Oregon State University
Utility Pole Research Cooperative

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Department of Wood Science
& Engineering

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http://www.cof.orst.edu/coops/utilpole/

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ISK Biocides Inc.

Protective Packaging Ltd.

Osmose Utilities Services, Inc.

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Executive Summary

The Utility Pole Research Cooperative has continued to grow over the past year, adding two new Utility members (Fortis Alberta and American Transmission Company), as well as two new Associate members, Protective Packaging and the Penta Council. We welcome your support and look forward to your involvement in the research program.

The Coop currently operates under six Objectives. Objective I seeks to develop improved internal remedial treatments. We continue to assess a number of internal fumigants and diffusible systems. Dazomet continues to perform well in a number of field trials. Field trials with a dazomet tube system indicate that the tube does not appear to interfere with either breakdown or movement of this chemical into poles. Studies to better understand the lack of a dosage effect with boron and fluoride rods systems were not conclusive and we are still unable to explain why increasing dosages of these rods does not always result in proportionally higher chemical levels in the wood.

Field trials to assess the effectiveness of preservative-coated bolts to protect field drilled bolt holes are now in their 6th year. While chemical movement from the rods has been limited, the treated bolts do result in a well protected zone around the bolt.

Under Objective III, efforts continue to add through-boring to the ANSI standards. A data packet has been submitted and a proposed Appendix in ASNI 05.1 will be submitted shortly for review. The goal will be to present this information at the Spring 2008 meeting. Assessments of barrier systems for poles are continuing. We have completed our 2 year evaluation of BioTrans and UPC coatings on cedar poles in water or soil. These poles have now been installed at our field test site for further monitoring. In addition, we have completed a field assessment of moisture content and condition of BioTrans wrapped western redcedar poles in the Seattle City Light System. The results showed that the outer surfaces of the poles were wet, but wood further in from the surface was dry. Further assessments of field exposed poles are planned.

An assessment of internal defects in above ground locations in Douglas-fir utility poles is also underway. Poles in service for 25 years were removed, cut into sections and are being sawn into slabs so that we can delineate defect locations. The slabs will be scanned so that we can create three dimensional images of the defect zones. The resulting data will be used to estimate the extent of damage from woodpeckers, buprestid beetles and dampwood termites. Most interesting was the association between woodpeckers and termites in locations 20 to 40 feet above ground.

Field trials of external preservative pastes and bandages are in their second year in Georgia. The results indicate that all but one of the copper based systems is moving into wood at protective levels, while the boron and fluoride components in the systems are moving more deeply and becoming more uniformly distributed. A laboratory trial intended to help establish realistic threshold levels for mixtures of these systems is underway. The first results on untreated wood established that we could produce substantial soft rot weight losses in 24 weeks, but further trials using mixtures of biocides in blocks has, as yet, failed to produce the desired threshold information. We will continue these evaluations this winter.

Evaluations of copper naphthenate treated western redcedar stakes indicate that wood treated with this chemical continues to perform well in fungus cellar trials. Lower levels of copper naphthenate on previously weathered stakes provided less protection than when freshly harvested (non-weathered) wood was used. These results suggest that it would be better to remove this weathered wood prior to retreatment when utilities are contemplating reuse of poles.

Assessments of preservative migration from pentachlorophenol treated poles have been completed and we are now using the data to predict the amounts of chemical that might move from poles in storage. The assessment predicted that migration from a collection of 15 Class 4 forty foot long poles would generally result in less than 1 ppm in soil 75 to 150 mm beneath poles after a 4 year exposure, except under the highest rainfall levels (1.5 m or 60 inches per year). Reducing the footprint occupied by the stored poles remains the best approach to minimizing overall chemical losses. We are currently examining low cost materials that might be placed beneath poles to capture penta in the runoff where poles must be stored for long periods.

Exposure of ammoniacal copper zinc arsenate (ACZA) treated poles under the same conditions used for the penta trials revealed that copper and zinc both migrated at steady levels from the poles with rainwater. There was no effect of total rainfall or time between rainfall events on metal concentration in the runoff. No arsenic was detected in the runoff; however, we made no effort to concentrate the runoff prior to analysis. The results suggest that ACZA migration, like that of penta, is predictable and can be easily managed in a yard.

Finally, a pole disposal survey was conducted among utilities in the Pacific Northwest revealed that utilities remain concerned about disposal, but most do not experience difficulty disposing of their used poles. Utility replacement rates were about 0.8 % per year, but almost half of these replacements were for line upgrades or road activities. Nearly all utilities operated some type of maintenance and inspection program with most inspecting poles at cycles of 12 years or less. Overall, the respondents were satisfied with the wood in their systems.

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. Early remedial treatments were broadly toxic, volatile chemicals, but changes to formulations and delivery systems have produced more controllable treatments with improved handling characteristics. This shift has resulted in the availability of a variety of internal treatments for arresting fungal attack (Table I-1). The fungitoxicity of some of these treatments are is based upon movement of gases through the wood, while others are 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 for arresting internal decay in North America. Initially, two fumigants were registered for wood, metam sodium (32.1 % sodium n-methyldithiocarbamate) and chloropicrin (96% trichloronitromethane) (Table I-1). Of these, chloropicrin was the most effective, but both systems were prone to spills and carried the risk of worker exposure.

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

Trade Name	Active Ingredient	Conc. (%)	EPA Registration Number	Supplier
TimberFume	trichloronitromethane	96	3008-39	Osmose Utilities Services, Inc.
WoodFume Pol Fume SMDC-FUM-E	sodium n-methyldithiocarbamate	32.1	3008-33 1022-562-50534 1448-85-54471	Osmose Utilities Services, Inc. ISK Biocides Copper Care Wood Preservatives, Inc.
MITC-FUME	methylisothiocyanate	96	69850-1-3008	Osmose Utilities Services, Inc.
Super-Fume UltraFume DuraFume	Tetrahydro-3,5-dimethyl--2H- 1,3,5-thiodiazine-2-thione (dazomet)	98-99	1448-104-54471 7969-162-10465 01448-00104-7-5341	Copper Care Wood Preservatives, Inc. Intec, Inc. Osmose Utilities Services, Inc.
Impel Rods	anhydrous disodium octaborate	100	10465-30	Intec, Inc.
Polesaver Rods	disodium octaborate tetrahydrate/sodium fluoride	58/24	not registered in U.S.	Preschem Pty Ltd.
Flurods	sodium fluoride	98	3008-63	Osmose Utilities Services, Inc.
Cobra-Rods	disodium octaborate tetrahydrate and boric acid/copper hydroxide	97/3	71653-2	Genics Inc.

Utility Pole Research Cooperative (UPRC) research identified two alternatives, solid methylisothiocyanate (MITC) and dazomet. Both chemicals are solid at room temperature which reduces the risk of spills and simplifies cleanup of any spills that do occur. MITC was commercialized as MITC-FUME, while dazomet has been labeled as Super-Fume, UltraFume and Dura-Fume. Important aspects of the development process for these systems have been continued performance evaluation to determine when retreatment is necessary, and identifying any characteristics that might affect performance.

1. Effect of Temperature on Release Rates of MITC from MITC-FUME Ampules

MITC-FUME has been commercially available for over 15 years, first as a glass encapsulated material and later in aluminum ampules. In both cases, the cap was punctured and the tube was inserted, open end down, into the treatment hole. As with any encapsulated material, the time required for the chemical to move from the tubes and into the surrounding wood has important implications on efficacy. As a part of our initial evaluations of MITC-FUME, we established small scale trials to assess the rates of MITC release under varying temperature conditions.

Eighteen non-treated Douglas-fir pole sections (250 mm in diameter by 750 mm long) were obtained either freshly cut or air-seasoned. The objective of using green material was to determine if excess moisture would affect release rate. A single hole (205 mm long by 19 mm in diameter) was drilled at a 45 degree angle near the center of each pole section and a single MITC-FUME ampule containing 29 g of MITC was added to the hole. The holes were plugged with wooden plugs, and then sets of three poles each were stored at 5 C, outdoors at ambient temperatures or at 32 C and 90 % relative humidity. The ampules were periodically removed and weighed to determine the rate of MITC release.

The ampules stored at 5 C continue to retain some chemical (Figure I-1). As noted in previous annual report, few regions of the country would present such consistently low temperatures, but the data do illustrate the potential for MITC to remain in the ampules for many years in cooler sites such as those in more northerly climates or at high elevations.

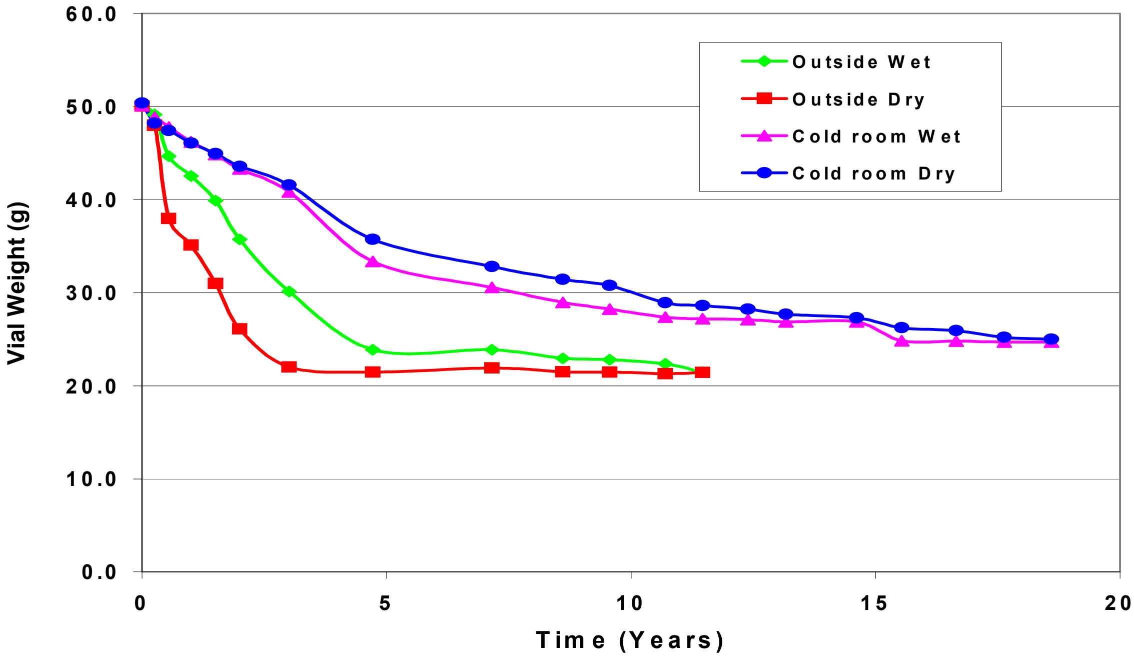


Figure I-1. MITC remaining in glass ampules installed in Douglas-fir pole sections exposed at 5 C, 32 C or ambient outdoor conditions.

2. Performance of Copper Amended Dazomet in Douglas-fir Transmission Poles

The poles treated with dazomet plus copper were not inspected this year, but will be sampled in 2008.

3. Use of Copper Naphthenate to Enhance Release of MITC from Dazomet

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

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

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

Chemical distribution was assessed annually after treatment by removing increment cores from three equidistant points around each pole at sites 0.3, 1.3, and 2.3 m above the groundline. The outer 25 mm of each core was discarded. The next 25 mm, and the 25 mm section closest to the pith (Figure I-2), of each core were placed into vials containing 5 ml of ethyl acetate, extracted for 48 hours at room temperature, and the resulting extracts were analyzed for residual MITC by gas chromatography as previously described. The remainder of each core was then placed on the surface of a 1.5 % malt extract agar petri dish and observed for evidence of fungal growth. Any fungi growing from the cores were examined for characteristics typical of Basidiomycetes, a class of fungi containing many important wood decayers.

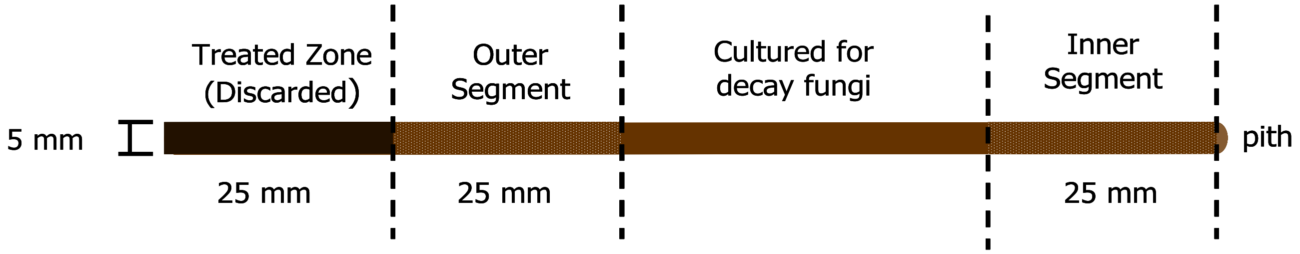


Figure I-2. Representation of increment core showing inner and outer 25 mm segments analyzed for fumigant content.

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. MITC levels in poles receiving nosupplemental treatment reached the threshold level 0.3 m above ground 1 year after treatment (Figure I-3). MITC levels increased slightly over the next 4 years in these poles, but appear to have stabilized 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. Chemical levels at locations above this height were extremely low, suggesting that the treatment effect was confined to a relatively narrow zone around the application point (Table I-2).

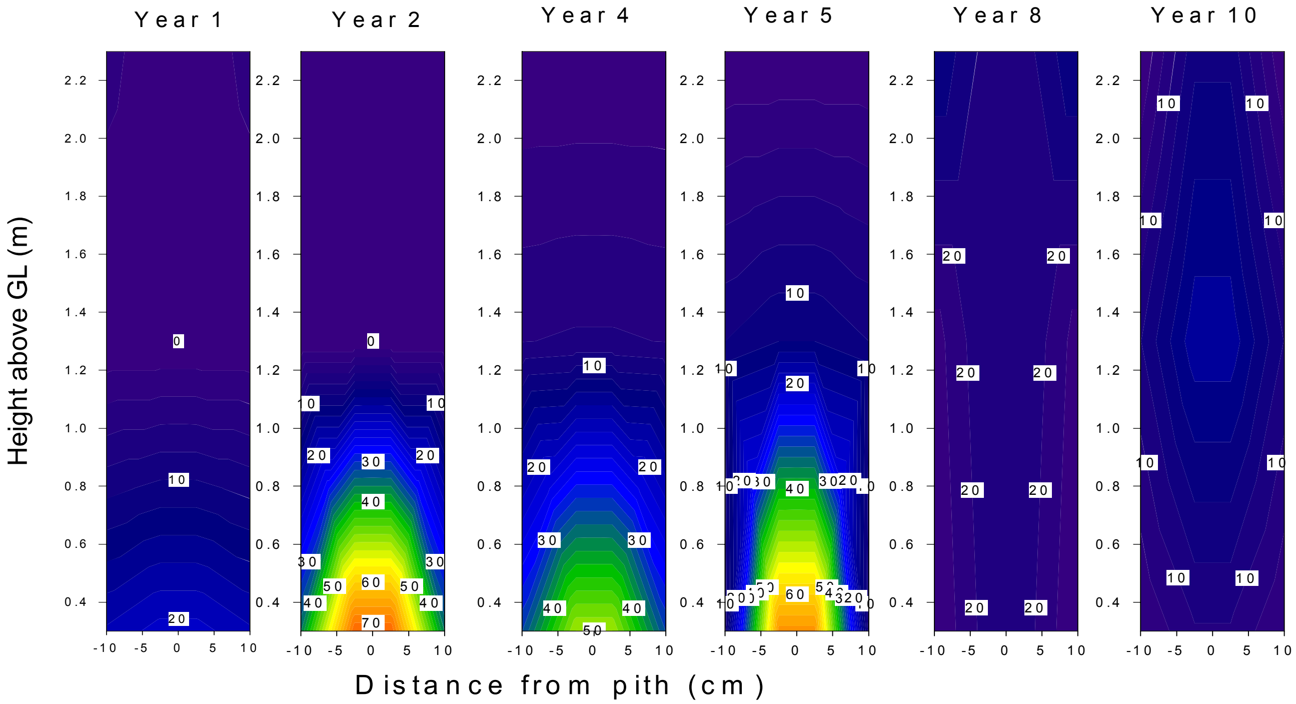


Figure I-3. Distribution of residual MITC in Douglas-fir poles 1 to 10 years after treatment with 200 g of dazomet. Dark blue indicates MITC levels below the threshold. Light blue and all other colors indicate MITC levels above that level.

Table I-2. Residual MITC in Douglas-fir pole sections 1 to 10 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)
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)
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)

[a] Values represent means of nine analyses per position. Figures in parentheses represent one standard deviation. Numbers in bold represent MITC livels above the toxic threshold.

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-4). 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 the initial release rate.

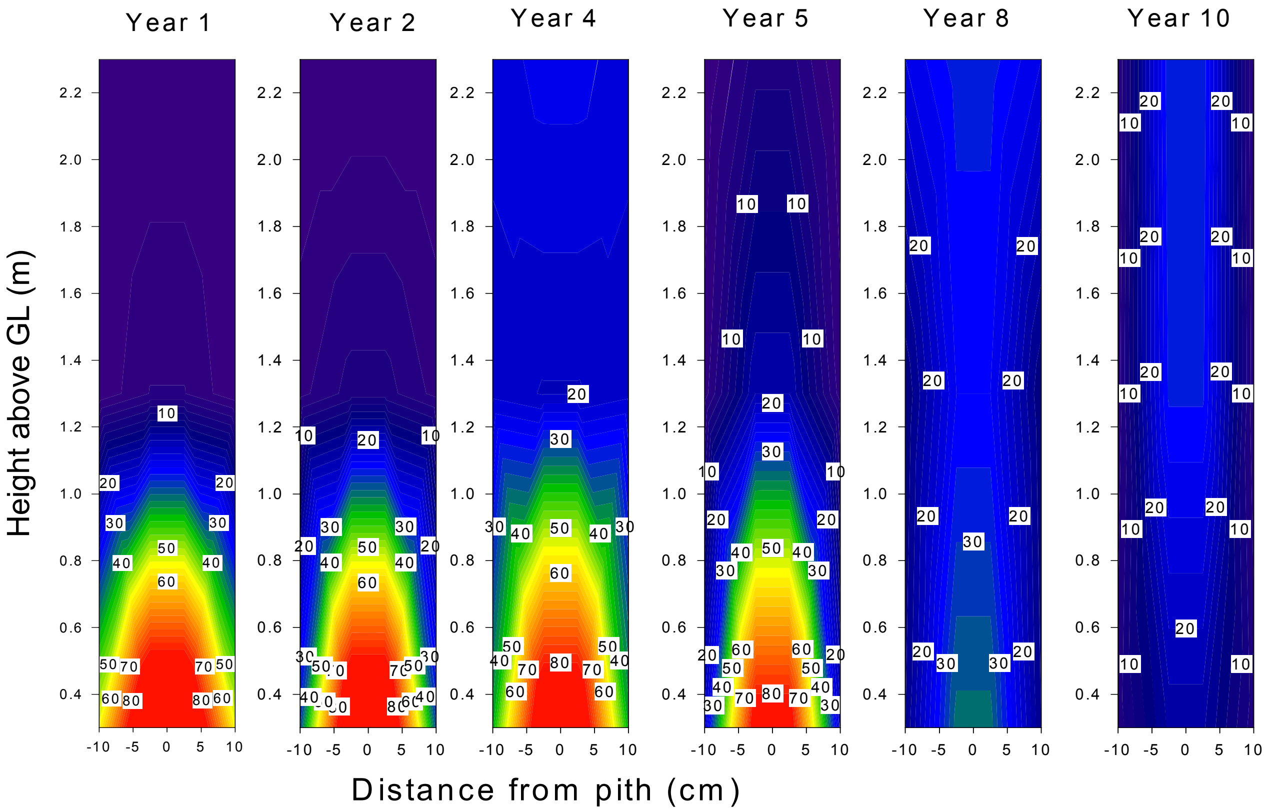


Figure I-4. Distribution of residual MITC in Douglas-fir poles 1 to 10 years after treatment with 200 g of dazomet plus 20 g of copper sulfate. Dark blue indicates MITC levels below the threshold. Light blue and all other colors indicate MITC levels above that level.

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-5). 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 10 year sampling, but were again well above those found with the non-amended treatment.

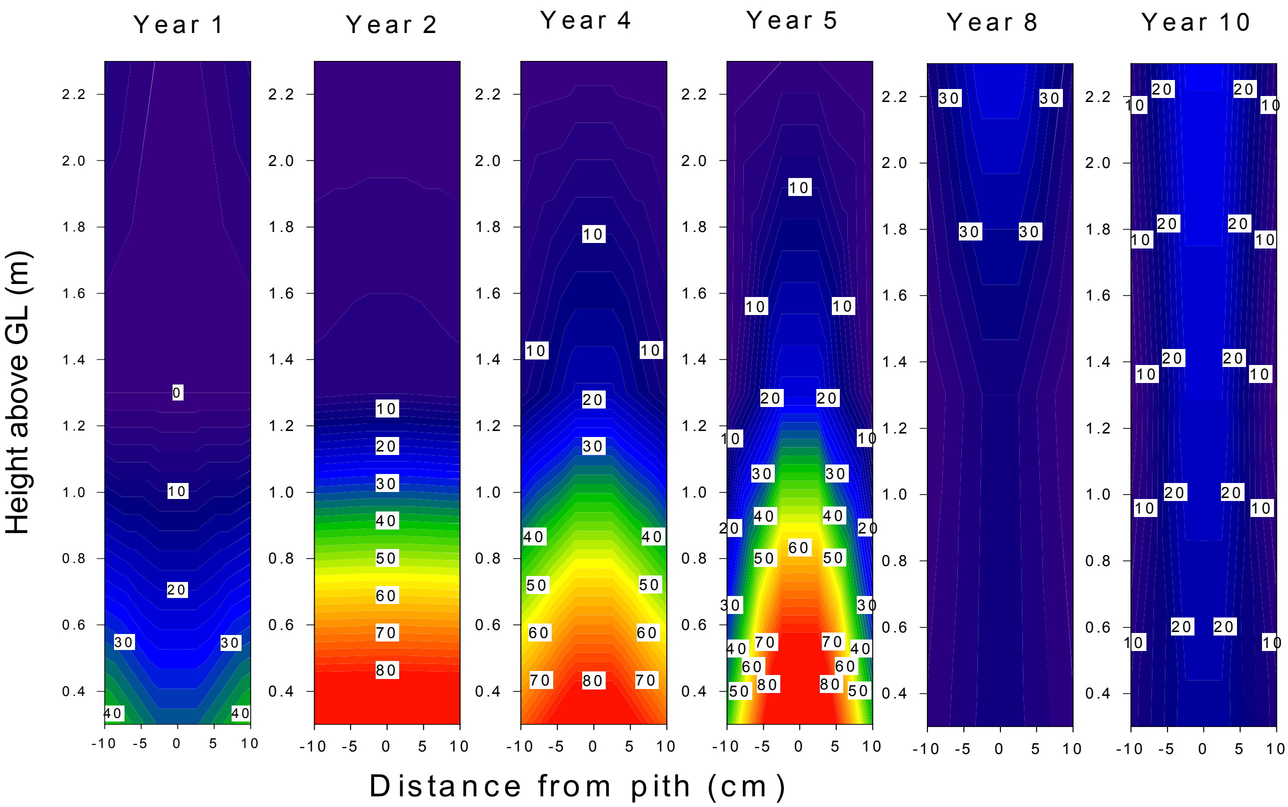


Figure I-5. Distribution of residual MITC in Douglas-fir poles 1 to 10 years after treatment with 200 g of dazomet plus 20 g of copper naphthenate. Dark blue indicates MITC levels below the threshold. Light blue and all other colors indicate MITC levels above that level.

Isolation 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 the poles, but the isolations were sporadic and suggest that isolated fungal colonies are 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. 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 higher dosages. 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.

Table I-3. Percentage of increment cores containing decay and non-decay fungi 1 to 10 years after application of dazomet with or without copper sulfate or copper naphthenate.

Copper Treatment	Year Sampled	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}
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}
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}

[a] Values represent means of decay fungi isolations from nine increment cores per treatment. Superscripts represent average of non-decay fungi isolated from the same cores.

4. 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 rapidly reacts with water and decomposes to produce 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 of dazomet. These rods simplified application, but we wondered whether the decreased wood/chemical contact associated with the rods, might reduce dazomet decomposition, thereby slowing fungal control.

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

The poles were sampled 1 to 7 years after treatment by removing increment cores from equidistant points around each pole at 0.3, 0.8, and 1.3 m above the groundline. The outer, heavily treated zone was discarded, and then the outer and inner 25 mm of each core was removed and placed into 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 gram of wood basis. The remainder of each core was cultured on malt extract agar for the presence of Basidiomycetes, a group of fungi containing many important wood decayers. Other fungi present were classified as non-decay fungi. Although these fungi do not cause wood decay, their role in chemical performance remains unknown.

MITC levels 0.3 m above groundline were all above the 20 ug threshold for protection against fungal attack 1 year after treatment regardless of chemical applied (Table I-4; Figure I-6 to I-11). The addition of

Table I-4. Residual MITC in Douglas-fir pole sections 1 to 7 years after treatment with metam sodium or dazomet in powder or rod form with and without copper naphthenate.

Treatment	Dosage	Supplement	Year sampled	Residual MITC (ug/g wood)[a]											
				0.3 m				0.8 m				1.3 m			
				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	**53**	(49)	**132**	(45)	7	(9)	**25**	(23)	2	(5)	5	(6)
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	**67**	(58)	**211**	(324)	17	(11)	**36**	(18)	2	(4)	11	(10)
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	**35**	(28)	**91**	(63)	14	(13)	**22**	(12)	1	(3)	4	(9)
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	**82**	(51)	**125**	(70)	13	(12)	**36**	(45)	4	(5)	14	(19)
Dazomet Rods (9)	160 g	100 g water	1	**22**	(21)	**29**	(35)	4	(6)	6	(10)	0	(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	**32**	(29)	**71**	(37)	10	(11)	**23**	(16)	1	(3)	3	(5)
Metam 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	(5)	3	(6)	1	(3)	3	(6)	0	0	0	0

[a]Values represent means of fifteen analyses per position. Figures in parentheses represent one standard deviation. Numbers in bold represent MITC levels above the toxic threshold.

copper compounds to the dazomet treatments had little effect on MITC levels in the inner zones 1 year after treatment, but MITC levels appeared to be slightly elevated in the outer zones of poles receiving supplemental copper. MITC levels declined markedly in the outer zones 2 years after treatment, regardless of treatment. The addition of copper produced more variable results in the outer zone, but did appear to enhance MITC levels in the inner zones. MITC levels in the inner zones 3 years after treatment were similar to or slightly higher than those found after 2 years in the copper amended treatments and in the 160 g dazomet treatment. The levels in the other treatments continued to decline. MITC levels in the outer zones increased markedly in most treatments 0.3 m above groundline after 3 years and remain above threshold after 7 years. The reasons for the decline after 2 years are unknown, but it appears that MITC continues to move into the wood near the surface for all treatments.

MITC levels in poles treated with metam sodium were initially high near the groundline, and then fell off sharply (Figure I-6). At present all levels in poles receiving this treatment are below the minimum for fungal attack.

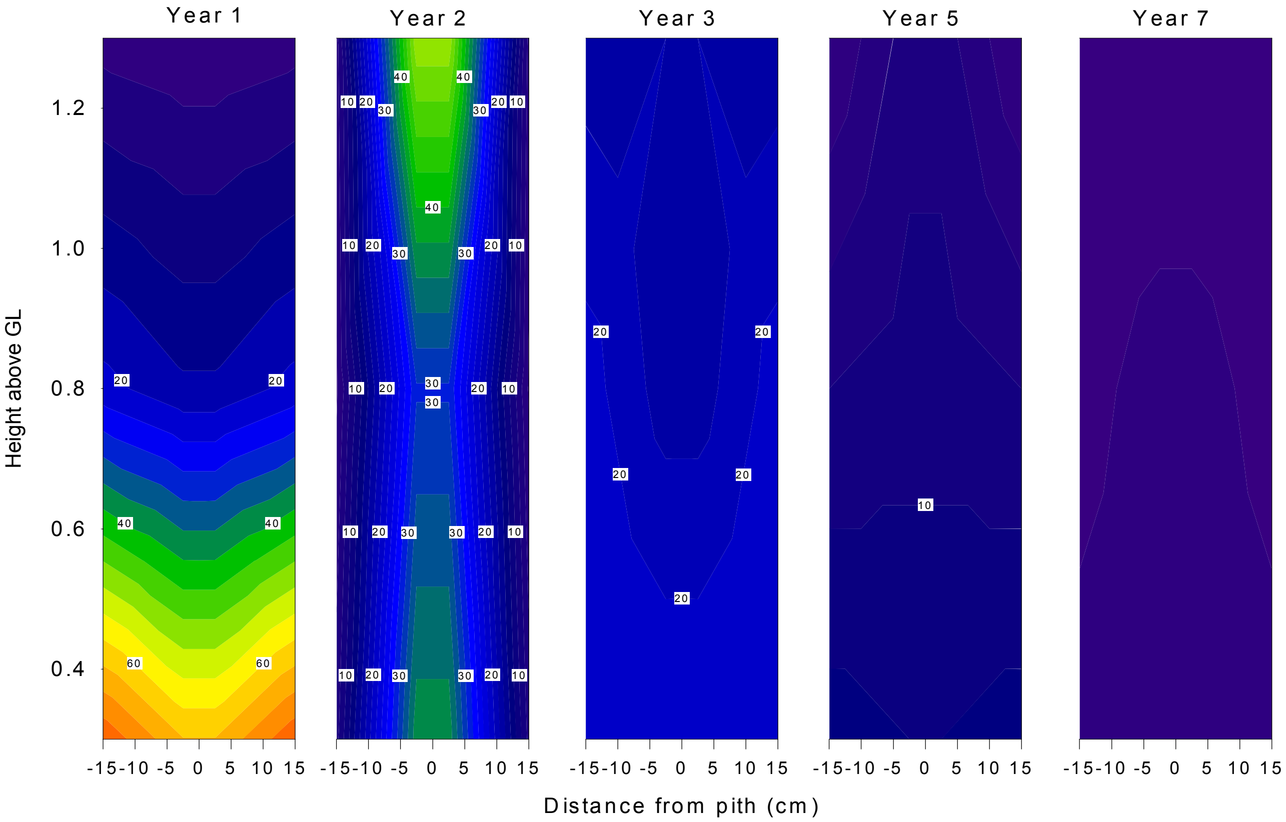


Figure I-6. Residual MITC in Douglas-fir poles 1 to 7 years after treatment with 490 ml of metam sodium. Dark blue indicates MITC levels below the threshold for fungal attack. Light blue and other colors indicate MITC levels above the lethal threshold.

