Oregon State University
Utility Pole Research Cooperative

Department of Wood Science and Engineering
Oregon Wood Innovation Center

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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

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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

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EXECUTIVE SUMMARY

The coop continues to examine questions related to the performance of wood in utility systems under six objectives. Progress on these objectives will be addressed sequentially. Objective I addresses the evaluation of internal remedial treatments for arresting fungal decay. This past year, we evaluated two tests of dazomet, one examining the use of copper based accelerants for improving dazomet decomposition and the other examining the differences between rod and powder formulations of this chemical. Copper compounds both initially improved the release rate of MITC from dazomet, although this effect eventually disappeared over time. Copper naphthenate and copper sulfate both appeared to be suitable accelerants. The performance of dazomet in rods was compared with that of the typical powdered formulation. The systems performed similarly in terms of residual MITC present in pole stubs. Rods may be more easily applied, with reduced risk of spills.

We have also examined the efficacy of internal treatments under drier conditions in a field test in Utah. The results show the importance of water for releasing some treatments such as dazomet and boron rods. Treatments that were not dependent on moisture appeared to be moving well into the surrounding wood.

We also evaluated the degree of residual fumigant protection in poles in a California utility 10 years after inspection and treatment. The results illustrate the benefits of closer examination of pole condition when determining retreatment cycle. The results suggested that inspection and retreatment cycles could be more closely tailored to pole characteristics and that this might help utilities allocate resources to poles that will most benefit from treatment.

No work was performed under Objective II, which examines methods for reducing decay in field drilled bolt holes. The continuation of this topic will be addressed at the Advisory Committee meeting.

Objective III involves a host of topics related to improving specifications for wood used by utilities. No additional work was performed on through-boring, although we continue to field inquiries from utilities concerned with the possible effects of this process on wood properties. We have assembled additional data to forward to the ASC 05 committee for consideration. We have also examined the effects of barriers on the performance of both crossarms and pole tops. Polyurea coatings limited moisture uptake, but did not prevent termites from attacking either non-treated wood or borate treated wood. These results suggest that a more robust treatment must be employed with the barriers. Coating of pole tops has resulted in much lower internal moisture contents that should result in a reduced risk of top decay. Similar results have been found with traditional pole caps and illustrate the value of excluding moisture, even above the groundline.

The potential effects of biodiesel as a co-solvent on performance of pentachlorophenol (penta) remain under study. Field stake tests from Hilo, Hawaii indicate that stakes treated with penta in conventional diesel and a biodiesel-amended solvent are performing similarly after 31 months of exposure. Analyses suggest that penta is depleting more rapidly from stakes treated with the biodiesel-amended solvent. These stakes are extremely thin and are designed to accelerate chemical loss. We will examine poles treated with this solvent in the coming year to determine if similar depletion is occurring.

Under Objective IV, we are examining the performance of various groundline barriers and remedial treatments. Barriers have been developed to both hold in chemical and limit contact between wood and soil inhabiting fungi. One concern with these barriers is that they will trap moisture and result in poles that are much wetter above the groundline. Field trials indicate that moisture contents in poles with and without barriers tended to vary seasonally, but that moisture does not appear to be building up in the poles with barriers. Soil analyses indicate that metal levels remain low in soil away from the pole regardless of the presence of barrier. A field trial of external preservative pastes in Arizona was sampled 17 months after treatment. Copper levels tended to be high near the wood surface, while boron and fluoride moved more deeply inward. Copper levels in the system containing a micronized formulation were lower and largely confined to the outer layer. This same system contained bifenthrin (an insecticide) and tebuconazole (a fungicide). These components were present in the outer 12 mm of the pole. The importance of surface vs internal protection with external pastes is discussed.

Objective V addresses the performance of copper naphthenate. Western redcedar stakes treated with this chemical continue to perform well, although stakes cut from freshly harvested western redcedar have out-performed those cut from weathered poles. Examination of the effect of biodiesel on copper naphthenate performance continues. Tests to examine the risk of soft rot on poles treated with copper naphthenate in biodiesel have been established and the results will be reported in the next annual report. In addition, poles treated with this chemical/solvent combination and installed in the Puget Sound area have been identified and inspected. These poles will be monitored over time to determine if the solvent has a long term effect on field performance.

Objective VI examines the migration of preservative components from poles in storage. Poles treated with ACZA or copper naphthenate in a conventional diesel solvent were examined. Metal levels in rainfall runoff from ACZA treated poles were initially elevated, but declined to background levels after the first few rainfalls. Copper in rainwater runoff from copper naphthenate treated poles was uniform over the 5 month exposure period. The results indicate that components of these preservatives in rainwater form stored poles are predictable and can be managed.

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 im-

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

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

portant part of the development process for these systems has been continuing performance evaluations to determine when retreatment is necessary and to identify any factors that might affect performance. 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
MITC movement from Dazomet Treated Posts under Dry Conditions	2012	Dazomet with accelerants	lab	2012	
MITC Content of Residual Dazomet in Treatment Holes	2010	Dazomet	Corvallis, OR & AZ	2011	
Ability of Internal Remedial Preservative Systems to Migrate into Distribution Poles in an Arid Climate	2010	Dazomet, MITC, metham sodium, boron rods	UT	2012	2013
Full Scale Field Trial of All Internal Remedial Treatments	2008	Dazomet (5 products), MITC, metham sodium (3 products), chloropicrin, boron rods, fluoride rods (2 products)	Corvallis, OR	2011	2013
Performance of dazomet in tube and granular formulations	2006	Dazomet	Corvallis, OR	2011	2013
Performance of a copper amended boron rod	2001	Copper/boron rods	Corvallis, OR	2011	2013
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	2008	2013

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.

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

Chemical distribution was assessed 1, 2, 4, 5, 8, 10, 12 and 15 years after treatment by removing increment cores from three equidistant points around each pole at sites 0.3, 1.3, and 2.3 m above the groundline. The outer 25 mm of each core was discarded. The next 25 mm, and the 25 mm section closest to the pith (Figure I-1), of each core were placed into vials containing 5 ml of ethyl acetate. The cores were stored at room temperature for 48 hours to extract any MITC in the wood, then the increment core was removed, oven-dried, and weighed. The core weight was later used to calculate chemical content on a wood weight basis. The ethyl acetate extracts were injected into a Shimadzu gas chromatograph equipped with a flame photometric detector with filters specific for sulfur (a component of MITC). MITC levels in the extracts were quantified by comparison with prepared standards and results were expressed on an ug MITC/oven dried g of wood basis.

The remainder of each core was then placed on the surface of a 1.5% malt extract agar petri dish and observed for evidence of fungal growth. Any fungi growing from the cores were examined for characteristics typical of wood decay fungi.

As with our other tests, the threshold for MITC is considered to be 20 ug or more of MITC/oven dried gram of wood. MITC levels tended to be greater in the inner zones, reflecting the tendency of the treatment holes to encourage chemical movement to the pole center (Table I-3). MITC tended to be present at levels above the threshold in the 0.3 m above groundline zone. While MITC was detected above this level, it was rarely above the threshold. For example, MITC levels 1.3 or 2.3 m above groundline in poles with no supplemental copper were only above the threshold 5 years after treatment.

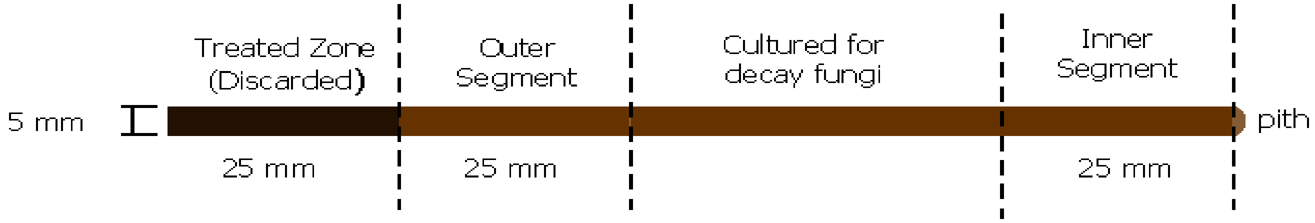

Figure I-1. Representation of increment core showing inner and outer 25 mm segments analyzed for fumigant content. The length of the segment cultured for decay fungi varies in length depending on the size of the pole.

For this reason, the results will be discussed from the perspective of protection around the lowest sampling point above the original treatment site. MITC levels in poles receiving no supplemental treatment reached the threshold level 0.3 m above ground 1 year after treatment (Figure I-2). MITC levels 0.3 m above groundline increased slightly over the next 4 years in these poles, but appeared to stabilize at levels well above the threshold by 4 years after treatment. MITC levels in these poles declined to just at or below the threshold after 8 years and below that level after 10 years. Levels were again above the threshold 12 and 15 years after treatment, but only at 0.3 m above groundline. The presence of protective levels in these poles is consistent with previous tests showing that dazomet continues to release low levels of MITC for prolonged periods.

MITC levels 0.3 m above the groundline one year after treatment were 2 to 5 times higher when copper sulfate was added to the dazomet and these levels continued to remain elevated over the next 4 years (Figure I-3). MITC was also detectable 1.3 and 2.3 m above groundline 4 years after treatment at levels above the threshold. Chemical levels remained elevated 5 years after treatment, but then declined to levels just above the threshold 8 years after chemical application. Threshold levels were only present at four sampling locations 10 years after treatment, although all of these were in copper amended poles. These results clearly support the application of copper sulfate at the time of dazomet treatment to increase initial release rate. Results at 12 years indicated that threshold levels were only present 0.3 m above groundline, while MITC was either barely detectable or not detectable at higher locations. These results indicate that any protective effect of dazomet had been lost except at the application point and that retreatment would be advisable.

MITC levels in pole sections 1 year after receiving copper naphthenate appeared to experience less of an initial boost in release rate than poles receiving copper sulfate; however, chemical levels rose sharply 2 years after treatment and have remained elevated and similar to those for the copper sulfate treatment (Figure I-4). MITC was also detectable 1.3 and 2.3 m above groundline, but was only just approaching the threshold 1.3 above groundline in the inner assay zone. These results indicate that copper naphthenate enhanced dazomet decomposition to MITC, but the levels were slightly lower than those found for copper sulfate. Despite the lower levels, copper naphthenate does appear to be useful for encouraging MITC production to more rapidly eliminate any decay fungi established in the wood. As with copper sulfate, MITC levels have declined at the 12 year sampling, becoming similar to those found with the copper sulfate and non-copper amended controls.

Table I-3. Residual MITC in Douglas-fir pole sections 1 to 15 years after treatment with dazomet with or without copper sulfate or copper naphthenate.

Copper Treatment	Year sampled	Residual MITC (ug/g of wood)[a]					
		0.3 m		1.3 m		2.3 m	
		inner	outer	inner	outer	inner	outer
None	1	**21** (14)	18 (37)	0 (0)	0 (0)	0 (0)	3 (8)
	2	**72** (47)	**36** (33)	0 (0)	0 (0)	0 (0)	0 (0)
	3	**57** (27)	**32** (42)	0 (0)	0 (0)	0 (0)	0 (0)
	4	**50** (41)	**32** (32)	6 (5)	6 (6)	0 (0)	0 (0)
	5	**67** (31)	9 (8)	12 (4)	10 (29)	0 (0)	0 (0)
	8	**21** (26)	16 (21)	**22** (24)	17 (28)	**21** (23)	**26** (39)
	10	10 (13)	6 (12)	19 (34)	12 (21)	13 (22)	4 (6)
	12	**35** (38)	**20** (22)	4 (5)	1 (4)	2 (6)	0 0
	15	**23** (14)	8 (3)	3 (3)	1 (1)	1 (1)	1 (1)
20 g Copper sulfate ($CuSO_4 \cdot 5H_2O$)	1	**103** (78)	**55** (86)	4 (6)	0 (0)	0 (0)	0 (0)
	2	**101** (36)	**32** (17)	7 (7)	3 (7)	0 (0)	0 (0)
	3	**78** (25)	**29** (17)	7 (7)	5 (8)	0 (0)	0 (0)
	4	**95** (61)	**40** (20)	20 (21)	**21** (27)	**25** (35)	**23** (33)
	5	**87** (12)	**21** (6)	18 (15)	3 (6)	7 (10)	0 (0)
	8	**35** (43)	14 (20)	**26** (29)	12 (21)	**29** (36)	**24** (40)
	10	16 (24)	7 (9)	**28** (41)	5 (8)	**30** (46)	4 (6)
	12	**40** (16)	**21** (16)	13 (6)	1 (2)	4 (6)	0 0
	15	12 (18)	2 (2)	13 (34)	3 (10)	**21** (26)	5 (7)
20 g Copper naphthenate (2% Cu in mineral spirits)	1	**34** (19)	**43** (54)	0 (0)	0 (0)	2 (5)	6 (19)
	2	**94** (45)	**94** (64)	6 (7)	5 (11)	0 (0)	0 (0)
	3	**110** (29)	**59** (46)	7 (7)	4 (8)	0 (0)	0 (0)
	4	**89** (33)	**73** (24)	18 (9)	9 (7)	1 (2)	0 (0)
	5	**102** (18)	**41** (39)	**23** (7)	1 (2)	2 (3)	0 (0)
	8	**27** (26)	**22** (23)	**26** (35)	20 (24)	**26** (26)	**38** (55)
	10	19 (28)	11 (13)	**24** (37)	4 (9)	**28** (43)	9 (18)
	12	**57** (17)	**29** (14)	8 (30)	2 (4)	3 (6)	0 0
	15	**33** (19)	**20** (24)	6 (3)	3 (2)	1 (1)	1 (1)

[a] Values in bold type represent chemical levels at or above the fungal threshold. Figures in parentheses represent one standard deviation.

Isolations of decay fungi from the inner zones of the poles 1 year after treatment were limited except from poles treated with dazomet amended with copper compounds. Fungi continue to be isolated from the above ground zones of these poles, but the isolations have been sporadic and suggest that isolated fungal colonies were present in the above ground zones of the poles (Table I-3). We suspect that the fungi present after 1 year were probably present at the time of treatment. The relatively low levels of chemical 1.3 and 2.3 m above groundline likely limited the potential for control in these zones. Decay fungi were isolated at various locations along the poles at 1.3 m and above the groundline, but there was no consistent pattern. In addition, no decay fungi were isolated from any cores this past year (Table I-4). These results suggest that treatment patterns and the zone of protection are more limited with these controlled release formulations than they are with liquid formulations that are applied at much

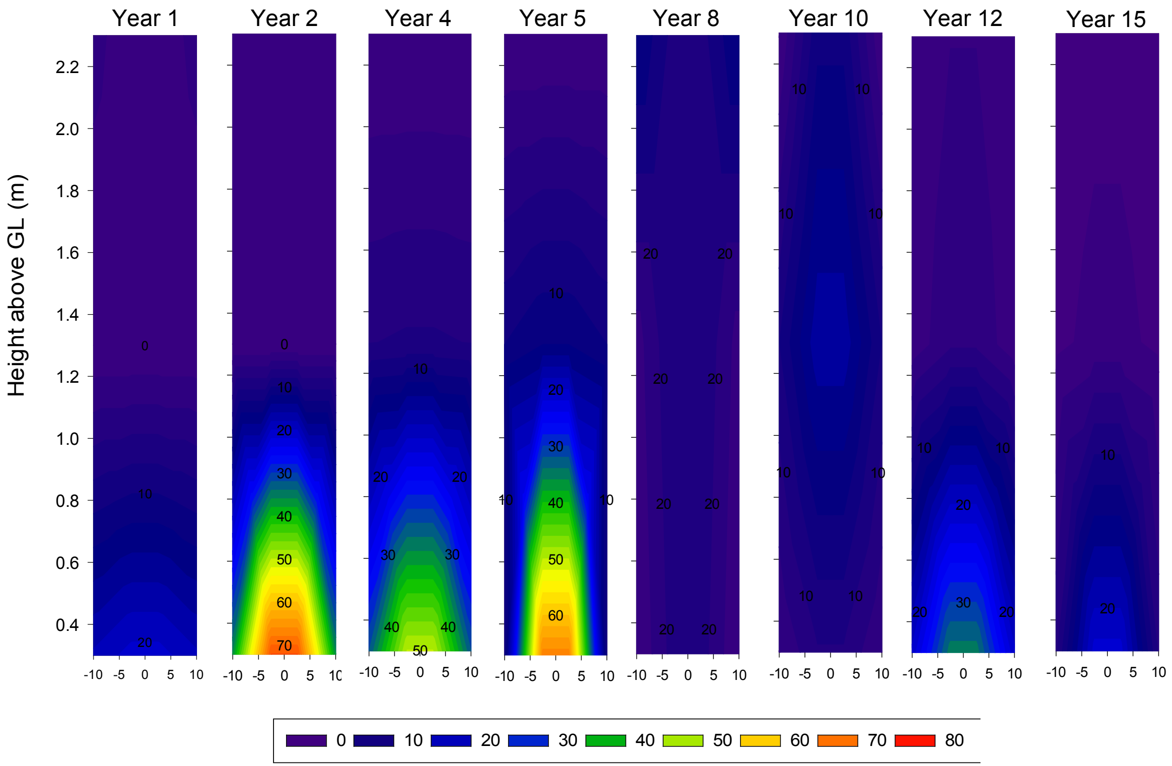

Figure I-2. Distribution of residual MITC in Douglas-fir pole sections 1 to 15 years after treatment with 200 g of dazomet. Dark blue indicates MITC levels below the threshold. Light blue and all other colors indicate MITC levels above that level.

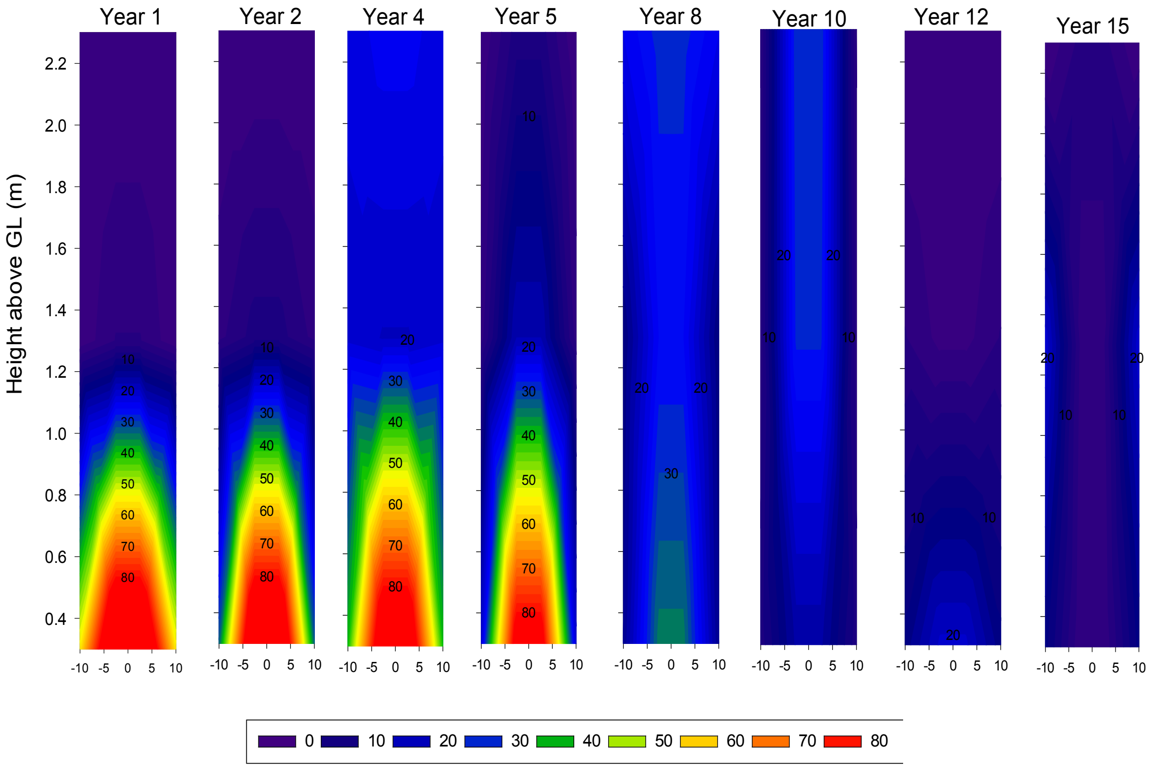

Figure I-3. Distribution of residual MITC in Douglas-fir pole sections 1 to 15 years after treatment with 200 g of dazomet plus 20 g of copper sulfate. Dark blue indicates MITC levels below the threshold. Light blue and all other colors indicate MITC levels above that level.

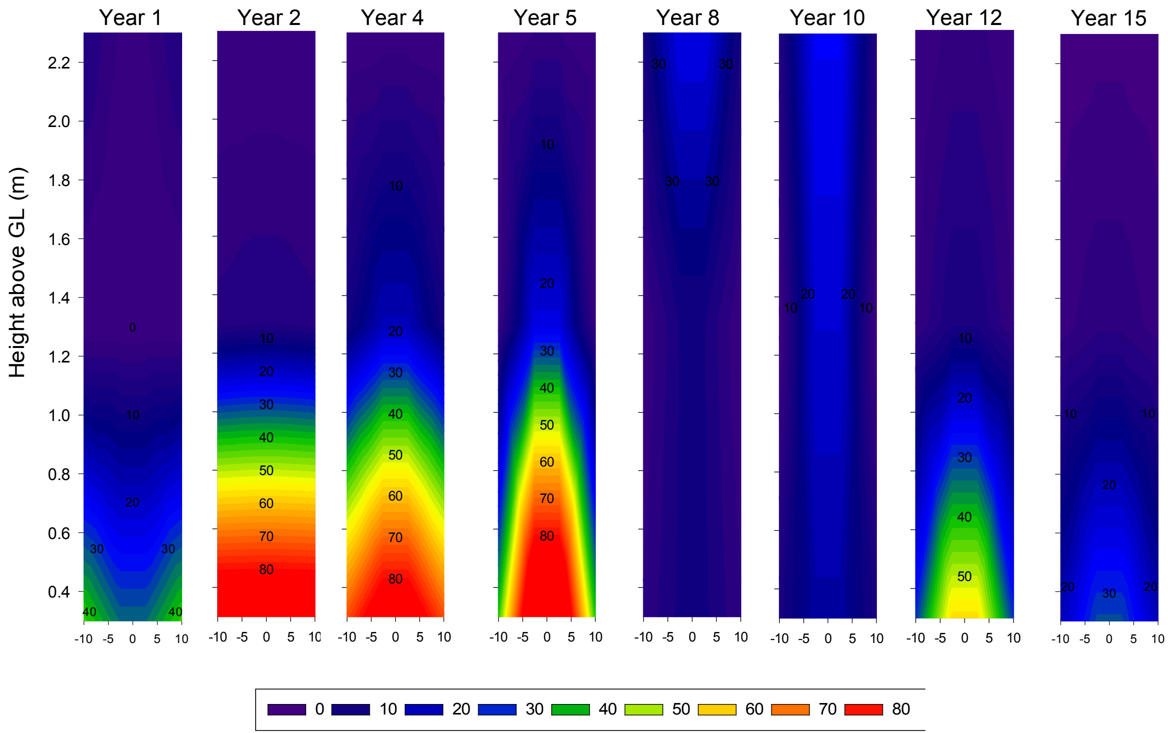

Figure I-4. Distribution of residual MITC in Douglas-fir pole sections 1 to 15 years after treatment with 200 g of dazomet plus 20 g of copper naphthenate. Dark blue indicates MITC levels below the threshold. Light blue and all other colors indicate MITC levels above that level.

higher doses. As a result, some adaptation of treatment patterns may be necessary where decay control is desired above the groundline; however, one advantage of these treatments over liquids is the ability to more safely apply the chemical above the groundline.

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)

Table I-4. Percentage of increment cores containing decay and non-decay fungi (superscript) 1 to 15 years after application of dazomet with or without copper sulfate or copper naphthenate.

Copper Treatment	Years after treatment	Isolation Frequency (%)^{a}		
		0.3 m	1.3 m	2.3 m
None	1	0^{11}	0^{11}	0^{11}
	2	0^{0}	0^{33}	0^{33}
	3	0^{0}	0^{33}	0^{0}
	4	0^{11}	0^{33}	0^{56}
	5	0^{0}	0^{0}	0^{100}
	8	0^{0}	0^{11}	0^{56}
	10	0^{0}	0^{33}	0^{0}
	12	0^{0}	11^{0}	0^{22}
	15	0^{0}	22^{0}	0^{11}
20 g Copper sulfate ($CuSO_4 \cdot 5H_2O$)	1	0^{11}	22^{33}	0^{44}
	2	0^{0}	44^{56}	0^{33}
	3	0^{0}	11^{11}	0^{33}
	4	0^{11}	22^{33}	11^{33}
	5	0^{0}	0^{67}	0^{89}
	8	0^{0}	0^{22}	0^{44}
	10	0^{0}	11^{44}	0^{11}
	12	0^{0}	0^{0}	0^{33}
	15	0^{11}	0^{44}	0^{0}
20 g Copper naphthenate (2% Cu in mineral spirits)	1	33^{33}	0^{22}	0^{44}
	2	0^{0}	0^{0}	0^{67}
	3	0^{0}	0^{0}	0^{22}
	4	0^{0}	0^{0}	0^{67}
	5	0^{0}	11^{11}	0^{78}
	8	0^{11}	0^{0}	0^{33}
	10	0^{0}	0^{11}	0^{44}
	12	0^{0}	0^{11}	0^{22}
	15	0^{0}	0^{22}	0^{0}

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 ammendments were placed into the treatment holes on top of the fumigants. Each treatment was replicated on five poles.

Chemical distribution was assessed 1,2, 3, 5, 7, 8, 10 and 12 years after treatment by removing increment cores from locations at three equidistant locations around each pole at 0.3, 0.8 or 1.3 m above the groundline. The outer treated zone of each core was discarded, and then the inner and outer 25 mm of the remainder of each core was placed into a tube containing 5 ml of ethyl acetate as previously described. The core was extracted in ethyl acetate for 48 hours at room temperature, then the core was removed to be oven dried and weighed. The ethyl acetate extract was analyzed for residual MITC by gas chromatography as previously described. The remainder of each core was placed on 1.5 % malt extract agar and observed for evidence of fungal growth. Any fungal growth was examined for characteristics typical of wood decay fungi.

In evaluating the effectiveness of treatment, we have traditionally used a threshold for fungal protection of 20 ug of MITC/oven dried g of wood. This value is based upon an examination of previous fungal culturing and chemical analysis data from our many field trials. In general, MITC levels 1.3 m above the groundline were rarely above the threshold over the 10 year test although MITC was generally detectable at this level (Table I-5, Figures I-5 to I-10). MITC was also consistently detected 0.8 m above groundline. Levels in the outer zones at this height were also below the threshold, but those in the inner zone at this height were above or very near the threshold for all dazomet treatments regardless of whether copper was added. MITC levels 0.8 m above groundline in metham sodium treated poles were only above the threshold 1 to 3 years after treatment. MITC levels at this same sampling height then fell off sharply illustrating the tendency for metham sodium to provide a large burst of initial activity followed by a sharp drop in residual protection.

MITC levels 0.3 m above the groundline in metham sodium treated poles were well above the threshold one year after treatment, particularly in the inner zone, but then declined sharply thereafter. The MITC levels at groundline were somewhat lower than those found in other tests, although the reasons for the lower levels are not clear. MITC levels in metham sodium treated poles had declined below the threshold for fungal attack at 5 years and have remained below that level since that time. The relatively short term protective period provided by metham sodium is consistent with its ephemeral nature. This system, which contains mostly water, must decompose to become effective, but does so at a low efficiency in wood. As a result, it tends to provide the shortest protective period of the internal remedial treatments although it certainly provides a very large initial surge of MITC that eliminates any fungi present in the wood.

MITC levels in poles treated with dazomet were also above the threshold 1 year after treatment, regardless of the addition of either copper or water. Interestingly, the dazomet rod with water treatment appeared to result in the lowest MITC levels in the inner zone, while the two copper naphthenate treatments with rods produced the highest MITC levels. MITC levels in all dazomet treatments have remained well above the threshold for fungal protection 12 years after treatment. The results indicate that formulating dazomet in rod form had no negative effect on performance.

No decay fungi have been isolated from any of the poles in the 12 years of this test (Table I-6). Non-decay fungi have also been almost eliminated from the 0.3 and 0.8 m sampling

Table I-5. Residual MITC in Douglas-fir pole sections 1 to 12 years after treatment with metham sodium or combinations of dazomet in rod or powdered form and copper naphthenate or water.

Treatment	Dosage	Supplement	Year sampled	Residual MITC (ug/g wood)[a]					
				0.3 m above GL		0.8 m above GL		1.3 m above GL	
				inner	outer	inner	outer	inner	outer
Dazomet Powder	160 g	None	1	**50** (35)	**24** (23)	6 (17)	4 (8)	0 (0)	0 (1)
			2	**52** (70)	16 (55)	**42** (54)	1 (3)	**25** (31)	**27** (41)
			3	**38** (41)	**28** (44)	**28** (28)	**39** (65)	**54** (98)	**34** (51)
			5	**145** (99)	**97** (81)	**32** (19)	**22** (20)	8 (11)	4 (7)
			7	**132** (45)	**53** (49)	**25** (23)	7 (9)	5 (6)	2 (5)
			8	**132** (74)	**88** (52)	**42** (57)	18 (8)	12 (16)	4 6
			10	**109** (70)	**58** (44)	18 (16)	13 (10)	5 (7)	4 (7)
			12	**74** (38)	**28** (26)	14 (10)	7 (4)	4 (3)	2 (2)
Dazomet Rods (6)	107 g	100 g copper naphthenate	1	**44** (57)	**46** (44)	2 (4)	6 (8)	0 (0)	0 (0)
			2	**51** (70)	0 (2)	**36** (51)	1 (3)	**73** (101)	14 (28)
			3	**67** (81)	**66** (102)	**52** (98)	**31** (46)	**49** (67)	**37** (71)
			5	**118** (53)	**85** (52)	**56** (38)	**42** (73)	16 (11)	5 (11)
			7	**211** (324)	**67** (58)	**36** (18)	17 (11)	11 (10)	2 (4)
			8	**118** (70)	**115** (116)	**33** (12)	20 (9)	14 (7)	6 4
			10	**88** (54)	**73** (62)	**30** (21)	14 (10)	7 (6)	4 (6)
			12	**63** (32)	**32** (29)	20 (11)	8 (3)	6 (3)	2 (1)
Dazomet Rods (9)	160 g	None	1	**54** (95)	**30** (30)	2 (4)	4 (7)	0 (2)	1 (3)
			2	**29** (37)	3 (6)	**35** (53)	1 (3)	**33** (46)	6 (11)
			3	**26** (36)	**31** (43)	**38** (51)	15 (20)	**29** (34)	**21** (49)
			5	**113** (56)	**80** (66)	**38** (29)	**21** (11)	6 (11)	3 (7)
			7	**91** (63)	**35** (28)	**22** (12)	14 (13)	4 (9)	1 (3)
			8	**93** (47)	**119** (102)	**33** (22)	**22** (15)	9 (12)	4 8
			10	**116** (97)	**67** (58)	**28** (34)	15 (17)	5 (10)	5 (10)
			12	**60** (39)	**31** (20)	**21** (30)	11 (9)	7 (12)	3 (4)
Dazomet Rods (9)	160 g	100 g copper naphthenate	1	**49** (63)	**85** (88)	9 (16)	9 (16)	1 (2)	0 (2)
			2	**80** (104)	17 (45)	**49** (64)	4 (9)	**62** (75)	5 (11)
			3	**76** (101)	**39** (53)	**47** (55)	**73** (115)	**47** (52)	**28** (48)
			5	**175** (197)	**159** (139)	**62** (88)	**46** (87)	18 (30)	11 (21)
			7	**125** (70)	**82** (51)	**36** (45)	13 (12)	14 (19)	4 (5)
			8	**114** (81)	**92** (80)	**33** (28)	**21** (15)	13 (17)	5 7
			10	**87** (47)	**62** (50)	**27** (25)	17 (14)	6 (13)	4 (7)
			12	**72** (54)	**34** (18)	17 (16)	9 (9)	8 (11)	3 (5)
Dazomet Rods (9)	160 g	100 g water	1	**22** (21)	**29** (35)	4 (6)	6 (10)	0 (0)	1 (2)
			2	**33** (47)	1 (2)	**32** (34)	1 (5)	**41** (41)	6 (11)
			3	**25** (23)	**24** (28)	**22** (31)	14 (26)	**37** (45)	14 (27)
			5	**63** (28)	**87** (104)	**29** (14)	15 (18)	5 (7)	1 (3)
			7	**71** (37)	**32** (29)	**23** (16)	10 (11)	3 (5)	1 (3)
			8	**70** (22)	**89** (74)	**25** (11)	15 (9)	7 (8)	4 6
			10	**67** (38)	**68** (58)	19 (9)	12 (14)	2 (5)	1 (2)
			12	**69** (30)	**41** (37)	16 (10)	8 (4)	3 (3)	2 (2)
Metham Sodium	490 ml	None	1	**64** (43)	**75** (73)	17 (18)	**22** (27)	1 (2)	2 (4)
			2	**37** (49)	7 (11)	**30** (27)	4 (7)	**50** (78)	5 (10)
			3	**22** (19)	**22** (22)	17 (18)	**21** (20)	18 (15)	17 (19)
			5	12 (11)	13 (10)	9 (9)	8 (10)	7 (8)	2 (5)
			7	3 (6)	3 (5)	3 (6)	1 (3)	0 (0)	0 (0)
			8	5 (8)	5 (7)	2 (4)	2 (4)	3 (6)	0 1
			10	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
			12	0 (1)	0 (1)	0 (1)	0 (0)	0 (0)	0 (0)

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

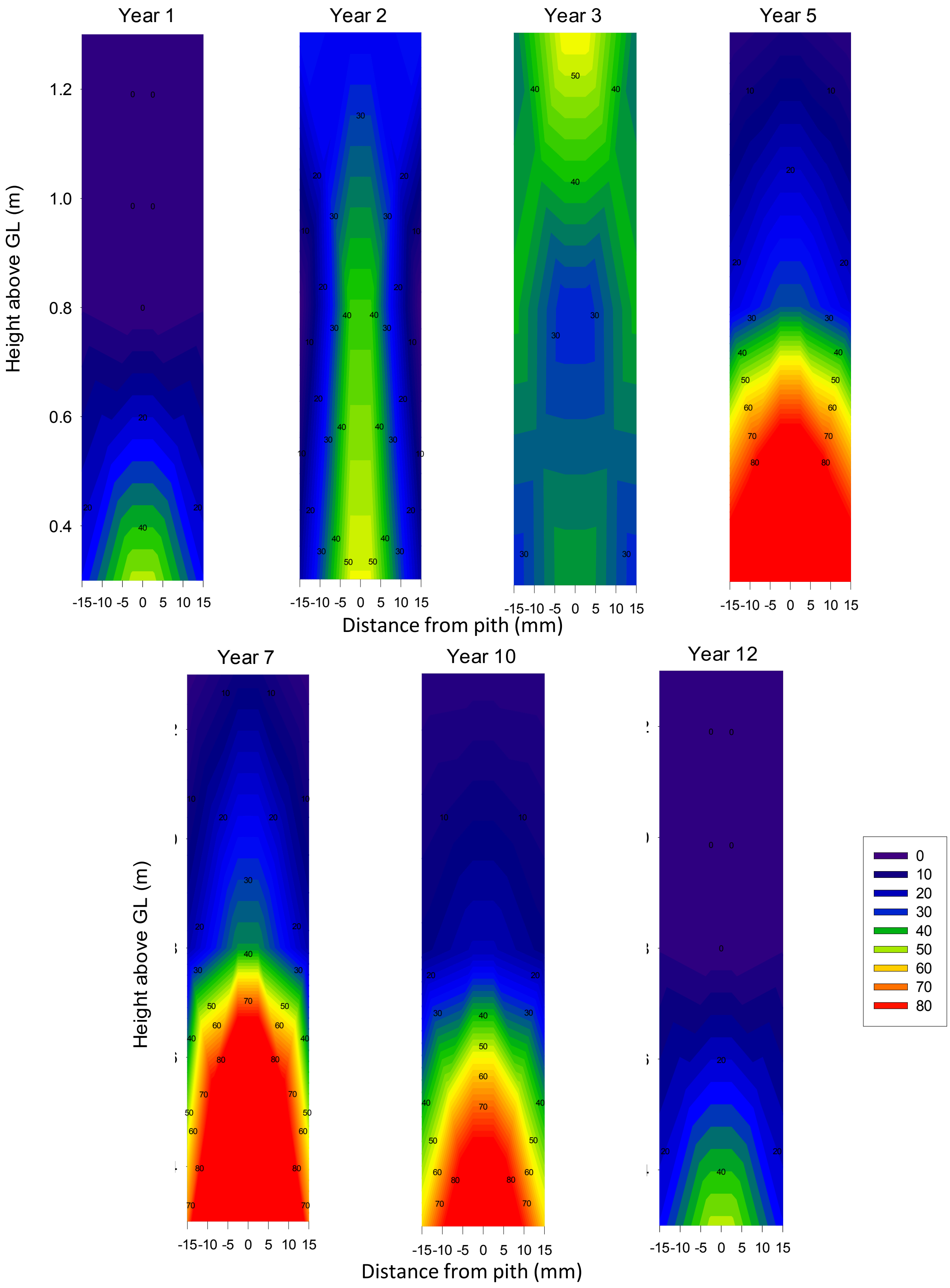

Figure I-5. Residual MITC in Douglas-fir poles 1 to 12 years after treatment with 160 g of powdered dazomet. Dark blue indicates MITC levels below the threshold. Light blue and all other colors indicate MITC levels above the threshold.

