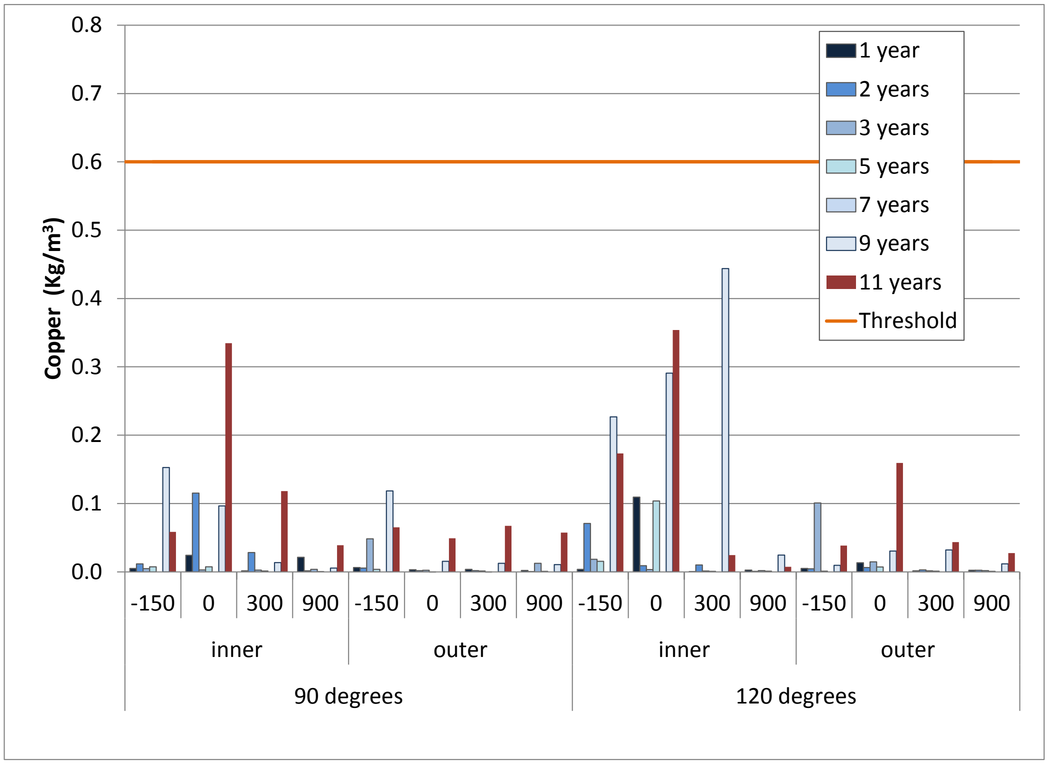


Figure I-9. Boron levels at selected locations above or below groundline in Douglas-fir poles one to 11 years after treatment with 8 boron/copper rods.

A



B

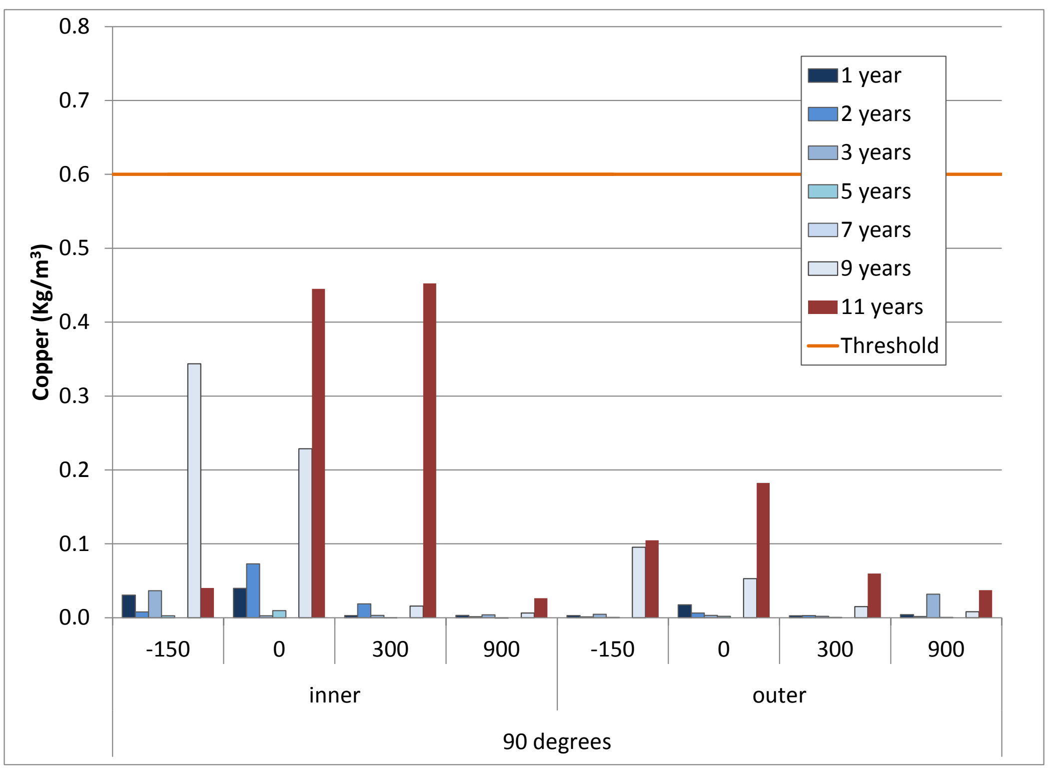


Figure I-10. Copper levels at selected locations above or below groundline in Douglas-fir poles one to 11 years after treatment with A. 4 or B. 8 boron/copper rods. Note: The values for the inner zones on the 120 degree pattern at year 9 differ from those in the 2011 Annual Report- the numbers were reversed in that report and are corrected here.

I-10). While copper levels have increased, they are still well below those required to provide any substantive wood protection. We have established a number of tests of blocks containing diffusible treatments, but have had difficulty establishing threshold levels for copper plus boron. We will continue to work to better understand the nature, if any, of interactions between copper and boron in this treatment.

Culturing of increment cores revealed the presence of some decay fungi in the poles, especially at groundline (Table I-7). 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 consistent 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 have provided similar protection over the 11 year test.

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

Date Established:	May 1993
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @ GL (avg., max., min.)	101, 114, 89 cm

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 19 mm diameter by 200 mm long holes were drilled perpendicular to the grain beginning at groundline and moving around the pole 120 degrees and upward 15 cm. 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, 15 and 20 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 combined according to treatment and height, then ground to pass a 20 mesh screen, 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.

Non-treated control poles naturally contained low levels of background boron ranging from 0.01

Table I-7. Fungi (decay$^{non\text{-}decay}$) isolated from Douglas-fir poles 1 to 11 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}
		11	0 ^{27}	0 ^{10}	0 ^{11}	0 ^{0}
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}
		11	0 ^{6}	0 ^{0}	0 ^{0}	0 ^{0}
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}
		11	0 ^{0}	0 ^{8}	0 ^{8}	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}
		11	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{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}
		11	0 ^{12}	0 ^{0}	0 ^{0}	0 ^{0}

Table I-8. Boron levels in pole segments one to 20 years after treatment with fused boron rods.

Dosage (g)	Sampling Ht. (cm)	Core Section	Boron (kg/m³ BAE)[1]								
			Year 1	Year 3	Year 4	Year 5	Year 7	Year 10	Year 12	Year 15	Year 20
180	-15	inner	0.38	**1.81**	**2.39**	**1.85**	**1.54**	**2.16**	**3.33**	**0.50**	**0.59**
		outer	0.24	0.25	0.49	**1.14**	**0.70**	**1.32**	**0.94**	**0.62**	0.23
	7.5	inner	**2.82**	**3.75**	**6.02**	**6.40**	**2.05**	**2.83**	**4.65**	**1.25**	**0.52**
		outer	**0.65**	**1.10**	**1.16**	**2.32**	**3.38**	**1.84**	**2.28**	**0.82**	0.31
	22.5	inner	**0.89**	**3.16**	**2.09**	**2.82**	**1.47**	**0.81**	**0.52**	**0.86**	**1.15**
		outer	**0.98**	**0.58**	0.35	**1.10**	0.31	0.14	**1.70**	**0.96**	**0.67**
	45	inner	**0.54**	0.22	0.21	0.17	0.15	0.00	0.28	0.05	0.22
		outer	0.22	0.20	0.11	0.09	0.12	0.00	0.12	0.07	0.10
	60	inner	0.18	0.24	0.19	0.41	0.08	0.00	0.11	0.02	0.11
		outer	0.14	0.09	0.06	0.25	**1.80**	0.00	0.04	0.00	0.03
360	-15	inner	0.09	**0.76**	**0.62**	**0.60**	**1.00**	0.09	**1.94**	**2.29**	**2.09**
		outer	0.07	0.23	0.27	**3.00**	**1.42**	**3.94**	**0.82**	**1.62**	**0.88**
	7.5	inner	**0.96**	**10.88**	**7.27**	**12.01**	**3.28**	0.11	**2.77**	**1.56**	**3.43**
		outer	**0.59**	**0.61**	**1.33**	**3.93**	**0.85**	**0.89**	**1.39**	**3.01**	**1.51**
	22.5	inner	0.48	**3.21**	**1.35**	**7.30**	**0.95**	**2.27**	**0.81**	**5.23**	**3.28**
		outer	0.13	0.14	0.42	**4.34**	**0.77**	0.07	**3.30**	**2.57**	**1.17**
	45	inner	0.04	0.11	0.08	**1.24**	0.21	0.00	0.50	**1.20**	**0.99**
		outer	0.02	0.09	0.07	**0.83**	0.17	0.00	0.21	0.12	0.48
	60	inner	0.05	0.39	0.21	0.16	0.10	0.00	0.13	0.27	0.25
		outer	0.02	0.09	0.09	0.16	**1.02**	0.00	0.06	0.13	0.13
Control	-15	inner	0.02	0.09	0.02	0.05	0.06	0.00	0.01	0.00	0.00
		outer	0.02	0.09	0.02	0.07	0.06	0.00	0.00	0.00	0.05
	7.5	inner	0.02	0.06	0.06	0.03	0.05	0.00	0.02	0.00	0.03
		outer	0.02	0.07	0.02	0.02	0.05	0.00	0.02	0.00	0.04
	22.5	inner	0.01	0.08	0.02	0.05	0.05	0.00	0.05	0.00	0.16
		outer	0.01	0.07	0.02	0.03	0.04	0.00	0.01	0.00	0.07
	45	inner	0.03	0.06	0.02	0.03	0.03	0.00	0.04	0.00	0.04
		outer	0.02	0.10	0.02	0.02	0.03	0.00	0.06	0.00	0.03
	60	inner	0.02	0.08	0.02	0.27	0.08	0.00	0.06	0.01	0.07
		outer	0.01	0.09	0.03	0.11	0.04	0.00	0.02	0.02	0.01

Numbers in bold are above the fungitoxic threshold of 0.5 Kg/m³.

to 0.27 kg/m³ (Table I-8). These levels are well below the threshold for protection. Boron levels in the inner zones of poles treated with 180 g of boron rod were at or above the threshold 150 mm below ground as well as 75 and 225 mm above the groundline throughout the test (Figure I-11). Levels in these inner zones were still 0.5 to 1.15 kg/m³ 20 years after treatment. Boron is traditionally viewed as extremely water soluble and likely to rapidly diffuse from treated wood in soil contact; however, it is likely that the oil treated shell limited the ability of boron to diffuse outward. Boron levels 450 and 600 mm above groundline were much lower and generally below the

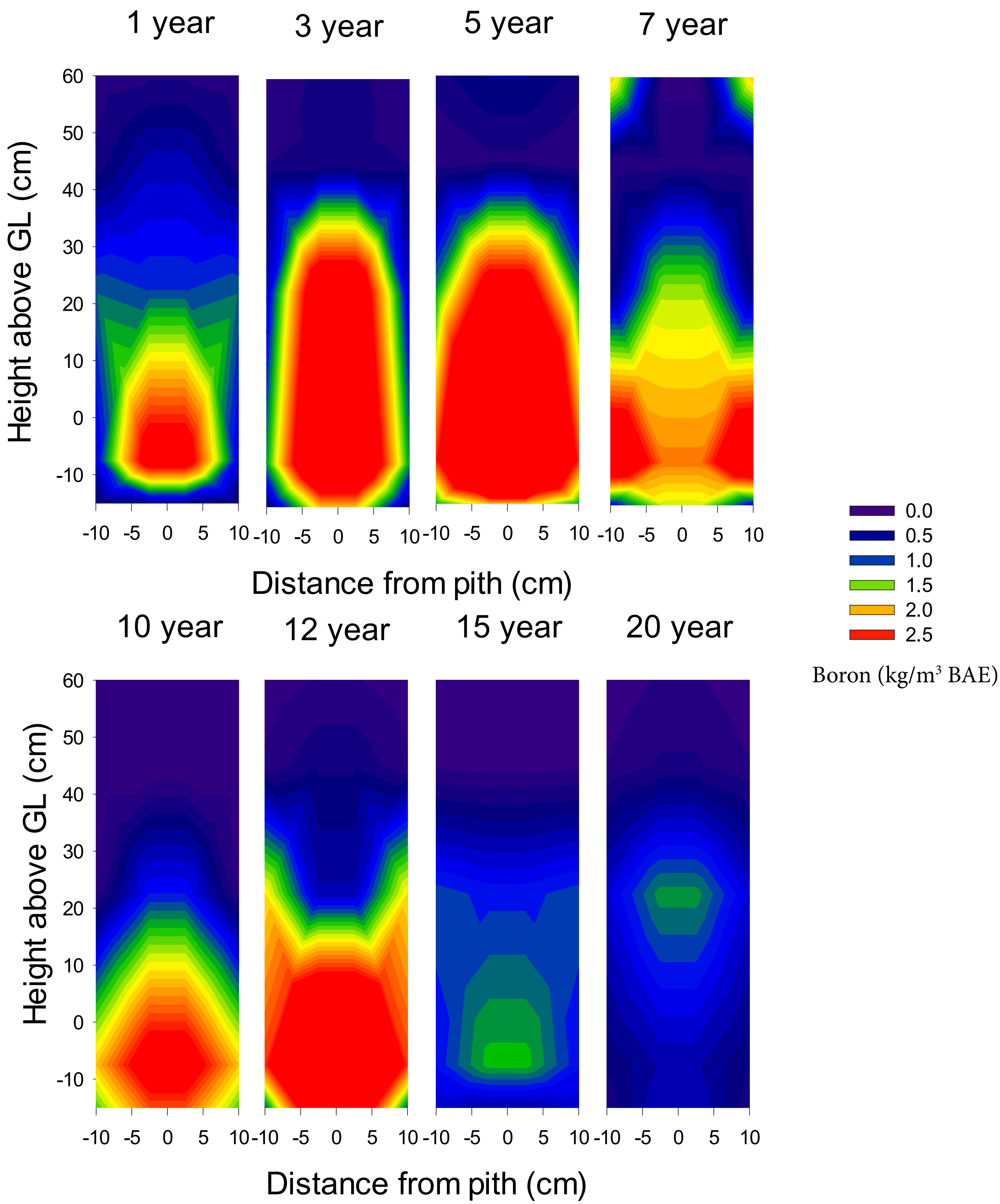


Figure I-11. Maps showing relative levels of boron in Douglas-fir poles 1 to 20 years after treatment with 180 g of fused borate rod.

protective threshold over the course of the test. These sampling sites were well above the original treatment zone. Given the limited ability of boron to move upward, it is not surprising to see low boron levels in these zones.

Boron levels in the outer zones tended to be more variable 150 mm below ground as well as 75 and 225 mm above ground. Despite this variability, boron levels were still above the threshold up to 225 mm above groundline 20 years after treatment.

Boron levels in poles treated with 360 g of boron rod followed similar trends to those for the 180 g treatment, although the levels of boron detected were sometimes much greater, particularly in the inner zone 75 mm above groundline (Figure I-12). This area corresponded to the center of the treated zone. We often observe the absence of a dosage effect with boron rods and have attributed this lack of effect to inadequate moisture in the wood; however, there did appear to be some difference in boron levels between the two dosages early in the test. This effect disappeared after five years but appeared again 15 and 20 years after treatment.

Fungal isolations were only performed in the later years of this test and the results varied widely among the poles and with distance from the groundline (Table I-9). Decay fungi were isolated from the groundline region in many poles 20 years after treatment even though the average boron levels in the inner zones of the cores were above the threshold. These results indicate that any protective effect associated with the boron has dissipated and that re-treatment is needed. The results indicate that boron continues to remain in the treated zone of the poles at levels capable of conferring protection against fungal attack 20 years after treatment, although the protected zone is likely too limited to provide protection to the entire pole.

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 ^{o} downward sloping angle in each pole, begin-

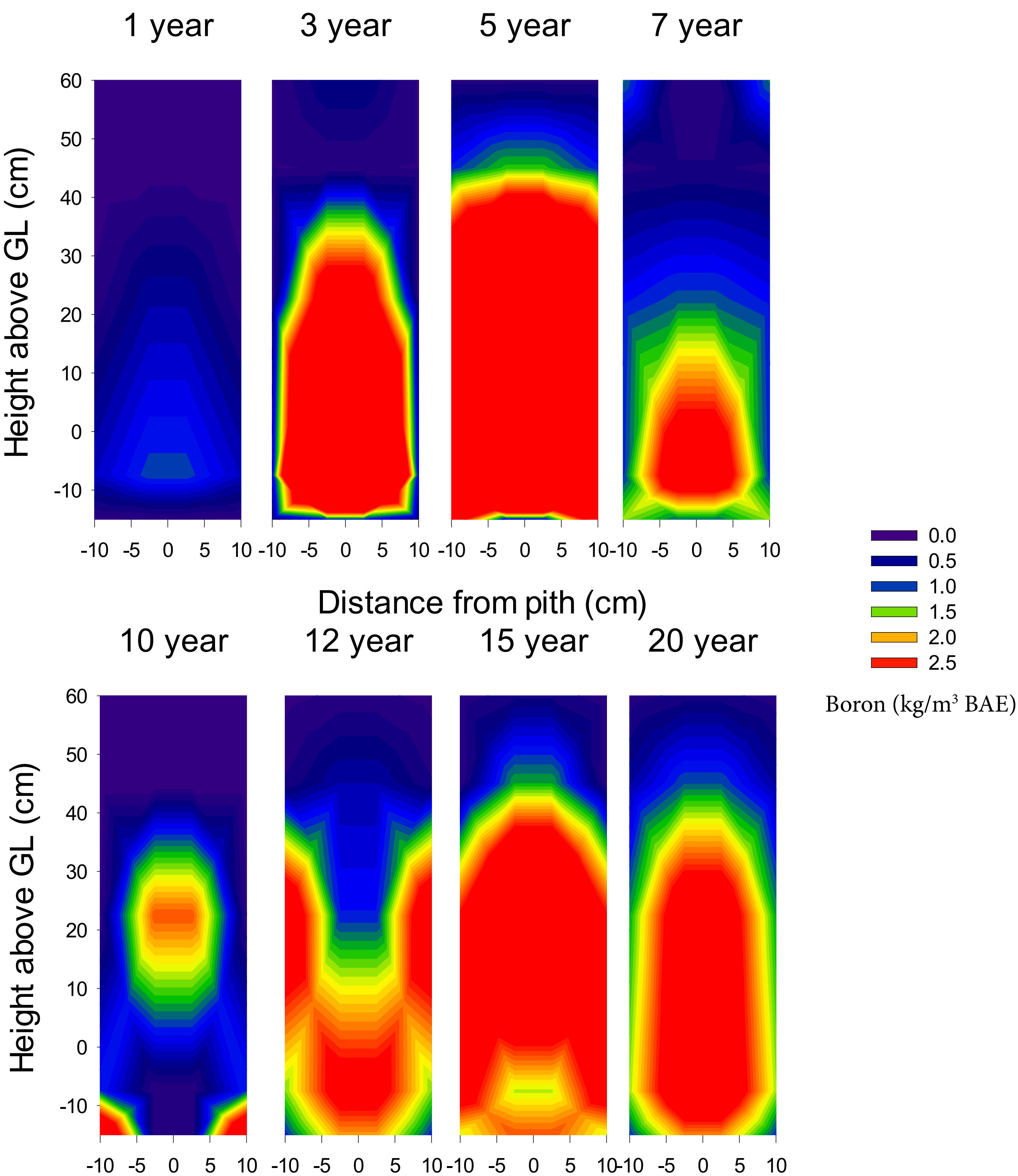


Figure I-12. Maps showing relative levels of boron in Douglas-fir poles 1 to 20 years after treatment with 360 g of fused borate rod.

Table I-9. Percentage of cores from poles 16 or 20 years after treatment with 180 or 360 g of fused borate rods from which decay fungi were isolated.

Dosage (g)	Years after treatment	Cores with decay fungi (%)				
		Height above groundline (cm)				
		-15	7.5	22.5	45	60
180	16	0	0	0	7	21
	20	3	0	0	11	19
360	16	3	0	3	15	19
	20	3	0	4	7	19

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

C. Tests Including Both Fumigants and Diffusibles.

1. 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-10).

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. The addition of copper naphthenate at concentrations higher than 1% is a violation of the product label and not allowed for commercial applications. 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, 42 and 54 months after treatment by removing increment cores from three equidistant sites beginning 150 mm below ground, then 0, 300, 450 and 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 appropriate 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.

Table I-10. 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	-	methylisothiocyanate	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

Chemical levels in most poles were elevated 18 months after treatment and then gradually declined 54 months after treatment (Table I-11). Fumigant levels tended to be highest toward the center of the poles at a given height, reflecting the tendency for the sloping holes to direct chemical toward the center. Chemical levels were also highest at or below groundline and then typically declined with distance upward. This is also consistent with the application of the chemicals near groundline. Based upon previous field and laboratory studies, we have used a level of 20 ug of active/oven dried g of wood as a protective threshold for fumigants. This level is based upon extensive chemical analysis of cores removed from poles coupled with culturing of adjacent wood for the presence of decay fungi. Although the properties of the two primary active ingredients in all currently registered fumigants differ dramatically, the threshold for both chloropicrin and methylisothiocyanate (MITC) is the same.

Wood samples removed from the sodium n-methyldithiocarbamate based (NaMDC) treatments (Pol-Fume, SMDC-Fume, and WoodFume) contained MITC levels that were 3 to 5 times the 20 ug of MITC/oven dried g of wood threshold 18 months after treatment. These levels then declined steadily over the next 24 months but were still over this threshold at most sampling locations 42 months after treatment. MITC levels have continued to decline and are all uniformly below the threshold level 54 months after treatment (Figure I-13). These findings are consistent with previous tests of this chemical. These formulations contain 32.1 % NaMDC in water. The NaMDC

Table I-11. Residual MITC levels in Douglas-fir poles 18-54 months after application of selected remedial treatments[1].

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)
		54	1 (1)	0 (1)	6 (13)	1 (2)	1 (1)	1 (1)
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)
		54	**102** (86)	**63** (45)	**472** (662)	**76** (74)	**123** (116)	**57** (36)
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)
		54	**233** (256)	**107** (104)	**413** (564)	**107** (95)	**201** (311)	**66** (50)
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)
		54	**116** (122)	**60** (59)	**134** (131)	**55** (32)	**158** (209)	**54** (44)
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)
		54	**612** (1472)	**155** (115)	**180** (123)	**150** (155)	**115** (83)	**78** (61)
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)
		54	14 (20)	8 (12)	18 (22)	11 (18)	8 (15)	3 (1)
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)
		54	11 (8)	6 (6)	11 (13)	4 (3)	10 (18)	5 (4)
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)
		54	**120** (211)	**63** (84)	**61** (44)	**36** (18)	**43** (20)	**42** (32)
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)
		54	**158** (116)	**131** (126)	**179** (81)	**97** (59)	**119** (89)	**113** (150)
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)
		54	16 (13)	6 (5)	15 (11)	5 (5)	9 (8)	8 (9)
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	**6488** (6654)	**2904** (3671)	**4606** (3245)	**1257** (2437)	**3438** (2753)	**4059** (5007)
		54	**2317** (1768)	**267** (413)	**1808** (1503)	**331** (375)	**1023** (1088)	**226** (295)

1. Numbers in parentheses represent one standard deviation around the mean of 15 replicates. Numbers in bold type are above the toxic threshold of 20 ug/g of wood.

Table I-11 continued. Residual MITC levels in Douglas-fir poles 18-54 months after application of selected remedial treatments[1].

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)
		54	3 (5)	2 (4)	1 (1)	1 (1)	1 (1)	0 (1)
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)
		54	**90** (70)	**49** (26)	**87** (67)	**51** (39)	**65** (48)	**42** (56)
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)
		54	**105** (96)	**59** (47)	**83** (58)	**80** (82)	**49** (39)	**89** (99)
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)
		54	**60** (32)	**67** (64)	**68** (54)	**64** (88)	**60** (53)	**68** (97)
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)
		54	**107** (70)	**77** (50)	**85** (41)	**68** (51)	**73** (50)	**98** (104)
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)
		54	3 (2)	3 (2)	3 (1)	4 (2)	8 (13)	4 (2)
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)
		54	4 (2)	4 (2)	5 (3)	3 (2)	9 (19)	3 (3)
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)
		54	**30** (12)	**26** (21)	**37** (29)	**40** (67)	**27** (31)	**33** (54)
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)
		54	**69** (36)	**211** (530)	**55** (24)	**52** (31)	**39** (19)	**30** (29)
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)
		54	6 (5)	8 (13)	5 (5)	4 (3)	6 (4)	4 (4)
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	**1546** (1472)	**1363** (1131)	**1720** (1489)	**678** (837)	**1639** (1990)	**310** (560)
		54	**867** (931)	**276** (376)	**984** (1040)	**381** (621)	**387** (509)	**604** (1219)

1. Numbers in parentheses represent one standard deviation around the mean of 15 replicates. Numbers in bold type are above the toxic threshold of 20 ug/g of wood.

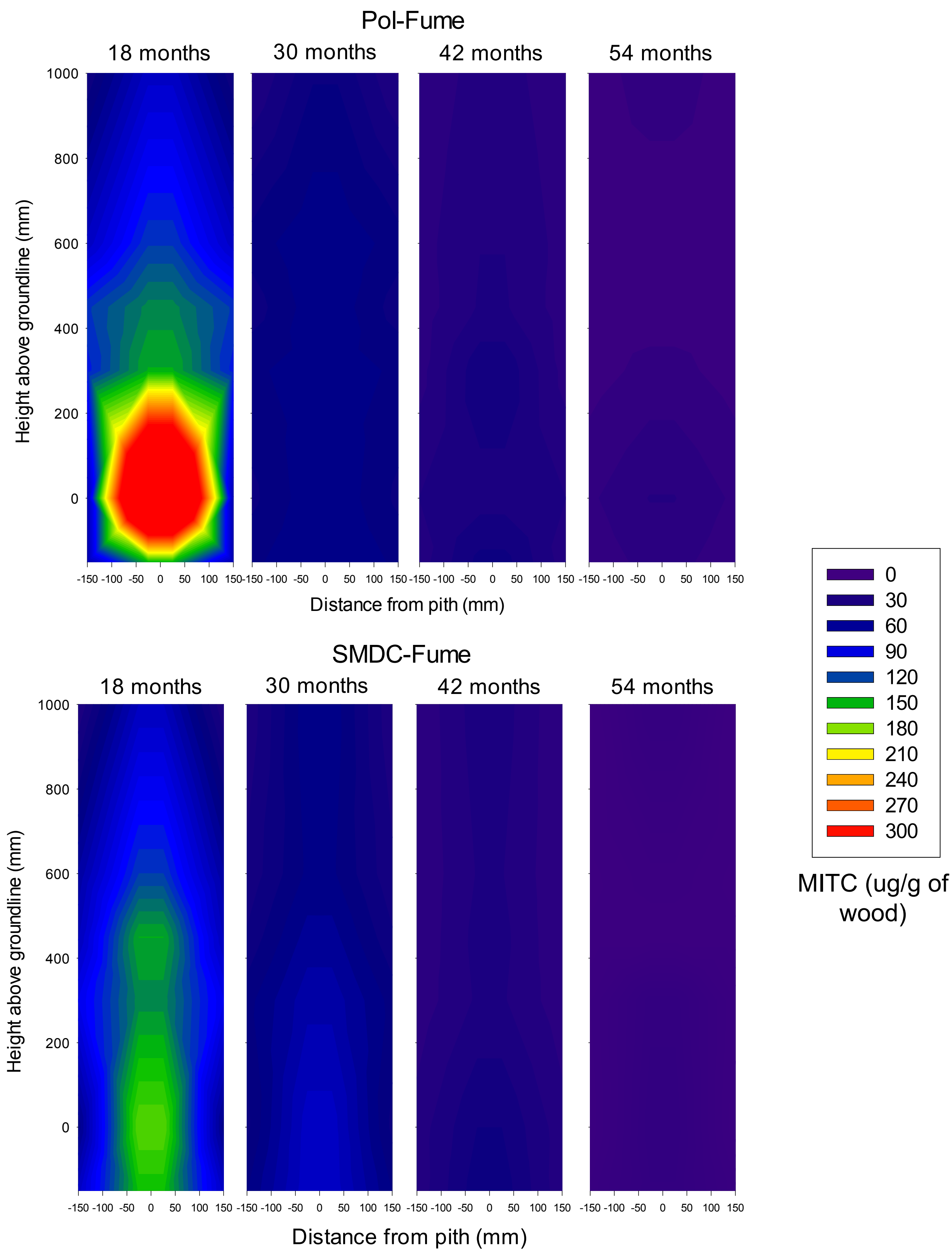


Figure I-13 Distribution of MITC in Douglas-fir poles sections 18 to 54 months after treatment with Pol-Fume, SMDC-Fume, or WoodFume.

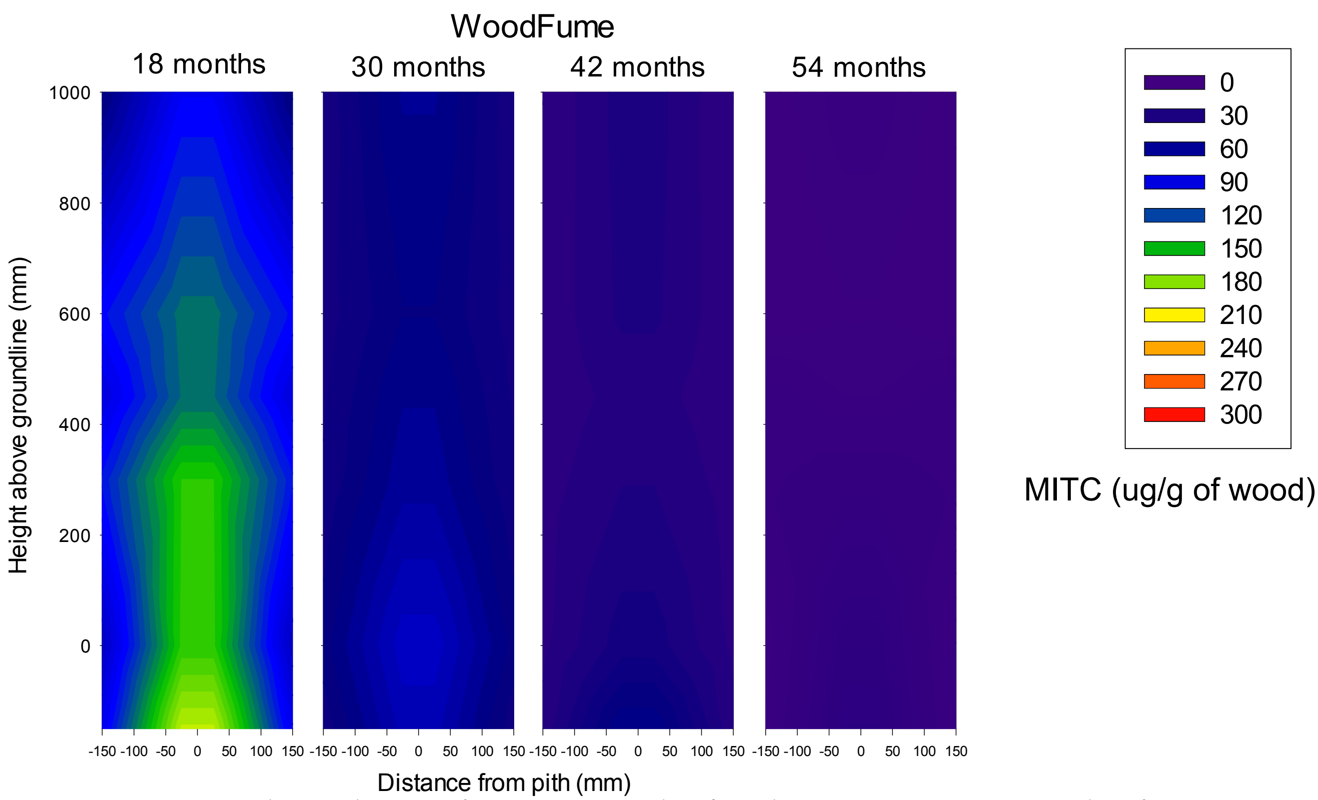


Figure I-13 continued Distribution of MITC in Douglas-fir poles sections 18 to 54 months after treatment with Pol-Fume, SMDC-Fume, or WoodFume.

decomposes in the presence of organic matter (like wood) to produce a range of sulfur containing compounds including carbon disulfide, carbonyl sulfide, and, most importantly, MITC.

The theoretical decomposition rate of NaMDC to MITC is 40% of the original 32.1%, but numerous tests suggest that the rate in wood is actually nearer to 20 % of the original treatment. As a result, NaMDC based treatments should produce much lower levels of chemical in the wood and their retention should be relatively short. Some users of these treatments have raised concerns about the potential for this shorter protective period to allow decay fungi to re-colonize the poles and cause renewed damage before the next treatment cycle (which should be 10 years). However, there is evidence that decay fungi do not re-colonize the poles very quickly and, in some cases, they never reach the levels at which they were present prior to treatment. For this reason, there is a substantial time lag between loss of chemical protection and re-colonization that permits the use of this treatment.

MITC-FUME treated poles contained the highest levels of MITC of any treatment 18 months after treatment, with levels approaching 100 times the threshold 150 mm below groundline and 300 mm above that line. MITC levels have declined steadily since that time, but are still well above the threshold for protection against fungal attack (Figure I-14). For example, MITC levels in the inner zones of cores removed 150 mm below groundline average 612 ug/g of wood, over 30 times the threshold. MITC levels at other locations are somewhat lower, but are still three to nine times the threshold. These results illustrate the excellent properties of this treatment and are consistent with the original field trials showing that protective levels remained in Douglas-fir poles 7 years after treatment. These results indicate that MITC-FUME would easily provide protection

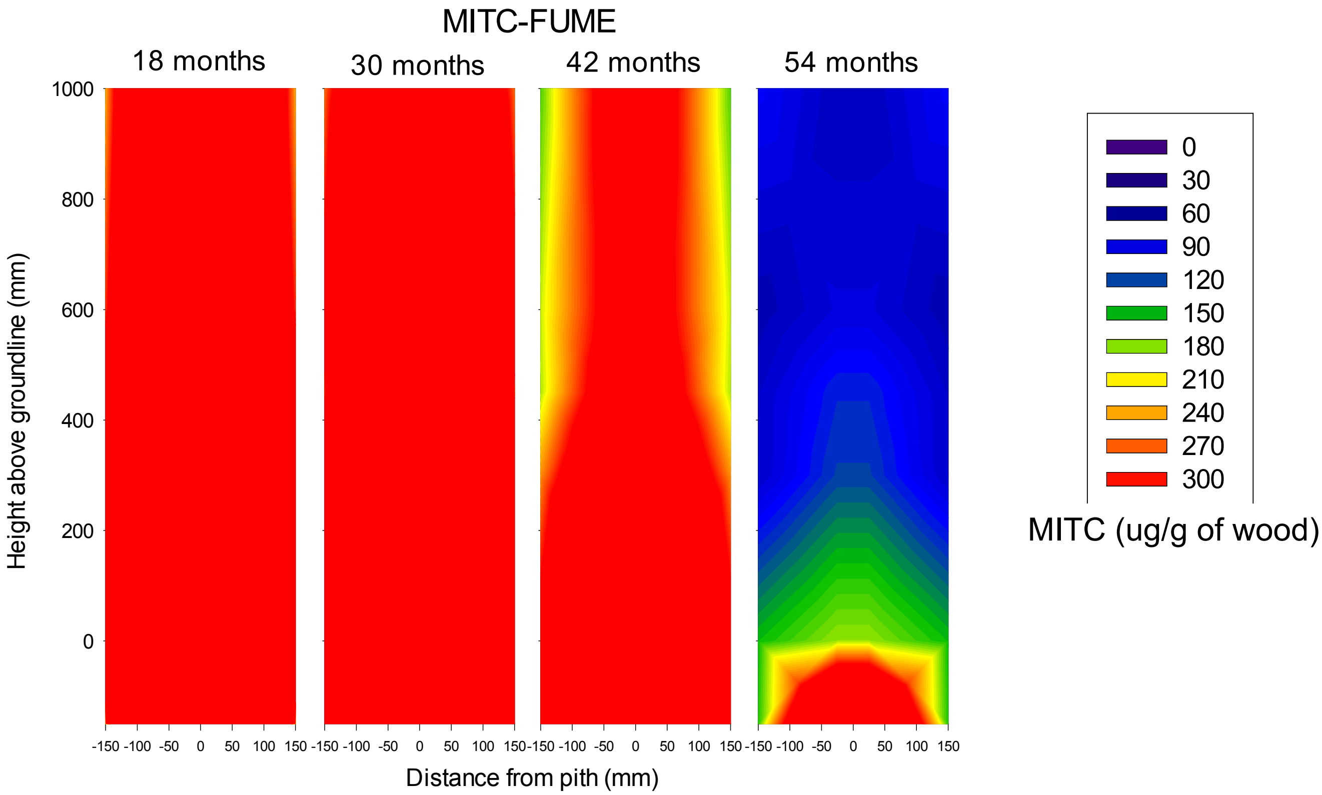


Figure I-14 Distribution of MITC in Douglas-fir poles sections 18 to 54 months after treatment with MITC-FUME.

against renewed fungal attack for 10 years.

Dazomet is an increasingly common remedial treatment for poles. Like NaMDC, dazomet decomposes to produce a range of sulfur containing compounds. The most important of these decomposition products is MITC. Unlike NaMDC, dazomet is a powder, which sharply reduces the risk of worker contact or spilling. Originally, dazomet decomposition in wood was viewed as too slow for this chemical to be of use as a remedial pole treatment, but extensive research indicated that the process could be accelerated by adding copper compounds to the powder at the time of application to accelerate decomposition to MITC. At present, dazomet is commonly applied with a small dosage of oilborne copper naphthenate.