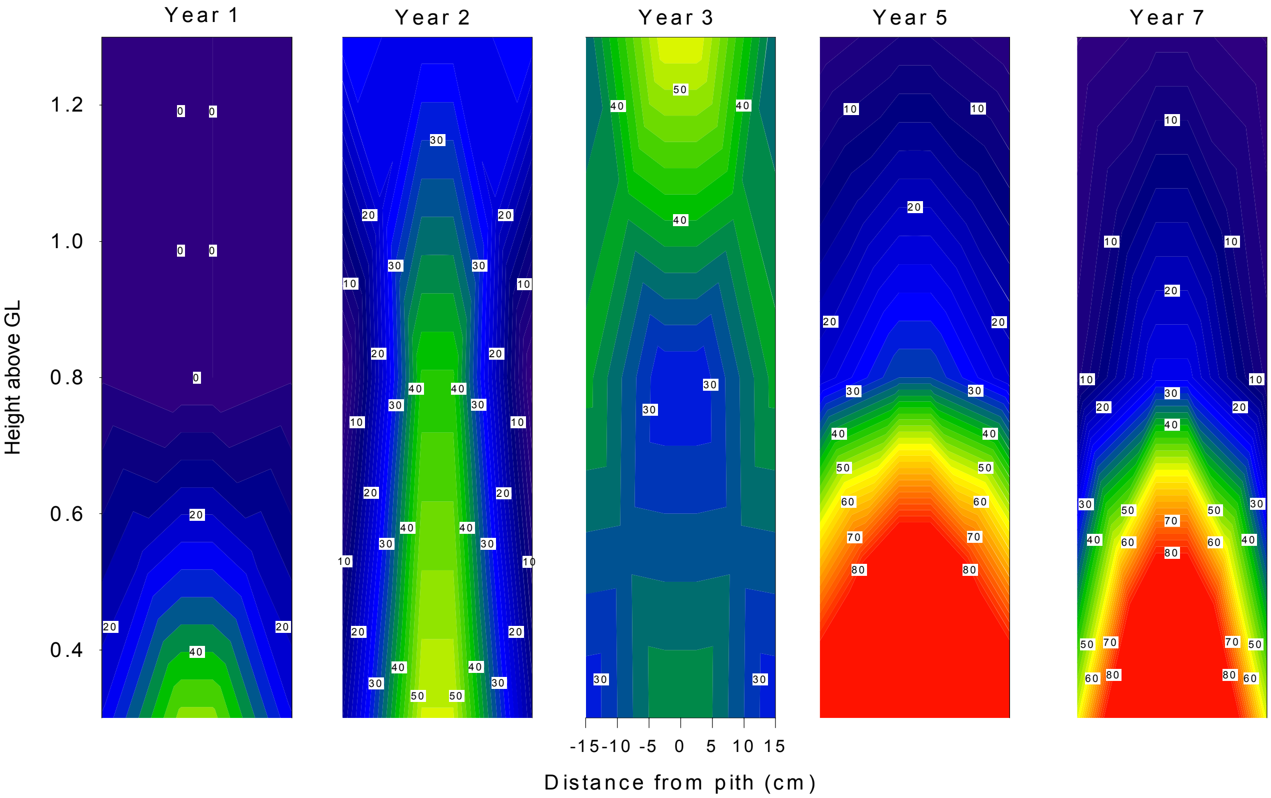


Figure I-7. Residual MITC in Douglas-fir poles 1 to 7 years after treatment with 160 g of powdered dazomet. Dark blue indicates MITC levels below the threshold for fungal attack. Light blue and other colors indicate MITC levels above the lethal threshold.

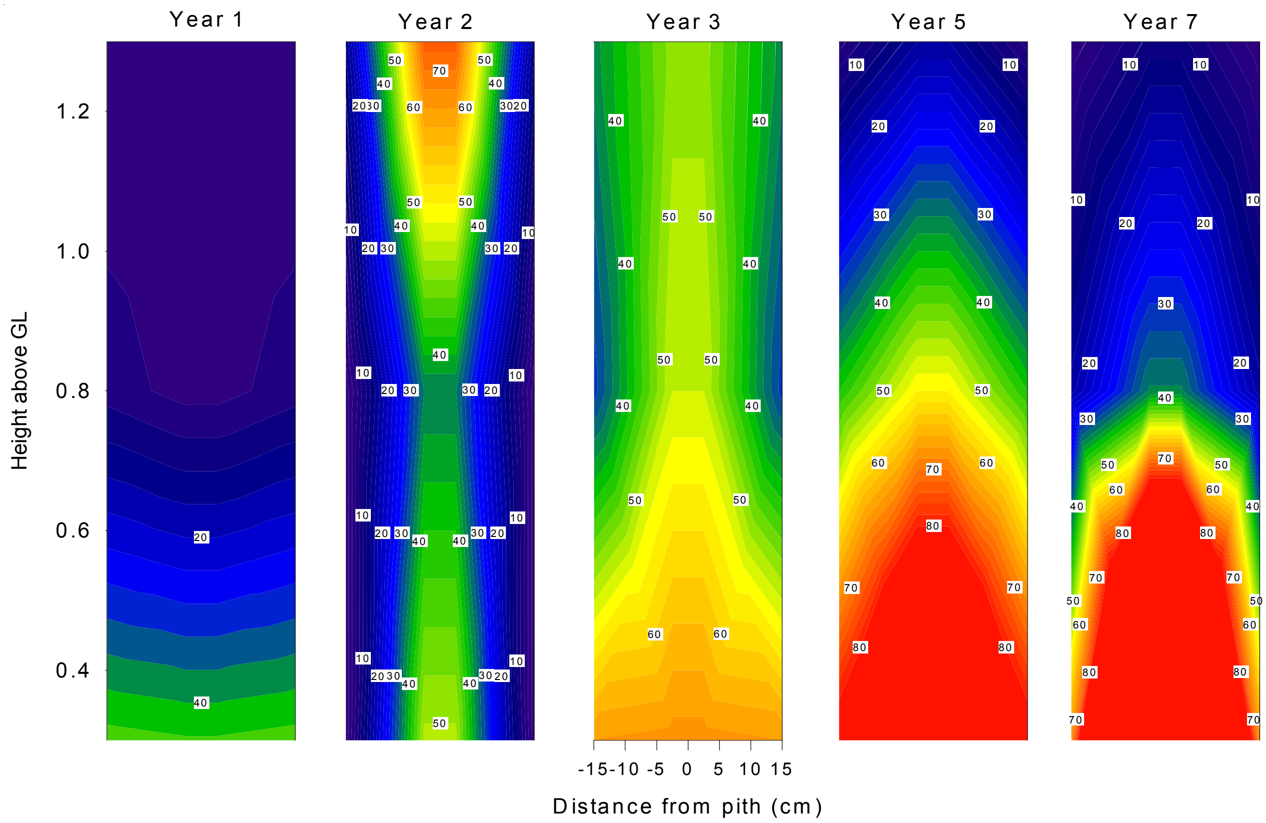


Figure I-8. Residual MITC in Douglas-fir poles 1 to 7 years after treatment with 107 g of dazomet rod plus 100 g of copper naphthenate. Dark blue indicates MITC levels below the threshold for fungal attack. Light blue and other colors indicate MITC levels above the lethal threshold.

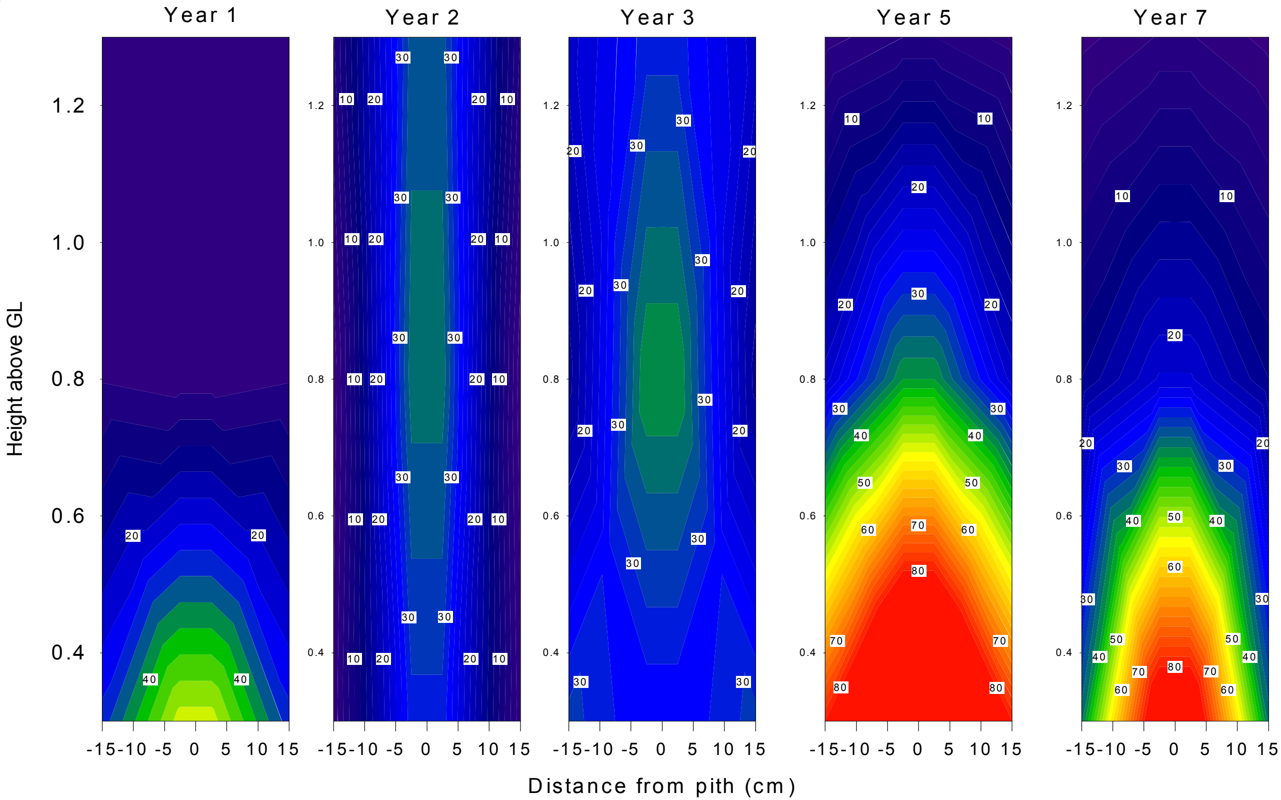


Figure I-9. Residual MITC in Douglas-fir poles 1 to 7 years after treatment with 160 g of dazomet rod alone. Dark blue indicates MITC levels below the threshold for fungal attack. Light blue and other colors indicate MITC levels above the lethal threshold.

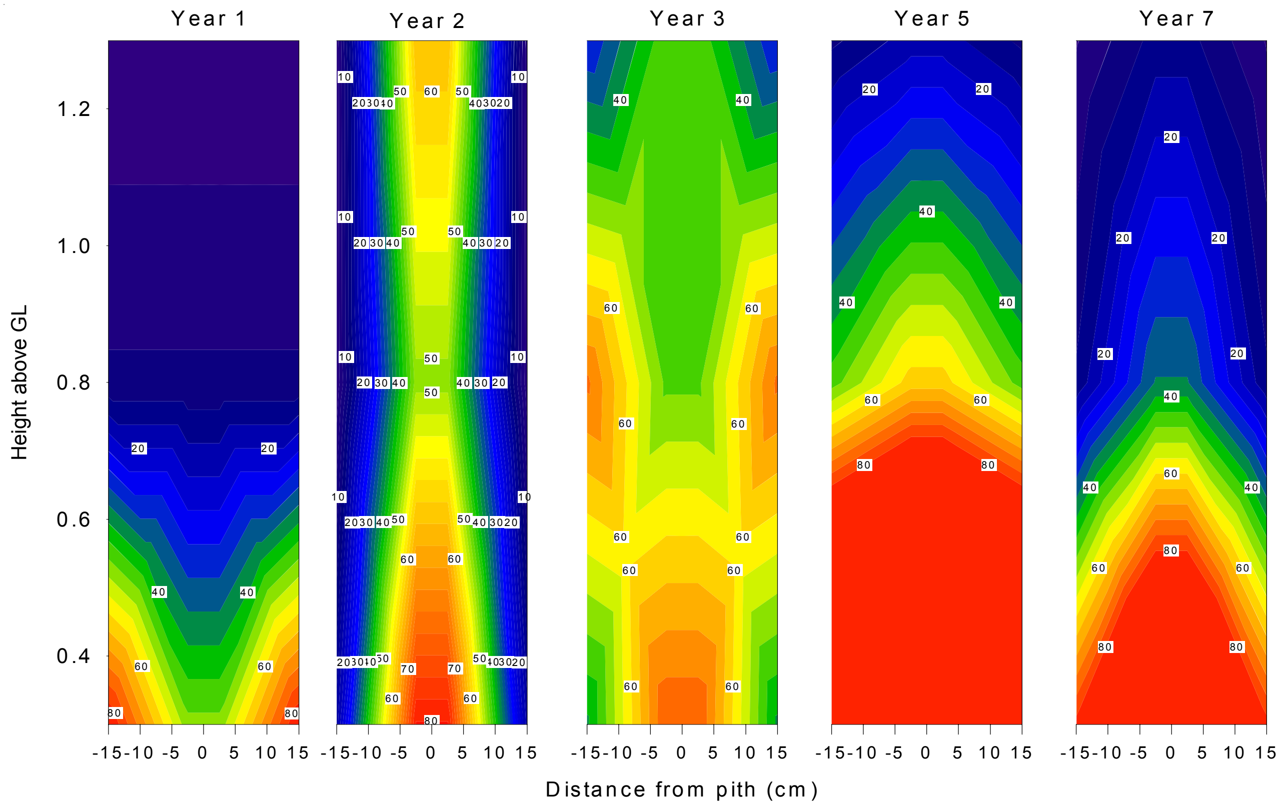


Figure I-10. Residual MITC in Douglas-fir poles 1 to 7 years after treatment with 160 g of dazomet rod plus 100 g of copper naphthenate. Dark blue indicates MITC levels below the threshold for fungal attack. Light blue and other colors indicate MITC levels above the lethal threshold.

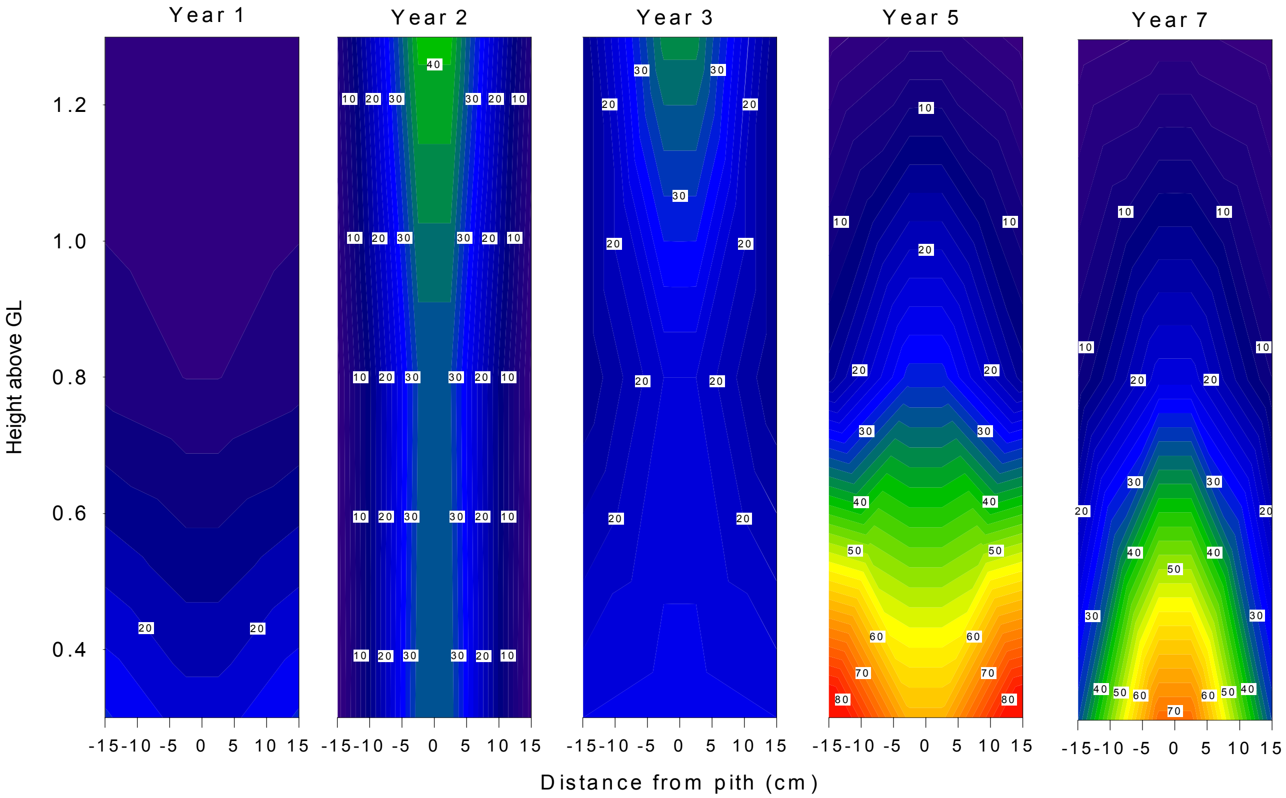


Figure I-11. Residual MITC in Douglas-fir poles 1 to 7 years after treatment with 160 g of dazomet rod plus 100 g of water. Dark blue indicates MITC levels below the threshold for fungal attack. Light blue and other colors indicate MITC levels above the lethal threshold

MITC levels 0.8 m above groundline were generally below the 20 ug threshold one year after treatment except for the outer zone in the metam sodium treatment. Chemical levels in the inner zone all rose above the threshold 2 years after treatment and there appeared to be no real difference between metam sodium and any of the dazomet treatments. These trends continued after 3 years. Differences in MITC levels between dazomet and metam sodium treatments began to emerge after 5 years, with levels declining in metam sodium poles and remaining stable in all dazomet treatments.

MITC levels 0.8 m above the groundline in poles receiving powdered or rod dazomet all remained above the threshold 5 years after treatment. Levels tended to be similar for the powdered and rod treatments, but the presence of copper still had a stimulatory effect. MITC levels 0.8 m above ground had declined below the protective threshold 7 years after treatment and there appeared to be little or no effect of added copper.

Chemicals levels 1.3 m above groundline were all uniformly low 1 year after treatment, then rose dramatically in the inner zones in the second year. The presence of copper had a marked effect on MITC levels in these locations, a finding that appears to contradict the results closer to the groundline. MITC levels 3 years after treatment were still largely above the threshold 1.3 m above ground, except for the inner and outer zones in the metam sodium treatment and the outer zone in the 160 g of dazomet plus water treatment. These results also appear to contradict those found with the original dazomet test which had low MITC levels 2 to 3 m above the groundline; however, the test poles in the earlier test were much larger. As a result, the MITC from the 200 g dosage treatment in the original trial would have diffused into a larger area, resulting in correspondingly lower chemical levels per unit area.

MITC levels 1.3 m above the groundline have declined below the threshold in all treatments 7 years after chemical application. These results suggested that none of these treatments provide long term protection at this distance from the point of application. These results differ from the initial fumigant trials performed in the 1960's; however, the dosages used in those early trials were five to seven times those used in the current tests.

There appeared to be little or no difference in MITC levels between poles receiving dazomet in rod or powdered form. This suggests that moisture in the wood was adequate for release of chemicals despite the potential for reduced wood/dazomet contact in the rods.

The absence of a copper naphthenate effect with the rods may reflect a tendency for more of the liquid copper naphthenate to be sorbed by the wood rather than the rod. Although not included in this test, powdered formulations may be more likely to sorb copper naphthenate making more copper available to participate in decomposition reactions. Further sampling will be required to determine if there is a real copper stimulatory effect.

No decay fungi were isolated from any of the treated poles, suggesting that all of the treatments were effective (Table I-5). Non-decay fungi were isolated from a number of treatments, but there appeared to be no specific pattern to the isolations. We will continue to monitor fungal levels in these poles over the remainder of the test to determine when chemical levels fall below the minimum for fungal growth.

The groundline regions of the poles are well protected 7 years after treatment, with dazomet rods or powder, especially near the pith. MITC levels decline with increasing height above groundline leaving the inner portion of poles minimally protected and the outer portions unprotected after 7 years 0.8 m above groundline. No protection remains 1.3 m above groundline. The addition of copper naphthenate had little effect on MITC levels.

Table I-5. Percentage of increment cores containing decay and non-decay fungi 1 to 7 years after application of metam sodium or dazomet in rod or powder form with and without copper naphthenate.

Treatment	Dosage	Supplement	Year Sampled	Isolation Frequency (%)[a]		
				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}
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}
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}
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}
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}
Metam 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}

[a] Values represent means of fifteen cultures per treatment. Superscripts denote non-decay fungi.

5. Performance of granular dazomet

Date Established:	August 2006
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @ GL (avg., max., min.)	35.1, 38, 32 in

Dazomet has been successfully applied to wood poles for almost 6 years; however, one concern with this system is the risk of spilling the granules during application. In previous tests, we explored the use of dazomet in pellet form, but this does not appear to be a commercially viable product. As an alternative, dazomet could be placed in degradable tubes that contained the chemical prior to application. One concern with the tubes is that they may affect subsequent dazomet decomposition and release of methylisothiocyanate. In order to investigate this possibility, the following trial was established.

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

Seventy grams of dazomet was pre-weighed into 125 ml glass bottles. The content of one bottle was then applied to each of the three holes in each of 10 poles. The holes in 10 additional poles received a 400 to 450 mm long by 19 mm diameter paper tube containing 60g of dazomet. The tubes were gently rotated as they were inserted to avoid damage to the paper. The holes in one half of the poles treated with either granular or tubular dazomet also received 7 g of 2% copper naphthenate in mineral spirits (Tenino copper naphthenate). The holes were plugged with tight fitting plastic plugs (Scotty Plugs).

MITC distribution was assessed 1 year after treatment by removing increment cores from three equidistant locations around each pole section at locations 150 mm below groundline, at groundline and 300, 450, 600 and 900 mm above groundline. The outer and inner 25 mm of each core was extracted in ethyl acetate and these extracts were analyzed by gas chromatography for MITC as described earlier.

As with most fumigant tests, MITC levels tended to be higher in cores from the interior of the pole sections (Figure I-12, Table I-6). MITC levels tended to be highest in inner zones 150 mm below groundline and at groundline, although there was little difference between poles with or without added copper, nor were there appreciable differences between granular and tubed dazomet formulations. MITC levels tended to decline with distance above the groundline. While six of eight samples at 450 mm were above threshold, only three were above the 20 ug level 600 mm above groundline and only one achieved this level 1m above the ground. The declines in MITC with distance above ground were consistent between the two systems, suggesting that the cardboard tube had little or no effect on the initial rate of dazomet decomposition.

The results indicate that the tube system can be used in the same manner as the traditional granular dazomet system.

In August of 2007, an additional six poles were treated with granular dazomet enclosed in biodegradable plastic tubes. Two tubes, each containing approximately 17 g of dazomet, were placed into each of three holes in each pole as above, and supplemental Tenino copper naphthenate was added. These poles will be sampled beginning in 2008.

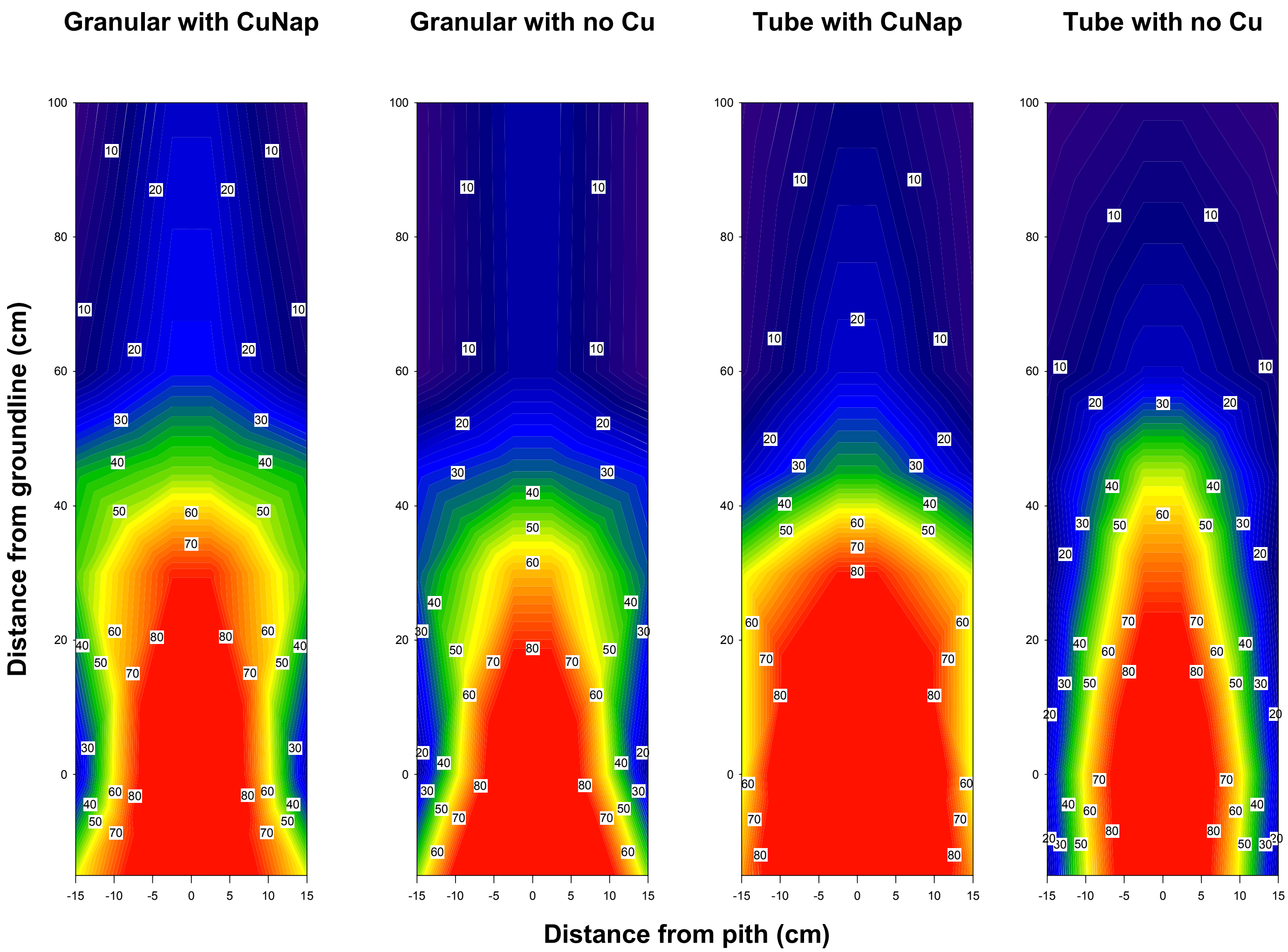


Figure I-12. Residual MITC Douglas-fir poles 1 year after application of dazomet as a granular system or in cardboard tubes with or without supplemental copper naphthenate.

Table I-6. MITC levels in Douglas-fir poles 1 year after application of dazomet as a granular system or in cardboard tubes with or without supplemental copper naphthenate.

Treatment	Dosage (g/pole)	Supplement	Residual MITC (ug/g of wood)[a]											
			-15 cm		0 cm		30 cm		45 cm		60 cm		90 cm	
			Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer	Inner	Outer
Granular	210	CuNaph	**108**	**53**	**114**	19	**79**	**45**	**47**	**39**	**27**	10	**21**	1
		None	**144**	**48**	**108**	15	**63**	**32**	**34**	**27**	17	2	17	2
Tube	180	CuNaph	**133**	**66**	**158**	**53**	**81**	**53**	**39**	19	**22**	5	12	2
		None	**108**	16	**112**	**21**	**72**	10	**51**	14	20	9	7	1
Control	0	None	0	1	8	0	1	0	0	0	2	0	0	0

[a] Values represent means of fifteen analyses per position. Numbers in bold represent MITC levels above the toxic threshold.

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 and limit the extent of internal decay, some users have expressed concern about the risk of these chemicals. Water diffusible preservatives such as boron and fluoride have been developed as potentially less toxic, more easily handled alternatives to fumigants.

Boron has a long history of use as an initial treatment of freshly sawn lumber to prevent infestations by various species of powder post beetles in both Europe and New Zealand. 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 pure boron or boron plus copper. These rods are produced by heating boron to its molten state, then pouring the molten boron into a mold. The cooled boron rods are easily handled and applied. In theory, the boron is released as the rods come in contact with water.

Fluoride has also been used in a variety of preservative formulations going back to the 1930's when fluor-chrome-arsenic-phenol was employed as an initial treatment. Fluoride, in rod form, has long been used to treat the area under tie plates in railroad tracks and has been used as a dip-diffusion treatment in Europe. Fluoride can be corrosive to metals, although this should not be a problem in the groundline area. Sodium fluoride can also be formed into rods for application, although the rods are less dense than the 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. As a result, there is considerable performance data on boron and fluoride as remedial treatments on European species, but little data on performance on U.S. species used for utility poles.

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, 101, 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 four or eight copper/boron rods or four boron rods. The holes were then plugged with tight fitting plastic plugs.

Chemical movement was assessed 1, 2, 3 and 5 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 three poles at a given height and treatment were combined and then ground to pass a 20 mesh screen. The resulting sawdust was first analyzed for copper by x-ray fluorescence spectroscopy, and then extracted in hot water. The extract was analyzed for boron content using the azomethine-H method.

Copper levels in poles treated with four rods were slightly elevated at groundline in the inner zones of poles treated using both the 90 and 120 degree treating patterns 2 years after treatment, but even these levels were well below the threshold for wood protection (Figure I-13). Copper was barely detectable away from these zones.

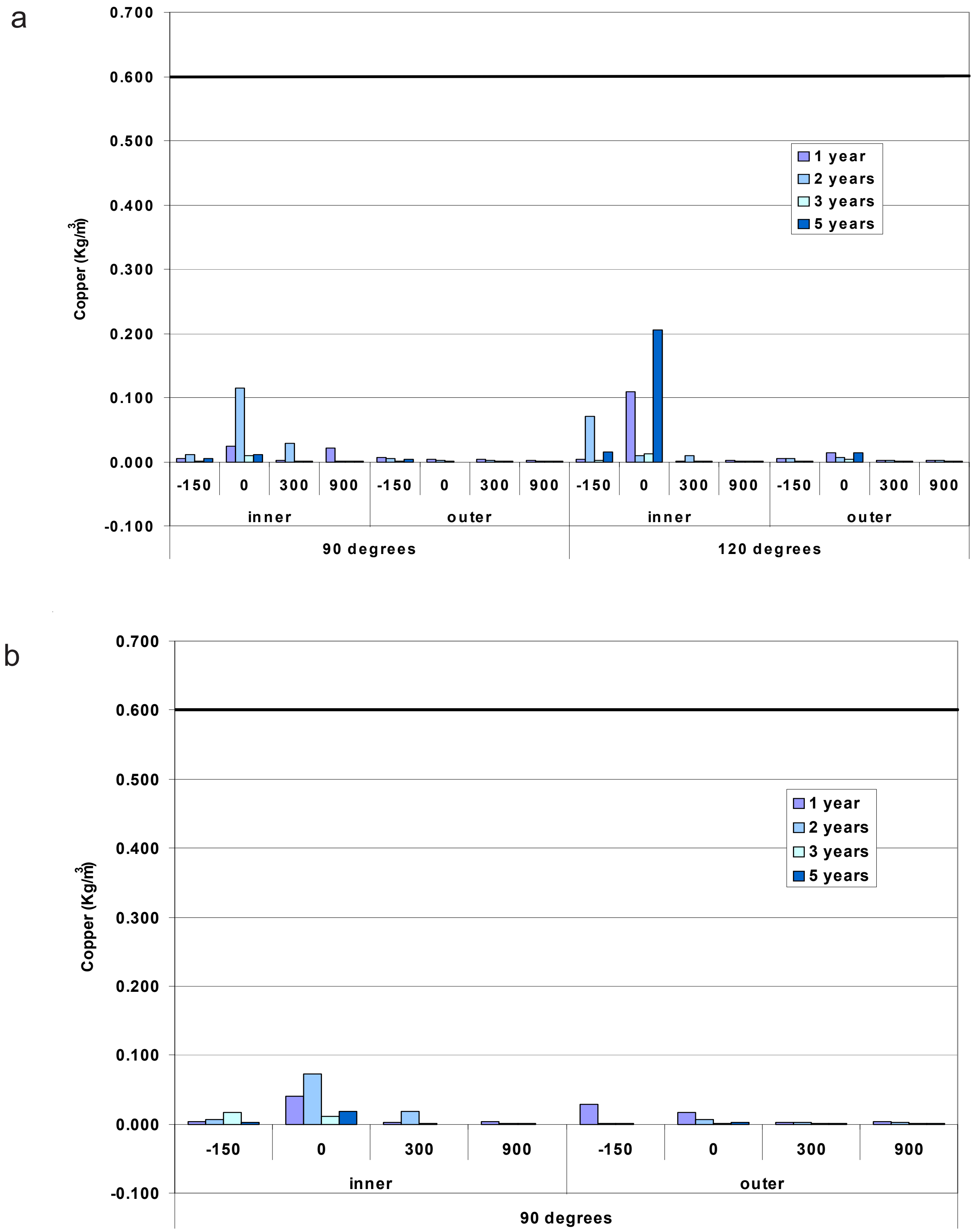


Figure I-13. Copper levels in increment cores removed from selected locations above and below the groundline in Douglas-fir pole sections 1 to 5 years after treatment with a) 4 or b) 8 copper/boron rods. The threshold for copper is 0.6 kg/m^3.