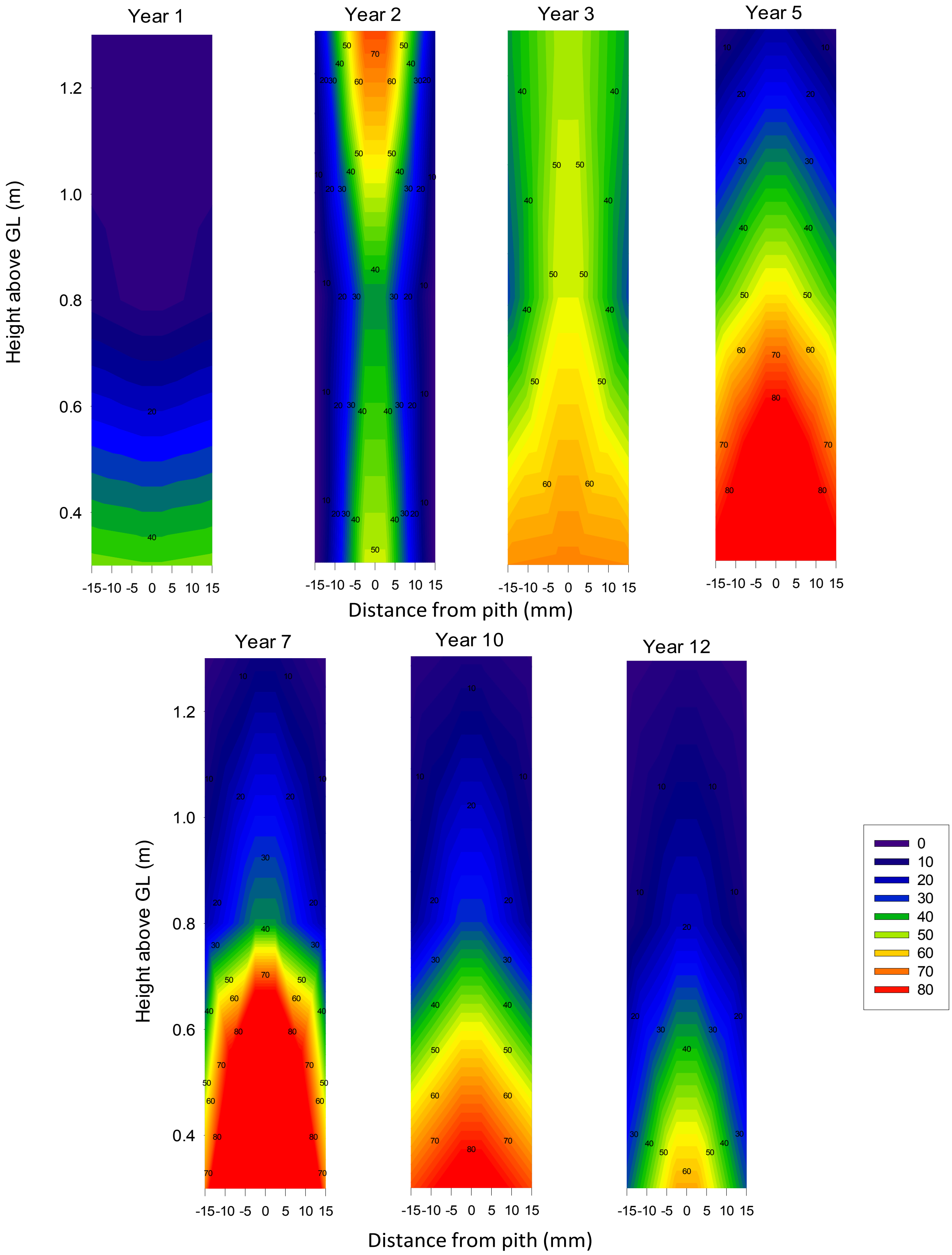

Figure I-6. Residual MITC in Douglas-fir poles 1 to 12 years after treatment with 6 dazomet rods (107 g) plus 100 g of copper naphthenate (2% Cu). Dark blue indicates MITC levels below the threshold. Light blue and all other colors indicate MITC levels above the threshold.

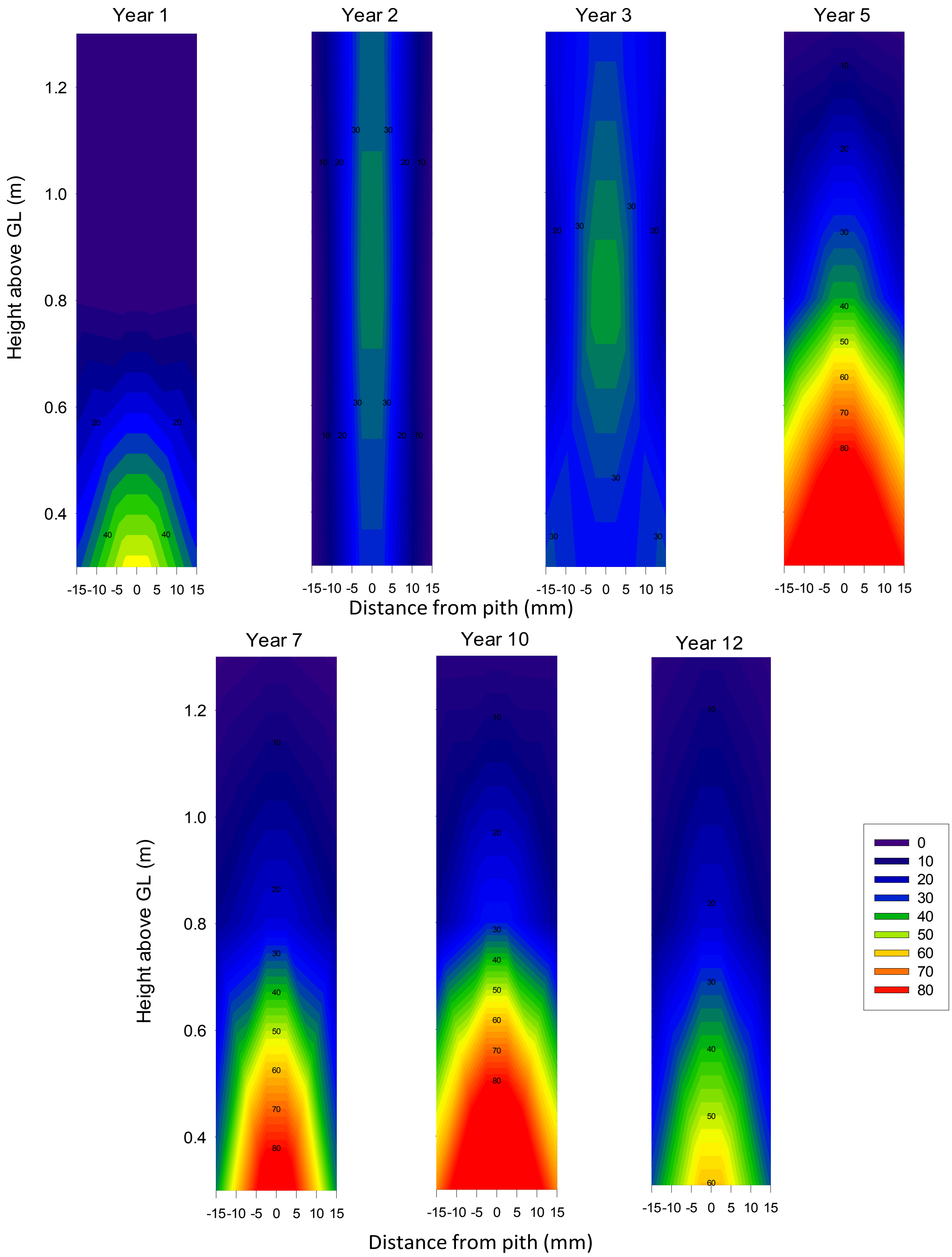

Figure I-7. Residual MITC in Douglas-fir poles 1 to 12 years after treatment with 9 dazomet rods (160 g). Dark blue indicates MITC levels below the threshold. Light blue and all other colors indicate MITC levels above the threshold.

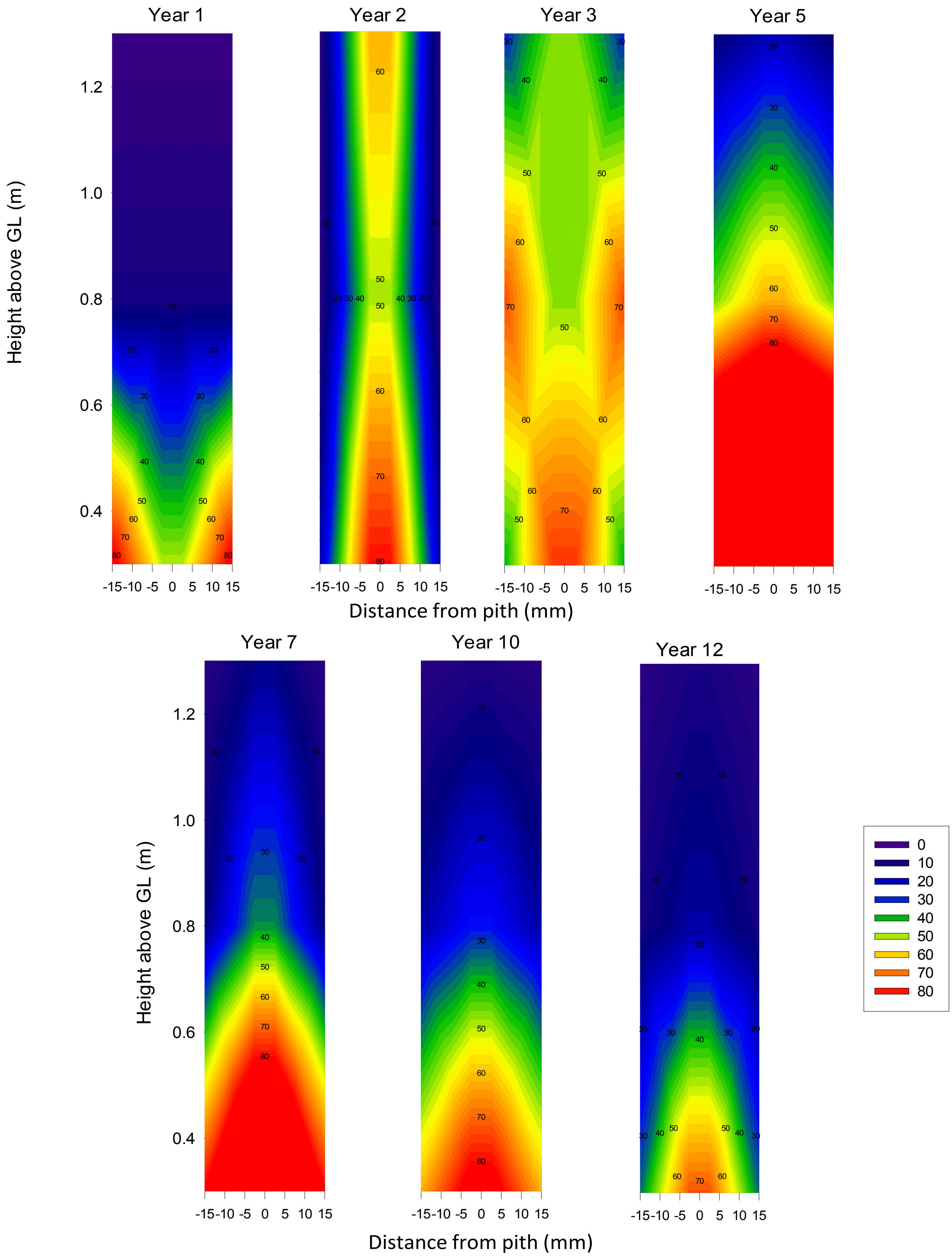

Figure I-8. Residual MITC in Douglas-fir poles 1 to 12 years after treatment with 9 dazomet rods (160 g plus 100 g of copper naphthenate (2% Cu). Dark blue indicates MITC levels below the threshold. Light blue and all other colors indicate MITC levels above the threshold.

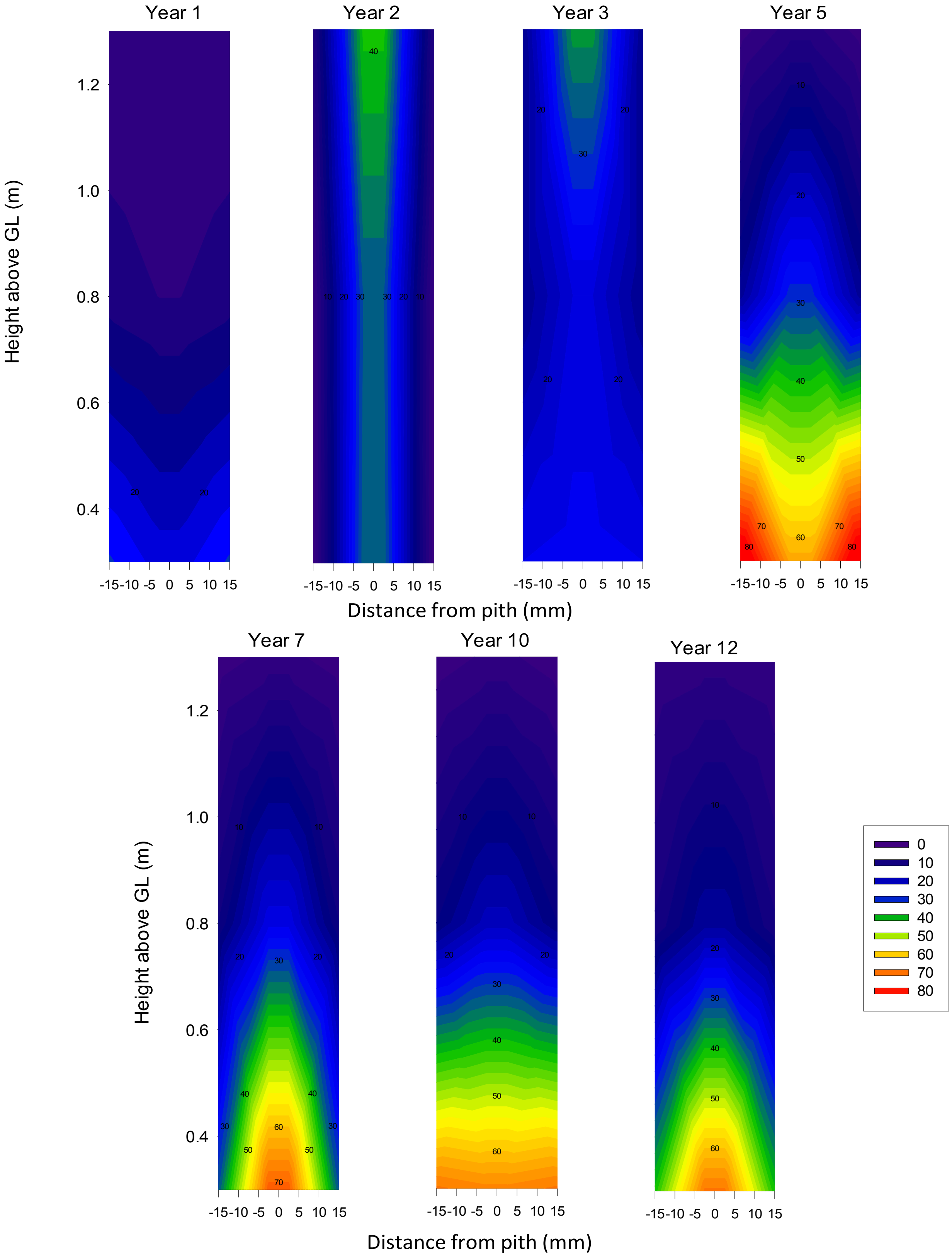

Figure I-9. Residual MITC in Douglas-fir poles 1 to 12 years after treatment with 9 dazomet rods (160 g plus 100 g of water. Dark blue indicates MITC levels below the threshold. Light blue and all other colors indicate MITC levels above the threshold.

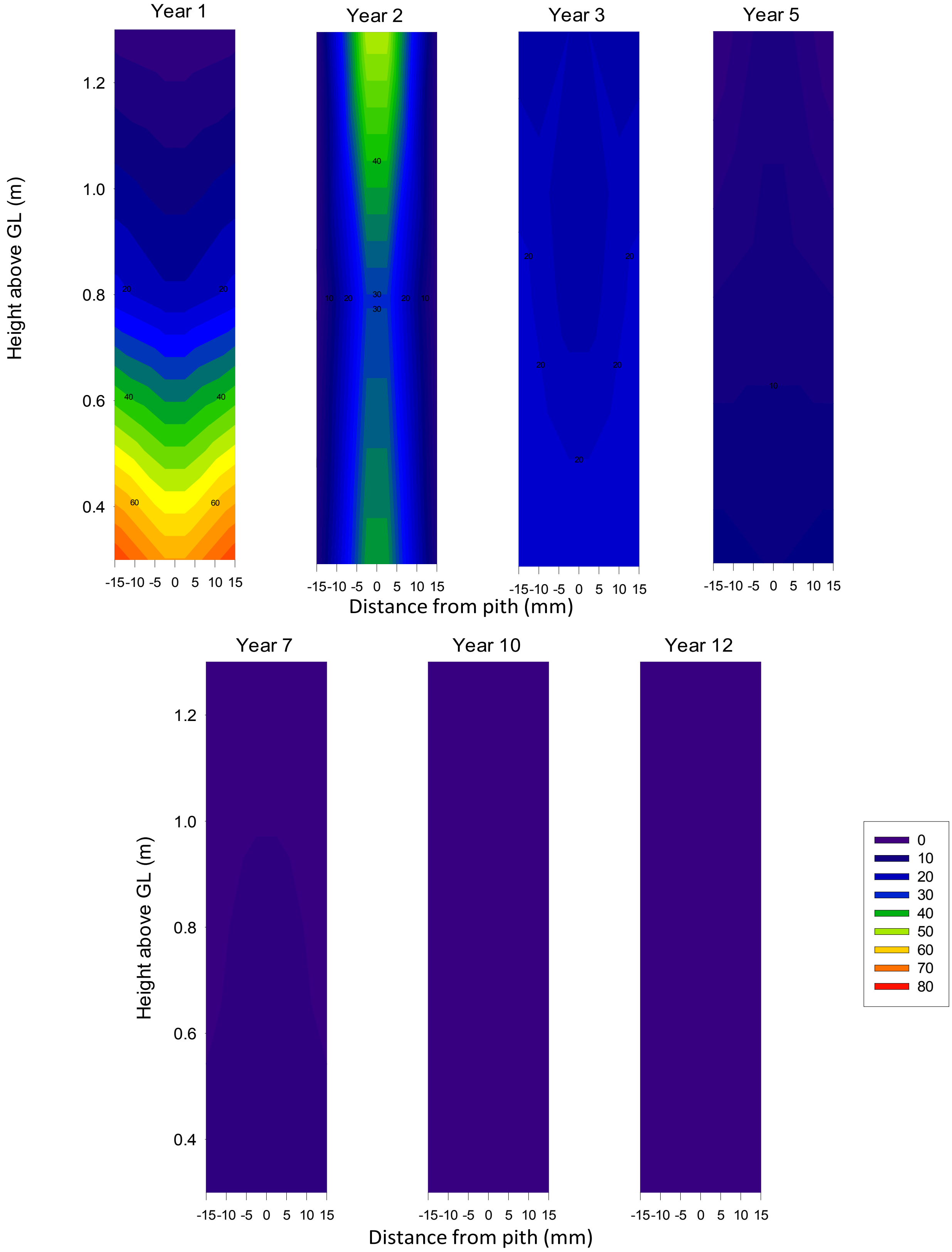

Figure I-10. Residual MITC in Douglas-fir poles 1 to 12 years after treatment with metham sodium. Dark blue indicates MITC levels below the threshold. Light blue and all other colors indicate MITC levels above the threshold.

heights for all the treatments except metham sodium.

Once again, it is also important to note that all of the treatments tended to provide protection that, while well distributed in the treatment zone, was relatively narrowly distributed vertically. Thus, groundline treatment with fumigants should be considered to be primarily confined to that zone, although our consistent detection of MITC 1.3 m above the groundline indicates that chemical does migrate at sub-threshold levels away from that zone. The results also show the long term benefits of dazomet in terms of maintaining a protective zone in the poles where moisture levels are suitable for dazomet decomposition.

3. MITC Content of Residual Dazomet in Treatment Holes

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

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

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

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

Table I-6. Isolation frequency of decay and non-decay (superscript) fungi from Douglas-fir poles treated with metham sodium or combinations of dazomet in rod or powder form and copper naphthenate.

Treatment	Dosage	Supplement	Year Sampled	Isolation Frequency (%)		
				0.3 m	0.8 m	1.3 m
Dazomet Powder	160 g	None	1	0^{7}	0^{7}	0^{20}
			2	0^{7}	7^{27}	0^{47}
			3	0^{0}	0^{7}	0^{0}
			5	0^{0}	0^{0}	0^{20}
			7	0^{0}	0^{0}	0^{27}
			8	0^{0}	0^{7}	0^{13}
			10	0^{0}	0^{0}	0^{20}
			12	0^{7}	0^{0}	0^{7}
Dazomet Rods (6)	107 g	100 g copper naphthenate	1	0^{0}	0^{0}	0^{0}
			2	0^{33}	0^{27}	0^{7}
			3	0^{0}	0^{0}	0^{0}
			5	0^{0}	0^{7}	0^{7}
			7	0^{7}	0^{13}	0^{0}
			8	0^{0}	0^{0}	0^{0}
			10	0^{0}	0^{0}	0^{0}
			12	0^{7}	0^{0}	0^{13}
Dazomet Rods (9)	160 g	None	1	0^{13}	0^{0}	0^{0}
			2	0^{13}	0^{47}	0^{53}
			3	0^{0}	0^{0}	0^{0}
			5	0^{0}	0^{13}	0^{40}
			7	0^{0}	0^{0}	0^{13}
			8	0^{0}	0^{7}	0^{60}
			10	0^{0}	0^{7}	0^{0}
			12	0^{0}	0^{0}	0^{13}
Dazomet Rods (9)	160 g	100 g copper naphthenate	1	0^{0}	0^{0}	0^{7}
			2	0^{7}	0^{27}	0^{20}
			3	0^{0}	0^{0}	0^{0}
			5	0^{0}	0^{13}	0^{7}
			7	0^{0}	0^{20}	0^{20}
			8	0^{0}	0^{0}	0^{0}
			10	0^{0}	0^{0}	0^{7}
			12	0^{0}	0^{7}	0^{13}
Dazomet Rods (9)	160 g	100 g water	1	0^{7}	0^{7}	0^{0}
			2	0^{20}	0^{13}	0^{53}
			3	0^{13}	0^{7}	0^{13}
			5	0^{0}	0^{0}	0^{27}
			7	0^{0}	0^{7}	0^{33}
			8	0^{0}	0^{0}	0^{13}
			10	0^{0}	0^{0}	0^{0}
			12	0^{0}	0^{0}	0^{7}
Metham Sodium	490 ml	None	1	0^{20}	0^{13}	0^{13}
			2	0^{33}	0^{20}	0^{13}
			3	0^{7}	0^{7}	0^{7}
			5	0^{0}	0^{0}	0^{7}
			7	0^{20}	0^{0}	0^{47}
			8	0^{27}	0^{0}	0^{60}
			10	0^{20}	0^{7}	0^{20}
			12	0^{27}	0^{33}	0^{33}

The impact of residual dazomet on its decomposition products or retreatment is under study.

In order to partially address some of these issues, poles that had received dazomet were identified in Oregon and Arizona. The eight Oregon poles had been part of an initial field study established in 1993 evaluating the effect of copper sulfate on dazomet performance. Douglas-fir transmission poles (420 to 510 mm in diameter) in a line located near Corvallis, Oregon were selected for the test. The poles were American National Standard Institute Standard 05.1 Class 1 and 2 twenty-one meter long poles that had been in service for 10-15 years at the time of the test. Very little residual dazomet was found in the treatment holes of the poles near Corvallis after 13 years indicating nearly complete decomposition in a moderately wet environment. Observations from the Arizona test indicated that dazomet decomposition under dry conditions was minimal. The color of the residual powder removed from the holes was also a good indicator of how much dazomet remained. Powder that was white to yellowish contained high levels of activity while darker colored powder contained little residual dazomet. This material could be dirt that infiltrated the treatment hole. These results suggest that retreatment for these holes should consist of additional dazomet along with more accelerant to reactivate the decomposition process.

4. Condition of Utility Poles at Various Times after Internal Remedial Treatment

The typical inspection process for Douglas-fir poles consists of sounding and boring each pole to detect internal decay and, when indicated, excavating to detect surface deterioration. The external surfaces below ground are then treated with a supplemental preservative paste before the soil is returned to the hole. The inspection holes are used to apply internal remedial treatments such as fumigants or water diffusible rods.

Many utilities still use metham sodium, a fumigant that decomposes to release methylisothiocyanate (MITC), for internal treatment. MITC moves as a gas through the wood, killing any fungi present. The MITC from metham sodium decomposition is normally detectable in wood for 3 to 5 years after treatment, but the slow process of fungal re-colonization allows the re-treatment cycle to be extended to 10 years.

Many utilities are exploring cost efficiencies and are interested in determining if the current 10 year re-treatment cycle is suitable for all poles. Clearly, extending the cycle or skipping treatment of some poles could produce substantial cost savings. While the results from the second cycle of field inspection will help answer that question, it might be possible to use a more intensive sampling of smaller populations of poles to examine this issue earlier in the inspection cycle. Samples from these poles would then be examined for residual remedial fumigant levels as well as for the presence of decay fungi. Chemical analysis provides information on the potential for the remedial treatment to provide continued protection against fungal attack, while culturing provides a measure of the ability of decay fungi to re-invade the poles under the conditions specific to that site.

The objective of this study was to determine residual fumigant levels and degree of fungal colonization in a population of poles that had received remedial treatments between 2001 and 2006.

Poles in northern California that had been inspected at various times were selected for examination (Table I-7). At each pole, the pole tag information was recorded, then one side of the pole was excavated to a depth of 200 mm. A single increment core was removed 150 mm below groundline, and additional increment cores were removed immediately adjacent to fumigant holes at groundline and at other locations up to 300-450 mm above the groundline. The inner and outer 25 mm of each increment core were removed and placed into individual glass vials with Teflon lined caps. The remainder of each core was placed into a plastic drinking straw which was labeled with pole ID information and sealed. The cores and vials were returned to Oregon State where they were processed. The core segments for fumigant analysis were added to test tubes containing 5 mL ethyl acetate, tightly capped and allowed to sit at room temperature for 48 hours to allow the MITC to be extracted from the wood. An aliquot of the ethyl acetate was then poured into a separate container for analysis. The increment cores in the tubes were allowed to air dry, then oven-dried and weighed so that the amount of residual fumigant in the wood could be expressed on a wood weight basis.

The ethyl acetate extracts were analyzed for MITC on a Shimadzu Gas Chromatograph equipped with a flame photometric detector with filters specific for sulfur. Results were quantified by comparison with prepared standards. Although metham sodium decomposes into a number of products, MITC is the primary fungitoxic compound. Previous research in our laboratory has shown that a concentration of 20 µg of MITC per oven-dried gram of wood is sufficient to protect the wood against renewed fungal attack (UPRC annual Report 2010).

The remainder of each core was removed from the plastic straw and briefly passed through a flame to kill contaminants on the wood surface. Each core was placed on 1.5 % malt extract agar in a plastic petri dish and observed for fungal growth over a 30 day period. Any growth was examined under a microscope for characteristics typical of wood decay fungi.

The combination of chemical level and the presence of fungi served as an indicator of residual protection afforded by prior remedial treatment.

A total of 48 poles were sampled, including 30 cedar, 16 Douglas-fir and two western or ponderosa pine (Table I-7). Poles sampled had been remedially treated in 2001 (11 poles), 2002 (18 poles), 2003 (13 poles) or 2006 (1 pole).

Metham sodium is generally viewed as a relatively short term treatment that decomposes to release relatively large quantities of MITC that then diffuses through the wood surrounding the treatment hole. Unlike fumigants such as methyl bromide or sulfuryl fluoride that are used to treat insect infestations in houses and rapidly dissipate from the wood after treatment, MITC has fairly strongly physical interactions with wood. As a result, MITC can still be detected in wood several years after application. Metham sodium normally provides the shortest period of residual MITC in wood of the currently registered MITC-based fumigants and is typically not detectable 5 to 7 years after treatment.

MITC was detected in 15 of the 48 poles sampled. Eight of these poles were cedar and the remaining poles were Douglas-fir (Table I-8). MITC was detected in 4 of 11 poles treated in

Table I-7. Characteristics of poles in northern California examined for evidence of MITC and fungal colonization in November 2010.