Dazomet was applied to the test poles as a powder, in rod form or in tubes. All holes received copper naphthenate at the time of treatment to accelerate decomposition. MITC levels 150 mm below groundline in poles receiving dazomet powder (dazomet, DuraFume, or UltraFume) 18 months earlier ranged from 8-11 times the threshold in UltraFume treated poles to 7 to 16 times threshold in the dazomet treated poles. In general, MITC levels were well over the threshold in all dazomet treatments although the levels 900 mm above groundline were sometimes below that level. MITC levels were all above the threshold 30 and 42 months after treatment, reflecting the ability of this treatment to continue to decompose to produce MITC over time. MITC levels 54 months after treatment were still above the threshold at all sampling locations, but the overall levels had declined by 30 to 50% over the 12 month interval (Figure I-15). MITC levels after 54 months were still 3 to 11 times above the minimum threshold, and, as in previous trials, we have observed surges in MITC levels in dazomet-treated poles. We have attributed these increases to

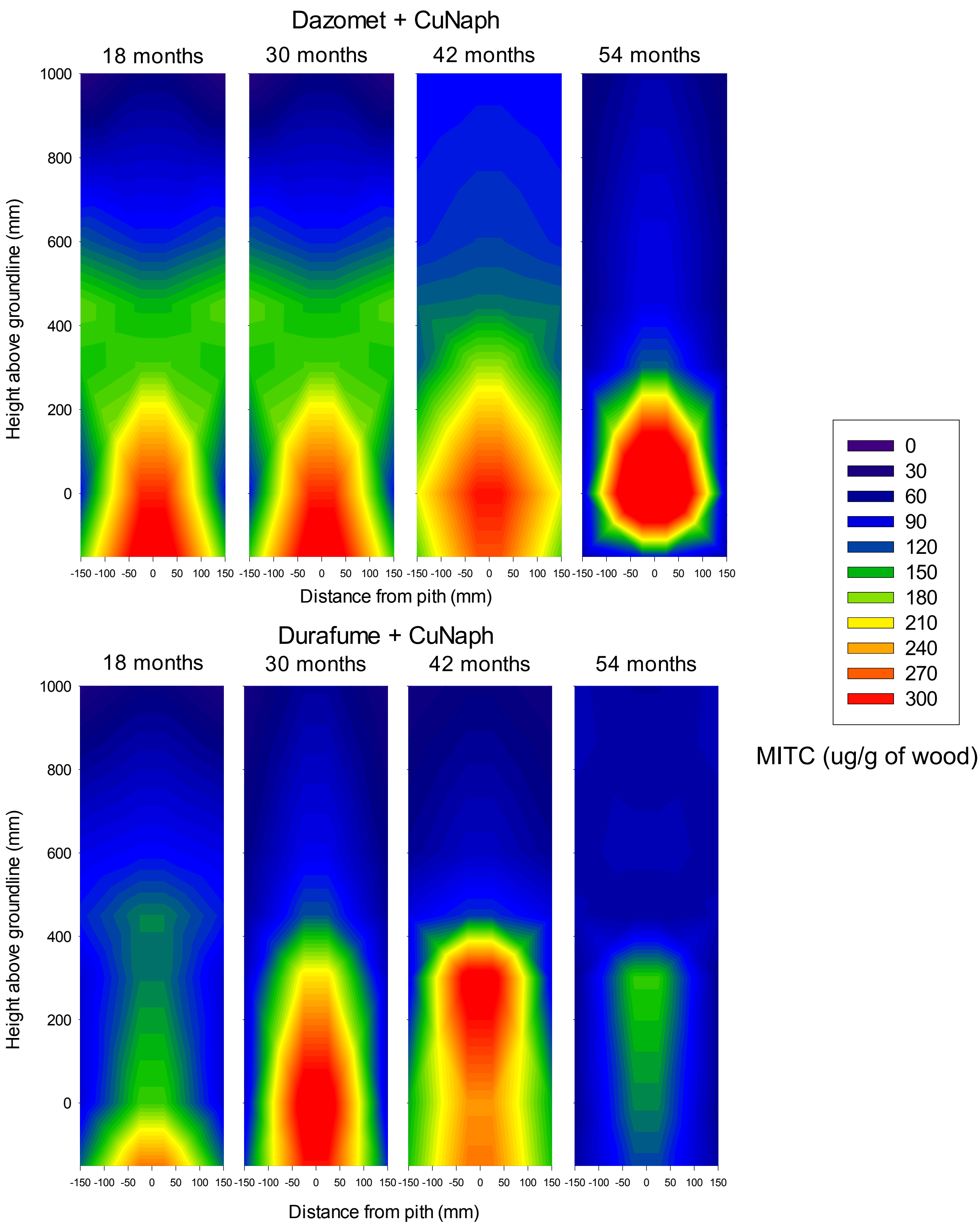


Figure I-15. Distribution of MITC in Douglas-fir poles sections 18 to 54 months after treatment with dazomet, DuraFume or UltraFume plus copper naphthenate.

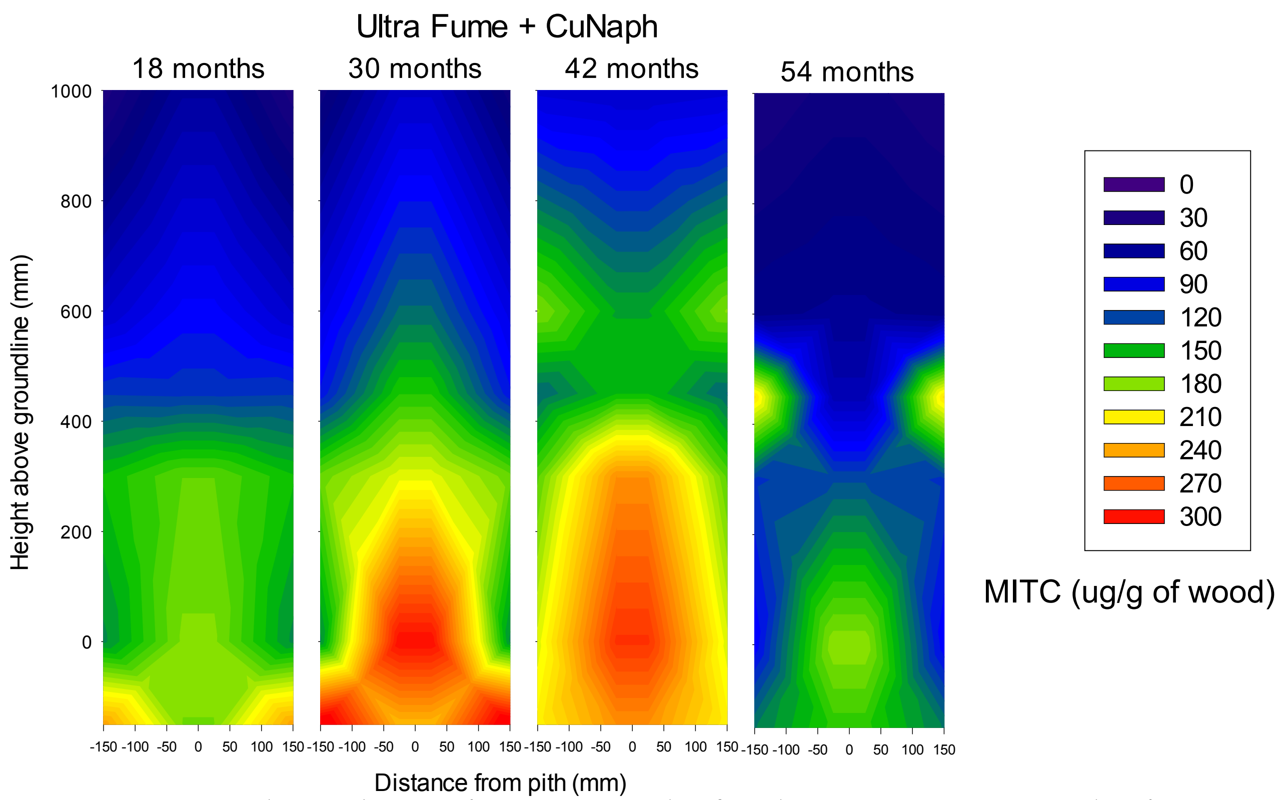


Figure I-15 continued. Distribution of MITC in Douglas-fir poles sections 18 to 54 months after treatment with dazomet, DuraFume or UltraFume plus copper naphthenate.

periods of elevated rainfall that increased the wood moisture content, thereby enhancing decomposition of residual dazomet in the treatment holes. It is impossible to predict whether this will occur during our testing, but MITC levels do remain more than sufficient to provide protection against fungal attack in all dazomet treatments.

MITC levels in poles receiving either dazomet in rod form or in tubes (Super-Fume tubes) tended to be lower than levels found in poles receiving powdered treatments, but were still above the threshold at all sampling points below groundline and up to the 900 mm above groundline point. Chemical levels near the surface at 900 mm were a bit more variable than in the powdered treatments (Figure I-16). The rods and tubes both may restrict contact between the wood and the chemical, creating the potential for reduced decomposition. There were negligible differences in MITC levels between poles receiving powdered or rod dazomet. The tubes appeared to have a greater effect on MITC levels, with consistently lower MITC levels than the other dazomet based systems; however, levels remained 1.5 to 6 times the threshold at 54 months at all sampling locations. These results indicate that, while the tubes slow MITC release, this does not result in chemical levels below the threshold.

Chloropicrin levels in the poles were more than 2000 times the 20 ug/oven dried g of wood threshold in the inner zone of poles below ground 18 months after treatment. Levels declined slightly 30 months after treatment, but remained extremely high. Chloropicrin levels appeared to increase in the wood at the 42 month evaluation, but a re-examination of the data revealed that the levels reported in the 2012 annual report were approximately double the actual value. The

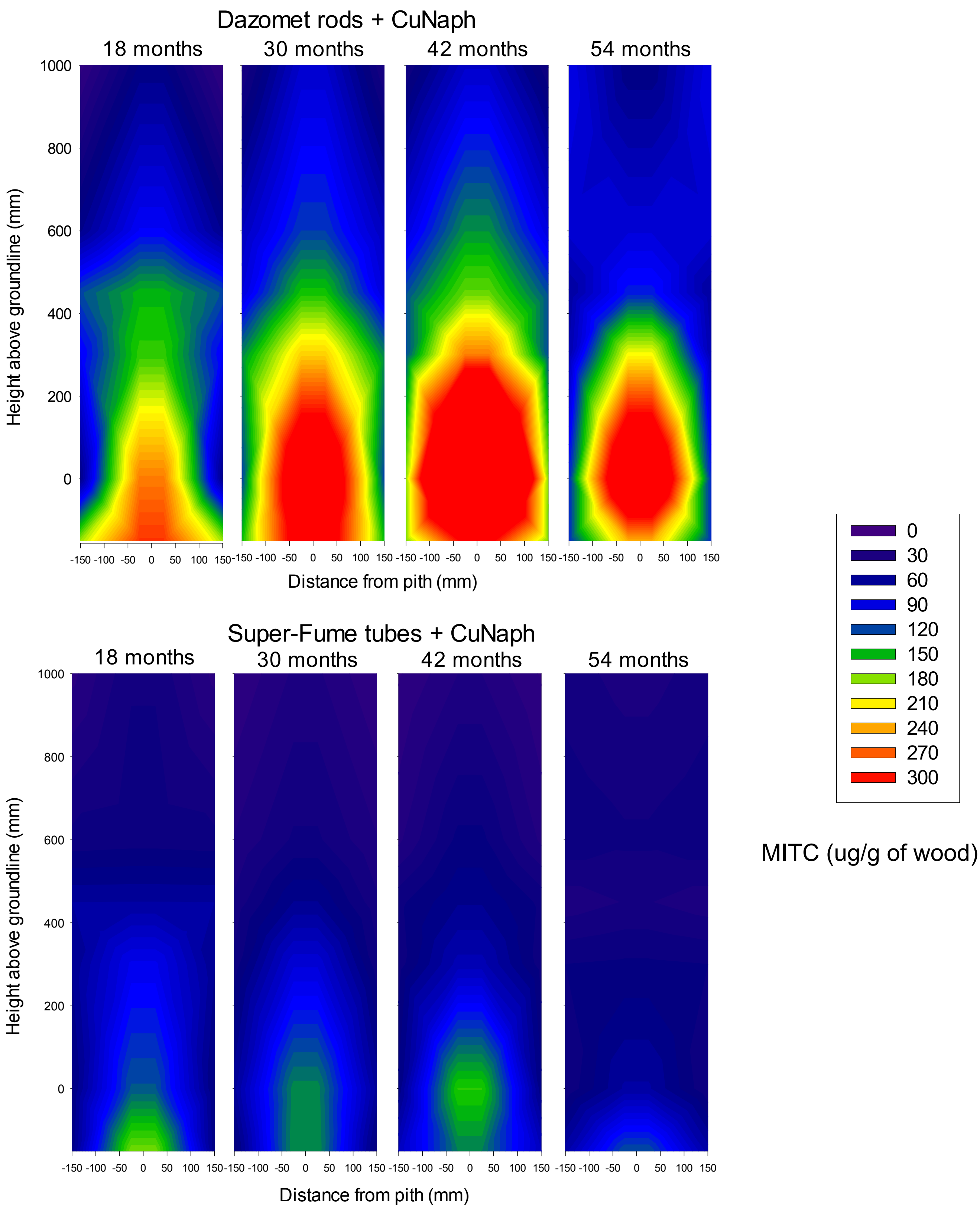


Figure I-16. Distribution of MITC in Douglas-fir poles sections 18 to 54 months after treatment with dazomet rods or Super-Fume tubes plus copper naphthenate.

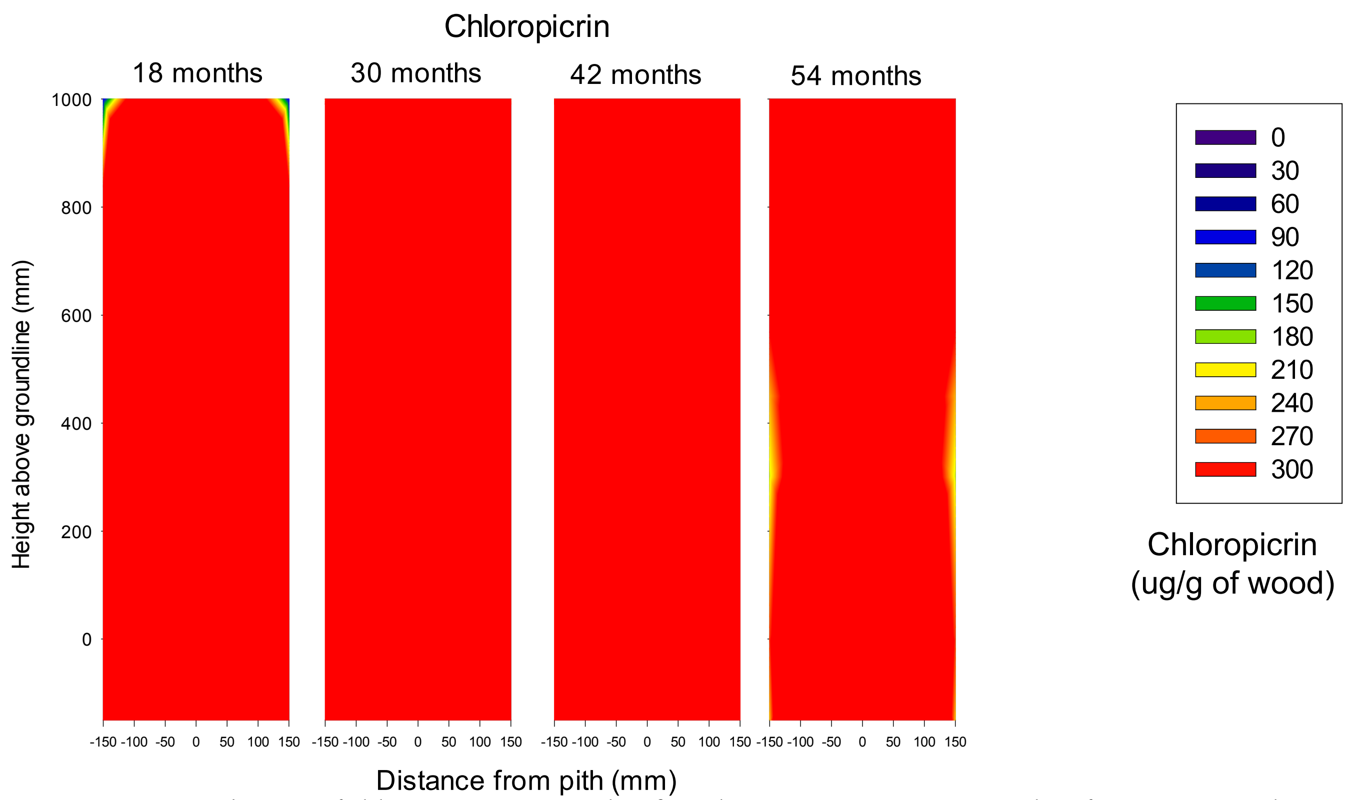


Figure I-17. Distribution of chloropicrin in Douglas-fir poles sections 18 to 54 months after treatment showing uniformly high chemical levels in the test zone.

revised values continue to show a steady decline at the 42 month point, but chloropicrin levels remained 17 to 350 times the threshold. Chloropicrin retentions 54 months after treatment continue to decline, but were still 13 to 100 times the threshold (Figure I-17). Unlike MITC, chloropicrin has strong chemical interactions with wood which results in much longer residual times. We have found detectable chloropicrin in poles 20 years after treatment and the results in the current studyare consistent with a long residual protective period for this fumigant.

The threshold for boron for protection against internal decay has been calculated at 0.5 kg/m^3 (Freitag and Morrell 2005). This value is based upon carefully controlled trials of wafers treated to specific levels with boron.

The boron levels in poles receiving either Impel rods or Post Saver rods tended to be below the threshold 300 or more mm above the groundline, regardless of sampling time or core position (inner/outer) (Table 1-12). While boron is water diffusible, it has only a limited ability to diffuse upward. Boron levels 150 mm below groundline and at groundline were above the threshold in the inner zone for both Impel Rod and Post Saver rod-treated poles 18 months after treatment, but below the threshold in the outer zone. The difference again reflects the tendency of the sloping treatment holes to direct chemical downward toward the center of the pole. Boron levels were above the threshold for both inner and outer zones 30 months after treatment with either rod system, but still below threshold in the outer zone 150 mm below groundline. Boron levels were all well above threshold both below and at groundline 42 and 54 months after treatment (Figure I-18). These results are consistent with previous tests showing that uniform movement of boron requires several years. If these trends continue, we would expect to find elevated boron levels

Table I-12. Boron levels at various distances above and below the groundline in Douglas-fir poles 18 to 54 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)
	54	0.00 (0.00)	0.04 (0.02)	0.03 (0.04)	0.01 (0.01)	0.00 0.00	0.00 0.00
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)
	54	**3.34** (2.06)	**1.12** (1.42)	**3.57** (2.76)	**0.84** (0.46)	0.47 (0.87)	0.13 (0.18)
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)
	54	**0.74** (0.67)	**0.53** (0.49)	**3.56** (3.90)	**1.17** (0.93)	0.15 (0.05)	0.05 (0.04)

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)
	54	0.00 0.00	0.01 (0.00)	0.00 0.00	0.03 (0.04)
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)
	54	0.12 (0.13)	0.09 (0.14)	0.06 (0.08)	0.04 (0.05)
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)
	54	0.06 (0.08)	0.03 (0.05)	0.05 (0.03)	0.00 0.00

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.

in the poles for 5 to 7 more years. Boron levels in Impel Rods and Post Saver rods appear to be similar near groundline while boron levels are higher in the Impel Rod-treated poles in the inner zone below ground.

The overall trends indicate that the boron-based systems are producing protective levels within the groundline zone, but diffusion above this zone is very limited.

2. Performance of Internal Remedial Treatments in Arid Climates: Rocky Mountain Power Test

Date Established:	August 2010

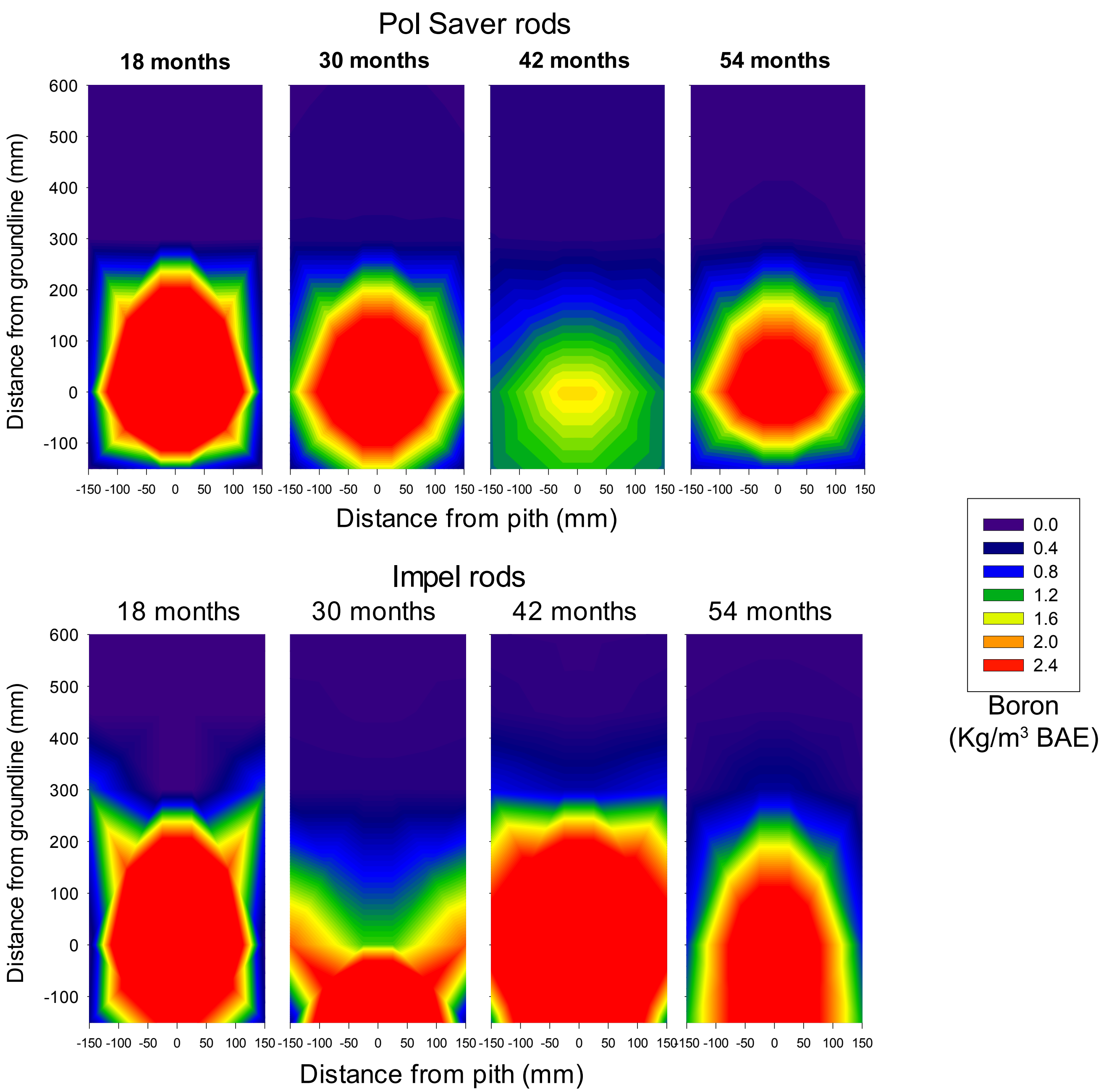


Figure I-18. Boron distribution in Douglas-fir poles 18 to 54 months after application of Impel or Pol Saver rods.

Location:	Utah
Pole Species, Treatment, Size	Pine, cedar, Douglas-fir, penta, creo, cellon
Circumference @ GL (avg., max., min.)	87, 107, 71 cm

Internal remedial treatments are widely used to arrest internal fungal decay in poles. These treatments have proven to be highly effective, rapidly eliminating fungi and protecting against reinvasion for periods ranging from 7 to 10 or more years. While these treatments are highly effective, nearly all of the testing has been performed in wet temperate climates and there is little data on the efficacy of these treatments under the drier conditions common to most of the western United

States. While the decay risk is also lower in these locations, the absence of moisture in the wood at the time of treatment can result in inadequate release of fungicidal compounds. Moisture can be a critical requirement for decomposition of dazomet to produce MITC and it is essential for diffusion of boron from fused boron rods.
Douglas-fir, western redcedar and lodgepole pine poles located 220 kilometers south of Salt Lake City, Utah were selected for study. The poles were selected on the basis of accessibility and absence of prior internal treatment. The site is a high desert and receives little rainfall (Salt Lake gets an average of 400 mm of rain and 1.4 m of snow/year). The research area receives 150-200 mm of precipitation, primarily as snow, per year.

Each pole was sounded, then inspection/treatment holes were drilled beginning at groundline adjacent to the largest check and moving around the pole 120 degrees and upward 150 mm. The poles were treated, following label recommendations, with dazomet alone, dazomet with 1% copper naphthenate (10% w/w), MITC-FUME, metham sodium, fused borate rods (one 3 inch rod per hole) with water (10% w/w), fused borate rods without water or were left untreated. The treatment holes were plugged with tight fitting plastic plugs.

The treatments applied were:

- Dazomet with accelerant (2 % elemental copper)
- Dazomet with no accelerant
- MITC-FUME
- Metham sodium
- Fused boron rods with water
- Fused Boron rods without water
- Non-treated control

The poles were sampled 14 months after treatment by removing increment cores from three equidistant locations around a pole at heights of 150 mm below groundline, at groundline, as well as 300, 450, 600 and 900 mm above groundline. The treated shell was discarded and then the outer and inner 25 mm of the remainder of each core was removed. The core segments from poles treated with dazomet, metham sodium or MITC-FUME were placed into a glass vial and sealed with a Teflon lined cap. The remainder of the core was placed into a plastic drinking straw which was labeled with the pole #/sampling height and location and then stapled shut. For poles treated with fused boron rods, the entire core was placed in a drinking straw. The vials and straws were returned to Oregon State University for processing.

In the lab, the cores from the vials were transferred individually to tubes containing 5 ml of ethyl acetate and extracted for a minimum of 48 hours at room temperature before the extract was analyzed for MITC content by gas chromatography. The cores were then oven-dried and weighed. MITC content was expressed on a µg MITC/oven dried gram of wood basis. The outer and inner 25 mm segments of cores from boron treated poles were combined from the three cores from the same height on a pole and ground to pass a 20 mesh screen and then extracted in hot water. The resulting extract was then analyzed by the Azomethine H method. Results were expressed on a kg/m^3 of boric acid equivalent (BAE).

The remaining center sections of all the cores were briefly flamed to reduce the risk of surface contamination and then placed on 1 % malt extract agar in plastic petri dishes. The cores were observed for evidence of fungal growth on the agar and any growth was examined for characteristics typical of wood decay fungi.

The year 3 sampling will occur in October 2013.

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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 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. 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. 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.

No additional tests were performed on these poles.

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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. Survey of Utility Practices

In 2000, we undertook a large survey of utility practices with regard to pole purchasing, inspection cycles, remedial treatments and a host of other activities. The goal was to help utilities identify common problems and practices. The survey results were somewhat expected. Southern pine was the dominant wood pole species and pentachlorophenol was the dominant wood preservative. Most utilities estimated that the average service life of their poles was between 31 and 40 years. Most utilities had some type of inspection program, but the practices varied from simple visual inspection to the use of sound and bore coupled with other devices. Most utilities used some sort of remedial treatment.

The current survey asked many of the same questions, but added a few more about pole disposal and the use of crossarms. The 2000 survey used repeated mailings to a list obtained from a cooperator. The survey was mailed to 1100 utility engineers, purchasing agents and specifiers across the United States. Two hundred sixty-two responses were received.

In our most recent effort, we used an e-mail list provided by another cooperator and a survey prepared through SurveyMonkey.com. The results are preliminary, but we received 94 usable surveys. The majority of respondents were from the U.S. (93%), but there were several responses from Canada. The majority of respondents were investor owned utilities (44%), with the remainder being cooperatives (25 %), Municipals (19 %) and Public Utility Districts (12%) (Figure III-1). Most of the utilities were in regions classified as having a moderate risk of decay (46 %), with smaller percentages from utilities from either a low (24%) or a high risk zone (16%) (Figure III-2).

As expected from the range of ownership, the number of poles in a system varied widely from as few as 500 to as many as 6,000,000. The average number of poles reported by the 92 respondents to this question was 492,667 (standard deviation = 1,069,689). Over 25% of respondents owned between 10 and 50,000 poles, while another 15 of 92 respondents owned fewer than 10,000 poles (Figure III-3). There are an estimated 167 million poles in service across North America and our respondents owned 44.8 million poles representing approximately 25% of the total pole population. The total number of poles owned by respondents in the current survey was similar to that found in the 2000 survey. The results suggest that the current responses represent a reasonable survey population.

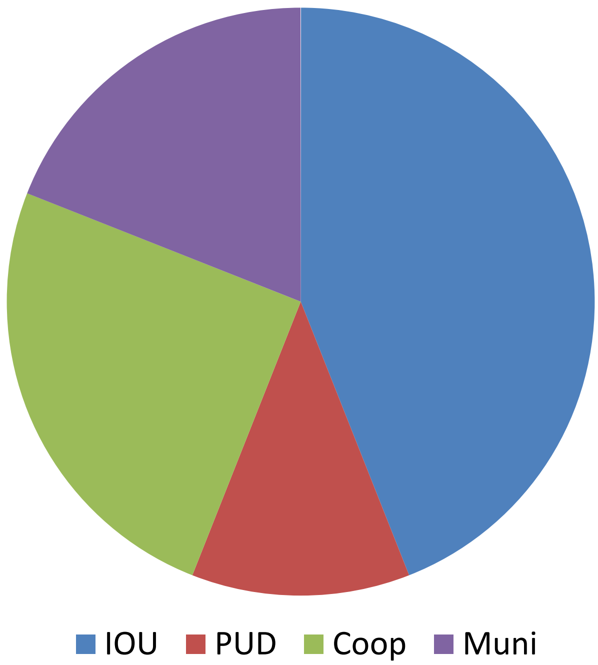

Figure III-1. Categories of respondents to the survey (n=91) where IOU= investor owned utility, PUD= public utility district, Coop= cooperative, and Muni= Municipal.

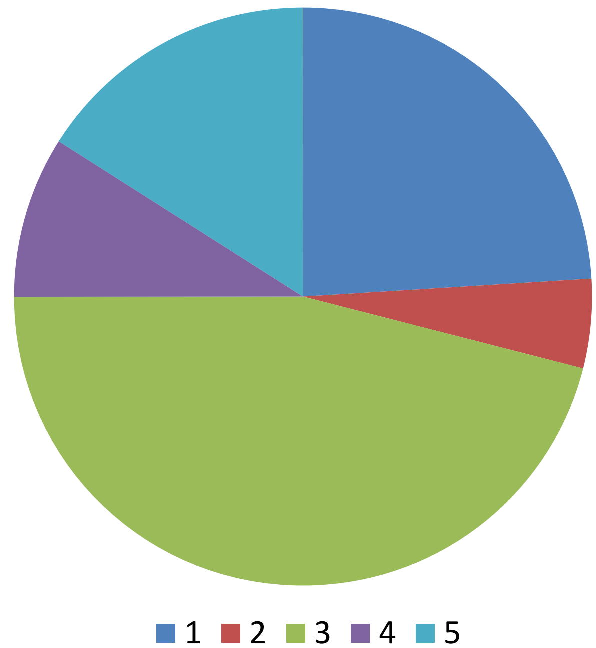

Figure III-2. Percentages of responding utilities whose territories lie in a given decay hazard zone according to the American Wood Protection Association Map in Standard U1-12 Commodity Specification D: Poles.

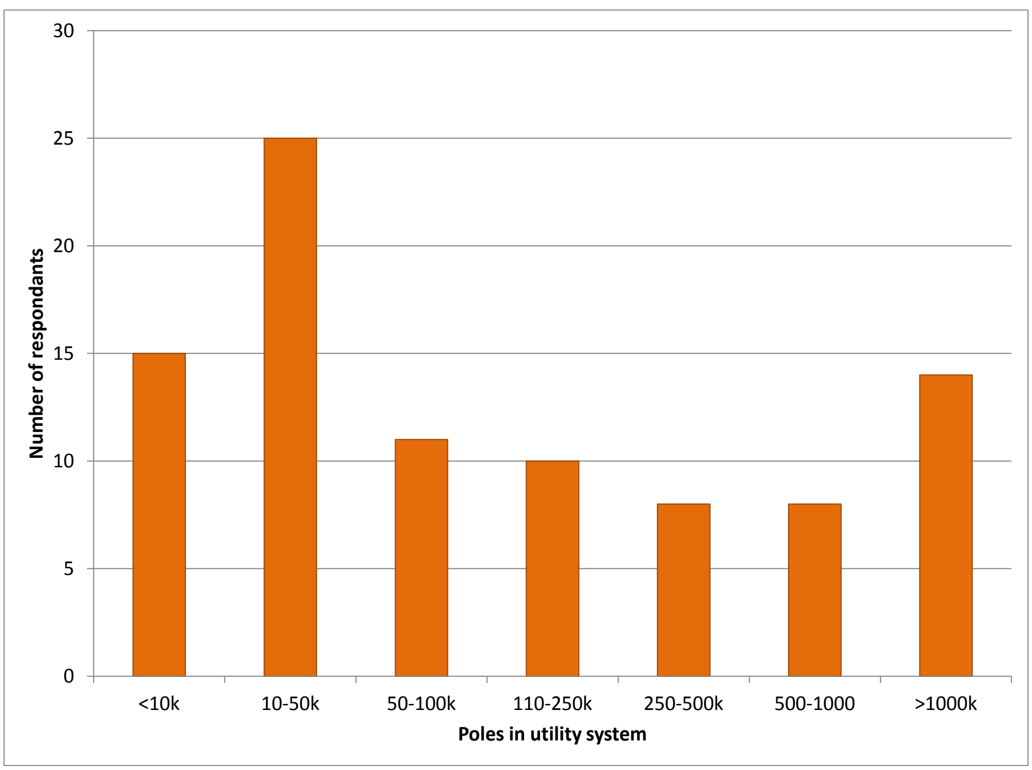

Figure III-3 Number of poles owned by responding utilities.

The 86 utilities responding to a question on pole purchasing reported buying an average of 5845 poles per year (standard deviation=11324), but there were wide variations in the number of poles purchased. Most responding utilities purchased fewer than 500 poles per year, although 10 responding utilities purchased over 20,000 poles per year (Figure III-4). Pole purchasing can be used, in conjunction with the total pole population to estimate pole replacement rates. Using these responses, the estimated pole replacement rate would be 1.12% per year. This value is somewhat higher than the 0.7% rate found in the 2000 survey; however, this rate must be viewed with some caution since the pole purchases include poles for new construction.

Pole removals would provide a much better measure of pole service life. The 83 respondents to the pole removal question removed an average of 2778.5 poles per year (Standard deviation=5694) for a total of 230,612 poles. When these values are compared with the total poles owned by the respondents, the replacement rate drops to 0.56%, which is more in line with previous reports. Most responding utilities removed 100 to 500 poles per year (Figure III-5). These results support the premise that pole service lives are far in excess of the 30 to 40 years estimated by many utilities.

Crossarms are an important, but often overlooked utility component. Anecdotally, utilities estimate that they use two crossarms over the life of a single pole. The 88 respondents to the questions regarding crossarms purchased almost 531,000 crossarms per year. Crossarm purchases ranged from 0 to 65,000 arms, for an average of 6034 arms per respondent. Utilities purchased a range of arms, with just over one half of all respondents purchasing 500 arms or fewer per year (Figure III-6). Several utilities (8) purchased at least 25,000 arms per year, but the vast majority of respondents purchased modest numbers of arms. The vast majority of the crossarms purchased were Douglas-fir (64%), but an additional 25.5% were southern pine (Figure III-7). Some

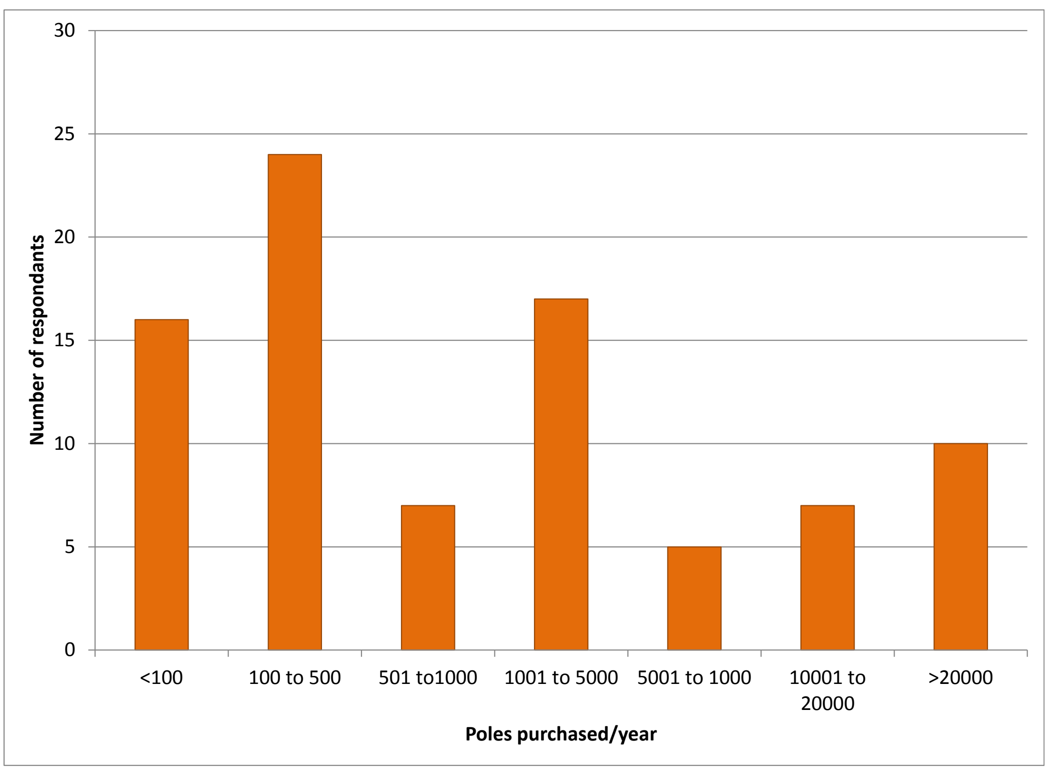

Figure III-4. Number of poles purchased per year by responding utilities.