Copper levels in the eight-rod treatment tended to be lower than those found with the 4-rod treatment. While the lower levels appear to be counterintuitive, they are consistent with previous tests of water diffusible systems. In many cases, higher dosages appear to slow initial chemical movement, possibly as the rods sorb moisture from the surrounding wood, thereby reducing water available for diffusion to occur. In summary, copper does not appear to be moving from the rods at levels that would confer protection away from the original point of treatment.

Boron levels in the inner zones of poles receiving 4 copper/boron rods were above the threshold for internal protection at and below groundline 2 years after treatment regardless of hole orientation (Figure I-14). Levels in poles treated with the 90 degree spacing fell sharply, but were still at the lower boron threshold 3 years after treatment, while levels in the poles with the 120 degree hole spacing remained elevated.

Boron levels were at or slightly below the threshold 300 mm above groundline after 2 years, then declined to near background levels 3 years after treatment. Boron levels rose at the 5 year point, suggesting that boron continued to move out of the treatment holes and into the wood. Boron levels at groundline in both the 90 and 120 degree treatments were well above the threshold and much higher than at any previous time. It is unclear why boron levels increased so substantially at the 5 year point, but these results suggest that the boron was diffusing well from the rods at or below groundline, but faced challenges in the above ground zones. Boron levels in the outer zones tended to be lower, but were above the lower threshold at groundline 5 years after treatment.

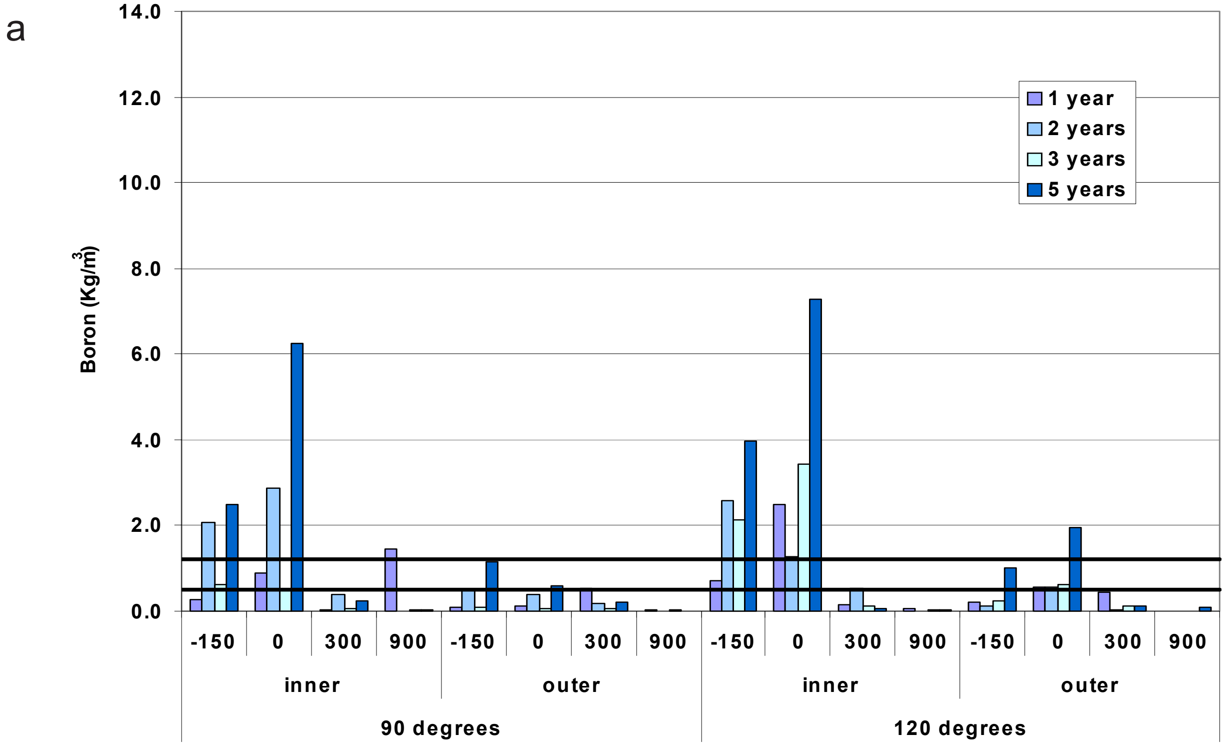
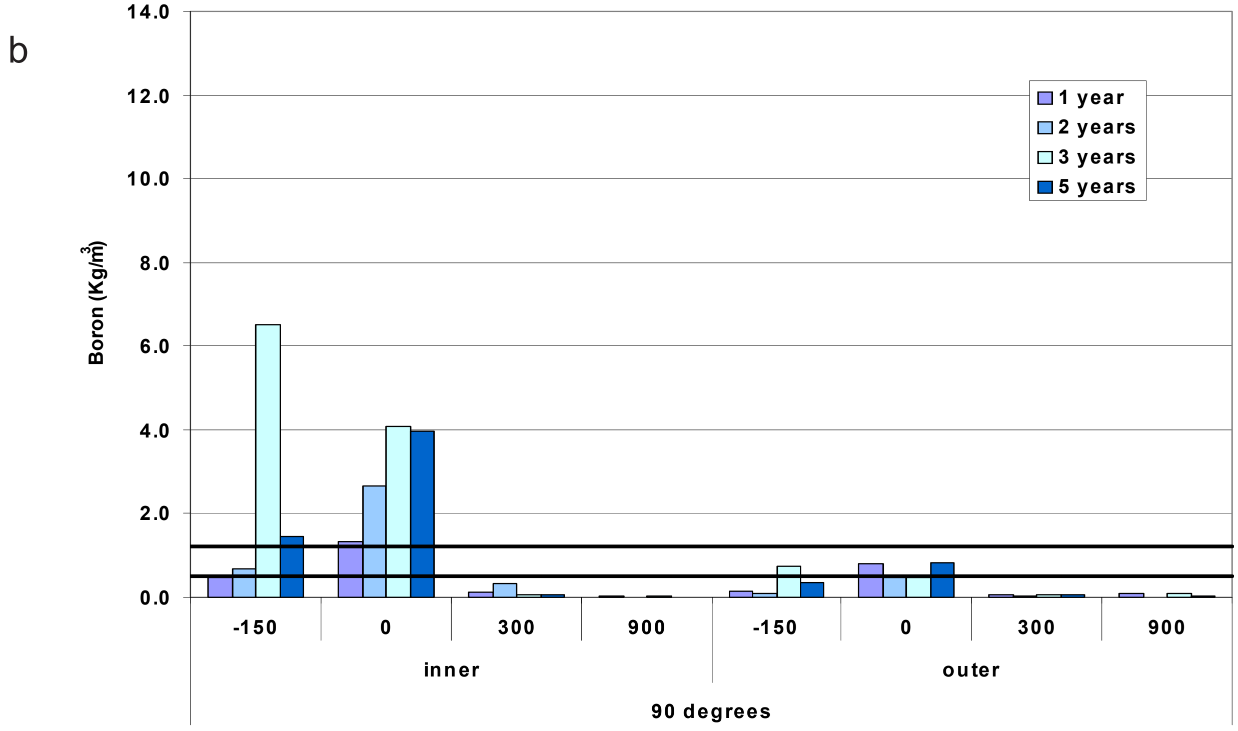


Figure I-14. Boron levels in increment cores removed from selected locations above and below the groundline in Douglas-fir pole sections 1 to 5 years after treatment with a) four copper/boron rods, b) eight copper/boron rods or c) four boron rods. Lower and upper boron threshold levels are 0.5 and 1.2 kg/m^3 boric acid equivalent (BAE).



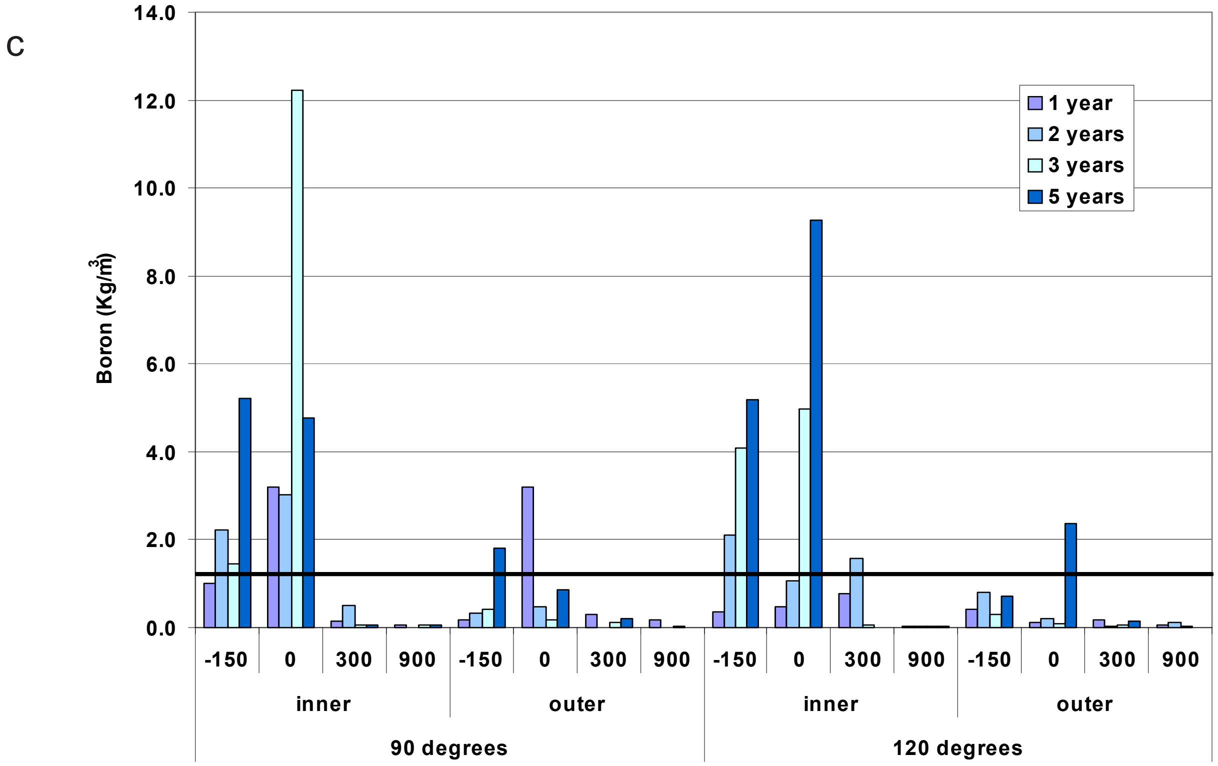


Figure I-14 (cont.). Boron levels in increment cores removed from selected locations above and below the groundline in Douglas-fir pole sections 1 to 5 years after treatment with a) four copper/boron rods, b) eight copper/boron rods or c) four boron rods. Lower and upper boron threshold levels are 0.5 and 1.2 kg/m^3 boric acid equivalent (BAE).

Boron levels in the poles treated with non-copper amended boron rods were sometimes slightly higher than those for the poles receiving copper/boron rods, but the differences appeared to be slight. Once again, the boron levels below groundline and at groundline were at or above the threshold. Although we did not measure the moisture contents of the poles in this test, in other field trials moisture contents in poles at groundline are well over 30% and the cone of moisture extends upward a meter or so during our wet winter months. The results indicate that the boron from the rods is moving within the groundline zone where moisture is adequate for diffusion to occur.

Boron levels in poles treated with 8 copper/boron rods tended to be lower than those found with the 4-rod treatment over the 5 year test, again suggesting that excessive chemical in the hole retards initial boron distribution. As a result, more chemical may not necessarily be the best approach for rapid decay control when these systems are employed. Instead, supplemental moisture addition may be a more fruitful approach to enhance boron movement and more quickly arrest fungal attack. Since the installation of this test, some producers recommend adding a dilute boron solution to the treatment hole when installing rods . No supplement was added to the rods when this test was installed, but our previous tests indicate that this solution produces a long lasting boost to boron levels in the wood.

Cultural results of wood removed from the boron and copper/boron rod treated poles suggest that the poles are being invaded by a number of non-decay fungi at or near groundline. These fungi do not cause degradation of the wood structure, but they can condition the wood and allow other fungi to colonize the substrate.

Basidiomycete isolations are still low at most locations, however, the levels have risen in the boron rod treated poles, both at groundline and 900 mm above that zone (Table I-7). Decay fungi were also isolated from the upper height in the poles receiving 4 boron/copper rods, but decay fungi were only isolated

Table I-7. Isolation frequency of decay and non decay fungi from Douglas-fir pole sections 1 to 5 years after treatment with boron or copper/boron rods in two different spacing patterns.

Treatment	Rod Spacing	Year Sampled	Isolation Frequency (%)[a]			
			-150 mm	0 mm	300 mm	900 mm
4 copper/boron rods	90°	1	0^{7}	0^{10}	0^{20}	0^{7}
		2	0^{33}	0^{20}	0^{10}	7^{0}
		3	0^{27}	0^{10}	0^{0}	7^{13}
		5	0^{33}	0^{30}	20^{0}	7^{13}
4 copper/boron rods	120°	1	0^{40}	0^{0}	0^{0}	0^{13}
		2	0^{33}	0^{20}	0^{0}	0^{0}
		3	0^{47}	0^{30}	0^{0}	7^{7}
		5	0^{40}	0^{10}	0^{10}	0^{0}
4 boron rods	90°	1	0^{7}	0^{10}	0^{0}	0^{0}
		2	0^{20}	10^{10}	0^{0}	7^{0}
		3	0^{40}	10^{50}	0^{0}	13^{7}
		5	7^{27}	10^{20}	10^{0}	13^{0}
4 boron rods	120°	1	0^{0}	0^{0}	0^{0}	0^{20}
		2	0^{20}	10^{10}	0^{0}	7^{0}
		3	0^{40}	10^{50}	0^{0}	13^{7}
		5	0^{47}	10^{30}	0^{10}	7^{0}
8 copper/boron rods	90°	1	0^{0}	0^{0}	0^{0}	0^{7}
		2	0^{0}	0^{0}	0^{20}	0^{7}
		3	0^{27}	0^{10}	0^{0}	0^{0}
		5	0^{33}	0^{0}	0^{0}	13^{33}

[a] Values represent means of fifteen cultures per treatment. Superscripts denote non-decay fungi.

900 mm above groundline in the poles receiving 8 rods. The gradual increase in fungal isolations from the poles is not surprising given the relatively low levels of boron present. Clearly, these isolation levels remain low, but will need to be monitored over the next few years to determine if the treatments can provide any protection to the poles.

Decay fungi were isolated from positions in poles for which the average residual boron is well above threshold (for example, 4 boron rods at 120 degrees at groundline at 3 and 5 years). Although the wood for chemical analysis and culturing comes from the same increment cores, the data cannot be matched on an individual basis because wood from three poles and two or three sampling heights (six or nine cores depending on sampling height) was combined to provide sufficient wood for analysis. It is likely, especially at groundline, that some cores are much closer to the rods than others.

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

Date Established:	May 1993
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @ GL (avg., max., min.)	100, 114, 89 cm

Thirty pentachlorophenol treated Douglas-fir poles (283-364 mm in diameter by 2 m long) were set to a depth of 0.6 m at the Peavy Arboretum test site. Three 19 mm diameter by 200 mm long holes were drilled perpendicular to the grain beginning at groundline and moving around the pole 120 degrees and upward 15 cm. Each hole received either one or two boron rods (180 or 360 g of rod, respectively). The holes were then plugged with tight fitting wood dowels. Each treatment was replicated on ten poles.

The poles were sampled 1, 3, 4, 5, 7, 10, and 12 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. Boron levels above the toxic threshold were detected 12 years after treatment. These poles will next be inspected in 2008, 15 years after treatment.

3. Effect of Glycol on Movement of Boron from Fused Borate 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 slow movement that has been used in Europe has been the addition of glycol. Glycol is believed to stimulate movement through dry wood that would normally not support diffusion (Bech-Anderson, 1987; Edlund et al., 1983).

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

Four 19 mm diameter holes were drilled at a 45 ^{o} downward sloping angle in each pole, 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 (Table I-8). The borate rods were 100 mm long by 12.7 mm in diameter and weighed 24.4 g each. The weight of boron rod required to achieve 227 g BAE was equally divided between the three holes, resulting in one whole rod and a portion of another in each hole. The appropriate liquid supplement was added or the rods 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 and 12 years after treatment by removing two increment cores 180 degrees apart from 30 cm 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 pole were combined and ground to pass a 20 mesh screen. The resulting sawdust was then extracted and analyzed using the azomethine-H method.

Table I-8. Combinations of boron rods and various boron additives applied internally to Douglas-fir pole sections in 1995. All treatments deliver 227 g BAE per pole.

Boron Rod (g)	Supplement	Amount of Supplement (g)	Total Glycol (g)	Total Water (g)	Supplement Source	Supplement Formulation
156	None	0	0	0		
137	Boracare 1:1 in water	118	28	65	Nisus Corp. Rockford, TN	Disodium octaborate tetrahydrate plus poly and monoethylene glycol
137	Boracol 20	122	77	20	CSI Inc. Charlotte, NC	Disodium octaborate tetrahydrate plus polyethylene glycol (20%)
104	Boracol 40	164	95	0	CSI Inc. Charlotte, NC	Disodium octaborate tetrahydrate plus polyethylene glycol (40%)
156	Poly ethylene glycol	100	100	0	VanWaters And Rogers Seattle, WA	
146	Timbor 10% in water	118	0	106	U.S. Borax Inc.	Disodium octaborate tetrahydrate

Boron continues to be detectable in virtually all pole sections 12 years after treatment. As in previous boron tests, chemical levels were lower in poles receiving only the borate rods after one year (Table I-9). Boron levels 7 years after treatment were much higher in poles receiving any of the various combinations of Boracare, Boracol, Timbor, or glycol, suggesting that some supplemental liquid enhanced boron movement, whether or not the additive contained boron or glycol.

Boron levels at the 12 year point were lowest in poles receiving only the boron rods (Table I-9). The addition of any supplemental treatment enhanced boron levels, although there were some differences between the various additives. Boron levels tended to be lower in poles amended with Boracare or with Boracol 40 than with Timbor, glycol (no added boron) or Boracol 20 (Figures I-15 to I-20). The enhanced effect of Boracol 20 in comparison with Boracol 40 is perplexing since the primary difference between these systems is the level of boron present in the solution. Given the higher level of boron in the Boracol 40, one should expect higher levels in the wood. It is unclear why this did not occur, although one possibility would be that the Boracol 40 could not solubilize as much boron in the rods as the Boracol 20 and was therefore less effective as a mobilizing agent.

The results indicate that adding glycol or water based boron to boron rods at the time of treatment resulted in much more rapid born 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.

Table I-9. Boron levels in Douglas-fir poles 1 to 12 years after treatment with various combinations of fused boron rod and various water or glycol based additives.

Treatment	Height (mm)	Depth	Boron (Kg/m^3 BAE)[a]						
			Year 1	Year 2	Year 3	Year 5	Year 7	Year 10	Year 12
Rods alone	-300	I	**0.52** (0.45)	**1.40** (1.23)	**0.87** (0.82)	**0.53** (0.92)	0.46 (0.64)	0.35 (0.17)	0.23 (0.40)
		M	**0.81** (1.34)	**0.83** (0.91)	0.37 (0.30)	0.37 (0.69)	0.37 (0.56)	0.21 (0.35)	0.22 (0.39)
		O	0.30 (0.10)	0.43 (0.56)	0.24 (0.23)	0.50 (0.59)	0.10 (0.08)	0.28 (0.35)	0.11 (0.20)
	0	I	**1.31** (1.91)	**2.16** (0.97)	**2.15** (1.97)	**2.88** (1.98)	**1.10** (0.87)	**1.23** (0.38)	**0.81** (0.44)
		M	0.34 (0.24)	**1.05** (0.85)	**2.43** (2.66)	**1.86** (0.82)	**1.07** (0.92)	**0.69** (0.14)	**0.63** (0.65)
		O	0.24 (0.13)	0.23 (0.29)	**1.67** (2.09)	0.42 (0.46)	**0.69** (0.78)	0.32 (0.14)	0.25 (0.35)
	150	I	0.45 (0.29)	**1.65** (2.24)	**2.12** (1.62)	**1.87** (1.72)	**2.54** (1.82)	**1.64** (0.72)	**0.57** (0.46)
		M	0.22 (0.07)	**1.39** (2.47)	**2.88** (3.32)	**1.47** (1.43)	**1.83** (1.66)	**2.74** (2.89)	**0.87** (0.59)
		O	0.29 (0.18)	0.43 (0.86)	**0.54** (0.86)	0.41 (0.49)	0.27 (0.28)	**0.54** (0.34)	**0.55** (0.50)
	300	I	0.23 (0.13)	0.30 (0.54)	0.49 (0.59)	**1.14** (2.03)	**14.16** (29.02)	**0.73** (0.74)	0.01 (0.02)
		M	0.20 (0.06)	0.17 (0.16)	0.33 (0.34)	**1.79** (3.13)	**0.81** (0.90)	0.48 (0.52)	0.02 (0.03)
		O	0.16 (0.09)	0.10 (0.10)	0.11 (0.10)	**1.06** (1.77)	0.40 (0.46)	0.25 (0.15)	0.07 (0.11)
Rods plus Boracare	-300	I	**1.57** (1.80)	0.36 (0.25)	**0.51** (0.32)	0.20 (0.16)	0.15 (0.14)	0.30 (0.24)	0.41 (0.62)
		M	0.36 (0.20)	0.43 (0.37)	**0.56** (0.28)	0.07 (0.10)	0.12 (0.10)	0.28 (0.17)	0.18 (0.18)
		O	0.23 (0.05)	0.16 (0.03)	**0.58** (0.59)	0.04 (0.06)	0.10 (0.04)	0.22 (0.14)	0.03 (0.05)
	0	I	**2.80** (1.86)	**7.59** (6.38)	**2.40** (1.51)	**5.68** (6.61)	**10.39** (9.85)	**2.00** (1.52)	**1.85** (1.45)
		M	0.32 (0.18)	**4.77** (4.78)	**1.34** (0.92)	**5.03** (4.71)	**0.78** (0.90)	**0.87** (0.67)	**1.00** (0.72)
		O	0.22 (0.05)	0.40 (0.39)	**0.87** (0.93)	**0.83** (0.91)	**0.53** (0.67)	0.18 (0.11)	0.20 (0.18)
	150	I	**4.35** (3.61)	**3.55** (1.22)	**4.13** (4.66)	**5.17** (3.72)	**3.14** (2.65)	**1.84** (1.88)	**1.11** (1.42)
		M	**1.06** (1.10)	**1.32** (1.67)	**4.10** (4.50)	**1.86** (0.97)	**1.69** (1.72)	**0.80** (1.01)	**1.04** (0.88)
		O	0.50 (0.34)	0.49 (0.90)	0.40 (0.30)	**1.08** (1.85)	0.21 (0.23)	0.28 (0.20)	0.35 (0.41)
	300	I	**1.79** (1.16)	**1.22** (1.09)	**0.81** (1.05)	**2.27** (3.19)	**1.83** (1.29)	**1.92** (1.64)	**1.31** (1.12)
		M	**1.16** (1.91)	0.33 (0.29)	**0.89** (1.36)	**4.23** (8.09)	**0.89** (0.68)	**1.09** (0.90)	**0.53** (0.72)
		O	0.33 (0.19)	0.15 (0.18)	**1.00** (1.77)	**1.62** (2.88)	0.12 (0.06)	0.20 (0.14)	0.12 (0.18)
Rods plus Boracol 20	-300	I	**0.87** (0.71)	**0.69** (0.75)	0.50 (0.53)	0.26 (0.19)	**1.61** (1.06)	**0.73** (0.33)	**0.92** (0.72)
		M	0.49 (0.48)	0.29 (0.26)	0.26 (0.24)	0.22 (0.23)	**0.99** (0.90)	**0.63** (0.21)	**0.79** (0.57)
		O	0.47 (0.49)	0.20 (0.21)	0.22 (0.15)	**1.62** (3.36)	0.13 (0.19)	0.49 (0.22)	0.21 (0.26)
	0	I	**4.51** (5.32)	**2.41** (0.73)	**3.93** (2.95)	**3.33** (1.95)	**2.22** (2.74)	**1.87** (1.56)	**3.82** (4.14)
		M	**1.44** (2.09)	**0.79** (0.53)	**2.38** (2.32)	**1.99** (1.25)	**0.89** (0.58)	**1.07** (1.08)	**0.89** (0.70)
		O	0.32 (0.12)	**1.11** (2.11)	**2.96** (2.91)	**0.55** (0.63)	0.11 (0.11)	**0.57** (0.35)	0.46 (0.36)
	150	I	**1.84** (0.95)	**3.64** (4.00)	**1.65** (1.79)	**3.69** (1.56)	**2.06** (1.47)	**2.39** (1.49)	**3.49** (1.98)
		M	**0.73** (0.70)	**1.00** (0.65)	**3.39** (5.04)	**1.85** (1.16)	**3.86** (1.89)	**1.02** (0.97)	**1.25** (0.40)
		O	0.36 (0.23)	**0.93** (1.45)	0.30 (0.27)	0.44 (0.41)	0.27 (0.20)	0.15 (0.09)	0.46 (0.29)
	300	I	**2.87** (4.37)	**0.70** (0.72)	**0.93** (1.12)	0.36 (0.70)	**0.91** (1.22)	0.31 (0.24)	**0.89** (0.92)
		M	**0.67** (0.62)	**1.09** (1.16)	**0.58** (0.82)	0.27 (0.56)	**1.04** (1.66)	0.18 (0.15)	**0.59** (0.51)
		O	0.24 (0.07)	**1.37** (2.44)	0.20 (0.24)	0.40 (0.72)	0.20 (0.36)	0.06 (0.03)	0.06 (0.05)

[a] Numbers in bold represent boron levels above the toxic threshold of 0.5 kg/m^3 BAE. Figures in parentheses represent one standard deviation.

Table I-9 (cont.). Boron levels in Douglas-fir poles 1 to 12 years after treatment with various combinations of fused boron rod and various water or glycol based additives.

Treatment	Height (mm)	Depth	Boron (Kg/m^3 BAE)[a]													
			Year 1		Year 2		Year 3		Year 5		Year 7		Year 10		Year 12	
Rods plus Boracol 40	-300	I	**2.49**	(2.38)	**0.92**	(0.63)	**0.71**	(0.62)	**0.62**	(0.73)	**1.32**	(1.17)	0.46	(0.30)	**0.51**	(0.49)
		M	**0.55**	(0.41)	**0.71**	(1.09)	**1.53**	(2.57)	0.37	(0.36)	0.41	(0.34)	**0.55**	(0.49)	0.20	(0.31)
		O	0.21	(0.08)	**0.74**	(0.99)	**1.36**	(2.66)	0.07	(0.07)	0.14	(0.28)	0.40	(0.22)	0.22	(0.39)
	0	I	**11.15**	(6.98)	**10.41**	(9.50)	**5.82**	(3.21)	**10.82**	(9.22)	**5.86**	(4.24)	**2.16**	(0.06)	**1.31**	(0.35)
		M	**3.38**	(2.69)	**5.16**	(3.23)	**9.54**	(10.73)	**13.82**	(10.66)	**7.49**	(3.73)	**1.23**	(0.46)	**1.17**	(0.23)
		O	0.45	(0.31)	**1.26**	(1.47)	**2.65**	(2.21)	**2.53**	(1.85)	**0.53**	(0.34)	0.42	(0.10)	0.34	(0.36)
	150	I	0.37	(0.24)	0.33	(0.30)	0.35	(0.30)	**0.63**	(0.86)	**1.39**	(1.58)	0.36	(0.49)	0.46	(0.37)
		M	0.22	(0.03)	0.44	(0.43)	0.41	(0.31)	0.33	(0.53)	0.47	(0.40)	0.44	(0.57)	0.40	(0.19)
		O	0.18	(0.11)	0.33	(0.28)	0.26	(0.08)	0.14	(0.27)	0.06	(0.04)	0.12	(0.14)	0.03	(0.03)
	300	I	0.18	(0.12)	0.10	(0.09)	0.08	(0.07)	0.03	(0.04)	0.37	(0.67)	0.04	(0.06)	0.03	(0.05)
		M	0.15	(0.10)	0.08	(0.05)	0.09	(0.08)	0.04	(0.05)	0.18	(0.17)	0.03	(0.01)	0.02	(0.03)
		O	0.15	(0.11)	0.07	(0.04)	0.08	(0.07)	0.02	(0.02)	0.04	(0.02)	0.27	(0.37)	0.00	0.00
Rods plus ethelyne glycol	-300	I	0.32	(0.29)	0.33	(0.20)	0.16	(0.13)	0.14	(0.21)	0.30	(0.24)	**0.52**	(0.38)	**0.96**	(0.93)
		M	0.19	(0.06)	0.18	(0.11)	0.07	(0.13)	0.04	(0.09)	0.10	(0.07)	**0.79**	(0.48)	**0.80**	(0.98)
		O	0.16	(0.10)	0.10	(0.11)	0.10	(0.13)	0.03	(0.05)	0.19	(0.31)	0.44	(0.36)	0.35	(0.52)
	0	I	**5.30**	(8.91)	**3.71**	(2.92)	**3.88**	(3.84)	**2.84**	(1.97)	**4.86**	(3.37)	**2.83**	(2.02)	**3.07**	(3.21)
		M	**0.97**	(1.20)	**0.61**	(0.39)	**0.67**	(0.46)	**2.81**	(2.00)	**5.17**	(7.26)	**1.70**	(0.80)	**2.45**	(2.07)
		O	0.21	(0.16)	0.17	(0.17)	**0.68**	(1.20)	**1.61**	(1.90)	0.49	(0.46)	**0.54**	(0.38)	0.24	(0.32)
	150	I	**2.98**	(3.50)	**5.02**	(4.32)	**5.31**	(1.72)	**2.77**	(2.53)	**2.89**	(1.34)	**3.00**	(3.04)	**1.99**	(2.08)
		M	**1.34**	(1.53)	**1.09**	(1.36)	**2.34**	(2.63)	**6.53**	(10.12)	**3.08**	(2.69)	**1.74**	(1.46)	**2.78**	(3.78)
		O	0.29	(0.22)	0.10	(0.08)	**1.45**	(2.03)	**4.29**	(7.08)	0.27	(0.18)	0.33	(0.11)	**1.04**	(1.51)
	300	I	0.17	(0.11)	0.24	(0.16)	**1.50**	(1.83)	**1.57**	(2.79)	**0.63**	(1.10)	0.33	(0.08)	**0.65**	(0.76)
		M	0.19	(0.05)	0.18	(0.22)	**0.56**	(0.69)	**3.44**	(6.66)	**1.16**	(1.73)	0.19	(0.08)	0.11	(0.10)
		O	0.20	(0.04)	**0.61**	(0.97)	**0.91**	(1.72)	**2.33**	(4.85)	0.43	(0.48)	0.09	(0.02)	0.29	(0.47)
Rods plus Timbor	-300	I	**0.83**	(0.43)	**0.67**	(0.37)	0.30	(0.22)	0.32	(0.39)	**1.12**	(1.58)	0.35	(0.24)	**0.69**	(0.50)
		M	0.30	(0.07)	0.26	(0.11)	**0.54**	(0.37)	0.13	(0.22)	0.32	(0.33)	0.40	(0.36)	**0.53**	(0.52)
		O	0.33	(0.18)	0.14	(0.06)	**0.51**	(0.60)	0.03	(0.04)	0.04	(0.06)	0.26	(0.25)	0.24	(0.29)
	0	I	**2.75**	(2.36)	**2.68**	(2.36)	**5.67**	(4.81)	**7.58**	(11.41)	**2.59**	(2.46)	**1.58**	(0.37)	**2.35**	(0.45)
		M	0.32	(0.17)	**1.84**	(1.99)	**1.46**	(1.35)	**1.54**	(0.78)	**0.85**	(0.53)	**1.24**	(0.65)	**1.60**	(1.07)
		O	0.34	(0.23)	0.20	(0.17)	**0.54**	(0.55)	0.47	(0.49)	**0.55**	(1.10)	**0.56**	(0.52)	**0.69**	(0.87)
	150	I	**3.53**	(3.44)	**2.89**	(2.22)	**2.83**	(2.85)	**2.22**	(1.10)	**14.00**	(21.75)	**3.47**	(0.32)	**2.96**	(0.60)
		M	**6.60**	(12.26)	**1.42**	(1.89)	**1.74**	(1.98)	**6.15**	(7.51)	**2.51**	(2.13)	**2.86**	(0.60)	**2.04**	(0.44)
		O	**0.72**	(0.79)	0.35	(0.30)	**0.94**	(0.74)	**1.13**	(0.83)	**0.54**	(0.43)	**0.88**	(0.65)	**0.74**	(0.54)
	300	I	**2.94**	(5.56)	**1.74**	(2.22)	**1.57**	(1.91)	**3.38**	(5.19)	**1.33**	(1.30)	**2.03**	(1.55)	**1.61**	(1.22)
		M	0.38	(0.23)	0.40	(0.35)	**1.84**	(2.42)	**0.68**	(0.66)	**1.00**	(0.54)	**0.91**	(0.30)	**0.78**	(0.12)
		O	0.45	(0.32)	0.15	(0.07)	**3.14**	(2.42)	0.34	(0.48)	0.22	(0.25)	0.31	(0.19)	0.28	(0.35)

[a] Numbers in bold represent boron levels above the toxic threshold of 0.5 kg/m^3 BAE. Figures in parentheses represent one standard deviation.