OSU Pole #	Species	Initial Treatment	Class	Size	Year Installed	Year Treated
1	WRC	Penta			1966	2003
2	WRC	Creosote	4	45	1998	none
3	WRC	Penta	5	40	1966	2003
4	DF	Gas	6	45	1987	2003
5	WRC	Penta			1960s	2003
6	WRC	Penta	5	40	1998	none
7	WRC	Penta	5	45	1998	none
8	WRC	Penta	5	40	1998	none
9	WRC	Penta			1973	2003
10	WRC	Penta	4	50	1992	2003
11	DF	Penta			1962	2003
12	DF	Penta	3	45	1992	2003
13	WRC	Creosote	4	45	1993	2003
14	WRC	Penta				2003
15	WRC	Penta	3	50	1993	2003
16	DF	Penta	4	55	1975	2003
17	DF	Penta			1960s	2003
18	DF	Penta			1975	2006
19	WRC	Penta			1961	2002
20	WRC	Creosote				2002
21	WRC	Creosote	5	30	1967	2001
22	WRC	Penta			1967	2001
23	PP	Penta				2001
24	WRC	Penta			1967	2001
25	DF	Penta		80	1963	2001
26	DF	Penta			1974	2001
27	DF	Penta	5	40	1967	2001
28	WRC	Penta			1946	2001
29	WRC	SJ	5	45	1978	2002
30	WRC	Penta			1975	2002
31	AYC	Penta	5	45	1968	2001
32	DF	Penta	4	40	1974	2001
33	DF	Penta	6	30	1963	2002
34	WRC	Penta	5	35	1997	none
35	DF	Penta			1961	2001
36	WRC	Penta			1961-1965	2002
37	WRC	Penta			1980	2002
38	DF	Penta			1966	2002
39	DF	Penta	2	50	1962	2002
40	WRC	Penta	2	50	1971	2002
41	WRC	Penta			1969	2002
42	WRC	Penta	3	50	1938	2002
43	DF	Penta	2	50	1964	2002
44	DF	Penta			1964	2002
45	PP	Penta	5	45	1974	2002
46	WRC	Penta	3	45	1971	2002
47	WRC	Penta	5	45	1992	2002
48	WRC	Penta	4	50	1970	2002

2001 (36 %), 6 of 18 poles treated in 2002 (33 %), and 4 of 13 poles treated in 2003 (31 %). None of the MITC levels in these poles were at the 20 ug/g of wood that our previous work has shown to be the threshold for protection against fungal growth. The one pole treated in 2006 did contain MITC at levels that would confer protection; however, this result must be viewed with some caution because of the lack of replication. In general, MITC levels in the poles treated in 2001 to 2003 were too low to provide continued protection against fungal attack.

The increment cores cultured for the presence of decay fungi were very clean. No non-decay fungi grew from any of the cores and only two decay fungi were isolated from the cores (Table I-9). Both decay fungi were isolated from poles with no detectable fumigant. One was isolated from 600 mm above the groundline of a western redcedar pole. This height above groundline would be at the edge of the treated zone. The isolations from cedar must be viewed with some caution because it is typically difficult to isolate decay fungi from wood of this species. The fungus in the other pole (Douglas-fir) was isolated from both 150 mm below groundline and at groundline, suggesting that the protective effect in the treatment zone had declined to the point where re-treatment would be necessary.

Most of the poles sampled contain little or no detectable MITC and are therefore at risk of being re-colonized by decay fungi. The cultural results indicate that fungi have not yet begun to re-colonize the poles in large numbers, despite the absence of chemical protection. It would be easy to draw the conclusion that the results would permit prolonging or perhaps entirely skipping re-treatment of the poles. There is no doubt that it is possible to skip treatment of some poles and that it is also possible to extend the time interval between pole inspections. However, before considering this prospect, it is important to weigh the advantages and disadvantages of such a decision.

In a typical utility system, poles are installed and receive little attention for the first 15 to 20 years of service. The poles season to their final moisture content and as they do, checks can open in the poles. Some of these checks penetrate beyond the original preservative treated shell, exposing untreated wood. Water and fungi from the surrounding soil come in contact with this untreated wood and the fungi begin to grow. Eventually, these fungi decay the wood to produce an internal decay pocket that continues to expand.

This process does not happen to all poles nor does it happen at the same rate for every pole. Some poles never experience internal decay, while others are heavily decayed within 20 years of installation. The problem is predicting which poles will experience this damage at any given time. The time intervals between inspections (10-12 years) and the high risk associated with failure to detect the decay at any given inspection cycle (pole failure coupled with costly outages and replacement costs) have resulted in most utilities inspecting all poles in their system.

A typical utility inspecting their system for the first time may find that 20-25 % of their poles have some internal decay, and that anywhere from 5 to 15 % of these poles meet their rejection criteria. Most utilities reduce this rejection rate by aggressive reinforcement. In the second cycle, most utilities see this rejection rate drop below 1 to 2 % and the rate continues to

Table I-8. Residual methylisothiocyanate (MITC) in increment cores removed in November 2010 from poles in northern California at selected times after inspection and remedial treatment[a].

Species	Ht Above GL (mm)	Segment	Year Metham sodium Applied			
			2001	2002	2003	2006
Alaska Yellow Cedar	-150	i	0	n/a	n/a	n/a
		o	0	n/a	n/a	n/a
	0-75	i	0	n/a	n/a	n/a
		o	0	n/a	n/a	n/a
	300-450	i	0	n/a	n/a	n/a
		o	6.6	n/a	n/a	n/a
Douglas-fir	-150	i	0	0	0	n/a
		o	0	0	0	n/a
	0-75	i	0	0	0	**49.5**
		o	0	0	0	**37.6**
	150-275	i	0	n/a	0	0
		o	3.9	n/a	0	0
	300-450	i	0	5.9	4.0	**142.7**
		o	0	0	3.8	**151.5**
	480-600	i	0	8.6	7.3	n/a
		o	0	13.2	0	n/a
Ponderosa Pine	-150	i	0	0	n/a	n/a
		o	0	0	n/a	n/a
	0-75	i	0	0	n/a	n/a
		o	0	0	n/a	n/a
	300-450	i	0	0	n/a	n/a
		o	0	0	n/a	n/a
Western redcedar	-150	i	0	0	0	n/a
		o	0	0	0	n/a
	0-75	i	1.6	0.6	0	n/a
		o	0	0	0	n/a
	150-275	i	n/a	n/a	2.3	n/a
		o	n/a	n/a	0	n/a
	300-450	i	7.1	1.1	3.4	n/a
		o	0	2.7	2.5	n/a
	480-600	i	7.4	2.5	0	n/a
		o	0	2.7	0	n/a
	> 600	i	n/a	1.6	0	n/a
		o	n/a	3.6	0	n/a

aValues represent means of varying numbers of increment core samples. Inner and outer denote the inner and outer 25 mm of each increment core, n/a=not tested. Numbers in bold indicate MITC levels above the fungitoxic threshold.

Table I-9. Percentage of increments cores removed from poles in Northern California of various species at various times after inspection and remedial treatment from which fungi were isolated in November 2010.

Wood Species *(n)*	Initial Treatment	Cores Containing Decay fungi (%)[a]				
		Year Treated				
		2001	2002	2003	2006	Unknown
		(n=11)	*(n=18)*	*(n=13)*	*(n=1)*	*(n=5)*
Douglas-fir *(16)*	MP	-	-	0	-	-
	Penta	0	0	17	0	-
Ponderosa pine *(2)*	Penta	0	0	-	-	-
Western redcedar *(29)*	Creosote	0	20	0	-	0
	Penta	0	0	0	-	0
	SJ	-	0	-	-	-
Alaska cedar *(1)*	Penta	0	-	-	-	-

aValues represent percentage of increments cores where decay fungi were present. Both positive values represent only one viable fungus and n= number of poles tested.

decline to around 0.5 % with continued inspection and application of remedial treatment.

This continued low rejection level can lead to thoughts about reducing the scope of inspection. This is entirely possible; however, the problem is that decay rates are predictable over an entire system, but not in individual structures. Decay is biological and it is inherently difficult to predict biological systems. Decay in a pole is a function of the degree of checking in the wood, the fungi present, the climate, and the moisture level in the soil.

Field tests indicate that moisture conditions are generally suitable for decay at or below the groundline of poles throughout the year in most areas. What can vary is the pole height at which decay occurs. Decay risk tends to be highest near the groundline in poles in wetter climates, but well below the groundline (450-600 mm) in drier climates.

Temperature also affects the rate of fungal growth and this, in turn, affects the rate of decay. Most decay fungi have temperature optima around 24-28 C (72-79 F), but they can grow at temperatures between 5 and 40 C (41-104 F). While decay rates slow in the winter, poles in many utility systems lie in areas where decay is likely to continue year-round.

There are innumerable fungal species present in soil surrounding a pole. Some are potent wood decayers, while others are common molds that will have little effect on the wood. The fungi that eventually move from the soil to the wood vary with soil condition. For example, copper tolerant fungi are present in many soils, but they only become a problem in soils with specific characteristics. Since utility lines transect a range of soil and moisture conditions, it is virtually impossible to determine which specific poles might be at risk for being attacked by a fungus with tolerance to a specific preservative. It is also difficult to determine which fungus might invade a pole and this can have implications on how fast decay will progress, since fungi vary in their ability to cause decay.

All of these factors make it difficult to make specific recommendations about individual pole treatments except where obvious decay or insect attack is present. Despite these problems, there are some possible approaches to tailoring inspection/treatment practices.

On a national scale, evaluation of field inspection data indicate that extending a maintenance cycle from 10 to 15 years produces a substantial rise in the rejection rate. As a result, any savings in inspection costs are offset by increased pole replacement costs. These figures do not include the costs for emergency change-outs nor can they include the value of increased liability as a result of allowing dangerous poles to remain in service longer. In general, however, the relatively small savings produced from reduced inspections do not justify the increased risk.

One alternative to prolonging inspection cycles on all poles is to selectively reduce maintenance on some poles and concentrate efforts on those poles most in need of treatment. This approach can be useful if the utility has good data on the types of treatments in their system, some prior history on how remedial treatments have worked on the poles in their system and if the poles to be maintained more aggressively are located in clusters that make it economical to travel between structures (since much of the cost of inspection is time between poles).

This approach might be possible when there is a preponderance of certain wood species/ chemical treatment combinations. For example, western redcedar has naturally durable heartwood, but some poles will experience internal decay. The combination of naturally durable heartwood coupled with a fumigant treatment that eliminates any established fungi might be sufficient to allow skipping a treatment cycle because it would take longer for fungi to reinvade this durable wood. This approach might be justified on the basis of the limited number of decay fungi isolated from the northern California poles sampled, although sampling in portions of the service territory with suspected higher decay risks would be strongly advisable. This would not, however, affect any external treatment issues associated with these poles nor would it allow the utility to ignore above ground issues. For example, the ages of many of the cedar poles in the system studied were such that they had considerable top decay that will ultimately affect the energized section of the pole.

It might also be possible to identify all poles of any species with no evidence of internal decay and skip an internal treatment, provided that one had been applied in the prior cycle to ensure that fungi had been eliminated.

Skipping treatment cycles is not without risk. It requires an assumption that the first inspection was properly performed, that any decay present was detected and that the treatment was applied in a pattern that ensured any fungi present in the pole were killed. Proper inspection is not a certainty. The inspection pattern is limited by the number of holes that can be drilled and there is always the potential for the pattern to miss a small decay pocket. Missing small pockets of decay is critical because skipping an inspection cycle would mean that a fungus would have twice as long to continue growing in the pole. This could allow a seemingly sound pole to progress to the reject stage between treatment cycles and helps explain why prolonging maintenance cycles has the ability to increase rejection rates to the point where replacement cost outweighs the reduced inspection cost.

Along with identifying poles that might sustain a reduced inspection cycle, it is also important to identify poles that absolutely must be inspected more frequently. Within a utility system, all poles treated with pentachlorophenol in either liquefied petroleum gas or methylene chloride would fit that requirement. These poles tend to be very prone to below-ground surface decay and, coupled with potential internal decay, pose a major maintenance headache. Despite these problems, rigorous inspection/maintenance is still far more cost effective than pole replacement. At no time should these poles be omitted from an inspection cycle.

There may be other ways to reduce maintenance costs based upon climatic conditions. For example, it might be possible to prolong inspection cycles in drier areas; however, it would be important to back up that decision with the establishment of smaller monitoring plots where poles were more frequently sampled to either support the decision or identify when the prolonged inspection cycle should end.

At this point, it is clear that the chemical levels in most of the poles fumigated 7 to 10 years ago have declined to a point below the threshold for fungal protection; however, fungal colonization has not yet begun to become prevalent. This suggests that the re-treatment cycle could be extended, particularly for cedar poles and potentially for poles that had no prior evidence of internal decay; however, any decision in that regard must be backed by the simultaneous establishment of a monitoring program of selected poles in the event re-colonization by decay fungi begins to occur more rapidly. These recommendations would apply only to poles in exposures similar to those in the northern California area and decisions regarding inspection cycles in areas with more aggressive decay environments would require sampling of poles in those areas.

5. MITC Movement from Dazomet Treated Douglas-fir Posts under Dry Conditions

The results from the Utah field test coupled with examination of residual dazomet from poles treated with this compound in Arizona suggest that there is only minimal decomposition to MITC under drier conditions. Water is essential for dazomet decomposition to MITC and the field trials clearly illustrate that fact. However, the addition of a copper accelerant was believed to overcome that sluggish decomposition. Almost all of our field data has been collected on poles exposed in wetter climates where moisture is not limited for some or all of the year. Identifying strategies for using dazomet in drier climates will be critical for utilities in these regions.

As a preliminary effort to explore enhanced dazomet decomposition under drier conditions, we established the following trial. Western red-cedar and Douglas-fir posts were obtained and cut into 600 mm long sections that were end sealed with wax to retard, but not completely limit chemical movement. The posts were conditioned at 32 C and 30 % relative humidity to a final moisture content around 8 %.   A single 12 mm diameter sloping (45 degrees) hole was drilled on one face at the mid-point to depth of 150 mm to serve as a treatment hole (Figure I-11).

Measured amounts of dazomet, water, copper naphthenate or metham sodium were added to the treatment holes, which were plugged with tight fitting rubber stoppers.
The treatments were as follows:

1. Dazomet (9 g) alone
2. Dazomet (9 g) with 11.5 g of water
3. Dazomet (9g) with 1 g of a 10 % boric acid equivalent solution
4. Dazomet (9 g) with 1 ml of 2 % (as Cu) copper naphthenate on top of the powder
5. Dazomet (9 g) with 1 ml of 2 % (as Cu) copper naphthenate with ½ added prior to dazomet addition and the remainder placed on top.
6. Dazomet (9 g) plus 10 ml of a 25% metham sodium solution (8.2 % NaMDC)
7. Dazomet (9 g) plus 10 ml of a 50% metham sodium solution (16.4 % NaMDC)
8. Dazomet (9 g) plus 10 ml of metham sodium (32.7 % NaMDC)

The treated post sections were then incubated at 32 C and 30 % RH for 4 or 13 weeks. Each treatment was replicated on 3 posts per incubation time.

At each interval, three posts from each treatment were sampled by removing increment cores from sites 50 and 100 mm above and below the original treatment zone (Figure I-11). Each core was divided into three segments (closest to the side with the treatment hole, center and opposite the treatment hole). Each core segment was placed into 5 ml of ethyl acetate and extracted for 48 hr at room temperature. The ethyl acetate extract was poured off and a sample of this material was analyzed for MITC by gas chromatograph. The increment core segment was oven dried and weighed so that MITC content could be expressed on a weight of MITC per oven-dried gram of wood basis (ug/OD g).

MITC levels after 4 weeks in any blocks receiving metham sodium were well above the 20 ug/oven dried g of wood threshold for protection against fungal attack with mean levels ranging from 26.9 on the same side as the treatment hole 102 mm below that site to 236 ug at the center of the samples 51 mm below the hole (Table I-10). There was a slight dose response curve with the higher MITC levels occurring in posts receiving the 32.7 % NaMDC treatment. These results reflect the exceptionally large release of MITC associated with the metham sodium. MITC levels in the other treatments were well below the threshold both above and below the treatment zone and were only above the threshold at the center of samples 50 mm below the treatment zones in blocks treated with either of the copper naphthenate treatments or with water. MITC levels were close to the threshold at this same location in blocks treated with dazomet alone or with dazomet plus 10 % boric acid. The results indicate that adding supplemental copper, boron or water had little effect away from the treatment site after 4 weeks.

MITC levels in post sections 13 weeks after treatment tended to be slightly lower in posts receiving metham sodium, but were still mostly above the threshold and higher than any of the other dazomet treatments. The higher levels are likely due to MITC release from the metham sodium rather than any improvement in dazomet decomposition. Metham sodium was examined because it is already registered for this application and a combination of fast and slow release components might be useful for prolonging any protective effect. However, the results

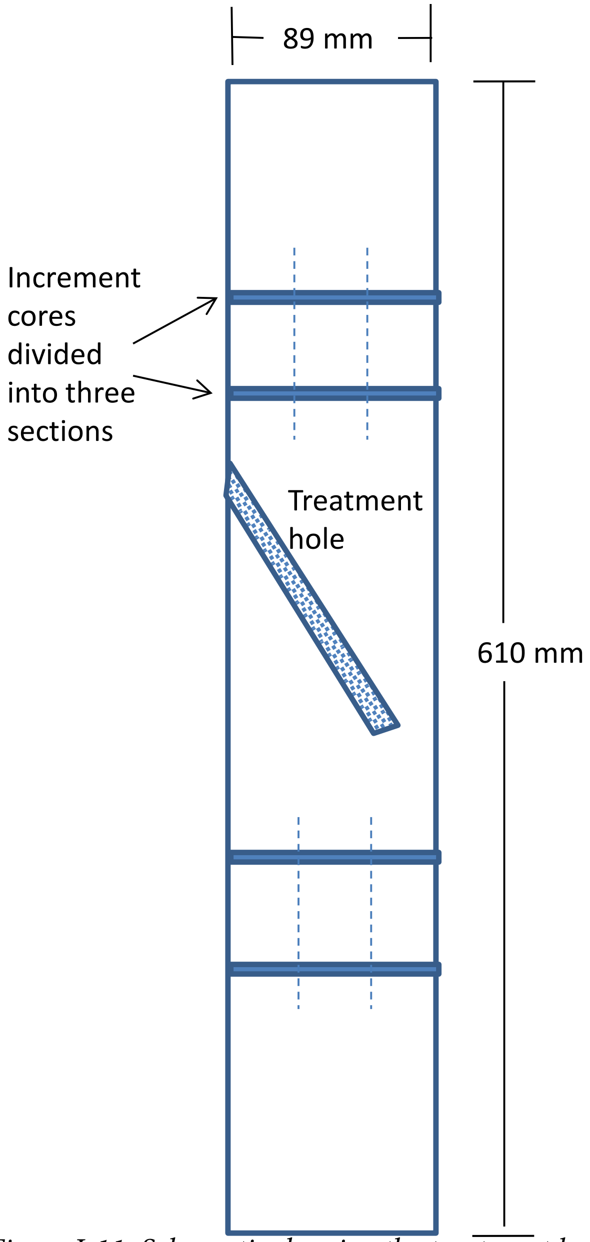

Figure I-11. Schematic showing the treatment hole and the increment borer sampling sites on a western redcedar or Douglas-fir post used to examine the effects of additives on dazomet decomposition under dry conditions.

suggest that metham sodium did not interact substantially with the dazomet.

MITC levels in posts receiving dazomet with the other supplemental treatments remained low 13 weeks after treatment (Table I-11). MITC levels were above the threshold at five locations in the various treatments, but the levels remained low in the other zones. For example, MITC levels were above the threshold at the center of the core 50 mm above or below the treatment hole in posts receiving 1 ml of copper naphthenate evenly split between the top and bottom of the treatment hole, but were below the threshold when the copper naphthenate was added only to the top. Splitting the copper naphthenate application was suggested as one method for ensuring that more dazomet interacted with chemical and the first assessment suggested that this did help with decomposition.

Levels above threshold were also found in posts receiving boric acid or water, but not all locations contained chemical above the threshold. The absence of a long term enhancement in MITC release with water addition likely reflects the tendency of any water in the hole to be absorbed by the wood surrounding the treatment hole and to then diffuse to areas with lower moisture content away from the residual dazomet. As a result, liquid water is unlikely to be present for any appreciable period after treatment. Copper compounds, and potentially boron, might be expected to have a longer term effect provided that the compound was in contact with dazomet.

The lack of a consistent enhancement in MITC decomposition rate in drier wood illustrates the challenges with activating this compound in the absence of free water in the wood. These results again highlight the need to reconsider how dazomet is used in drier areas where the above ground portion of the pole is unlikely to be wet enough for decomposition. At the same time it is important to note that the absence of moisture also sharply reduces the risk of fungal attack. Utilities need to consider the value of placing chemical where it is unlikely to be needed unless conditions at the site change (such as development that includes irrigation) vs. reconfiguring the treatment pattern to place the majority of the chemical below groundline where it is more

Table I-10. MITC levels in increments cores removed from western redcedar or Douglas-fir posts 4 weeks after treatment with dazomet with or without various amendments to aid in decomposition [a].

Additive	Above the hole					
	102 mm			51 mm		
	hole side	center	opposite side	hole side	center	opposite side
10% BAE	4.5	6.0	1.3	10.1	9.9	1.4
CuNap 1/2 on top	7.6	10.3	3.0	11.3	18.0	4.9
CuNap all on top	8.1	10.7	1.6	14.5	17.8	4.9
25% SMDC	**121.9**	**179.6**	**63.7**	**122.5**	**164.2**	**91.3**
50% SMDC	**102.5**	**128.1**	**40.7**	**113.8**	**128.5**	**47.8**
100% SMDC	**190.2**	**171.2**	**40.4**	**203.9**	**279.7**	**121.9**
none	6.2	11.1	4.2	8.3	14.7	2.4
water	11.6	10.6	0.8	14.9	13.8	0.9

Additive	Below the hole					
	102 mm			51 mm		
	hole side	center	opposite side	hole side	center	opposite side
10% BAE	5.1	9.2	1.5	11.0	18.8	2.5
CuNap 1/2 on top	7.6	14.5	4.4	16.8	**22.0**	6.5
CuNap all on top	7.4	11.1	3.6	14.3	**21.6**	3.8
25% SMDC	**30.4**	**112.1**	**116.4**	**41.9**	**121.0**	**112.8**
50% SMDC	**26.9**	**88.2**	**61.9**	**92.8**	**166.8**	**86.7**
100% SMDC	**47.2**	**144.5**	**61.2**	**113.4**	**236.1**	**175.8**
none	8.4	15.5	2.2	12.1	19.8	2.1
water	8.7	16.2	3.9	15.7	**21.5**	3.8

a Numbers in bold represent chemical levels over the toxic threshold of 20 ug/g of wood

likely to regularly encounter moisture. This may involve drilling holes further down the pole or condensing the treatment region within the existing zone to deliver chemical where it is most likely to be effective.

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-12).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 Zea-

Table I-11. MITC levels in increments cores removed from western redcedar or Douglas-fir posts 13 weeks after treatment with dazomet with or without various amendments to aid in decomposition.

Additive	Above the hole					
	102 mm			51 mm		
	hole side	center	opposite side	hole side	center	opposite side
10% BAE	12.2	16.5	1.7	9.3	**22.0**	4.2
CuNap 1/2 on top	12.5	16.8	1.0	14.2	**29.9**	1.4
CuNap all on top	9.3	10.7	0.0	12.9	14.8	1.8
25% SMDC	**103.5**	**120.3**	**56.6**	**99.3**	**122.3**	**60.5**
50% SMDC	**118.7**	**100.1**	**65.7**	**111.1**	**119.1**	**99.3**
100% SMDC	**127.9**	**133.6**	**56.4**	**140.5**	**129.2**	**52.7**
none	5.6	5.5	0.5	6.1	8.8	0.5
water	11.1	11.9	0.5	12.1	12.7	1.9

Additive	Below the hole					
	102 mm			51 mm		
	hole side	center	opposite side	hole side	center	opposite side
10% BAE	11.5	17.7	1.2	17.0	15.6	1.0
CuNap 1/2 on top	8.7	15.4	1.2	12.5	**24.9**	2.0
CuNap all on top	9.1	11.0	1.0	11.5	12.4	1.2
25% SMDC	0.6	**25.7**	9.0	**29.7**	**43.8**	18.3
50% SMDC	**50.3**	**88.2**	**114.3**	**51.7**	**92.3**	**47.1**
100% SMDC	**22.1**	**101.2**	**29.2**	**26.7**	**81.7**	**49.5**
none	5.6	8.8	0.4	8.7	11.8	0.5
water	10.8	**21.5**	4.6	18.9	**22.4**	2.5

a Numbers in bold represent chemical levels over the toxic threshold of 20 ug/g of wood

land (Becker, 1976, Cockcroft and Levy, 1973; Dickenson et al., 1988; Dietz and Schmidt, 1988, Dirol, 1988, Edlund et al., 1983; Ruddick and Kundzewicz, 1992, Smith and Williams, 1967; Williams and Amburgey, 1987). This chemical has also been used more recently for treatment of lumber in Hawaii to limit attack by the Formosan subterranean termite. Boron is attractive as a preservative because it has exceptionally low toxicity to non-target organisms, especially humans, and because it has the ability to diffuse through wet wood. In principle, a decaying utility pole should be wet, particularly near the groundline and this moisture can provide the vehicle for boron to move from the point of application to wherever decay is occurring. Boron is available for remedial treatments in a number of forms, but the most popular are fused borate rods which come as either pure boron or boron plus copper (Morrell et al., 1992, 1995; Morrell and Schneider, 1995; Schneider et al., 1993). These rods are produced by heating boron to its molten state, then pouring the molten boron into a mold. The cooled boron rods are easily handled and applied. In theory, the boron is released as the rods come

Table I-12. Characteristics of diffusible internal remedial treatments for wood poles.

Trade Name	Active Ingredient	Conc. (%)	Toxicity (LD_{50})	Manufacturer
Impel Rods Bor8-Rods	boron	96.65	>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.

in contact with water.

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

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

1. Performance of Copper Amended Fused Boron Rods

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

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

The results indicate that the boron from fused borate and fused borate plus copper rods is diffusing into Douglas-fir heartwood at rates capable of protecting against fungal attack. While there are some slight differences in chemical levels and in the presence of decay fungi, the results suggest that the systems provide similar protection. Copper movement was negligible This test was not sampled in 2012 and will next be sampled in 2013.

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

Date Established:	November 2001
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @ GL (avg., max., min.)	40, 45, 35 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 22.5 mm diameter holes were drilled perpendicular to the grain beginning at groundline and moving around the pole 120 degrees and upward 150 mm. Each hole received either 1 or 2 boron rods (180 or 360 g of rod, respectively). The holes were then plugged with tight fitting wooden dowels. Each treatment was replicated on 10 poles.

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

Boron levels remained above threshold at groundline for the entire 15 year sampling period. This test is now completed and showed that boron remained in the poles at protective levels for 10 or more years, although it did require slightly longer times to reach effective levels in the wood after application.

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

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

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

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

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

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

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

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

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

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

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

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

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

Chemical movement has 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-13).

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

Table I-13. 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

was poured onto the top of the dazomet in the treatment holes until the visible fumigant appeared to be saturated. No attempt was made to quantify the amount of copper naphthenate added to each treatment hole.

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

This test was not sampled in 2012 and will next be sampled in 2013.

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

Power Test

Date Established:	August 2010
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.

In this report, we describe the 1 year results of a field trial of selected internal remedial treatments in poles located within the Rocky Mountain Power System in southern Utah.

Douglas-fir, western redcedar and lodgepole pine poles located 220 kilometers south of Salt Lake City, Utah were selected for study (Table I-14). 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

Table I-14. Characteristics of poles in the Rocky Mountain Power system treated with selected internal remedial treatments.

OSU Pole #	RMP Pole #	Species	Primary Treatment	YI	Class	Length	Treatment
307	194508	pine	penta	1971	5	35	control
314	192530	pine	penta	1980	4	35	
321	197504	pine	penta	1981	5	40	
333	197501	Doug-fir	cellon (gas)	1981	4	40	
335	199312	cedar	penta	2007	3	40	
342	195900	cedar	penta	2002	4	45	
303	195501	pine	penta	1971	4	35	dazomet + CuNaph
310	193500	pine	penta	1980	5	35	
317	191503	pine	penta	1983	4	35	
324	301702	cedar	creosote	1999	5	30	
329	301906	Doug-fir	penta	1999	4	30	
338	197700	Doug-fir	penta	2008	4	35	
301	196502	pine	penta	1981	5	40	dazomet
308	193501	pine	penta	1981	5	35	
315	191505	pine	penta	1981	4	40	
322	301701	cedar	creosote	1999	4	40	
331	303900	Doug-fir	cellon (gas)	1996	5	35	
336	197705	cedar	penta	1999	4	40	
304	195502	pine	penta	1971	4	35	fused boron rods + water
311	192501	pine	penta	1980	4	35	
318	191501	pine	penta	1983	5	35	
325	301800	cedar	creosote	1999	4	40	
330	302900	Doug-fir	penta	1996	4	35	
339	184005	cedar	penta	2005	4	40	
302	195500	pine	penta	1971	4	35	fused boron rods
309	193502	pine	penta	1981	5	35	
316	191504	pine	penta	1983	5	35	
323	301700	cedar	creosote	1999	4	40	
327	301902	Doug-fir	cellon (gas)	1984	5	35	
337	197706	cedar	creosote	1999	4	40	
306	194501	pine	penta	1981	5	40	metham sodium
313	192531	pine	penta	1981	5	35	
320	191600	pine	penta	1983	4	40	
332	194406	Doug-fir	penta	2000	5	30	
334	199406	cedar	penta	2005	4	40	
341	194901	cedar	penta	2002	4	45	
305	195503	pine	penta	1984	4	40	MITC-FUME
312	192500	pine	penta	1981	5	35	
319	191500	pine	penta	1983	5	40	
326	301930	Doug-fir	penta	1995	4	35	
328	301905	cedar	creosote	1999	5	30	
340	186200	cedar	penta	2006	4	35	

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, 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.

Previous studies have shown that the threshold for fungal protection for MITC is approximately 20 $\mu g/m^3$, while the threshold for boron is approximately 0.5 kg/m^3 BAE. These values were used to assess the relative movement of the various internal treatments and estimate the degree of protection provided.

No MITC was detected and only background levels of boron were present in poles not receiving treatment. The presence of some boron in the wood is consistent with our previous results. These levels do not measurably affect fungal growth.

MITC levels in poles treated with MITC-FUME were one to two orders of magnitude above the reported threshold in the inner zone 150 mm below groundline as well as at groundline and 300 mm above that zone (Table I-15, Figure I-12). MITC levels were slightly lower 450 mm above groundline in Douglas-fir and lodgepole pine poles, but were still well above the protective level. They remained high at this level in western redcedar poles. MITC levels tended to be 80 to 90 % lower in outer zones than in the inner zones of the same poles at a given location but still well above the threshold. MITC levels remained above the threshold 900 mm above the groundline in the western redcedar poles treated with MITC-FUME, but were much lower in Douglas-fir and lodgepole pine poles. The extremely high levels of MITC in poles treated with MITC-FUME are consistent with previous studies showing that this chemical rapidly moves at very high levels throughout the wood.

MITC levels in poles treated with metham sodium were 7 to 15 times the threshold in the inner zone of cores removed from 150 mm below groundline, a bit lower at groundline and then were elevated at 300 or 450 mm above groundline (Figure I-13). MITC levels in the outer zones tended to be much lower than those in the inner zones. These trends are consistent with previous studies and reflect the fact that the treatment was directed toward the pole center. MITC levels tended to be higher in Douglas-fir poles than either western redcedar or

Table I-15. MITC levels in poles 14 months after treatment of Douglas-fir, western redcedar, and lodgepole pine poles with selected fumigants [a].

Treatment	Wood species	n	months after treatment	Height above groundline (mm)					
				-150		0		300	
				inner	outer	inner	outer	inner	outer
control	cedar	1	14	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	pine	2	14	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
dazomet	cedar	2	14	10 (12)	1 (3)	16 (25)	3 (8)	9 (17)	0 (0)
	DF	1	14	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	pine	3	14	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
dazomet + Cu	cedar	1	14	19 (12)	0 (0.0)	**33** (14)	0 (0.0)	11 (13)	9 (16)
	DF	2	14	**67** (72)	12 (24)	**54** (69)	1 (3)	18 (7)	3 (7)
	pine	3	14	17 (17)	7 (21)	**31** (27)	0 (0)	2 (3)	2 (6)
metham sodium	cedar	2	14	**155** (215)	15 (12)	**64** (34)	**29** (21)	**148** (18)	**48** (44)
	DF	1	14	**290** (355)	**37** (5)	**124** (54)	**76** (50)	**96** (82)	**88** (137)
	pine	3	14	**158** (165)	**169** (336)	**108** (75)	**48** (53)	**181** (209)	14 (21)
MITC-FUME	cedar	2	14	**1537** (887)	**227** (255)	**2954** (3080)	**439** (890)	**3902** (2648)	**527** (594)
	DF	1	14	**3616** (2938)	**420** (530)	**6911** (2969)	**332** (381)	**2136** (1589)	**178** (304)
	pine	3	14	**1549** (1454)	**149** (130)	**5647** (7469)	**195** (239)	**833** (1278)	**85** (218)

Treatment	Wood species	n	months after treatment	Height above groundline (mm)					
				450		600		900	
				inner	outer	inner	outer	inner	outer
control	cedar	1	14	0 (0)	8 (14)	0 (0)	0 (0)	0 (0)	0 (0)
	pine	2	14	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
dazomet	cedar	2	14	5 (7)	3 (4)	3 (5)	1 (3)	2 (4)	0 (0)
	DF	1	14	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	pine	3	14	2 (5)	0 (0)	5 (10)	20 (59)	1 (3)	0 (0)
dazomet + Cu	cedar	1	14	**158** (193)	0 (0)	16 (18)	0 (0)	14 (24)	0 (0)
	DF	2	14	10 (6)	0 (0)	3 (4)	0 (0)	0 (0)	0 (0)
	pine	3	14	0 (0)	0 (0)	0 (0)	1 (4)	0 (0)	0 (0)
metham sodium	cedar	2	14	**239** (127)	**34** (36)	**121** (79)	**22** (25)	**34** (30)	9 (15)
	DF	1	14	**497** (306)	5 (8)	**187** (154)	4 (7)	19 (14)	0 (0)
	pine	3	14	**23** (25)	**48** (44)	2 (5)	**34** (45)	0 (0)	6 (12)
MITC-FUME	cedar	2	14	**3019** (2235)	**557** (556)	**2083** (1094)	**329** (473)	**183** (158)	**94** (201)
	DF	1	14	**462** (783)	**67** (62)	**96** (137)	3 (6)	0 (0)	0 (0)
	pine	3	14	**60** (157)	**487** (1371)	0 (0.0)	8 (17)	1 (2)	0 (0)

a Numbers in bold represent chemical levels over the toxic threshold of 20 ug/g of wood. Numbers in parentheses represent one standard deviation from the mean.

lodgepole pine. Metham sodium tends to release high levels of MITC shortly after treatment, then chemical levels decline within 2 to 3 years. The results at 14 months are consistent with this performance trait.