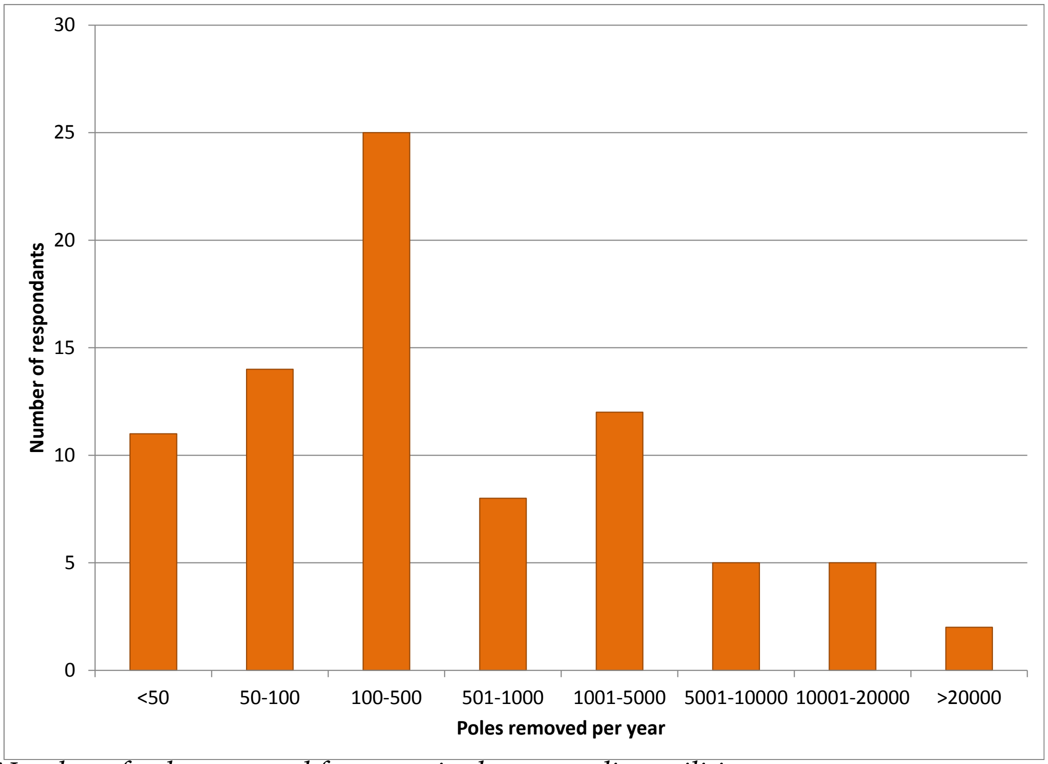

Figure III-5. Number of poles removed from service by responding utilities per year.

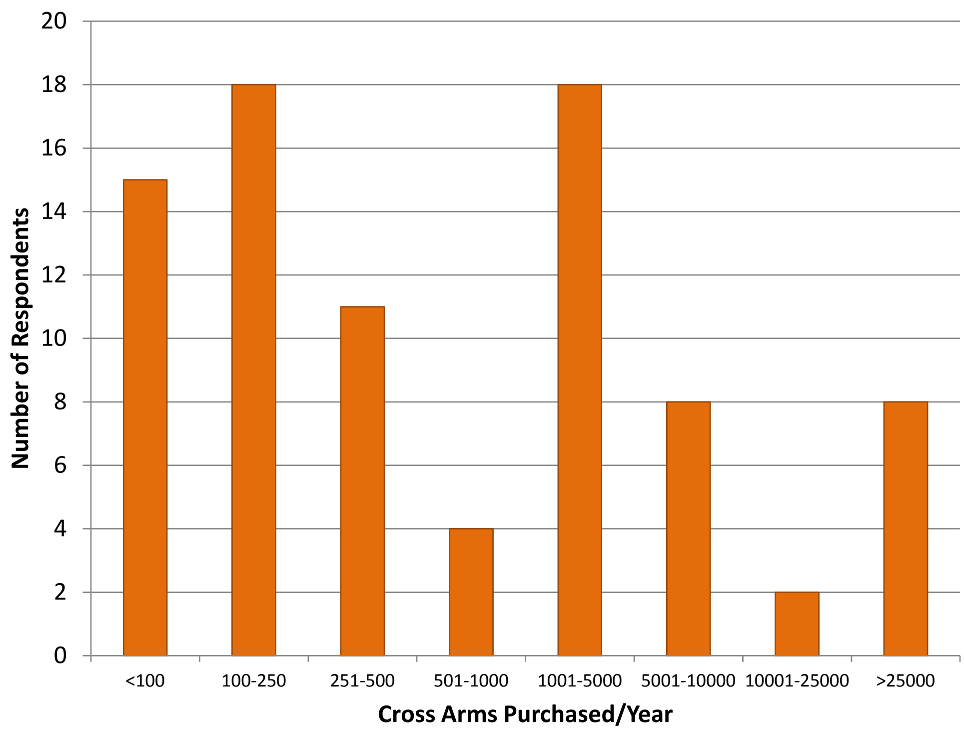

Figure III-6. Number of crossarms purchased per year by responding utilites (n=84).

respondents purchased limited numbers of fiberglass or steel arms. Fiberglass arms have become increasingly common in specific applications where additional capacity is needed or where weight is a factor, but they are generally on the order of 7 to 10 times more expensive. As a result, they are used sparingly.

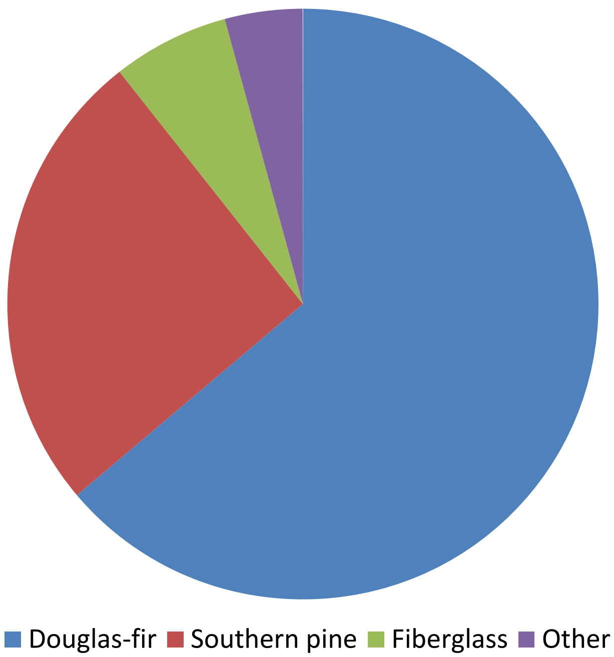

Figure III-7. Types of materials used for crossarms by responding utilities.

The use of alternative materials does highlight an increasing trend to segmentation of the market to meet specific material needs. Two utilities used alternative species (western redcedar and lodgepole pine). At least two utilities had ceased crossarm purchases because they had a goal of moving all of their distribution underground; however, both were relatively small, urban utilities.

All utilities in North America are required to inspect their poles on a regular basis, although the type of inspection and frequency are often not specified. Generally, pole inspection is recommended every 10 years, although the frequency can be shortened under more severe decay conditions or lengthened in drier or cooler climates. The previous survey suggested a frequency of 10 to 12 years. Forty three percent of respondents in the current survey inspected poles every 5 to 10 years, while an additional 38.7% used a 10 to 15 year cycle (Figure III-8). Some utilities used cycles greater than 15 years, while 2.2% had no inspection program. These results are similar to those found in the earlier survey and indicate that most utilities use inspection cycles around 10 years.

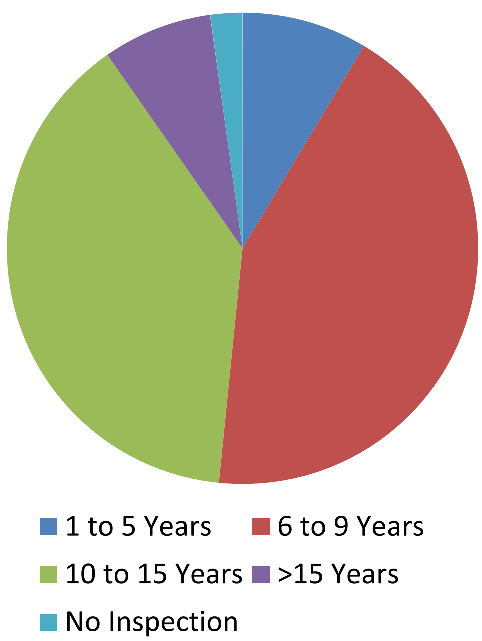

Figure III-8. Intervals employed for pole inspection by responding utilities.

All but one of the 93 survey respondents used some type of inspection process. Most (52) used partial excavation to detect surface decay coupled with sounding and boring to detect internal decay (Figure III-9). An additional 26 used sound and bore alone, while 28 used sound and bore coupled with a complete excavation. The results indicate that a majority of utilities use excavation coupled with sound and bore.

Detecting decay is important, but it serves little purpose if the decay is allowed to continue. Most utilities in the 2000 survey used internal and external treatments to arrest fungal attack. Utility respondents in the current survey appeared to use remedial treatments much less extensively. Sixteen of 83 respondents did not remedially treat any poles, while an additional 24 treated fewer than 25% of their poles (Figure III-10). Only 30 respondents treated 75% or more of their poles. Given the relatively high percentage of poles that are inspected, the remedial treatment rate seems to be very low. The cost of getting to and inspecting a pole represents a majority of the program cost. Chemical treatment adds to the cost of the process, but represents a relatively small percentage of the total cost and

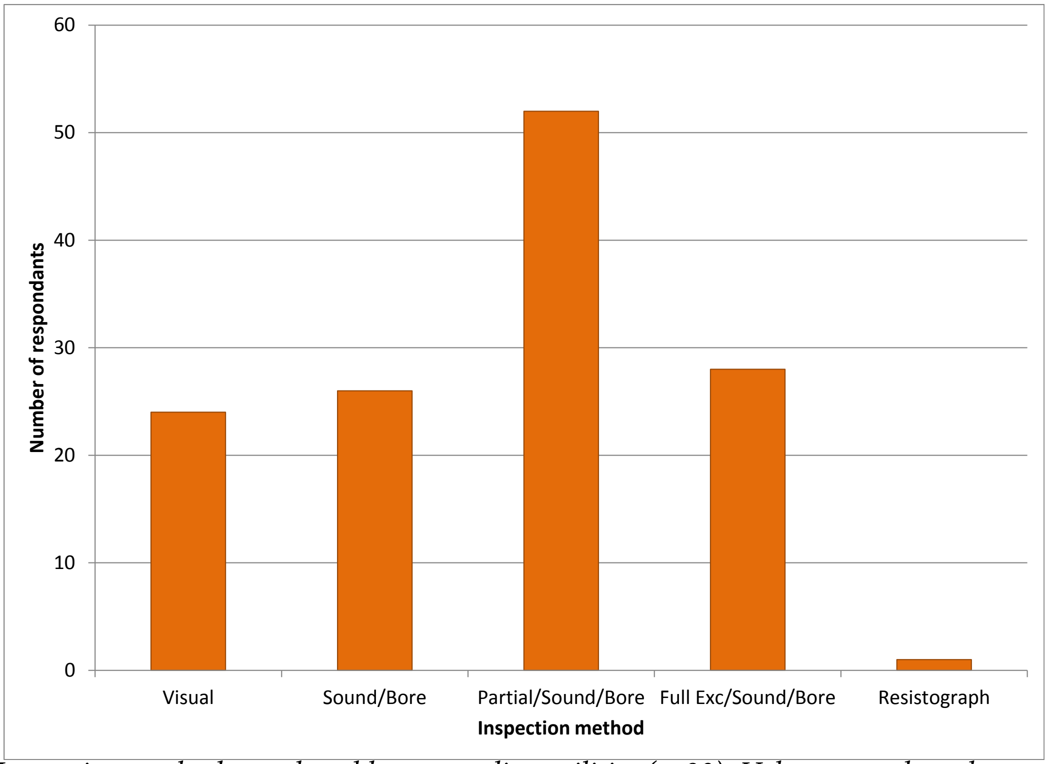

Figure III-9. Inspection methods employed by responding utilities (n-93). Values exceed total respondents because some utilities used more than one method, depending on pole species or treatment.

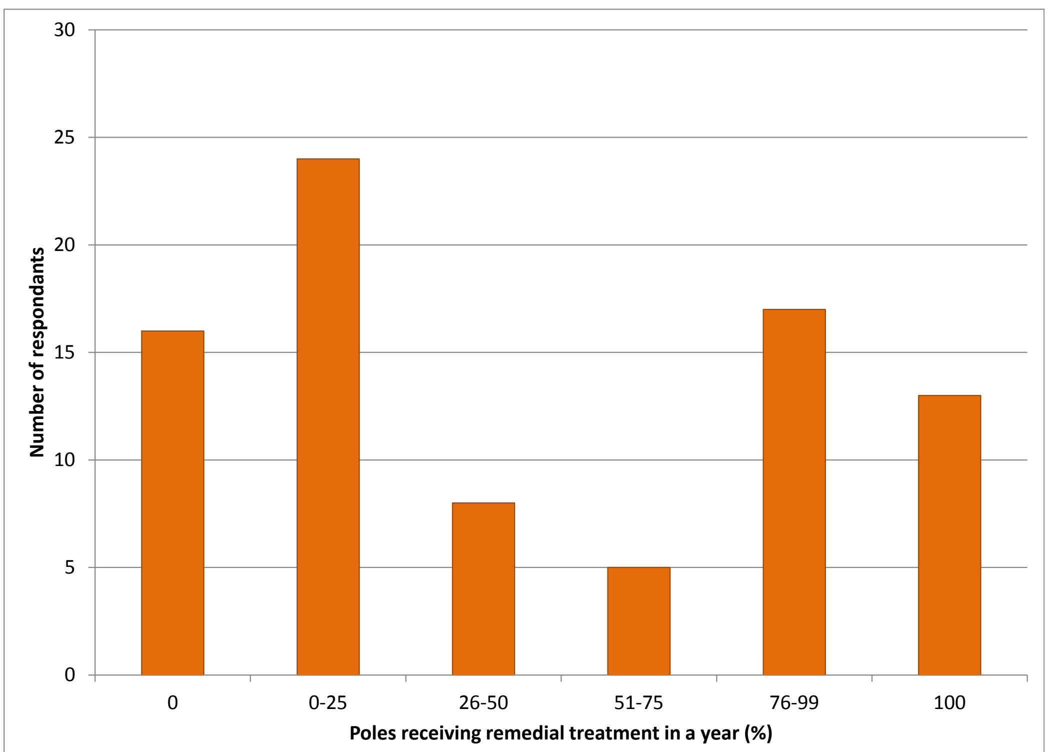

Figure III-10. Percentage of poles remedially treated by responding utilities.

provides a highly reliable method for arresting existing fungal and insect attack. Some utilities have been known to only inspect poles without the application of a remedial treatment, with the expectation that they will replace a pole once its condition reaches a certain level. It is unclear why so many utilities in the survey chose to limit their remedial treatments and we suspect that the question was not clear. The low rates of remedial treatment might reflect utilities noting the percent of poles treated each year as a proportion of the entire system rather than the total they have treated in their system and this would be consistent with the inspection cycles most employed.

The final aspect of pole management is disposal. Most utilities still give poles away along with an information sheet or have the recipients sign an indemnification agreement (65 and 75% of respondents, respectively). Nine of the 94 respondents reported that disposal had affected their attitudes toward wood poles, although none had altered their pole purchasing practices because of disposal concerns. A number of methods have been suggested for re-using poles. Re-sawing has long been used to recycle poles, notably western redcedar, which contains a relatively large proportion of clear, non-treated heartwood. Only 16% of respondents had used re-sawing for pole disposal (Figure III-11).

Another approach would be to use poles for energy production. While co-generation is not yet widely used for pole disposal, treated poles contain a substantial amount of energy. Thirty one percent of respondents would use combustion for pole disposal, while an additional 52.7% of respondents would consider the process (Figure III-12). These results suggest that co-generation has potential among utilities; although considerable work would be needed to license a suitable number of facilities and processes would need to be developed to move poles from individual utilities to the centralized generating facilities. The responses to the disposal questions suggest that the issue is of concern to utilities and that they are exploring alternative disposal methods. However, the issue has not risen to the level where it has affected purchasing practices. It will be

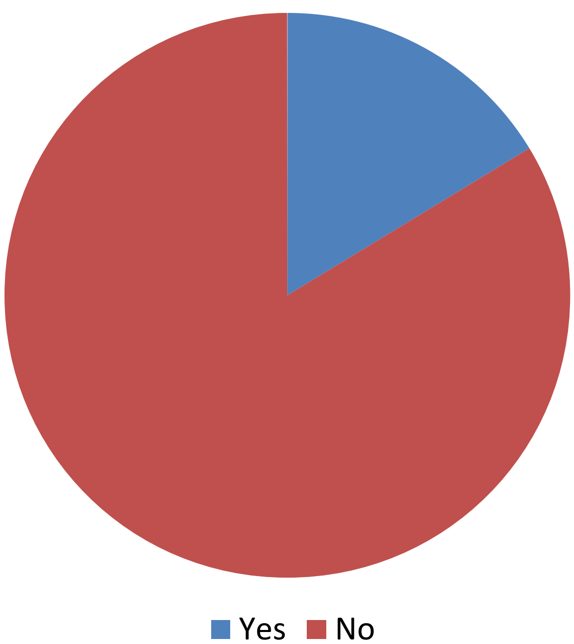

Figure III-11. Percentage of respondents who currently re-saw poles removed from service.

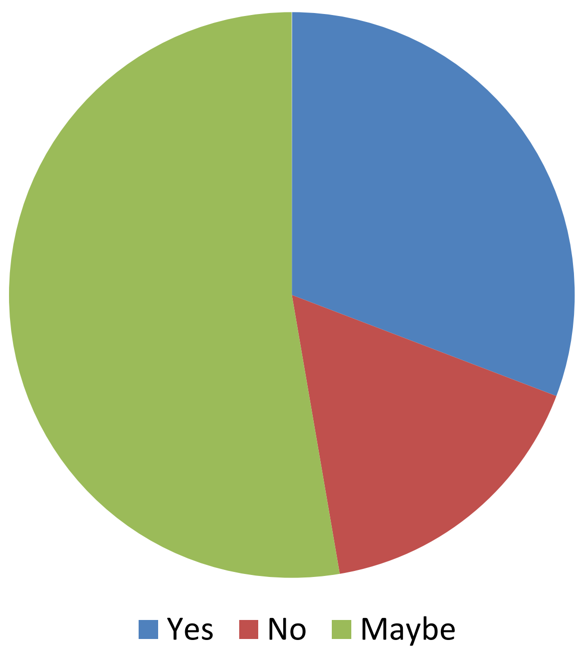

Figure III-12. Percentage of responding utilities that would consider combustion for energy production as a viable method for pole disposal.

important to continue to monitor utility attitudes toward disposal and to seek alternative uses for retired poles and crossarms.

B. Performance of Polyurea-Coated Douglas-fir Crossarm Sections Exposed in Hilo Hawaii: 48 month report

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. 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. Douglas-fir contains a high percentage of difficult to treat heartwood and it is generally not feasible to completely penetrate this material with preservative. One alternative 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 4 years near Hilo, Hawaii.

Decay Tests: Douglas-fir arm 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 treatment group 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. The site receives approximately 5 m of rainfall per year and the temperature remains a relatively constant 24-28 C. The site has an extreme biological hazard (280 on the Scheffer Climate Index Scale- which normally runs from 0 (low) to 100 (high decay risk) within the continental U.S.) and a severe UV exposure. Non-treated pine sapwood exposed above ground normally fails within 2 years at this site, compared to 4 to 5 years in western Oregon.

Assessment for the first 4 years has been primarily visual and consisted of examining coating condition on the upper (exposed) and lower surfaces (Figure III-13). Additional coated samples were exposed in June of 2011. The non-treated, non-coated Douglas-fir samples have begun to experience decay on the sides and undersides where moisture can collect and there is evidence of fungal fruiting bodies (Figure III-14). These samples have an average rating of 9.0 on a scale of 10 (perfectly sound, no evidence of biological attack) to 0 (complete failure). Non-coated penta treated samples remain sound and free of decay and all rate 10. Samples coated with polyurea are challenging to evaluate. Penta has migrated through the surfaces of the polyurea coated samples to a limited extent, but the samples otherwise appear to be free of attack. Similarly, the non-treated but coated samples also appear to be free of fungal attack. It would be useful to remove samples for destructive assessment, although we have not yet done this because of the limited number of replicates for each treatment. The ability of the

Figure III-13. Examples of Douglas-fir crossarm sections with and without polyurea coating immediately after exposure near Hilo, Hawaii.

Figure III-14. Example of a non-treated Douglas-fir crossarm section with visible decay after 4 years of exposure in Hilo, Hawaii.

barrier to limit fungal attack without preservative treatment would be especially useful and this may be possible for samples out of soil contact; however, as we shall see with the next part of this test, it is not as easily accomplished in soil contact.

Termite Tests: Polyurea-coated samples were evaluated for resistance to the Formosan termite (*Coptotermes formosanus)* at a test site located in Hilo (Figure III-15).

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 *Coptotermes formosanus*. This species is considered to be a very aggressive wood destroyer and is found in the southern US as well as Hawaii and the southern tip of California. A series of 19 mm by 19 mm southern pine sapwood stakes were driven into the ground in the 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 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. The entire assembly was covered to prevent overhead wetting. This arrangement posed little or no risk of chemical leaching.

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

Figure III-15. Example of a termite array containing coated and non-coated Douglas-fir lumber sections at the time of exposure.

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

Ideally, the polyurea would provide protection against termites without the addition of a preservative. The potential effectiveness of the polyurea as a barrier was initially assessed using 37.5 by 87.5 by 125 mm long Douglas-fir blocks that had been cut from boards that had either been left without treatment or had been treated with pentachlorophenol as described above. The sections were then coated with polyurea. These initial trials indicated that the termites were able to locate and attack non-treated samples, even inside the polyurea coating while the penta treated samples were left untouched (Figure III-16).

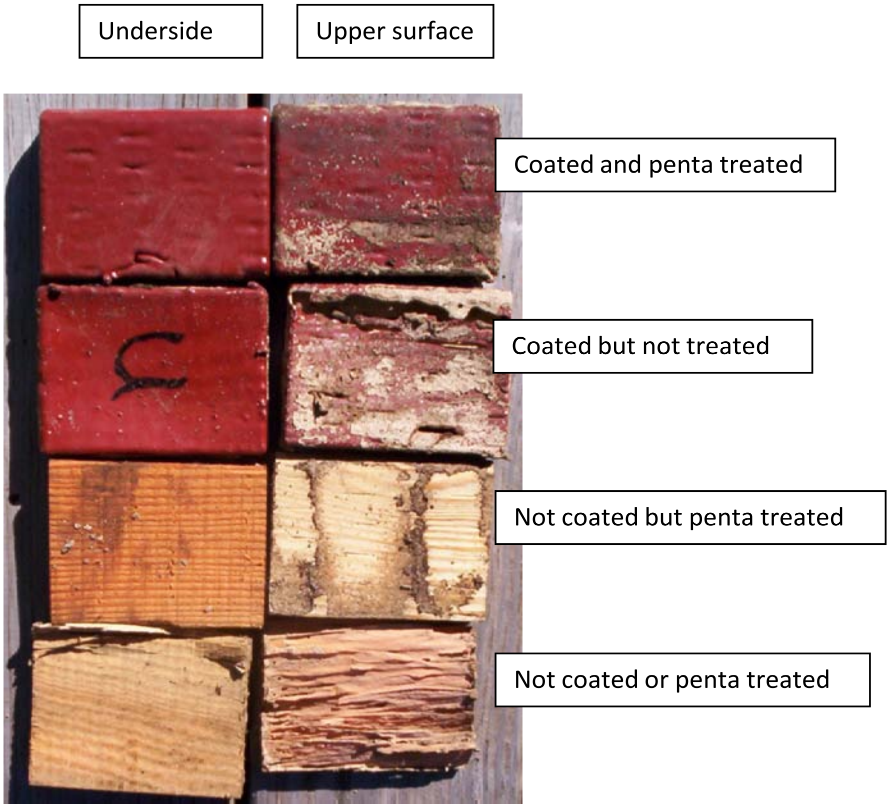

Figure III-16. Examples of undersides (left) and upper surfaces of coated and non-coated Douglas-fir lumber with and without penta treatment showing extensive termite attack of non-treated samples.

As a follow-up, additional samples were exposed using the same procedures except that one half of the samples were without treatment and the other half had been dipped in a 10% solution of disodium octaborate tetrahydrate (borate). One half of the samples were coated with polyurea and all samples were exposed on the termite array as previously described. Termite attack was somewhat slower on the samples in this test. Non-treated controls were largely destroyed 6 months after installation (Rating 4.0). The borate treated, non-coated specimens had evidence of attack, but were in better condition than the non-treated samples. The non-treated coated samples again experienced attack, as the workers located the non-treated wood and bored through the coating. Borate treated and coated samples experienced slightly lower levels of attack at the 6 month point than had been observed in the first test and the samples were reset with fresh non-treated feeder material to allow for additional attack.

Samples were again inspected in May 2013. Non-treated controls with or without coating were virtually destroyed. Borate treated samples without coating were rated as 4.0 or less, indicating substantial termite attack. Polyurea coated borate treated samples also experienced substantial attack suggesting that termites, while initially slowed by the presence of boron, eventually overcame this treatment to cause substantial damage even under a dry exposure where the borate had little or no chance of migrating from the wood (Figure III-17). The results indicate that neither polyurea coatings alone or with a supplemental dip in borate were sufficient to protect wood under severe termite exposures. As a result, more substantive protective measures will be required to take advantage of the polyurea surface barrier.

Figure III-17. Cross sections cut through polyurea coated sections of non-treated Douglas-fir (left) and Douglas-fir dip-diffusion treated with borates prior to coating (right) after 1 year of exposure to Formosan termite attack.

C. Effect of Solvent Characteristics on Fire Risk for Pentachlorophenol Treated Poles

Forest and field fires have always been a major concern for electric utilities. Brush fires can burn extremely hot, melting overhead lines and igniting poles. This problem is most acute with preservative systems containing metallic chromium or copper compounds, but poles treated with oil-borne solvents can also ignite. The resulting fires can reduce the effective circumference, compromise the treated barrier, and necessitate pole replacement if the fire is allowed to burn unchecked.

While all perservatives will combust at some temperature, the recent shift to systems using combinations of diesel with additives to meet the AWPA Standard for P9 Type A solvent has raised questions about the relative flammability of wood treated with newer P9 Type solvents.

There is no standard method for testing fire resistance of treated wood poles. Field trials typically involve piling a weighed amount of dry straw around a pole, igniting this material and then observing the degree of damage. These tests are relatively simple, but they are prone to wide variations because of differences in wind speed, relative humidity and temperature as well as wood moisture content at the time of test. High humidity leads to lower fire intensity as will wetter wood. Field trials; however, do have a place for assessing long term fire resistance.

In lieu of field trials, a more controlled approach to fire testing would be to expose the surfaces of post sized materials to a controlled flame for a given period of time while measuring surface temperature, time to ignition and rate of flame spread. Once the flame source is removed and the wood has been extinguished, the depth and extent of char can be measured. As with field trials, there are no standards for this approach, although the overall approach becomes more similar to some of the small scale tests used for assessing fire retardant treated lumber. This approach also allows tests to be performed without regard to weather conditions and permits more direct control of test variables.

We used small scale tests to assess the flammability of poles treated with pentachlorophenol and copper naphthenate in various solvents conforming to the current AWPA Standard P9 Type A. Ten non-treated, eight-foot long Douglas-fir posts (150 mm in diameter) were obtained from Pacific Wood Preserving, cut into 600 m long sections and end-sealed to retard preservative flow. The sections from a given pole were weighed and then allocated to four different treatment groups. One group of 10 sections were left without treatment to serve as controls. The other three groups were sent to treating plants in Nevada, Oregon, and Washington for pressure treatment with pentachlorophenol in P9 Type A oil. The instructions were to treat the posts in a charge for poles. The sections were then returned to OSU where they were weighed to determine gross solution uptake, then sampled to assess preservative penetration and retention by removing increment cores from one face of each section. Preservative penetration was visually assessed on each core, then the outer 6 to 25 mm was removed from each core from a given post. These segments were combined from a post, ground to pass a 20 mesh screen and then analyzed for pentachlorophenol by x-ray fluorescence spectroscopy.

Post sections were treated with the following systems:

Pentachlorophenol concentrate diluted in #2 diesel
Pentachlorophenol block dissolved in P9Type A oil
Pentachlorophenol block dissolved in P9Type A oil and coated
Pentachlorophenol diluted in FP-9 HTS
Copper naphthenate in diesel

The post sections were subjected to fire using a modified weed burner. A regulator was attached to the system to control the flow of fuel and reduce the size of the flame, then the post was placed in a stand so the fire was in direct contact with an area approximately 10 by 60 mm wide on each post (Figure III-18). Preliminary testing suggested that a fire exposure of approximately 15 minutes produced a degree of charring similar to that found in our most severe field fire test in 2008.

Temperatures at the tip of the flame reached 890 C during the burn. Thermocouples inserted into the post from the rear indicated that pole interior temperatures approached 100 C after 1 minute. At the conclusion of the torch exposure, the sample was allowed to burn. After cooling, the damage was assessed by measuring the total area charred, the maximum depth of char and the average char depth in the affected area. The results were used to determine if the solvent source affected flammability of the resulting treated wood.

Non-treated pole sections lost approximately 2% weight as a result of the fire exposure, representing a 7.3% loss in cross sectional area (Table III-1, Figure I-19). Exposure of penta treated sections to fire resulted in higher weight losses than in the non-treated controls regardless of oil source; however, we believe that most of this weight loss was due to loss of oil rather than wood

Figure III-18. Apparatus used to evaluate fire resistance of post sections treated with pentachlorophenol in various P9 Type A solvents.

loss. Pole sections in one treatment (penta concentrate) appeared to suffer a much higher weight loss; however, the value was skewed by several poles that experienced much greater damage. The remaining penta treated pole sections lost from 4 to 7% weight. Copper naphthenate treated poles experienced larger mass and circumference losses, although the reasons for the large differences are unclear (Figure III-20, 21).

While the diesel solvent may have played a role, other poles treated with penta in diesel solvent did not experience the same degree of fire damage. One other possibility is that the copper in the copper naphthenate contributed to the damage. Poles treated with alkaline copper quat or ammoniacal copper zinc arsenate both tend to experience greater fire damage than penta treated poles. While the copper levels are much lower in the copper naphthenate treated

Table III-1. Weight and circumference loss on post sections treated with pentachlorophenol in selected P9 Type A solvents and subjected to burning[a].

Treatment	Weight Loss (%)	Cross Sectional Loss (%)
Control (non-treated)	2.4 (0.2)	7.3 (4.1)
Penta concentrate	11.9 (24.4)	9.3 (8.4)
Penta in P9 Type A	4.7 (2.0)	7.8 (2.6)
Penta in P9 Type A-coated	4.0 (1.0)	7.3 (2.9)
Penta in FP9-HTS	7.0 (6.1)	7.3 (3.2)
Copper Naphthenate in diesel	39.2 (45.4)	16.7 (29.3)

a. Values in parentheses represent one standard deviation from the mean of 15 replicates for treated wood or 10 replicates for non-treated wood.

Figure III-19. Examples of penta (left) and non-treated (right) Douglas-fir pole sections after burning showing charring.

Figure III-20. Examples of copper naphthenate treated Douglas-fir pole sections after a burn exposure test.

Figure III-21. Example of a copper naphthenate treated Douglas-fir pole subjected to burning that completely burned.

poles, the added copper might have contributed to the flame spread. Cross sectional losses for the remaining treatments were all similar to those for the non-treated control, suggesting that, despite the loss of weight, the depth of char did not differ. These results are consistent with our original fire tests where we observed that penta treated poles tended to burn for long periods, but experienced minimal charring. Furthermore, testing of wood beneath the char in the previous tests indicated that the treated wood retained its efficacy against fungal attack. The results suggest that there is little practical difference in the risk of fire damage to poles treated with pentachlorophenol in conventional and biodiesel amended P9Type A oils. The results with copper naphthenate suggest that some additional evaluations may be necessary.

D. A Survey of Attitudes Toward Pole Fires

The recent large forest fires in the western U.S. have raised questions about the potential concerns of utilities using wood poles. It has been reported that some insurers are pressuring utilities to use non-combustible pole materials in fire prone areas and at least one utility has begun replacing wood with steel poles wherever possible. In order to examine these concerns, a brief survey was undertaken to assess the levels of pole losses from wild land fires, the attitudes among utilities about these losses and the actions undertaken to address them. The survey was distributed to a limited number of coop members in the Western U.S. and Canada (Table III-2). A total of 10 responses were obtained. While the respondents own a substantial proportion of the total poles in the region, the survey is clearly not comprehensive. Rather, it was designed to provide a relative feeling for attitudes about the issue and will be used to determine how the Coop should address fire-related wood research.

Table III-2 Survey sent to members of the UPRC based in the Western U.S. to determine losses and attitudes about poles in areas prone to wild land fires.

We hear periodic reports about wildfire affecting utilities in terms of materials choices, but there is very little solid information on the total losses caused by wildfires, nor the economic impacts. In order to determine if the Coop should enter into this area, we have created the following brief survey. We ask that you take a few minutes to answer the questions below. Any data that is released will be masked to hide specific utilities.

Have you lost structures due to wildfire in the past 5 years? If not, go to Question 7. **(4)**

1. If so, what was the primary cause? (circle)
    a. Wildfire **(5)**

b. Arson
c. Line Sag
d. Transformer
e. Auto Accident **(1)**
f. Unknown

2. Approximate number of structures lost to fire.
    a. Steel
    b. Wood 470
    c. Other
3. Did the structures sustain fire from the top or at the base?
    a. Top **15 %**
    b. Base **50 %**
    c. Both **35 %**
4. What was the primary type of preservative used on wood poles lost to fire? (circle)
    a. ACZA (0)
    b. CCA (0)
    c. Copper naphthenate (1)
    d. Creosote (2)
    e. Pentachlorophenol (4)
    f. Butt treated only (1)
    g. Other (specify)
5. What percent of your total wood pole inventory does the loss to fire represent? <0.01 % (0.01 to <1 % range)
6. What types of poles were lost? (circle)
    a. Transmission (1)
    b. Distribution (2)
    c. Both (2)
7. Has the public pressured you to make changes to minimize interruption in their service? (circle)
    a. Yes (2)
    b. No (6)
8. If answer is "Yes" to Question 7, what following actions were you led to do (circle all that apply)?
    a. Increase vegetative management in right of ways and/or around poles
    b. Consider use of fire protection products (1)
    c. Consider alternate structures (1)

   d. Use larger structures to improve clearance
   e. Move facilities underground
   f. Maintain status quo
   g. Other (please specify)

9. Has loss of structures due to fire led you to voluntarily do any of the following (circle all that apply)?
   a. Increase vegetative management in right of ways and/or around structures (2)
   b. Consider use of fire protection products (3)
   c. Consider alternate structures (2)
   d. Use larger structures to improve clearance
   e. Move facilities underground
   f. Maintain status quo (1)
   g. Other (please specify) (better maintenance)
10. Has your insurance carrier mandated changes in operation to reduce fire risk? (circle)
    a. Yes (0)
    b. No (5)
    c. Not sure (1)
11. If answer is "Yes" to Question 10, what were the changes (circle all that apply)?
    a. Increase vegetative management in right of ways and/or around structures
    b. Consider use of fire protection products
    c. Consider alternate structures
    d. Use larger structures to improve clearance
    e. Move facilities underground
    f. Maintain status quo
    g. Other (please specify)
12. Do you depend on internal resources, or outside fire departments to handle wood poles that are on fire? (circle)
    a. Internal (1)l
    b. Outside (2)
    c. Both (2)
13. If handled by internal resource, do you have a training program in place to properly extinguish wood poles that are on fire? (circle)
    a. Yes (2)
    b. No (1)

Although the survey responses are limited, they suggest that the impact of fire on utility systems is limited and not evenly distributed. Four utilities reported losing a total of 470 structures to fire, while the other 5 respondents lost none. Taken as a sum, fires affected less than 0.01 % of poles in the responding systems; however, it would be misleading to ignore the localized impacts and their potential effects on behavior. None of the respondents had been pressured to change their strategies, but some had looked at better right of way maintenance to reduce risk and some had examined fire protection products. We have previously examined the performance of several products and this might be a useful approach to help utilities respond to potential fires. The survey did not suggest that utilities were considering moving to alternative structures and this generally makes sense because the fires are so infrequent and the outages often reflect downed wires, not failed poles. As a result, material replacement might not markedly improve fire performance.

E. Effect of Woodpecker Holes on Bending Flexural Properties of Douglas-fir Utility Poles

Woodpeckers have a well-deserved reputation for their ability to rapidly reduce the flexural properties of utility poles. There are a number of woodpecker species that cause damage and their attack can vary from small exploratory holes to large scale cavities that markedly reduce pole properties. These birds attack poles for a variety of reasons including using the pole to make sounds, as possible sources of insect larvae and as locations for nesting cavities. In addition to the obvious effects on pole properties due to cavity creation, woodpecker damage exposes untreated wood in the pole interior to possible fungal and insect attack.

In previous reports, we have described the extent of woodpecker cavities in 25 year old Douglas-fir poles from western Oregon. Cavities up to 12 m in length were found in some poles along with extensive decay and active dampwood termite colonies.

Detecting poles with this extent of damage is relatively simple, but by the time large cavities are detected the pole is generally so badly damaged that it must be replaced. In an ideal system, line patrols would detect woodpecker damage at the early stages before further damage is caused by fungi and insects invading through the hole. Commercially available fillers could then be used to seal the holes and exclude subsequent water and fungal entry.

One problem with accomplishing this task is determining the extent of damage and the effect of this damage on flexural properties without having to climb the pole. In some instances, a small hole can be connected to a large internal cavity that has caused markedly reduced pole strength. The task is further complicated because the effect of the hole and any connected internal damage on pole properties is affected by location along the pole length and any attached pole hardware that might affect stress concentrations. Thus, a woodpecker hole in the middle of a pole might have little effect on overall capacity, but this would change dramatically if the hole were located immediately adjacent to a guy wire or an x-brace.

It is virtually impossible to assess the extent of woodpecker associated damage from the ground. Line crews often sound the pole as they climb and this can provide some information on the extent of large woodpecker associated cavities, but it provides little in the way of useful data on shell thickness, or cavity shape. Coring or drilling can help delineate cavity length and shell thickness but is costly and time consuming. Attempts have been made to use acoustic devices to detect these defects, but they also have limitations. First, they are most accurate across the pole cross section. This requires multiple tests along a pole length which is, again, time consuming when performed above the ground. In addition, acoustic tests usually use time of flight, which estimates dynamic properties and indirectly strength, but cannot distinguish between wood that is inherently weak and wood with some internal defect that is in the process of weakening the structure (for example fungal or insect attack). As a result, the ability to assess woodpecker damage is limited and unless the cavity is small, most utilities find it necessary to replace poles with these defects to maintain line reliability. Better detection and residual strength prediction methods could lower cost while improving reliability.

While woodpeckers can cause dramatic damage to poles, there is surprisingly little information on their effects on pole strength and even less on detecting the extent of their damage. A 2000 survey of utilities across North America indicated that woodpeckers, while considered to be important causes of pole failure, affected fewer than 2 % of poles inspected.

In an effort to begin investigating the effects of woodpeckers on pole properties, six distribution poles were collected from Southern Oregon and evaluated in our lab. The poles had varying, but advanced, degrees of decay. In some instances, the cavities had extended to the point where all of the non-treated wood had decayed, while others had extensive lines of cavities on the surface.

The poles were examined with a FLIR infrared (IR) camera, which detects differences in substrate temperature. These differences should reflect variations in both wood moisture content and the presence of cavities. Wetter wood should change temperature at a different rate than dry since it conducts heat differently. Similarly, voids should have a different IR signature than solid or even decayed wood. These differences in temperature can be used to detect anomalies in the poles that can then be further explored using conventional physical testing. The goal would be to reduce the number of poles that would need further physical examination. Similar approaches are used to detect points for moisture intrusion in houses, which are then examined further to determine if decay is present.