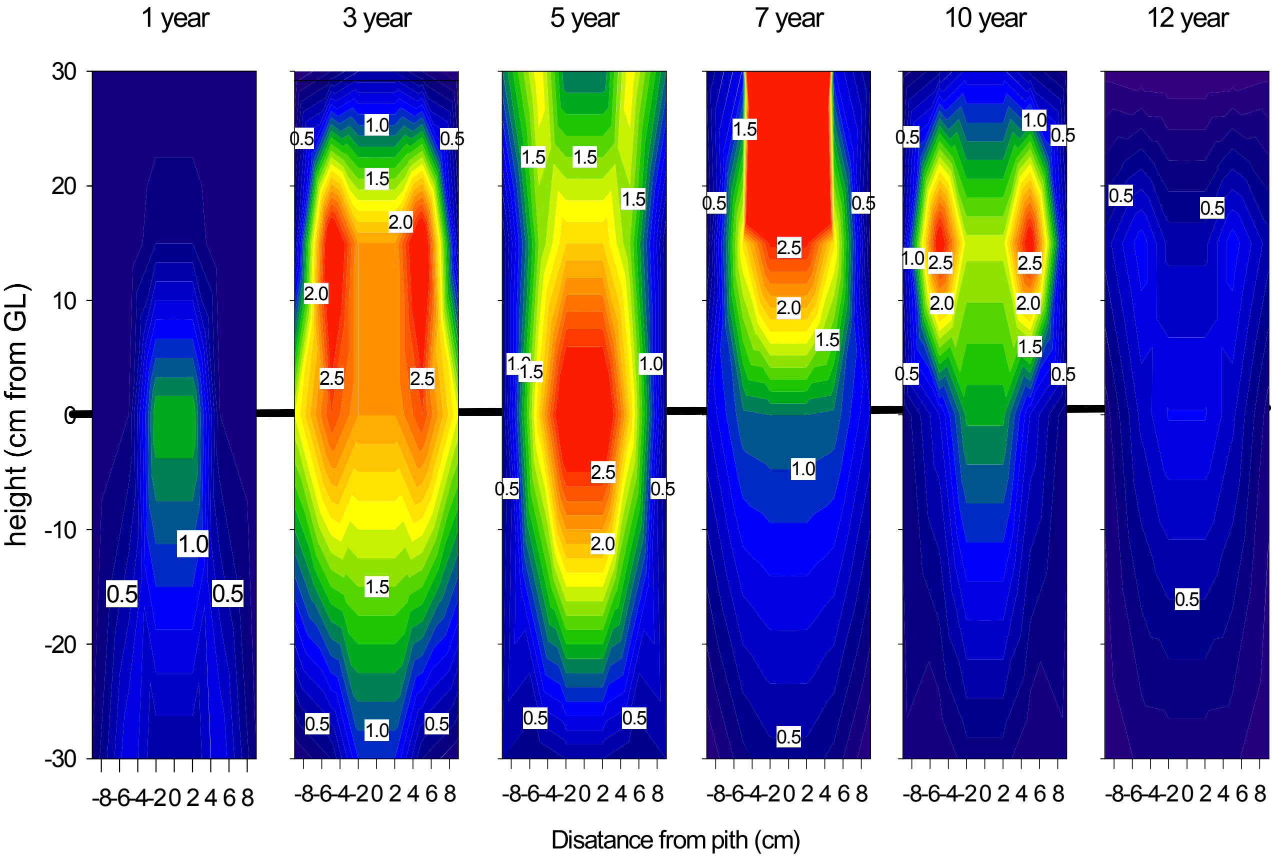


Figure I-15. Boron distribution in Douglas-fir poles 1 to 12 years after treatment with fused boron rods. Dark blue represent levels below the threshold for protection against fungal attack, while lighter blue, green and orange colors represent increasing boron concentrations in the wood.

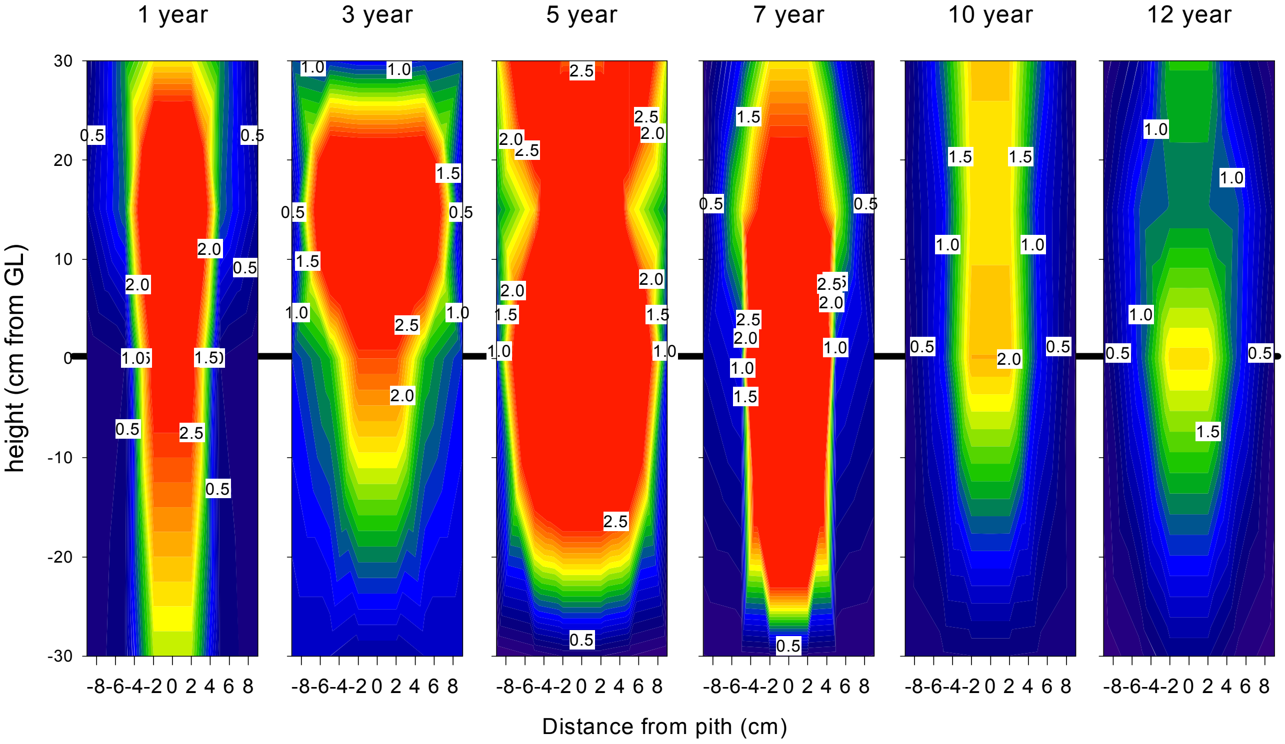


Figure I-16. Boron distribution in Douglas-fir poles 1 to 12 years after treatment with fused boron rods and Boracare. Dark blue represent levels below the threshold for protection against fungal attack, while lighter blue, green and orange colors represent increasing boron concentrations in the wood.

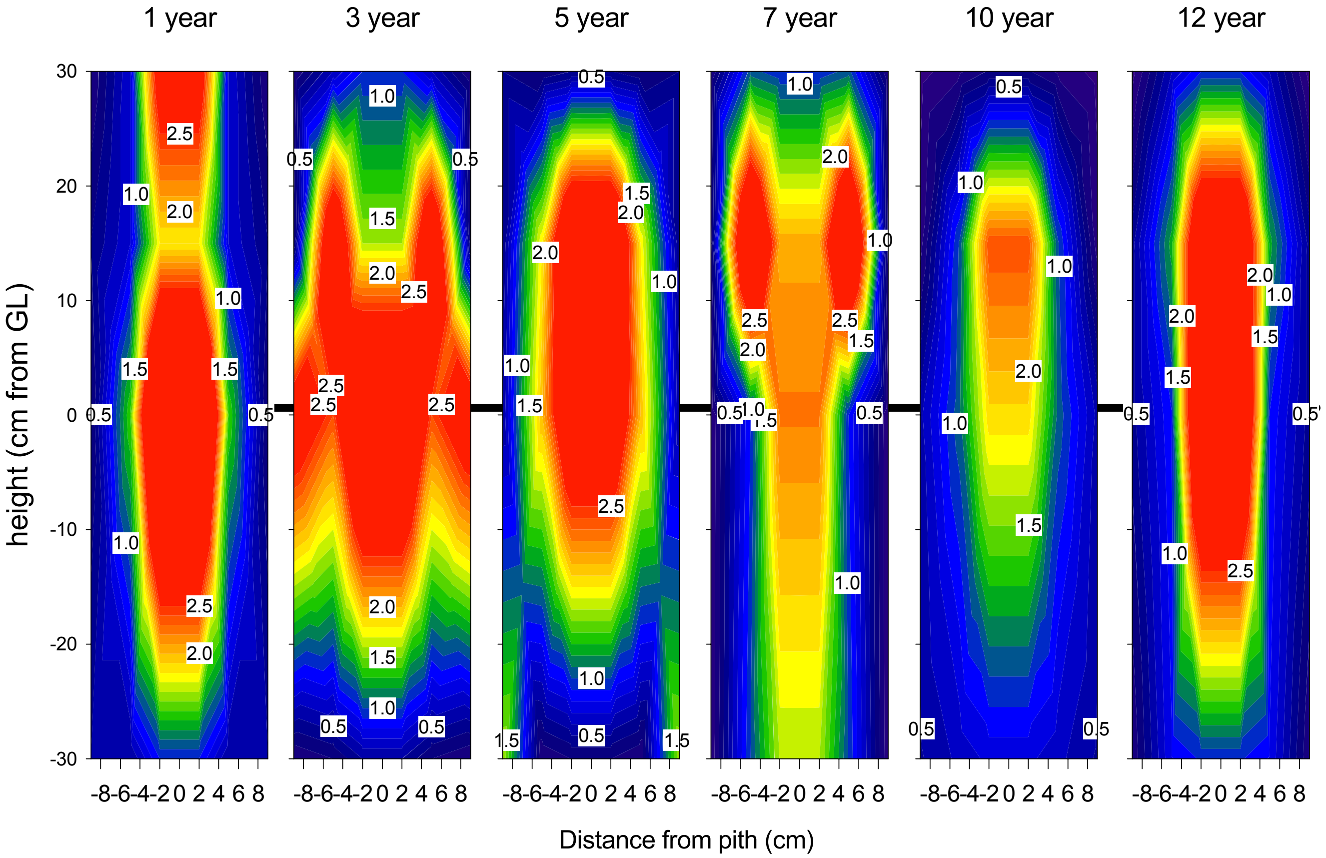


Figure I-17. Boron distribution in Douglas-fir poles 1 to 12 years after treatment with fused boron rods and Boracol 20. Dark blue represent levels below the threshold for protection against fungal attack, while lighter blue, green and orange colors represent increasing boron concentrations in the wood.

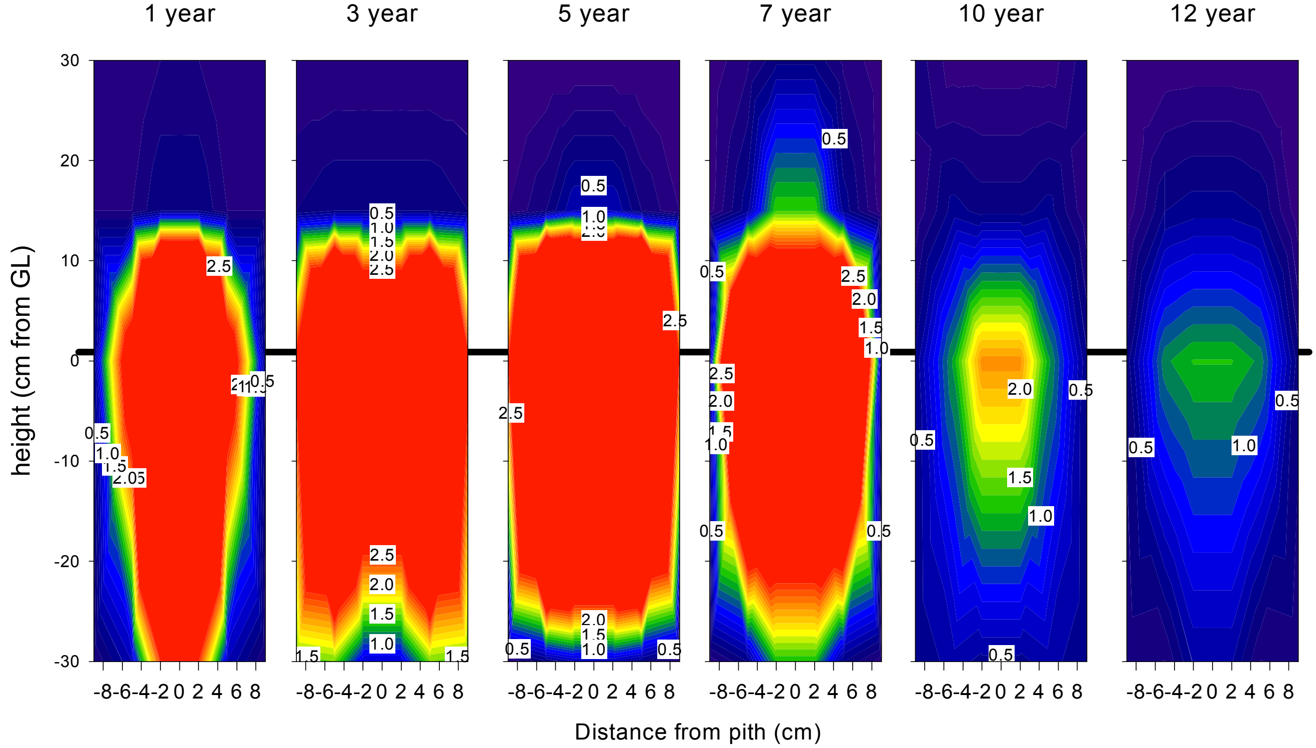


Figure I-18. Boron distribution in Douglas-fir poles 1 to 12 years after treatment with fused boron rods and Boracol 40. Dark blue represent levels below the threshold for protection against fungal attack, while lighter blue, green and orange colors represent increasing boron concentrations in the wood.

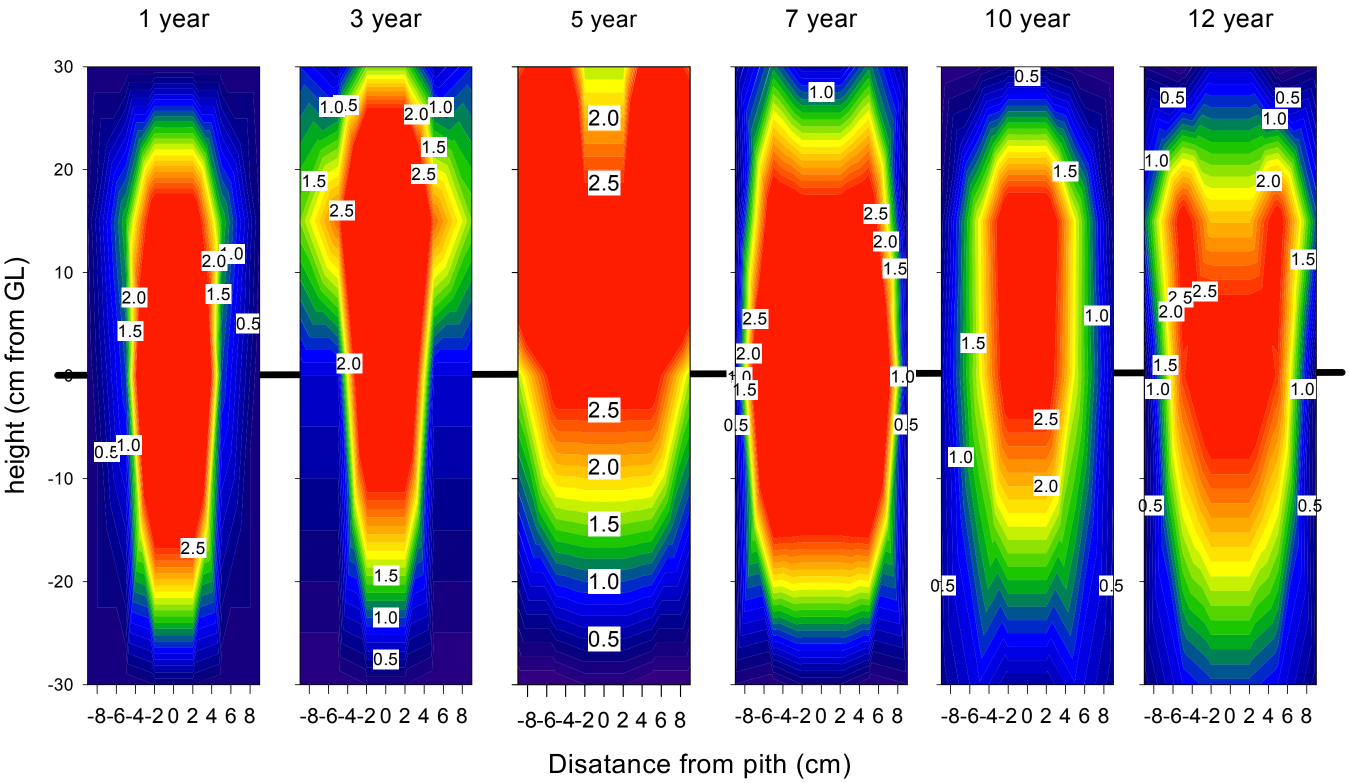


Figure I-19. Boron distribution in Douglas-fir poles 1 to 12 years after treatment with fused boron rods and glycol. Dark blue represent levels below the threshold for protection against fungal attack, while lighter blue, green and orange colors represent increasing boron concentrations in the wood.

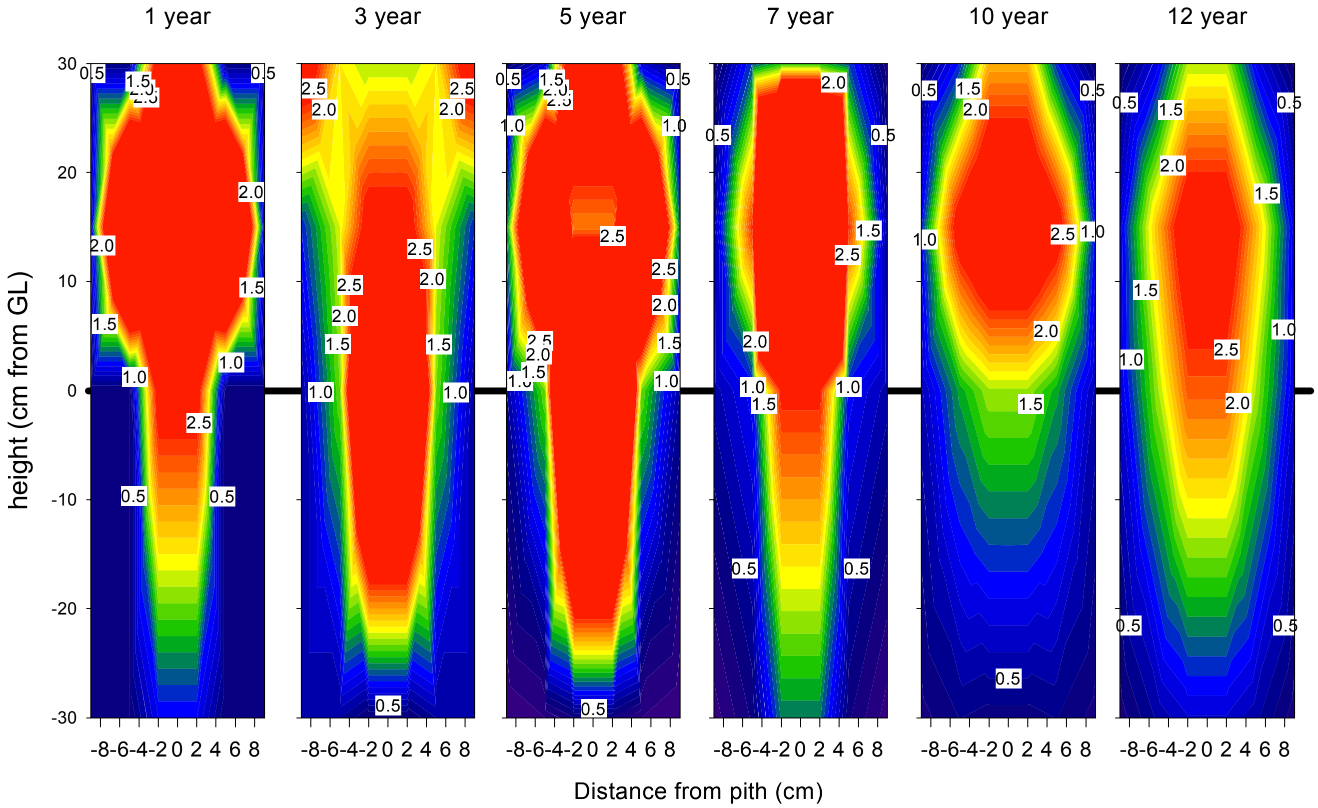


Figure I-20. Boron distribution in Douglas-fir poles 1 to 12 years after treatment with fused boron rods and Timbor solution. Dark blue represent levels below the threshold for protection against fungal attack, while lighter blue, green and orange colors represent increasing boron concentrations in the wood.

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, 86, 74 cm

Fluoride/boron rods are used in Australia for remedial treatment of internal decay in Eucalyptus poles. Although not labeled 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 to non-target organisms 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 upwards 150 mm and around the pole 90 or 120 degrees. A total of 70.5 or 141 g of boron/fluoride rod (3 or 6 rods per pole) was equally distributed among the three holes which were plugged with tight fitting wooden dowels. Each treatment was replicated on five poles.

Chemical movement has assessed 1, 2, 3, 5, 7, 10 and 12 years after treatment. After 12 years boron levels were mostly below the toxic threshold and fluoride levels were low. The poles were not sampled this year but will be inspected in 2008, 15 years after treatment.

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.)	87, 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. 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 were sampled in subsequent years.

Fluoride levels in the poles were assessed by removing increment cores from three equidistant points around the poles 15 cm below groundline as well as 22.5 cm above groundline and 15 cm above the highest treatment hole (45 cm above groundline). The outer treated shell was discarded, and then the remainder of each core was split into inner and outer halves which were combined for a given height prior to being ground to pass a 20 mesh screen. Fluoride levels in the wood were assessed on a blind sample basis by Osmose Utilities Services, Inc. for the first 5 years using AWPA Standard A2 Method 7, then the last three samples at 7, 10 and 12 years were performed by hot water extraction followed by specific ion electrode measurement of fluoride levels in the extract. Trials indicated that these methods produced comparable results.

Fluoride levels in the 6-rod treatments increased at year 2 in the below ground and 22.5 cm sampling zones except in the outer zone below ground (Figure I-21). Fluoride levels further up the poles have remained low for the entire test. Fluoride levels closer to the groundline have varied somewhat. For example, levels 22.5 cm above ground rose sharply in the outer zone after 5 years, then declined again. Fluoride levels in the 3-rod treatments have tended to be much lower; although there was also a spike in levels 5 years after treatment. This increase suggests that moisture regimes were improved during the sampling cycle, thereby enhancing fluoride diffusion. Fluoride levels at the 10 year point are all generally below the threshold for fungal protection except at the inner below ground zone for the 6-rod treatment and the inner and outer zones 22.5 cm above groundline for the 3-rod treatment.

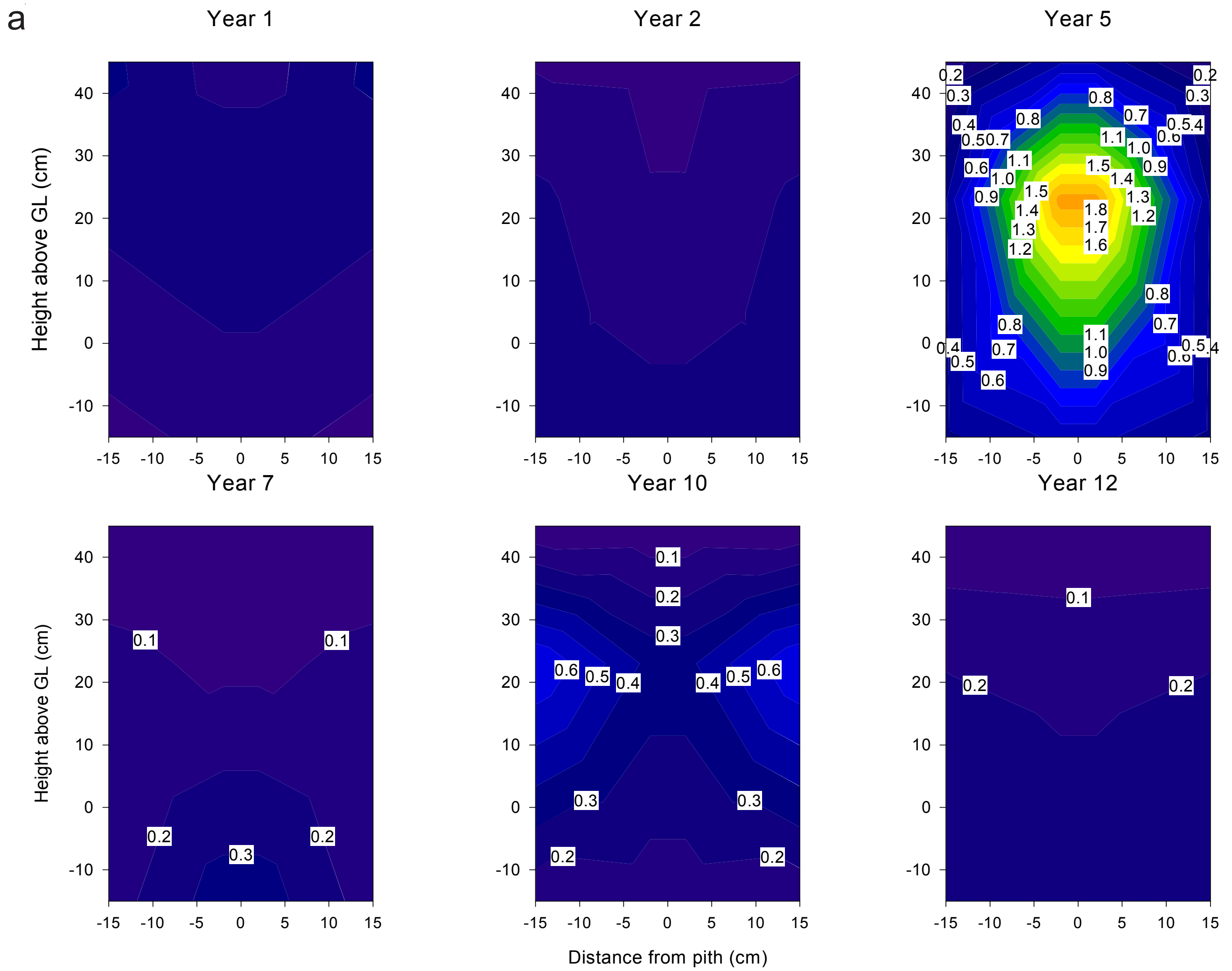


Figure I-21. Fluoride levels at selected heights above or below the groundline of Douglas-fir pole sections 1 to 12 years after application of a) 3 or b) 6 sodium fluoride rods per pole. Lower and upper threshold levels for fluoride for internal decay control are 0.25 and 2.20 kg/m^3, respectively.

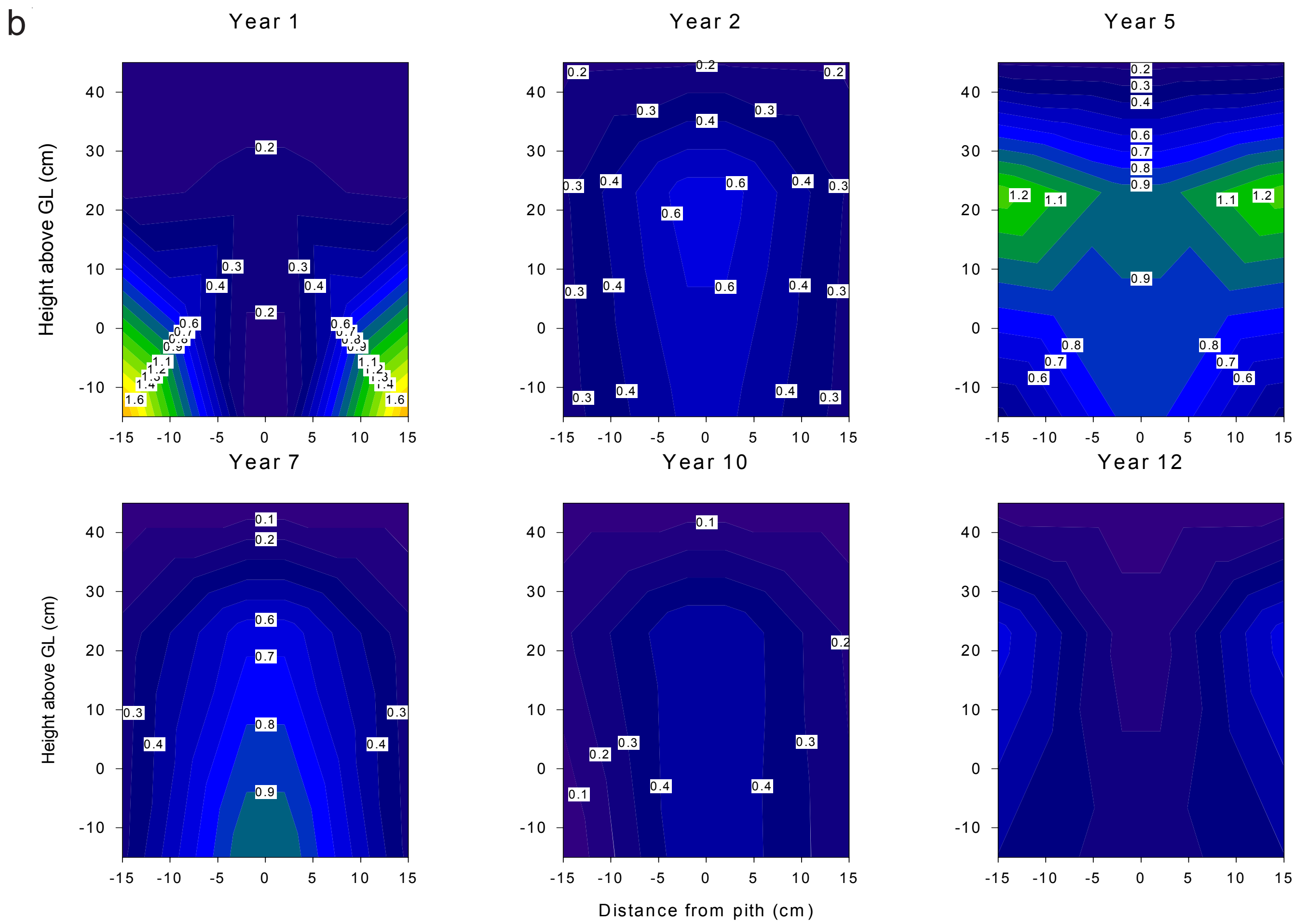


Figure I-21(cont.). Fluoride levels at selected heights above or below the groundline of Douglas-fir pole sections 1 to 12 years after application of a) 3 or b) 6 sodium fluoride rods per pole. Lower and upper threshold levels for fluoride for internal decay control are 0.25 and 2.20 kg/m^3, respectively.