Poles treated with dazomet alone contained extremely low levels of MITC that did not exceed the threshold for fungal protection at any location, even below the groundline where moisture levels might be expected to be adequate for dazomet decomposition (Figure I-14). The results indicate that conditions were not suitable for dazomet decomposition when no copper accelerant was added.

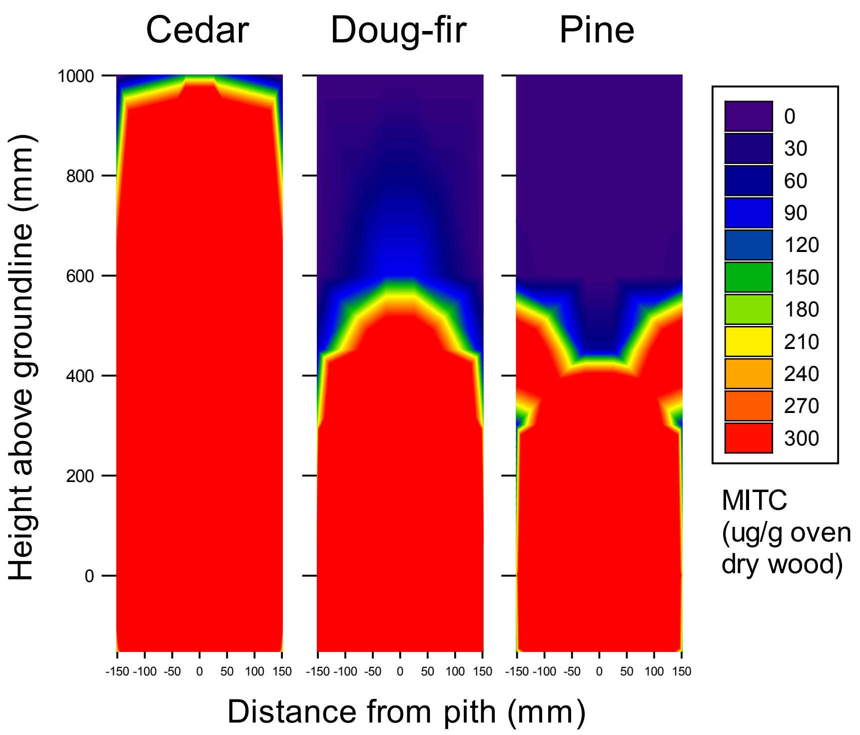

Figure I-12. Distribution of MITC in pole sections 14 months after treatment with MITC-FUME. Dark blue represents a MITC level below the threshold for fungal protection while lighter shades of blue as well as green, yellow and finally red signify that protective levels are present in those zones.

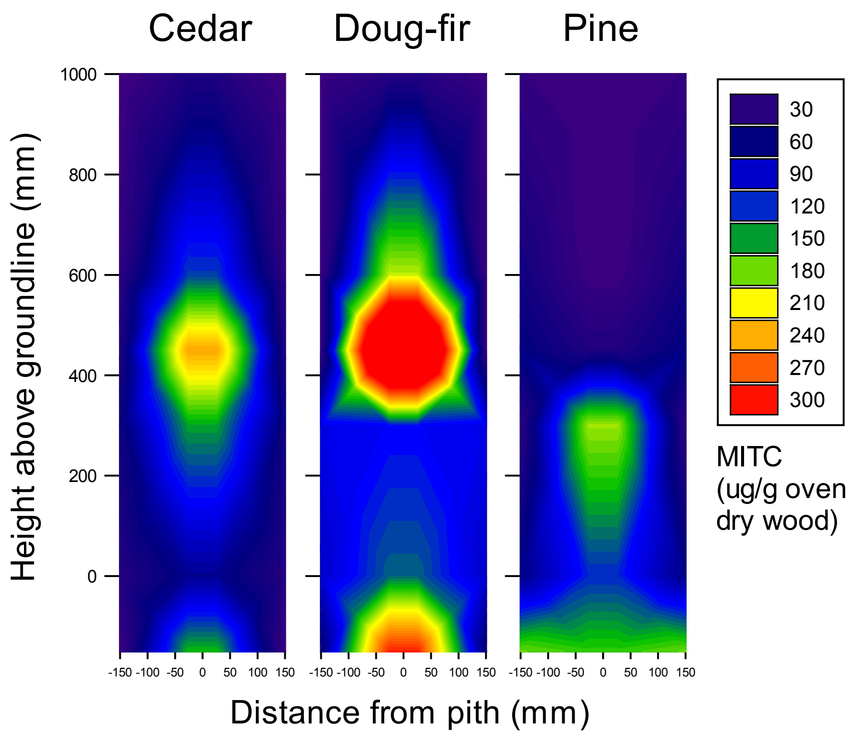

Figure I-13. Distribution of MITC in pole sections 14 months after treatment with metham sodium. Dark blue represents a MITC level below the threshold for fungal protection while lighter shades of blue as well as green, yellow and finally red signify that protective levels are present in those zones.

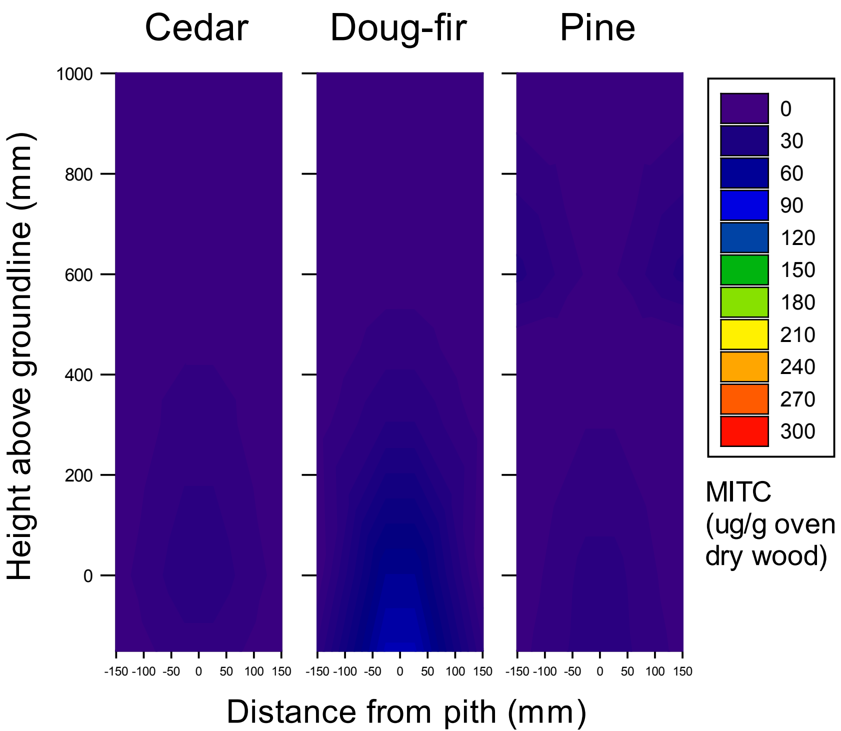

Figure I-14. Distribution of MITC in pole sections 14 months after treatment with dazomet alone. Dark blue represents a MITC level below the threshold for fungal protection while lighter shades of blue as well as green, yellow and finally red signify that protective levels are present in those zones.

MITC levels in poles treated with dazomet plus copper naphthenate were higher than those found with dazomet alone, but much lower than those found with either metham sodium or MITC-FUME (Figure I-15). MITC levels were above the toxic threshold in the inner zone 150 mm below groundline and at groundline, but not in the outer zone at either level. MITC was detectable further up the pole, but the levels were below the threshold. The results illustrate the benefits of the copper naphthenate accelerant for improving dazomet decomposition to MITC, but they also indicate that the resulting chemical levels are much lower than levels found in previous studies in wetter locations.

In addition to the substantial differences in MITC levels between the four fumigant treatments, MITC levels in the outer zones tend to be far lower than those in the interior. While an inner/outer gradient is consistent with previous studies showing the tendency of the angled treatment holes to direct chemical toward the center of the poles, the differences observed were far greater than those observed in studies in wetter climates. The reasons for these differences are unclear, although they may reflect the presence of much drier wood or the high summer temperatures to which these poles are exposed. Elevated temperatures could increase chemical movement out of the pole. Regardless of the cause, the results indicate that dazomet is ineffective without added accelerant and is unlikely to be useful when applied above ground in these regions.

Boron levels in poles treated with fused boron rods alone tended to be extremely low 14 months after treatment (Table I-16). The exception was found in the inner zone 150 mm below groundline in the one lodgepole pine pole. The addition of the water to the treatment holes at

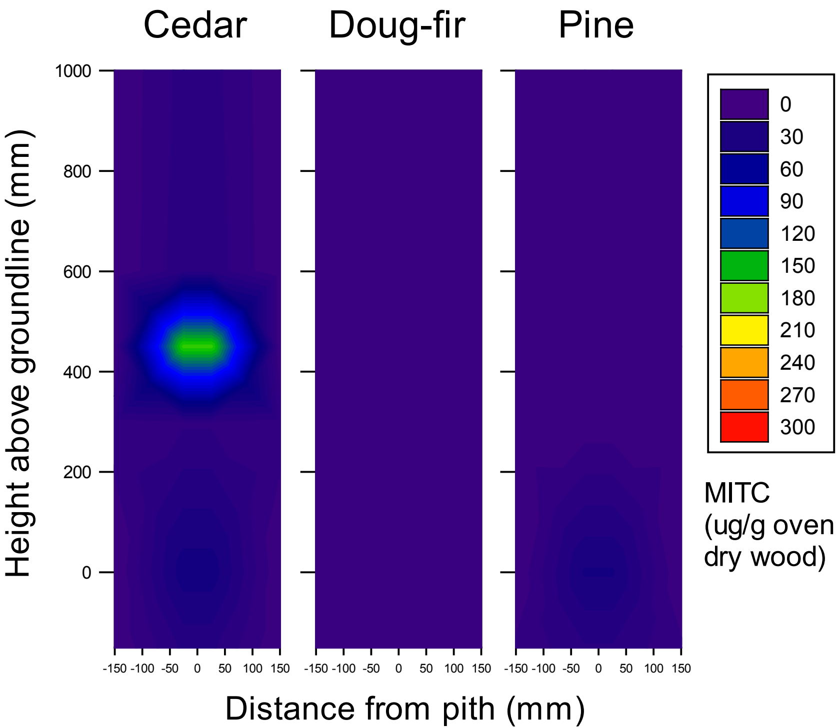

Figure I-15. Distribution of MITC in pole sections 14 months after treatment with dazomet plus copper naphthenate (1 % as Cu). Dark blue represents a MITC level below the threshold for fungal protection while lighter shades of blue as well as green, yellow and finally red signify that protective levels are present in those zones.

the time of application should have improved release to some extent; however, boron levels remained well below the threshold except in the one western redcedar and the one lodgepole pine pole. All of the other values were well below the threshold for fungal protection. Boron requires moisture for movement and these data clearly indicate that moisture levels in these poles are too low to allow for boron movement from the rods. If boron based materials are used in poles in drier climates, it will be important to place the chemicals well below the groundline where there is a potential for subsurface moisture to create conditions suitable for boron diffusion to occur. This may require a reconsideration of the treatment pattern used for these systems.

The results indicate that MITC movement from MITC-FUME and metham sodium treated poles did not appear to be affected by low moisture levels in poles in a dry climate. Dazomet and boron rods were both substantially affected by the low moisture contents in the poles. The results indicate the need for changes in how dazomet is employed in drier climates. Placement of dazomet in holes above the groundline is not advisable in these poles unless there is evidence that external wetting occurs. Further studies are planned to determine if there are other methods for enhancing dazomet decomposition in dry climates.

Literature Cited

American Wood Preservers' Association (AWPA). 2004. Standard A2. Analysis of waterborne preservatives and fire-retardant formulations. Method 16. Determination of boron in treated wood- using Azomethine H or carminic acid. In: AWPA Book of Standard, Selma, Alabama.

Table I-16. Boron levels in poles 14 months after treatment of Douglas-fir, western redcedar, and lodgepole pine poles with fused boron rods with or without water [a]*.*

Treatment	Wood species	n	months after treatment	Height above groundline (mm)					
				-150		0		300	
				inner	outer	inner	outer	inner	outer
Control	cedar	1	14	0.05	0.03	0.01	0.06	0.02	0.08
	DF	1	14	0.00	0.03	0.00	0.00	0.00	0.00
	pine	1	14	0.00	0.01	0.00	0.00	0.00	0.00
Fused boron rods	cedar	2	14	0.06 (0.06)	0.04 (0.02)	0.01 (0.02)	0.03 (0.00)	0.03 (0.03)	0.04 (0.02)
	DF	1	14	0.01	0.04	0.01	0.00	0.00	0.03
	pine	3	14	0.26 (0.38)	0.02 (0.02)	0.05 (0.01)	0.01 (0.02)	0.06 (0.03)	0.04 (0.04)
Fused boron rods + water	cedar	2	14	**0.74** (1.00)	0.02 (0.02)	0.05 (0.02)	0.06 (0.01)	0.02 (0.03)	0.29 (0.32)
	DF	1	14	0.06	0.22	0.07	0.00	0.01	0.00
	pine	3	14	0.57 (0.96)	0.02 (0.02)	0.10 (0.02)	0.02 (0.02)	0.01 (0.01)	0.03 (0.03)

Treatment	Wood species	n	months after treatment	Height above groundline (mm)					
				450		600		900	
				inner	outer	inner	outer	inner	outer
Control	cedar	1	14	0.03	0.05	0.07	0.04	0.05	0.10
	DF	1	14	0.00	0.00	0.00	0.00	0.00	0.00
	pine	1	14	0.03	0.02	0.02	0.02	0.00	0.03
Fused boron rods	cedar	2	14	0.03 (0.00)	0.07 (0.01)	0.00 (0.00)	0.08 (0.01)	0.02 (0.03)	0.07 (0.01)
	DF	1	14	0.00	0.01	0.00	0.03	0.01	0.02
	pine	3	14	0.02 (0.02)	0.02 (0.02)	0.02 (0.02)	0.03 (0.02)	0.03 (0.04)	0.03 (0.02)
Fused boron rods + water	cedar	2	14	0.03 (0.02)	0.01 (0.02)	0.03 (0.04)	0.03 (0.03)	0.04 (0.01)	0.05 (0.03)
	DF	1	14	0.06	0.02	0.00	0.00	0.00	0.00
	pine	3	14	0.03 (0.03)	0.01 (0.01)	0.03 (0.06)	0.02 (0.02)	0.02 (0.02)	0.02 (0.03)

a Numbers in bold represent chemical levels over the toxic threshold of 0.5 Kg/m^3 BAE. Numbers in parentheses represent one standard deviation from the mean.

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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 (Tables II-1, 2). Average copper penetration for the COP-R-PLASTIC treated rods was 2.7 mm after 6 years, while that around the CuRap 20 treated bolts was 3.8 mm. The copper in both systems was not designed to be mobile and these results reflect that limited ability to migrate.

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

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

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

The proposed through-boring standard is under consideration by the ASC 05 committee.

B. Performance of Fire Retardants on Douglas-fir poles

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

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

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

In previous reports, we have described tests to assess the effects of end-plates on checking of Douglas-fir crossarms by exposing arms to repeated wet/dry cycles. The results after 13 cycles showed that plated ends of arms tended to experience fewer checks than the non-plated end of the same arm and that the checks that did develop were narrower. These arms have now been installed at the Peavy Arboretum test site and will continue to be monitored on an annual basis (Figure III-1)

Figure III-1. Douglas-fir crossarms with end plates on one end and no plate on the other on racks above the ground at the Peavy Arboretum test site.

D. Performance of Polyurea Coatings on Douglas-fir Sections Exposed in Hilo, Hawaii.

Preservative treated Douglas-fir performs extremely well when exposed above the ground such as when used as a crossarm to support overhead electrical lines on a utility pole. 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 heartwood which is difficult to treat 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 30 months near Hilo, Hawaii.

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 group (non-treated or treated) were then coated with polyurea. The arms were then shipped to Hilo, Hawaii, where they were exposed on test racks 450 mm above the ground (Figure III-2). The site receives approximately 5 m of rainfall per year and the temperatures remains a relatively constant 24-26 C. The site has a severe 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 wood normally fails within 2 years at this site, compared to 4 to 5 years in western Oregon.

Assessment was primarily visual and consisted of examining coating condition on the upper

Figure III-2. Examples of Douglas-fir crossarm sections with and without polyurea coating immediately after exposure near Hilo, Hawaii.

(exposed) and lower surfaces of each arm. Additional coated samples were exposed in June of 2011 (Figure III-3).

The integrity of the coatings on the various treated and non-treated materials was assessed by probing the upper and lower surfaces of each material with a sharpened awl. The upper surface has presumably been exposed to severe UV attack, while the lower surface was protected.

Non-treated samples without coatings had begun to experience some decay, as evidenced by the presence of fungal fruiting bodies on the end grain of some pieces. The wood surfaces, however, remained intact and, since no internal probing was performed, it was not possible to determine if decay had progressed beyond the early stages. The treated pieces were all free of any evidence of damage. Examination of the coatings indicated that the upper surfaces had weathered and lightened; however, probing of the surface, revealed that this weathering was extremely shallow (>0.5 mm) and the wood beneath was firm and undamaged (Figure III-4). One concern about such shallow weathering in a very wet climate would be that the weathered material would be washed away by repeated rainfall, continually exposing non-

Figure III-3. Polyurea coated Douglas-fir arm sections exposed in June 2011.

Figure III-4. Examples of the upper surfaces (UV exposed, left) and undersides (right) of coated and non-coated Douglas-fir crossarm sections 18 months after installation near Hilo, Hawaii.

weathered material to UV damage. At this time, that does not appear to be occurring; the coating appears to have experienced shallow weathering that has protected the coating beneath. As these tests progress, we will remove some samples for coating tests in at Oregon State University.

Ideally, the polyurea would provide protection against termites without the addition of a preservative. The potential effectiveness of the polyurea as a barrier was assessed using 127 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 describe above. The sections were then coated with polyurea. The samples were evaluated for resistance to the Formosan termite (*Coptotermes formosanus)* at a test site located near Hilo, HI.

In the termite tests, hollow concrete blocks were laid directly on the soil in a 1 m square in an area with known attack by *C. formosanus*. This species is considered to be a very aggressive wood destroyer and is found in the southern U.S. as well as in Hawaii and the tip of southern 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 (Figure III-5). 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:

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

Additional samples were exposed using the same procedures except that one half of the samples were not treated and the other half had been dipped in a 10 % solution of disodium octaborate tetrahydrate (borate) to explore the potential for using boron as an under-treatment for the polyurea coated materials. The dipped samples were wrapped in plastic bags for 4 weeks to allow for boron diffusion, and then the samples were air dried and coated with polyurea. Each treatment was replicated on 10 samples with or without boron and with or without coating. The samples were exposed in the same manner as described for the first test and termite attack was assessed 6 months after installation.

Non-coated, non-treated wood was destroyed by Formosan termite attack 6 months after in-

Figure III-5. Example of a termite array containing coated and non-coated Douglas-fir lumber sections at the time of exposure.

stallation as was the non-treated feeder stock placed around the array (Table III-1). These results indicate that conditions were suitable for aggressive termite attack. Interestingly, coated, but non-treated blocks were also completely destroyed at the 6 month point. The coatings; however, were largely intact, except for entry holes along the end-grain (Figure III-5). The ability of the termites to locate non-treated wood beneath the coating also illustrates the aggressive nature of these insects. The test configuration is designed to limit the potential for moisture entry that might result in leaching of extractives from the wood that could be attractive to foraging workers. The results suggest that the attack was initiated by volatiles moving through the coatings and into the covered chamber. These also indicate that barriers alone are insufficient to limit attack by this insect.

Penta treated wood in the array was free of termite attack regardless of whether it was coated or not, although the surfaces were heavily mudded by the workers (Figure III-6). This lack of damage reflects the exceptional performance of penta as a wood preservative. Additional non-treated wood was placed around the surviving samples to encourage further termite attack. Six months later, the non-treated wood surrounding the test samples was again, completely destroyed, indicating that conditions continued to be suitable for aggressive Formosan termite attack. Although workers had attempted to cover the penta treated samples with mud, there was no evidence of attack of the wood at the 1 year inspection. These results illustrate the efficacy of penta against the Formosan termite.

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

Preservative Treatment	Average Termite Rating[1]					
	Non-Coated			Coated		
	6 months	12 months	18 months	6 months	12 months	18 months
Non-treated	0	-	-	0	-	-
Penta-treated	10	10	10	10	10	10

1 Values represent means of 10 replicates per treatment

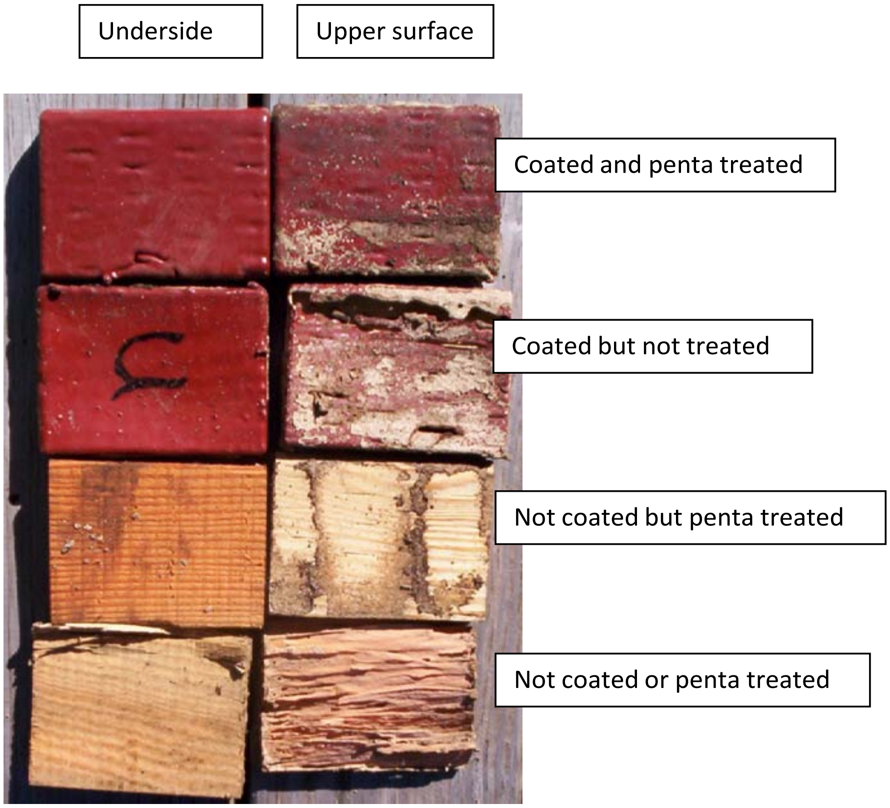

Figure III-6. Examples of undersides (left) and upper surfaces of coated and non-coated Douglas-fir lumber with and without penta treatment.

Inspection of the arrays containing samples with and without boron treatment again showed that both non-treated feeder material and the non-treated control specimens were heavily attacked by termites. Non-treated, non-coated material had an average rating of 4.0, while non-treated material that was coated had a rating of 8.8 (Table III-2). While the degrees of attack were lower than those from the first test, they did indicate that termites were active and that they were capable of penetrating through the coating to attack the non-treated wood inside. Borate-treated samples without coating experienced slightly lower degrees of attack than similar untreated pieces, but it was evident that the termites were capable of attack. Polyurea coating did result in much reduced termite attack for the borate treated materials, although some attack was still noted on six of the eight specimens tested.

The results suggest that termites will attack wood that has been dip-diffusion treated with boron, even with the polyurea coating, while penta provided an excellent barrier against attack regardless of coating.

Table III-2. Effect of a polyurea coating on degree of damage experienced by boron-treated and non-treated Douglas-fir lumber.

Preservative Treatment	Average Termite Rating[1]	
	Non-Coated	Coated
Non-treated	4.4	8.8
Boron-treated	6.6	9.3
[1]Values represent means of 10 replicates per treatment		

E. 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 these poles. Capping can prevent this damage, but there is relatively little data on the ability of these devices to limit moisture entry.

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

Figure III-7. Example of a capped pole used to assess the effects of capping on wood moisture content.

Five of the poles were left without caps while the remainder received Osmose pole caps. Initial moisture contents were determined by removing increment cores 150 mm below the top of each pole (Figure III-7). 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, 12, 28, 32, 40, 44 and 52 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 while they were 17 and 19 % for the outer 25 mm of non-capped and capped poles, respectively (Table III-3). The elevated levels in the inner zones of the capped poles were due to one very wet pole. Moisture contents at the 4 month point 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 declined over the drier summer months. This means that moisture conditions are suitable for microbial attack for a large proportion of the year. Moisture levels in capped poles have remained consistently

Table III-3. Moisture contents of increment cores removed from sites just below the tops of Douglas-fir pole sections with and without water shedding caps.

Exposure (mo)	Sampling Month	Control		Pole Cap	
		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]

1. *No data for this sample time.*

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-8). We will continue monitoring these pole sections over the coming seasons to establish internal moisture trends associated with the caps and to examine cap condition.

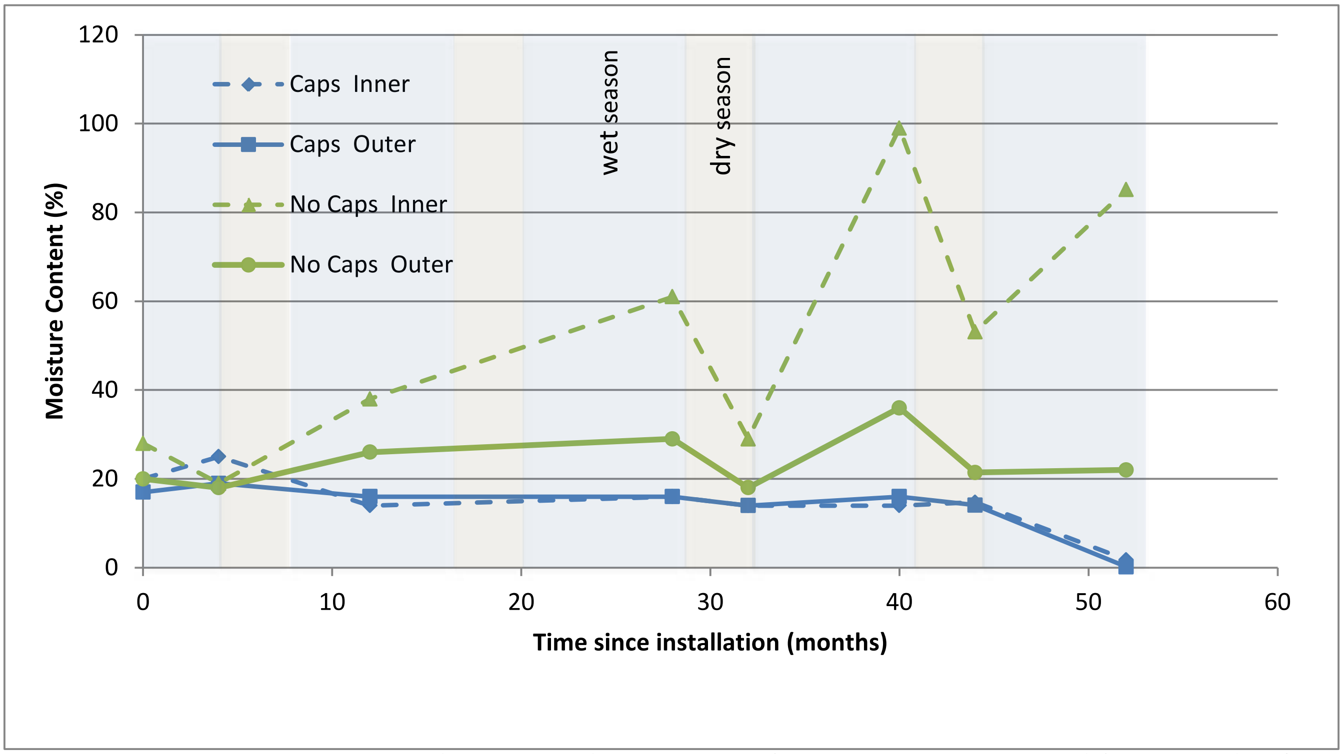

Figure III-8. Moisture contents in the inner and outer zones of increment cores removed from Douglas-fir poles with and without moisture shedding caps.

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

Figure III-9. Example of a polyurea coated pole top.

The polyurea barriers have proven to be durable on crossarms in sub-tropical exposures at Hilo, Hawaii. We wondered if these materials would also be effective for protecting the tops of newly installed poles. To investigate this possibility, six pentachlorophenol treated Douglas-fir pole sections (3 m long) were coated with polyurea from the tip to approximately 0.9 m below that zone (Figure III-9). The poles were set to a depth of 0.6 m at a test site on the OSU campus. Increment cores were removed from the zone below the coated surface and divided into inner and outer 25 mm sections as described above. Each core section was weighed immediately after removal from the pole, then oven-dried and re-weighed. The difference was used to determine installation moisture content. Moisture contents at the time of installation ranged from 16.0 to 31.8%. The averages for the inner and outer zones were 23.8% and 19.0%, respectively. These poles were installed in the spring of 2011 and were sampled after 4 and 12 months of exposure to assess the effect of the coating on internal moisture by removing increment cores in the same manner as described previously. After plugging the sampling holes, the polyurea was repaired by affixing a section of Mule Hide Seal-Fast Tape over the hole. 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 averaging 5.9 and 7.5 % for the inner and outer zones, respectively (Figure III-10). Moisture levels continued to decline over the next 8 months even though this was the rainiest part of the year. 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 Hilo, 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 an additional method for controlling moisture entry through pole tops.

G. Ability of Ground Wire Staples to Resist Withdrawal

Staples are commonly used to hold ground wires to poles. For many years, there was relatively little concern about these staples. Recently, however, thieves have targeted copper ground wires and the ability of these staples to provide maximum resistance to withdrawal has taken on added importance. Last year, we reported on extensive tests of groundwire staples used by cooperators. No new staples were provided, although we are ready to perform addi-

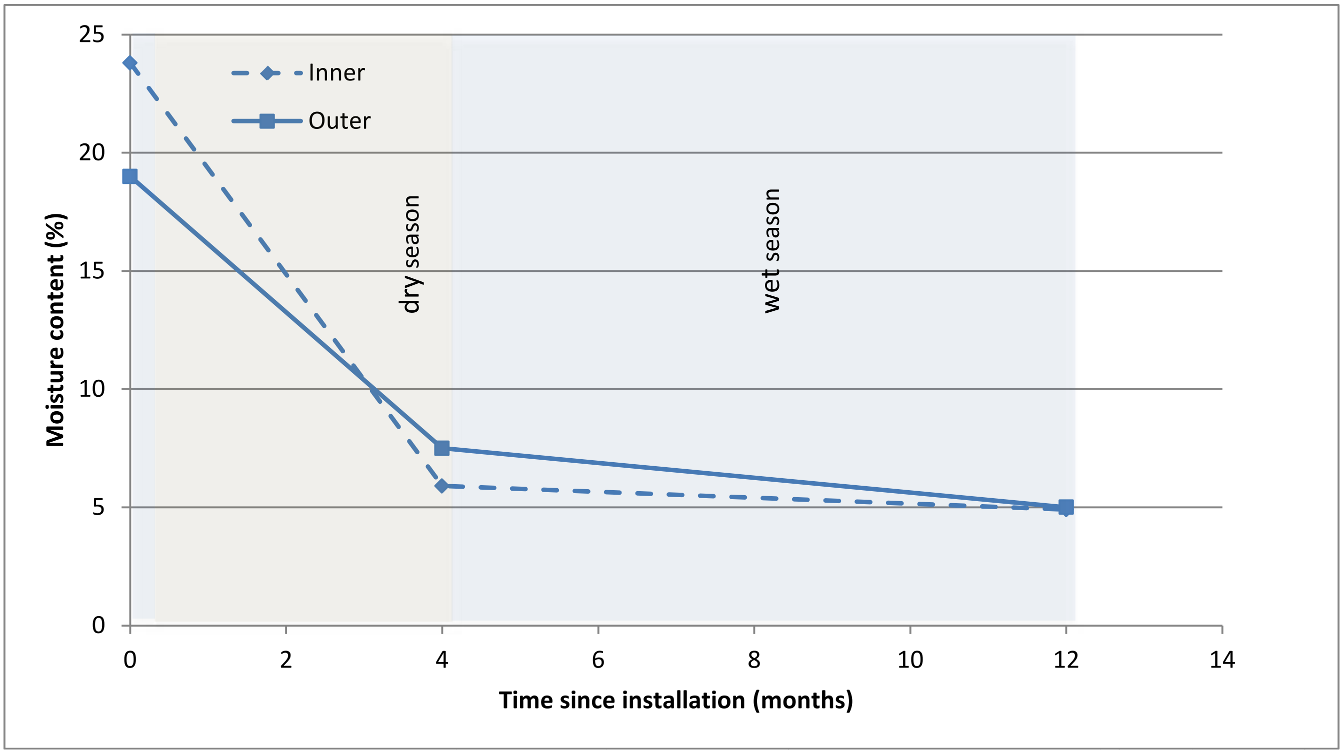

Figure III-10. Moisture contents in the inner and outer zones of increment cores removed from the tops of poles with a polyurea coating designed to shed moisture.

tional tests as materials become available.

H. 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 actual 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 the exposure process.