After IR imaging, the poles were tested to failure in a modified third point loading where the load was applied at or as closely as possible to the woodpecker hole. This allowed for testing of the tip of the pole where the woodpecker damage was primarily located and the butt, where damage was more limited. Load and deflection were continuously recorded and were later used to determine modulus of rupture. The tests were set up so that a longer pole section could be tested at two locations, including the groundline, so that properties could be assessed along the length to determine if the woodpecker hole was big enough for that defect to be the limiting factor in pole performance. Stress concentration along a distribution pole is typically highest near groundline and declines with distance toward the tip and the butt. Thus, small woodpecker cavities could negatively affect the above ground strength of a pole without adversely affecting the overall reliability of the pole. The difficulty lies is determining when reductions in capacity at the site of the above ground damage become the limiting defect in pole loading.

For the purposes of this test, failure stress was computed at the center point of each piece and no taper was used in the calculation of breaking stress. After testing, the poles were cut lengthwise with a band saw to expose the internal defects, permitting comparisons between the IR images and the actual defects. These poles were intended to serve as proof of concept with an expectation that additional poles with a wider range of woodpecker-associated defects would be obtained for further testing.

Pole breaking stresses were generally low and well below the 8000 psi normally assigned by ANSI 05.1 to green Douglas-fir (Table III-3). These poles all had substantial defects and the load was applied through these defects to maximize any effect. In general, tips were weaker than the butts for a given pole, but the differences were slight. These poles were removed from service because they had advanced woodpecker damage that would have already required replacement. Ideally, future tests would involve poles with woodpecker-associated defects ranging from those that would merely be repaired using filler, to those closer to the point where they would be rejected and slated for replacement.

Infra-red imaging clearly showed the defect locations although, it was sometimes difficult to determine the extent of damage because the poles had been allowed to dry out prior to testing (Figures III-22-27). The camera could clearly image the locations of cavities, bolt holes and checks. Poles in the field should have more variation in moisture distribution and this variation should be influenced by the presence of defects such as woodpecker cavities that expose the untreated interior to moisture entry. These first tests did not turn out as planned because of the delays between arrival of the poles and testing. We will seek additional poles for further evaluation of this technology.

Dissection of poles after imaging and flexural testing revealed that many of the woodpecker cavities were associated with extensive internal decay that extended for considerable distances below the original point of woodpecker entry (Figures III-28-31). In previous tests, we also detected similar large areas of damage associated with relatively small woodpecker holes (UPRC 29th Annual Report, 2009, page 46). The infra-red imaging system was available for a very limited time and the poles dried out before we were able to examine them. Thus, we were not able to clearly associate IR images with internal defects.

We plan to further explore the use of the infrared imaging system to better delineate the shape of these defects and then to follow up this imaging with destructive testing of pole sections. If successful, the goal will be to develop guidelines for using IR imaging to delineate internal defects above ground so that line crews can concentrate their efforts on poles most likely to have damage and be more confident in their decisions to either reject or treat poles with damage. We would envision this technology being used by regular line patrols to select poles that might be subjected to more intensive intrusive inspection at a later time. The goal would be to concentrate

Table III-3. Characteristics of poles with woodpecker damage that were removed from service and subjected to flexural testing to failure at the point of the largest defect in a given section.

Pole #	Class	Original Length (ft)	Circumference (inches)	Breaking Stress (psi)
1 (Tip)	4	40	23	4396
1 (Butt)	4	40	29	5740
2 (Tip)	3	40	29	3514
2 (Butt)	3	40	37	4989
3	-	-	29	869
4 (Butt)	5	40	32	4804
5 (Tip)	6	30	26	2414
5 (Butt)	6	30	30	2513
6 (Tip)	-	-	27	3835

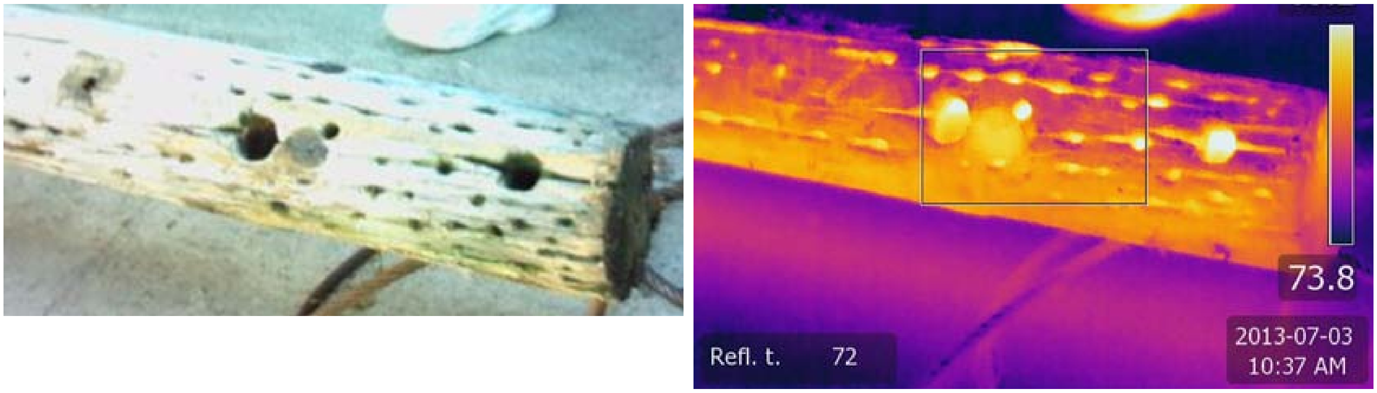

Figure III-22. Example of normal light image and an IR image of a pole top showing two large woodpecker holes and two smaller bolt holes.

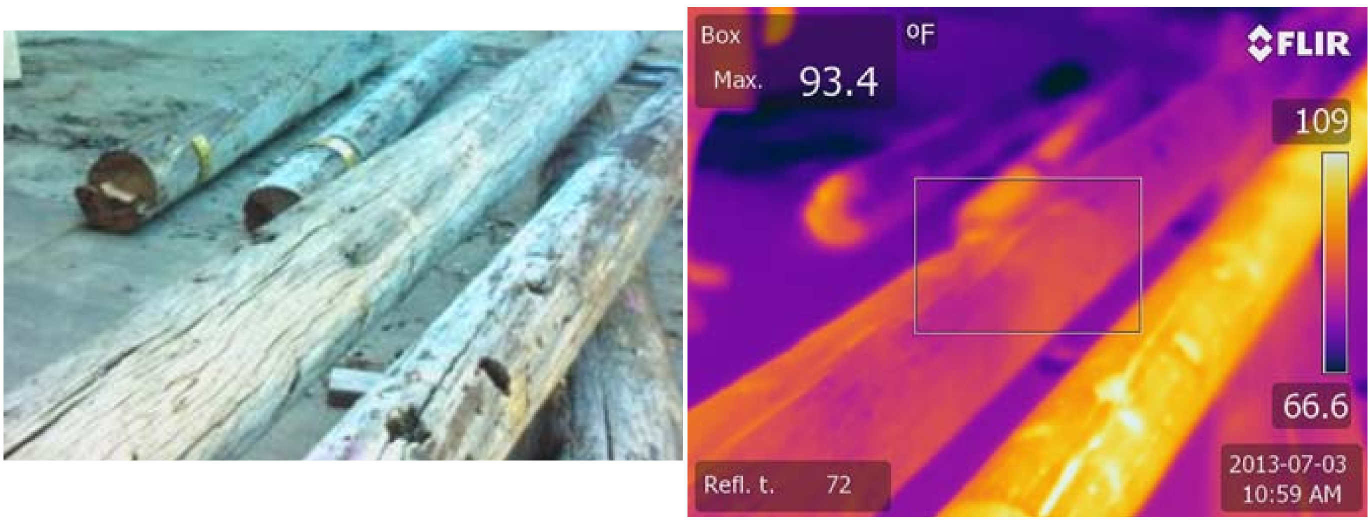

Figure III-23. Example of normal light image and an IR image of a pole top showing two large woodpecker holes and a check on the pole on the right. The boxed area on the pole on the left is the failure zone after flexural testing..

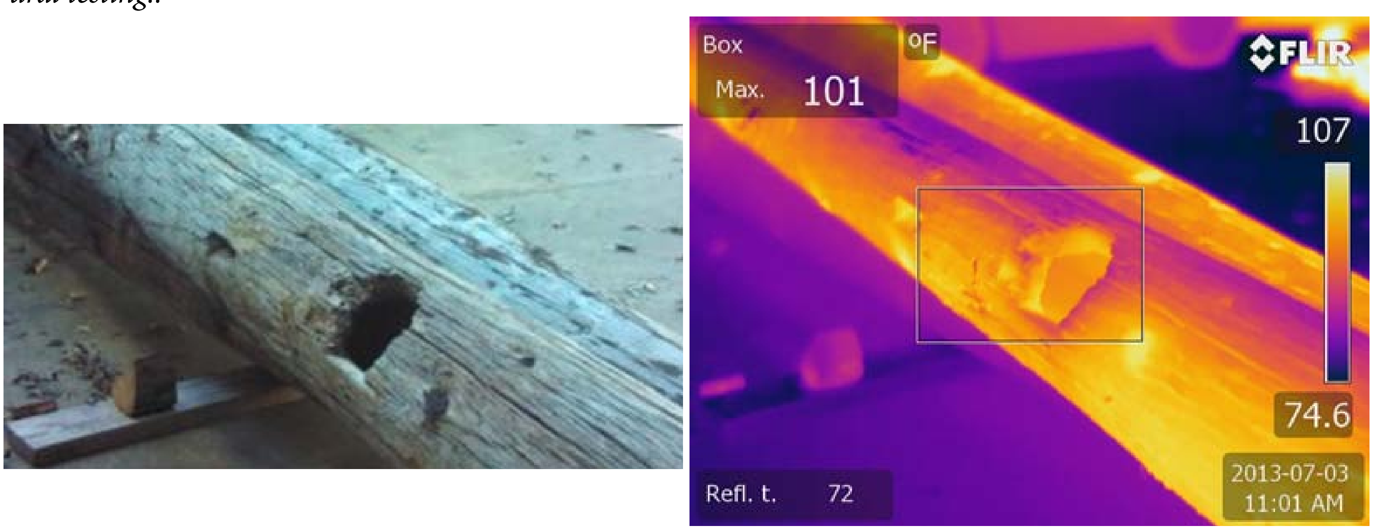

Figure III-24. Example of normal light image and an IR image of a pole top showing a very large woodpecker cavity.

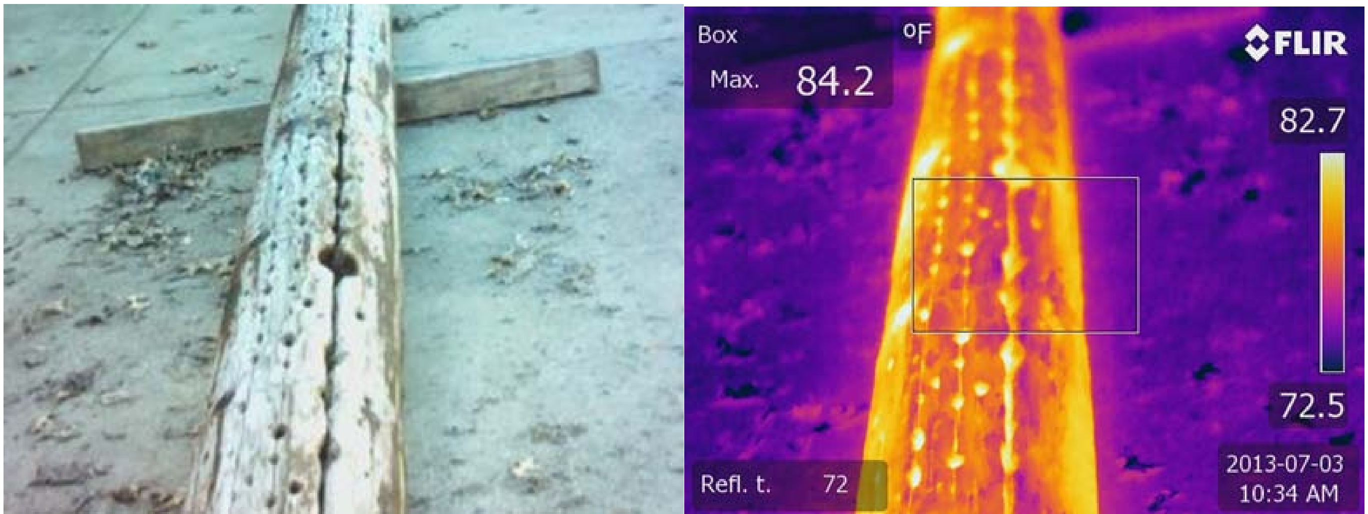

Figure III-25. Example of normal light image and an IR image of a pole a long check along with numerous woodpecker cavities.

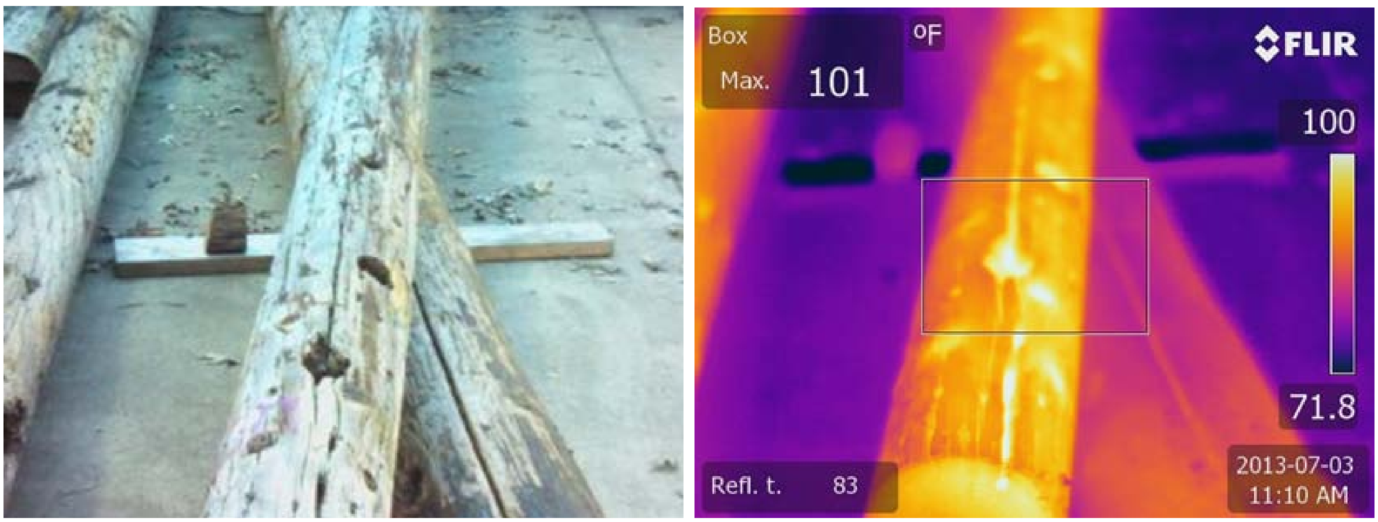

Figure III-26 Figure III-a. Example of normal light image and an IR image of a pole top showing two large woodpecker holes and a check.

inspection funds on poles most in need of action.

Figure III-27. Longitudinal cross section through a two part of a pole showing clear wood near the butt (top section) and extensive internal decay near the top (bottom section).

Figure III-28 Longitudinal cross section through a two part of a pole showing clear wood near the butt (top section) and extensive internal decay near the top (bottom section).

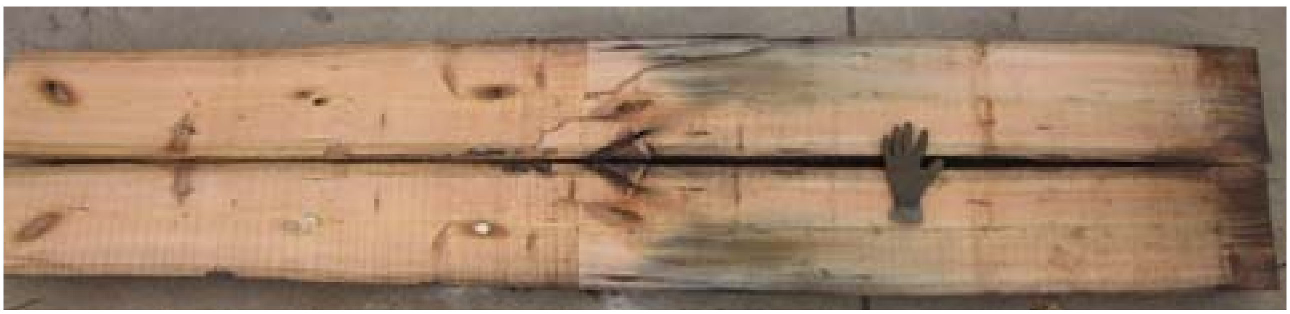

Figure III-29 Longitudinal section cut through the butt of a pole showing preservative end-penetration (left) and the sloping hole from a inspection/remedial treatment site, but no evidence of internal decay.

Figure III-30. Longitudinal section through a pole showing a woodpecker gallery associated with extensive internal decay.

Figure III-31. Longitudinal section through a pole showing a wood pecker entry point and some associated damage. This pole corresponds to the images in Figure III-c.

F. Performance of Southern Pine Stakes Treated with Pentachlorophenol in Diesel or HTS Solvent

There has been considerable controversy over the use of biodiesel as a co-solvent for treatment of wood with pentachlorophenol (penta). Extensive laboratory trials indicated that the presence of biodiesel did not negatively affect the performance of penta in southern pine sapwood blocks, but the artificial nature of laboratory tests can sometimes produce anomalous or misleading results. The best way to evaluate preservative performance is to test under field conditions at a number of sites with varying environmental conditions. This process can take many years to produce meaningful results under some conditions, but one way to accelerate the process is to use smaller test media with increased surface to volume ratios that magnify the decay effects. Fahlstrom stakes are an excellent example of this approach, wherein traditional 19 mm by 19 mm stakes are replaced with 4 x 38 x 254 mm long stakes. The smaller stakes magnify any surface decay effects, producing results much earlier in an exposure process.

In this report, we describe field test results of Fahlstrom stakes treated with penta using diesel or a biodiesel (HTS) amended solvent and exposed at two sites for 18 to 43 months.

Southern pine sapwood stakes were prepared and treated by Forest Products Research Laboratory Inc. personnel according to the procedures described in AWPA Standard E7 and supplied to OSU for exposure. Stakes were treated with diesel or HTS solvent alone to serve as solvent controls. Additional sets of 20 stakes were treated to target retentions of 0.1, 0.2, 0.3 or 0.6 pounds per cubic foot of penta (1.6, 3.2, 4.8, and 9.6 kg/m^3). An additional 30 stakes were treated to 0.6 pcf with penta in either diesel or HTS. The latter stakes were intended for periodic removal to assess preservative depletion. The treated stakes were allocated to two groups, one for exposure in Oregon and the other for exposure in Hawaii.

The Oregon exposure site was sprayed with glyphosate just prior to setting stakes. A synthetic landscape fabric was then placed on the site and a metal dibble was used to create holes for the stakes. While the fabric creates a slightly different exposure than allowing vegetation to accumulate around the stakes, we felt that it would avoid the need to mow or remove grass, thereby reducing the risk of stake damage. The treated stakes were then buried in soil to half their length approximately 300 mm apart. The Oregon site has a maritime climate and receives approximately 1.15 m of rainfall per year, primarily between October and June. The Hawaii site is sub-tropical, has a well-drained volcanic clay soil and receives nearly 5 m of rainfall per year.

Stake condition was evaluated at the Oregon site after 1 year of exposure while stakes at the Hawaii site were assessed after 6, 12, 24, 31 and 43 months of exposure. Each stake was removed from the soil, wiped clean and probed with small screwdriver for evidence of softening. Stake condition was rating on a scale from 10 to 0 as described in AWPA Standard E7 where:

Grade No.	Description of Condition
10	Sound. Suspicion of decay permitted
9	Trace decay to 3% of cross section
8	Decay from 3 to 10% of cross section
7	Decay from 10 to 30% of cross section
6	Decay from 30 to 50% of cross section

4 Decay from 50 to 75% of cross section
0 Failure

In some cases, the fragile condition of the stakes made removal from the soil difficult. The Hawaii site has no termite activity, while the Oregon site has minor termite activity. No evidence of termite activity was observed on the stakes. Depletion stakes were also removed from the Hawaii site after 31 months for residual preservative analysis. The stakes were removed and the bottom 50 mm, top 60 mm and the 50 mm zone around the groundline were removed, ground to pass a 20 mesh screen and analyzed for penta by X-ray fluorescence spectroscopy. These values were compared with matched retained pieces that had not been exposed in the field.

Activity at the Oregon site was very limited, with only minor damage to any of the stakes. The location chosen was near the bottom of the test site and was extremely wet for most of the year. We suspect that it was too wet and presented an oxygen-limiting environment. We have moved the stakes to a better drained site. For the present, the ratings for all samples from this site were at or near 10, indicating little or no decay activity.

Fungal activity at the Hawaii test site was markedly greater with evidence of early failures after only 6 months of exposure (Table III-4 and 5). Stakes treated with either diesel or HTS alone both exhibited evidence of decay within 6 months of exposure and their condition continued to decline over the remainder of the test. Both sets of stakes have completely failed. Interestingly, two non-solvent treated stakes remain in test, although they are badly decayed. It is unclear why these stakes continue in service, although they may contain some heartwood.

The condition of stakes treated with lower levels of penta in either solvent also steadily declined

Table 111-4 Average condition of Fahlstrom stakes treated to varying retentions with pentachlorophenol in either diesel or HTS and exposed in Hilo Hawaii for 43 months.

Retention (lbs/ft^3)	Carrier	Reps	Average Condition Rating[1]				
			6 mo	12 mo	24 mo	31 mo	43 mo
0	Diesel	10	7.7 (4.2)	5.6 (4.9)	0 (0)	0 (0)	0 (0)
0.1	Diesel	10	9.7 (0.9)	4.9 (5.2)	1.7 (3.7)	0 (0)	0 (0)
0.2	Diesel	10	9.9 (0.3)	8.7 (1.9)	5.1 (4.6)	2.4 (3.9)	0.4 (1.3)
0.3	Diesel	10	9.9 (0.3)	9.9 (0.3)	6.7 (4.7)	4.7 (5.0)	1.0 (3.2)
0.6	Diesel	25	9.7 (0.8)	9.8 (0.6)	8.7 (2.8)	6.7 (4.3)	6.4 (3.9)
0	HTS	10	8.8 (1.3)	2.6 (4.2)	1.0 (3.2)	0 (0)	0 (0)
0.1	HTS	10	9.6 (1.0)	6.6 (4.6)	3.3 (5.0)	2.3 (3.5)	0 (0)
0.2	HTS	10	8.8 (1.3)	6.7 (4.7)	2.9 (4.7)	1.1 (2.4)	0 (0)
0.3	HTS	10	10.0 (0)	5.1 (4.8)	2.5 (4.1)	2.6 (4.2)	0(0)
0.6	HTS	25	9.8 (0.7)	9.8 (0.4)	8.7 (2.8)	7.1 (4.3)	5.0 (4.0)
Non-treated control		5	10.0 (0)	8.2 (1.6)	2.6 (4.0)	1.8 (4.0)	1.4 (3.1)

1. Values represent means, while figures in parentheses represent one standard deviation. Ratings are discontinuous with stakes being rated 10, 9, 7, 4 or 0 at each time point as per AWPA Standard E7.

Table III-5. Stakes treated with pentachlorophenol in either diesel or HTS solvent that remained in test after 6 to 43 months of exposure in Hilo, Hawaii.

Retention (lbs/ft^3)	Solvent	Reps	Stakes Remaining in Test (%)				
			6 mo	12 Mo	24 Mo	31 mo	43 mo
0	Diesel	10	80	60	0	0	0
0.1		10	100	50	20	0	0
0.2		10	100	100	60	30	20
0.3		10	100	100	70	50	10
0.6		25	100	100	96	80	80
0	HTS	10	100	30	10	0	0
0.1		10	100	70	30	30	0
0.2		10	100	70	30	20	0
0.3		10	100	60	30	30	0
0.6		24	100	100	92	80	80
Non-treated control		5	100	100	40	20	20

over the exposure. Stakes treated with penta in diesel appeared to follow more of a dose response curve, with increased ratings with higher target retentions (Figure III-31). Stakes treated with lower levels of penta in HTS had relatively uniform ratings regardless of retention. The reasons for the lack of a dose response between 0.1 and 0.3 pcf with this solvent are unclear. Stakes treated with 0.1 or 0.2 pcf penta tended to experience heavy attack regardless of solvent, while stakes treated with 0.3 pcf penta in diesel performed slightly better than the 0.3 pcf penta in HTS stakes. The differences could reflect the slightly higher retention level. Stakes treated to the target retention of 0.6 pcf with either diesel or HTS had similar ratings after 6, 12, 24, 31 and

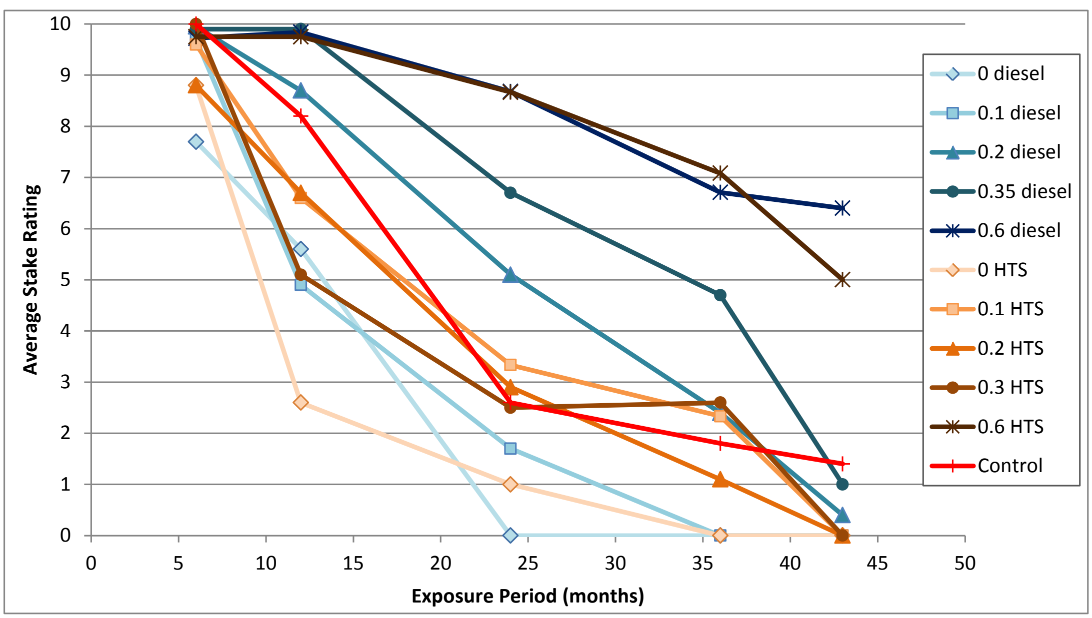

Figure III-31. Condition of stakes treated with pentachlorophenol in either diesel or HTS solvent and exposed in soil for 43 months at a test site near Hilo, Hawaii.

43 months. Thus, while there were sometimes differences in ratings over the 43 month test, the differences were not consistent and the two biocide/solvent systems generally performed similarly.

Stakes treated with the two preservative systems experienced similar failure rates over the four year test (Table III-5). Stakes treated to increasing retentions of penta in diesel experienced decreasing failure rates with dosage, while those treated with penta in HTS had similar failure rates when treated to 0.1 to 0.3 pcf penta (Table III-5). Stakes treated to a target level of 0.6 pcf penta had similar failure rates for the two solvents and an equal number of stakes remaining in test at the end of 43 months.

Penta analysis of stakes treated to the target retention of 0.6 pcf and not exposed under field conditions indicated that the actual retentions were much lower than the target. Stakes treated with penta in diesel oil had average retentions of 0.323 pcf while retentions in stakes treated with penta in HTS oil averaged 0.212 pcf. The reasons for the lower retentions are unclear; however, they suggest that the long term performance of the stakes could be reduced in comparison with wood treated to the proper retention.

Penta retentions in stakes after 31 months of field exposure in Hawaii were much lower than the non-exposed stakes (Table III-6). Stakes treated with penta in diesel averaged 0.074 pcf in the below ground zone, 0.105 pcf in the groundline and 0.168 pcf near the top. Stakes treated with penta in HTS had lower retentions with 0.019 at the bottom, 0.033 at groundline and 0.053 pcf at the top. The penta in HTS treated stakes would be expected to have lower retentions since they contained less preservative at the start of the test however, the differences after 31 months were not proportional to the original retention differences.

Stakes assayed after 43 months of exposure contained lower levels of penta than those examined after 31 months, reflecting the continued depletion from these very thin test pieces (Table III-6). No penta was detected in the stakes treated to 0.6 pcf using diesel as the solvent, while the below ground portion of the stakes treated to 0.6 pcf using HTS could not be retrieved. In both cases, the stakes were approaching the end of their effective service live. Penta retentions in samples removed from the groundline region of the stakes tended to be much higher in samples treated using diesel as the solvent. While this was consistent with the 31 month data, the dif-

Table III-6. Pentachlorophenol retentions at selection locations on southern pine sapwood stakes immediately prior to exposure and after 31 or 43 months of exposure in Hilo, Hawaii.[1]

Solvent	Time (months)	Pentachlorophenol Retention (lb/ft^3)			
		Initial retention	Bottom	Groundline	Top
Diesel	31	0.323 (0.106)	0.074 (0.028)	0.105 (0.030)	0.168 (0.023)
	43		0	0.074	0.217
HTS	31	0.212 (0.036)	0.019 (0.006)	0.033 (0.040)	0.053 (0.017)
	43		0	0.012	0.034

1. Values represent means of 13 stakes in the initial retention and four stakes for each solvent in the field exposed materials. Figures in parentheses represent one standard deviation ferences had increased, suggesting that penta had depleted more quickly from the HTS treated material. Penta retentions in stakes removed at 43 months were also extremely low at or below groundline, regardless of solvent. While penta retentions in the diesel stakes were higher, it is important to remember that they were initially higher as well. Penta retentions in the top of the stakes were 0.169 and 0.099 pcf, for the diesel and HTS treated stakes, respectively. These differences are somewhat proportional to the original retention differences (66 % more penta in the 0.6 pcf diesel stakes at time 0 vs. 59 % more penta at the end of the test).

The stakes used in these tests expose an extreme level of surface area and are not designed for either depletion studies or long term tests. They are designed to produce results rapidly and the early failures in both treatments clearly illustrate the accelerated nature of these trials. Interestingly, while the penta levels in both treatments have depleted to levels below the typical threshold for penta (approximately 0.15 pcf) and the stakes treated with penta in HTS have even lower levels, the stakes treated to the retention specified for utility poles (0.60pcf) were performing similarly with both solvents.

The original intent of these tests was to determine if there were performance differences due to the solvent. While the depletion data differed after 43 months of exposure, the condition of the stakes treated with penta in diesel and HTS did not differ. Solvent can have dramatic effects on penta performance and our data suggestions that, while there are residual differences in chemical level, penta continues to perform comparably well in either solvent.

These tests have been removed and will be replaced by a more comprehensive stake test evaluating both penta and copper naphthenate in a range of solvents.

G. Effect of Biodiesel on Field Performance of Pentachlorophenol and Copper Naphthenate: A Preliminary Proposal

Over the past 2 years, we have developed a large volume of data on the effects of biodiesel on the performance of copper naphthenate and pentachlorophenol; however, the majority of these data have been produced in laboratory soil block tests and the limited field data was developed using a specific oil blend that contained biodiesel on very thin stakes that accelerated depletion. There is a need for data examining the effects of biodiesel as an additive or co-solvent when added to solutions of either of these biocides with more generic diesel.

U.S. Forest Products Laboratory field stake data indicates that retention of penta in wood is related to the type of oil. Aromatic oils perform better than naphthenic oils, which perform better than paraffinic oils. This data was developed without co-solvents at a time when solvents used in the wood treating industry were specially prepared by each treater. There are very few oils specially made for wood treating and most treaters either use diesel as a diluent for specially prepared concentrates of penta or they blended their own oils that have the ability to achieve the require penta solvency. Very few of these oils have been subjected to extensive field testing. One of the most controversial additives has been biodiesel, which has been added to some oils to enhance penta solvency and control odors. While limited testing suggests that at least one biodiesel blend had no negative effect on penta performance, this same oil had a negative effect on copper naphthenate. These results suggest the need for data examining the effects of biodiesel as a co-solvent with various types of petroleum solvents.

Solutions of copper naphthenate and pentachlorophenol will be used to impregnate Douglas fir sapwood stakes and these stakes will be exposed at two sites in Oregon where their condition will be monitored on a regular basis according to procedures described in American Wood Protection Association Standard E7.

Freshly sawn Douglas-fir lumber with a high percentage of sapwood was obtained and kiln dried to a target moisture content of 19 %. The dried lumber was then cut into stakes (19 by 19 by 600 mm long) that were sorted to ensure that they were at least 90 % sapwood. The stakes were conditioned to a stable weight at 23 C and 65 % relatively humidity before being weighed and allocated to treatments in groups of 20. These longer stakes will be used so that the middle 50 mm of each stake can be cut out and retained for retention analysis and one sub-stake from each end can be allocated to one of two exposure sites.

The stakes will be pressure treated with solutions containing pentachlorophenol or copper naphthenate in mixtures of petroleum solvents including #2 diesel and biodiesel to produce a net oil retention of approximately 192 kg/m^3. Since previous tests suggest that there is little difference in performance of the various biodiesels, a single soy based source will be used for all tests. The stakes will be placed in the pressure treatment vessel and a small amount of initial pressure (30 psi) will be applied before the treating solution is introduced and the pressure increased to 150 psi. The pressure will be released, the stakes will be removed, wiped clean and weighed to determine net solution uptake. The difference between initial and post-treated weight will be used to calculate net solution uptake. The stakes will then be covered for 48 hours to minimize drying before being allowed to air-dry. Once dry, each stake will be cut to produce two 275 mm long stakes and a residual 50 mm center piece that will be used for initial chemical retention.

The treated stakes, along with non-treated control stakes, will be set in the ground to one half their lengths at field sites near Corvallis, Oregon. One set will be placed in an open field near the OSU Peavy Arboretum test site, and the other set will be placed in forest soil. Ten stakes per solvent combination/preservative retention will be installed at each site. Stake condition will be visually assessed at 12 month intervals at each site using the scale outlined in AWPA Standard E7.

An additional 20 stakes will be treated with each solvent combination to a target retention of 0.6 pcf (9.6 kg/m^3) penta or 0.08 pcf (1.28 kg/m^3) copper naphthenate (as Cu). These stakes will be used to assess preservative depletion over time. Five stakes from each solvent combination at each test site will be removed after 1 and 2 years for analysis of residual preservative retention.

Each preservative depletion stake will be cut to recover a 50 mm long section from the area at and beneath the groundline as well as 40 to 90 mm above the zone. In addition, we may collect additional samples from the bottom and top 50 mm of each stake. The resulting wood from a given zone for each stake will be ground to pass a 20 mesh screen prior to being analyzed for residual preservative by x-ray fluorescence spectroscopy. Results will be compared with similar analyses of the original retained portion of each stake.

H. Effect of Boron Pre-treatment on Performance of Preservative-Treated Douglas-fir Poles

Douglas-fir heartwood has a well-deserved reputation for being difficult to impregnate with preservatives. While through-boring, radial drilling and deep incising can all improve treatment, their application is generally limited to the groundline zone. While this represents the area with the greatest risk of internal decay, fungi can attack non-treated heartwood above this zone. Decay above ground poses a major challenge in terms of future risk. A variety of entities are attaching equipment to poles and almost all are field-drilling holes for these attachments. While most specifications require preservative treatment of field damage such as holes, these specifications are routinely ignored.

Non-treated field-drilled holes represent access paths into the non-treated heartwood. While the holes are above ground where the progression of fungal attack and decay development will be slower, these sites will eventually become decay sites. Under Objective II, we have examined simple methods for treating these holes using boron compounds and have also evaluated the potential for using preservative-coated bolts, but none of these practices have been adopted or have led to changes in practices.

Another approach to reducing the risk of decay in non-treated heartwood might be to initially treat poles with a water diffusible chemical such as boron or fluoride prior to seasoning and treatment. The diffusible chemical would move into the heartwood as the pole dried and then be over-treated with a conventional oil-borne preservative such as copper naphthenate, pentachlorophenol or creosote.

We explored this possibility in the 1980s in order to reduce the risk of fungal colonization during air-seasoning, first with ammonium bifluoride (fluoride) and later with disodium octaborate tetrahydrate (DOT). The results with fluoride were initially promising. Poles were flooded with a 20 % solution of ammonium bifluoride and then exposed at four sites in the Pacific Northwest and California. Fungal colonization was assessed by removing increment cores for culturing over a 3 year period. The percentage of cores containing basidiomycetes was initially low at all sites, but steadily increased at the wetter sites (Table III-7). The results indicated that fluoride could initially limit fungal colonization, but eventually a more weather-resistant treatment would be required.

In a follow up study, Douglas-fir pole sections were either dipped for 3 minutes in a 20 % boric acid equivalent (BAE) solution of DOT or sprayed at 6 month intervals with a 10 % solution of DOT and exposed for 1 to 3 years near Corvallis, Oregon. Dip treated pole sections contained

Table III-7. Basidiomycete isolations from Douglas-fir poles sections with or without an ammonium bifluoride treatment after 1 to 3 years of exposure in various locations in the Pacific Northwest (from Morrell et al., 1989)

Seasoning location	Cores Containing Basidiomycetes (%)					
	Non-Treated			Fluoride Treated		
	1 Yr	2 Yr	3 Yr	1 Yr	2 Yr	3 Yr
Arlington,WA	39	74	71	14	38	69
Scappoose,OR	27	56	76	14	36	45
Eugene,OR	36	52	72	12	19	35
Oroville,CA	29	39	37	8	11	12

Table III-8. Basidiomycete isolations from Douglas-fir poles sections with or without a disodium octaborate tetrahydrate treatment after 1 to 3 years of exposure in various locations in the Pacific Northwest (from Morrell et al., 1991)

Treatment	Cores Containing Basidiomycetes (%)		
	Year 1	Year 2	Year 3
Control	23	59	87
Dip	9	47	30
Sprayed (0/6 mo)	19	43	61

much lower levels of basidiomycetes 1 year after treatment than non-treated controls, but isolation levels were similar after 2 years of exposure (Table III-8). Spray treatments followed similar patterns, even when the sprays were applied at 6 month intervals.

These results indicate that both boron and fluoride have the potential for limiting fungal attack, but their protective effect is limited and they must be followed with a traditional non-diffusible wood preservative to ensure the wood is protected.

The potential for using boron as a pre-treatment has also been explored on railroad ties in the southern United States. Extensive studies at Mississippi State University have clearly demonstrated that a dip or pressure treatment with boron followed by air seasoning and then creosote treatment markedly improved the performance of ties and this approach is now widely used by the mainline railroads. Boron may also have a value as a pre-treatment for utility poles. In order to assess this potential, we have undertaken the following test.