The enhancement in fluoride level with increasing dosage became apparent over time, suggesting that higher fluoride dosages may be beneficial, although they initially appeared to have no benefit. These results differ from those of other diffusible rod tests and will be addressed in a separate study of the effects of rod dosage on moisture conditions around treatment holes.

The overall results still indicate that fluoride, while reaching the lower threshold, does not move at high levels into the wood. In part, these low levels reflect the lower density of the fluoride rods in comparison with the denser fused borate rods. As such, an improved strategy for fluoride rod application would be to use additional holes to more evenly distribute the chemical throughout the wood, although care would need to be taken to ensure that these additional holes do not adversely affect pole properties.

6. Effect of Wood Moisture Content on Boron Movement Through Douglas-fir Heartwood

Boron has a long history of use as an initial treatment of freshly sawn lumber to prevent infestations by various species of powder post beetles in both Europe and New Zealand (Becker, 1976). 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

(Smith and Williams, 1967). Boron is available for remedial treatments in a number of forms, but the most popular are fused borate rods which are available as pure boron or boron plus copper. These rods are produced by heating boron to its molten state, then pouring the molten boron into a mold. The cooled boron rods are easily handled and applied. In theory, the boron is released as the rods come in contact with water.

Boron has been available for remedial treatments for several decades, but widespread use of these systems has only occurred in the last two decades and most of this application has occurred in Europe (Dickinson et al., 1988; Dirol, 1988; Edlund *et al*., 1983). As a result, there is considerable performance data on boron as a remedial treatment on European species, but little data on performance on U.S. species (Dietz and Schmidt, 1988; Freitag *et al*., 2000; Morrell *et al*., 1990; 1992; Morrell and Schneider, 1995, Ruddick and Kundzewicz, 1992; Schneider *et al*., 1993).

Laboratory and field trials with fused boron and fluoride rods suggest that increasing the rod dosage per hole results in lower boron levels in the wood (Morrell and Schneider, 1995). One possible explanation for this effect is that sorption of moisture from the wood surrounding the rod essentially reduces the wood moisture content to the point that the free water needed for diffusion is limiting; however, there are no data demonstrating this effect. In order to assess this potential phenomenon, the following trial was undertaken.

Douglas-fir heartwood (Psuedotsuga menziesii (Mirb) Franco) blocks (50 by 100 by 150 mm long) were oven-dried (105ºC / 24 hours), weighed and then pressure soaked with water. The blocks were then weighed prior to being air-dried to 30, 60, or 90% moisture content (MC). Once each block achieved its target MC, it was dipped in molten paraffin to retard further moisture loss, and then stored at 5ºC to allow for further equilibration.

A 9 mm diameter hole (20 mm deep) was drilled on the narrow face of each block and a single fused borate rod (6.45 g) was added. The treatment hole was sealed with duct tape and the blocks were incubated at room temperature for 7, 30, 90 and 180 days. At each time point, six blocks conditioned to a given MC were removed and sections were sawn immediately adjacent (0-5mm) to the original treatment hole as well as at 5-10 mm and 10-20 mm away from the treatment hole (Figure I-22). These sections

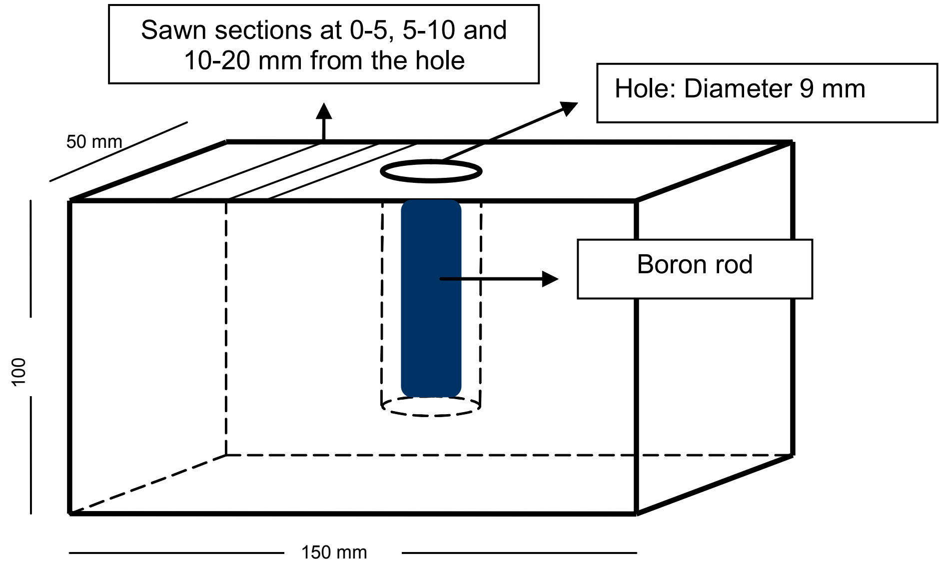


Figure I-22. Representation of a Douglas-fir heartwood block treated with a boron rod.

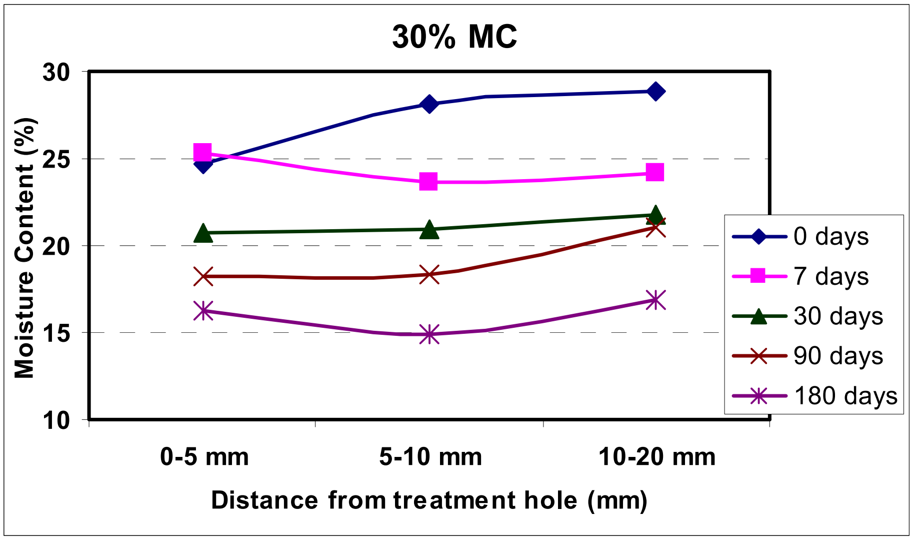
were immediately weighed, oven dried, and weighed again to determine wood MC. The wood was then ground to pass a 20 mesh screen. The sawdust was extracted with hot water. The extract was analyzed for boron using the azomethine H method (American Wood Preserves' Association Standard A2 Method 16, AWPA 2006).

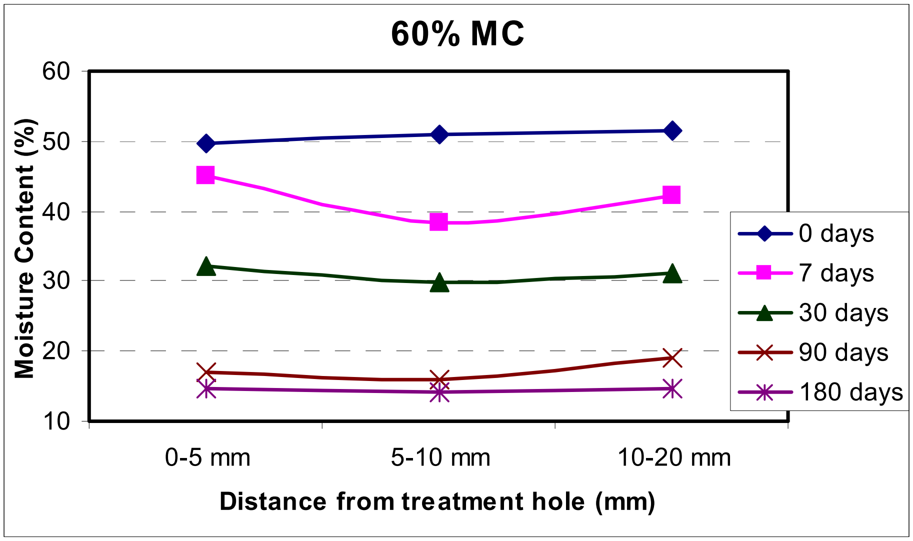
Moisture contents of the blocks were generally lower than the target levels for all three MC. The differences were slight at 30% MC, but became increasingly larger with target moisture level (Table I-10). Moisture contents immediately adjacent to the treatment hole at the time of cutting (0 days) for the 30, 60 and 90% blocks were 24.7, 49.6 and 79.6%, respectively. Moisture levels tended to be slightly higher 5 to 10 mm from the treatment site, but the differences were slight for the 60 and 90% MC blocks. Moisture levels in the 30% MC blocks at the time of treatment were almost one fourth lower than those 5-10 or 10-20 mm from the surface, suggesting that drilling altered the moisture gradient in these blocks (Figure I-23). However, moisture gradients tended to become uniform over time and there was little difference in moisture content 7 days after treatment.

Table I-10. Moisture and boron contents at selected locations away from the treatment zone in Douglas-fir blocks conditioned to 30, 60, or 90% MC and incubated for 0, 7, 30, 90 or 180 days at room temperature.

Incubation Time (days)	Assay Zone (mm)	Wood Moisture Content (%)			Boron Content (% BAE[a]) [a]Boric Acid Equivalent		
		30%	60%	90%	30%	60%	90%
7	0-5	25.3 (5.5)	45.2 (2.7)	68.9 (9.7)	0.94 (0.90)	8.10 (3.73)	12.28 (2.83)
	5-10	23.7 (1.6)	38.3 (6.1)	60.8 (9.2)	0.37 (0.52)	2.49 (2.55)	5.25 (3.83)
	10-20	24.2 (2.3)	42.2 (4.2)	62.0 (6.5)	0.15 (0.26)	0.78 (0.22)	2.45 (1.28)
30	0-5	20.7 (1.0)	32.2 (4.3)	69.1 (7.2)	0.45 (0.27)	4.70 (2.80)	6.22 (4.55)
	5-10	20.9 (1.5)	29.9 (3.3)	68.4 (8.9)	0.13 (0.08)	2.38 (1.55)	5.42 (3.20)
	10-20	21.8 (1.3)	31.1 (4.2)	70.3 (7.2)	0.04 (0.02)	0.91 (0.86)	3.47 (2.31)
90	0-5	18.2 (10.3)	17.0 (3.2)	46.8 (4.7)	2.68 (4.42)	9.19 (6.04)	10.97 (3.13)
	5-10	18.4 (10.5)	16.0 (2.3)	44.3 (4.1)	1.92 (4.08)	4.33 (1.83)	9.19 (2.61)
	10-20	21.1 (11.4)	18.9 (4.3)	50.9 (5.5)	1.15 (2.63)	1.46 (0.52)	5.07 (1.72)
180	0-5	16.3 (1.4)	14.6 (0.5)	56.1 (5.1)	0.90 (0.70)	7.72 (4.07)	8.39 (2.81)
	5-10	14.9 (1.9)	14.1 (0.3)	55.1 (6.6)	0.51 (0.63)	4.98 (2.67)	6.94 (1.13)
	10-20	16.9 (2.3)	14.5 (0.7)	53.3 (7.9)	0.09 (0.06)	2.13 (1.59)	4.44 (2.18)

Moisture levels declined over the 180 day period for blocks at all three moisture contents, reflecting the increased potential for moisture loss through the covered treatment hole (Figure I-24). At the end of the 180 day period, moisture contents for the 30 and 60% MC blocks were below the fiber saturation point, suggesting that free water was no longer available to allow boron to diffuse through wood. Moisture contents dropped more than 30% in blocks originally conditioned to 90% moisture content, but moisture was still available for boron diffusion. Our original hypothesis was that the rods sorbed moisture from the wood surrounding the hole, reducing moisture and then the ability of the boron to diffuse into the wood. If true, we would expect moisture levels around the hole to drop relatively sharply, creating a steep moisture gradient away from the treatment hole. While there were slight negative moisture gradients away from the treatment hole in the 30% MC blocks immediately after treatment, the difference had disappeared 7 days later. There was no evidence that the rod acted to reduce moisture availability around the hole.





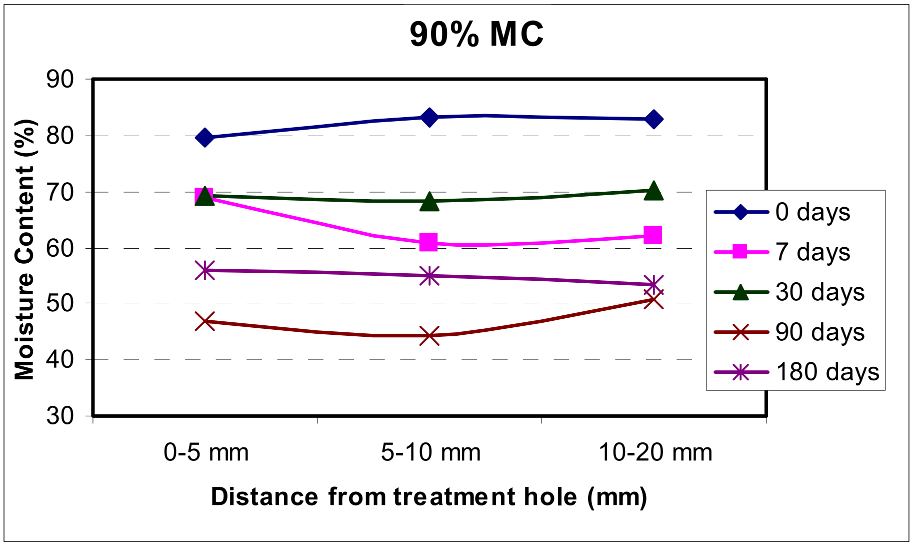


Figure I-23. Moisture content at selected distances from the treatment hole in Douglas-fir heartwood blocks conditioned to 30, 60 or 90 % moisture content and incubated for 0, 7, 30, 90 or 180 days.

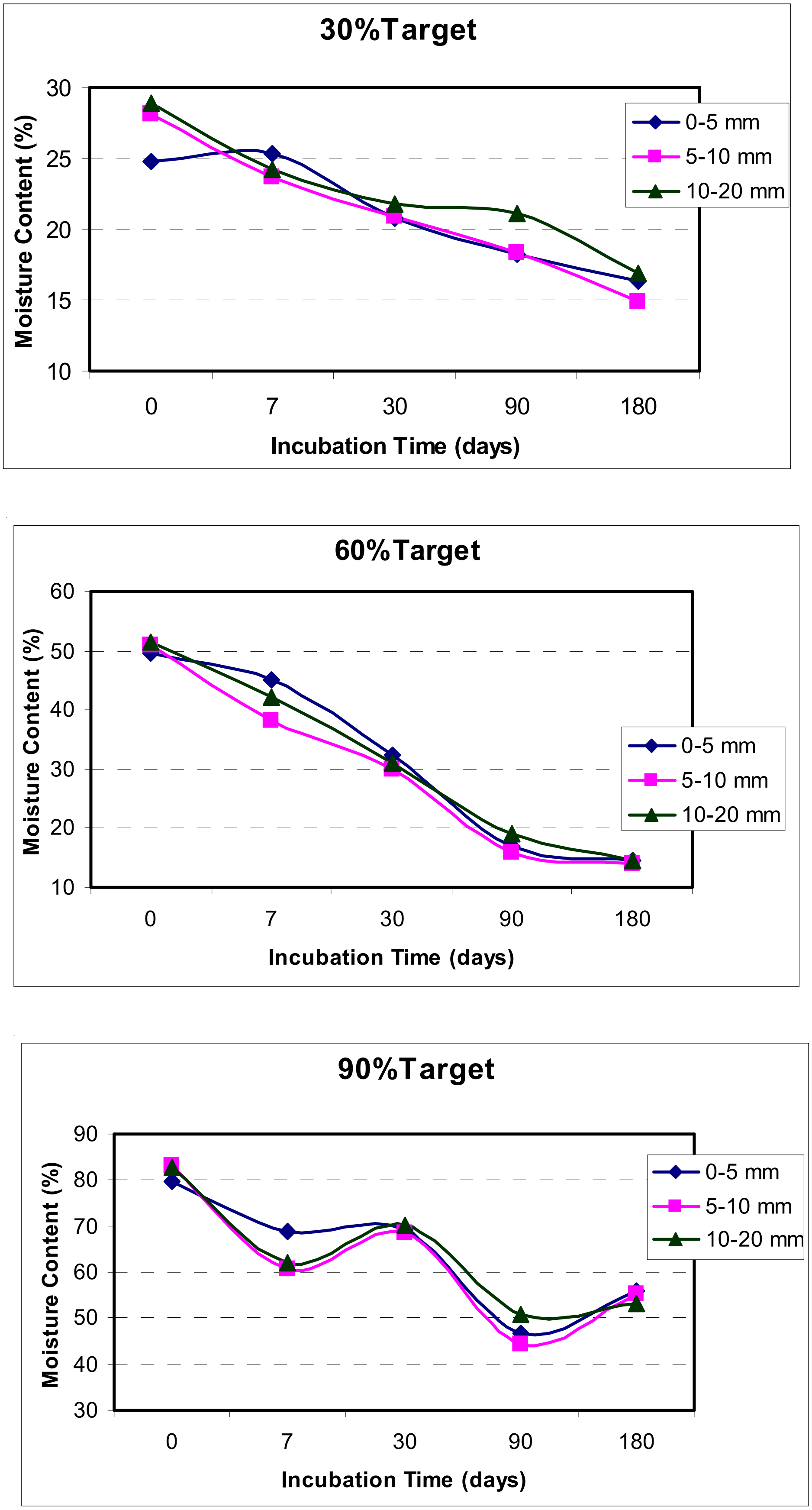


Figure I-24. Moisture losses over time at selected distances from the treatment hole in Douglas-fir heartwood blocks conditioned to 30, 60 or 90 % moisture content and incubated for 0, 7, 30, 90 or 180 days.

Analysis of boron at the same time points showed that boron contents tended to increase with increasing MC as well as with incubation time (Table I-10). Boron levels immediately adjacent to the treatment hole tended to be well above the threshold for protection against internal attack even at 30% MC (Williams and Amburgey, 1987; Freitag and Morrell, 2005). Boron levels were above the threshold at all distances sampled in blocks conditioned to 60 and 90% MC within 7 days after treatment, but remained below threshold 5 to 20 mm away from the treatment site in the 30% MC blocks until the 90 day sampling point (Figure I-25). Boron levels tended to follow consistent concentration gradients with distance away from the treatment hole. Chemical levels tended to be consistently higher in 60 and 90% MC blocks. Since free water is necessary for boron diffusion, this would suggest that sufficient moisture was present in the blocks to allow diffusion to occur at some point in the exposure period, even at the lowest moisture level tested. It is also clear that the rods do not sorb excessive moisture to the point where further movement of boron from the rods is inhibited. This finding still leaves us at a loss to explain the lack of a dose response when increasing amounts of boron are used.

Table I-10. Moisture content of fused boron rods inserted into holes in Douglas-fir blocks conditioned to 30, 60 or 90 % moisture content and incubated for 7 to 90 days.

Wood MC (%)	**Boron Rod Moisture Content (%)[a]**			
	7 Days	**30 Days**	**90 Days**	**180 Days**
30	3.46	4.24	5.91	10.62
60	6.12	22.5	N/A	N/A
90	3.59	N/A	N/A	N/A

[a] Values represent means of 6 rods per moisture content per time point.

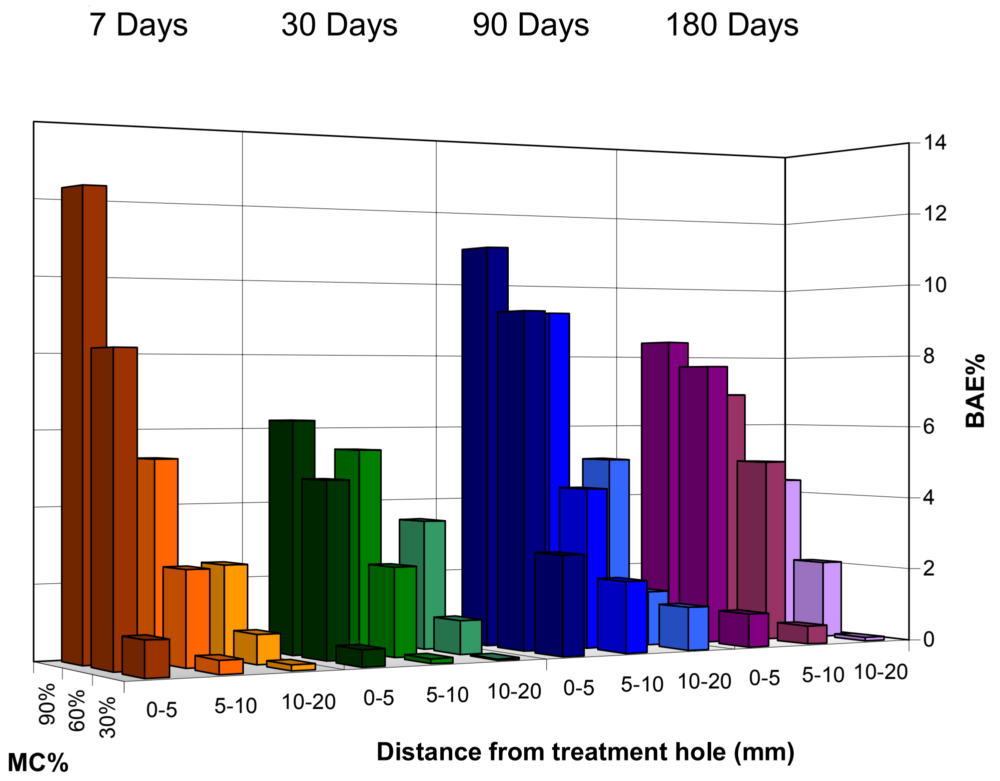


Figure I-25. Boron content at selected distances from the treatment hole in Douglas-fir heartwood blocks conditioned to 30, 60 or 90% moisture content and incubated for 0, 7, 30, 90 or 180 days.

The moisture contents of the boron rods tended to increase over time after application to the wood (Table I-11). Rods in 60 and 90% MC blocks could not be removed after 90 and 30 days, respectively, because they had sorbed moisture to the point where they crumbled when touched. Clearly, the rods had sorbed moisture from the surrounding wood, but the overall effect on wood moisture content was negligible, even immediately adjacent to the hole.

The negative dose-responses observed in field tests with boron rods do not appear to be caused by increased sorption of moisture by the higher rod dosages. Further studies are planned to understand the cause of the dosage effect.

C. Development of a Full Scale Field Trial of All Internal Remedial Treatments

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 sometimes make it difficult to compare data from different trials.

We propose to address this issue by establishing a single large scale test of all the EPA registered internal remedial treatments at our Corvallis test site.

Pentachlorophenol treated Douglas-fir pole stubs (280-300 mm in diameter by 2.1 m long) will be set to a depth of 0.6 m. Three steeply sloping treatment holes (19 mm x 350 mm long) will be drilled into the poles beginning at groundline and moving upward 150 mm and around the pole 120 degrees. For fumigant treatments four holes will be drilled in a similar manner. The various remedial treatments will be added to the holes at the recommended dosage for a pole of this diameter, along with any recommended additive, and then the holes will be plugged with plastic plugs. Each treatment will be replicated on five poles.

The proposed treatments include:

- Durafume
- MITC Fume
- SuperFume
- TimberFume
- Ultra Fume
- SMDC Fume
- Wood Fume
- Pol Fume
- Cobra rods
- Impel rods
- FluRods
- PoleSaver rods
- Dazomet rods

Chemical movement in the poles will be assessed 1, 2, 3, and 5 years after treatment by removing increment cores from three equidistant sites beginning 150 mm below ground, then 0, 300, 450, 600 and 900 mm above groundline. The outer, preservative-treated shell will be removed, and then the outer and inner 25 mm of each core will be retained for chemical analysis using a method that is appropriate for the treatment. We recognize that some treatments will not move completely through the assay zone and we will tailor our analyses to reflect this reality. The remainder of each core will be plated on malt extract agar and observed for fungal growth.

The results will be reported in the Annual Report for discussion. Ultimately, this data would also be published in peer reviewed journals.

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

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

A. Evaluate Treatments for Protecting Field Drilled Bolt Holes

The test to evaluate field drilled bolt holes was inspected in 2002 after 20 years of exposure. This test is largely completed, although some follow-up inspection to assess residual chemical levels around bolts in specific poles is planned.

B. Develop Methods for Ensuring Compliance With Requirements for Protecting Field-Damage to Treated Wood.

Date Established:	March 2001
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @ GL (range)	102 to 123 cm

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 person nel 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 potential for 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. Penetration was measured as average distance up or down from the bolt.

In the field trial, threaded galvanized rods were coated similarly with either copper naphthenate plus sodium fluoride (Cop-R-Plastic) or copper naphthenate plus sodium tetraborate decahydrate (CuRap 20) pastes and installed in Douglas-fir pole sections at our field site near Corvallis, Oregon in 2001. This past year, we removed four pole stubs containing each of the two treatments from our field site for sampling. The threaded rods were removed (Figures II-1, 2) and then the poles were sawn lengthwise through the holes so that we could assess chemical distribution around each rod. Copper was detected both visually and by spraying the cut surface with chrome azurol S.

Figure II-1. Condition of Cop-R-Plastic coated galvanized threaded rods after six years exposure in Douglas-fir pentachlorophenol treated pole stubs.

Figure II-2. Condition of CuRap 20 coated galvanized threaded rods after six years exposure in Douglas-fir pentachlorophenol treated pole stubs.

Copper penetration longitudinally away from the bolt holes has been limited over the 6 year test (Table II-1). Average copper penetration for the Cop-R-Plastic treated rods was 2.3 mm after 6 years, while that around the CuRap 20 treated bolts was 8.3 mm (Figures II-3, 4). The copper in both systems was not designed to be mobile and these results reflect that limited ability to migrate.

Table II-1. Penetration of copper, boron or fluoride around chemically treated threaded galvanized rods inserted in Douglas-fir pole sections and exposed in the field for 1 to 6 years.

Treatment	Diffusion	Degree of Chemical Movement (mm)[a]									
		Copper					Boron/Fluoride				
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 6	Yr 1	Yr 2	Yr 3	Yr 4	Yr 6
Cop-R-Plastic	Average	<1	2.3 (1.3)	3.0 (0.8	2.3 (1.0)	2.3 (0.5)	<1	2.0 (2.8)	2.0 (1.8)	7.0 (4.7)	7.3 (3.1)
	Maximum	29.8 (28.8)	237.5 (64.0)	50.5 (47.5)	8.8 (3.2)	7.0 (5.6)	117.5 (138.7)	107.5 (73.7)	15.3 (16.9)	28.3 (18.0)	15.5 (5.4)
CuRap 20	Average	3.0 (1.2)	2.3 (0.5)	<1	1.0 (0.8)	8.3 (11.8)	3.3 (0.5)	6.3 (3.4)	2.8 (2.2)	20.3 (16.1)	12.5 (6.7)
	Maximum	20.5 (9.7)	110.3 (98.3)	51.3 (52.5)	7.3 (9.0)	18.0 (19.8)	49.8 (10.5)	45.8 (28.5)	49.5 (55.1)	118.8 (69.4)	30.0 (29.5)

[a] Values represent the average of four rods per treatment.

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 6 year test period. Although maximum penetration was up to 119 mm from the rods, mean fluoride and boron penetration were only 7.3 and 12.5 mm, respectively(Figures II-3, 4). The results were perplexing, but may reflect the relatively tight fit of the rods.

The results, to date, show that the coated rods can deliver chemicals to a small area around the treatment hole. These results, coupled with previous trials of boron and fluoride sprays into field drilled bolt

Figure II-3. Degree of copper and fluoride movement away from the sites in Douglas-fir pole stubs where Cop-R-Plastic coated galvanized threaded rods were installed six years earlier. Yellow indicates the presence of fluoride and green-blue indicates the presence of copper.

Figure II-4. Degree of copper and boron movement away from the sites in Douglas-fir pole stubs where CuRap 20 coated galvanized threaded rods were installed six years earlier. Red indicates the presence of boron and blue-green indicates the presence of copper.

holes, suggest that treated bolts may represent one method for ensuring that field drilled wood is protected. This approach would allow utilities to specify specific treated bolts when other utilities (telecommunications and cable companies, for example) occupy portions of the pole and must field drill for attachments, allowing utilities to minimize the risk of decay in field drilled holes above the ground.

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. This type of treatment could be used to limit the potential for above ground decay, allowing utilities to continue to gain the benefits afforded by aggressive groundline maintenance.

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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

Over the past 4 years, we have performed an extensive series of laboratory and field trials to assess the effects of through-boring in the groundline on the properties of Douglas-fir poles. These studies have shown that through-boring with holes less than or equal to 12.5 mm in diameter has no significant negative effect on pole bending strength. This past year, we assembled all of the available data on through-boring and its effect on strength and submitted this information to the American National Standards Institute Sub-committee 05.1. In addition, we worked with Bonneville Power Administration, Southern California Edison, Portland General Electric and McFarland-Cascade to identify a single pattern that could be included in an ANSI standard.