In this report, we describe field test results of Fahlstrom stakes treated with penta using diesel or a biodiesel amended solvent (HTS) and exposed at two sites for 18 to 31 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 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 30 cm apart. The Corvallis, Oregon site has a maritime climate and receives approximately 1.15 m of rainfall per year, primarily between October and June. The Hilo, Hawaii site is sub-tropic and receives nearly 5 m of rainfall per year. This site has a well drained volcanic clay soil.

Stake condition was evaluated at the Corvallis site after 1 year of exposure while stakes at the Hilo site were assessed after 6, 12, 24 and 31 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 Hilo site has no termite activity, while the Corvallis site has minor termite activity. No evidence of termite activity was observed on any stakes. Depletion stakes were also removed after 31 months for residual preservative analysis. The stakes were removed and the bottom and top 50 mm as well as the 50 mm zone around the groundline were removed and separately ground to pass a 20 mesh screen then analyzed for penta by X-ray fluorescence spectroscopy. These values were compared with matched retained pieces that had not been exposed in the field.

Actual penta retentions tended to be much lower than the targets for stakes treated using either solvent, although the retentions were considerably lower with the HTS (Table III-7). The lower retentions with the latter solvent could reflect selective penta movement or possible solution mixing errors. Regardless, the differences in the retentions could lead to reduced performance of the stakes treated to these target levels. This would not be a problem in commercial practice because poles would be assayed for penta content prior to installation and any deficiencieswould be corrected prior to shipping.

Activity at the Corvallis site was very limited, with almost no damage to any of the stakes. The location chosen was at the lower end of the test site and was extremely wet for most of the year. We suspect that it was too wet and presented an oxygen limited 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 Hilo test site was markedly greater, with evidence of early failures after only 6 months of exposure (Tables III-4,5). 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 treated with only solvent have completely failed. Interestingly, two stakes that were not treated with solvent or penta 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 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-11). 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 0.35 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 a target retention of 0.6 pcf with either diesel or HTS had

Table III-4. Average condition of Fahlstrom stakes treated to varying retentions with pentachlorophenol in either diesel or HTS and exposed in Hilo Hawaii for 31 months.

Target Retention (PCF)	XRF Retention (PCF)	Carrier	Reps	Average Condition Rating[1]			
				6 mo	12 mo	24 mo	31 mo
-	X	Diesel	10	7.7 (4.2)	5.6 (4.9)	0.0 (0.0)	0.0 (0.0)
0.1	X	Diesel	10	9.7 (0.9)	4.9 (5.2)	1.7 (3.7)	0.0 (0.0)
0.2	X	Diesel	10	9.9 (0.3)	8.7 (1.9)	5.1 (4.6)	2.4 (3.9)
0.3	0.274 (0.062)	Diesel	10	9.9 (0.3)	9.9 (0.3)	6.7 (4.7)	4.7 (5.0)
0.6	0.432 (0.110)	Diesel	25	9.7 (0.8)	9.8 (0.6)	8.7 (2.8)	6.7 (4.3)
-	X	HTS	10	8.8 (1.3)	2.6 (4.2)	1.0 (3.2)	0.0 (0.0)
0.1	X	HTS	10	9.6 (1.0)	6.6 (4.6)	3.3 (5.0)	2.3 (3.5)
0.2	X	HTS	10	8.8 (1.3)	6.7 (4.7)	2.9 (4.7)	1.1 (2.4)
0.3	0.187 (0.022)	HTS	10	10.0 (0)	5.1 (4.8)	2.5 (4.1)	2.6 (4.2)
0.6	0.239 (0.028)	HTS	25	9.8 (0.7)	9.8 (0.4)	8.7 (2.8)	7.1 (4.3)
Non-treated control			5	10.0 (0.0)	8.2 (1.6)	2.6 (4.0)	1.8 (4.0)

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. "X" represents retained samples that have not yet been analyzed.

Table III-5. Stakes treated with pentachlorophenol in either diesel or HTS solvent that remained in test after 6 to 31 months of exposure in Hilo, Hawaii.

Target Retention	Solvent	Replicates	Stakes Remaining in Test (%)			
			6 months	12 Months	24 Months	31 months
-	Diesel	10	80	60	0	0
0.1		10	100	50	20	0
0.2		10	100	100	60	30
0.3		10	100	100	70	50
0.6		25	100	100	96	72
-	HTS	10	100	30	10	0
0.1		10	100	70	30	30
0.2		10	100	70	30	20
0.3		10	100	60	30	30
0.6		24	100	100	92	75
Non-treated control		5	100	100	40	20

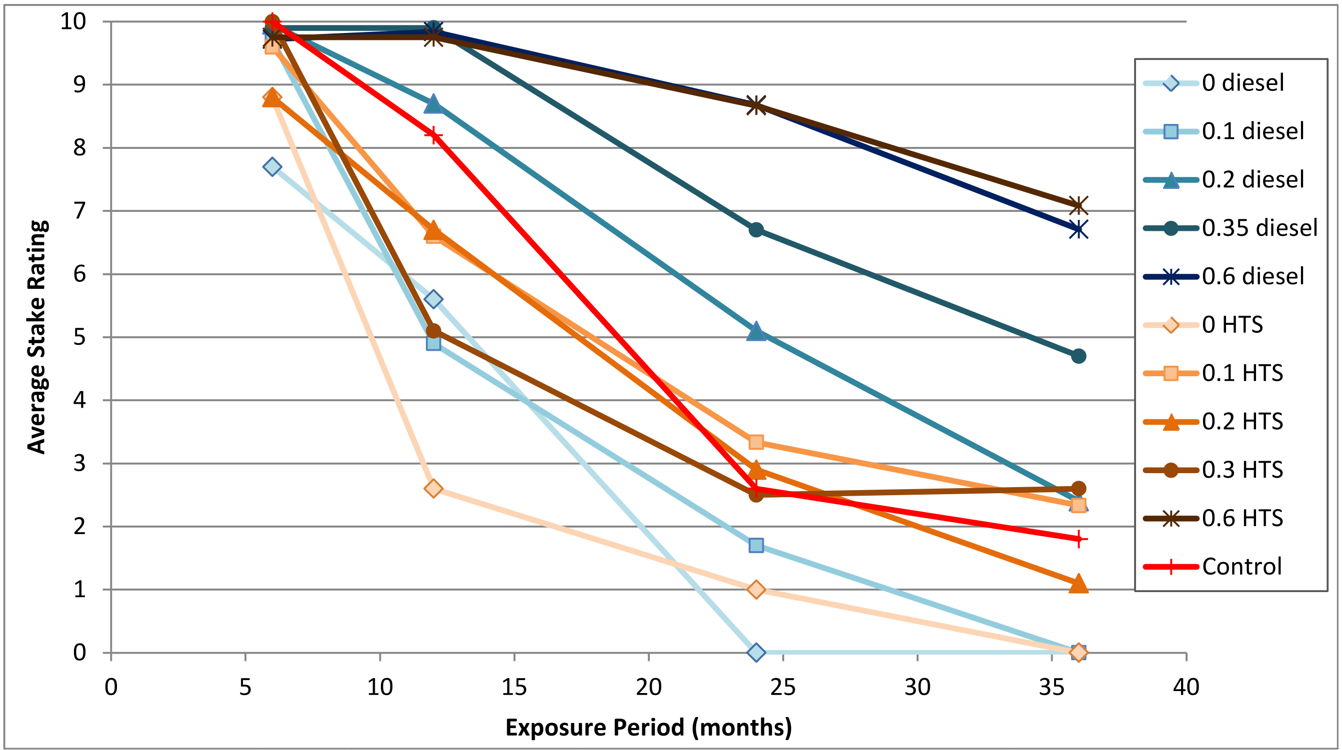

Figure III-11. Condition of stakes treated with pentachlorophenol in either diesel or HTS solvent and exposed in soil for 36 months at a test site near Hilo, Hawaii.

the similar ratings after 6, 12, 24 and 36 months.

Stakes treated with the two systems experienced similar failure rates (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.

Penta analysis of stakes treated to a target retention of 0.6 pcf and not exposed under field conditions indicated that the actual retentions were much lower than the target (Table III-7). 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 chould be reduced.

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.

The results for the Corvallis stakes after 36 months in test were similar except that the retention differences were much greater. The original site for the Corvallis stakes experienced winter flooding that should have produced much higher leaching levels. This was evidenced in the HTS stakes, but was less obvious in the diesel stakes. It is difficult to determine the effects of this leaching on performance at this site because the elevated moisture conditions were not suitable for microbial attack and virtually all of the stakes remain sound and in test. We have moved these stakes to a better drained site and will continue to monitor condition in relation to performance.

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 biological results rapidly and the early failures in both treatments clearly illustrate the accelerated nature of

Table III-7. Pentachlorophenol retentions at selection locations on southern pine sapwood stakes immediately prior to exposure and after 31 months of exposure in Hilo, Hawaii or for 36 months in Corvallis, OR .

Solvent	Location	Pentachlorophenol Retention (lb/ft^3)			
		Initial retention	Bottom	Groundline	Top
Diesel	Hilo	0.323 (0.106)	0.074 (0.028)	0.105 (0.030)	0.168 (0.023)
HTS	Hilo	0.212 (0.036)	0.019 (0.006)	0.033 (0.040)	0.053 (0.017)
Diesel	Corvallis	0.458 (0.109)	0.107 (0.029)	0.156 (0.042)	0.256 (0.050)
HTS	Corvallis	0.212 (0.036)	0.108 (0.020)	0.084 (0.030)	0.016 (0.016)

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.

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 with either solvent are performing similarly (Table III-7).

The original intent of these tests was to determine if there were performance differences due to the solvent. While the depletion data differed after 31 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 well in either solvent .

Conclusions

The performance of pentachlorophenol in biodiesel appeared to differ from material solubilized in diesel at lower retention levels; however, performance at the highest retention was markedly similar. These stakes will continue to be monitored to determine if the performance continues to be similar at the higher retention level.

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 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.

B. Performance of a Boron/Fluoride Paste on Douglas-fir, Western redcedar, and Southern Pine Poles

Preservative treatments provide an excellent barrier against fungal attack in soil contact, but over time, the effectiveness of these treatments declines to the point where external decay can develop. This damage is often arrested by excavating to a depth of 450 to 600 mm around a structure, scraping away any soil/damaged wood, and applying a supplemental preservative. The treatment is covered with a barrier and the hole is back-filled. Supplemental systems often contain several components including some that coat the surface to prevent renewed attack and others that diffuse inward from the surface to arrest growth of fungi already present in the wood (Love et al., 2004). Most external preservative systems used in North America contain copper as the surface barrier and either boron or fluoride as the diffusible component. These systems have generally provided excellent protection and are widely used to enhance the performance of western redcedar, oil-treated southern pine, Douglas-fir

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 Utility Services, Inc.	
Corvallis, OR	1990	Douglas-fir	none	CuRap 20	ISK Biosciences	1993
				Patox II	Osmose Utility 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 Utility 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 Utility Services, Inc.	2009
				PoleWrap	Osmose Utility 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 Utility Services, Inc.	
				PoleWrap (Bandage)	Osmose Utility Services, Inc.	

poles treated with pentachlorophenol in liquefied petroleum gas, or any pole that is set into concrete. Globally, however, there is a shift away from heavy metal based preservatives and this move is likely to affect North American utilities in the future. One possible alternative treatment is the boron/fluoride system currently used in Australia and South Africa. This system is applied in self contained bandages that are easy to handle and apply.

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

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

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

The estimated thresholds for wood protection determined using wood block exposures range widely for both boron and fluoride (Table IV-2). The wide range of values reflects, in part, the array of conditions under which the tests were performed as well as differences between the woods and fungal isolates tested. For example, thresholds are likely to be much higher if the tests allowed chemical leaching to occur. While this factor would be important in applications where the chemically treated wood is directly exposed to soil or liquid water, boron and fluoride are often used in rod forms that are intended for internal application. The risk of leaching is minimal under these conditions, making a leaching exposure threshold value suspect. The

Table IV-2. Thresholds for fluoride and boric acid against selected decay fungi as predicted in previous studies.

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

target chemical levels in wood become important when considering retreatment cycles. Remedial treatments are generally re-applied at regular intervals to provide continued supplemental protection to the wood, but the point at which re-application is necessary can be difficult to determine. Refining the retreatment cycles can produce considerable cost savings for electrical utilities if it allowed them to safely delay treatments. One approach for determining retreatment time has been to chemically analyze the wood to assess residual chemical levels, and then reapply once the levels decline below a given level. Determining the reapplication level, however, is difficult without more precise data on the threshold required for protection against fungal attack.

Because there are limited data on the effectiveness of these systems on U.S. pole species, a trial was installed at our research test site in 2006 to investigate boron and fluoride paste efficacy on North American pole species. Non-treated 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 obtained from McFarland Cascade, Inc. (Eugene, Oregon). The pole sections 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 1.15 m 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-3). 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.

Table IV-3. 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

Chemical movement in the poles was determined 1, 2, 3 and 5 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 combined, and then ground to pass a 20 mesh screen. The resulting sawdust was then divided into two samples for analysis.

One set of samples was hot water extracted and analyzed for boron content according to American Wood Preservers' Association Standard A2 Method 16, the Azomethine-H method (AWPA, 2004b). Boron levels in the samples were determined by comparison with standards containing known amounts of boron. For comparison purposes, boron was considered to be at an effective level for internal decay control when present at 0.03 pounds per cubic foot (pcf) (0.5 kg/m^3) BAE (boric acid equivalent) or greater (Table IV-2). The threshold for protection in external applications is believed to be approximately 0.14 pcf (2.24 kg/m^3), although this figure is probably a bit high because of the difficulty in estimated loadings needed for a mobile chemical.

Fluoride in the other set of sawdust samples was analyzed using a method described by Chen et al. (2003) in which the sawdust was extracted in 0.1 m $HClO_4$ for 3 hours at 176°F, then the supernatant was analyzed for fluoride using a specific ion electrode according to procedures described in AWPA Standard A2 Method 7 (AWPA, 2004a). Fluoride levels were quantified by comparison with similar tests on prepared standards and were expressed on a kg of fluoride per unit volume of wood basis using the assumed density values listed in AWPA Standard A12 (AWPA, 2004c). Fluoride thresholds have received less study, but appear to be equal to or lower than those for boron for internal decay control (Table IV-2). Our laboratory data suggests a threshold between 0.00626 and 0.0125 pcf (0.1 and 0.2 kg/m^3) for this application. External fluoride thresholds appear to vary more widely, but are probably similar to those for boron. There is no established threshold for the combination of boron and fluoride.

This test was not evaluated in 2012, but will be assessed this coming year.

C. 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-4). 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.

Table IV-4. 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-4 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-4 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 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-5). The bucket containing the paste was weighed and then the paste was applied to the pole from 75 mm above groundline to a depth of 460 mm below groundline using the calculated paste dosage. The bucket was reweighed and the difference between initial and final weight was used to ensure that the calculated paste coverage per unit area was achieved.

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

The degree of chemical migration was assessed 17 months after treatment by excavating on

Table IV-5. Material properties of the pastes tested in the Arizona field trial.

Paste	lb/gal	Active Ingredient	% Active
CuBor	10.1	copper hydroxide (2% metallic Cu) 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 tebuconazole bifenthrin	43.7 0.3 0.2 0.04
Osmose experimental paste	10.8	unknown	
Bioguard	11.0	boric acid sodium fluoride	30-40 10-25
Bioguard Tri-Bor experimental paste	11.0	boric acid Borax 5 mol (Neobor) Boroguard ZB (zinc borate hydrate)	30-50 7-15 7-15

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

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

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 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 (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 extraction 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-6). 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 penta in oil while the APS poles were pine, western redcedar and Douglas-fir variously treated with creosote 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 determined from shavings or increment cores did not differ markedly with treatment (Figure IV-5, Table IV-7). 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 fungal 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

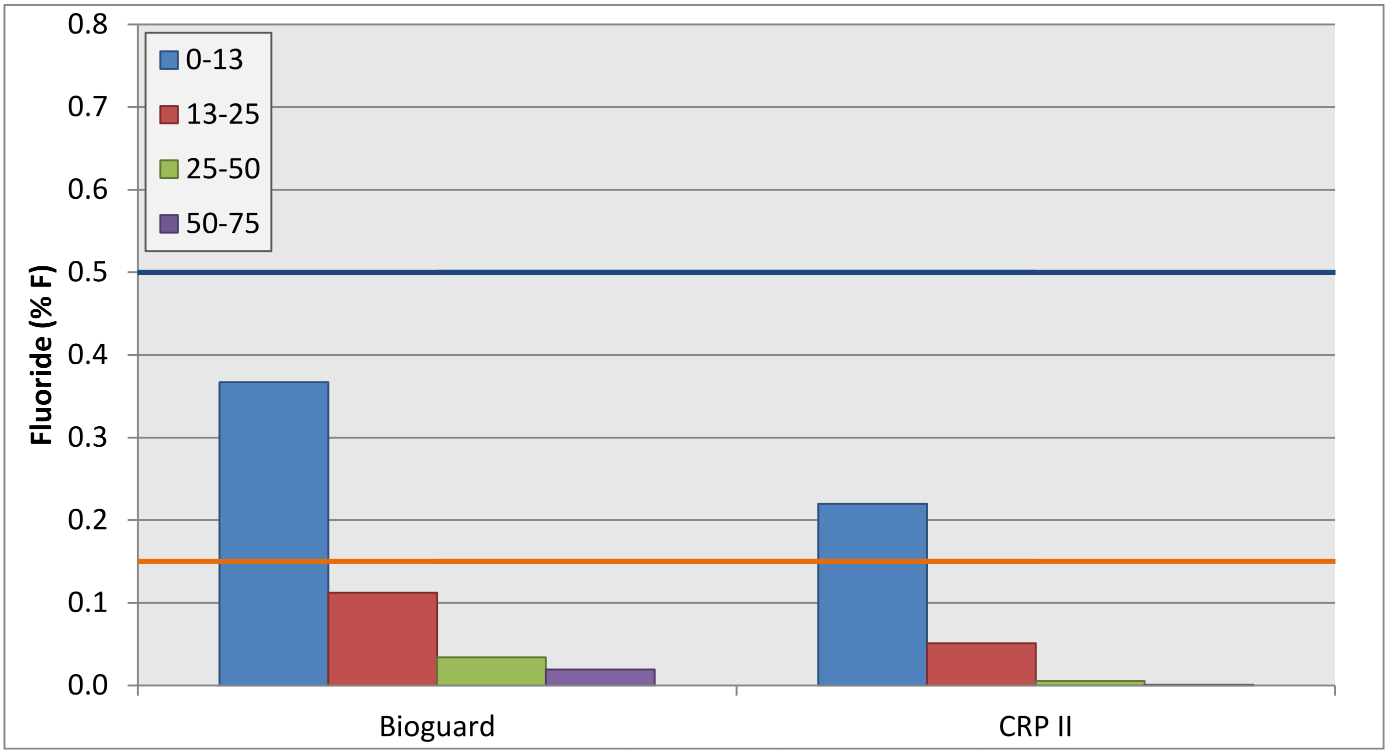

Figure IV-2. Fluoride levels with distance inward from the surface in Douglas-fir, western redcedar and pine poles 17 months after treatment with Bioguard or COP-R-PLASTIC II when all species are combined.

Table IV-6. 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 SRP	0.47 0.26	0.13 0.09	0.04 0.02	0.03 0.01
COP-R-PLASTIC II	APS SRP	0.19 0.25	0.01 0.09	0.00 0.01	0.00 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.

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). The

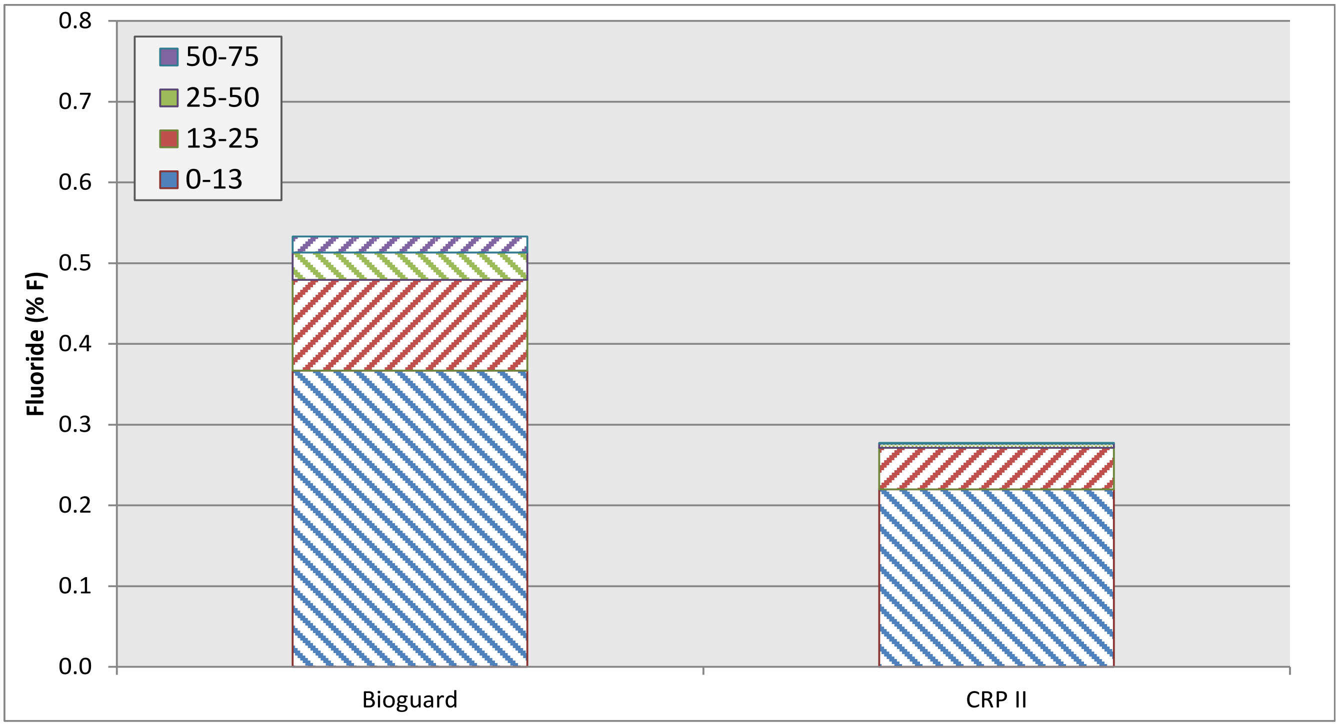

Figure IV-3. Fluoride levels with distance inward from the surface in Douglas-fir, western redcedar and pine poles 17 months after treatment with Bioguard or COP-R-PLASTIC II in a stacked bar graph where all species are combined showing the difference in total fluoride in the assay zones. Solid color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

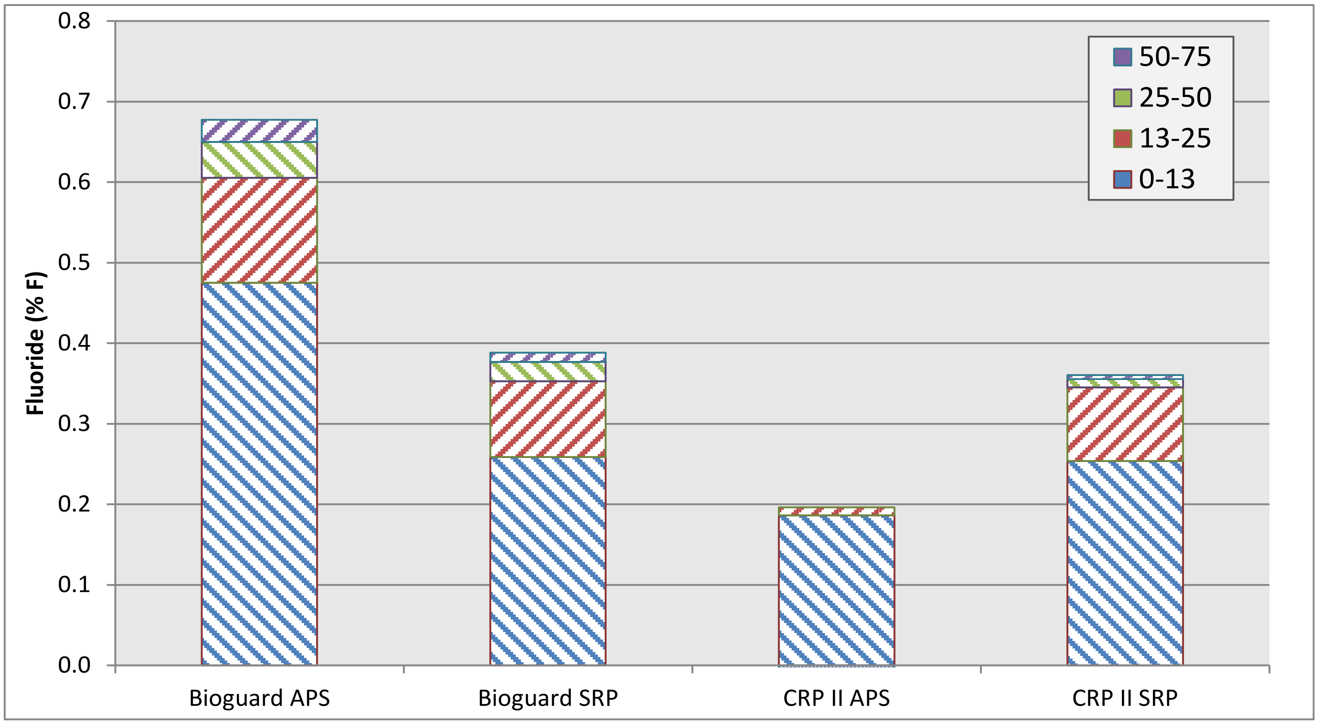

Figure IV-4. Stacked bar graphs showing fluoride levels with distance inward from the surface in Douglas-fir, western redcedar and pine poles 17 months after treatment with Bioguard or COP-R-PLASTIC II where poles segregated by treatment and utility. Solid color bars indicate levels over the toxic threshold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

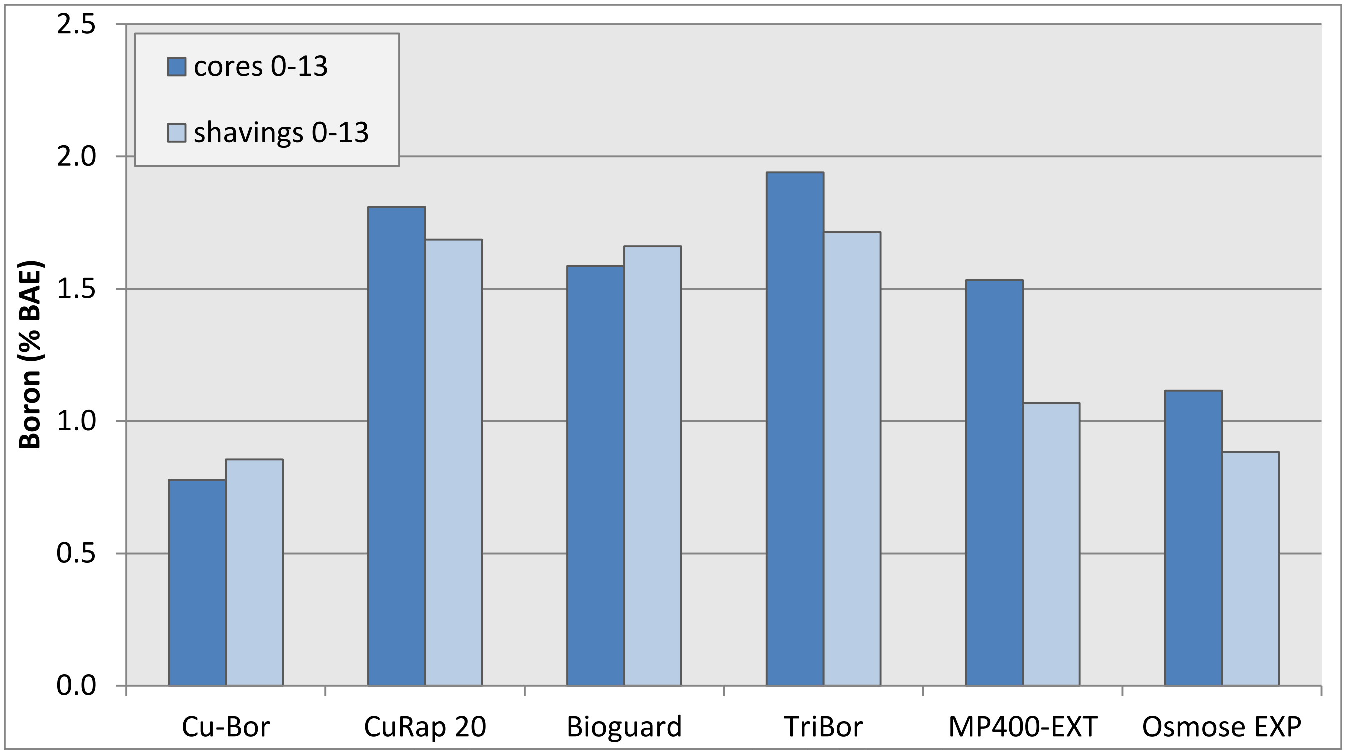

Figure IV-5. Boron content in poles of various species treated with different boron containing pastes as analyzed from either shavings collected with a Forstner bit or increment core segments.

Table IV-7. 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 for the three inner zones.

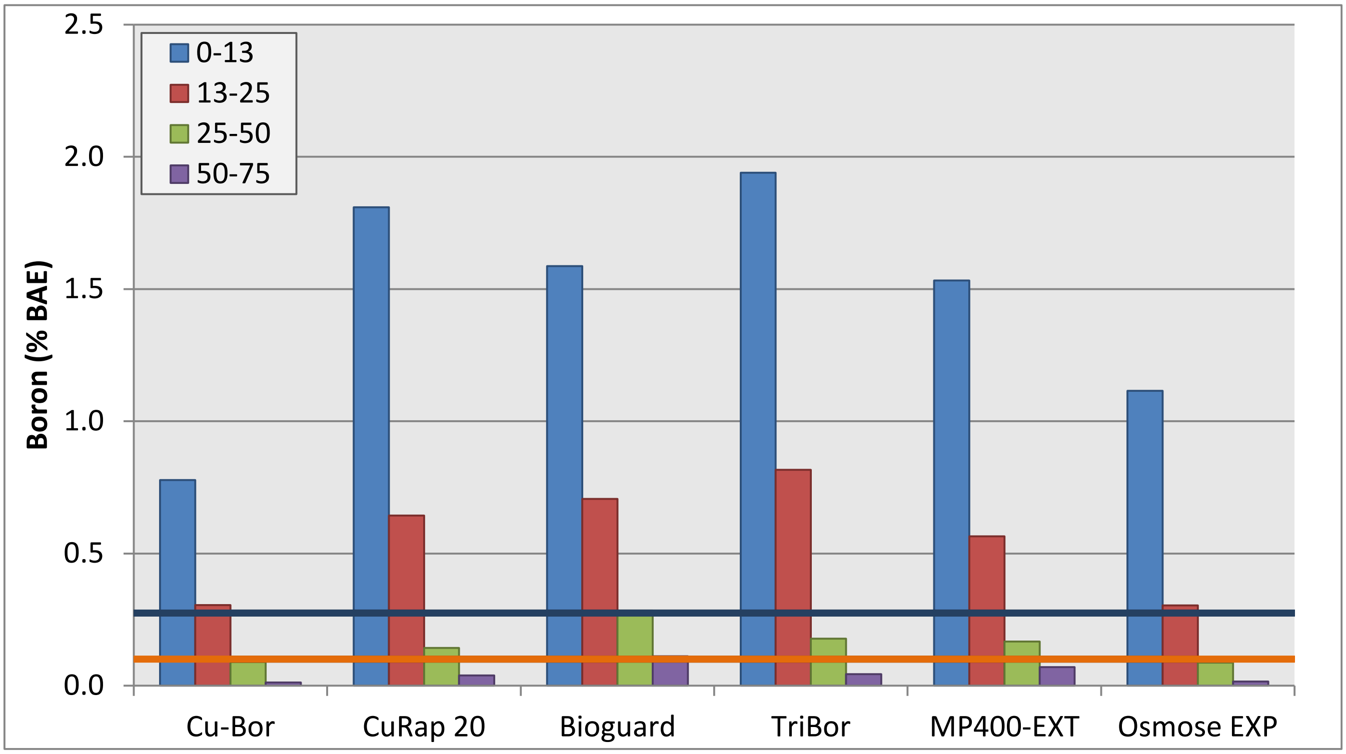

Figure IV-6. Boron levels at various distances from the surface inward in poles of various species 17 months after treatment with six different boron containing pastes.