Freshly peeled Douglas-fir pole sections (2.4 m long by 250-300 mm in diameter) were selected for the test. The pole sections were pressure treated with a 7 % solution (BAE) of DOT, then six increment cores were immediately removed from two sides near the middle of each pole. The cores were divided into 25 mm segments from the surface to the pith and then combined by depth for each pole. The combined cores were dried then ground to pass a 20 mesh screen before being extracted in hot water and analyzed for boron according to procedures described in AWPA Standard A65. There is currently no AWPA specified retention for borate treatment for this purpose. The current AWPA Standard for borate pre-treatment of ties specifies 2.7 kg/m^3 of boron (as B_2O_3, equal to 4.9 kg/m^3 BAE); however, our data suggests that the threshold for boron for protecting Douglas-fir from internal decay is far lower (0.8 kg/m^3). Clearly, a proper treatment level will need to be determined. For the purposes of this discussion the tie level will be used, although it is probably too high.

Five poles were set aside to air-dry and not subjected to further treatment. Five of the remaining ten poles were then kiln dried to the target moisture content of 25 % 50 mm from the pole surface, then pressure-treated with copper naphthenate to the AWPA U1 UC4B target retention of 0.095 pcf (as Cu). The remaining five poles were pressure treated with copper naphthenate to the same retention using Boulton seasoning. Following treatment, all of the poles were returned to the lab at OSU, where cores were again removed as described above and the resulting sawdust analyzed for boron content as described above. In addition, eight additional cores were taken from each copper naphthenate-treated pole so that the outer 6 to 25 mm could be assayed for copper by x-ray fluorescence spectroscopy.

As expected, boron retentions (as kg/m^3 BAE) were highest in the outer 25 mm of each pole, ranging from 4.56 to 15.17 kg/m^3 immediately after treatment but before drying (Table III-9). With the exception of one pole, retentions were extremely low in the next 25 mm inward and remained low to the center of the poles. These results are typical of short term pressure treatment of Douglas-fir poles.

Table III-9. Boron levels in Douglas-fir poles immediately after pressure treatment with disodium octaborate tetrahydrate and prior to drying/treatment.

Pole #	Treatment	Boron retention (Kg/m^3 BAE)					
		Distance from the surface of the pole (mm)					
		0-25	25-50	50-75	75-100	100-125	125-150
758	air-dried no CuNaph	15.17	8.85	0.36	0.30	5.85	7.95
761	air-dried no CuNaph	10.29	0.10	0.03	0.03	0.08	0.03
765	air-dried no CuNaph	7.23	0.11	0.08	0.08	0.08	0.31
786	air-dried no CuNaph	5.90	0.05	0.00	0.03	0.00	0.05
787	air-dried no CuNaph	7.16	0.16	0.00	0.07	0.00	0.35
759	boultonized CuNaph	10.30	0.21	0.16	0.08	0.73	0.11
760	boultonized CuNaph	7.22	0.09	0.12	0.06	0.11	0.02
762	boultonized CuNaph	7.47	0.11	0.11	0.07	0.09	0.05
763	boultonized CuNaph	10.24	0.23	0.06	0.08	0.05	0.08
764	boultonized CuNaph	4.56	0.12	0.05	0.04	0.08	0.06
766	kiln dried CuNaph	10.57	0.14	0.07	0.05	0.02	0.03
767	kiln dried CuNaph	11.66	0.19	0.08	0.00	0.16	0.11
770	kiln dried CuNaph	8.42	0.15	0.02	0.02	0.00	0.05
788	kiln dried CuNaph	14.21	0.24	0.16	0.08	0.07	0.00
789	kiln dried CuNaph	9.71	0.11	0.04	0.10	0.00	0.03
Average		9.34	0.72	0.09	0.07	0.49	0.61
Standard deviation		2.93	2.25	0.09	0.07	1.49	2.03

If all the boron in the pole sections immediately after treatment is considered, then the poles contained an average of 2.36 kg/m^3 BAE, or about half the required level. These values are skewed by one pole that had extremely high boron levels in four of the six assay zones. The remaining four poles had much lower boron levels and the chemical was largely confined to the outer 25 mm of the pole.

Boron levels after kiln drying were also elevated in the outer 25 mm of the pole sections, but declined sharply with distance from the surface (Table III-10). Boron levels, if averaged across the entire pole cross section would average 1.02 kg/m^3 BAE, far below the specified level. Boron levels in the outer 25 mm were lower after drying in nine of the ten pole sections and, in some cases the differences were substantial (Table III-11). Some of these reductions could be attributed to differences in sampling locations at different time points as well as to movement of boron into the next 25 mm from the surface, but the levels of loss also suggest that some of the boron was lost from the wood during drying. The results suggest that drying schedules will have to be adjusted to reduce boron loss.

Boron should become more uniformly distributed as it diffuses inward from the surface. Boron levels in the poles 2 months after treatment averaged 2.14 kg/m^3 BAE, and levels were slightly higher in the 25 to 50 mm zone inward from the surface. However, boron levels in four of the five poles in this treatment group remained very low 50 mm or further inward from the surface and the overall shape of the preservative gradient changed only slightly (Figure III-32). The results suggest that the majority of the boron remains in the outer zones of the pole.

Table III-10. Boron levels in Douglas-fir poles immediately after pressure treatment with disodium octaborate tetrahydrate and following drying/treatment.

Pole #	Treatment	Boron retention (Kg/m^3 BAE)					
		Distance from the surface of the pole (mm)					
		0-25	25-50	50-75	75-100	100-125	125-150
759	boultonized CuNaph	3.21	0.42	0.01	0.02	0.12	1.80
760	boultonized CuNaph	4.22	0.60	0.06	0.00	0.01	0.05
762	boultonized CuNaph	6.60	0.14	0.03	0.00	0.00	0.06
763	boultonized CuNaph	4.04	0.12	0.01	0.01	0.02	0.03
764	boultonized CuNaph	3.37	0.26	0.02	0.03	0.08	0.07
766	kiln dried CuNaph	3.50	0.07	0.01	0.01	0.00	0.01
767	kiln dried CuNaph	3.74	0.15	0.08	0.03	0.01	0.02
770	kiln dried CuNaph	4.30	1.06	0.12	0.06	0.31	0.13
788	kiln dried CuNaph	14.82	0.63	0.03	0.01	0.00	0.00
789	kiln dried CuNaph	6.17	0.45	0.04	0.00	0.02	0.02
Average		5.40	0.39	0.04	0.02	0.06	0.22
Standard deviation		3.50	0.31	0.03	0.02	0.10	0.56

Table III-11 Differences in boron retentions in the outer 25 mm of poles immediately after treatment and after kiln drying

Pole #	Boron Retention (kg/m^3) in the outer 25 mm		
	Pre-Drying	Post-Drying	Difference
759	10.30	3.21	7.09
760	7.22	4.22	3.00
762	7.47	6.60	0.87
763	10.24	4.04	6.20
764	4.56	3.37	1.19
766	10.57	3.50	7.07
767	11.66	3.74	7.92
770	8.42	4.30	4.12
788	14.21	14.82	-0.61
789	9.71	6.17	3.54

The poles will be re-sampled shortly and the results from these tests will be used to determine if the boron in the outer shell has begun to diffuse further inward where it is needed.

I. 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.

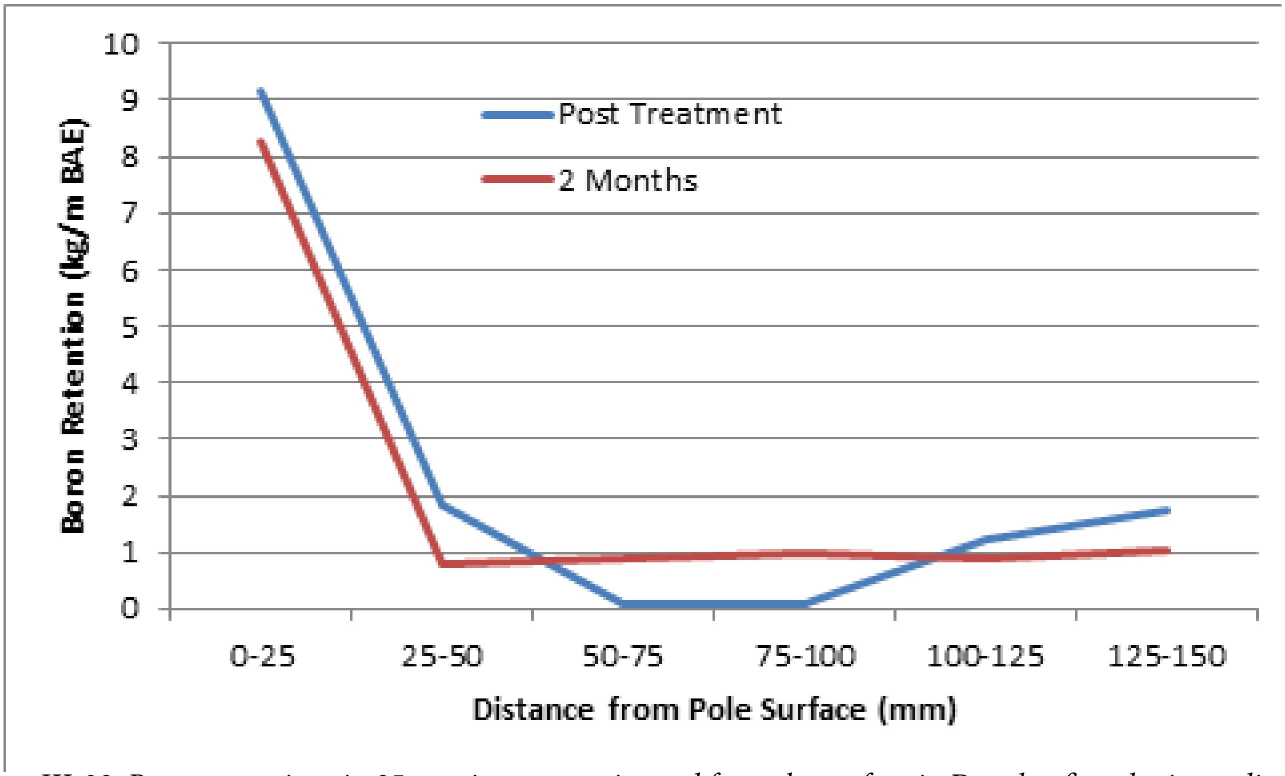

Figure III-32. Boron retentions in 25 mm increments inward from the surface in Douglas-fir poles immediately after pressure treatment with disodium octaborate tetrahydrate and again 2 months later.

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.

Figure III-33. Example of a capped pole used to assess the effects of capping on wood moisture content.

Initial moisture contents for each pole were determined during installation from increment cores taken 150 mm below the top of the pole (Figure III-33). The outer treated zone was discarded, and then the inner and outer 25 mm of 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 to 64 months after installation by removing increment cores 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 and 17 and 19 % for the outer 25 mm of non-capped and capped poles, respectively (Table III-12). The elevated levels in the inner zones of the capped poles were due to high moisture contents on one very wet pole. Moisture contents at the 4 month point in non-capped poles were slightly higher than those at the time of installation while those in capped poles had declined in both the inner and outer zones, even though sampling took place during our winter rainy season. While the moisture increases in the non-capped poles were not major, they did show the effect of capping on moisture entry.

Continued monitoring has shown that moisture levels in non-capped poles tended to increase sharply in the winter, then decline over the drier summer months. Moisture contents in the inner zones of cores removed from non-capped poles in June near the end of our rainy season have ranged from 48 % this past year to as high as 99% after 40 months in service. Moisture levels nearer the surface are much lower, reflecting the greater potential for the surface of the pole to dry as the rain stops and temperatures increase. The results indicate that moisture conditions in the pole interiors are suitable for microbial attack for a large proportion of the year.

Moisture levels in capped poles have remained consistently below 17 % since the 12 month point. These moisture regimes are far lower than those required for fungal attack, indicating that capping should virtually eliminate the risk of top decay (Figure III-34).

Moisture is critical for fungal growth and development. Maintaining wood moisture content below 20 % represents a simple method for protecting the non-treated wood in the pole interior from decay. Capping is an inexpensive method for accomplishing this task.

We will continue monitoring these pole sections over the coming seasons to establish internal moisture trends associated with the caps and to monitor cap condition.

Table III-.12 Moisture contents of increment cores removed from sites just below the tops of Douglas-fir pole sections with and without water shedding caps.

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	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
44	October	53.1	21.5	14.7	14.1
52	June	85.1	22.0	—[1]	—[1]
56	October	41.7	23.3	9.8	9.4
64	June	48.4	13.0	8.8	8.3

1. Data lost during processing

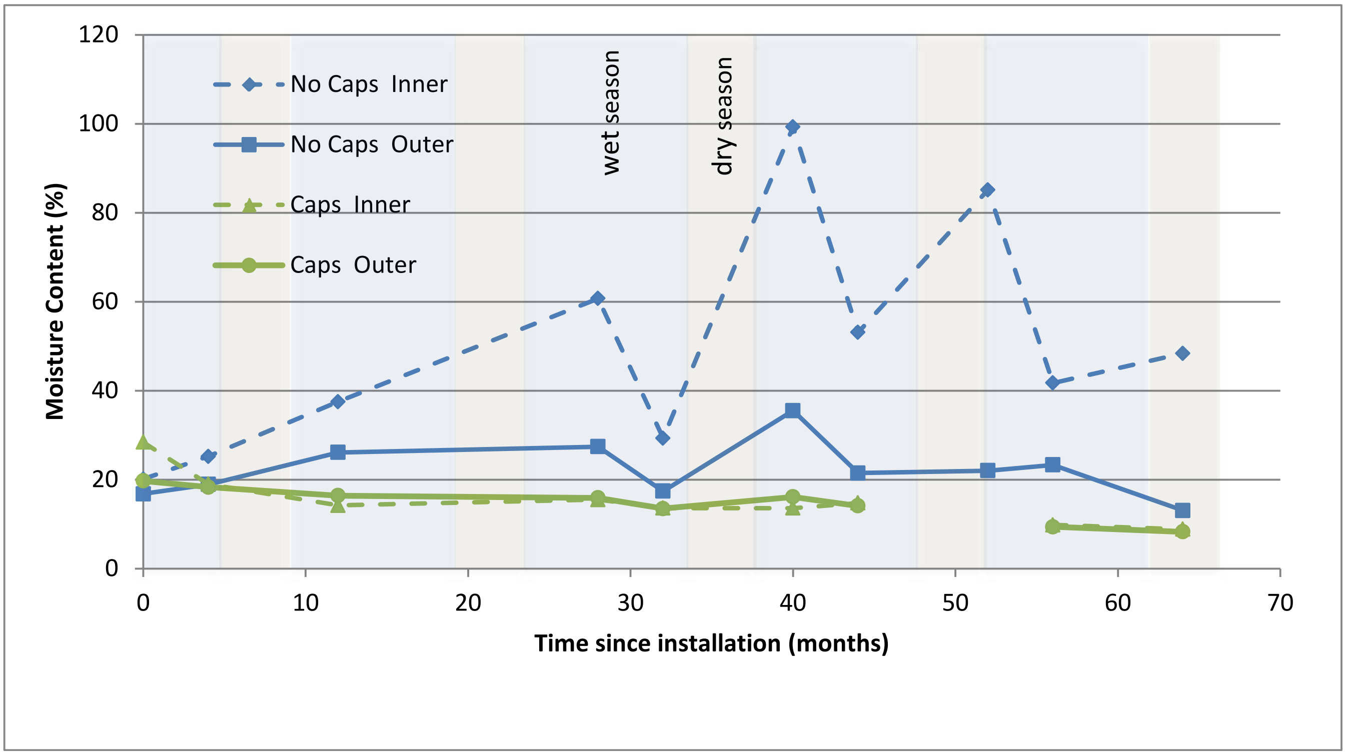

Figure III-34. Moisture contents in the inner and outer zones of increment cores removed from Douglas-fir poles with and without moisture shedding caps.

Figure III-35. Example of a polyurea coated pole top.

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

Polyurea barriers have proven to be durable on crossarm sections in sub-tropical exposures at Hilo, Hawaii. We wondered if these materials would also be effective for protecting the tops of newly installed utility 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 (Figure III-35). 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 non-coated section of the pole 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 moisture content. The sampling hole was covered with a patch of seal-fast tape (Mule-Hide Products, Beloit, WI). 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. The poles, installed in the spring of 2011, were sampled after 4, 12, 16 and 24 months of exposure to assess the effect of the coating on internal moisture. Increment cores were removed in the same manner as previously described and moisture content was determined for each pole. Non-coated, non-capped poles from the previously-installed moisture shedding pole cap study served as controls. The condition of the surface coating was also visually monitored for evidence of adhesion with the wood as well as the development of any surface degradation.

Pole moisture contents declined sharply over the first 4 months of exposure and averaged 5.9 and 7.5 % for the inner and outer zones, respectively (Figure III-36). Moisture levels continued to decline over the next 8 months through the rainiest part of the year (Table III-13). Moisture contents have risen over the past 12 months but are all still below 18 % moisture content. The threshold for fungal attack is typically considered to be the fiber saturation point or approximately 30 % moisture content. Architects and engineers generally use 20 % as the maximum moisture content for wood in buildings. This provides a margin of safety since wood moisture contents in the absence of liquid water will rarely rise above 19 %, even under the most humid conditions. Our results with the coated tops indicate that the barriers are resulting in moisture contents well below this safety level.

The results indicate that the barriers are effectively limiting moisture entry. The barriers show little evidence of weathering and appear to be in excellent condition. The coating integrity is consistent with results from the polyurea coated crossarms in Hawaii, which have been exposed for a longer period under much more severe UV conditions. We will continue to monitor these poles over time; however, the results suggest that coatings provide a reliable method for limiting moisture entry through pole tops.

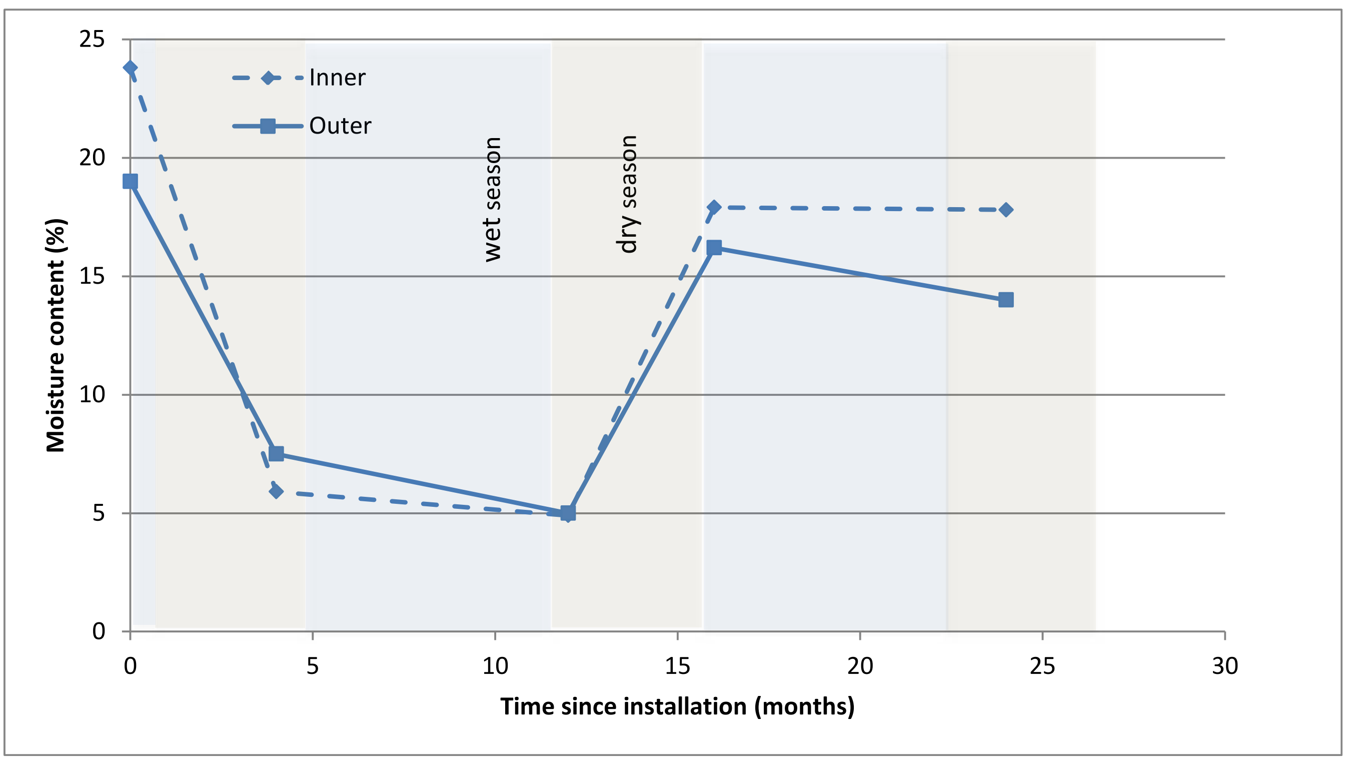

Figure III-36 Moisture contents in the inner and outer zones of increment cores removed from the tops of poles with a polyurea coating designed to shed moisture.

Table III-13. Wood moisture contents beneath the tops of Douglas-fir pole sections with polyurea caps.

Exposure (mo)	Sampling Month	Coated Poles		Control[1]	
		inner	outer	inner	outer
0	June	23.8	19.0	99.3	35.5
4	October	21.6	13.2	53.1	21.5
12	June	4.6	8.3	85.1	22.0
16	October	17.9	16.2	41.7	23.3
24	June	17.8	14.0	48.4	13.0

K. RFID Tagging of Poles for Inventory and Pole Inspection

Tracking poles through seasoning, treatment and installation, while challenging, can provide useful information such as rates of usage of different pole sizes as well as in-service pole performance. At present, there are no dependable methods for tracking a pole over its entire life. Radio-frequency identification (RFID) is a wireless, non-contact use of radio-frequency electromagnetic fields to collect and transfer data. RFID is widely used for unobtrusively tracking people, materials and a host of other items. In principal, RFID tags could be placed on poles at the time of peeling so individual poles could be tracked through drying, preservative treatment, storage in a pole yard, installation, and ultimately field performance. The data on an individual RFID chip could be as simple as a unique number that is linked to a data file or, in more elaborate systems, specific information on a given structure.

In terms of inventory, treatment facilities would tag logs at the butt either as soon as they arrived at the plant or after they were peeled and cut to length. Treaters could also set up an antennae array at the entrance to their facility that would detect any tags moving in or out of the facility. Tags could simply contain pole class, pole length and a date so that inventory could be tracked or they might contain more detailed information such as preservative retention, the presence of pretreatments (through-boring, Star-Loks, etc.) and the intended utility. Every pole leaving the facility would be tracked. Utilities could set up similar arrays at their store yards so that they could track poles as they entered and left the facility. RFID butt tags could serve this function, but would be of little use once the pole was installed. Utilities considering using RFID tags for in-service monitoring would likely place another tag near the current brand or belly tag. This tag might contain more information or it might merely contain a unique identifier that could link to company service records so that field inspectors, line crews or other utility personnel could readily access information on a given structure from their data base. This data base might include prior condition assessments, treatment data or even joint use information that can be compared with the current pole configuration.

The American Wood Protection Association has recently established a task group to examine standardization of tags for wood poles and are discussing the possible use of RFID tags for poles with several manufacturers of these tags. Ideally, an RFID tag would have the following characteristics:

1. Easily read

2. Resistant to the heat and pressure associated with the seasoning/treating processes
3. Resistant to physical damage
4. Resistant to preservatives
5. Resistant to ultraviolet light if used above ground
6. Inexpensive

The manufacturers have identified a number of possible tags and the task group is awaiting their arrival (Figure III-37). Once the tags arrive, testing will begin by exploring the ability of these tags to withstand treatment conditions. The work will initially concentrate on tagged Douglas-fir, but similar work will soon be underway on southern pine. The effects of the following processes will be examined initially:

1. Kiln drying
2. Penta treatment with Boulton seasoning
3. Copper naphthenate treatment with or without Boulton seasoning

It is anticipated that six tag types containing different materials or sealed in different ways to retard chemical penetration will be examined.

Figure III-37 Examples of several RFID tags that will be evaluated in treatment trials.

Literature cited

Morrell, J.J., R.D. Graham, M.E. Corden, C.M. Sexton, and B.R. Kropp. 1989. Ammonium bifluoride treatment of air-seasoning Douglas-fir poles. Forest Products Journal 39(1):51-54.

Morrell, J.J., M.A. Newbill, and C.M. Sexton. 1991. Basidiomycete colonization of Douglas-fir poles after polyborate treatments. Forest Products Journal 41(6):28-30.

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 from 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 (primarily copper naphthenate and boron, but more recently other organic biocides) 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. Previous External Groundline Treatment Tests

Over the past 20 years, we have established a number of field trials of external groundline preservative pastes on pole stubs at our Peavy Arboretum field test site or on poles within active utility lines. Most of these trials have been completed. A summary of these trials can be found in Table IV-1 along with references to the last annual report for which results are presented.

Table IV-1. Summary of completed tests evaluating external groundline preservatives.

Location	Year Initiated	Wood Species	Primary Treatments	Treatments tested	Manufactuer	Final report
Corvallis, OR	1989	Douglas-fir	none	CuNap-Wrap	Tenino Chem. Co (Viance)	1996
				CuRap 20 II	ISK Biosciences	
				Pol-Nu	ISK Biosciences	
				Cop-R-Wrap	ISK Biosciences	
				CRP 82631	Osmose Utilities Services, Inc.	
Corvallis, OR	1990	Douglas-fir	none	CuRap 20	ISK Biosciences	1993
				Patox II	Osmose Utilities Services, Inc.	
				CuNap-Wrap	Viance	
Merced, CA	1991	Douglas-fir W. redcedar S. pine	penta	CuNap-Wrap	Viance	2002
				CuRap 20	ISK Biosciences	
				Patox II	Osmose Utilities Services, Inc.	
Binghamton, NY	1995	W. redcedar S. pine	penta creosote	CuRap 20	ISK Biosciences	2003
				CuNap-Wrap	Viance	
				Cop-R-Wrap	ISK Biosciences	
Corvallis, OR	1998	Douglas-fir	none	Propiconazole	Janssen Pharm.	2003
				Dr. Wolman Cu/F/B	BASF	
				CuRap 20	ISK Biosciences	
Beacon, NY	2001	S. pine	penta	COP-R-PLASTIC	Osmose Utilities Services, Inc.	2009
				PoleWrap	Osmose Utilities Services, Inc.	
				Dr. Wolman Wrap Cu/F/B	BASF	
				Dr. Wolman Wrap Cu/B	BASF	
				Cobra Wrap	Genics, Inc.	
				Cobra Slim	Genics, Inc.	
Douglas, GA	2004	S. pine	creosote	Cu-Bor (paste and bandage)	Copper Care Wood Preserving, Inc.	2010
				CuRap 20 (paste and bandage)	ISK Biosciences	
				Cobra Wrap	Genics, Inc.	
				COP-R-PLASTIC	Osmose Utilities Services, Inc.	
				PoleWrap (Bandage)	Osmose Utilities Services, Inc.	

B. Performance of External Groundline Treatments in Drier Climates

External groundline preservatives are applied throughout the United States and we have previously 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 (Table IV-2). 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, hundreds of thousands of poles that were initially treated with these systems remain in service.

Each of the seven treatments (Table IV-5) 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 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 wood samples were surface sterilized then 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-3). 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.

Table IV-2. Characteristics of poles receiving external preservative treatments in the Phoenix, Arizona area.

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

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

Table IV-2 continued. Characteristics of poles receiving external preservative treatments in the Phoenix, Arizona area.

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

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

Table IV-2 continued. Characteristics of poles receiving external preservative treatments in the Phoenix, Arizona area.

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

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

The degree of chemical migration was assessed 17 months 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. Wraps on some of the poles had been damaged by animal gnawing (Figure IV-1) and this was noted wherever present. Two sections of shavings were removed using a 38 mm diameter Forstner bit; the first from the outer surface to approximately 6 mm and the second continuing in the same hole to a depth of about 13 mm. In the lab, a portion of the shavings were briefly flamed and then placed on malt extract agar in petri plates to determine if soft rot fungi were present. The remainder of the shavings sample was ground to pass a 20 mesh screen. One half was analyzed for copper and boron, if necessary, and the other half was analyzed for any organic preservative present in the system. An additional six increment cores were removed from the exposed zone. The cores were 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 was combined and ground to pass a 20 mesh screen. We also found

Table IV-3. Material properties of the pastes tested in the Arizona field trial.

Paste	lb/gal	Active Ingredient	% Active
Cu-Bor	10.1	copper hydroxide (2% metallic Cu) sodium tetraborate decahydrate	3.1 43.5
CuRap 20	10.1	copper naphthenate (2% metallic Cu) sodium tetraborate decahydrate	18.2 40.0
COP-R-PLASTIC II	12.4	sodium fluoride copper naphthenate (2% metallic Cu)	44.4 17.7
MP400-EXT	10.6	sodium tetraborate decahydrate copper-8 quinolinolate (micronized) tebuconazole bifenthrin	43.7 0.3 0.2 0.04
Osmose experimental paste	10.8	unknown (copper carbonate)	
Bioguard paste	11.0	boric acid sodium fluoride	40.8 22.5
Bioguard Tri-Bor experimental paste	11.0	boric acid Borax 5 mol (Neobor) Boroguard ZB (zinc borate hydrate)	10 40 5

it necessary to combine the wood from the outer 0 to 6 and 6-16 mm zone from several poles in a treatment to accumulate a sufficient quantity of material for copper analysis. Wood from three poles from the same utility was combined for these zones resulting in two copper analyses per treatment. The resulting wood samples were analyzed for residual chemical using the most appropriate method. Boron was analyzed by the Azomethine-H method, while copper was analyzed by x-ray fluorescence spectroscopy (XRF) or inductively-coupled plasma spectroscopy (ICP). Supplemental analysis of wood for boron by ICP was well correlated with the Azomethine-H analyses. We analyzed both cores and the shavings for copper and boron in order to determine whether the two sampling methods produced similar values. Bifenthrin was analyzed by extrac-

Figure IV-1. Poles in the APS system after excavation showing evidence of animal gnawing on the barrier bandage.

tion and gas chromatography, while tebuconazole was analyzed by extraction and high performance liquid chromatography.

The results have been expressed several ways because chemical distribution differed slightly with wood species and original treatment differences among the two utilities. In most cases, we used have used percent by weight.

Fluoride levels in poles treated with either Bioguard or COP-R-PLASTIC II (CRP II) were both well above the threshold for protection against internal fungal attack in the outer 13 mm of the poles (0.15 % wt/wt), and then declined with distance from the surface (Figure IV-2, Table IV-4). However, these levels were still below the 0.5 % (wt/wt) level believed to be protective of the pole exterior. Fluoride levels were slightly higher in the outer zone of the Bioguard treated poles. Levels for both treatments further inward from the surface were below the internal threshold although the total amount of fluoride in the sampled zone was higher with the Bioguard system (Figure IV-3). Fluoride has the ability to migrate into wood with moisture and eventually, as previous test results suggest, should become more evenly distributed within the pole cross section. Data from the Arizona test suggests that this process is occurring more slowly under drier conditions.

In addition to differences in fluoride levels between treatments, there also appeared to be some differences in levels by utility. Fluoride in Bioguard treatments appeared to be present at higher levels in poles within the APS system than in the SRP system, while the opposite was true with CRP II (Figure IV-4). It is unclear why such differences might develop, although initial treatment and pole species appear to play a role. The SRP poles were all Douglas-fir treated with penta in oil while the APS poles were pine, western redcedar and Douglas-fir variously treated with creo-

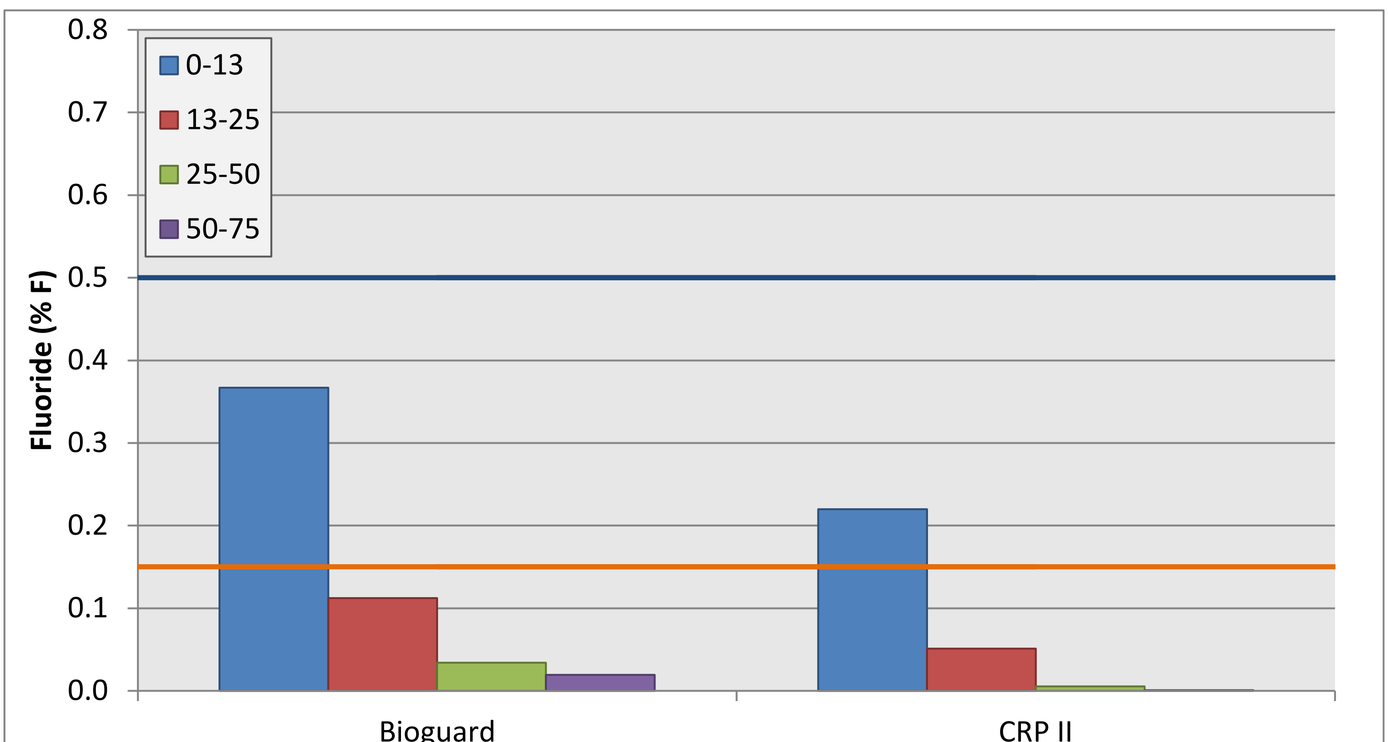

Figure IV-2. Fluoride levels with distance inward from the surface in Douglas-fir, western redcedar and pine poles 17 months after treatment with Bioguard or COP-R-PLASTIC II when all species are combined.

Table IV-4. Fluoride levels in poles of various species 17 months after application of Bioguard or COP-R-PLASTIC II.[1]

Treatment	Utility	Fluoride level (% wt/wt)			
		Distance from the surface (mm)			
		0-13	13-25	25-50	50-75
Bioguard	APS	0.47	0.13	0.04	0.03
	SRP	0.26	0.09	0.02	0.01
COP-R-PLASTIC II	APS	0.19	0.01	0.00	0.00
	SRP	0.25	0.09	0.01	0.00

1. Numbers in bold are above the toxic threshold of 0.50%F for the outer zone and 0.15 for the three inner zones.

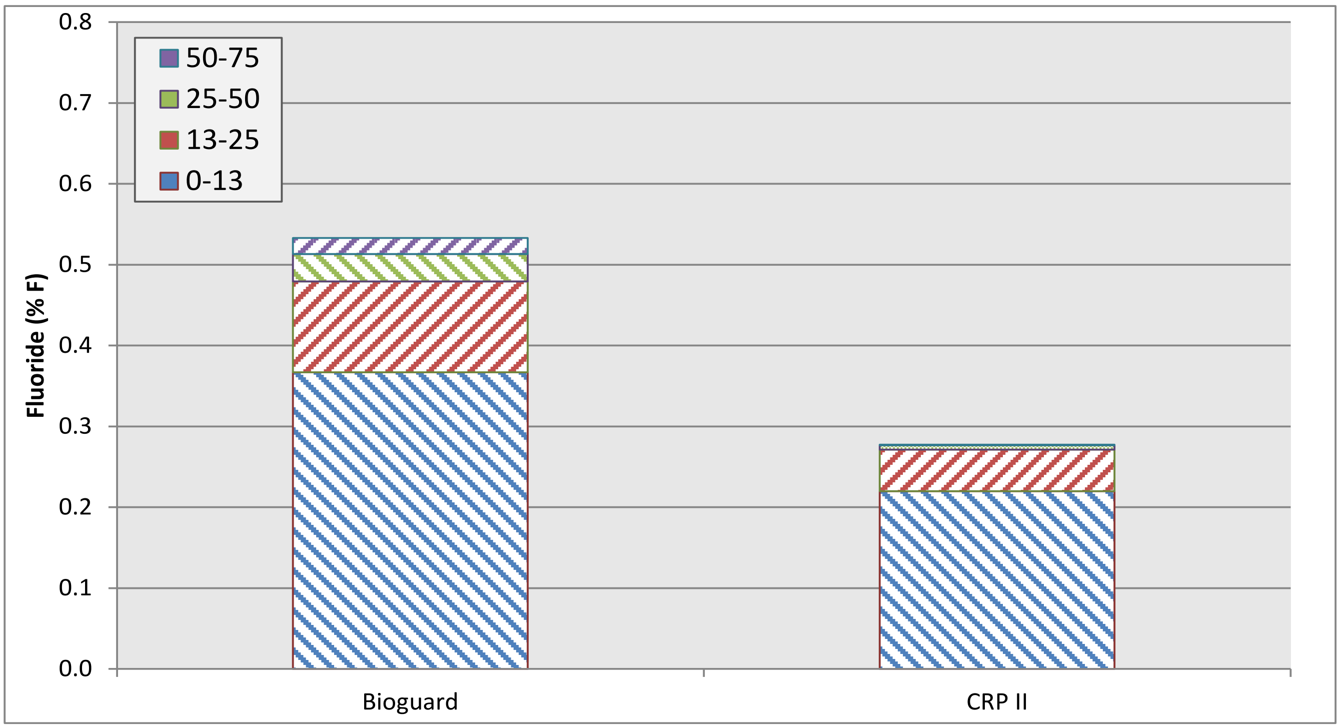

Figure IV-3. Fluoride levels with distance inward from the surface in Douglas-fir, western redcedar and pine poles 17 months after treatment with Bioguard or COP-R-PLASTIC II in a stacked bar graph where all species are combined showing the difference in total fluoride in the assay zones. Solid color bars indicate levels over the toxic threshold for the zone and striped bars indicate levels below.

sote and penta in both oil and liquefied petroleum gas. It is possible that the carriers influenced movement, although it is unclear why they might do so differentially. We will continue to monitor this test to determine if this difference is real, or merely the result of natural variation among poles.