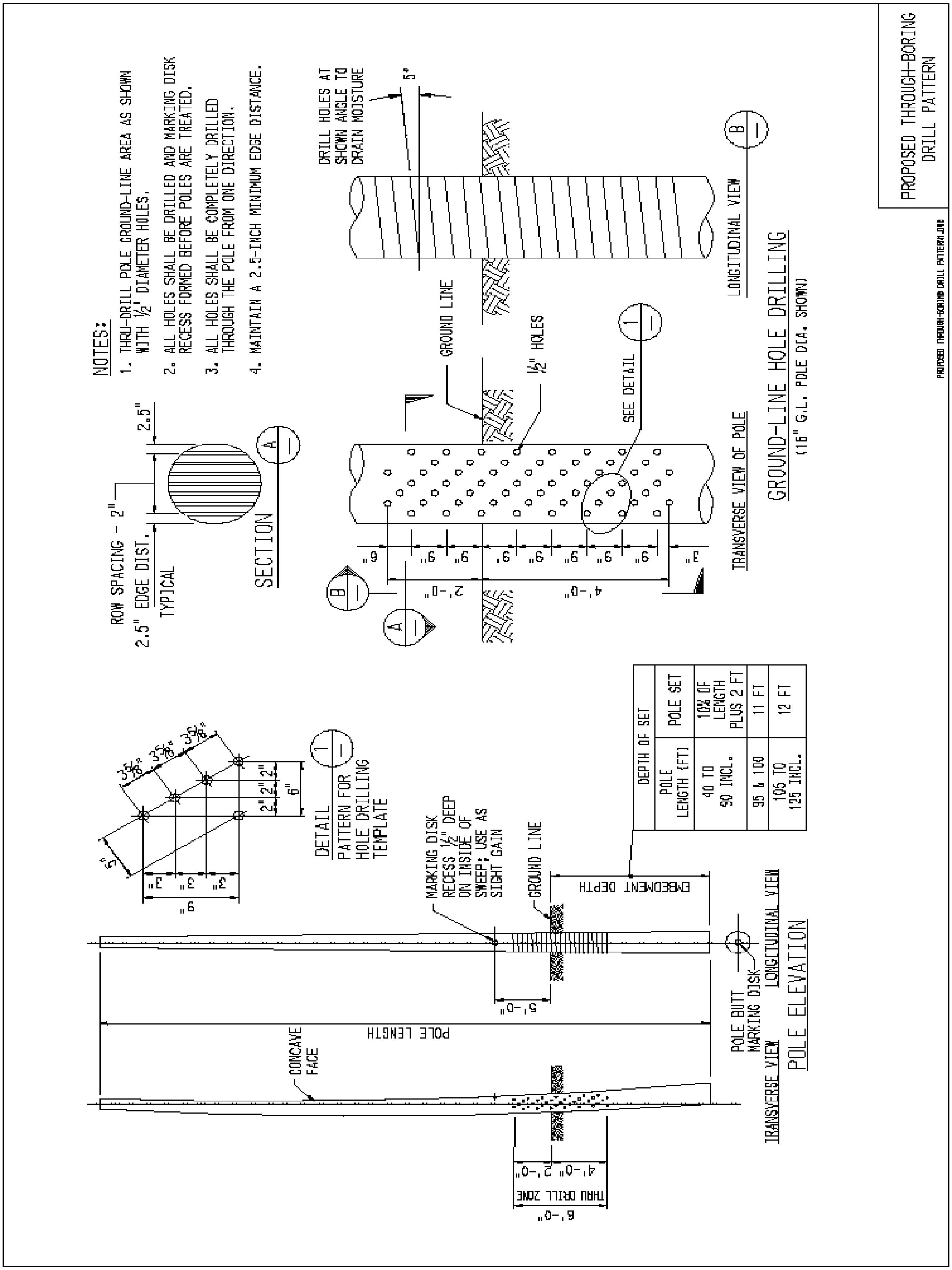
The resulting pattern takes advantage of the information produced in the finite element analysis to move holes a minimum of 2.5 inches inward from the pole edge and uses the spacing patterns identified in both the finite element modeling and the subsequent field tests with a 12.5 mm diameter hole size (Figure III-1)

As proposed, the through-boring specification would be as follows:

Scope: This annex covers the background, purposes and methods for using through-boring to improve preservative treatment of Douglas-fir poles

Background: Douglas-fir poles have thin treatable sapwood surrounding a difficult to treat heartwood core. This heartwood core can be exposed to possible fungal or insect attack as a result of checks that develop after treatment. This internal deterioration can eventually shorten pole service life. Through-boring is used to improve the treatment of critical zones of the pole, notably at or near the groundline, but also in the crossarm region.

Through-boring region: Pole shall be through-bored a minimum of 2 feet above and below the expected groundline. This zone can be extended either up or downward depending on the decay risks. Zones extend downward up to 4 feet below groundline in drier areas and upward 3 to 4 feet in wetter areas.**Hole Size:** Extensive testing has shown that holes sizes up to 0.5 inches in diameter can be used with no significant effect on pole bending strength. While smaller diameter holes can be used, they tend to lead to bit breakage and slower drilling.



NOTES:

1. THRU-DRILL POLE GROUND-LINE AREA AS SHOWN WITH ½" DIAMETER HOLES.
2. ALL HOLES SHALL BE DRILLED AND MARKING DISK RECESS FORMED BEFORE POLES ARE TREATED.
3. ALL HOLES SHALL BE COMPLETELY DRILLED THROUGH THE POLE FROM ONE DIRECTION.
4. MAINTAIN A 2.5-INCH MINIMUM EDGE DISTANCE.

DEPTH OF SET	
POLE LENGTH (FT)	POLE SET
40 TO 90 INCL.	10% OF LENGTH PLUS 2 FT
95 & 100	11 FT
105 TO 125 INCL.	12 FT

Figure III-1. Proposed pattern for through-boring of Douglas-fir poles.

Hole locations: Holes shall be drilled on the pole face intended to be in the line direction. As shown in Figure I-1, holes shall be at least 2.5 inches inward from either edge of the pole. Holes shall be drilled with a slight downward slope to allow for drainage (3 to 5 degrees).

Treatment: The results of treatment shall be assessed by taking an increment core from the zone between two longitudinally spaced holes. Preservative penetration shall be assessed visually or by using the appropriate indicator. Penetration must be complete in the outer 2 inches. Up to two annual rings may be untreated in the remainder of the core. Preservative retention in the through-bored zone shall be assessed in the usual 0.25 to 1.0 inch assay zone, but a second assay shall also be taken 2.0 to 2.5 inches inward from the surface. Retention in this zone shall be a minimum of one half of that in the outer assay zone.

B. Ability of External Pole Barriers to Limit Moisture Ingress into Copper Naphthenate and Pentachlorophenol Treated Western Redcedar Poles

Preservative treatment is a remarkably effective barrier against biological attack, but these same chemicals also remain 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 structure and that the levels present do not pose a hazard in terms of environmental impact or disposal. Despite these data, some utilities have explored the use of external barriers to contain any migrating preservative. These barriers, while not necessary in terms of environmental issues, may have a secondary benefit in terms of both retaining the original chemical and limiting the entry of moisture and fungi. The potential for barriers to limit moisture uptake in poles was assessed in a trial where pole sections with two different barriers were installed in either soil or water. The poles were maintained indoors and were not subjected to overhead watering. The results showed that considerable moisture wicked up poles in this exposure and moisture contents at groundline were suitable for decay development, even with the barriers. These poles have now been moved to our field test site, where we will continue to monitor moisture content seasonally, but this time the poles will be subjected to both soil and overhead moisture intrusion.

In addition, we had an opportunity to assess the condition of poles in service that had received the BioTrans liners. The poles were located in the Seattle City Light system and all were butt-treated with copper naphthenate. One pole had been installed in 1999, while the remainder had been installed in 2005 and 2006. Ten poles installed between 2005 and 2006 were sampled by removing increment cores from below the groundline at three equidistant points around the pole. The cores were divided into zones corresponding to 0 to 7 mm, 25 to 50 mm and 50-75 mm in from the surface. Moisture content was determined by weighing cores before and after oven drying. The resulting moisture values were averaged by depth for the ten poles. The remaining 7 to 25 mm segment of each core was retained for analysis of copper by x-ray fluorescence spectroscopy.

Moisture content in the zone immediately adjacent to the surface was 47%, reflecting the season of sampling (Table III-1). Moisture levels in this zone did vary widely from 20 to 63%. Moisture levels 25 to50 mm and 50 to 75 mm inward from the pole surface averaged 24.8 and 23.6% respectively and the overall moisture values tended to be more uniform among the poles. The sharp decline in moisture content with distance from the surface is not surprising.

In addition to the ten recently installed poles that were sampled, one pole installed in 1999 was also inspected. Moisture contents in this pole were extremely high, ranging from 167% in the outer 7 mm to 110.9% in the inner zone (Table III-2). The high moisture contents in this pole were surprising, but we have found similarly high moisture contents in cedar poles sampled near Corvallis. In the latter case, the poles were much older. Western redcedar, despite it excellent naturally durability, does tend to sorb water extremely quickly and this may account for the exceptionally high moisture readings obtained with this pole.

Table III-1. Moisture contents at selected distances from the surface of western redcedar poles with BioTrans field liners installed in 2005-2006.

Distance from Surface (mm)	Moisture content (%)[a]
0-7	47.0 (20.7)
25-50	24.8 (13.2)
50-75	23.6 (14.6)

[a]Values represent means of 30 values, while figures in parentheses represent one standard deviation.

Table III- 2. Moisture contents at selected distances from the surface of a western redcedar pole with a BioTrans field liner installed in 1999.

Distance from Surface (mm)	Moisture content (%)[a]
0-7	167.3 (41.1)
25-50	137.6 (20.2)
50-75	110.9 (10.1)

[a]Values represent means of three values, while figures in parentheses represent one standard deviation

The AWPA Standards require a minimum of 13 mm of penetration or 100% of the sapwood in western redcedar and a minimum of 1.92 kg/m^3 of copper naphthenate (as Cu) in the assay zone. Penetration was acceptable for all but two poles, while retention was acceptable for 8 of 11 poles (Table III-3). The two poles with lower penetration also had lower retentions, which was not unexpected since the assay zones included untreated wood. The low retention in the other pole was near the required level (1.7 vs. 1.92 kg/m^3). These values should be viewed with caution since assays are not normally conducted on individual poles, but rather a batch. As a result, some poles will invariably contain slightly less than the required amount while others will contain more. Overall copper levels easily met the required retention for the ten newer poles. Copper levels in the older pole were well above the minimum requirements. The results indicate that the poles are well treated.

Table III-3. Mean retention and penetration of copper naphthenate in BioTrans wrapped western redcedar poles.

Pole	Retention (kg/m^3)[a]	Penetration (mm)
1	2.19	25.7 (5.7)
2	1.71	21.3 (19.1)
3	2.51	29.7 (6.50
4	2.27	43.7 (10.7)
5	2.03	30.2 (11.4)
6	2.36	41.2 (6.3)
7	3.49	67.0 (6.7)
8	0.92	6.7 (2.8)
9	0.91	5.7 (1.5)
10	2.50	16.5 (8.1)
11 (1999)	6.75	18.3 (2.3)

[a]The minimum retention for western redcedar is 1.92 kg/m^3 as copper

In addition to the pole barriers, we have installed a second test on barriers using a product called Post-Saver. As the name implies, Post-Saver was originally designed for posts, but it could also be used for poles. We installed a series of posts with and without preservative treatment 3 years ago and have been periodically monitoring moisture content of the various treatments. In addition, we have been assessing the condition of the external barrier; however, given the short time period of the test, there has been little or no effect on the barrier condition.

The posts were sampled in May near the end of our wet season. Increment cores were taken from selected posts 300 mm above groundline, at groundline and 150 mm below the groundline. The groundline sample was 50 mm below the top of the barrier. The core locations were plugged with treated wood plugs after sampling and the plugs were covered with a special patch material (Seal-Fast Tape, Mule-Hide Products Co., Inc., Beloit, WI) to avoid future moisture ingress through the sampling sites. The cores were divided into inner and outer zones, each approximately 25 mm long. Each half was weighed, and then oven dried and weighed again to determine wood moisture content.

Moisture contents below ground ranged from 25 to 72% (Table III-4). The higher moisture levels were found in the untreated posts with a barrier. The lowest moisture levels were found in copper azole treated southern pine posts and ACQ treated spruce posts. Boron treated posts tended to have elevated moisture levels below ground. Moisture levels in the outer and inner zones tended to be similar for a given treatment which was not surprising given the small size of the posts (nominal 4 inch). Moisture contents 300 mm above the groundline tended to be much lower than levels at the groundline. The lower moisture levels at this height probably reflect the ability of the posts to dry between rain events.

The results indicate that moisture contents do differ within the barrier systems based upon the initial treatment applied, though it is unclear at this point if these moisture differences will affect performance.

Table III-4. Wood moisture contents above and below groundline in posts of various species protected with an external barrier and exposed at a field test site located near Corvallis, Oregon.

Treatment	Species	Height Above GL	Moisture content (%)[a]	
		(mm)	Inner 25 mm	Outer 25 mm
Assumed None	SYP	-150	44.6	42.7
		0	44.1	33.5
		300	22.2	16.7
Boron - above ground exposure	SYP	-150	47.1	50.9
		0	51.3	44.7
		300	21.2	19.9
ACQ 0.25	SYP #1	-150	37.6	36.6
		0	37.2	31.2
		300	21.8	18.3
Unknown	SYP	-150	30.7	31.2
		0	26.8	25.8
		300	21.6	21.1
NON-FOR Boron	SYP #1	-150	58.7	52.1
		0	52.0	41.9
		300	40.0	20.0
ACQ 0.25, Incised	Spruce-fir #2	-150	26.9	25.6
		0	28.0	26.8
		300	21.9	23.7
Non-treated	SYP #1	-150	72.3	57.2
		0	60.5	48.7
		300	30.2	20.2
0.21 pcf CA-B	SYP	-150	25.6	24.2
		0	27.5	24.5
		300	22.2	21.8

[a] Values represent the average of five cores

C. Performance of Fire Retardants on Douglas-fir poles

Transmission lines, 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 acted to trap 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. In order to develop this information, the following test was initiated.

Douglas-fir pole sections (200-300 mm in diameter by 1.4 m long) that had been removed from service were set in the ground to a depth of 0.6 m at our Peavy Arboretum test site. The poles were allowed to weather for approximately 8 months. The poles were allocated into treatment groups of six or nine poles each. Each set of poles received one of the following treatments, either applied by the manufacturer or according to the manufacturer’s instructions:

1. Osmose Fire-Guard
2. CuRap 20 as a below-ground treatment
3. J.H. Baxter Elastomeric Epoxy Roof Coating
4. No treatment

Late spring and early fall rains have produced unsuitable conditions for a test burn this past year. We intend to assess residual fire retardancy on these materials this coming spring as conditions allow.

D. Effect of End Plates on Checking of Douglas-fir Cross arms

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

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

Thirteen pentachlorophenol treated Douglas-fir cross arm sections (87.5 mm by 112.5 mm by 1.2 m) long were end-plated on both ends then cut in half to leave one plated end and one non-plated end on each arm (Figure III-2). The objective was to compare checking with and without plates on comparable wood samples. The plates were developed by Brooks Manufacturing (Bellingham, WA). The arms were initially examined for the presence of checks. The arms were then immersed in water for 30 days before being removed and assessed for check development. The total number of checks longer than 2.5 cm on each face was recorded, and the width of the widest check on each face was measured. The arm sections were air dried and measurements were made again. The arms were then returned to the water tank for an additional 30 days before the cycle was repeated. The arms were air dried in the first cycle, then kiln dried for the remaining six cycles.

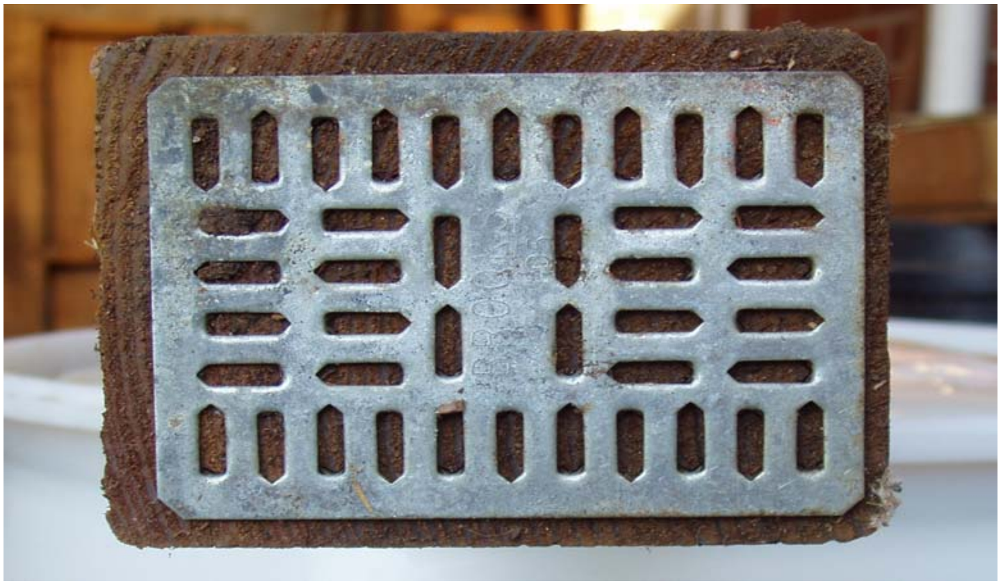


Figure III-2. Example of an end-plate on a penta treated Douglas-fir cross arm.

Check measurements tended to vary over time, reflecting the tendency for different checks to open in different cycles (Table III-5). As a result, the average number of checks per arm was sometimes greater on non-plated ends, and then reversed at the end of the next cycle. Check width varied widely, even on opposite ends of the same arm. The mean number of checks per arm increased sharply from 0.50 to 2.00 per arm on non-plated ends after six wet/dry cycles. The number of checks on plated arms decreased slightly after 6 wet dry cycles, then increased sharply after the seventh cycle to 2.0 checks per arm.

The continued wet/dry cycles have also begun to affect the width of checks on the arms (Table III-5). Mean check widths were similar for plated and non-plated ends after the sixth cycle (1.3 mm vs. 1.2 mm wide, respectively), but the differences increased sharply after the seventh cycle (2.24 vs. 1.44 mm, for non-plated vs. plated ends). In addition, the maximum check width was 3.6 mm for the non-plated vs. 2.1 mm for the plated end. These results suggest that the plates have begun to affect the rate and extension

Table III-5. Degree of checking on penta treated Douglas-fir cross arm sections with and without end plates.

Number of Wet/Dry Cycles	Check Frequency (#/arm) [a]		Maximum check width (mm)	
	No Endplate	Endplate	No Endplate	Endplate
3	1.12	0.50	0.83	0.95
4	0.25	0.25	0.81	1.06
5	0.50	0.96	0.74	0.76
6	2.00	0.36	2.50	2.00
7	2.24	2.00	3.60	2.10

[a] Values represent means of 25 arms per treatment

of check development. Unfortunately, none of the arms selected had severe check development, making it difficult to extend the results to truly severely checked samples; however, these systems are similar to the end-plates used on railroad ties. Tie end-plates are routinely used to control splitting on ties and have resulted in the use of millions of ties that would formerly have been relegated to use as industrial ties with much lower value.

The results after seven wet/dry cycles indicate that the end-plates are beginning to show an effect on checking and might be useful for limiting such defects in service. Given the high cost for changing out arms, they may be a prudent tool for improving the performance of wood crossarms.

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

The susceptibility of Douglas-fir to internal decay at groundline is well documented and can be easily rectified by through boring. In many locations, however, Douglas-fir poles can also develop internal decay well above the groundline. This is particularly true in areas which experience wind-driven rainfall such as those regions along the Oregon and Washington coasts. The extent of this damage and the ability to accurately assess the impact on pole properties varies. This past year, we were fortunate to gain access to a series of Douglas-fir transmission poles that had been installed in 1982 in the Consumers Power, Inc. system in Western Oregon. The poles were pentachlorophenol treated Class 1 to 2 poles between 65 and 80 feet long. An above ground inspection revealed that approximately 25% of the poles in the line were decayed and needed replacement. A number of these poles also had evidence of buprestid beetle attack, suggesting that they had not been properly treated at the time of installation (i.e. they had not been sterilized). There is debate among treaters and utilities concerning the ability of the golden buprestid beetle to invade finished products. Generally, this beetle only attacks freshly fallen trees that retain their bark. When adult exit holes are found on poles, it is generally assumed that the larvae survived the treatment process, but some observers have suggested that the beetle could also infest in-service poles through checks that extended past the original treatment zone.

Several years ago, we surveyed Douglas-fir poles in the Bonneville Power Administration (BPA) system in the same region to determine the level of beetle incidence on their poles. BPA has an extensive heating requirement that should preclude beetle survival and we found little evidence that beetles survive the treatment process. Nor did we see evidence that buprestid beetles were invading in-service poles. However, we also could not disprove the possibility. In this trial, Consumers Power, Inc. personnel agreed to remove the poles in marked sections so that we could reconstruct defect locations, including the pathways of the beetle larvae. We were also fortunate to have access to a portable band saw that allowed us to dissect the poles and map internal defects. This project is still underway but we will provide preliminary information herein.

The pole sections removed from the field were cut into 8 foot long sections and these were transported to our laboratory. These sections were then sliced longitudinally into 1 to 2 inch thick slabs. Slabs were marked so that we can track them through the process and selected slabs with interesting defects were photographed. Once we have a sufficient number of slabs, we will scan the surfaces and use these images to map defects. We will then work with the Wood Science and Engineering Wood Processing group to reassemble the images and produce three dimensional images of the defects. This will allow us to then quantify the extent of a given defect. The results can then be used to assess the effects of the defect on pole properties when the defect is positioned at various sites along a pole.

The poles sampled to date have a number of defects including obvious internal decay (Figure III-3). Most notable was the presence of buprestid attack in a number of locations and some woodpecker attack. As

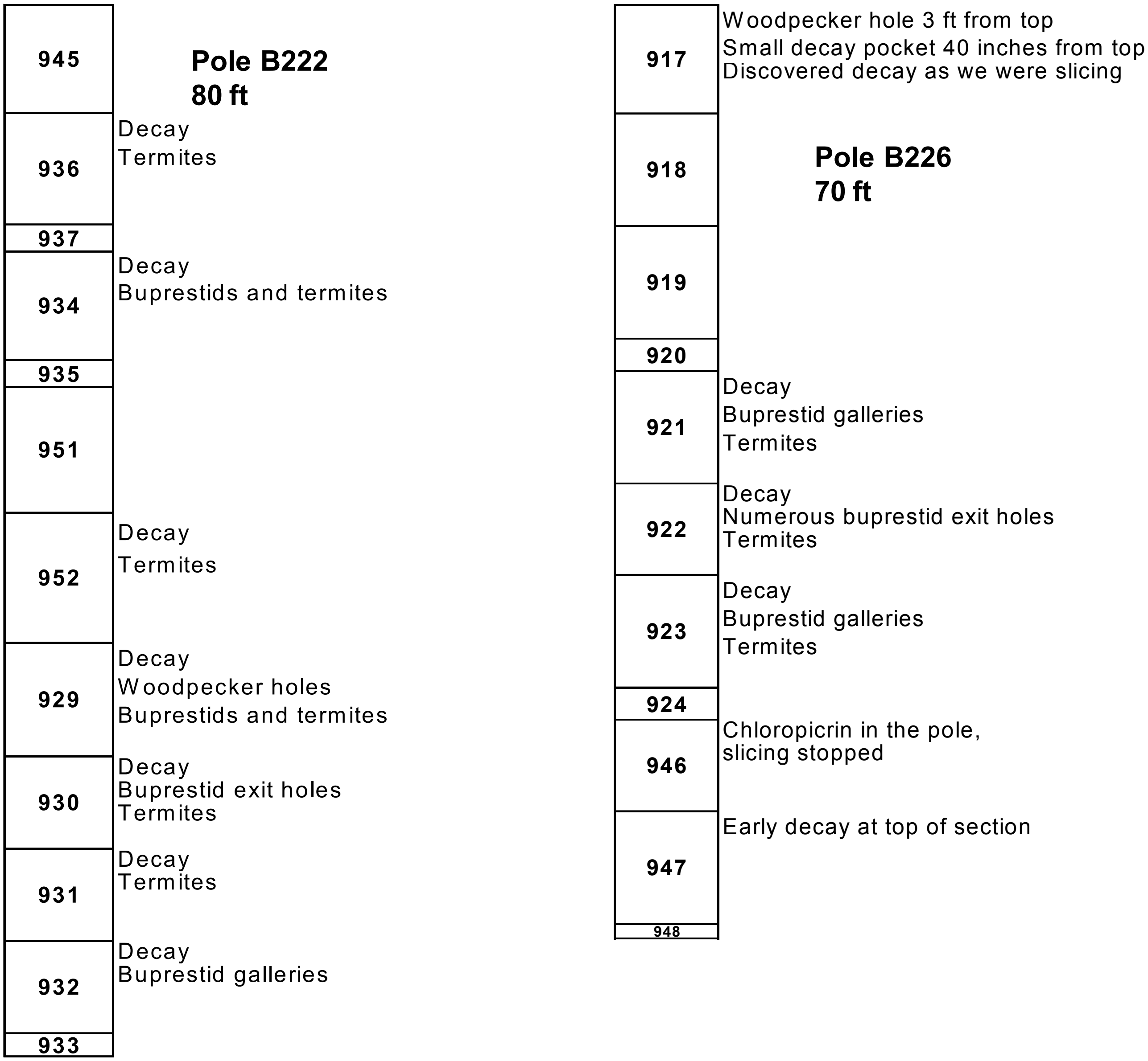


Figure III-3. Schematics of two Douglas-fir poles showing total pole length along with locations of major defects found in each dissected section.

we have cut the poles, we have noted first, the extensive damage associated with woodpecker galleries. Often a single hole is connected to a decay pocket extending 3 or more feet downward from the opening (Figure III-4).

In addition, we often find evidence of buprestid attack in the woodpecker area. The attack appears to precede woodpecker attack, suggesting that the bird might have excavated in search of the larvae. In addition, we have generally found dampwood termite galleries associated with these defects (Figure III-5). This finding was most surprising because the defects were sometimes located 20 to 40 feet above the groundline. Dampwood termites, as their name implies, require very wet wood and we generally did not think pole moisture contents were suitable this far above ground. We suspect that the woodpecker opening allows for extensive moisture entry during our wetter winter months and that these galleries are then invaded by dampwood reproductives that initiate colonies. If correct, we have a sequence that begins with a buprestid gallery, progresses through woodpecker excavation in search of the larvae and then finally termite attack through the now opened pole.

Figure III-4. Example of sections through a Douglas-fir pole showing a woodpecker hole on the surface (a) and the extent of the internal damage associated with the hole (b).

Figure III-5. Example of a section through a Douglas-fir pole showing an association between golden buprestid galleries (circled areas) and dampwood termites.

We will continue sawing and scanning over the coming months and hope to produce more definitive information on the extent of damage in these poles as well as the possible causes for such extensive losses in such young poles (<25 years in service).

F. Condition of Southern Pine Crossarms

Last year, we reported on the condition of southern pine cross arms that had been in service for over 30 years in Central New York. The results indicated that most of the arms were extremely weak and needed to be replaced. These results were in sharp contrast to previous tests of Douglas-fir arms that were similarly tested. We attributed the poor results to the exposure conditions rather than any difference in species. The Douglas-fir arms were exposed in a wishbone configuration which allowed for some water shedding, while the pine arms were in a horizontal exposure that allowed for rainwater to collect in upward facing checks.

One issue that concerns any utilities about older arms is how to separate sound arms from bad arms. We have explored a number of non-destructive test methods, but none have proven successful. This past year, we examined the external condition of the arms that were tested last year and compared these visual observations with the modulus of rupture. Arms were assessed for evidence of visual decay as characterized for wood density.

The arms were then grouped into MOR ranges as follows: <2500 psi, 2501 to 3999 psi, 400-5225 psi, and >5225 psi. The results indicated that visible decay was a good indicator for almost all of the arms that tested below 2500 psi, but this method was only effective at detecting approximately 50 % of the arms with MORs between 2500 and 3999 psi (Figure III-6). As might be expected, decay was much less evident in arms testing above 4000 psi. The results suggest that while visual indicators could be used to detect very severely decayed arms, a number of arms that still retained adequate strength would be rejected on this basis.

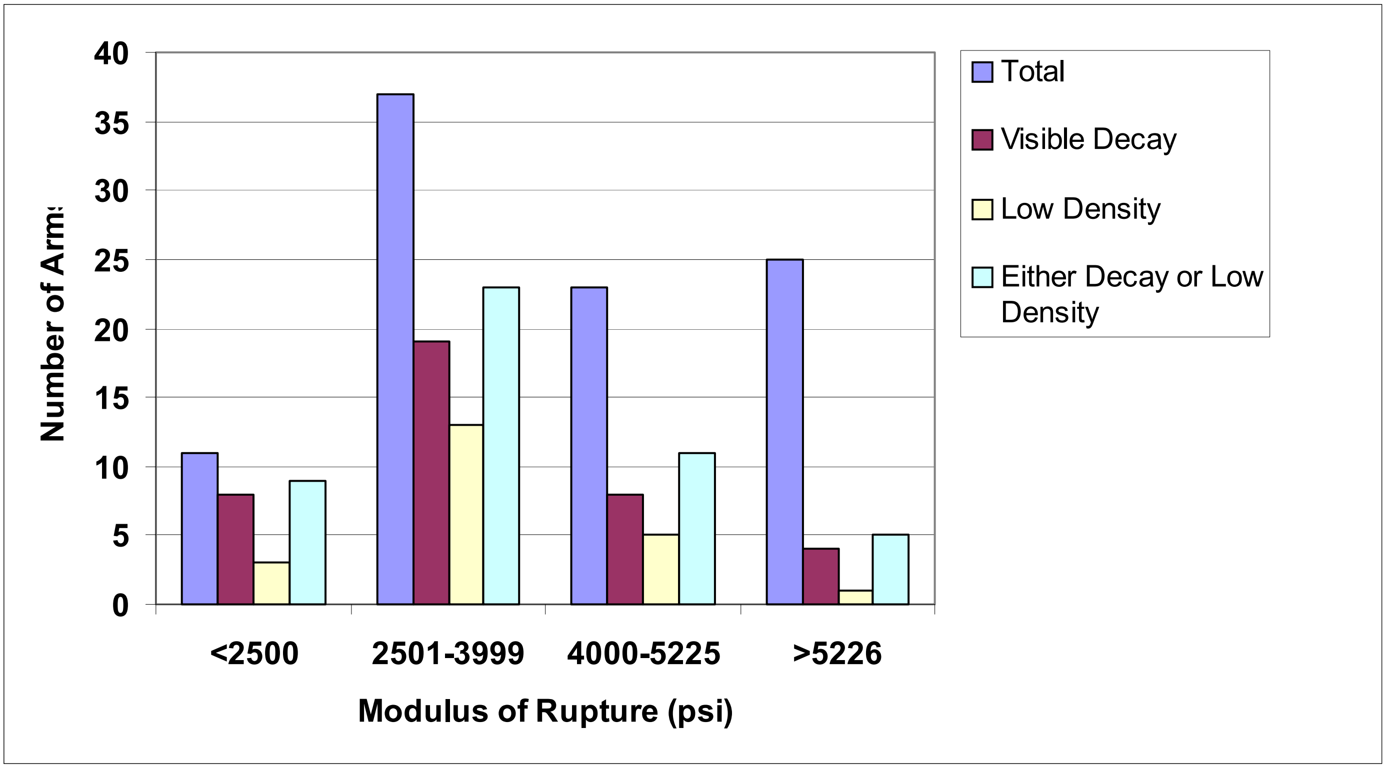


Figure III-6. Relationship between visual condition, density, and modulus of rupture of southern pine crossarms in service for over 30 years in Central New York.

The addition of density as a co-factor for assessing arm condition might be expected to improve detection of weaker arms; however, this parameter only improved the ability to segregate sound arms slightly. The results indicate that carefully trained observers can detect very seriously decayed arms, but detecting arms that are in intermediate stages of decay poses a much greater challenge. Further evaluations are planned to determine how other simple tests might be employed to further enhance the ability to detect less severely decayed arms.

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Objective IV

PERFORMANCE OF EXTERNAL GROUNDLINE PRESERVATIVE SYSTEMS

While preservative treatment provides excellent long term protection against fungal attack in a variety of environments, there are a number of service applications where the treatment eventually loses its effectiveness. Soft rot fungi can then decay the wood surface, gradually reducing the effective circumference of the pole until replacement is necessary (Figure IV-1). 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 reinvasion by fungi in the surrounding soil (Figure IV-2).

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 1980's 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.

Figure IV-1. Examples of soft rot at or below the groundline.

Figure IV-2. Example of an external paste being brushed onto the below ground surface of an in-service utility pole.

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

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

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

The pole sections in the field test of copper/boron and copper/boron/fluoride pastes have declined to the point where they can no longer be sampled and this test was terminated in 2003.

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

Date Established:	November 2004
Location:	Douglas, Georgia
Pole Species, Treatment, Size	Southern pine, creosote
Circumference @ GL (avg., max., min.)	101, 119, 83 cm

Eighty southern pine transmission poles in the Central Hudson Electric and Gas system were selected for study. The poles were randomly allocated to groups of 10 and received one of the following treatments:

Osmose Cop-R-Plastic
Osmose PoleWrap RTU
BASF Wrap with Cu/F/B
BASF Wrap with Cu/B
Genics Cobra Wrap
Genics Cobra Slim (an experimental wrap)
Triangle Laboratories Biological Treatment

The treatments were applied 0 to 450 mm below the groundline, according to the manufacturer's instructions, and then the soil was backfilled. The total amount of chemical applied to each pole was determined by weighing the containers and applicator brushes before and after chemical application ,or by measuring the total amount of prepared wrap applied. An additional set of ten poles served as untreated controls.