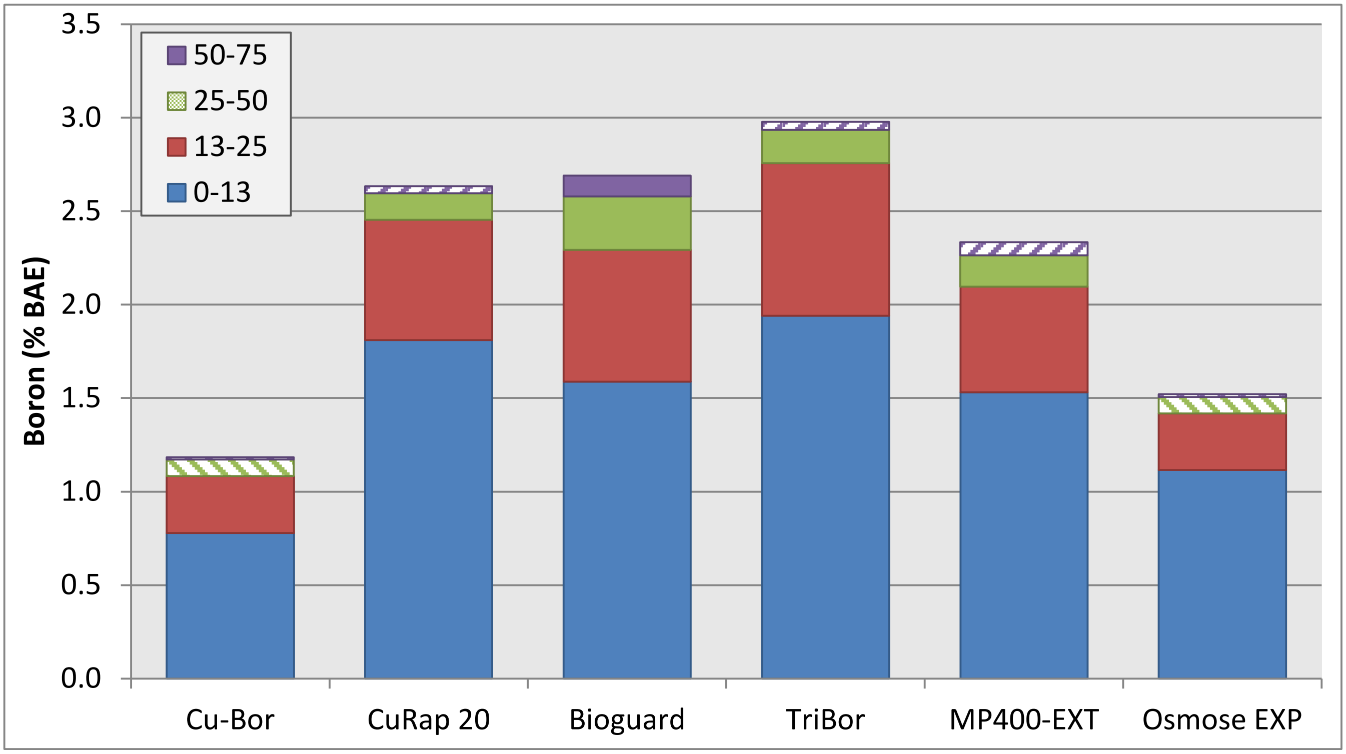

Figure IV-7. Total boron measured in the outer 50 mm of poles 17 months after treatment with selected boron-containing pastes. Solid color bars indicate levels over the toxic threshold for the zone and striped bars indicate levels below.

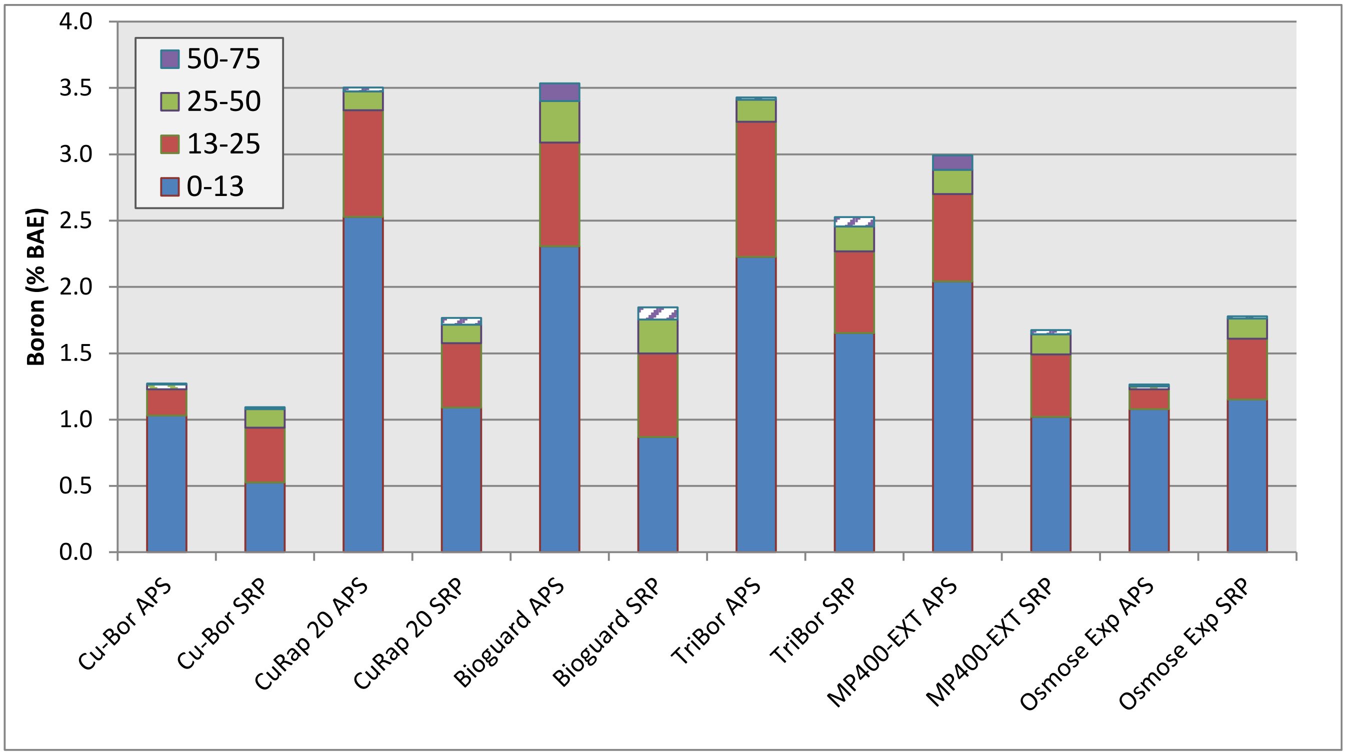

Figure IV-8. Boron content in the outer 50 mm of poles combined for species but segregated by utility 17 months after application of various boron-containing pastes. Solid color bars indicate levels over the toxic threshold for the zone and striped bars indicate levels below.

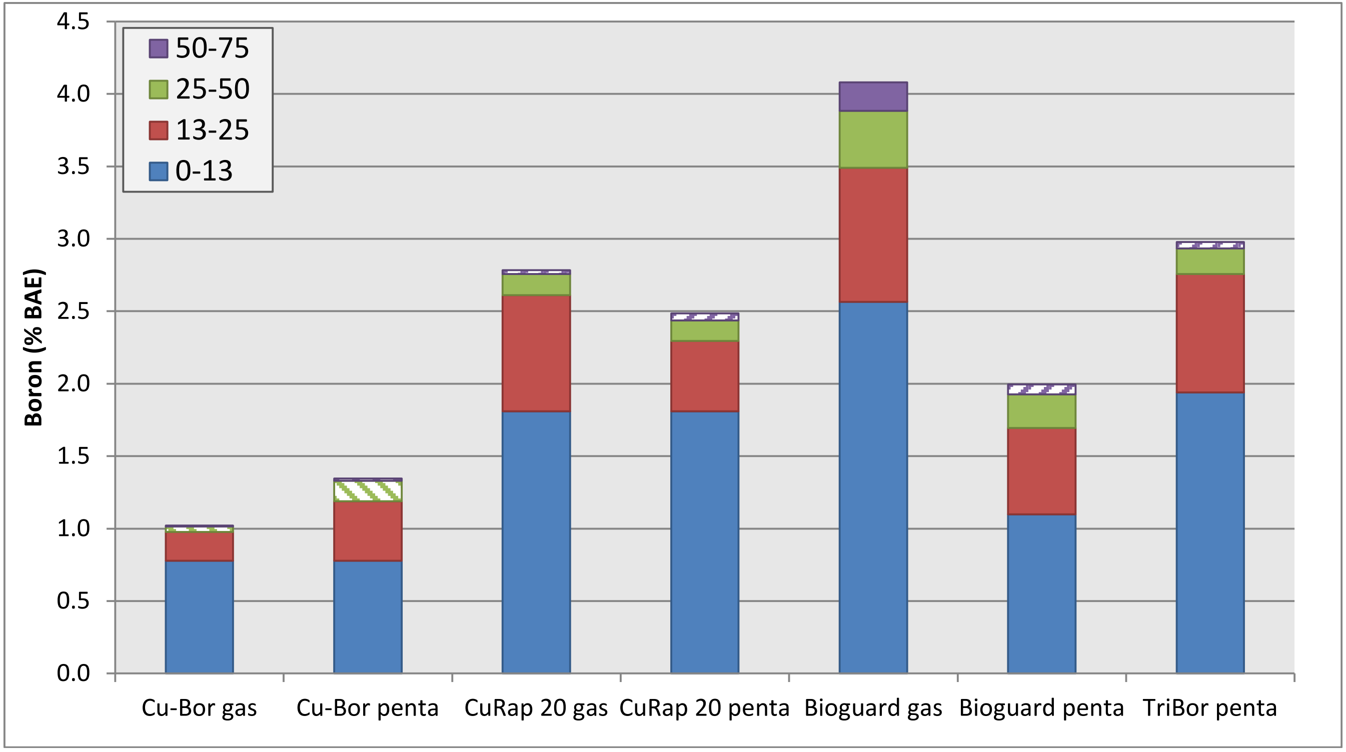

Figure IV-9. Boron content in the outer 50 mm of poles of various species segregated by primary treatment 17 months after application of various boron-containing pastes. Solid color bars indicate levels over the toxic threshold for the zone and striped bars indicate levels below.

preliminary results 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 and Cu-Bor, but the results were lower in shavings from the outer 6 mm of poles treated with CuRap 20 (Table IV-8, 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, 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 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 fun-

Table IV-8. 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	0.00	0.01	0.00		
	SRP	0.00	0.00	0.00		
Osmose Exp	APS	0.03	0.00	0.00		
	SRP	0.08	0.00	0.00		

1. Numbers in bold are above the toxic threshold of 0.15% Cu.

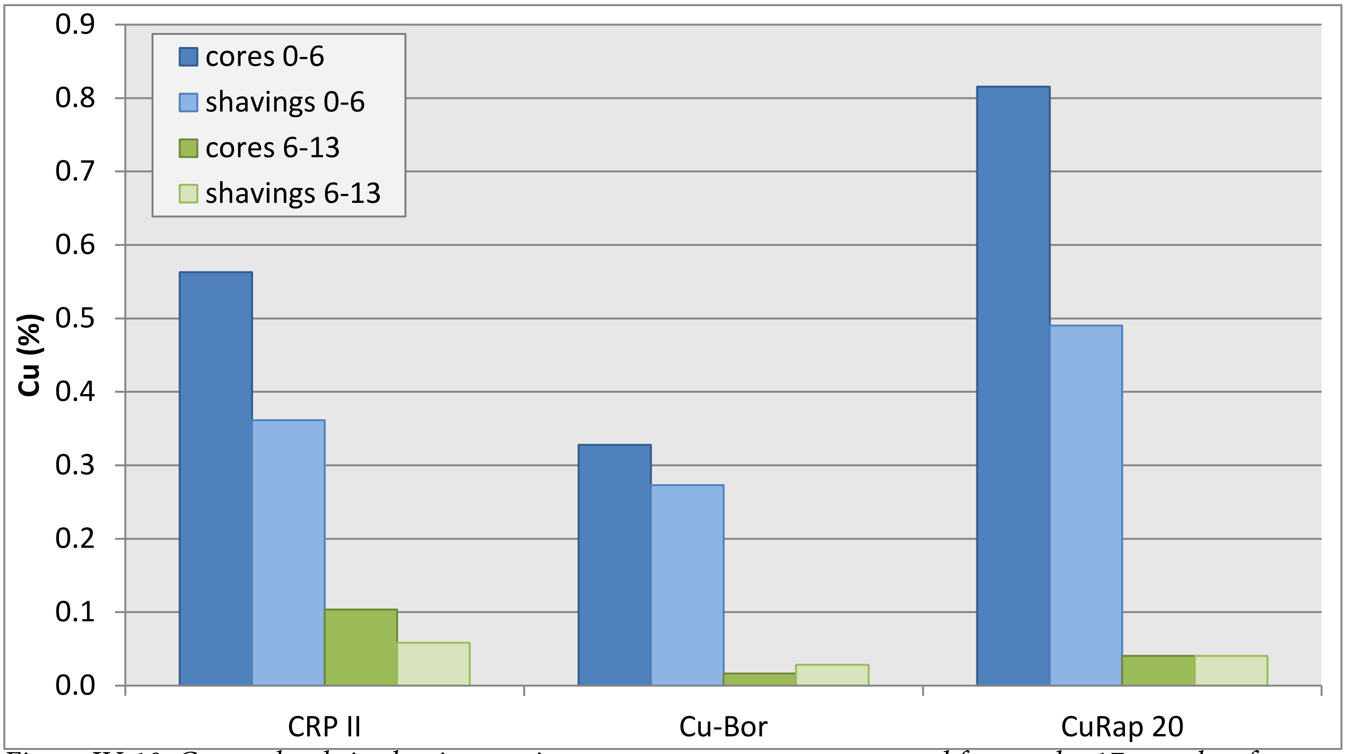

Figure IV-10. Copper levels in shavings vs. increment core segments removed from poles 17 months after treatment with various copper containing preservative pastes.

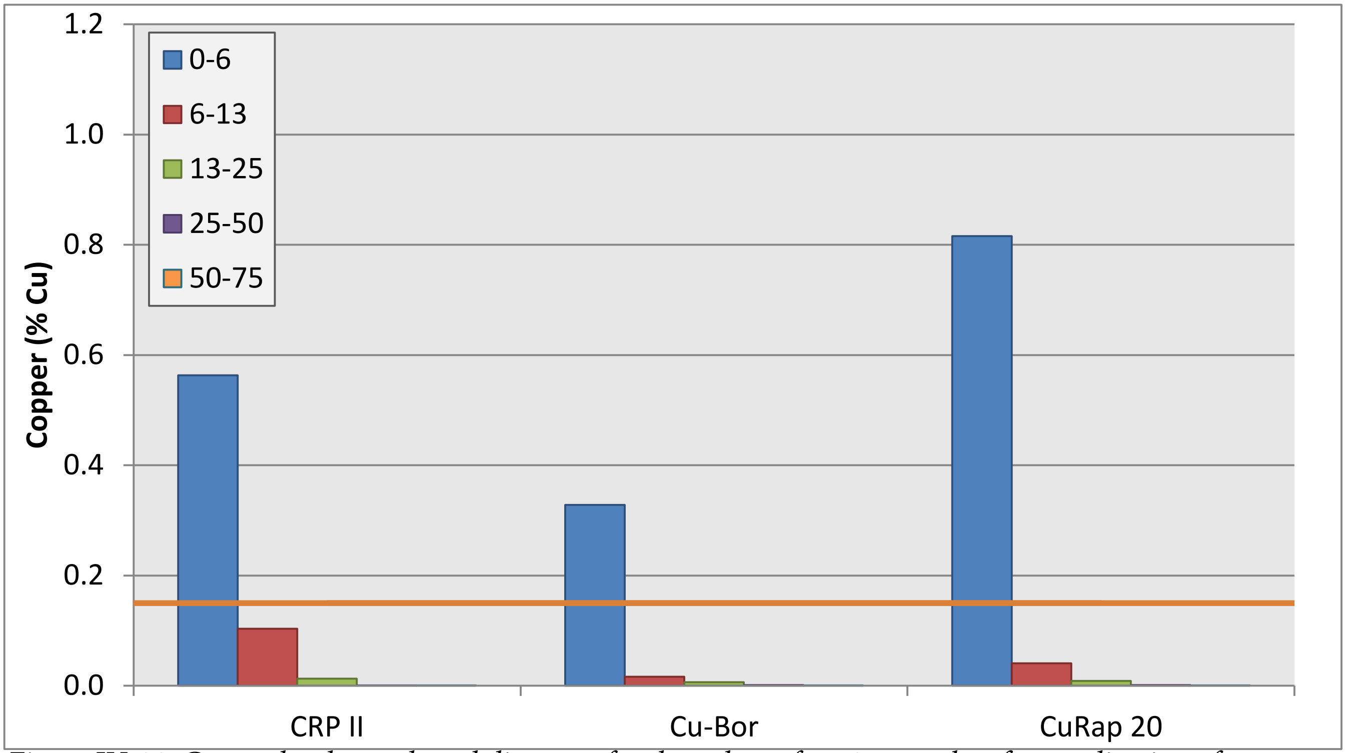

Figure IV-11. Copper levels at selected distances for the pole surface 17 months after application of copper containing preservative pastes. The horizontal line indicates the toxic threshold for the form of copper in these chemicals.

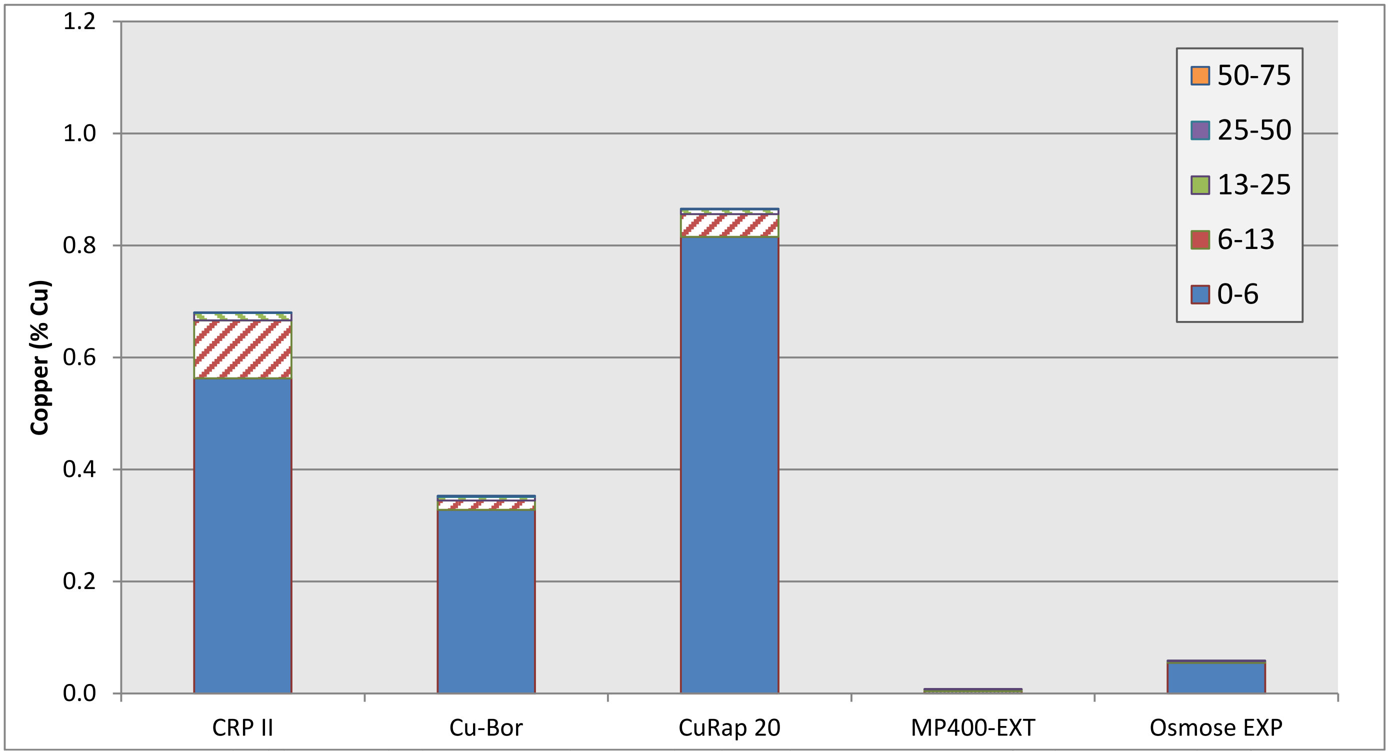

Figure IV-12. Stacked bar graph showing total copper levels in the outer 75 mm of poles 17 months after application of copper containing preservative pastes. Note that most copper is in the outer assay zone. Solid color bars indicate levels over the toxic threshold for the zone and striped bars indicate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

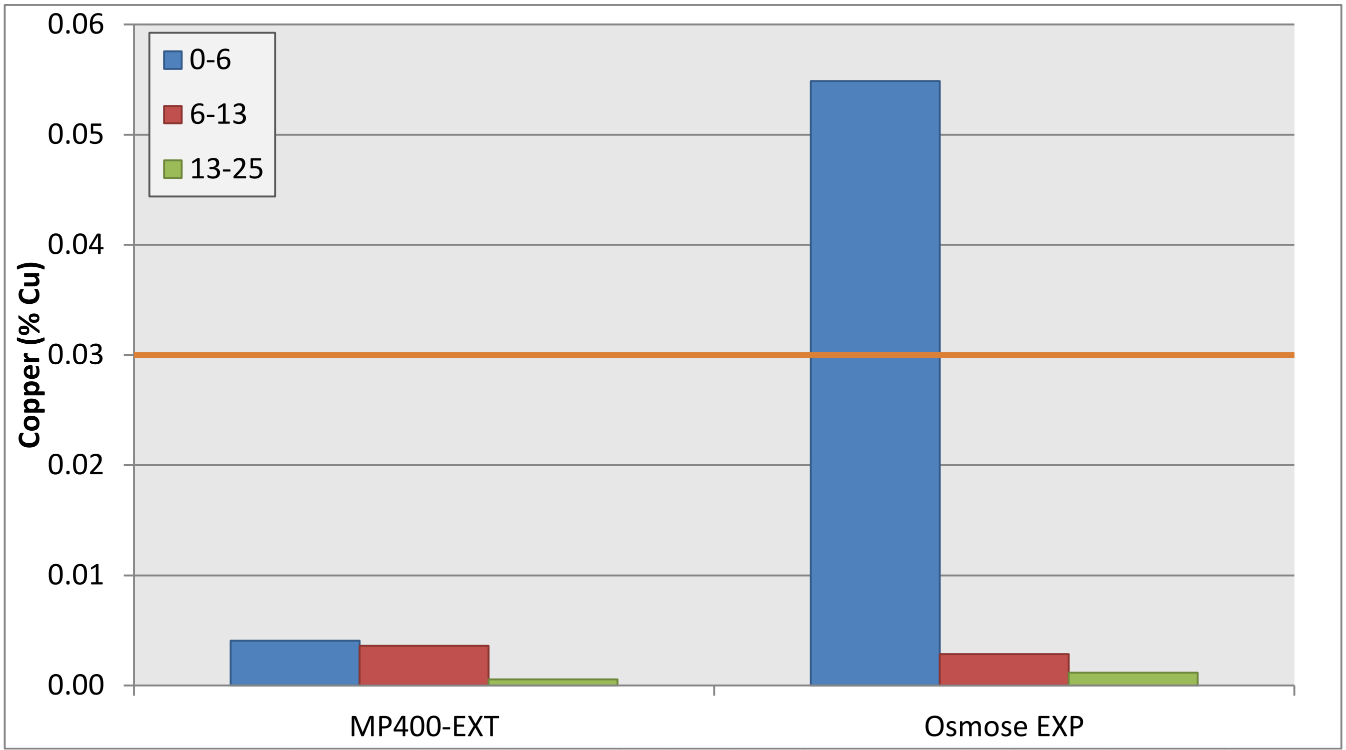

Figure IV-13. Copper levels at selected distances for the pole surface 17 months after application of copper containing preservative pastes. The horizontal line indicates the toxic threshold for the form of copper in these chemicals.

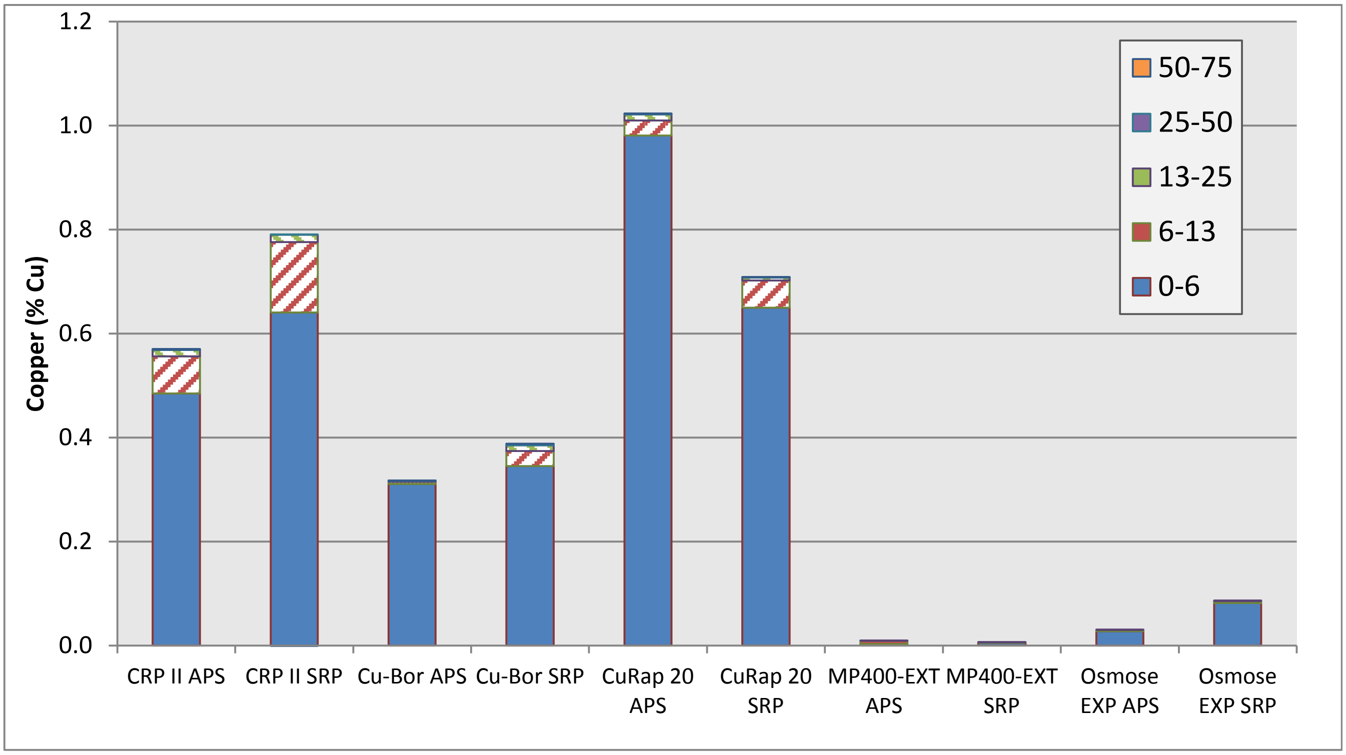

Figure IV-14. Copper levels in poles 17 months after treatment with selected copper containing preservative pastes segregated by treatment and utility. Solid color bars indicate levels over the toxic threshold for the zone and striped bars indicate levels below.

Table IV-9. 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.

gal 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). 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 to13 mm zones were quantifiable for bifenthrin.

Both bifenthrin and tebuconazole were detected in the outer 6 mm of the cores (Table IV-9). 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 would be considered to be protective against fungal attack in laboratory soil block tests 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 MP400-EXT was above the threshold for protection. The levels in the next zone from the surface were below that level for both pastes.

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.

D. Develop Thresholds for Commonly Used External Preservative Systems

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

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

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

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

E. Effect of External Barriers on Pole Performance

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

Figure IV-15. Example of a Biotrans liner at the Peavy Arboretum test site.

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

In 2007, an additional set of penta-treated Douglas-fir pole stubs were encased in the newest generation of Biotrans liner and set into the ground at our Peavy Arboretum research site (Figure IV-15). The poles were each sampled prior to installation to determine chemical penetration and retention and baseline moisture content. Five poles received a Biotrans liner

Table IV-10. Moisture contents of penta treated Douglas-fir poles with and without Biotrans liners as monitored over a 45 month period.[11]*.*

Treatment	Months After Installation	Segment (mm)			
		0-13	13-25	25-50	50-75
Biotrans 150 mm	0 (installation)	39.5 (10.0)	35.1 (7.4)	34.0 (11.8)	33.5 (10.5)
	6 (wet season)	57.8 (19.0)	48.1 (10.5)	37.6 (2.6)	37.7 (5.5)
	12 (dry season)	48.7 (13.9)	35.6 (10.3)	35.7 (14.6)	34.6 (16.1)
	18 (wet season)	48.8 (11.9)	40.6 (11.2)	34.7 (5.3)	31.6 (4.7)
	42 (wet season)	53.1 (31.1)	42.7 (15.8)	47.6 (26.2)	46.2 (26.6)
	45 (dry season)	32.2 (11.1)	28.7 (4.1)	32.3 (10.1)	34.4 (6.6)
Biotrans 300 mm	0 (installation)	38.5 (7.7)	32.2 (3.9)	32.2 (8.1)	40.3 (24.3)
	6 (wet season)	67.1 (18.3)	49.5 (5.7)	38.8 (3.0)	35.5 (3.2)
	12 (dry season)	45.1 (20.7)	34.6 (9.8)	33.3 (7.0)	33.1 (6.7)
	18 (wet season)	60.0 (14.6)	40.1 (6.3)	37.4 (5.0)	36.5 (5.6)
	42 (wet season)	63.3 (23.2)	47.4 (31.3)	45.8 (26.1)	53.5 (35.2)
	45 (dry season)	55.4 (18.6)	36.7 (9.0)	37.0 (5.6)	37.2 (5.9)
Unlined Control	0 (installation)	34.4 (3.5)	28.9 (2.7)	27.2 (3.2)	29.1 (3.3)
	6 (wet season)	54.3 (14.9)	47.1 (7.4)	42.1 (7.9)	43.7 (10.8)
	12 (dry season)	20.2 (4.9)	28.7 (15.7)	28.8 (8.3)	29.5 (4.3)
	18 (wet season)	47.3 (15.0)	34.7 (6.1)	31.5 (3.6)	31.7 (5.4)
	42 (wet season)	49.7 (23.3)	45.4 (25.7)	62.6 (55.6)	61.1 (59.1)
	45 (dry season)	17.9 (9.4)	24.7 (8.6)	39.9 (19.6)	63.5 (18.6)

1. Numbers in parentheses represent one standard deviation around the mean of 12 (150 mm), 9 (300 mm) or 24 (control) measurements.

that extended 150 mm above groundline; five received a Biotrans liner that extended 300 mm above groundline and eleven poles were left without liners.

Six, 12, 18, 42 and 45 months after installation the poles were sampled by removing three increment cores from a single location 150 mm below groundline. The cores were cut into zones corresponding to 0-13, 13-25, 25-50, and 50-75 mm from the wood surface. Each segment was placed into an individual tared vial, capped tightly and returned to the lab. The cores were weighed, oven-dried, and then weighed again. The difference between initial and oven-dry weight was used to determine moisture content. The sampling holes were plugged and any damage to the external coating was repaired to limit the potential for moisture to move into the wood through the sample holes.

Sampling of these poles 6 months after installation revealed that moisture contents 150 mm above the groundline were similar although the moisture levels in poles without a liner were slightly lower. Moisture contents 6 months after installation were elevated in the outer zone (0-13 mm from the surface) and declined with distance inward (Table IV-10). There appeared to be little difference in above ground moisture content between poles with and without barriers. The 6 month sampling coincided with the middle of our rainy season when wood moisture content would be expected to be elevated. Sampling 12 months after setting revealed moisture contents that were uniformly low in the poles without a barrier, while those with barriers remained at or above 45 % moisture content in the outer 13 mm. These results suggest that the barrier limited drying. While this does not necessarily mean that barriers will affect the rate of decay, it does mean that conditions suitable for decay extend further upward from the groundline than they do in poles without barriers and inspectors would need to alter their inspection procedures to ensure that they detected decay in these structures.

Moisture contents 18 months after setting once again rose to levels above the fiber saturation point in the non-barrier treated poles, but changed little in the barrier protected poles. These results indicate that poles without barriers experience much greater seasonal fluctuations in moisture content although all of the moisture contents measured were near or above the point where fungal attack can begin.

Although there were some anomalies in our assessments, moisture contents at 42 months in these poles were slightly higher than those found at 18 months in both lined and non-lined poles. Moisture levels were higher in the outer zones of lined poles, but similar to slightly lower further inward. Moisture contents at the end of the dry period (45 months) tended to be lower than those found at 42 months, reflecting the absence of substantial rainfall in the intervening months. The test site becomes extremely dry during the summer and previous studies have shown that wood moisture contents decline to near the fiber saturation point (30 %) near the wood surface. Most fungi cannot degrade wood at moisture levels below 30 %. Moisture levels further inward, however, can remain elevated. The results after 45 months indicated that there were few differences in moisture content between lined and non-lined poles.

In our original assessment, one possible concern was that water would to continue to move down checks and into the below ground portions of the poles where it would accumulate. This would result in an ever increasing water addition that might produce very high moisture contents that could limit oxygen and thereby inhibit decay. This has not, to date, occurred.

F. Establish a Field Trial of Current Liner Systems

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

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

Douglas-fir pole sections (250-300 mm in diameter by 3.1 m long) were treated to 9.6 kg/m^3 with pentachlorophenol and southern pine pole sections of the same dimensions were treated with CCA to a retention of 9.6 kg/m^3 or penta to a retention of 7.2 kg/m^3. Additional non-treated poles were included in the test as controls. The pole sections were sampled using

Table IV-11. 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

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 will be used for monitoring potential migration of preservative components into the surrounding soil, and the other half will be used for measuring wood moisture content above and below the barrier.

Soil samples were collected prior to pole installation from 20 random locations at the test site using a trowel. A small pit was dug at each sampling location and soil was removed from depths of 0 to 25 mm, 25 to 50 mm, 50 to 75 mm and 75 to 150 mm below the ground level. The soil was air dried, screened through a #6 brass sieve and then divided into two samples. The first was analyzed for copper, chrome and arsenic by ICP (Table IV-11). The remaining sample will be analyzed by solvent extraction and, after cleaning up, analysis by GC-MS for penta. These results will be used to establish baseline levels of preservative in the soil for comparison to soil samples removed in subsequent years.

At annual intervals after installation, soil cores will be removed beginning immediately adjacent to the poles, as well as 150 and 300 mm away. The soil cores will be divided into zones as described above and then analyzed for the appropriate preservative. We would move the sampling further outward if we detect increased chemical levels at the initial sampling sites.