Analysis of boron in the outer 13 mm of poles showed that chemical content in shavings or increment cores did not differ markedly with treatment (Figure IV-5, Table IV-5). As a result, we elected to use the results from cores for further discussion. Boron levels in poles treated with six different preservative pastes were all at or above the threshold for protection against external fun-

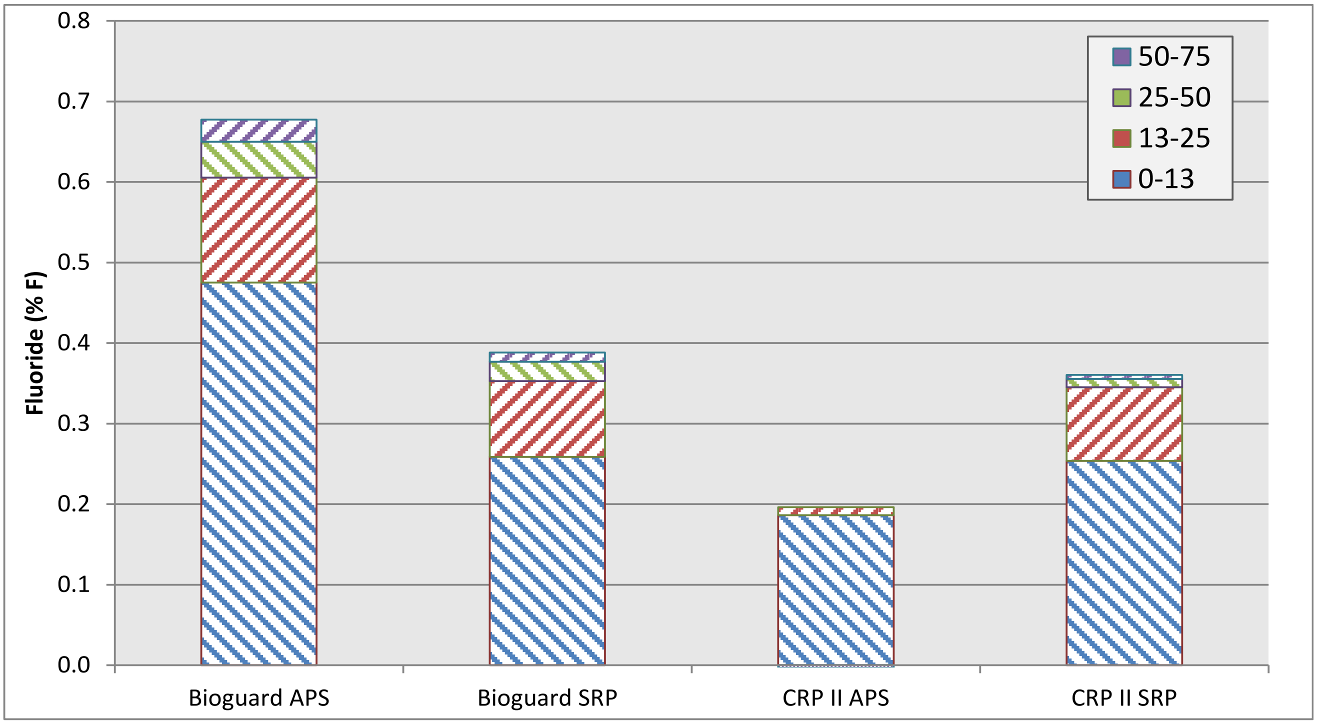

Figure IV-4. Stacked bar graphs showing fluoride levels with distance inward from the surface in Douglas-fir, western redcedar and pine poles 17 months after treatment with Bioguard or COP-R-PLASTIC II where poles segregated by treatment and utility. Solid color bars indicate levels over the toxic threshold for the zone and striped bars indicate levels below.

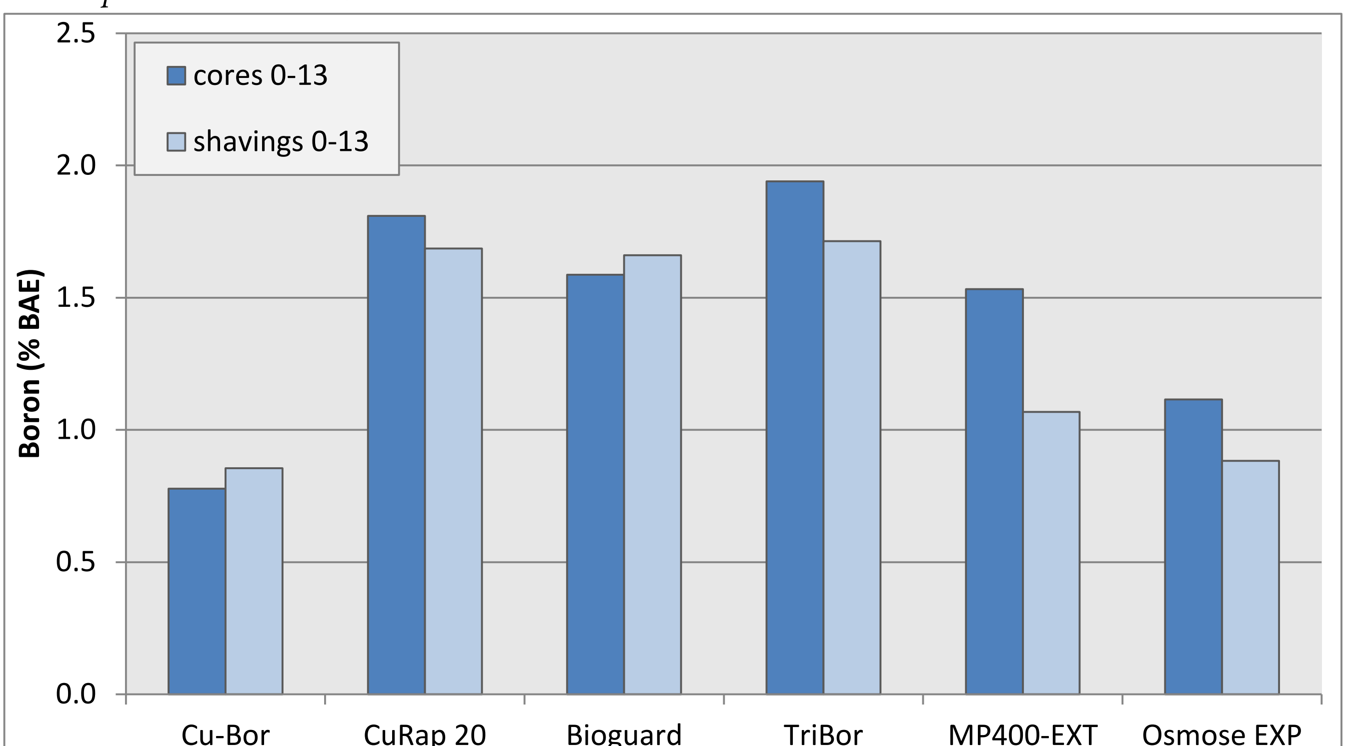

Figure IV-5. Boron content in poles of various species treated with different boron containing pastes as analyzed from either shavings collected with a Forstner bit or increment core segments.

Table IV-5. Boron levels at selected distances from the wood surface in Douglas-fir, western redcedar or pine poles 17 months after treatment with boron containing pastes with data combined for species[1].

Treatment	Utility	Boron levels (% wt/wt BAE) Distance from the surface (mm)			
		0-13	13-25	25-50	50-75
Cu-Bor	APS	**1.03**	**0.20**	0.04	0.01
	SRP	**0.53**	**0.41**	**0.14**	0.02
CuRap 20	APS	**2.53**	**0.80**	**0.14**	0.03
	SRP	**1.09**	**0.49**	**0.14**	0.05
Bioguard	APS	**2.31**	**0.78**	**0.31**	**0.13**
	SRP	**0.87**	**0.63**	**0.26**	0.09
TriBor	APS	**2.23**	**1.02**	**0.17**	0.02
	SRP	**1.65**	**0.61**	**0.19**	0.07
MP400-EXT	APS	**2.04**	**0.66**	**0.18**	**0.11**
	SRP	**1.02**	**0.47**	**0.15**	0.03
Osmose Exp	APS	**1.08**	**0.15**	0.02	0.01
	SRP	**1.15**	**0.46**	**0.15**	0.02

1. Numbers in bold are above the toxic threshold of 0.275% BAE for the outer zone or 0.10 BAE for the three inner zones.

gal attack in the outer 25 mm 17 months after application (Figure IV-6, 7). Boron levels further in from the surface declined, but were still above the threshold for protection against internal fungal attack 50 mm from the surface in all treatments. These results suggest that the boron is moving well into the poles; however, there were some interesting effects of initial treatment or wood species on the results (Figure IV-8). Boron levels in the outer zones tended to be higher in poles from the APS system than those in the SRP system except for the Osmose Experimental, where the levels were slightly lower for the APS poles. The reasons for the overall lower levels of boron in the SRP poles are unclear, but they suggest that the initial treatment can influence subsequent performance of supplemental system. The potential role of species in boron distribution was also examined; however, because samples from a given treatment were combined by treatment when copper was present, it is not possible to examine the effect of species on boron levels with the exception of the Bioguard treatment (Figure IV-9). These results are preliminary, but do suggest that field performance of external preservative systems may differ in drier climates although they also show that boron is moving at effective levels into the wood from all six of the systems tested.

Copper was present in five of the external preservative paste treatments tested. For the purposes of this test, the minimum protective threshold was assumed to be 0.15 % (wt/wt). As noted in numerous previous reports, there are no data on the effects of multiple component systems on the threshold of individual constituents; we have used the threshold for each component assuming that there is no interaction. Copper analyses of wood obtained from cores and shavings were similar for both CRP II or Cu-Bor, but the results were lower in shavings from the outer 6 mm of poles treated with CuRap 20 (Table IV-6, Figure IV-10). It is unclear why this occurred, since results were similar in the inner zones of poles receiving the three pastes. However, given the general agreement between the results, we elected to use the core analyses for comparisons. Copper was present above the threshold in the outer zones of poles receiving CRP II,

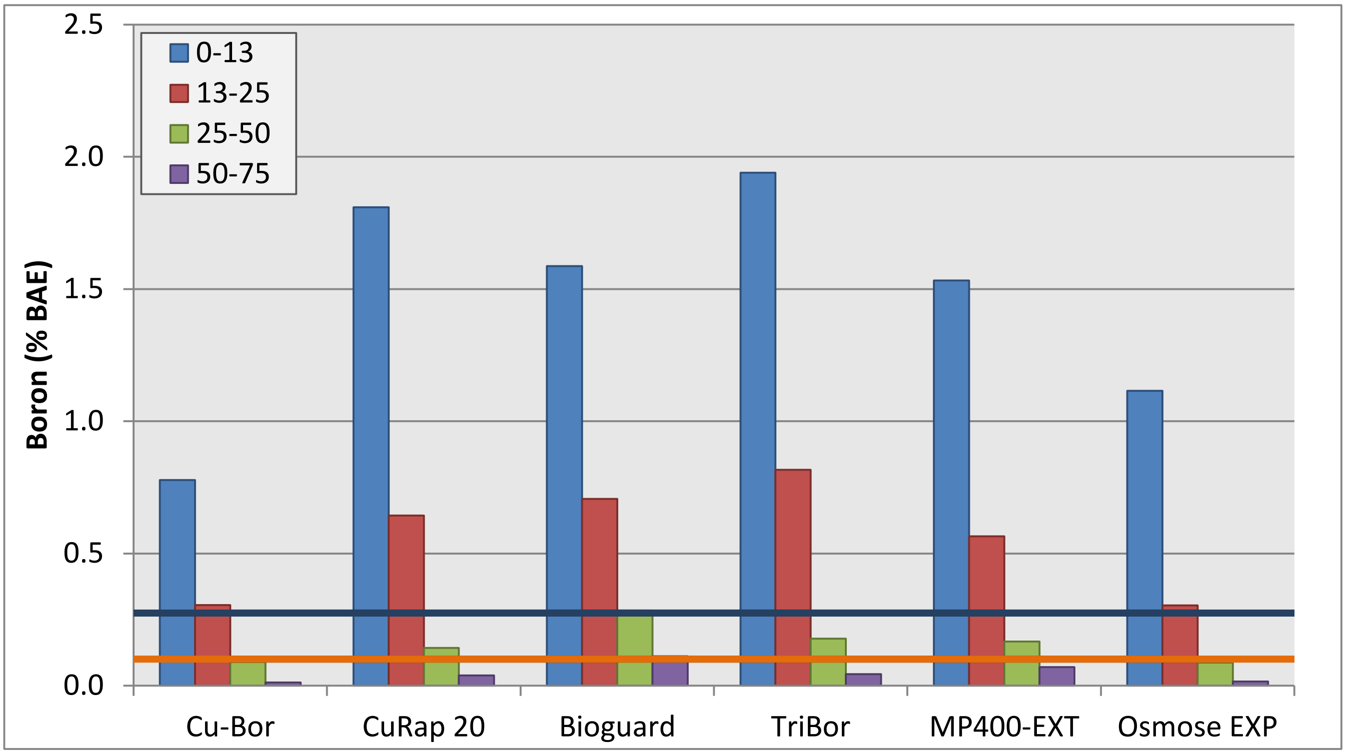

Figure IV-6. Boron levels at various distances from the surface inward in poles of various species 17 months after treatment with six different boron containing pastes.

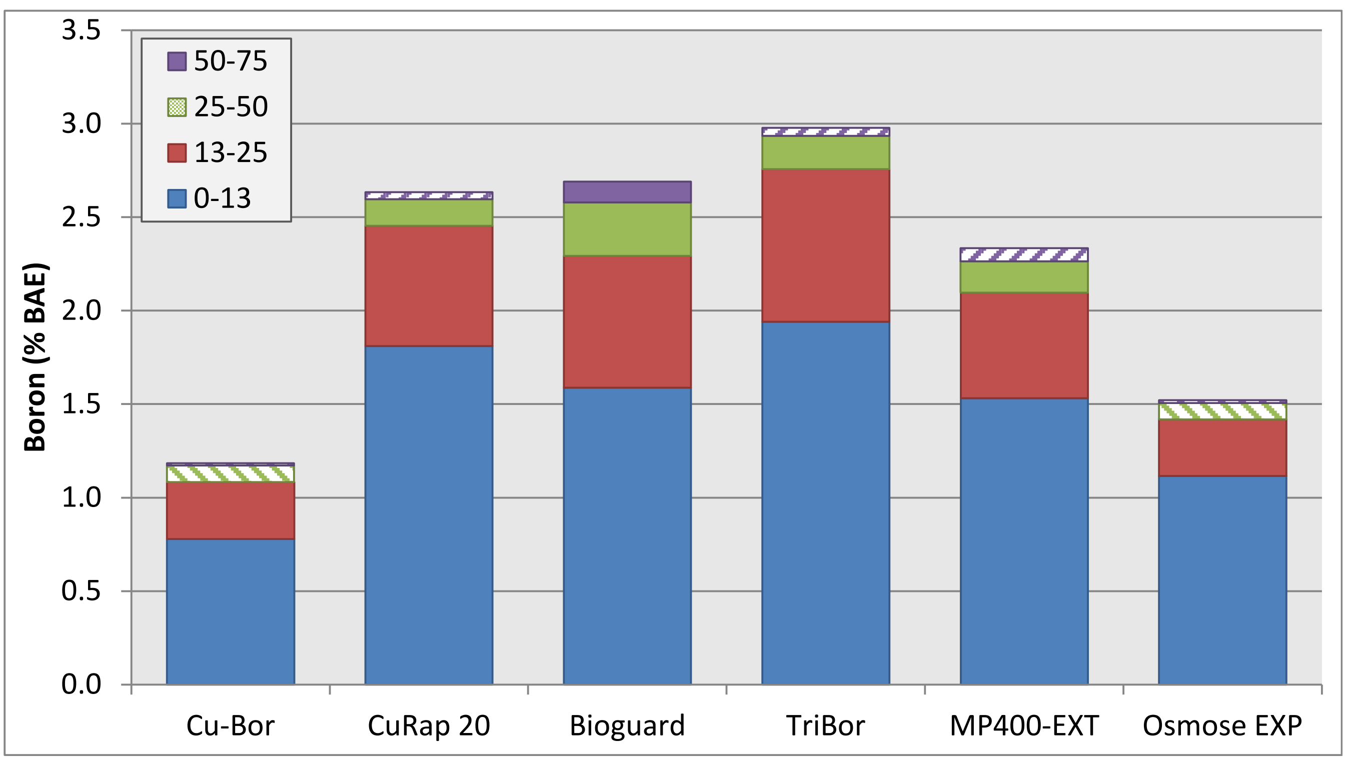

Figure IV-7. Total boron measured in the outer 50 mm of poles 17 months after treatment with selected boron-containing pastes. Solid color bars indicate levels over the toxic threshold for the zone and striped bars indicate levels below.

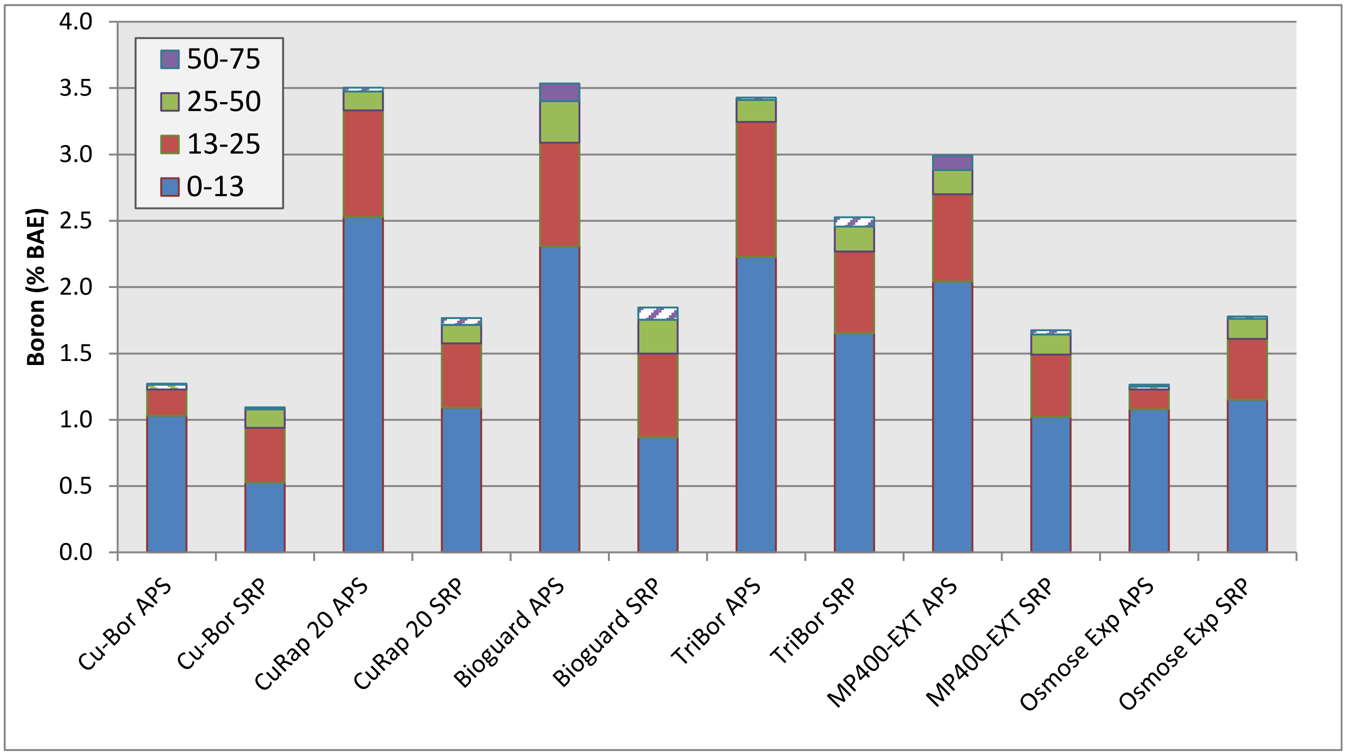

Figure IV-8. Boron content in the outer 50 mm of poles combined for species but segregated by utility 17 months after application of various boron-containing pastes. Solid color bars indicate levels over the toxic threshold for the zone and striped bars indicate levels below.

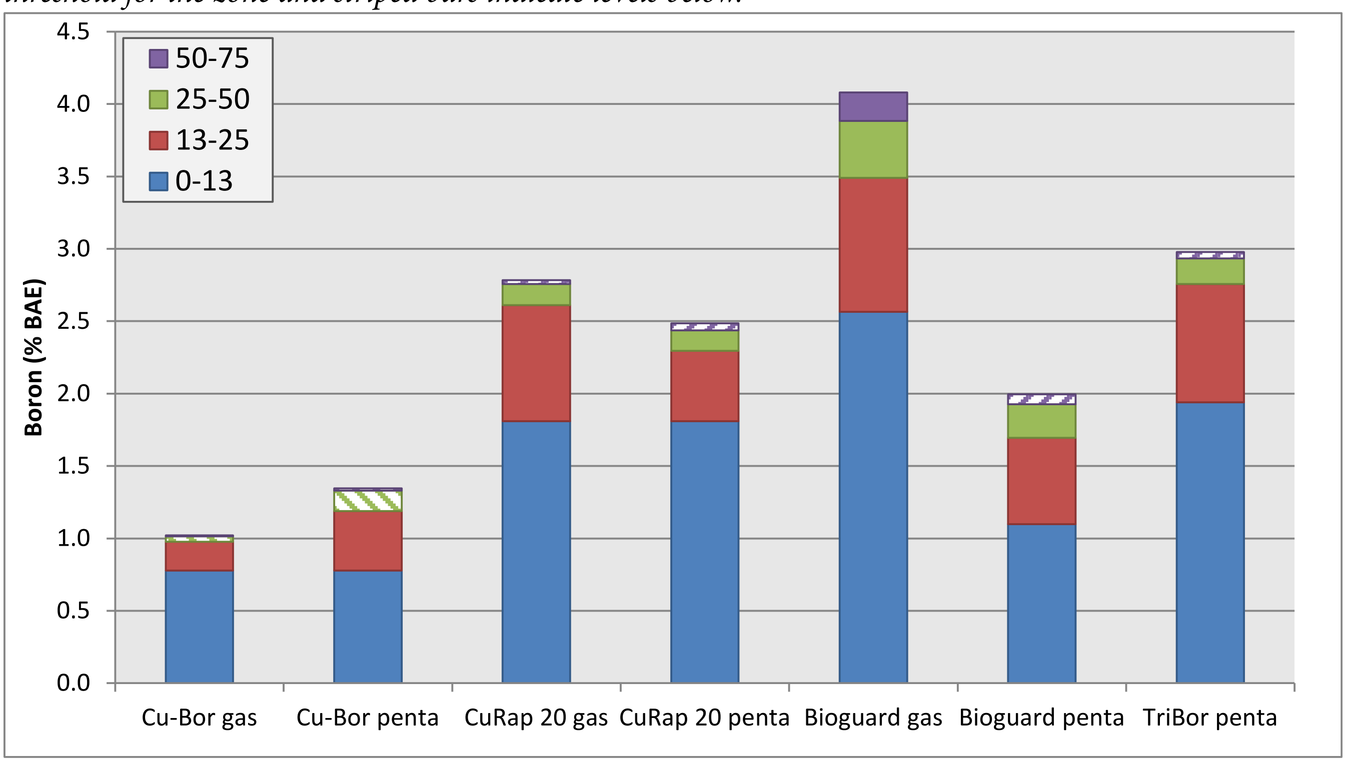

Figure IV-9. Boron content in the outer 50 mm of poles of various species segregated by primary treatment 17 months after application of various boron-containing pastes. Solid color bars indicate levels over the toxic threshold for the zone and striped bars indicate levels below.

Table IV-6. Copper levels at selected distances from the wood surface in poles of various species 17 months after application of copper containing preservative pastes.[1]

Treatment	Utility	Copper level (% wt/wt as Cu)				
		Distance from the surface (mm)				
		0-6	6-13	13-25	25-50	50-75
Cu-Bor	APS	**0.31**	0.00	0.00	0.00	0.00
	SRP	**0.35**	0.03	0.01	0.00	0.00
CuRap 20	APS	**0.98**	0.03	0.01	0.00	0.00
	SRP	**0.65**	0.05	0.01	0.00	0.00
COP-R-PLASTIC II	APS	**0.49**	0.07	0.01	0.00	0.00
	SRP	**0.64**	0.14	0.01	0.00	0.00
MP400-EXT	APS	0.003	0.006	0.000		
	SRP	0.005	0.001	0.001		
Osmose Exp	APS	**0.028**	0.002	0.001		
	SRP	**0.082**	0.003	0.001		

1. Numbers in bold are above the toxic threshold of 0.15% Cu for copper naphthenate or 0.0142% Cu for MP400-EXT.

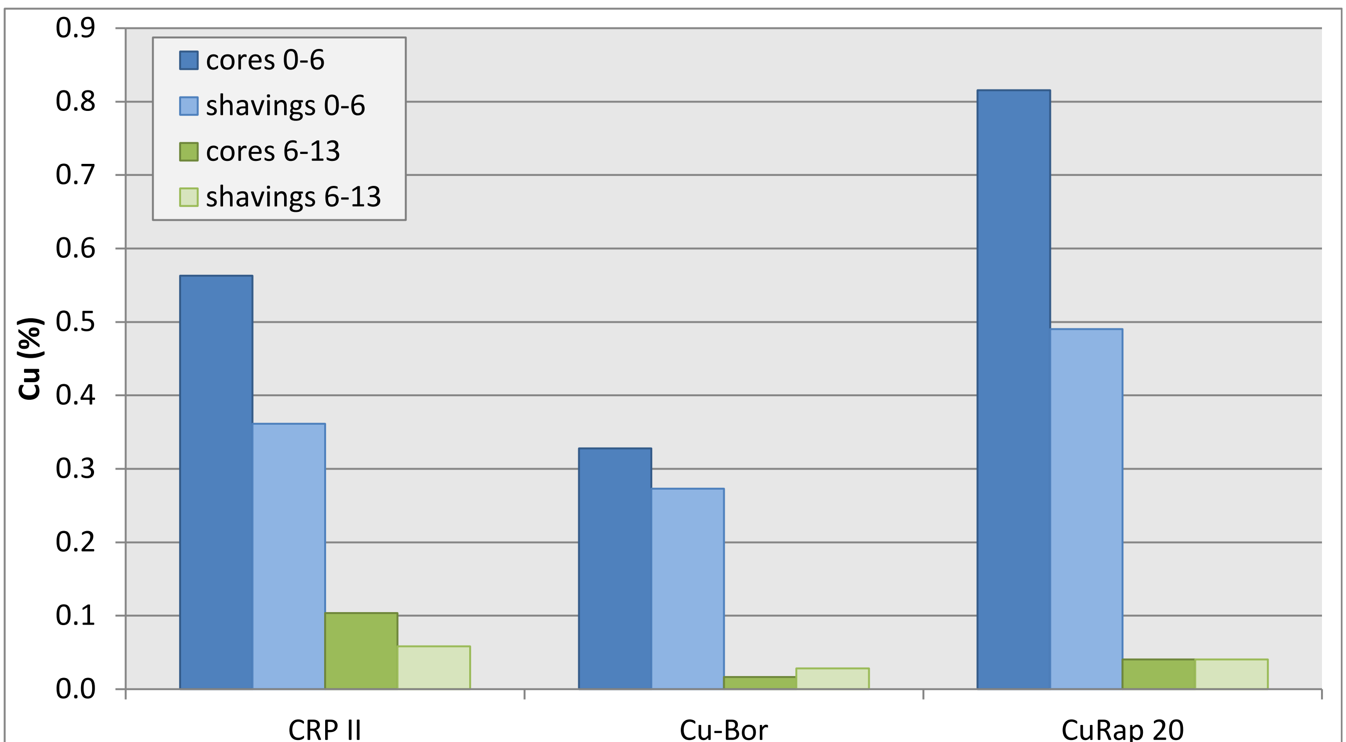

Figure IV-10. Copper levels in shavings vs. increment core segments removed from poles 17 months after treatment with various copper containing preservative pastes.

Cu-Bor, and CuRap 20 (Figures IV-11, 12). Copper levels declined to well below this level in the next zone inward for Cu-Bor and CuRap 20, but approached the threshold for CRP II. Copper was detected at very low levels in the outer zone of the MP400 -EXT as well as with the Osmose Experimental system (Figure IV-13). These results bear some explanation. The MP400-EXT system utilizes a micronized copper component that is suspended rather than solubilized and the

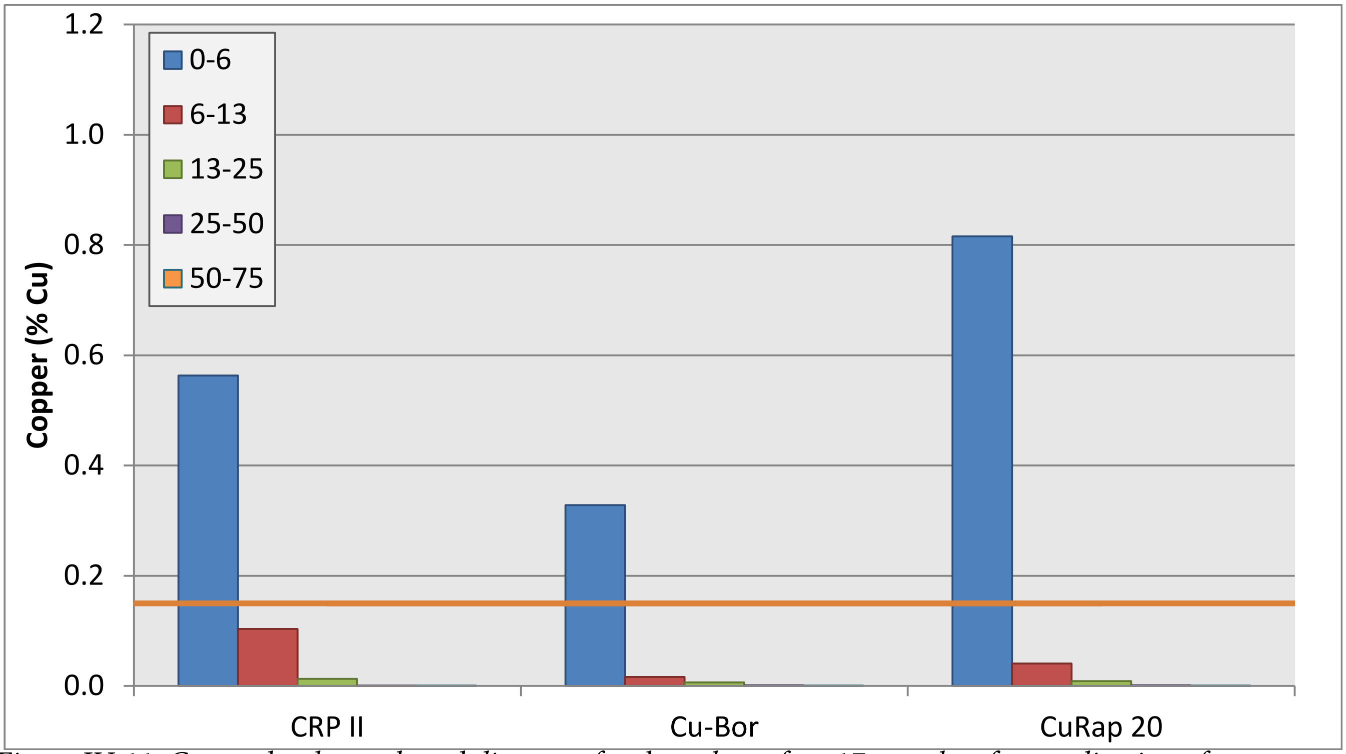

Figure IV-11. Copper levels at selected distances for the pole surface 17 months after application of copper containing preservative pastes. The horizontal line indicates the toxic threshold for the form of copper in these chemicals.

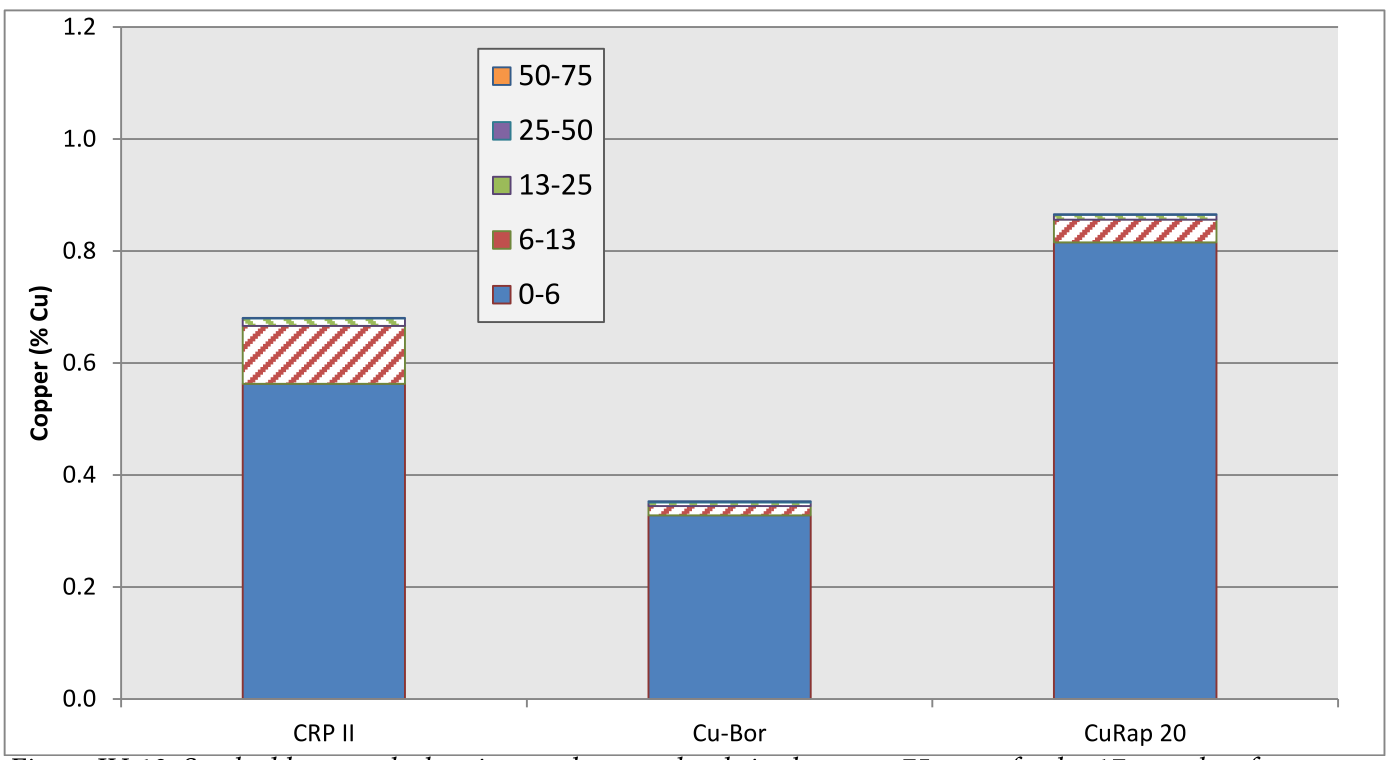

Figure IV-12. Stacked bar graph showing total copper levels in the outer 75 mm of poles 17 months after application of copper containing preservative pastes. Note that most copper is in the outer assay zone. Solid color bars indicate levels over the toxic threshold for the zone and striped bars indicate levels below.

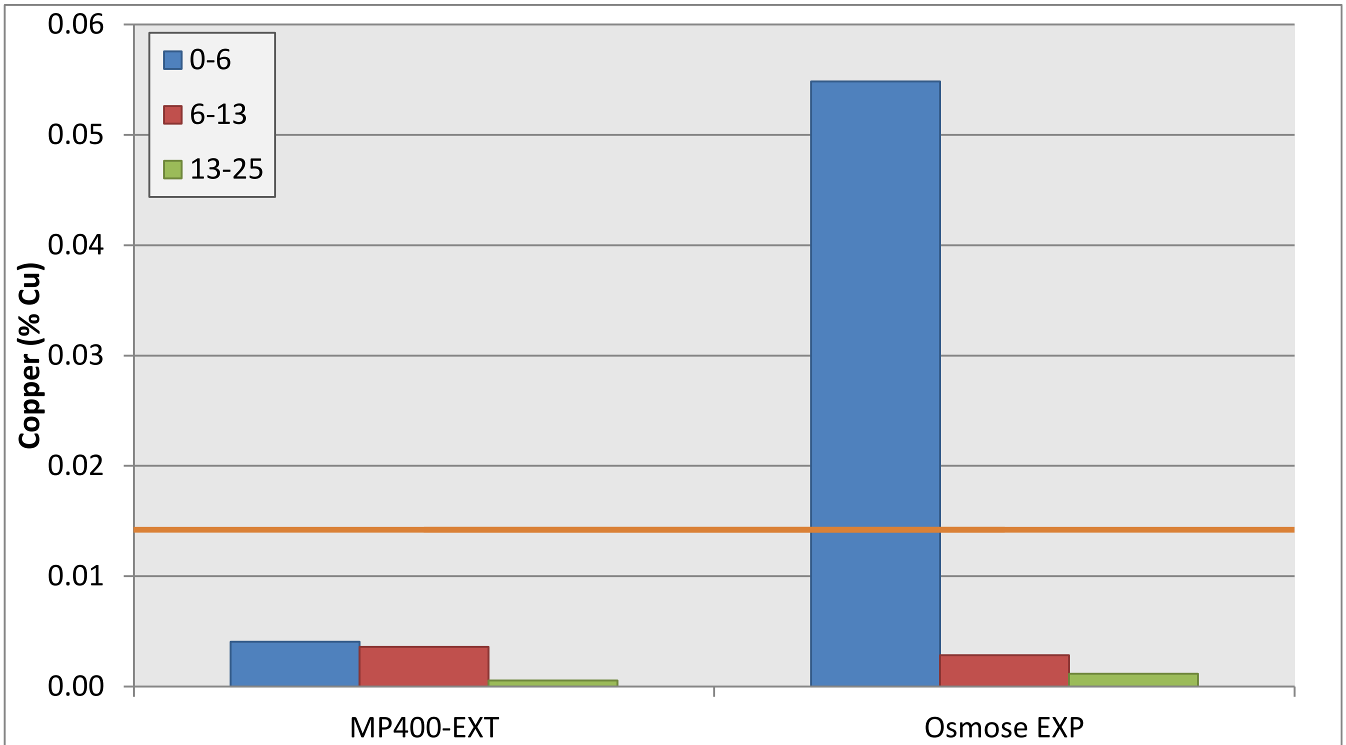

Figure IV-13. Copper levels at selected distances for the pole surface 17 months after application of copper containing preservative pastes. The horizontal line indicates the toxic threshold for oxine copper (0.0142)

toxic threshold for this form of copper is lower than that for solubilized copper. There is some evidence that, while this approach works well with southern pine, the copper does not penetrate into less permeable woods such as Douglas-fir. Therefore, it is possible that copper penetration into the wood is limited in this system. Ultimately, this may not affect the overall performance of the preservative because copper is just one component and is primarily present to provide a surface barrier against renewed fungal attack, while boron is expected to move more deeply into the wood to arrest any existing fungal attack. Further evaluations will be required to determine if this premise is correct.