The poles were sampled 2, 3 and 5 years after treatment by removing increment cores from selected locations below groundline. The data from the 5 year sampling were reported last year. After 5 years copper levels have started to decline in all four wraps containing copper, and boron levels in both wraps containing boron are low. Fluoride levels remain above threshold in two of the three wraps containing fluoride. The test is next scheduled to be inspected in 2008.

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

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

Southern pine poles that were in service for at least 10 years were selected for the test. The poles were located in easily accessible right-of-ways to minimize the time required to travel between structures, were treated with oil-based treatments (CCA would interfere with analysis of copper containing systems) and would not have been subjected to prior supplemental surface treatment. Unfortunately, we could not locate poles in the Southern Company system that had not been previously treated. All of the poles in this test had previously been treated with OsmoPlastic in 1980 and/or 1994. While the oilborne components in this formulation will not interfere with future analysis, this system also contains fluoride. This necessitated some prior sampling of poles to assess residual fluoride levels for the poles that were to be treated with the two fluoride containing Osmose formulations. We recognize that it would have been better to have poles that had not received prior treatment; however, this was not possible within the system. Prior treatment can have a number of potential effects. Obviously, residual fluoride can increase the amounts of fluoride found in the test poles; however, we hope to be able to factor this chemical loading out using our pre-treatment sampling. The presence of residual chemical may have other effects on diffusion of newly applied chemicals (potentially both positive and negative); however, this subject has received little attention.

Initial fluoride levels in poles receiving either Cop-R-Plastic or Pole Wrap averaged 1.18 and 0.96 kg/m^3, respectively, in the outer 25 mm prior to treatment (Table IV-1). These levels are well above the internal threshold for fluoride (0.67 kg/m^3) but still below the level we have traditionally used for performance of fluoride based materials in soil contact (2.24 kg/m^3). Fluoride levels further inward ranged from 0.46 to 0.62 kg/m^3. These levels are at or just below the internal threshold. It is clear that we will have to use caution in interpreting the results from these tests. On the positive side, however, the results suggest that some re-examination of the retreatment cycle might be advisable to determine if the period between treatments might be extended.

Table IV-1. Fluoride levels at selected distances from the surface of southern pine poles 10 years after application of a fluoride-containing external preservative system.

Proposed Treatment	Distance from Surface (mm)	Fluoride Level (kg/m3)
Cop-R-Plastic	0-25	1.18 (1.77)
	25-50	0.46 (0.35)
	50-75	0.53 (0.36)
Pole Wrap	0-25	0.96 (0.89)
	25-50	0.54 (0.25)
	50-75	0.62 (0.28)

Poles in the test were allocated to a given treatment and each treatment was replicated on a minimum of 10 poles. An additional 10 poles were included as non-treated controls.

The treatments in this test were:

CuBor (paste and bandage)
CuRap 20 (paste and bandage)
Cobra Wrap
Cop-R-Plastic
Pole Wrap (Bandage)

Each pole was excavated to a depth of 600mm (24 inches) and any weakened wood was scraped away. Although each pesticide label recommends scraping or shaving the pole surface prior to application, not all of the poles in the test were scraped. The poles in this test had been previously treated and most had little or no advanced decay when this test was installed. It is unknown what effect, if any, the lack of shaving had on chemical movement from the pastes and bandages into the wood. The residual circumference of the pole was measured at groundline then the chemical was applied according to the manufacturer's recommendations. In cases where the label allows for a range, it was agreed in the field to use the same thickness for all paste systems (see discussion below). The amount of chemical applied to each pole was determined by weighing the container and brush applicator before and after treatment. The difference was used, along with the surface area to which chemical was applied, to calculate a rate per unit area of pole surface. The treated areas were covered with whatever material was recommended by the manufacturers of that formulation, then the soil was replaced around the pole. In the case of the CuBor, which allows a range of thicknesses to be used, the thinnest paste thickness was used. The remaining systems allow for one paste thickness.

Chemical movement from the pastes into the wood was assessed in five poles per treatment one year after treatment by removing increment cores from approximately 150 mm below the groundline. A small patch of the exterior bandage and any adhering paste was scraped away, then increment cores were removed from the exposed wood on one side of the pole.

The cores were cut into two different patterns. Chemicals containing copper-based biocides were segmented into zones corresponding to 0-6, 6-13 and 13-25 mm from the wood surface. Wood from a given zone from each pole were combined and then ground to pass a 20 mesh screen. Copper was assayed by x-ray fluorescence spectroscopy (XRF). Cores removed from poles treated with boron and fluoride containing systems were cut into zones corresponding to 0-13, 13-25, 25-50 and 50-75 from the wood surface. These segments were processed in the same manner as described for the copper containing cores. Boron was analyzed by extracting the ground wood in hot water, then analyzing the extract using the azomethine-H method, while fluoride was analyzed by neutron activation analysis.

Several months after this test was installed, a number of questions were raised by various cooperators about aspects of the treatment including the application of a pasture wrap to the tops of some poles but not others, the possible interference of prior fluoride presence on the new treatment, and most importantly, the decision to use a single thickness for all of the paste systems. The pasture wrap was apparently offered to all cooperators and is required in the Georgia Power Specification for poles in livestock fields, but was not used on all poles. The potential fluoride interference was a known when the test was established. While we recognize that fluoride levels vary by location in the poles, we believe that, as a composite of the poles in the test, we can develop a correction factor to apply to those poles treated with the fluoride containing systems.

There was considerable discussion about this test at the 2005 Fall Advisory committee meeting. After much discussion, it was agreed that we would proceed with the test with the understanding that we would note that the CuBor was applied at the lowest label recommendation, that there were objections to the presence of the original fluoride and that we would continue to assess the effects of variables such as the presence of the pasture wrap on wrap performance. Finally, at the time, the producers of CuRap 20 asked that we not sample their poles in this test. Although they later changed their mind, this decision was made after the one year sample. As a result, there were no 1 year CuRap 20 data.

For the purposes of protective levels required for the performance of each system, we took the following approach. We recognize that remedial treatments are applied to in-service poles that still contain some initial treatment; however, there is no way that an inspector could realistically quantify that level for an individual pole. As a result, chemical loadings could vary from virtually none to far more than was originally specified. We took a conservative approach in this case and assumed that the initial treatment did not contribute to the efficacy of a barrier system, although we recognize that, in most cases, it does.

In addition, there are no good data for the thresholds of multi-component systems currently on the market though Fahlstrom (1964) produced some excellent data on a number of the earlier systems. Although we recognize the potential for synergy among the biocides in multi-component systems, we are just now beginning to produce data on how effective these systems are at preventing surface decay. Again, as a result of the lack of definitive information, we do not consider multi-component systems. Instead, we use the previously reported threshold for protection of wood against decay in soil contact. In the case of copper-based biocides, we have used a single threshold for copper naphthenate, while we use upper and lower thresholds for the boron and fluoride. We have taken this approach because of the differential movement of the oil and water based systems. In virtually all previous tests, the copper based biocides have moved only a short distance intro the wood from the surface. Thus, the primary function of the copper compound is surface protection against soil inhabiting organisms.

Conversely, the boron and fluoride are both capable of diffusing inward for considerable distances from the surface. As a result, they have the potential to provide protection against both internal decay fungi and insects. The dual thresholds reflect that potential. Thus, for these chemicals, the lower threshold is presented to provide some guide to the potential performance of these systems away from the surface, while the upper threshold is the more direct measure of surface protection.

We are currently attempting to develop more definitive data on the thresholds for multi-component systems that takes into account the role of the initial treatment and the benefits of multi-component systems, but for the present, we will continue to take a very conservative approach to interpreting our external barrier data.

Copper levels in the four copper containing systems ranged from 0.35 to well over 1.5 kg/m^3 in the outer 6 mm one year after treatment and did not change appreciably in the second year (Figure IV-3). Copper levels in the CRP system increased between 1 and 2 years in the outer 6 mm , while those for the two CuBor systems declined slightly in this zone. Copper levels in the 6 to 12 mm zone increased slightly in the two CuBor treatments and were the only treatments above the threshold in this zone at 2 years. At this point, there is little difference in copper levels between the three systems. Copper levels in the CuRap 20 paste and bandage systems were similar to those found for the CRP and CuBor systems 2 years after treatment. These results are consistent with previous tests of this system on other wood species. Copper levels in the Cobra system were below the threshold for copper naphthenate in soil contact at both time points.

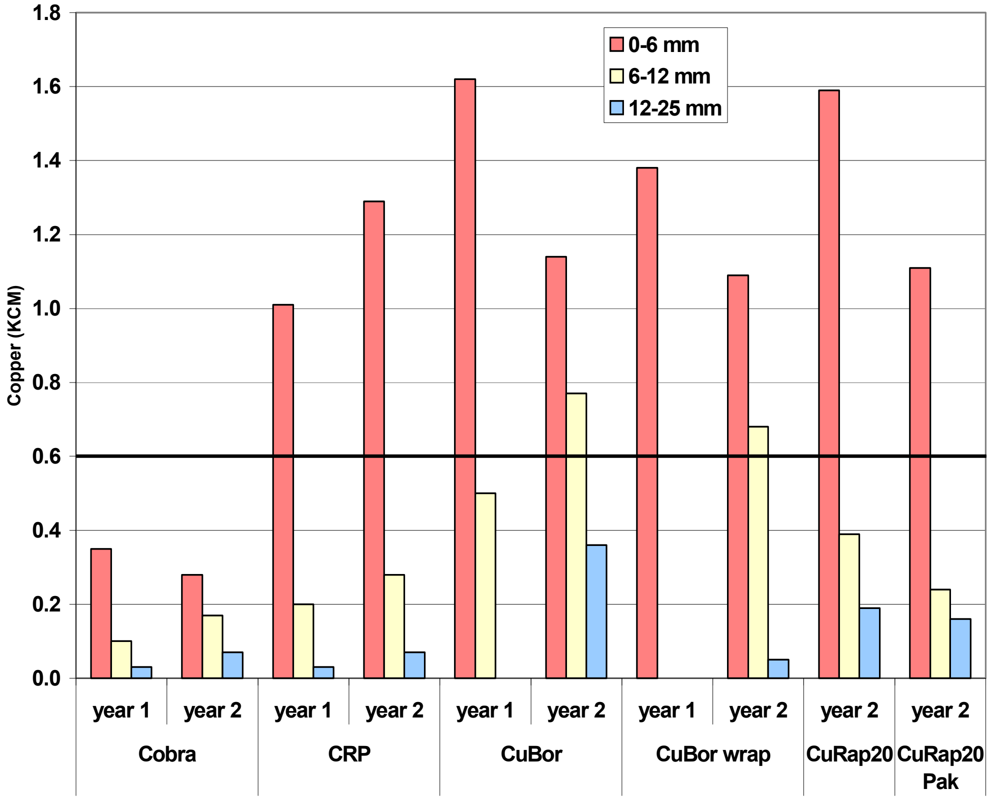

Figure IV-3. Residual copper levels at selected distances from the wood surface 150 mm below groundline on southern pine poles 1 and 2 years after treatment with Cobra Wrap, Cop-R-Plastic (CRP) or CuBor in paste or bandage form.

Copper levels fell off sharply from the 0 to 6 mm segments to the 6 to 12 mm segments for all treatments, particularly with the prepared CuBor bandage 1 year after treatment. Copper levels in the 6-12 mm zone increased markedly in year 2 with the CuBor wrap. Copper levels in the Cobra and CRP treatments were generally lower in the 6 to 12 mm zone than those in the CuBor treatments as were the copper levels in the inner zones for the 2 year CuRap 20 treatment. Copper levels were low in the zone 12 to 25 mm from the surface for all four systems. The sharp drop-off in chemical loading with distance from the surface is typical of copper based systems, which will tend to migrate for only short distances from the wood surface. Since the primary function of the copper component is surface protection, the immobilization of copper in the outer zone is a useful attribute for these systems.

Boron was a component of both the CuBor and CuRap 20 systems. Boron levels in poles receiving these treatments were nearly all well over the threshold for surface fungal attack in the outer 13 mm of the pole (Figure IV-4). Boron levels dropped steadily with distance from the pole surface, but were still above the lower threshold 13 to 25 mm from the pole surface with both systems. Interestingly, boron levels were higher for the bandage than the paste for CuRap 20 but the levels in the CuBor were similar for wrap and paste systems 2 years after treatment. We typically consider pastes to provide more intimate wood contact than bandages, but this does not always appear to affect the resulting chemical levels. Boron levels 25 to 50 mm and 50 to 75 mm below the surface were above the thresholds for both systems, indicating that this chemical has moved well into the wood over the 2 years after application.

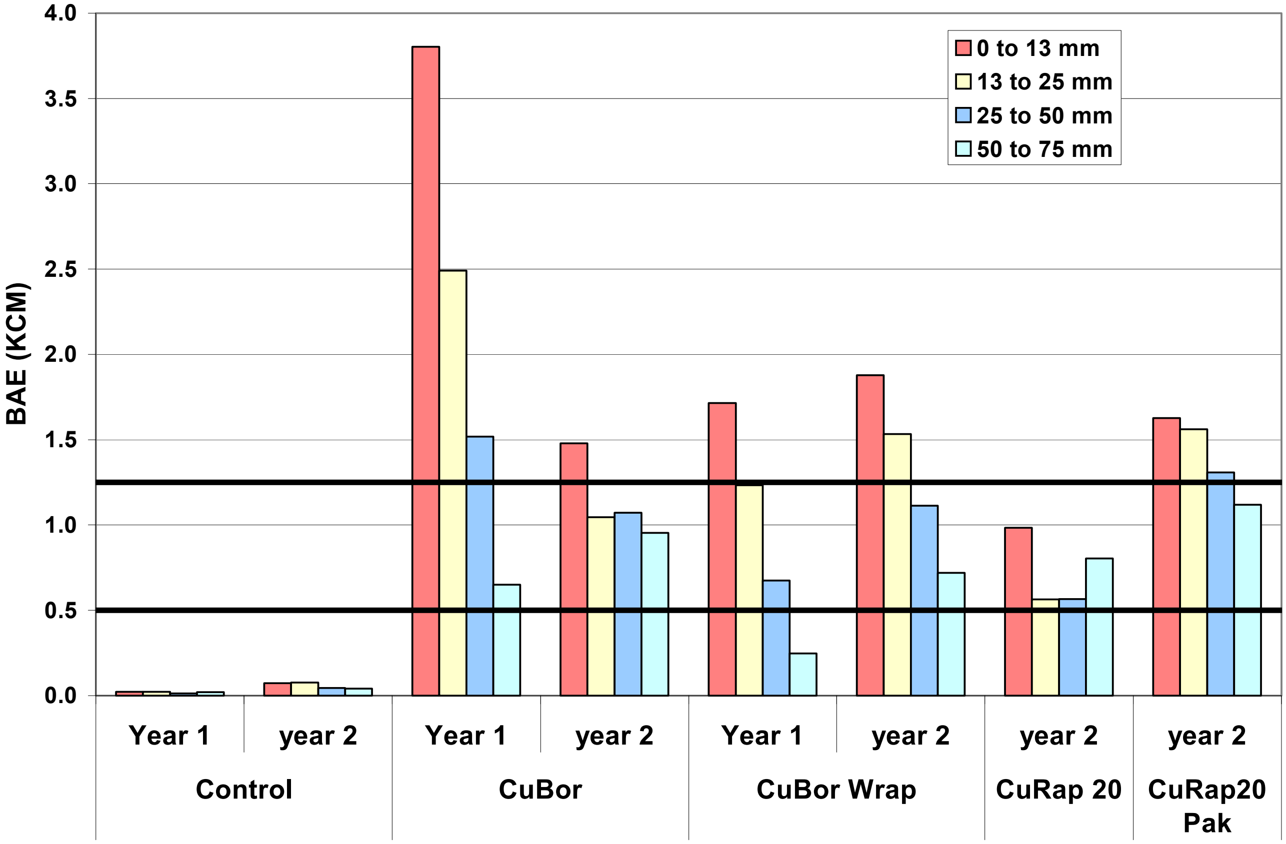

Figure IV-4. Residual boron levels at selected distances from the wood surface 150 mm below groundline on southern pine poles 1 and 2 years after treatment with CuBor and CuRap 20 in paste and bandage form.

Fluoride levels in poles treated with Cop-R-Plastic and Pole Wrap were all well above the threshold from the surface to 75 mm inward (Figure IV-5). As noted earlier, all of the poles in the test had received a fluoride containing groundline treatment (OsmoPlastic) 10and/or 24 years earlier. Initial sampling indicated that fluoride remained in these poles, albeit at low levels. Fluoride levels in the outer zones of the same poles 1 year after treatment were 4 to 6 times higher than the background levels. Fluoride levels in poles 2 years after treatment were generally similar to those found after one year. There was slight concentration gradient inward from the surface, but the trends were not always consistent. Fluoride levels at all depths sampled remain above the threshold.

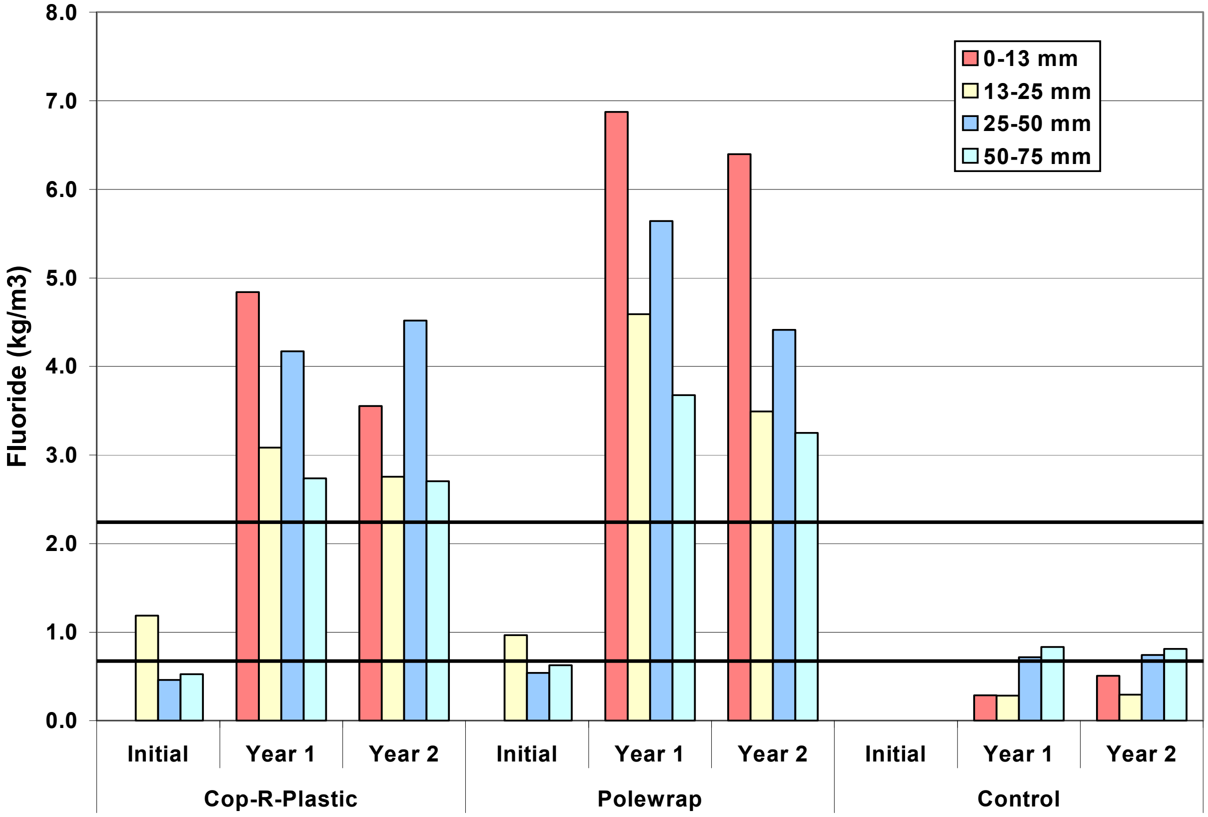

Figure IV-5. Residual fluoride levels at selected distances from the wood surface 150 mm below groundline on southern pine poles 1 or 2 years after treatment with Cop-R-Plastic or Pole Wrap.

The 2 year results with all five systems inspected indicate that components of all of the systems have moved into the wood, although there are clearly differences in degree of movement among the systems and with the use of pastes vs. bandages.

E. Effect of Moisture Content on Movement of Copper and Boron from CuBor and CuRap 20 Treated Douglas-fir Sapwood

Over the years, we have established both laboratory and field trials to assess the ability of various external preservative paste components to move into the sapwood of various wood species. The field trials provide excellent long term performance data and, because many of these tests take place on in-service utility poles, the data generated is directly applicable to the utility system. At the same time, the discussion in Section D highlights the problems associated with field tests. To partially address these issues, we have often established laboratory trials of external preservative systems to better understand the rates of chemical movement under more controlled conditions.

Douglas-fir sapwood blocks (37.5 by 87.5 by 100 mm long) were cut from kiln dried lumber. A round well, 25 mm in diameter and 10 mm deep was cut into one narrow face of each block. The blocks were then oven dried and weighed before being pressure soaked with water. The blocks were conditioned to either 30 or 60 % moisture content, a piece of duct tape was placed over the 25 mm diameter hole, and the block was then dipped twice in molten wax to retard further moisture loss. The blocks were then stored for 2 to 4 weeks to allow moisture to further equilibrate.

The blocks were then treated with either CuRap 20 or CuBor applied to a thickness of 1.6 mm or 6.0 mm in the well (Table IV-2). The paste was covered with duct tape, then the blocks were incubated at room temperature with the holes on the sides of the blocks for 4 to 24 weeks. The ability of copper and boron to move from the paste into the wood beneath was assessed 8, 16, and 24 weeks after treatment by destructively sampling five blocks per paste thickness per chemical system. A set of blocks remains for a 48 week sampling.

Table IV-2. Amounts of copper and boron applied to Douglas-fir sapwood blocks treated with two thicknesses of CuBor and CuRap 20 paste.

Paste Thickness (mm)	CuBor			CuRap 20		
	Total (g)	Boron (g)	Copper (g)	Total (g)	Boron (g)	Copper (g)
1.6	1.17	0.06	0.03	1.50	0.07	0.03
6.0	4.68	0.23	0.13	6.00	0.27	0.12

At each sampling, the tape was removed from the 25 mm well and any residual chemical was scraped away. The treated zone was cut from the rest of the wood with a band saw and the remaining core directly below the treatment well was then divided into zones corresponding to 0 to 6, 6-13, 13-25, 25-38 and 38-64 mm from the original point of paste application. The wood from a given zone was combined for a given treatment, then this material was ground to pass a 20 mesh screen. The samples were first analyzed for copper by x-ray fluorescence spectroscopy, then the samples were hot water extracted and analyzed for boron by the azomethine-H method.

As expected, copper levels were only meaningful in the outer 6 mm of the test blocks over the 24 week test period (Table IV-3). Copper levels increased slightly between 8 and 16 weeks for the thicker CuBor treatment, but then declined in the 24 week sample in blocks at 30% moisture content (Figure IV-6). Copper levels were elevated 8 weeks after treatment with the same treatment in blocks at 60 % moisture content, reflecting the availability of moisture aid in chemical movement. Copper levels were more variable in blocks treated with the thinner CuBor paste.

Copper levels in CuRap 20 treated blocks tended to be higher in blocks at 60% than in those at 30% for the thicker paste rate, but the results were much more variable in blocks receiving the thinner dosage. The results suggest that paste thickness may not necessary translate into proportionally larger amounts of chemical in the wood, but they may help insure more uniform movement.

Boron levels in blocks treated with CuBor or CuRap 20 tended to be largely confined to the outer 6 mm over the 24 week period, although some movement was noted into the 6 to 13 mm assay zone (Table IV-4). Boron levels tended to be higher in the outer zones of blocks conditioned to 60% moisture content, reflecting the need for moisture for diffusion to occur; however, the lack of substantial boron movement remains perplexing (Figure IV-7). Boron levels also appeared to be less affected by paste thickness, again suggesting that paste thickness may not necessarily affect initial loadings, but may play a longer term role in terms of treatment uniformity.

Table IV-3. Copper levels at selected distances from the surface in Douglas-fir sapwood blocks conditioned to 30 or 60% moisture content and then treated with a 1.5 or 6 mm thick layer of CuRap 20 or CuBor and incubated for 8 to 24 weeks.

Chemical	Distance from treatment	Copper (KCM)											
		1/4"						1/16"					
		30% MC			60% MC			30% MC			60% MC		
	(mm)	8 week	16 wk	24 wk	8 week	16 wk	24 wk	8 week	16 wk	24 wk	8 week	16 wk	24 wk
CuBor	0-6	0.31	**1.65**	**0.95**	**2.57**	**1.48**	**2.16**	**1.13**	**2.72**	**0.65**	**1.60**	**3.24**	**1.61**
	6-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	13-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	25-38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	38-64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CuRap 20	0-6	**1.36**	**1.13**	**1.02**	**2.18**	**1.26**	**2.78**	**1.01**	**2.42**	0.32	**1.03**	**3.26**	0.01
	6-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	13-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	25-38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	38-64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Control	0-6	0.01	0.00	0.00	0.00	0.00							
	6-13	0.00	0.00	0.00	0.00	0.00							
	13-25	0.00	0.00	0.00	0.00	0.00							
	25-38	0.00	0.00	0.00	0.00	0.00							
	38-64	0.00	0.00	0.00	0.00	0.00							

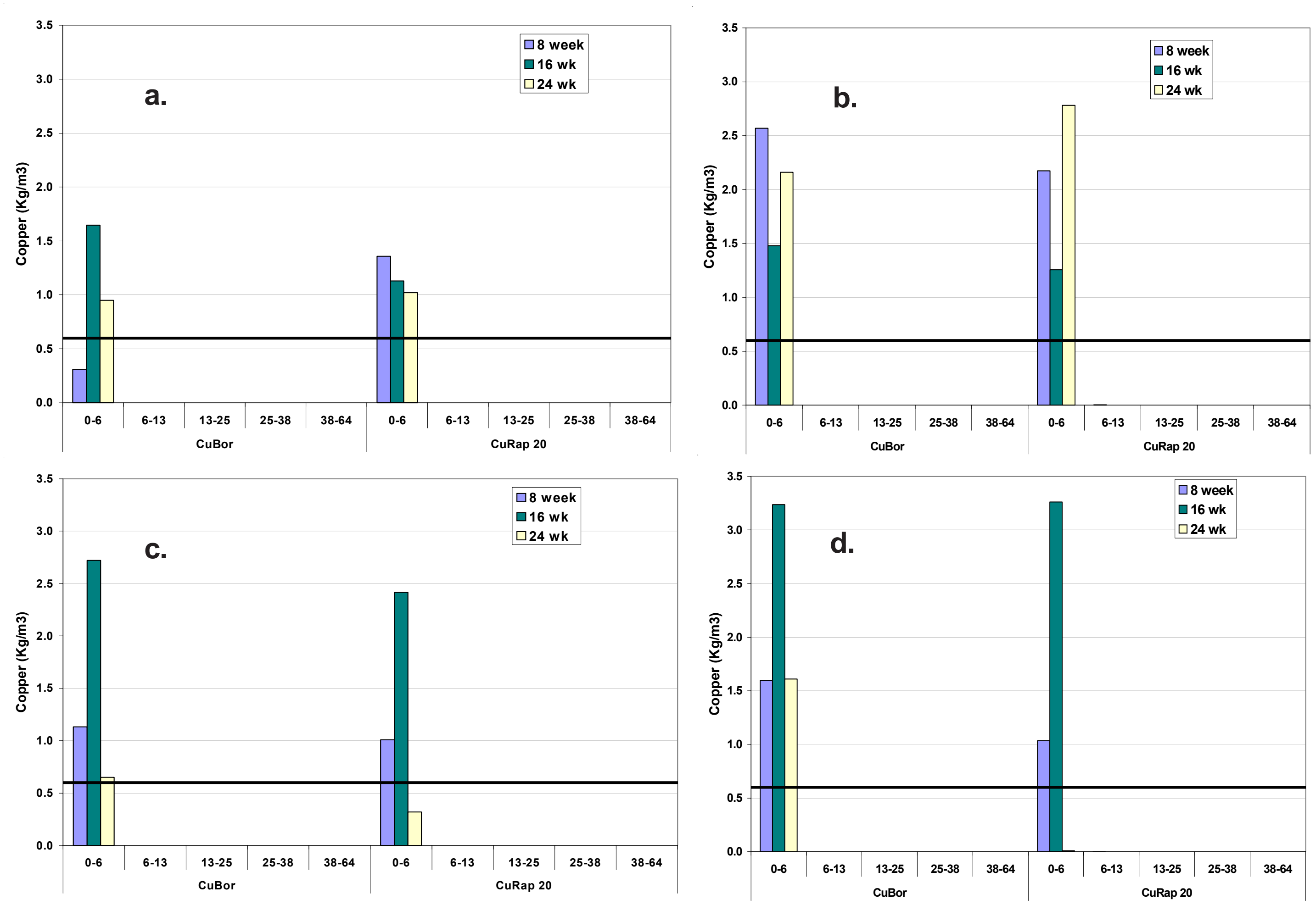

Figure IV-6. Residual copper levels at selected distances from the surface of Douglas-fir sapwood blocks at 30% (a,c) or 60% (b,d) moisture content 4 to 24 weeks after application of 1.6 mm (c,d) or 6.0 mm (a,b) of two copper/boron pastes. The threshold level for copper is 0.6 kg/m^3.

Table IV-4. Boron levels at selected distances from the surface in Douglas-fir sapwood blocks conditioned to 30 or 60% moisture content and then treated with a 1.5 or 6 mm thick layer of CuRap 20 or CuBor and incubated for 8 to 24 weeks.