Table IV-12. 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%)

Wood moisture content was assessed at the time of installation and 14 and 22 months later and will continue to be assessed periodically over a 3 year period. 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 reweighed 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-12; Figures IV-16-18). 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 penta-treated 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 dry 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. Air seasoning and Boultonizing are essential for Douglas-fir, because deep checks that develop after pressure treatment will invariably expose non-treated wood to possible fungal attack and eventual internal decay.

Table IV-13. 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.

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%)

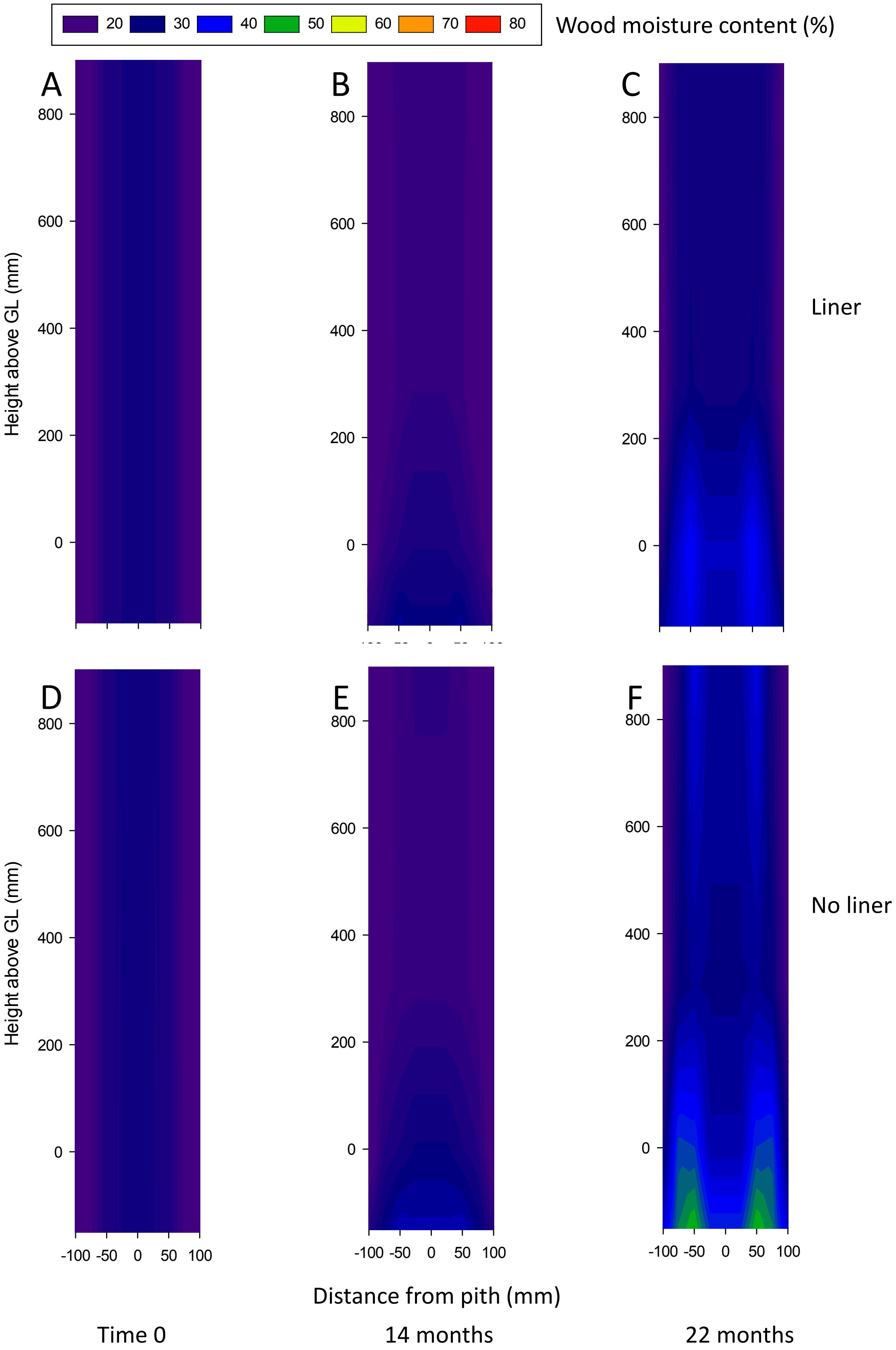

Figure IV-16. Moisture contents in penta-treated Douglas-fir poles with (A, B, C) or without (D,E, F) liners at time of installation (A, D), after 14 months (B, E), or after 22 months (C, F) in the ground at the Peavy Arboretum test site.

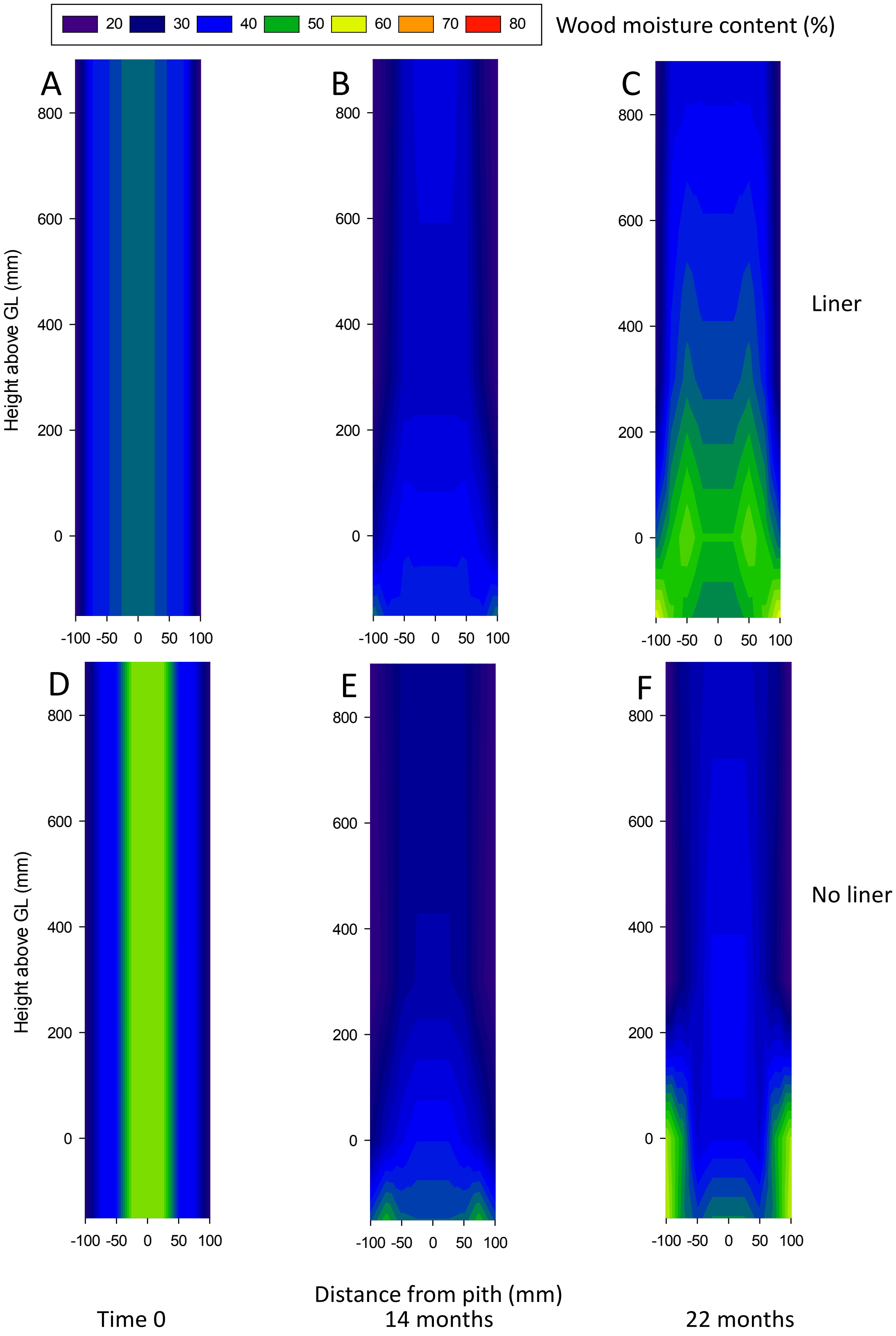

Figure IV-17. Moisture contents in penta-treated southern pine poles with (A, B, C) or without (D,E, F) liners at time of installation (A, D), after 14 months (B, E), or after 22 months (C, F) in the ground at the Peavy Arboretum test site.

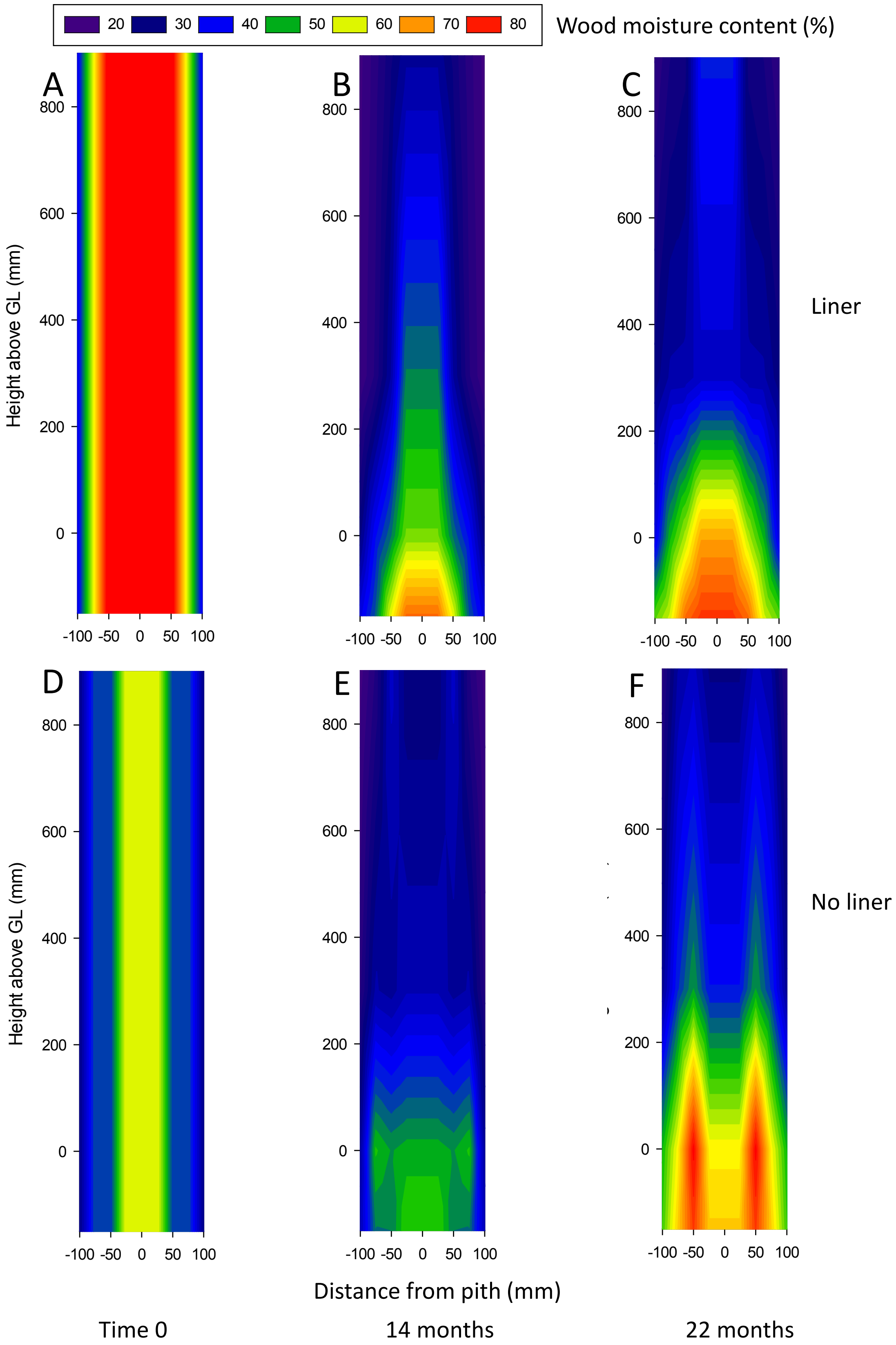

Figure IV-18. Moisture contents in CCA-treated southern pine poles with (A, B, C) or without (D,E, F) liners at time of installation (A, D), after 14 months (B, E), or after 22 months (C, F) in the ground at the Peavy Arboretum test site.

Initial 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 contents 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.

Moisture contents of the poles 14 months after installation again varied with initial treatment and wood species (Table IV-13; Figures IV-16-18). 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 Douglas-fir. 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

Table IV-14. 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.

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%)

of the same species, reflecting the tendency of this treatment to increase hygroscopicity of the wood, but again 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-14; Figures IV-16-18). 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 the water table is very high during the wet season. This creates ideal conditions for moisture uptake. In addition, regular rainfall creates ample opportunity for water to run down the pole in checks to the pole base where it can be more slowly absorbed by the wood. 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. These poles will continue to be monitored for at least another year, but they suggest that moisture condition in lined poles do not differ appreciably from non-lined poles.

Table IV-15 Effect of field liners on copper levels in soils removed from areas around non-treated or CCA treated southern pine poles 22 months after installation.[a]

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

[a] *Numbers in parentheses represent one standard deviation from the mean.*

Chromium levels in soil removed from around the poles were all at or below the detection limit.(0.1 ppm). The lack of substantial chromium movement is consistent with the conversion of hexavalent chromium to the trivalent state as part of the CCA fixation process. This process renders the chromium less mobile and, therefore, far less likely to migrate from the pole. Arsenic levels ranged from 0.3 to 0.6 ppm, but there were no consistent differences in levels between non-treated and CCA treated poles. These results are also consistent with previous studies suggesting that arsenic migration from CCA Type C treated wood is minimal.

Copper levels were at background levels in samples removed 150 or 300 mm away from the CCA treated poles 17 months after installation regardless of the presence of a field liner (Table IV-15). Copper levels in soil samples removed from immediately adjacent to the poles were elevated in all four zones analyzed up to 150 mm away from the pole. Metal levels were highest in the upper soil layer (0-25 mm) and then declined with depth. This trend was observed in CCA treated poles with and without liners. While copper levels were slightly higher in soil around poles with liners, the variations in individual analyses (as shown by the standard deviations) indicate that there were no meaningful differences with a liner at this time point. The liners are believed to limit preservative migration from the poles; however, they cannot stop rainwater from striking the upper surface of the pole, and then running down the sides into the surrounding soil. The results suggest that this migration is occurring at similar rates from both lined and non-lined poles. We will continue to monitor the soil around these poles to determine if differences emerge between the lined and non-lined poles over time.

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OBJECTIVE V

PERFORMANCE OF COPPER NAPHTHENATE TREATED WESTERN WOOD SPECIES

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

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

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

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

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

The stakes were then exposed in a fungus cellar maintained at 30 C and approximately 90% relative humidity. Soil moisture was allowed to cycle between wet and 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).

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

Freshly sawn stakes continue to outperform weathered stakes at all retention levels. (Figures

V-1, 2). All of the freshly sawn stakes treated with copper naphthenate to retentions of 4.0 kg/m^3 continue to provide excellent protection after 268 months, while the conditions of the stakes treated to the two lower retentions continued to decline this past year. Stakes treated to the two lowest retentions have declined below a 5.0 rating suggesting that decay has significantly degraded the wood. Ratings for the intermediate retention were just above 6.0, indicating that the treatment had also begun to lose some of its efficacy.

Weathered stakes tended to exhibit much greater degrees of damage at a given retention than the freshly treated stakes. 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 condition of stakes treated to the two higher retentions also declined in the past year. Ratings for the highest retention were below 6, while those for the next highest retention were approaching 4. Clearly, prior surface degradation from both microbial activity and UV light tended to sharply reduce the performance of the weathered material.

Weathered wood was originally included in this test because the cooperating utility had planned to remove poles from service for retreatment and reuse in other parts of the system. While this process remains possible, it is clear that the performance characteristics of the

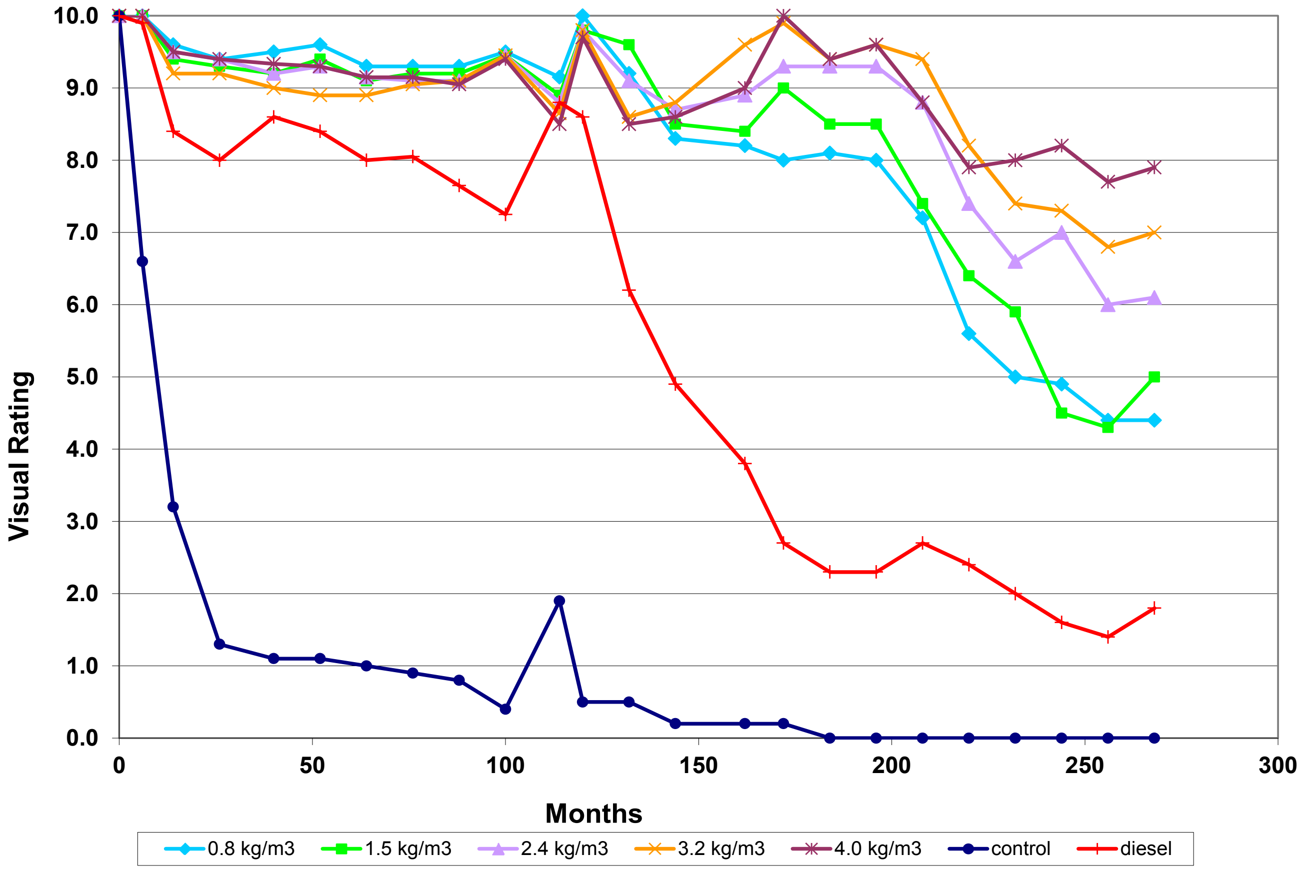

Figure V-1. Condition of freshly sawn western redcedar sapwood stakes treated with selected retentions of copper naphthenate in diesel oil and exposed in a soil bed for 268 months.

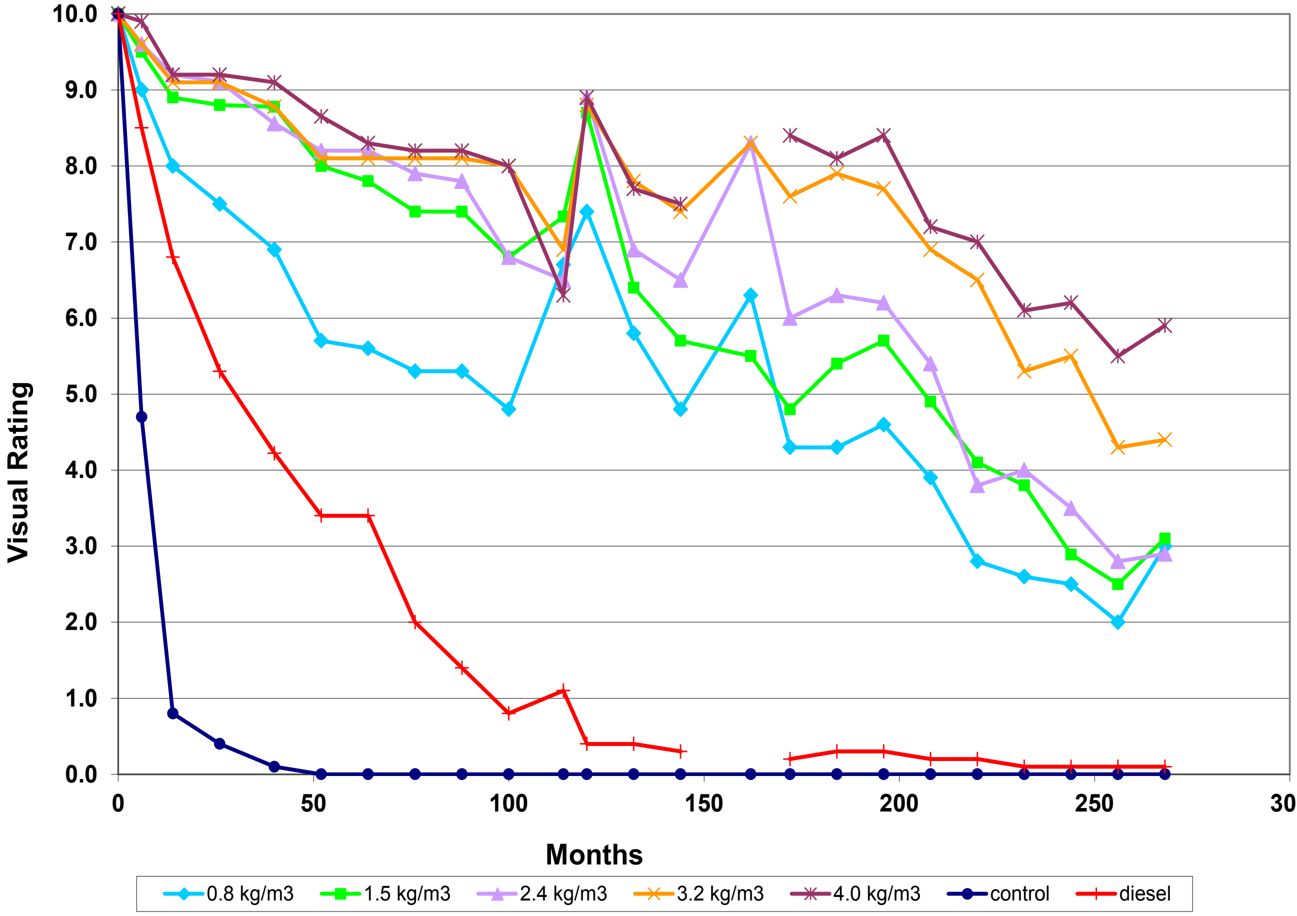

Figure V-2. Condition of weathered western redcedar sapwood stakes treated with selected retentions of copper naphthenate in diesel oil and exposed in a soil bed for 268 months.

weathered retreated material will differ substantially from that of freshly sawn material. The effects of these differences on overall performance may be minimal since, even if the outer, weathered wood were to degrade over time, this zone is relatively shallow on cedar and would not markedly affect overall pole properties.

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

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

The results with freshly sawn and treated western redcedar clearly show good performance of copper naphthenate 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 preservative.

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

As a part of our continuing assessment of the potential impacts of biodiesel on copper naphthenate performance a population of 30 poles treated with this chemical in biodiesel-amended solvent was selected in the area between Renton and Centralia, WA. 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 also collected.

Preservative penetration was measured on each core, and then they will be processed in the following manner. First, the outer 6 mm will be removed and split radially. One half of this section will be briefly flamed to minimize surface contamination before being placed on a malt extract agar plate. The plates will be observed for evidence of fungal growth and any fungi will either be directly examined or sub-cultured onto fresh media for later identification. The other half of the radially split segment will be chemically macerated using sodium hypochlorite then a sample of the resulting fibers will be examined under a light microscope equipped with polarizing filters for evidence of soft rot damage. The segment of each core from 6 to 19 mm will be used to determine copper retention. Segments from cores from a given treatment year will be combined into groups of 9 cores. They will be ground to pass a 20 mesh screen and the resulting dust will be analyzed for copper by x-ray fluorescence spectroscopy. These initial samples were collected to establish a baseline of pole condition for subsequent monitoring.

A portion of the collected shavings will be plated on malt extract agar plates. The remainder of the shavings will be retained for possible processing and examination for evidence of soft rot fungi as described above.

Of the 30 poles examined, three were treated in 2008, four in 2009 and the remainder were treated in 2010. The dates are important because the treater varied the amounts of biodiesel in the solvent over time. The majority of the poles are transmission sized, but four are 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 decay trial results showing that biodiesel was detrimental to copper naphthenate performance translate into issues in the field.

Table V1. Characteristics of Douglas-fir poles treated with copper naphthenate in various blends of biodiesel and installed in western Washington from 2008 to 2010.

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. Vaules represent the mean of three increment cores per pole

C. Resistance to soft rot 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 pole strength. With the exception of poles treated using pentachlorophenol in either liquefied petroleum gas or methylene chloride, preservative treated 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 leaching procedure and these findings suggest that biodiesel amended solvents may encourage leaching of copper from wood in service. 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 clarify these potential 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 standard E-10.

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 one of the test soils. A single test block was placed on a piece of filter paper on the soil surface then additional soil was added to fill the jar. The jars then received water to raise the soil moisture content to 90-140 % of water holding capacity depending on the soil. Deionized water was used directly or was amended with 0.014 g of nitrogen/jar 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 contain a variety of soft rot fungi. Ground, decayed wood that had been in soil contact was added to each soil to provide additional inoculum. The conditions were designed to allow these fungi to flourish and attack the wood.

These tests are underway. The jars will be incubated at 32 C for 16-24 weeks. At the end of the test the blocks will be oven dried and weighed to determine mass loss. Where necessary, thin sections will be cut from the wafers and examined under a light microscope for evidence of soft rot attack. Blocks will also be retained for possible copper analysis if mass losses suggest elevated soft rot activity.

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 Metal Elements from Douglas-fir Poles Treated with Ammoniacal Copper Zinc Arsenate According to Best Management Practices

Previous trials with penta-treated Douglas-fir indicated that migration of preservative from oil-borne systems was relatively easily predicted, it was unclear, however, whether these results would translate to poles treated with water based preservatives. The following trial was established to address this question.

Douglas-fir poles sections (250 to 300 mm in diameter by 1.0 m long) were air-seasoned and pressure-treated with ACZA to a target retention of 9.6 kg/m^3 in the outer 6 to 25 mm of the wood. Treatment conditions followed the current Best Management Practices as outlined by the Western Wood Preservers' Institute. Following treatment, one end of each pole was end sealed with an elastomeric paint designed to reduce the potential for chemical loss from that surface, while the other end was not sealed. The idea was to simulate a longer pole section where some end-grain loss was possible, but the amount of exposed end-grain did not dominate the overall surface area exposed. Six poles were then stacked on stainless steel supports in a stainless steel tank designed so that all rainfall striking the poles would be captured (Figure VI-1). The poles were set 150 mm above the tank bottom to reduce the risk that the wood would become submerged and, therefore, have the potential to lose more chemical. The poles were exposed outside the Richardson Hall laboratories on the Oregon State University campus where they were subjected to natural weathering and rainfall.


Figure VI-1 Poles in the rainfall runoff collection tank.

The water from the tank was collected periodically by draining all of the water collected in the bottom of the tank and these samples were then analyzed for copper, zinc or arsenic by inductively coupled plasma spectroscopy. The data were arrayed by date of collection, total rainfall, and days between rainfall events (Figures VI-2-VI-5).

Exposure began in the middle of the rainy season (December, 2007). Arsenic levels were below detection limits for the duration of the trial. Both zinc and copper levels were initially high, but then fell sharply for the remainder of the first winter (Figure VI-2). Copper concentrations in two of the early collections were between 75 and 90 ppm, but most were between 15 and 50 ppm. Zinc levels were also elevated at the same two collection points. Zinc and copper are believed to co-precipitate in ACZA treated wood as the ammonia dissipates. The relationship between copper and zinc migration supports that premise (Figure VI-3). After a 2 ½ month dry spell in the summer, zinc and copper levels were again high with the first rain and then declined over the winter. The first rain following the next seasonal dry spell resulted in a similar, but smaller spike in metal concentrations. Zinc levels remained somewhat elevated throughout the following winter, but copper levels fell to below 10 ppm. Metal levels declined further between Fall 2009 and Spring 2010, and there was no spike in metal levels in water from the first rainfall. These results suggest that any migration of metal to the surface during drying at the end of the rainy season was limited to the period shortly after installation.

There was a slight correlation between total volume of rainfall and metal concentrations (Figure VI-4), but it seems more likely that the high values in low total volumes were caused by the time of year the samples were taken. Summer rainfall tends to be brief, and a large percentage is absorbed by the wood. This may result in much higher metal concentrations from summer rain. A second factor might be degree of drying. While some drying occurs between rainfalls during the winter, the wood dries to a much greater extent during the summer. As a

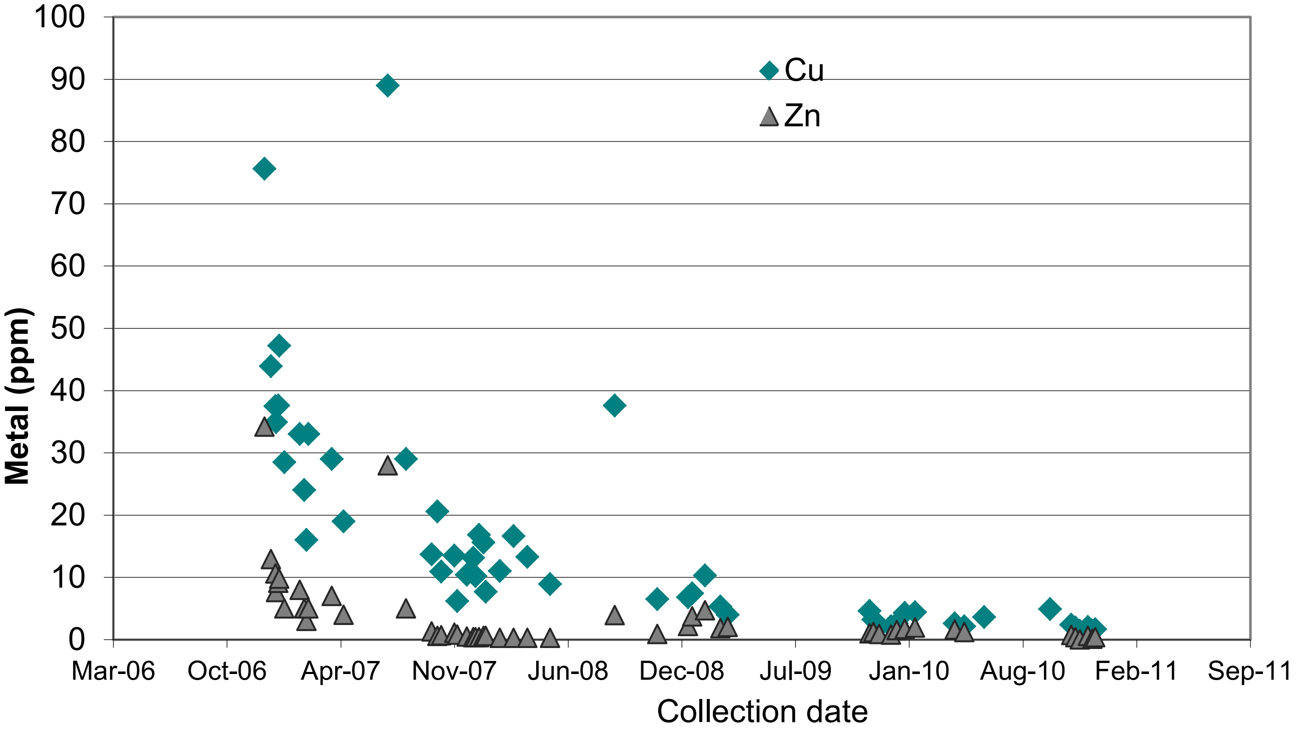

Figure VI-2. Copper and zinc levels in rainwater runoff from ACZA treated Douglas-fir poles exposed outdoors over a 4 year period in western Oregon as a function of rainfall date.