Unlike boron, where initial pole treatment appeared to influence subsequent distribution of the remedial treatment of this chemical, there were no consistent differences in copper levels among the treatments by utility (Figure IV-14 and 15). The lack of difference may reflect the shallow overall penetration of copper compared with the more mobile boron.

The analysis of both bifenthrin and tebuconazole in preservative treated wood is challenging because of the difficulty in obtaining a sufficient quantity of wood to extract, coupled with the fact that materials in the original preservative solvent can interfere with analysis. In the case of tebuconazole, several alkanes eluted at the same time as the active ingredient. These compounds were likely residuals from the original solvent and their presence made it difficult to quantify or to even say with certainty that tebuconazole was present. This problem occurred most often in the zones away for the wood surface where tebuconazole was less likely to be present and where the levels that could be determined by comparison with standards were extremely low. As a result, we have reported values only where the levels of interference were low enough to allow for reliable quantification. For tebuconazole, this was the 0 to 6 mm assay zone, while the 0-6 and 6

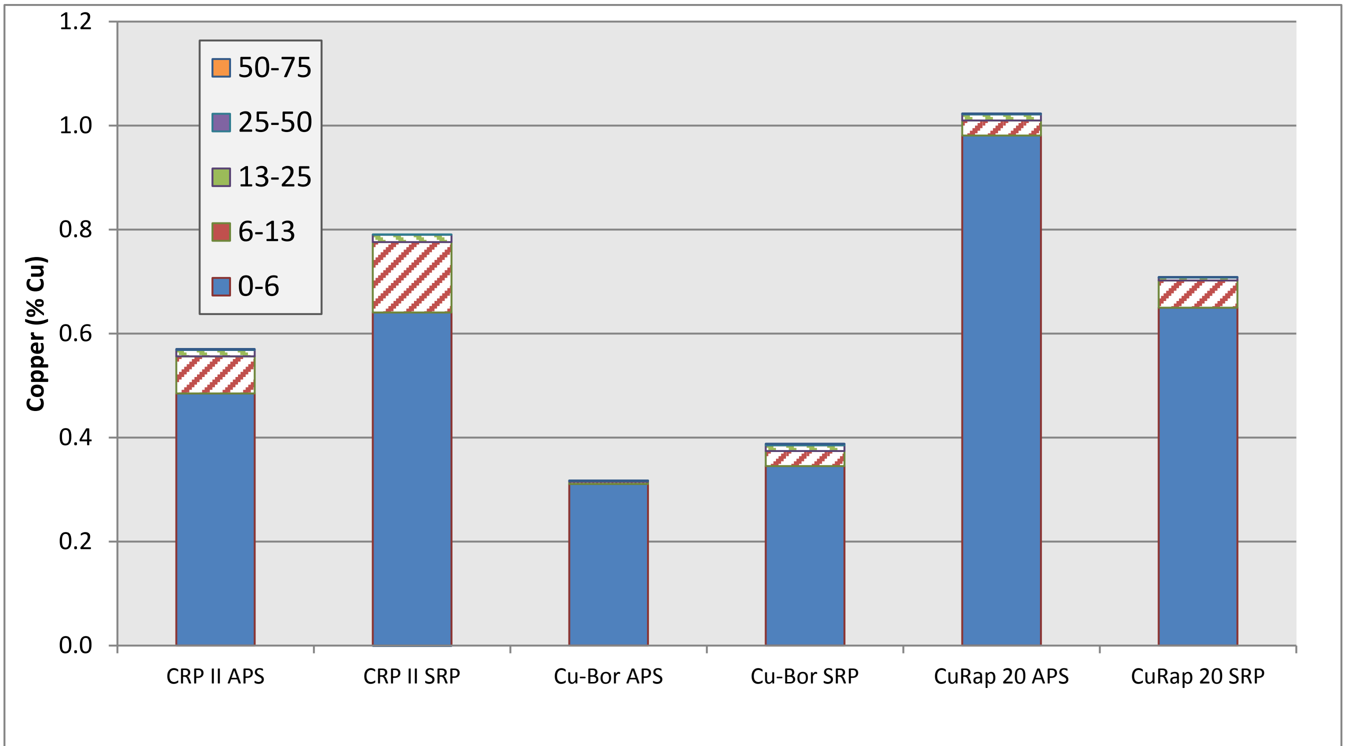

Figure IV-14. Copper levels in poles 17 months after treatment with selected copper containing preservative pastes segregated by treatment and utility. Solid color bars indicate levels over the toxic threshold for the zone and striped bars indicate levels below.

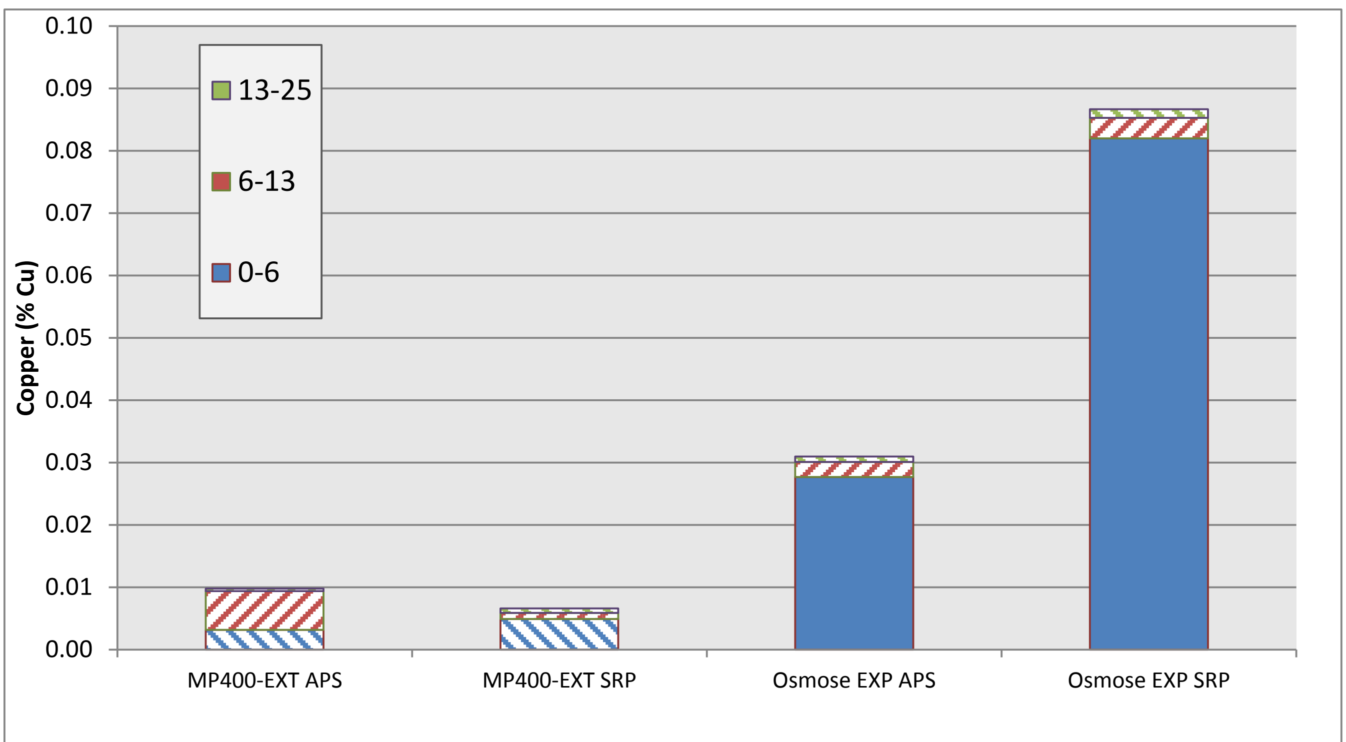

Figure IV-15. Copper levels in poles 17 months after treatment with selected copper containing preservative pastes segregated by treatment and utility. Solid color bars indicate levels over the toxic threshold for the zone and striped bars indicate levels below.

to13 mm zones were quantifiable for bifenthrin.

Both bifenthrin and tebuconazole were detected in the outer 6 mm of the cores (Table IV-7). Questions about detection and interference on samples further inward make it difficult to reliably say that either compound was present more than 12 mm from the surface. Tebuconazole levels in the outer 6 mm ranged from 464 to 521 ppm. These values are well above the threshold for preventing fungal attack and indicate that this component is providing some protection against reinvasion by decay fungi.

Bifenthrin was detected in the two outer assay zones, although the levels declined sharply in the second zone from the surface. Bifenthrin is not widely used in the U.S. for wood treatment but it is specified in Australia for treatment of framing lumber at a target retention of 12 ppm. If we use this value as a minimum threshold for protection, then the outer zone of poles treated with either MP400-EXT or the Osmose Experimental were above the threshold for protection. The levels in the next zone from the surface were slightly below that level for both pastes. The results indicate that bifenthrin is available on the outer surface to provide a barrier against insect attack.

These results are preliminary, but they suggest that the copper, tebuconazole and bifenthrin form a barrier near the wood surface while the boron diffuses more deeply into the wood. This pattern is similar to that seen with other multi-component external preservative barriers.

Table IV-7. Bifenthrin and tebuconazole levels in selected zones of poles of various species 17 months after application of MP400-EXT or Osmose Experimental Paste.

Treatment	Assay Zone (mm)	Chemical Retention (ppm)[a]			
		Bifenthrin		Tebuconazole	
		Increment cores	Shavings	Increment Cores	Shavings
MP400-EXT	0-6	**65.9**	N/A	**521**	N/A
	6-13	8.2	N/A	N/A	N/A
O-EXP	0-6	—	—	**462**	**625**
	6-13	—	—	N/A	N/A

aValues represent mean analyses of 2 to 5 samples. N/A signifies results that were inconclusive regarding the presence of a given compound. Values in bold exceed the threshold for that active ingredient.

C. 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:

1. To assess the ability of external barriers to retard preservative migration from poles in soil contact.
2. 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 a retention of 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. Additional non-treated poles were included in the test as controls. The pole sections were sampled using an increment borer prior to setting 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 half of the poles were used for monitoring potential migration of preservative components into the surrounding soil, and the other half were 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-8). The remaining samples were intended to be analyzed for penta but we have experienced difficulties in running these analyses and will need to develop an alternative method.

At annual intervals after installation, soil cores were removed beginning immediately adjacent to the poles, as well as 150 and 300 mm away. The soil cores were divided into zones as described above and then analyzed for the appropriate preservative. The sampling points will be extended

Table IV-8. Initial copper, chromium and arsenic levels at selected depths in the soil at the site used to monitor metal migration from CCA treated poles with and without 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

further outward if we detect increased chemical levels at the initial sampling sites.

Wood moisture content was assessed at the time of installation as well as 14, 22 and 33 months later and will continue to be assessed thereafter as needed. At each time point, increment cores were removed from one side of each pole beginning 150 mm below groundline, then moving upward to groundline, and 300 and 900 mm above groundline. Each increment core was divided into zones corresponding to 0 to 25 mm, 25 to 50 mm, 50 to 75 mm and 75 mm to the pith. Each core section was placed into a tared glass vial which was sealed and returned to the lab where the cores were weighed, oven dried and re-weighed to determine wood moisture content. The sampling holes were plugged with wood plugs and the liner repaired. These results will be used to develop moisture content profiles over time for the lined and non-lined poles.

Moisture contents of the penta treated Douglas-fir poles were below 30 % at all four sampling locations and ranged from 9.7 % in the outer zone of the lined poles to 26.7 % in the inner zones of the non-lined poles at the time of installation (Table IV-9; Figures IV-16-19). Non-treated southern pine poles without liners followed similar trends. Moisture contents of penta treated southern pine poles tended to be higher than the Douglas-fir poles, ranging from 22.3 % in the outer zone to 54.3 % in the inner zone. The differences in initial moisture content between penta-treated pine and Douglas-fir may reflect differences in post-treatment drying processes. The pine poles were kiln dried while the Douglas-fir poles were dried using a combination of air seasoning and Boultonizing (boiling in oil under vacuum). The kiln drying process used for southern pine is fairly aggressive and can be manipulated to limit drying to the outer shell. Air-seasoning and Boultonizing tend to produce a more uniformly seasoned pole. This is less important in pine, which will tend to have a deeper zone of treatment that is more forgiving of checks that might develop after treatment. It is essential for Douglas-fir, because deep checks that develop after treatment will invariably expose non-treated wood to possible fungal attack and eventual development of internal decay.

Moisture contents of CCA treated southern pine were well above those found in the penta treated poles, reflecting the introduction of large amounts of water in the treating process. Moisture con-

Table IV-9. Moisture contents at the time of installation at selected distances from the surface at various locations along the pole length in Douglas-fir and southern pine poles with various treatments with or without a field liner. [1]

Wood species	Treatment	Lined or not	Distance from the surface of the pole (mm)			
			0-25	25-50	50-75	75+
DF	Control	Non				
	Penta	Lined	10	19	25	26
		Non	11	19	25	27
SYP	CCA	Lined	**37**	**59**	**84**	**81**
		Non	29	**44**	**42**	**60**
	Control	Non	13	20	26	26
	Penta	Lined	22	**38**	**41**	**42**
		Non	24	**38**	**40**	**54**

1. Numbers in bold are above the wood fiber saturation point (30%)

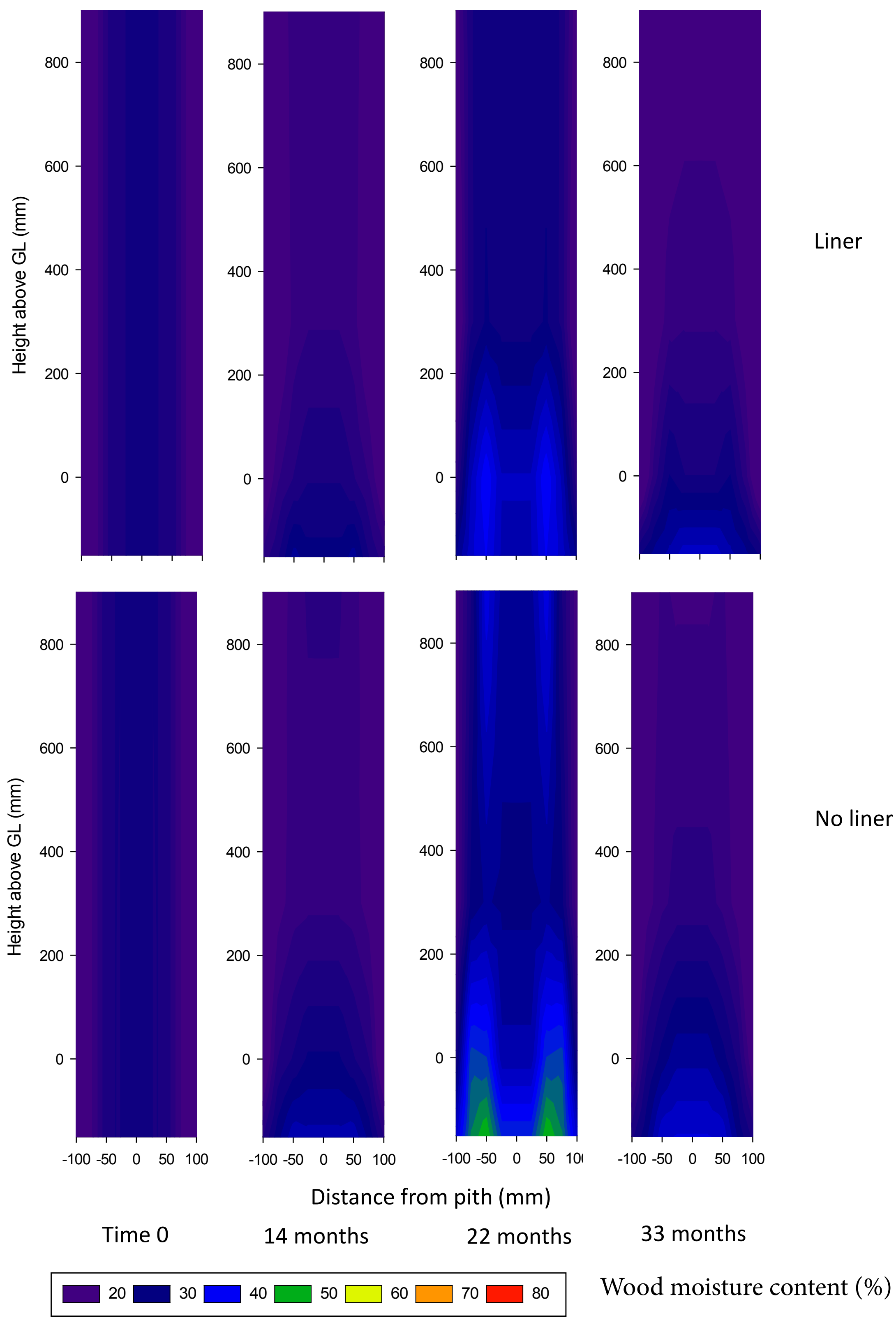

Figure IV-1. Moisture contents in penta-treated Douglas-fir poles with or without a field liner after 0, 14, 22 or 33 months in the ground at the Peavy Arboretum test site.

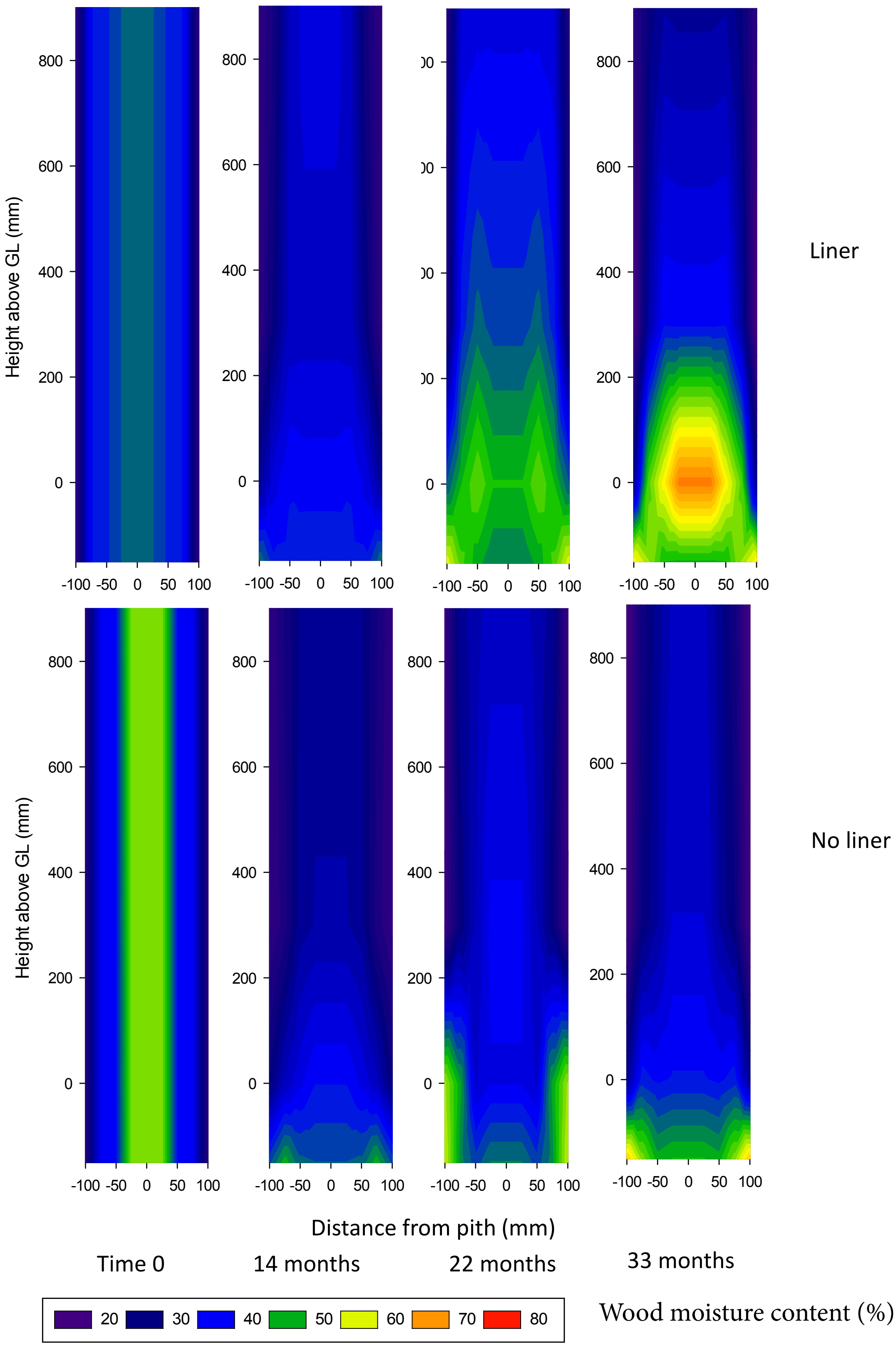

Figure IV-2 Moisture contents in penta-treated southern pine poles with or without a field liner after 0, 14, 22 or 33 months in the ground at the Peavy Arboretum test site.

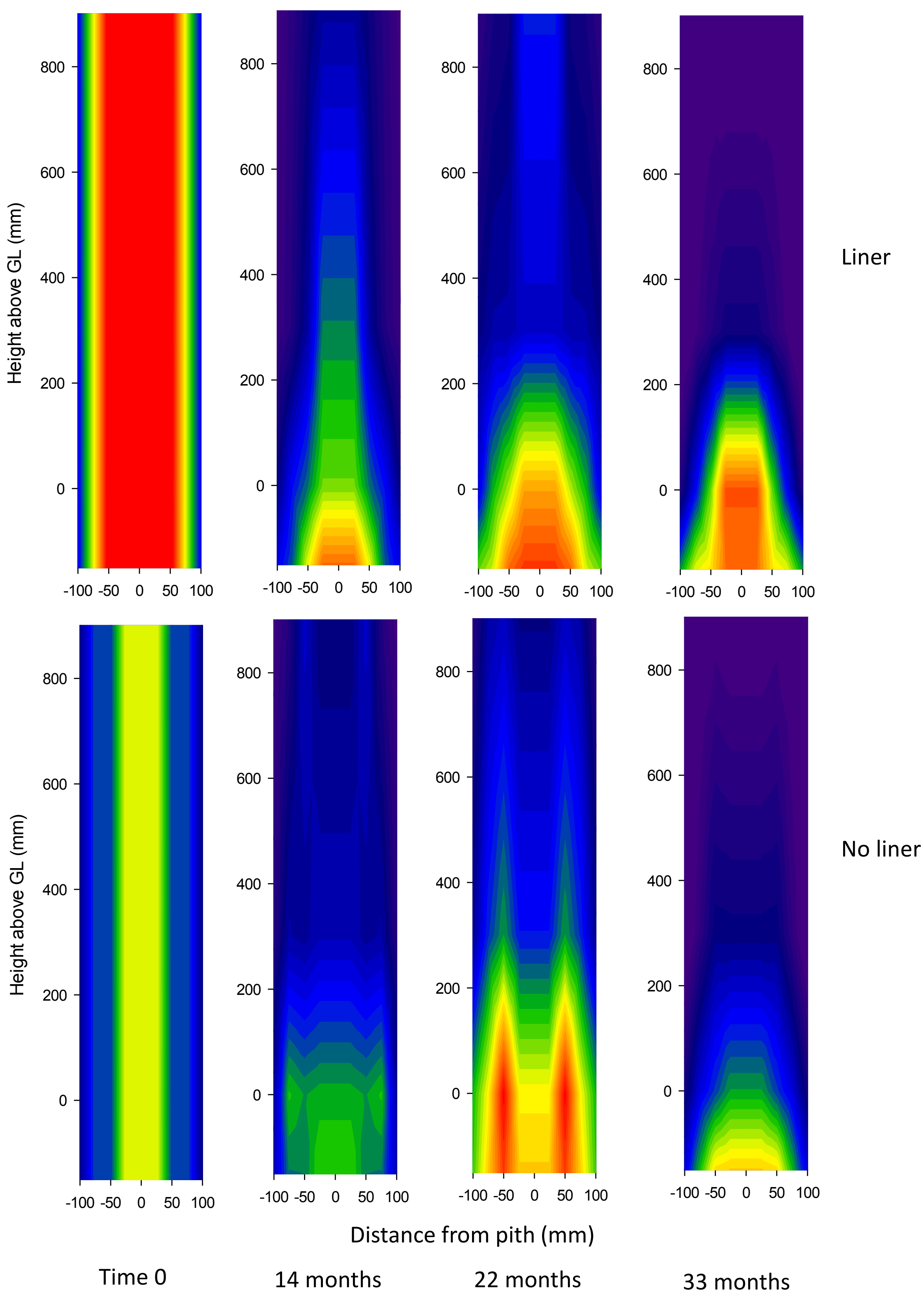

Figure IV-3. Moisture contents in CCA treated southern pine poles with or without a field liner after 0, 14, 22 or 33 months in the ground at the Peavy Arboretum test site.

tents in the inner zone were over 80 % at the time of installation.

Although there were sometimes large differences in moisture content between species and treatments, there were no differences between lined and non-lined poles with the same treatment at installation.

Moisture contents of the poles 14 months after installation again varied with initial treatment and wood species (Table IV-10; Figures IV-1-3). This sampling occurred at the end of our long, dry season and the results reflect that prolonged drying. Moisture contents for both non-treated and penta-treated Douglas-fir poles were below 35 % and most were below 20 %. Moisture contents were slightly higher near the groundline, but conditions were generally not suitable for fungal growth. There also appeared to be no difference in moisture contents for penta-treated Douglas-fir poles with and without a liner.

Non-treated southern pine poles tended to have higher moisture contents at groundline than non-treated Douglas-fir poles. Pine is more permeable and susceptible to fungal attack and the higher moisture contents could reflect both the greater tendency of this species to absorb water and the potential for fungal colonization to further enhance permeability. Moisture contents of penta-treated southern pine poles were higher than those for Douglas-fir at or below groundline and ranged from 28 to 45 %. Moisture contents 300 and 900 mm above groundline were lower than those at groundline but still higher than those for Douglas-fir. There appeared to be no consistent differences in moisture contents between poles with and without barriers. Moisture contents for CCA treated southern pine were higher than those found with penta treated poles of the same species, reflecting the tendency of this treatment to increase hygroscopicity of the wood, but there were no noticeable differences in moisture contents between poles with and without barriers.

Sampling of poles 22 months after installation at the end of the wet season indicated that the trends with regard to wood treatment and species were the same as those found after 14 months

Table IV-10. Moisture contents 14 months after installation at selected distances from the surface at various locations along the pole length in Douglas-fir and southern pine poles with various treatments with or without a field liner[1].

Wood species	Treatment	Lined or not	Distance from groundline (mm)															
			-150				0				300				900			
			Distance from the surface of the pole (mm)															
			0-25	25-50	50-75	75+	0-25	25-50	50-75	75+	0-25	25-50	50-75	75+	0-25	25-50	50-75	75+
DF	Control	Non	**33**	**31**	28	**34**	24	20	26	**32**	17	17	22	24	16	20	22	25
	Penta	Lined	23	26	**31**	29	17	22	24	26	12	17	21	22	12	18	21	21
		Non	24	29	**33**	**33**	16	24	26	28	14	19	21	21	13	17	21	22
SYP	CCA	Lined	**37**	**44**	**59**	**72**	29	**39**	**45**	**54**	20	24	**32**	**46**	19	23	27	**31**
		Non	**33**	**46**	**46**	**52**	**31**	**50**	**48**	**49**	23	**32**	**31**	**34**	19	24	**35**	29
	Control	Non	**35**	**70**	**65**	**41**	**45**	**34**	**47**	**33**	20	19	23	24	17	16	28	18
	Penta	Lined	**45**	**40**	**40**	**41**	**31**	**37**	**40**	**39**	22	29	**35**	**35**	22	26	**34**	**37**
		Non	**43**	**49**	**44**	**44**	28	**34**	**37**	**40**	21	25	**31**	**32**	22	26	**30**	**31**

1. Numbers in bold are above the wood fiber saturation point (30%)

(Table IV-11; Figures IV-1-3). Moisture contents were much higher than those found at 14 months with levels in the inner zones of non-treated southern pine poles exceeding 100 % below groundline. This test site has poor drainage and tends to collect water during the wet season. This creates ideal conditions for moisture uptake. In addition, regular rainfall creates ample opportunity for water to run down checks in the pole to the base where it can be more slowly absorbed by the wood.

Table IV-11. Moisture contents 22 months after installation at selected distances from the surface at various locations along the pole length in Douglas-fir and southern pine poles with various treatments with or without a field liner[1].

Wood species	Treatment	Lined or not	Distance from groundline (mm)															
			-150				0				300				900			
			Distance from the surface of the pole (mm)															
			0-25	25-50	50-75	75+	0-25	25-50	50-75	75+	0-25	25-50	50-75	75+	0-25	25-50	50-75	75+
DF	Control	Non	**33**	26	27	30	27	26	27	28	14	16	19	21	14	17	19	20
	Penta	Lined	30	**35**	**38**	**34**	23	**34**	**40**	**34**	15	26	28	27	18	26	28	26
		Non	**35**	**46**	**50**	**42**	26	**43**	**42**	**33**	18	28	**30**	29	18	26	**37**	**31**
SYP	CCA	Lined	**53**	**59**	**72**	**77**	**37**	**49**	**57**	**68**	29	**32**	**33**	**35**	22	26	27	**40**
		Non	**52**	**64**	**76**	**64**	**50**	**61**	**81**	**61**	**30**	**41**	**48**	**40**	23	**32**	**35**	30
	Control	Non	**59**	**72**	**104**	**86**	**68**	**68**	**60**	**44**	17	17	20	21	13	16	18	20
	Penta	Lined	**59**	**52**	**49**	**46**	**44**	**50**	**54**	**50**	24	**41**	**45**	**43**	24	**36**	**37**	**37**
		Non	**58**	**47**	**43**	**46**	**56**	**48**	**36**	**38**	20	29	**34**	**39**	21	**31**	**33**	**35**

1. Numbers in bold are above the wood fiber saturation point (30%)

Moisture contents after 33 months continue to show little or no difference between lined and non-lined poles, regardless of treatment (Table IV-12, Figures IV-1-3). Moisture levels in penta treated Douglas-fir poles were just near the fiber saturation point below groundline and then declined with distance above that zone. There were no measurable differences in moisture contents between lined and non-lined poles. Moisture contents below ground were higher in pine than in Douglas-fir poles. For example, moisture contents below ground were all above the fiber saturation point for both the CCA and penta treated southern pine from the surface to the pith of the poles. Moisture contents were slightly higher in CCA treated pine poles than in penta treated poles of the same species, possibly reflecting the residual water repellency of the penta solvent. Moisture levels were also higher at groundline in the pine poles. Once again, however, moisture levels in the lined poles were very similar to those found in non-lined poles with the same treatment.

Over time, we might expect moisture contents in poles with the field liners to increase because of the limited opportunities for drying. However, there appear to be few consistent differences in moisture contents between poles with and without field liners. The results indicate that liners do not appreciably affect the moisture conditions in the poles.

Soils analysis of samples removed 22 and 33 months after treatment indicated that metal levels were elevated immediately adjacent to the CCA treated poles, regardless of whether a liner was applied (Tables IV-13 and 14). The increased metal levels around lined poles likely reflect migra-

Table IV-12. Moisture contents 33 months after installation at selected distances from the surface at various locations along the pole length in Douglas-fir and southern pine poles with various treatments with or without a field liner[1].

Wood species	Treatment	Lined or not	Distance from groundline (mm)															
			-150				0				300				900			
			Distance from the surface of the pole (mm)															
			0-25	25-50	50-75	75+	0-25	25-50	50-75	75+	0-25	25-50	50-75	75+	0-25	25-50	50-75	75+
DF	Control	Non	**36**	**33**	29	30	24	25	26	26	14	17	19	20	12	16	18	17
	Penta	Lined	27	**31**	**32**	**35**	14	23	28	26	11	18	21	22	12	17	18	18
		Non	25	30	**35**	**36**	18	25	29	**31**	11	19	21	23	11	18	20	20
SYP	CCA	Lined	**47**	**59**	**62**	**72**	24	**38**	**54**	**75**	13	19	24	27	12	16	17	16
		Non	**36**	**50**	**63**	**64**	26	**36**	**42**	**48**	15	22	29	29	13	17	18	17
	Control	Non	**75**	**74**	**86**	**76**	**42**	**51**	**50**	**48**	15	20	27	24	14	18	22	21
	Penta	Lined	**61**	**56**	**50**	**50**	29	**53**	**61**	**71**	18	**32**	**40**	**40**	22	29	**32**	**31**
		Non	**64**	**55**	**49**	**50**	**30**	**41**	**39**	**40**	19	28	**32**	**36**	18	27	**31**	**35**

1. Numbers in bold are above the wood fiber saturation point (30%)

Table IV-13. Copper, chromium, and arsenic levels in soils removed from selected distances away from CCA treated southern pine poles with or without a field liner 22 months after installation

Treatment	Liner	Copper content (ppm)					Arsenic content (ppm)				
		Adjacent to pole									
		0-25	25-50	50-75	75-150	Avg	0-25	25-50	50-75	75-150	Avg
CCA	-	46.7 (26.9)	16.6 (16.6)	9.4 (7.7)	8.4 (6.4)	20.3	0.4 (0.0)	0.4 (0.1)	0.5 (0.1)	0.5 (0.0)	0.5
	+	34.6 (23.1)	10.4 (0.8)	7.1 (1.5)	6.5 (2.3)	14.6	0.4 (0.0)	0.4 (0.0)	0.5 (0.1)	0.5 (0.1)	0.4
None	-	3.4 (1.1)	3.5 (1.3)	3.4 (1.3)	3.5 (1.3)	3.4	0.5 0.0	0.5 0.0	0.6 (0.1)	0.6 0.0	0.5
Background Soil		3.5	3.3	3.0	3.0	3.2	0.3	0.3	0.3	0.3	0.3
		150 mm from pole									
CCA	-	6.1 (2.6)	4.5 (1.6)	4.4 (1.5)	4.0 (1.6)	4.7	0.5 (0.1)	0.6 (0.1)	0.5 (0.0)	0.6 (0.1)	0.5
	+	4.8 (1.3)	3.9 (1.3)	3.1 (1.1)	3.0 (1.1)	3.7	0.5 (0.1)	0.5 (0.0)	0.5 (0.0)	0.5 (0.1)	0.5
None	-	3.3 (1.1)	3.6 (1.3)	3.4 (1.6)	3.2 (1.6)	3.4	0.5 0.0	0.6 (0.1)	0.6 (0.1)	0.6 (0.1)	0.5
		300 mm from pole									
CCA	-	5.2 (2.1)	4.1 (1.8)	3.8 (1.7)	3.4 (1.8)	4.1	0.6 (0.1)	0.6 (0.1)	0.5 (0.1)	0.6 (0.1)	0.6
	+	4.6 (1.2)	3.6 (0.8)	3.1 (1.0)	3.1 (1.0)	3.6	0.5 (0.1)	0.6 (0.0)	0.5 (0.1)	0.5 (0.1)	0.5
None	-	3.4 (1.4)	3.3 (1.6)	3.3 (1.4)	3.3 (1.4)	3.3	0.6 (0.1)	0.6 (0.1)	0.6 (0.1)	0.6 (0.1)	0.6

tion of metals from the upper surfaces of poles as rainfall runs downward along the wood. The liners will have no effect on this movement although they should reduce any movement of chemical from the portion of the pole in direct soil contact.

Table IV-14. Copper, chromium, and arsenic levels in soils removed from selected distances away from CCA treated southern pine poles with or without a field liner 33 months after installation

Treatment	Liner	Copper content (ppm)		Arsenic content (ppm)	
		Adjacent to Pole			
		0-25	75-150	0-25	75-150
CCA	-	36.3 (19.4)	16.1 (8.9)	0.1 (0.1)	0.1
	+	28.9 (13.5)	11.4 (5.3)	0.2 (0.1)	0.1
None	-	0.8 (0.1)	0.6 (0.1)	0.1	0.0
Background Soil		3.5	3.3	0.3	0.3
		150 mm from pole			
CCA	-	3.1 (0.3)	1.3 (0.5)	0.1	0.1
	+	2.8 (0.8)	1.3 (0.2)	0.1	0.1
None	-	0.7	0.7 (0.2)	0.0	0.0

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

External remedial preservative systems are used around the world to supplement the preservative protection afforded by the initial treatment. In previous tests we have concentrated on systems used in the U.S. but several years ago, we also examined several systems used in Australia. These systems contained boron alone or with fluoride.   There are only limited data on the effectiveness of these systems on U.S pole species. In this report, we describe 7 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).

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-15). 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, 5 and 7 years after treatment by removing 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 com-

Table IV-15. 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

bined, 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 Protection' Association Standard A2-04, the Azomethine H method (AWPA, 2012b). 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/m3) BAE (boric acid equivalent) or greater. The threshold for protection in external applications is believed to be approximately 0.14 pcf (2.24 kg/m3), although this figure is probably a bit high because of the difficulty in estimating 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 HClO4 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 A2-04 Method 7 (AWPA, 2012a). 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, 2012c).

Fluoride thresholds have received less study, but appear to be equal to or lower than those for boron for internal decay control. Our laboratory data suggests a threshold for protection against internal decay of between 0.00626 and 0.0125 pcf (0.1 and 0.2 kg/m3) 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-16, 17). 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 de-

Table IV-16. 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 the 2.24 kg/m3 fluoride threshold in the outer 12 mm and the 0.6 kg/m3 threshold beyond that depth.

clined 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. 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-12). 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 gener-

Table IV-17 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)
			7	0.09	0.04	0.00	0.14
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)
			7	0.88 (0.87)	0.57 (0.57)	0.49 (0.34)	0.38 (0.17)
	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)
			7	0.17 (0.14)	0.07 (0.07)	0.07 (0.05)	0.07 (0.06)
	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)
			7	**1.37** (0.82)	1.15 (0.84)	**0.82** (0.15)	0.50 (0.09)
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)
			7	0.60 (0.59)	0.44 (0.36)	0.58 (0.32)	0.54 (0.24)
	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)
			7	0.06 (0.05)	0.05 (0.04)	0.06 (0.02)	0.07 (0.07)
	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)
			7	0.09 (0.05)	0.19 (0.07)	0.56 (0.21)	0.44 (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)
			7	0.37 (0.25)	0.24 (0.15)	0.34 (0.22)	0.40 (0.24)
	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)
			7	0.00	0.03 (0.05)	0.01 (0.02)	0.05 (0.05)
	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)
			7	0.25 (0.26)	0.81 (0.32)	**0.80** (0.37)	0.35 (0.22)

a. Numbers in parentheses represent one standard deviation. Numbers in bold are above the toxic threshold of 1.28 Kg/m³ BAE for the outer 25 mm or 0.67 Kg/m³ BAE from 25-75 mm from the pole surface. b. The control pole stubs were too degraded to sample.

Table IV-17 continued. 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)
			7	0.04 (0.04)	0.01 (0.01)	0.04 (0.03)	0.03 (0.05)
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)
			7	**2.39** (1.81)	**2.91** (3.78)	**0.96** (0.91)	**2.18** (0.82)
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**
			7	**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)
			7	**b**	**b**	**b**	**b**
	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
			7	0.13 (0.14)	0.11 (0.07)	0.06 (0.06)	0.09 (0.04)

a. Numbers in parentheses represent one standard deviation. Numbers in bold are above the toxic threshold of 1.28 Kg/m^3 BAE for the outer 25 mm or 0.67 Kg/m^3 BAE from 25-75 mm from the pole surface. b. The control pole stubs were too degraded to sample.

al, 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-13). 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. The potential differences in performance between pastes and bandages merit further study.

Boron levels in the poles had continued to decline with an additional two years of exposure. Boron was present at threshold levels or higher in four of the treatments (Bioguard bandage on Douglas-fir or western redcedar, Bioguard paste taped at GL on western redcedar and Bioguard boron paste on Douglas-fir) seven years after installation. The highest levels were found in the Bioguard boron paste with Douglas-fir, where above threshold levels were present at all four zones assayed to a depth of 75 mm from the wood surface. Western redcedar poles also appeared to retain higher loadings of boron in the Bioguard bandage and paste treatments. Both of these wood species are less permeable and, while they would initially be more resistant to biocide movement, they should be more resistant to loss over time.

In general, the results suggest that boron levels in the remaining treatments have declined to the point where they are no longer protective. As with other remedial treatments; however, this does not mean that they will be immediately colonized by decay or soft rot fungi. Rather, they will be slowly attacked over time as any traces of protection dissipate. It is also important to remember that these poles were not treated. Oilborne preservatives would likely slow this progression.

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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 1940s, but the commercial use of this system as a preservative for treating utility poles 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 western redcedar lumber or from the outer surfaces of the above ground zones of western redcedar 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 slightly 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).

In 2007, 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/

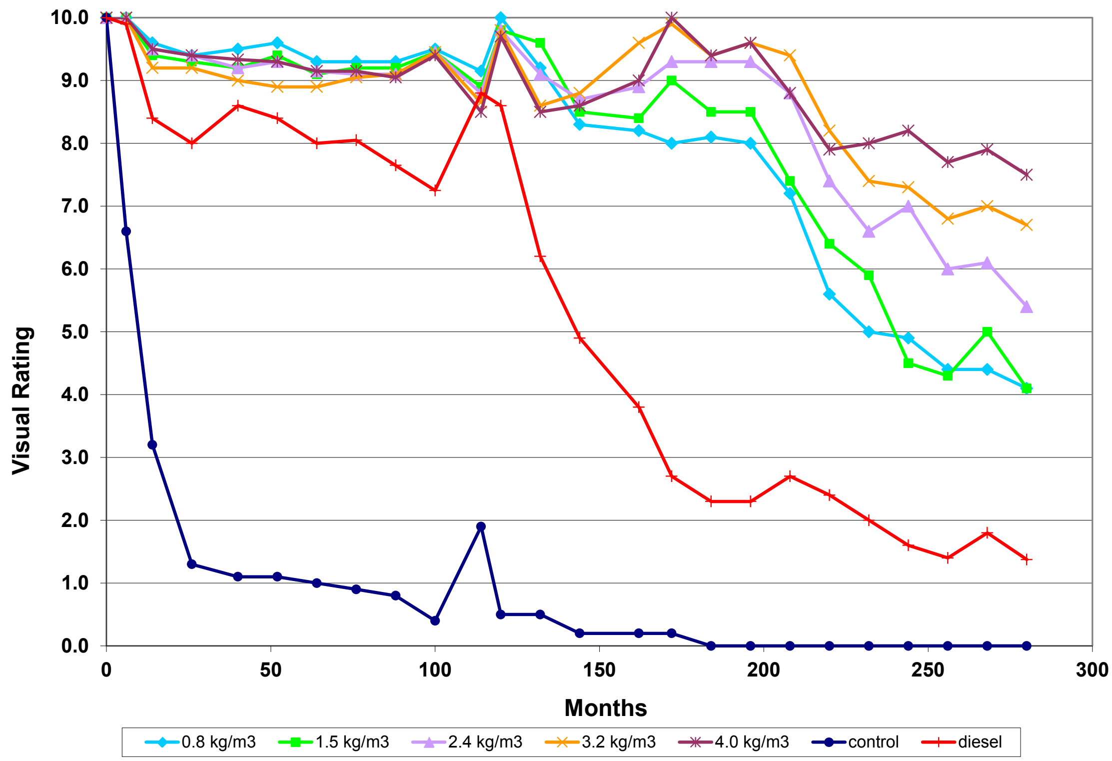


Figure V-1. Condition of freshly sawn western redcedar sapwood stakes treated with selected retentions of copper naphthenate in diesel oil and exposed in a soil bed for 280 months.

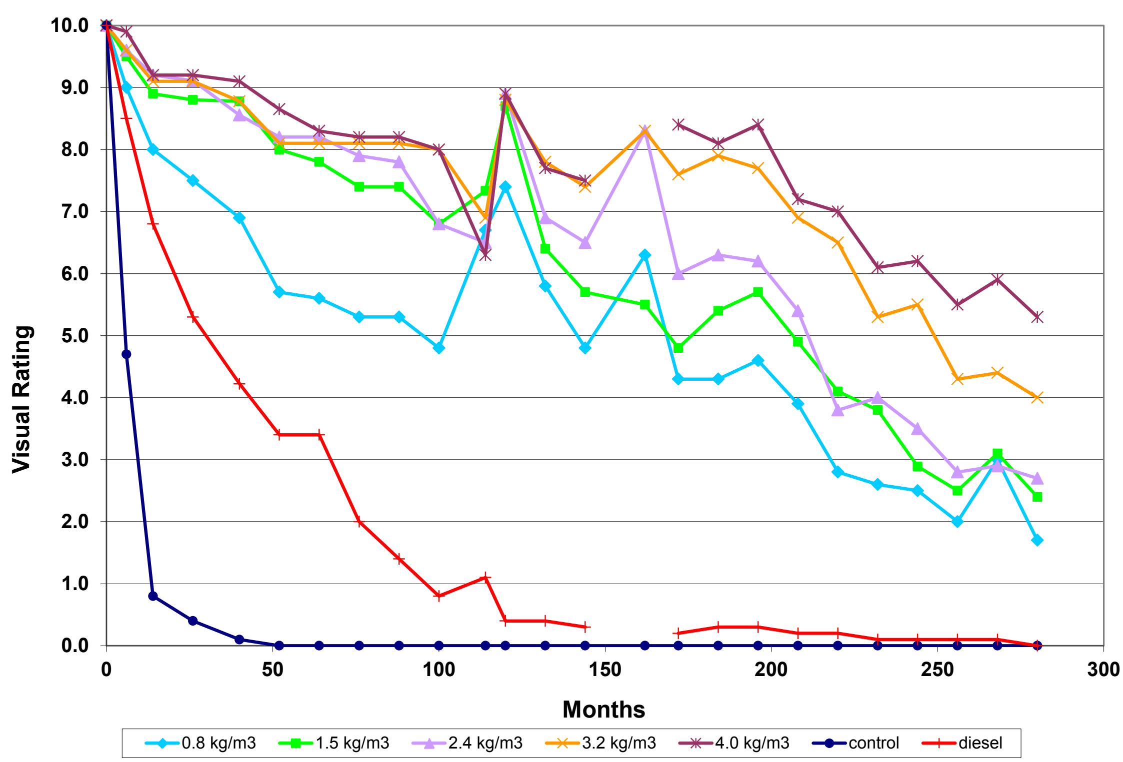


Figure V-2. Condition of weathered western redcedar sapwood stakes treated with selected retentions of copper naphthenate in diesel oil and exposed in a soil bed for 280 months.

m^3 continue to provide excellent protection after 280 months, while the conditions of the stakes treated to the two lower retentions continued to decline over the past 2 years. 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 fell below 6.0, indicating that the treatment is losing 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 had declined to an average of 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 re-treatment and reuse in other parts of the system. While this process remains possible, it is clear that the performance characteristics of the weathered re-treated 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 western redcedar and would not markedly affect overall pole properties.

The copper naphthenate should continue to protect the weathered redcedar 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 western redcedar 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. Field Performance of Copper Naphthenate Treated Douglas-fir Poles in Western Washington

Last year, we reported on a treatment results for a population of 30 poles in the Puget Sound area that had been treated with copper naphthenate in various combinations of diesel and biodiesel oil. This investigation was part of our continuing assessment of the potential impacts of biodiesel on copper naphthenate performance. The initial pole inspection consisted of excavating to a depth of 200 mm on one side of each pole, cleaning the wood surface with a check scraper and probing with a sharpened screwdriver to detect any evidence of surface softening that might be indicative of soft rot decay. Three increment cores were removed from the below-ground region of each pole and placed into drinking straws. In addition, shavings from the pole surface to a depth of 6 mm were collected.

Preservative penetration was measured on each core, and they were processed in the following manner. The outer 6 mm was removed and split radially. One half of this section was briefly flamed to minimize surface contamination before being placed on a malt extract agar plate. The plates were observed for evidence of fungal growth and any fungi were either directly examined or sub-cultured onto fresh media for later identification. The other half of the radially split segment was chemically macerated using a mixture of 30% sodium hypochlorite and glacial acetic acid then a sample of the resulting fibers was examined under a light microscope equipped with polarizing filters for evidence of soft rot damage. The remainder of each core was cultured as described above to determine if viable decay fungi were present. These initial samples were collected to establish a baseline of pole condition for subsequent monitoring.

A portion of the collected shavings were surface sterilized using the flame of an alcohol burner then plated on malt extract agar plates. The remaining shavings were retained for possible processing and examination for evidence of soft rot fungi as described above.

Of the 30 poles examined in 2012, three were treated in 2008, four in 2009 and the remainder were treated in 2010. The treatment dates are important because the treater varied the amounts of biodiesel in the solvent over time. The majority of the poles were transmission sized, but four were class 3 or 4 distribution poles.

The depth of preservative penetration ranged from 15 to 73 mm with 28 of 30 poles meeting the 19 mm minimum penetration (Table V-1). The results suggest that the poles are generally well treated. These poles will continue to be monitored over time to determine if previous laboratory tests showing that biodiesel was detrimental to copper naphthenate performance translate into issues in the field.

Microscopic examination of wood from the surfaces of the poles showed that most poles had little evidence of surface decay or soft rot attack. However, soft rot damage was detected in 3 poles, one each from those installed in 2008, 2009 or 2010 (Figure V-3). Soft rot damage, by itself is not necessarily bad if it remains shallow, but prolonged soft rot attack that extends further inward can be very detrimental to pole properties since the majority of pole bending capacity is in the outer 50 mm of the cross section.

Fungal isolations were somewhat variable. A total of 80 fungi were isolated from the cores and shavings (Table V-2). Four of these isolates, all from the same pole, were decay fungi, which was surprising given the relatively recent installation dates for these poles. Of the remaining fungi, 38 were dark pigmented or dematiaceous fungi. This group of fungi contains many species that are capable of causing soft rot damage although we have not yet tested those that were isolated for this test. The number of all fungi isolated as well as the dematiaceous species were higher in poles installed in 2008 or 2009. This could reflect the steady progression of fungal colonization

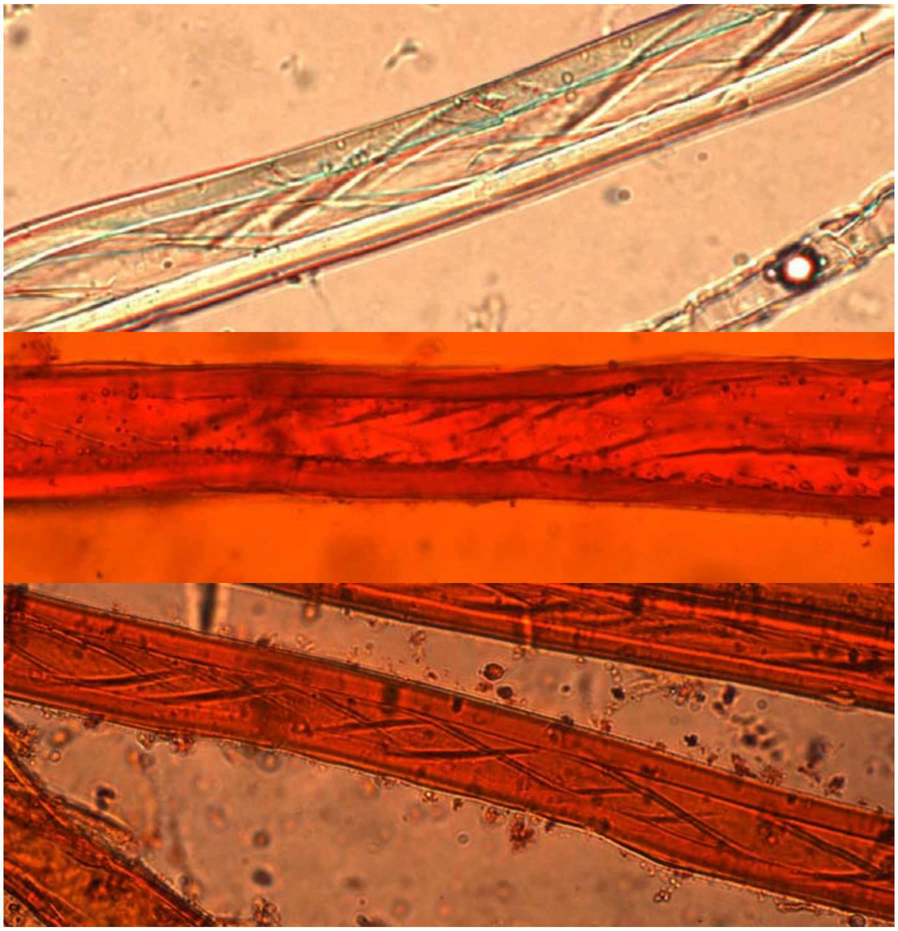
Table V-1. Characteristics of Douglas-fir poles treated with copper naphthenate in biodiesel and installed in the Puget Sound area. Poles were sampled in 2012 and evaluated for copper retention, the presence of soft rot attack and the degree of colonization by copper tolerant fungi.

Pole #	Class	Height (ft)	Year Treated	Through-bored	Preservative Penetration[a]	Pole Environment
1	H3	80	2009	+	68.8	grass, english laurel
2	H2	75	2009	+	73.9	grass, scotch broom, other weeds
3	3	45	2010	+	64.1	grass, ivy
4	3	45	2010	+	44	grass, lawn weeds
5	1	70	2010	+	52.8	grass, weeds
6	1	45	2009	+	37.5	salal, blackberries
7	H1	85	2009	+	85	tall grass, perennial plants
8	2	45	2008	-	25.6	grass, weeds, near evergreen shrub
9	4	45	2008	-	15.2	grass, english laurel
10	2	45	2008	-	16.8	grass, false dandelions
11	H1	75	2010	+	31.9	mowed roadside grass, Douglas-fir trees nearby
12	1	70	2010	+	40.3	tall grass, blackberries, other weeds
13	1	70	2010	+	31.4	mowed grass, ferns
14	1	70	2010	+	58.4	tall wetland grass, skunk cabbage, blackberries
15	H1	70	2010	+	21.2	ferns, grass, blackberries, trees nearby
16	1	75	2010	+	45.8	salal, sweetpeas, grass
17	1	65	2010	+	21.4	grass, scotch broom, salal
18	1	65	2010	+	40.4	grass, scotch broom, salal
19	1	65	2010	+	58.1	grass, scotch broom, salal
20	1	65	2010	+	38.9	scotch broom, salal, blackberries
21	1	65	2010	+	27.5	scotch broom, salal, blackberries, tall grass, thistles, ferns
22	H1	75	2010	+	34.3	roadside grass, ferns
23	H1	70	2010	+	42.8	grass, scotch broom, fir tree plantation nearby
24	H1	70	2010	+	37.2	grass, scotch broom
25	H3	85	2010	+	18.6	roadside grass, queen anne's lace, ferns
26	1	50	2010	+	36.9	grass, blackberries, small alders, maple, salmonberry, Douglas-fir trees
27	1	60	2010	+	27.2	grass, blackberries, small alders, maple, salmonberry, Douglas-fir trees
28	H1	75	2010	+	30.5	wetland grasses, blackberries, alder
29	1	55	2010	+	30.9	grass, scotch broom, blackberries Douglas-fir trees 25' from pole
30	H1	80	2010	+	27.7	grass, sweet peas, blackberries

a. Values represent the mean of three increment cores per pole

that occurs in poles in service over time. Fungal isolations also tended to be higher from poles in grassy areas compared to those in brushy areas. This might reflect the effects of vegetation on moisture conditions or soil flora.

We will need additional data from more poles to better delineate the possible effects of pole age or vegetation conditions on fungal colonization. For the moment, we can see that the poles are



Pole 2

Pole 9

Pole 30

Figure V-3. Soft rot cavities in wood cells removed from the surfaces of three copper naphthenate treated poles installed between 2008 and 2010 in the Puget Sound area.

being colonized by a variety of fungi, some of which are possible soft rot fungi, but we see little evidence of actual soft rot attack (Table V-3). The presence of fungi capable of causing soft rot does not always mean that soft rot attack is occurring. Soft rot attack is generally slow and many of the fungi capable of causing this type of attack tend to initially utilize the stored sugars and proteins in the wood. We will continue to monitor these poles to determine if wood damage occurs or extends further inward.

This past year, we collected cores from an additional 35 poles in the area between Renton and Everett, WA. The goal was to broaden the sample base and include poles from several different years when the treatment was employed in a variety of soil types (wetland, dry slope, etc.). Cores

Table V-2. Fungal isolations from increment cores and shavings removed from copper naphthenate treated Douglas-fir poles installed between 2008 and 2010[a].

vegetation type	Number of Fungi				Fungi per Pole		
	2008	2009	2010	**Total**	2008	2009	2010
Brush	-	10	14	**24**	-	5	1
Grass	24	15	16	**25**	8	7.5	2.3
Wetland	0	0	1	**1**	-	-	0.5
Total	**24**	**25**	**31**	**80**			

a A “-“denotes no poles in that category

Table V-3. Isolations of dematiaceous fungi from increment cores and shavings removed from copper naphthenate treated Douglas-fir poles installed between 2008 and 2010[a].

vegetation type	Number of Fungi				Fungi per Pole		
	2008	2009	2010	**Total**	2008	2009	2010
Brush	-	2	3	**5**	-	1	0.2
Grass	11	15	7	**33**	3.7	7.5	1
Wetland	-	-	0	**0**	-	-	0
Total	**11**	**17**	**10**	**38**			

a A "-"denotes no poles in that category

were obtained and processed in the same manner as described above except that the outer 2 mm of the core was digested for examination for soft rot cavities. The segment from 2 to 6 mm was saved in case the examination of the outer section indicated that soft rot might be present deeper in the wood. The segment from 6 to 25 mm was combined with other poles from the same treatment year and analyzed for copper by x-ray fluorescence spectroscopy.

Of the 35 poles inspected in 2013, four were treated in 2005, 19 were treated in 2008 and 12 were treated in 2009. Eight of the poles treated in 2008 were distribution poles while the remaining 27 poles were transmission poles. A majority of the poles were located in grassy areas. Average preservative penetration on the cores removed from the poles ranged from 8.3 to 91.7 mm (Table V-4). Nine of the 35 poles failed to meet the minimum penetration value; three from 2009 and the remainder from 2008. Eleven of the 2008 poles were not through-bored. Four of the poles where penetration fell below the minimum had penetration values that were within 2 mm of the requirement. The remainder, however, were far below that value. Post installation inspection does not always produce results similar to those found at the time of treatment because the sampling points differ; but the number of poles with sub-standard penetration suggests the need for more vigilance in inspection prior to installation.

Samples from these poles are in process and results will be presented in the 2014 report.

C. Resistance of Douglas-fir Sapwood Cut from Poles Treated with Copper Naphthenate With or Without Biodiesel as a Co-Solvent

Our previous tests indicated that biodiesel was detrimental to the performance of copper naphthenate in soil block tests against copper tolerant decay fungi. Decay fungi are only part of the fungal flora that can degrade wood. Soft rot fungi are another group that can be especially important near the wood surface. These fungi are members of the Ascomycota and tend to attack wood surfaces. These fungi produce two types of attack. In Type 1 soft rot attack, the fungi grow within the wood cell walls, producing diamond shaped cavities that can profoundly reduce the mechanical properties of the wood. In Type 2 soft rot attack, the fungi erode the wood cell walls from within the cells. Some fungi can produce both types of attack depending on environmental conditions.

Soft rot fungi attack wood from the outside inward and tend to be tolerant of chemicals. The tendency to attack from the outside inward is especially important for wood poles because most of the pole bending strength lies in the outer 50 mm and any damage to this area sharply reduces

Table V-4. Characteristics of copper naphthenate in biodiesel treated-Douglas-fir poles in western Washington sampled in 2013 and evaluated for copper retention, the presence of soft rot attack and the degree of colonization by copper tolerant fungi.

Pole #	Class	Height (ft)	Year Treated	Through-bore	Prerservative Penetration (mm)[a]	Pole Environment
S1	HC 6	85	2009	No	33.4	ferns, blackberries
S2	HC 6	85	2009	No	55.2	none
S3	HC 6	85	2009	No	51.8	ivy, blackberries
S4	HC 6	85	2009	No	16.8	fireweed, ferns, blackberries
S5	HC 6	85	2009	No	38.0	small blackberries
S6	HC 6	85	2009	No	42.4	grass, small blackberries, fireweed
S7	HC 6	85	2009	No	51.2	thick vegetation - salmonberry, ferns, blackberry
S8	HC 6	85	2009	No	38.8	blackberries, grass, ivy
S9	HC 6	85	2009	No	18.0	blackberry, wild grape, salmonberry, grass
S10	HC 6	85	2009	No	17.8	blackberries
S11	HC 6	85	2009	No	25.4	mowed grass
S12	HC 6	85	2009	No	34.8	backberries, ferns
P1[b,c]	1	65	2005	Yes	33.3	kinnikinnick, weathered barkdust
P1 a [b,c]	1	65	2005	Yes	40.3	kinnikinnick, weathered barkdust
P2 [c]	1	55	2008	No	28.7	kinnikinnick, weathered barkdust
P3 [b,c]	1	80	2005	Yes	39.3	irrigated, mowed grass, shrubs
P3 a [b,c]	1	80	2005	Yes	40.3	irrigated, mowed grass, shrubs
P4	H1	80	2008	Yes	33.0	tall grass, horsetail
P5	1	55	2008	No	8.3	mowed grass
P5 a	1	55	2008	No	26.0	mowed grass, hostas
P6	H1	80	2008	Yes	44.0	none, gravel
P7	1	80	2008	Yes	91.7	mowed grass
P8	1	75	2008	Yes	23.0	mowed grass
P9	3	40	2008	No	11.0	tall grass, rhododendrons
P10	1	80	2008	Yes	48.3	grass
P11 [c]	3	45	2008	No	31.7	short grass, weeds, gravel
P12 [c]	2	45	2008	No	13.0	ivy, blackberries, shrubs
P13 [c]	3	40	2008	No	41.0	tall grass, english laural, birch trees
P14 [c]	3	45	2008	No	40.3	mowed grass, blackberries
P15 [c]	1	50	2008	No	9.3	ivy, grass, blackberries
P16 [c]	1	50	2008	No	14.0	ivy, grass, blackberries
P17	3	45	2008	No	17.0	ivy, blackberries, birch trees, low-growing weeds
P18	1	65	2008	Yes	37.7	juniper in barkdust
P19	1	55	2008	Yes	13.3	mowed tall grass
P20	1	60	2008	Yes	36.7	mowed grass and weeds

a. Values represent the mean of three increment cores per pole. AWPA minimum penetration is 19 mm and 85% of the sapwood. In a through-bored pole penetration should be complete on a core.
b. Poles were treated with copper naphthenate in diesel by a different treater.
c. Pole were inspected by a contractor and a groundline paste or wrap was applied.

pole strength. With the exception of poles treated using pentachlorophenol in either liquefied petroleum gas or methylene chloride, Douglas-fir poles are normally relatively immune to soft rot attack. However, the soil block tests showed that weight losses were much higher when blocks were subjected to a weathering procedure and these findings suggest that biodiesel amended solvents may encourage leaching of copper from in service poles. The tendency for soft rot fungi to be more chemically tolerant coupled with the potential for increased copper losses may render poles treated with biodiesel amended solvents more susceptible to soft rot attack. It will take years of field monitoring to determine if this is true; however, small scale laboratory trials may help identify these problems more rapidly.

Poles treated with copper naphthenate in conventional diesel with or without biodiesel were obtained from local suppliers. Small wood wafers were cut from the outer 10 mm of the pole (10 mm by 20 mm by 20 mm long). The intent was to assess the risk of fungal attack on the outer pole surface where leaching and fungal attack were most likely to occur. Half of the wafers were weathered following procedures in the AWPA E-10 standard.

The blocks were allocated to one of three soils; our usual soil block soil, purchased potting mix or a clay soil dug up from our Oak Creek test site. The soil block and Oak Creek soils were used with and without added nitrogen. This resulted in 20 treatment groups. The test blocks were oven dried (50 C) and weighed to determine initial mass.

The test chambers consisted of 100 ml glass jars which were filled to one half of their height with soil. A single test block was placed on a 30 mm filter paper disc sitting on the soil surface then additional soil was added to the full jar height and a second filter paper disc was placed on the soil surface. The jars then received water to raise the soil moisture content to 90-140 % of water holding capacity depending on the soil. The water was sterile or amended with 0.014 g of nitrogen as ammonium nitrate. Soft rot fungi tend to be more aggressive under wetter moisture regimes and in soils with higher nitrogen contents. The tests were designed to produce conditions more conducive to soft rot attack. No specific soft rot fungi were added to the chambers because most soils already contained a variety of soft rot fungi. Decayed wood that had been in soil contact was ground and added to each soil chamber to provide inoculum. The conditions were designed to allow these fungi to flourish and attack the wood.

The results to date have been extremely poor. We have obtained weight loses on many blocks, however, the wood has little evidence of soft rot damage and we believe that most of the mass loss reflects solvent leaching (Table V-5). These tests have been in place for over two years and a final harvest will take place in October, 2013. The results will be reported in the 2014 Annual Report.

Table V-5. Weight losses of sapwood samples cut from Douglas-fir poles treated with copper naphthenate using either diesel or biodiesel/diesel as a solvent and exposed to possible soft rot attack using three different soils types with or without added nitrogen.

soil	nitrogen added	Wood weight loss (%)			
		Biodiesel		Diesel	
		non-weathered	weathered	non-weathered	weathered
Oak Creek	no	11.70 (1.34)	7.55 (1.34)	7.62 (1.24)	2.21 (0.52)
	yes	10.99 (1.23)	7.95 (0.87)	6.58 (1.29)	3.19 (1.24)
potting	no	10.69 (1.62)	6.63 (0.63)	7.13 (0.93)	3.36 (0.97)
soil block	no	10.45 (1.60)	6.87 (1.00)	6.58 (1.12)	3.08 (0.71)
	yes	10.70 (1.22)	6.58 (0.61)	6.13 (1.18)	2.29 (0.39)

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.

A. Migration of Copper from Douglas-fir Poles Treated with Copper Naphthenate According to Best Management Practices

Douglas-fir poles sections (250 to 300 mm in diameter by 1.0 m long) were air-seasoned and pressure-treated with copper naphthenate to a target retention of 9.6 kg/m^3 in the outer 6 to 25 mm of the poles. Treatment conditions followed the current Best Management Practices as outlined by the Western Wood Preservers' Institute. Following treatment, one end of each pole was sealed with an elastomeric paint as described in Section A. The poles were then placed in a stainless steel rainwater collection tank and rainwater was collected periodically. The water was weighed, then a small subsample was taken, acidified with 1N nitric acid and then analyzed for copper content by ICP. The results were then assessed on the basis of surface area of wood exposed to precipitation, amount of rainfall, and time between rainfall events in the same manner as described for the ACZA and pentachlorophenol treated poles.

Copper levels in runoff from Douglas-fir poles treated with copper naphthenate using Best Management Practices (BMP's) have generally remained low over the sixteen collection points. Copper concentrations ranged between 3 and 11 ppm over the first eight time points (Figure VI-1). Copper levels in runoff were almost 2.5 times higher in the first two collections after our typical dry summer. Copper levels then declined to levels similar to those found in the first eight collections. The results suggest that some copper naphthenate may have migrated to the wood surface over the dry period where it was readily available when the rains began. The elevated levels were exacerbated by the fact that the rainfall totals for these first two collections were relatively low (Figure VI-2). With the exception of these two events, there appeared to be no consistent relationship between copper levels in the runoff and rainfall amounts or the time interval between rainfall events (Figure VI-3). A small, but similar trend was observed with pentachlorophenol (penta) treated poles where penta levels in runoff were elevated after the summer. As with the copper naphthenate, this effect disappeared with continued rainfall.

The results generally indicate that copper levels in runoff from the poles are consistent and predictable. As with the penta and ACZA tests, the results indicate that any losses can be predicted and management steps can be taken where necessary to minimize losses.

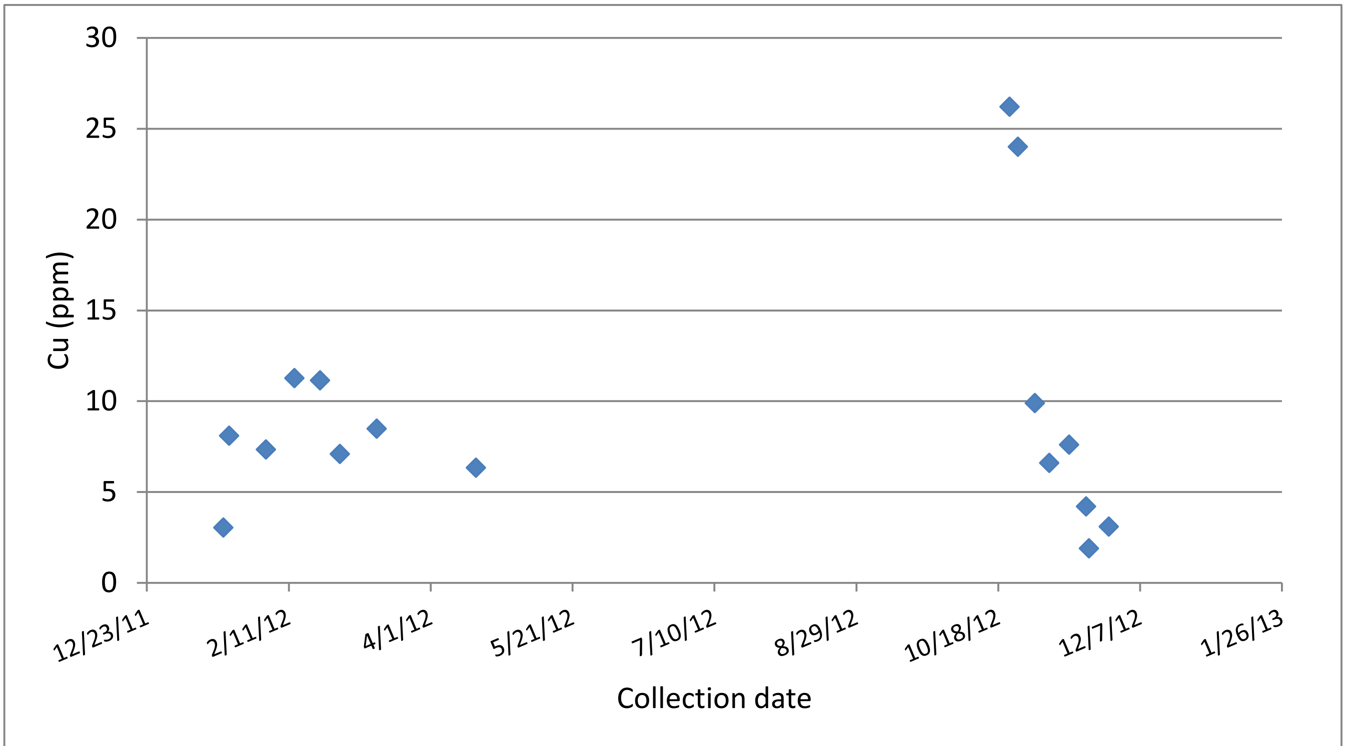


Figure VI-1. Copper levels in runoff from Douglas-fir poles treated with copper naphthenate using Best Management Practices and exposed outdoors in western Oregon for 1 year by collection date.

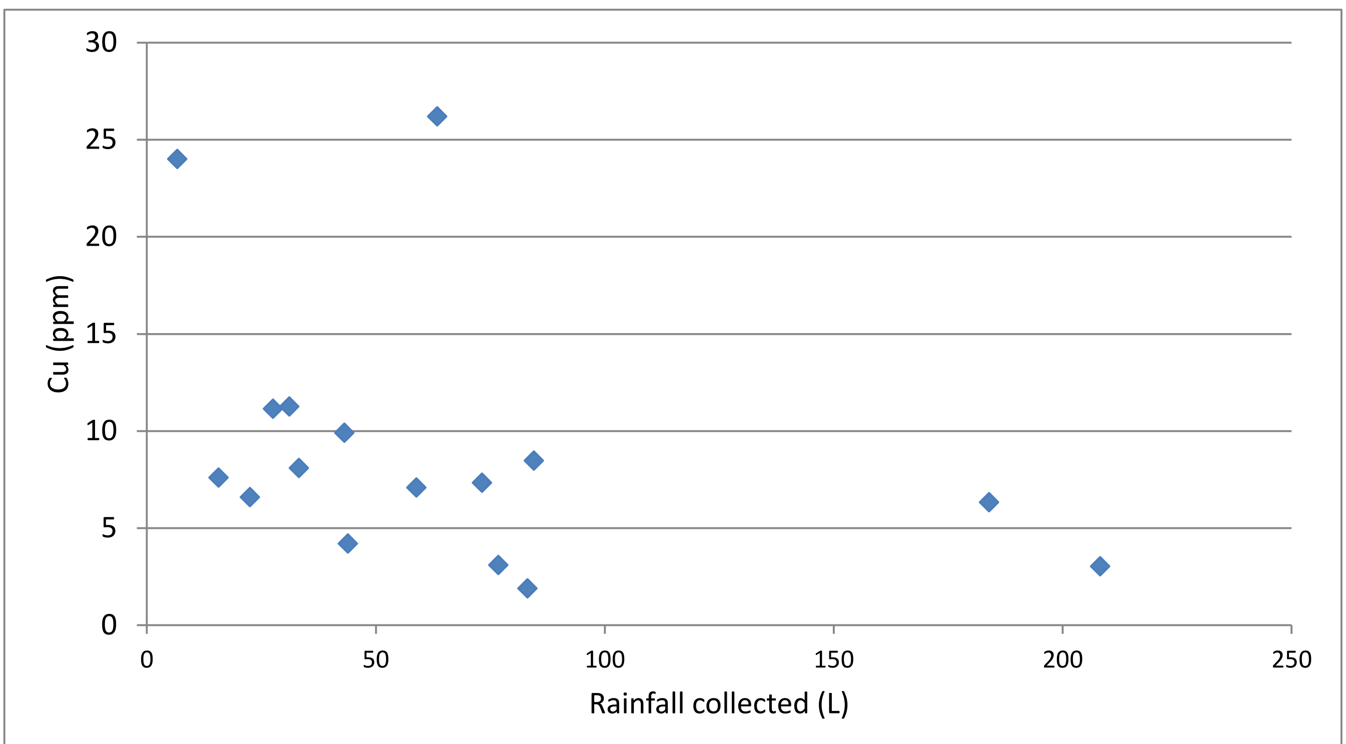


Figure VI-2. Copper levels in runoff from Douglas-fir poles treated with copper naphthenate using Best Management Practices and exposed outdoors in western Oregon for 1 year as a function of total amount of water collected.

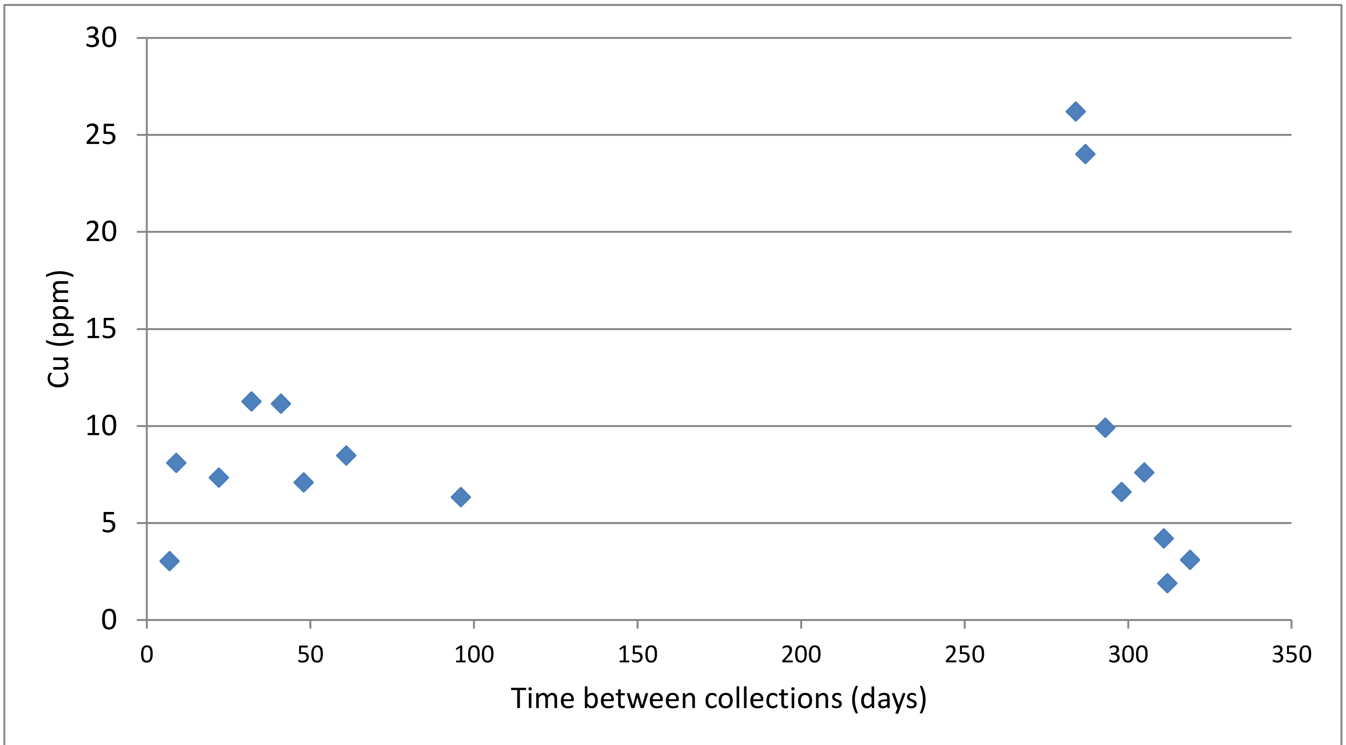


Figure VI-3. Copper levels in runoff from Douglas-fir poles treated with copper naphthenate using Best Management Practices and exposed outdoors in western Oregon for 2 years as a function of time periods between rainfall events.