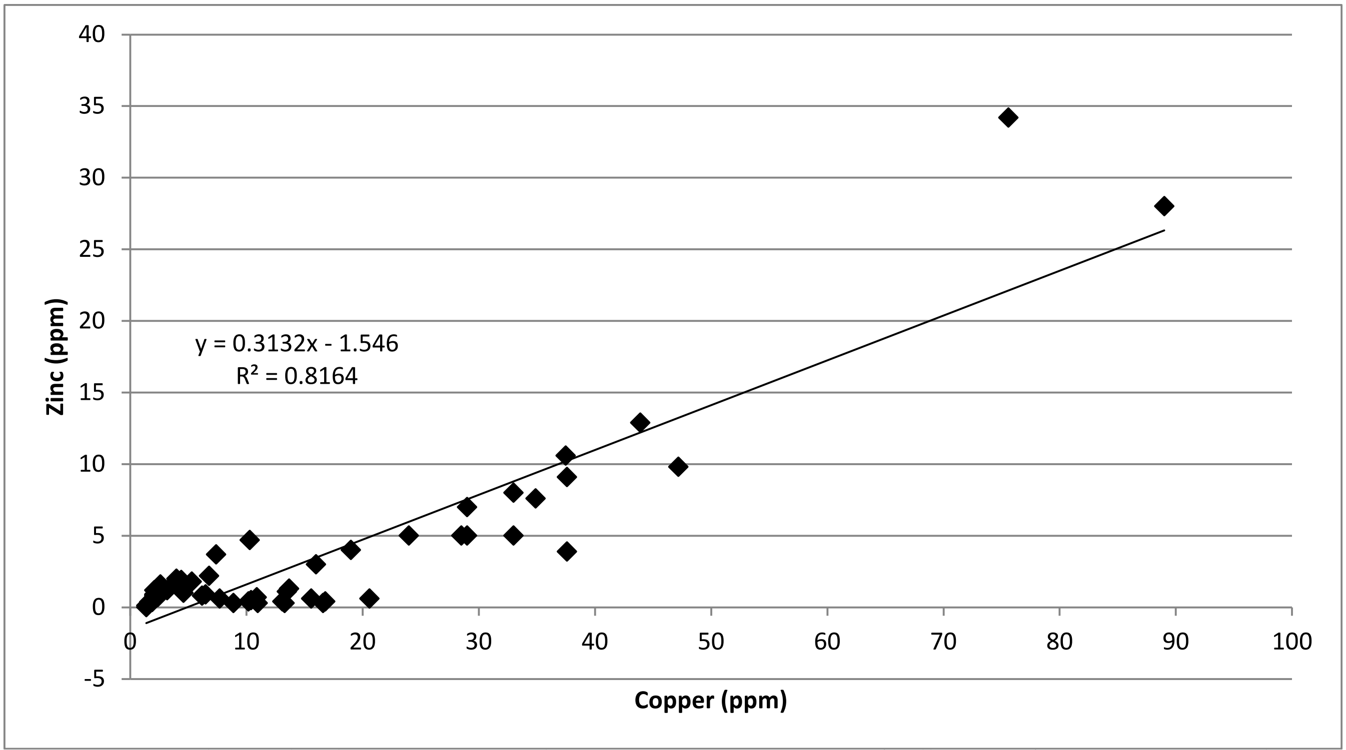

Figure VI-3. Relationship between zinc and copper in rainwater runoff collections from ACZA treated Douglas-fir poles exposed outdoors over a 4 year period in western Oregon.

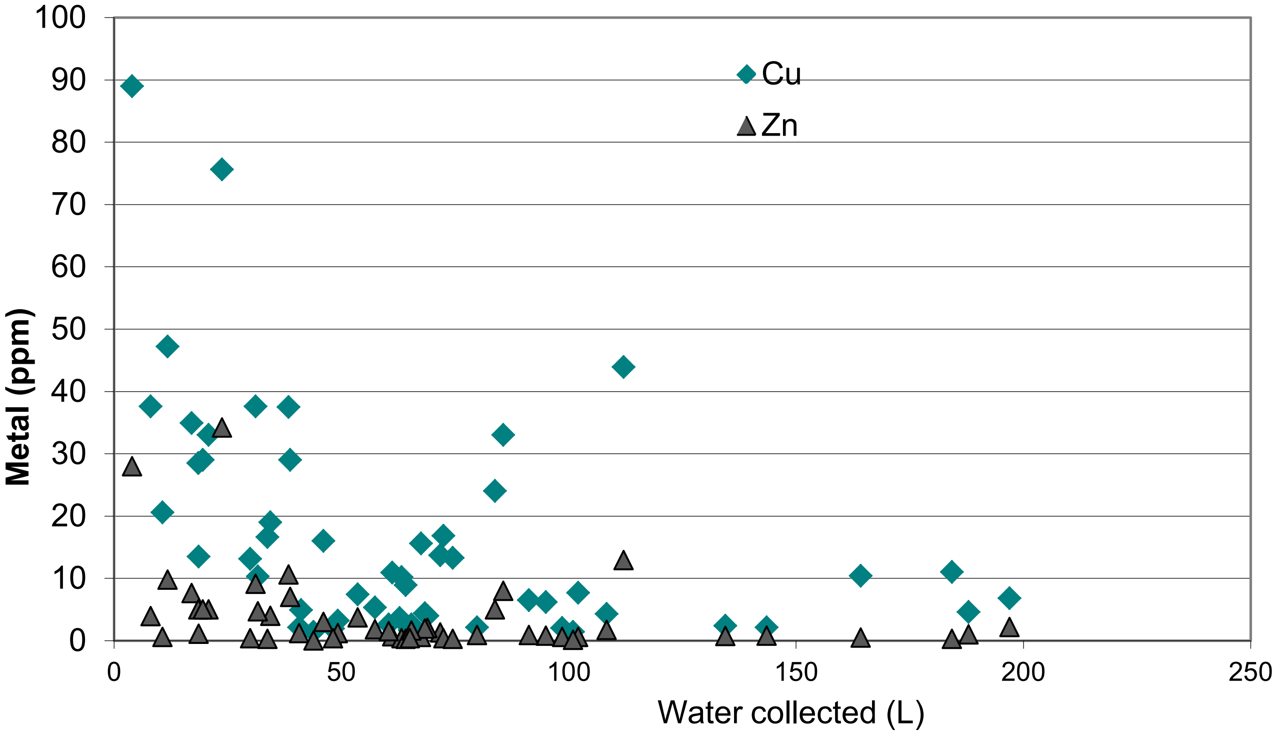

Figure VI-4. Copper and zinc levels in rainwater runoff from ACZA treated Douglas-fir poles exposed outdoors over a 4 year period in western Oregon as a function of rainfall volume.

result, any moisture moving to the surface that carries metals is likely to deposit these elements at or near the surface where they will be available during the next rain event.

The lack of correlation between the number of days between collections and metal concentrations (Figure VI-5) can also be explained by looking at sampling season. Except for the zero samples (the first sample time), collections after dry spells tended to contain higher metal concentrations. The most notable exception to this was a sample after a 75 day interval which was low in both copper and zinc. This sample was taken in November and the previous sample in August had the highest level of copper and the second highest level of zinc. It is likely that any surface accumulation of metals from the summer had washed off in August and there had been little additional accumulation during the fall.

Overall metal concentrations in the runoff steadily declined with increasing exposure. For copper, concentrations in the runoff were approximately 30, 17, 7 and 3 mg/l after 1, 2, 3, and 4 years of exposure, respectively. Zinc levels in the same runoff were 7, 1, 2, and 1 mg/l for the same time periods.

The results indicate that water striking the poles disolves a given amount of chemical, which appears to be independent of rainfall variables. As with penta, this suggests that it will be relatively easy to predict the rates of metal loss based upon exposed surface area. This creates the potential for creating relatively simple management tools for mitigating any possible risks associated with storage of ACZA treated poles. For example, it might be possible to examine the total surface area of wood exposed to initial rainfall to predict total potential runoff. This value could then be coupled with the upper concentration of zinc or copper in the water

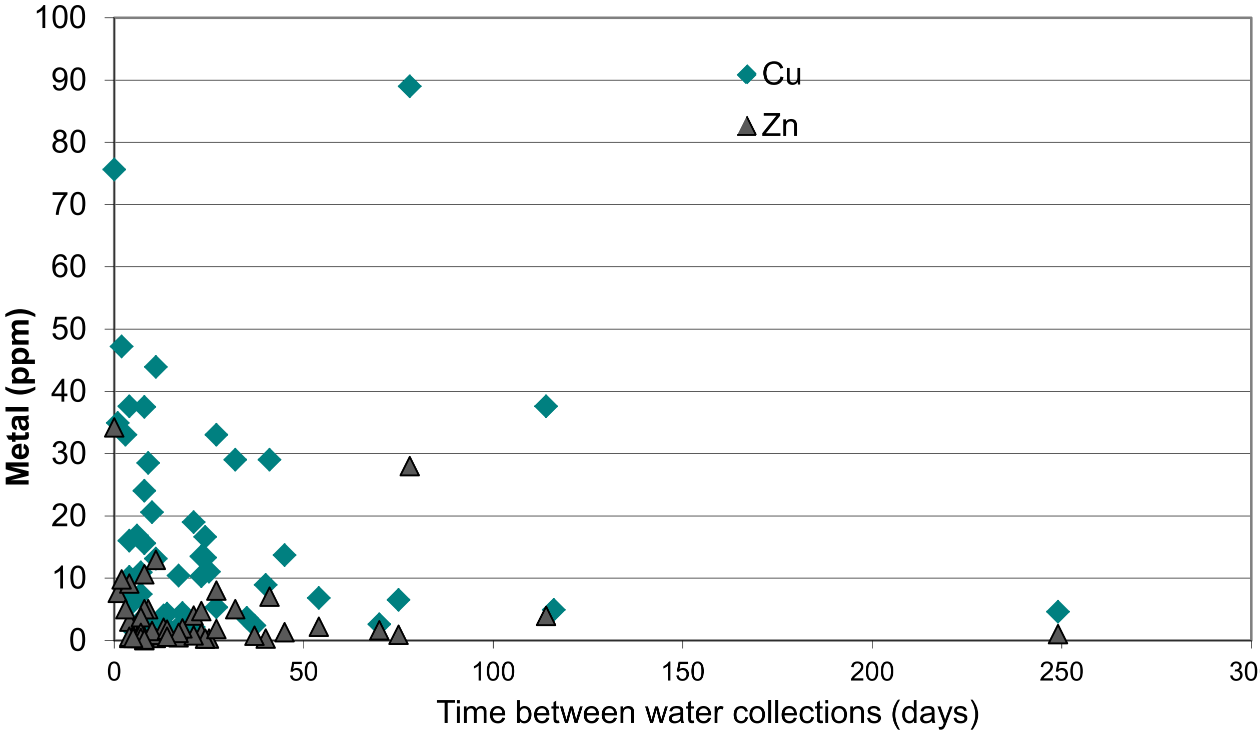

Figure VI-5. Copper and zinc levels in rainwater runoff from ACZA treated Douglas-fir poles exposed outdoors over a 4 year period in western Oregon as a function of days between rainfall events.

to predict the total amount of metal released at a given site. This information would allow planners to determine the feasibility of using a given site to store poles as well as when mitigation might be necessary.

B. 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.

There were a limited number of collections from the copper naphthenate treated poles. Copper levels in the runoff ranged from 3 to 11 ppm (Figure VI-6). The lowest copper level was found in the first water collection, while the 4th and 5th collections contained the highest levels. Copper concentrations in the runoff were still 6 ppm at the end of the rainy season. These results differ slightly from those found with penta or ACZA in that the copper levels have remained low, but relatively similar over the 5 month exposure period.

The small number of water collections made it difficult to determine the relationship between copper levels in the runoff and the total amount of rainfall collected per event although the lowest copper concentration occurred with the highest collection volume (Figure VI-7). Further collections will be necessary to determine if total rainfall affects copper concentration. The same was true of the relationship between copper concentration and time between rainfall events (Figure VI-8). We will continue to collect runoff from these poles over the coming rainy season to determine if copper migration from copper naphthenate treated wood is similar to the patterns observed with penta or ACZA treated poles

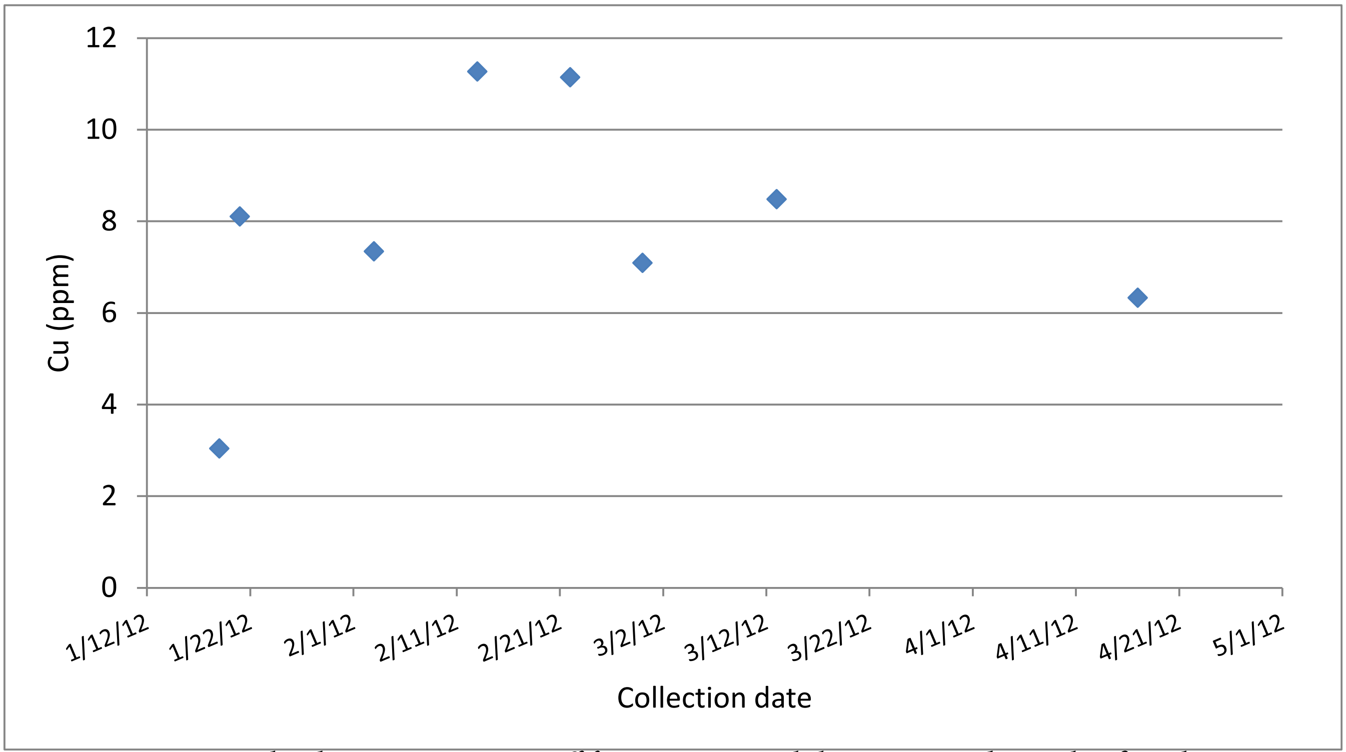

Figure VI-6. Copper levels in rainwater runoff from copper naphthenate treated Douglas-fir pole sections exposed outdoors in western Oregon as a function of rainfall date.

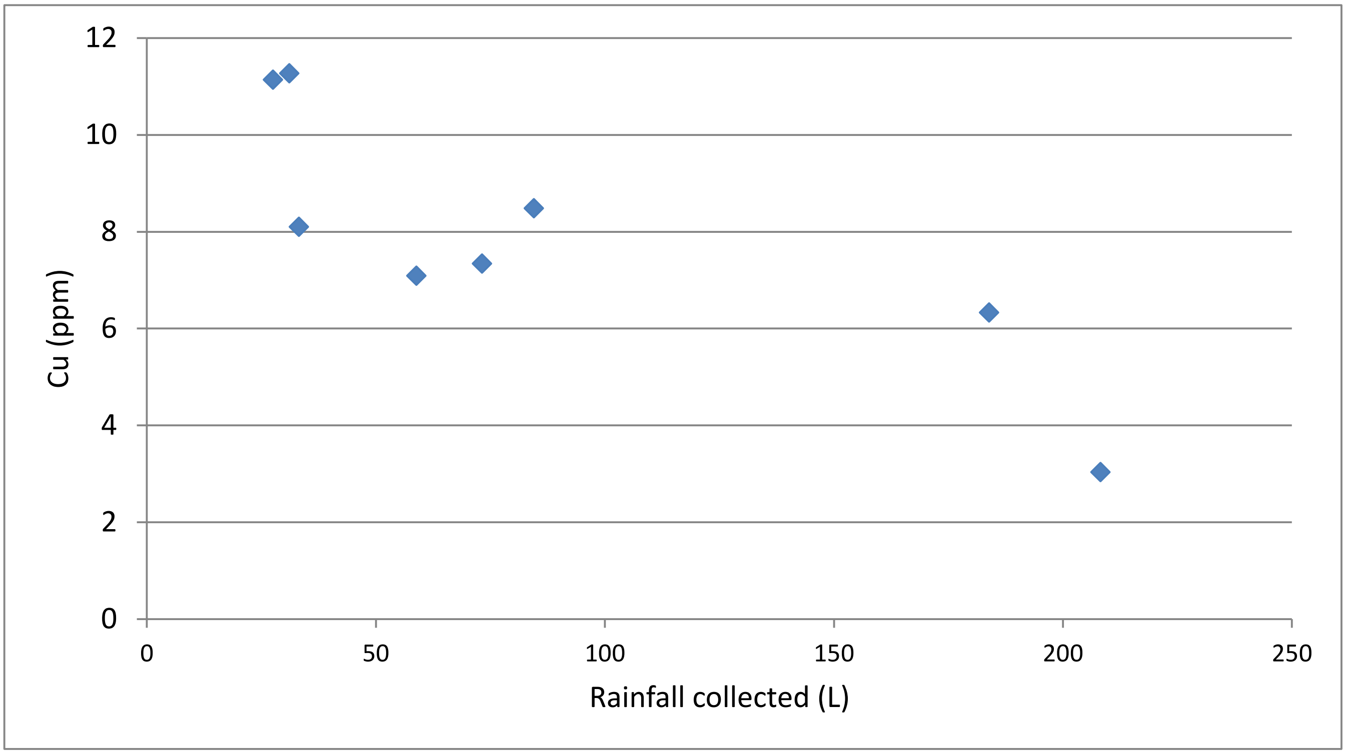

Figure VI-7. Copper levels in rainwater runoff from copper naphthenate treated Douglas-fir pole sections exposed outdoors in western Oregon as a function of total rainfall per collection.

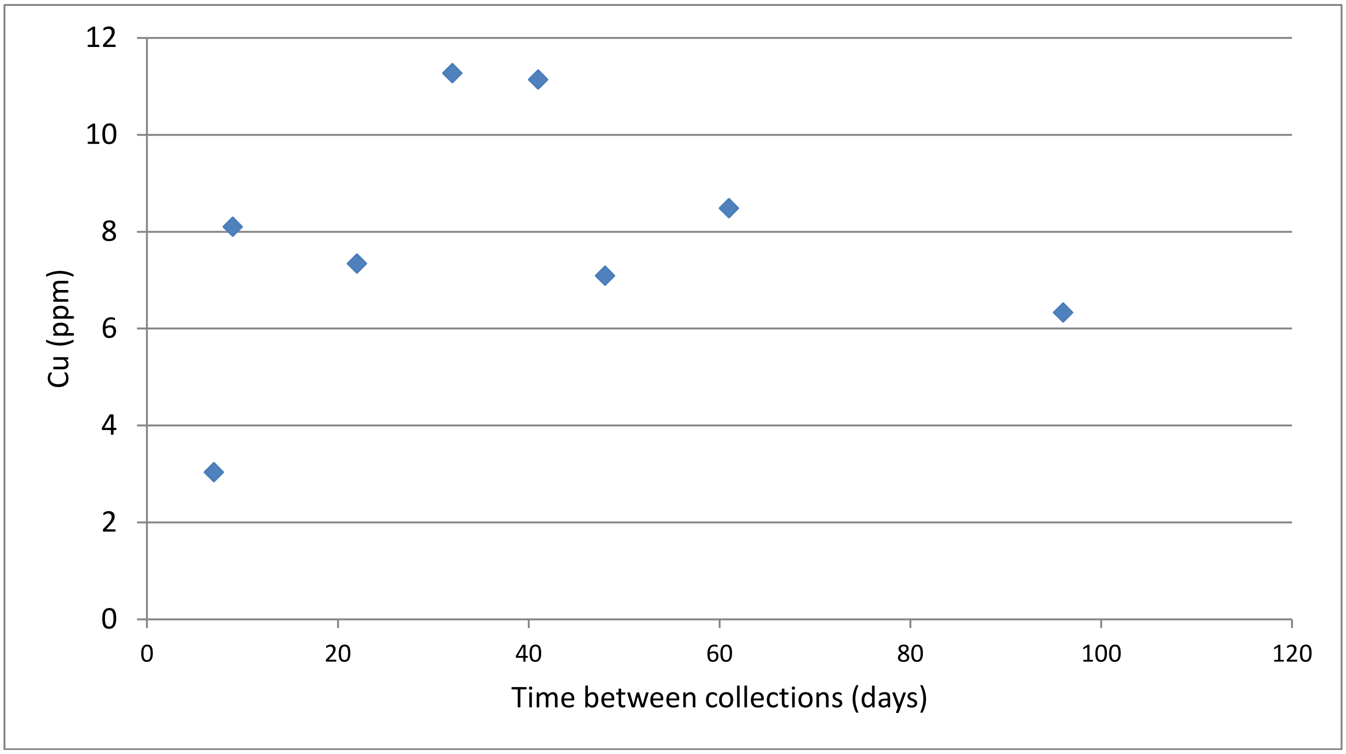

Figure VI-8. Copper levels in rainwater runoff from copper naphthenate treated Douglas-fir pole sections exposed outdoors in western Oregon as a function of days between rainfall collections.

APPENDIX I

INDEX OF PROJECTS UNDER OBJECTIVE I

Title	Year started	Treatments	Location	Dates reported
Potential Substitutes for Copper Naphthenate as a Dazomet Accelerant	2011	Dazomet	lab	2011
MITC Content of Residual Dazomet in Treatment Holes	2010	Dazomet	Corvallis, OR & AZ	2011-10
Ability of Internal Remedial Preservative Systems to Migrate into Distribution Poles in an Arid Climate	2010	Dazomet, MITC, metam sodium, boron rods	UT	2011-10
Effects of Remedial Internal Treatments on Drywood Termites	2010	MITC	lab	2011-10
The toxic threshold of MITC	2010	MITC	lab	2010
Full Scale Field Trial of All Internal Remedial Treatments	2008	Dazomet (5 products), MITC, metan sodium (3 products), chloropicrin, boron rods, fluoride rods (2 products)	Corvallis, OR	2011-08
Performance of dazomet in tube and granular formulations	2006	Dazomet	Corvallis, OR	2011, 2009-06
Effect of Wood Moisture Content on Boron Movement Through Douglas-fir Heartwood	2006	fused borate rods	lab	2008-06
Effect of voids on movement of remedial treatments in above ground locations of Douglas-fir poles	2002	fused borate rods, sodium fluoride rods, copper/boron rods, Basamid rods	Salem, OR	2008, 2003-02
Release rates of chloropicrin from controlled release ampules exposed in utility poles	2002	Chloropicrin	10 states	2003-02
Residual MITC in MITC-FUME ampules in Douglas-fir transmission poles in eastern and western Washington	2002	MITC-FUME	WA	2002
Resisual MITC in Douglas-fir posts treated with MITC-FUME	2002	MITC-FUME	Fort Vancouver, WA	2002
Performance of a copper amended boron rod	2001	copper/boron rods	Corvallis, OR	2011-10, 2007, 2005-03
Performance of basamid in rod or powdered formulations	2000	Basamid	Corvallis, OR	2010, 2008-07, 2005, 2003-01
Develop estimated thresholds for fumigants	2000	MITC	lab	2000
Development of threshold values for sodium fluoride as an internal remedial treatment	1998	sodium fluoride	lab	2003, 2000-1999
Treatment of Douglas-fir transmission poles with basamid and copper	1997	Basamid/CuNaph	Corvallis, OR	2009, 2007, 2005, 2003-1999
Development of threshold values for boron in Douglas-fir	1997	Timbor	lab	2003, 2000, 1998
Distribution of MITC in Douglas-fir and ponderosa pine poles treated with metam sodium	1996	Metam sodium	San Jose, CA	1999-97
Effect of copper napththenate on release of MITC from basamid	1996	Basamid and copper napthenate	lab	1997
Effect of selected clay materials on release of MITC from basamid	1996	Basamid	lab	1997

Appendix I, continued.

Title	Year started	Treatments	Location	Dates reported
Ability of sodium fluoride rods to move through Douglas-fir poles	1995	sodium fluoride rods	Corvallis, OR	2010,2007, 2005, 2003, 2001-1997, 1995
Effect of glycol and moisture content on diffusion of boron from fused boron rods	1995	fused borate rods, Boracol, Boracare, Timbor	lab	1997-96
Residual Boron Levels in CCA Treated Douglas-fir Poles 12 Years After Application of Fused Borate Rods Above Ground	1994	fused borate rods	NY	2006
Evaluation of 40% metam sodium in small block trials	1994	Metam sodium	lab	1995
Develop models which predict fumigant movement through Douglas-fir poles	1994	MITC, Chloropicrin	lab	1995
Performance of a fluoride/boron rod in laboratory trials	1994	fluoride/boron rods	lab	1995
Distribution of chloropicrin in Douglas-fir poles 1-7 years after remedial treatment	1994	Chloropicrin	Willamette Valley, OR	1994
Decomposition of Basamid in Douglas-fir heartwood: Laboratory studies of a potential wood fumigant	1994	Basamid	lab	1994
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, 2007, 2005, 2003, 2001-1999, 1996-94
Evaluation of a sodium fluoride/boron rod for internal treatment of Douglas-fir poles	1993	sodium fluoride/boron rods	Corvallis, OR	2009-08, 2005-04, 2001-1995, 1993
Basaimd treatment of Douglas-fir transmission poles HWY 99	1993	Basamid/CuSO4	Corvallis, OR	2008, 2005, 2003, 2001, 1999-94
Performance of fused boron rods in above ground exposures in Douglas-fir pole stubs	1993	fused borate rods	Corvallis, OR	2008, 2005, 2003, 1999, 1997, 1995
Performance of solid metham sodium/basamid mixtures for controlling wood decay fungi	1993	Metam sodium and basamid	lab	1995, 1993
Fungitoxicity of mixtures of MITC and carbon disulfide	1993	MITC	lab	1994-93
Evaluation of a copper naphthenate/boron paste for internal treatment of Douglas-fir posts	1992	copper naphthenate/boron paste	Corvallis, OR	2004, 2000, 1998, 1995, 1993-92
Evaluation of a gelled metham sodium formulation in Douglas-fir pole sections	1992	Metam sodium	Corvallis, OR	1995-93
Effect of selected additives on the decompostion of Basamid in Douglas-fir heartwood	1992	Basamid	lab	1993-92
Effect of wood species on decomposition efficiency of metham sodium	1992	Metam sodium	lab	1992
Distribution of MITC in Douglas-fir timbers following metham sodium treatment	1990	Metam sodium	Marion Co, OR	2002-01, 1998-97, 1994-92
Effectiveness of gelled NaMDC against decay fungi established in Douglas-fir heartwood blocks	1990	NaMDC (Vapam)	lab	1995, 1992-91
Steady state diffusipon of chloropicrin through Douglas-fir under controlled temperature and moisture conditions	1990	Chloropicrin	lab	1991
Toxicity of fused borate rods to decay fungi in Douglas-fir heartwood	1990	fused borate rods	lab	1991

Appendix I, continued.

Title	Year started	Treatments	Location	Dates reported
Ability of fused borate rods to move through Douglas-fir heartwood	1989	fused borate rods	Corvallis, OR, Hilo, HI	2003, 2001, 1996-94, 1992, 1990
Treatment of New Your State Electic and Gas poles with fused borate rods	1989	fused borate rods	Owego, NY	1999, 1995, 1992, 1989
Treatment of Douglas-fir and poderosa pine poles in California with MITC-FUME	1989	MITC-FUME	Half Moon Bay and Belmont, CA	1997, 1995-94
Effect of selected additives on the decompostion of Basamid in Douglas-fir pole sections	1989	Basamid	Corvallis, OR	1996-95, 1993-91
Development of a three-dimensional model which simulates binding and diffusion of MITC through Douglas-fir poles	1989	MITC	lab	1994-90
Optimizing MITC production from NaMDC	1989	NaMDC (Vapam)	lab	1991-90
Evaluation of MITC-FUME in douglas-fir and southern yeallow pine poles (relaese rates)	1988	MITC-FUME	lab	2008-89
Evaluation of MITC-FUME in Douglas-fir and southern yellow pine poles	1988	MITC-FUME	Corvallis, OR	1999, 1996-94, 1992-89
Evaluation of Mylone (Basamid) in Douglas-fir poles sections	1988	Mylone	Corvallis, OR	1989
The methyldithiocarbamate anion form Vapam and its derivatives	1988	Vapam	lab	1989
Effect of moisture content of Douglas-fir heartwood on diffusion of boron from fused borate rods	1988	fused borate rods	lab	1989
Ability of fused borate rods to prevent fungal infestaton in Douglas-fir poles	1988	fused borate rods	Corvallis, OR, Hilo, HI, Charlotte, NC	1989
Preliminary testing of the ability of Dazomet to decompose to produce MITC in Douglas-fir heartwood	1987	Dazomet	Corvallis, OR (posts)	1998, 1993, 1991-90
Development of controlled release fumigant pellets	1987	NaMDC (Vapam), Mylone	lab	1990, 1989-1988
Ability of fused borate rods to eliminate fungi from Douglas-fir heartwood	1987	fused borate rods	lab	1989-1988
Preliminary modeling of MITC movement throught Douglas-fir heartwood	1987	MITC	lab	1988
Effect of voids on fumigant movement and effectiveness	1986	Vapam, Chloropicrin	Corvallis, OR	1998, 1995, 1993-1987
Emmission of MITC, CS2 and COS from Vapam or MITC treated Douglas-fir heartwood	1986	MITC, Vapam	lab	1989-1987
Decomposition of NaMDC in the presence of wood, cellulose or glass	1986	NaMDC (Vapam)	lab	1987-86
Effect of pH on Mylone treatment of Douglas-fir poles	1986	Mylone	Corvallis, OR	1987
Pre-installation fumigation of Douglas-fir transmission poles	1986	MITC	Central Lincoln PUD, OR	1987
Development of a trapping procedure or determining MITC emmission	1986	MITC	lab	1987
Effect of wood moisture content on the fungitoxicity of MITC in Douglas-fir heartwood	1986	MITC	lab	1987

Appendix I, continued.

Title	Year started	Treatments	Location	Dates reported
Pre-installation fumigation of Douglas-fir transmission poles	1985	MITC	Coos Bay, OR	2004, 1997, 1990, 1988, 1986
Preliminary evaluation of Tridipam and Mylone as Wood Fumigants	1985	Tridipam, Mylone	lab	1987-86
Evaluate the degradation of sodium N-methyldithiocarbamate into methylisothiocyanate and related compounds	1985	NaMDC (Vapam)	lab	1987-86
South Beach marina pile top test site	1985	MITC, chloropicrin, Vorlex, ABF, NaF, FCAP, boron rods, Timbor, Pentachlorophenol, Pole Topper, Tie-Guard rods, Patox discs	Newport, OR	1986
Sensitivity of the closed tube bioassay to methylisothiocyanate in wood	1985	MITC	lab	1986
Effect of MITC on corrosion of galvanized hardware in wood	1984	MITC	lab	1987-85
Evaluate the effectiveness of Mylone for controlling internal decay and improve the rate of degredation into fungitoxic compounds	1984	Mylone	lab	1985
Methylisothiocyante movement through preservative treated wood	1984	MITC	lab	1984
Treatment of through-bored Douglas fir poles with gelatin encapsulated MITC or chloropicrin	1983	MITC, chloropicrin	Cottage Grove, OR	1997, 1992, 1990, 1986, 1984-83
Treatment of Douglas-fir poles with encapsulated MITC (moisture content)	1983	MITC	Salam-Gresham	1993, 1991-1984
New York field test with encapsulated MITC	1982	MITC, Vapam	Hamburg, NY	1993-92, 1989-82
Methylisothiocyanate treatment of Douglas-fir pole sections	1982	MITC (encapsulated and non), Vapam, Vorlex	lab	1984-83
Microdistribution and retention of chloropicrin in sound and decayed wood	1981	Chloropicrin	lab	1983-81
Preparation and evaluation of methylisothiocyanate in laboratory wood block tests	1981	MITC	lab	1983
Investigate the influence of environmental factors on effectiveness and persistence of fumigants	1980	MITC	lab	1983-81
Prepare and evaluate encapsulated fumigants in laboratory wood block tests	1980	MITC, NH_4HF_2	lab	1982-81
Evaluate new fumigants in the laboratory	1980	NH_4HF_2, NH_4F, FCAP, Formaldehyde, Nitroethane, Mylone, pelletized MITC, gelatin encapsulated MITC	lab	1985-84, 1981
Douglas-fir poles fumigant treated in 1977	1977	MITC, Allyl alcohol, Vorlex		1993-81
Fumigant protection of untreated Douglas-fir posts	1977	MITC, chloropicrin, Vapam	Corvallis, OR	1987
Douglas-fir marine piles treated with fumigants	1974	Vapam. Vorlex, Chloropicrin	Florence, OR	1988-85, 1983
Efectivness of externally applied pastes and internally applied chemicals for controlling internal decay of Douglas-fir	1973	Osmplastic, Hollowheart	Oregon City, OR	1985

Appendix I, continued.

Title	Year started	Treatments	Location	Dates reported
Summer vs. winter treatment of Douglas-fir poles with fumigants	1973	Vapam. Vorlex, Chloropicrin		1983
Douglas-fir poles treated with different quantities of fumigant	1973	Vapam. Vorlex, Chloropicrin		1983
Douglas-fir poles fumigant treated in 1969	1969	Vapam. Vorlex, Chloropicrin	Corvallis, OR	1990-81