Chemical	Distance from treatment (mm)	Boron (KCM BAE)											
		1/4"						1/16"					
		30% MC			60% MC			30% MC			60% MC		
		8 wk	16 wk	24 wk	8 wk	16 wk	24 wk	8 wk	16 wk	24 wk	8 wk	16 wk	24 wk
CuBor	0-6	**1.11**	**3.05**	0.33	**4.64**	**4.57**	**0.81**	**2.30**	**2.98**	0.20	**4.88**	**4.33**	**0.67**
	6-13	0.01	0.00	0.01	0.21	0.46	0.13	0.08	0.01	0.01	0.32	**0.68**	0.08
	13-25	0.03	0.00	0.01	0.04	0.01	0.02	0.02	0.01	0.01	0.04	0.14	0.01
	25-38	0.00	0.01	0.01	0.02	0.00	0.01	0.01	0.00	0.01	0.02	0.01	0.00
	38-64	0.01	0.00	0.01	0.00	0.00	0.01	0.03	0.01	0.01	0.03	0.00	0.00
CuRap 20	0-6	**2.76**	**3.59**	0.11	**3.39**	**3.98**	**0.97**	**2.72**	**2.32**	0.39	**2.24**	**3.15**	0.44
	6-13	0.02	0.00	0.01	0.14	0.38	0.29	0.17	0.00	0.01	0.10	**0.51**	0.10
	13-25	0.01	0.00	0.00	0.00	0.00	0.09	0.01	0.00	0.01	0.01	0.08	0.02
	25-38	0.01	0.00	0.00	0.01	0.00	0.01	0.02	0.00	0.01	0.03	0.00	0.01
	38-64	0.01	0.00	0.01	0.00	0.00	0.00	0.03	0.00	0.01	0.02	0.00	0.00
Control	0-6	0.00	0.00	0.01	0.00	0.00							
	6-13	0.02	0.00	0.00	0.02	0.00							
	13-25	0.00	0.00	0.00	0.00	0.00							
	25-38	0.00	0.00	0.00	0.00	0.00							
	38-64	0.00	0.00	0.00	0.00	0.00							

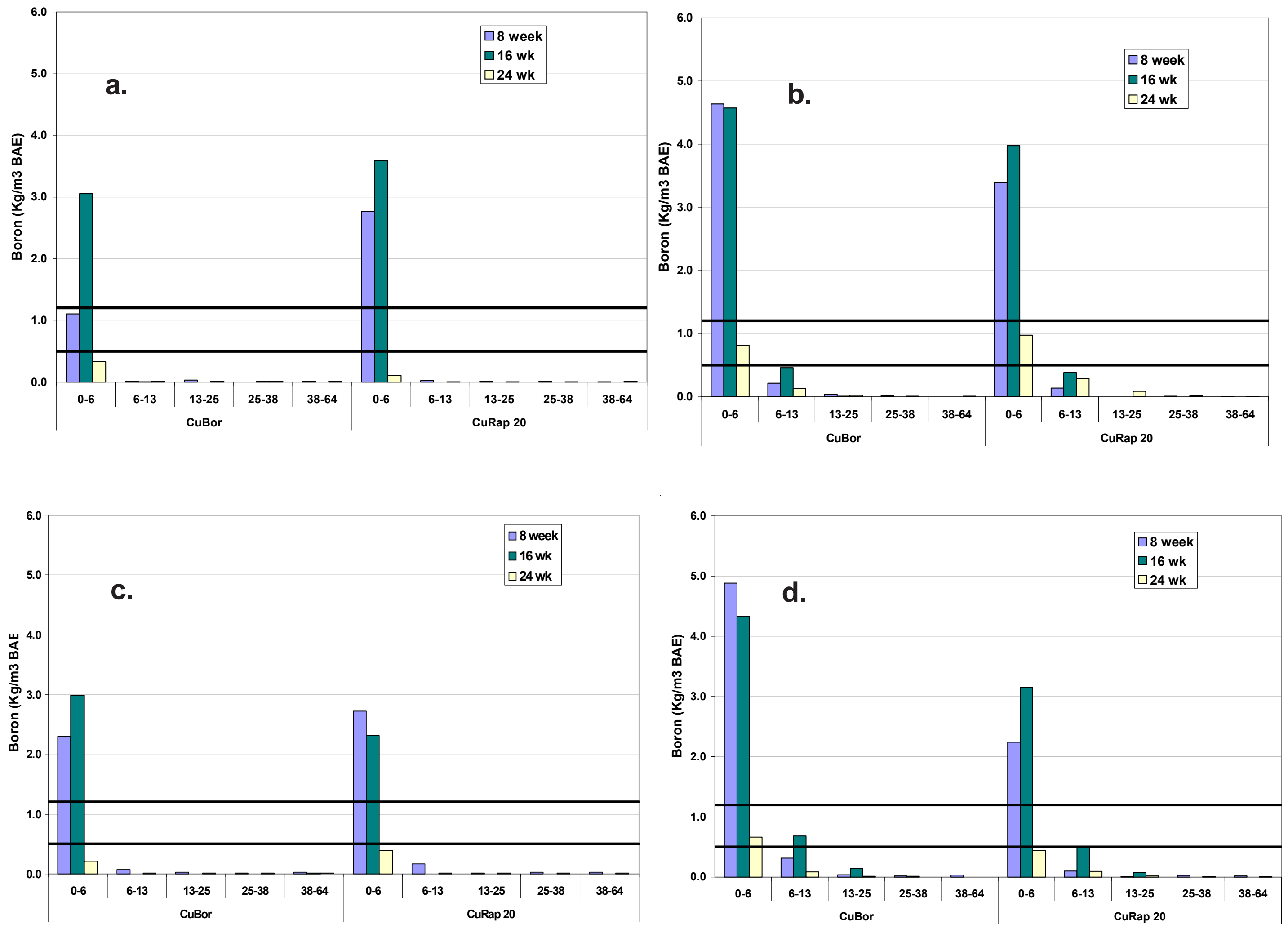

Figure IV-7. Residual boron levels at selected distances from the surface of Douglas-fir sapwood blocks at 30 % (a,c) or 60 % (b,d) moisture content 4 to 24 weeks after application of 1.6 mm (c,d) or 6.0 (a,b) of two copper/boron pastes. The upper and lower threshold levels for boron are 0.5 and 1.2kg/m^3, respectively.

F. 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 untreated 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 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 organisms in a soil environment are fairly aggressive 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, but 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 service, the changing chemical environment during the test made it difficult to develop reasonable threshold estimates. In an effort to develop this information, we performed the following trial.

Previous studies have shown that the choice of substrate and laboratory conditions can have a marked effect on the outcome of a decay test. Valcke (1991) concluded that “the use of different soil types in a laboratory test will result in variable threshold values and decay rates”. The species and surface area to volume ratio of the test specimens were also found to affect the outcome. Troya et. al. (1998) determined that the substrate chosen affects the decay rate on non-treated wood, but they did not attempt to determine thresholds.

There are many difficulties in determining the threshold of mobile chemicals. The concentration of chemical in the test pieces is in constant flux until it reaches equilibrium or is lost into the surrounding soil. The initial retention cannot be assumed to have stayed constant and if that concentration fails to control soft rot, there is no way to tell at what point during the decline failure began.

The picture is even more complicated when there are two or more components in a treatment moving at different rates. In a field application, fungi may be active in the wood before the treatment is applied and the threshold for eliminating actively growing fungi may be different than that for spore inoculum. The absence of the primary pentachlorophenol treatment in the test pieces, which contributes to the performance of the supplemental treatment, may cause the threshold to be under estimated.

Because there are many ways of conducting laboratory soft rot trials, we have decided to first establish a suitable method using non-treated wood. The following variables were examined.

Substrates:

Vermiculite moistened with a micronutrient solution. Vermiculite is commonly used in soft rot testing. It is a more standard medium than soil and might, therefore, allow better comparisons between tests.

Wood weight losses in vermiculite tend to be lower than in soil and are often insufficient for threshold determination. The vermiculite was wetted with a nutrient salt solution (0.5ml/g), autoclaved for 20 minutes (15 psi, 121 C) and inoculated with a spore suspension. The test wafers were autoclaved with the vermiculite.

<u>Sterile soil</u>. Soil is sterilized so that the fungal inoculum can be controlled. The soil chosen had a water holding capacity of 31% and was screened through a #6 sieve to remove large particles. The soil was wetted to 90% of the water holding capacity, autoclaved (15 psi. 121C) for 45 minutes and then inoculated with a spore suspension. The test wafers were autoclaved with the soil.

<u>Non-sterile soil</u>. The same soil used above was mixed with a small amount of active compost to increase the natural inoculum. Neither the soil nor the test pieces were autoclaved and no inoculum was added.

<u>Non-sterile soil with water absorbing gel</u>. As above, with the addition of water absorbing granules. (SoilMoist, JRM Chemical, Cleveland, OH). The granules were added according to the label directions. The granules may help maintain the correct moisture content for the duration of the test.

<u>Vermiculite and non-sterile soil</u>. This method has been used to provide a standard medium along with natural inoculum. The vermiculite was wetted with nutrient solution as above and the test pieces were set on the surface. A layer of moist soil was placed on top of the vermiculite. Neither the soil nor the test pieces were sterilized and no inoculum was added.

Where inoculum was required, a spore suspension of *Chaetomium globosum* was prepared. In previous studies, this fungus caused more weight loss alone than when used in a mixture (Valcke 1991 and Troya et. al.1998).

Wood test pieces:

Southern pine wafers (30 x 20 x 5 mm) were chosen because preservative pastes are commonly used on this species. The surface area to volume ratio of 5.0 falls in the range 3.0 to 5.8 specified in the European Soft Rot Standard (ENV-807). Because the test pieces present a much larger surface area to the soil than a utility pole, the wafers were used with no coating, with end coating only and coated on five sides leaving only one wide face exposed. The coating was a heavy duty, pliable rubber coating (Plastidip, PDI Inc, Circle Pines, MN) diluted with mineral spirits to a brush-on consistency. The coating limited exposure to moisture and fungi. If this method is eventually used with treated wood, the coating may also limit leaching loss to more accurately represent the potential loss pathways from a utility pole.

Temperature and time:

The jars were incubated at 26 or 32 C for 8, 16 or 24 weeks.

Once the most effective substrate, wood coating, temperature and time are determined we will begin testing treated wood. If possible, samples will be cut from weathered pentachlorophenol pole sections or cross arms. The wafers will be treated with the chemicals currently in use in preservative pastes both singly and in combination. Several retentions bracketing the currently used thresholds will be used for each chemical or combination.

This past year, we were able to evaluate the non-treated samples to refine the exposure method and also have data for 8 week exposures for blocks treated with two external groundline systems.

Weight losses in the blocks ranged from 2.9 to 15.3% after 8 weeks of exposure (Table IV-5). Weight losses tended to be greatest in non-coated blocks, reflecting the ease with which fungi could penetrate the material from any direction. Weight losses were consistently lower on the materials coated on five of the six faces. This would be representative of the decay risk posed on a pole surface. End-coated samples experienced slightly higher weight losses and might be more useful for accelerating decay without creating a totally artificial decay risk.

Weight losses increased steadily over the next 16 weeks, following the same approximate trends noted at 8 weeks. By the end of the test, weight losses for the non-coated samples ranged from 10.2 to 36.0%, while those for end coated blocks ranged from 9.4 to 31.6% and the blocks coated on five sides ranged from 7.2 to 21.5%.

Table IV-5. Weight losses of pine sapwood blocks coated on five sides with a plastic film, coated on the transverse faces, or left uncoated and exposed for 8 to 24 weeks to soft rot attack in different media at 32 C or 20-23 C.

Substrate	Incubation Temperature (^{o}C)	Coated on 5 sides						End coated						No coating					
		8 week		16 week		24 week		8 week		16 week		24 week		8 week		16 week		24 week	
		Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std
Non-sterile soil	32	4.0	1.0	10.9	2.3	15.6	2.1	5.9	1.5	14.6	1.9	26.2	6.3	7.1	1.2	14.7	1.7	24.4	6.0
	20-23	2.9	0.9	7.8	3.1	11.5	3.1	3.2	0.8	7.6	1.5	14.2	2.7	4.8	1.1	9.7	1.9	17.2	2.3
Sterile soil (inoculated)	32	3.4	0.2	6.8	2.5	9.0	3.8	2.9	2.9	6.5	1.2	9.6	3.8	6.0	2.1	7.0	2.9	10.2	4.0
	20-23	3.4	0.7	8.7	3.5	7.2	3.5	3.6	0.7	7.4	3.7	9.4	3.5	4.7	1.1	8.2	1.7	10.3	5.0
Vermiculite (inoculated)	32	4.9	2.1	11.1	5.6	9.4	7.1	4.9	1.6	8.4	3.9	10.1	6.6	7.1	3.4	12.3	7.3	11.3	8.2
	20-23	5.5	2.2	9.7	5.0	9.7	2.1	4.0	1.5	6.5	3.6	12.3	9.7	6.0	2.1	14.7	9.1	18.1	7.7
Vermiculite + soil	32	8.8	1.7	16.2	6.0	20.8	5.8	10.7	4.5	20.6	9.0	31.6	5.9	15.3	7.3	23.8	6.7	36.0	5.8
	20-23	3.3	1.8	11.0	3.9	17.4	6.3	5.2	1.9	18.0	3.8	28.3	3.6	5.2	2.0	17.2	5.8	29.9	6.2
Soil with gel	32	5.4	1.3	15.1	3.5	21.5	8.2	8.3	2.3	20.6	3.4	26.7	5.3	7.4	2.1	15.4	6.0	30.3	3.1
	20-23	3.0	1.1	7.1	1.6	7.9	2.6	2.9	1.3	8.6	2.0	15.1	3.6	3.6	0.9	7.3	1.2	12.0	1.7

Exposure of blocks at 32 C was generally associated with higher weight losses than exposure at 20-23 C, but the differences were often small. Soft rot fungi are typically considered to be more aggressive decayers at higher temperatures and the first descriptions of soft rot attack came from wood exposed to hot water in cooling towers. While elevated temperatures should increase the decay rate, it is clear that soil factors can also influence attack.

The various media used to expose the blocks also had a marked influence on weight loses. Generally, non-sterile soil, soil plus vermiculite and soil plus a water-holding gel were associated with higher weight losses at the end of the 24 week exposure (FiguresIV-8). The use of inoculated soil or vermiculite was less successful, reflecting the difficulty of matching soil characteristics with the growth requirements of a given test fungus. While inoculation offers the potential to produce more reproducible weight losses, the corresponding reductions in decay rate make this approach less attractive.

The results indicate that end-coated blocks with vermiculite or vermiculite/soil produces reasonable wood weight loss in pine sapwood blocks.

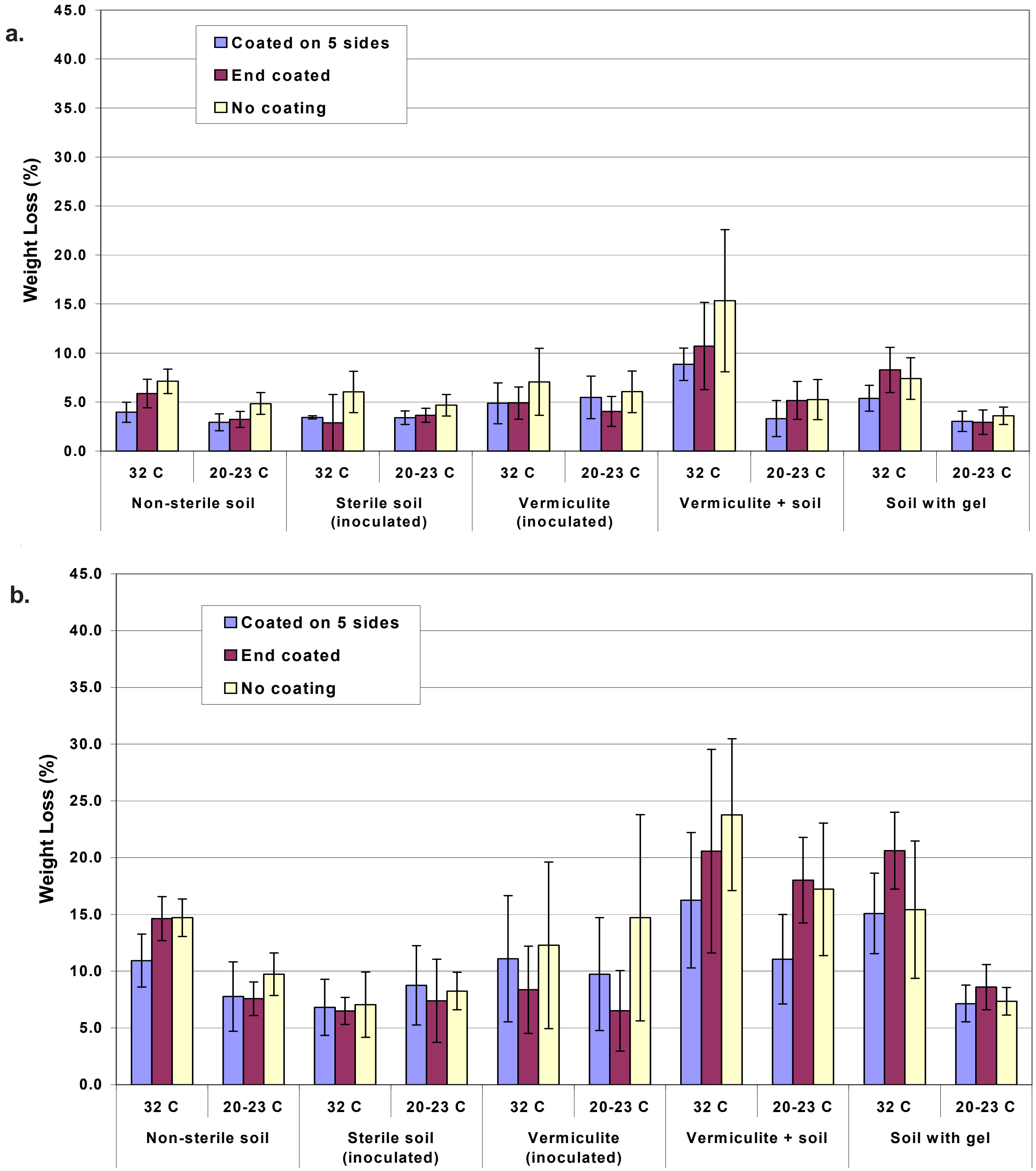

Figure IV-8. Weight losses for untreated southern pine sapwood blocks left uncoated, coated on the end grain, or coated on all but one radial face and exposed to soft rot attack at ambient temperature or 32 C for a) 8, b) 16 or c) 24 weeks in various media.

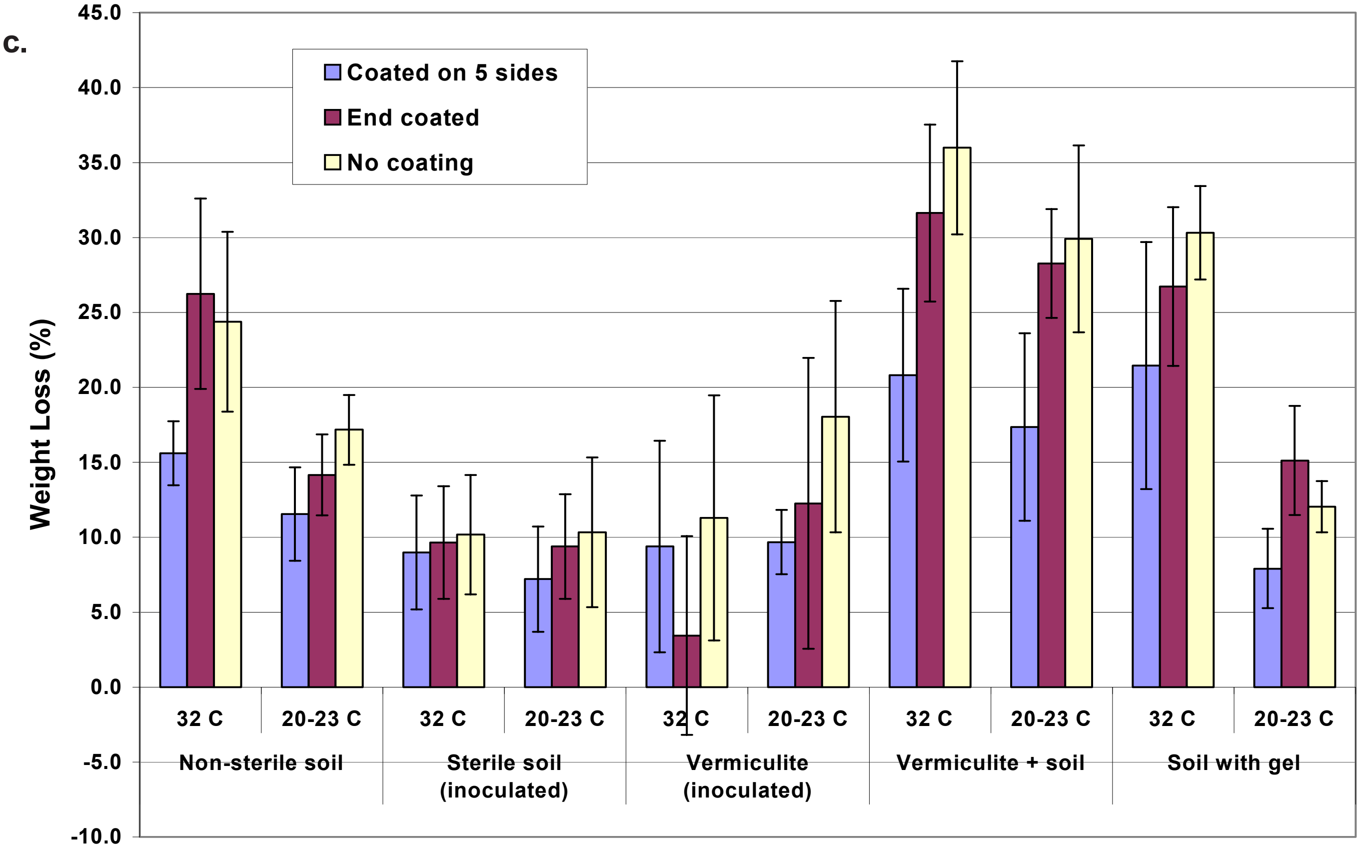

Figure IV-8 (cont.). Weight losses for untreated southern pine sapwood blocks left uncoated, coated on the end grain, or coated on all but one radial face and exposed to soft rot attack at ambient temperature or 32 C for a) 8, b) 16 or c) 24 weeks in various media.

The results indicated that surface sealing, while tedious, produced a more realistic method for assessing the performance of external treatments because the exposure conditions were similar.

Further tests are now underway exposing blocks treated with combinations of boron and copper in similarly sealed pine sapwood blocks. At present, the resulting weight losses have not allowed us to predict thresholds because of the rapid rate of loss of the diffusible boron into the soil. An example of the relationship between boron retention and weight loss for three copper retentions is shown in Figure IV-9. There is no clear dose response for the systems, leading us to suspect that chemical losses are affecting both the resulting weight loss and the ability of the fungi to attack the wood.

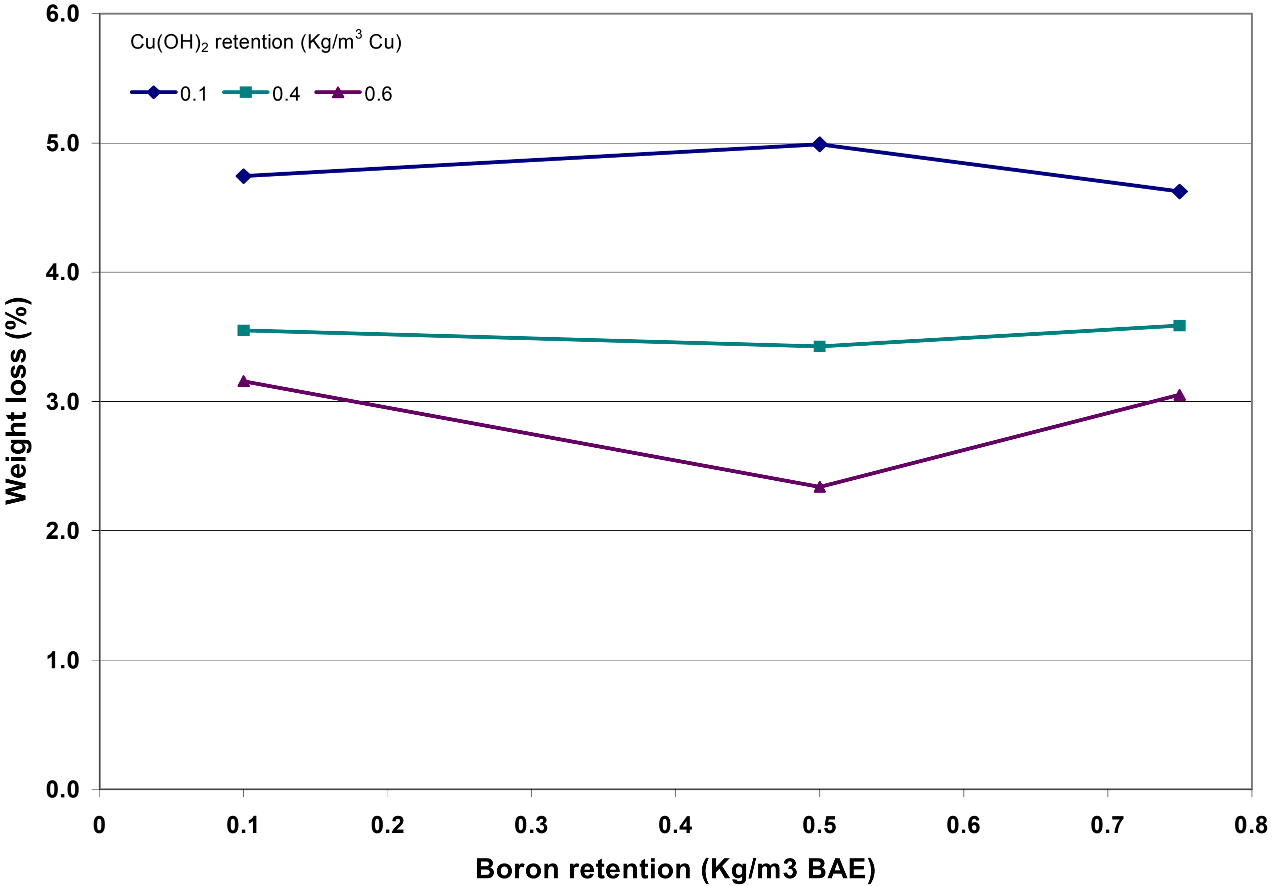

Figure IV-9. Wood weight losses in southern pine sapwood cubes treated with combinations of boron and copper and then exposed to soft rot attack in a mixed soil/vermiculite burial system.

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Valcke, A. R. 1991. Which substrate to use in a laboratory test with soft rot microfungi: vermiculite or unsterile soil. International Research Group on Wood Preservation Document No.91-2372. Stockholm, Sweden.

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 this chemical does not require special licensing. 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.

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 treatments 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 untreated to serve as controls.

The stakes were then exposed in a fungus cellar maintained at 28 C and approximately 80% relative humidity. Soil moisture was allowed to cycle between wet and dry conditions to avoid favoring soft rot attack (which tends to dominate in soils that are maintained at high moisture levels). The condition of each stake was visually assessed annually using a scale from 10 (completely sound) to 0 (completely destroyed).

Freshly sawn stakes continue to outperform weathered stakes at a given retention level. (Figures V-1, 2). All of the freshly sawn stakes treated with copper naphthenate continue to provide excellent protection after 208 months, although stake condition declined slightly this past year. Stakes treated to the two lowest retentions have declined to near a 7.0 rating suggesting that decay has begun to affect the wood. Ratings for the remaining stakes treated to the higher retentions were all near or above 9.0 suggesting that they continued to be resistant to fungal attack.

Weathered stakes tended to exhibit much greater degrees of damage at a given treatment level and all experienced declines in ratings this past year. Weathered stakes treated to the three lowest retentions had ratings below 6.0 and the two lowest had ratings below 5.0. Clearly, prior surface degradation from both microbial activity and UV light tended to sharply reduce the performance of the weathered material. Weathered stakes required almost five times the copper naphthenate to produce a performance level comparable to that found with the lowest retention on freshly sawn wood.

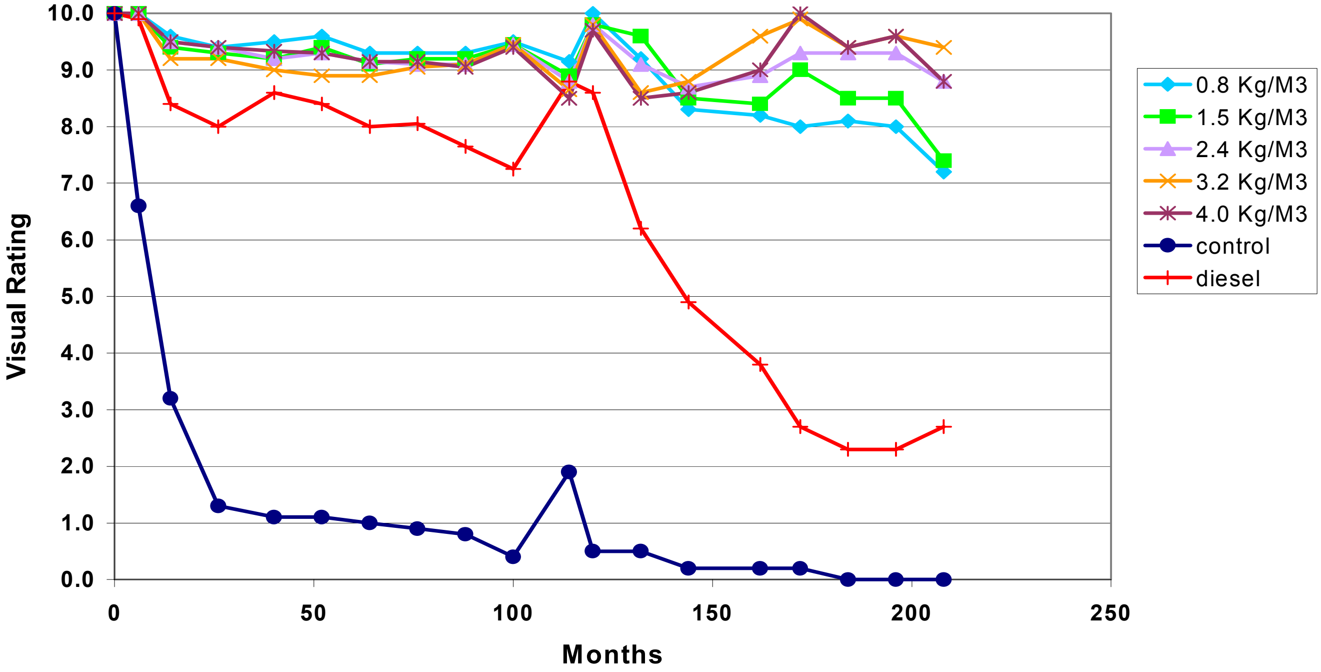


Figure V-1. Condition of freshly sawn western redcedar sapwood stakes treated with selected retentions of copper naphthenate in diesel oil and exposed in a soil bed for 208 months.

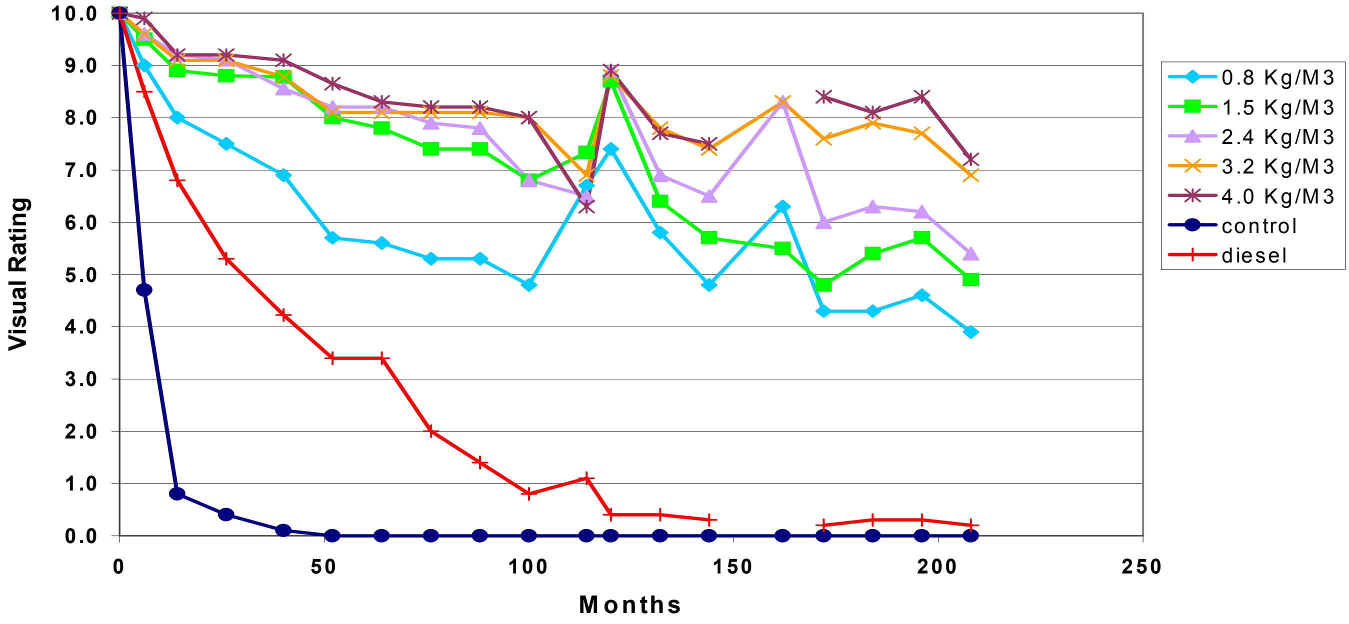


Figure V-2. Condition of weathered western redcedar sapwood stakes treated with selected retentions of copper naphthenate in diesel oil and exposed in a soil bed for 208 months.

Weathered wood was originally included in this test because the cooperating utility had planned to remove poles from service for retreatment and reuse in other parts of the system. While this process remains possible, it is clear that the performance characteristics of the weathered retreated material will differ substantially from that of freshly sawn material. The effects of these differences on overall performance may be minimal since, even if the outer, weathered wood were to degrade over time, this zone is relatively shallow on cedar and would not markedly affect overall pole properties. The copper naphthenate should continue to protect the weathered cedar sapwood above ground; allowing line personnel to continue to safely climb these poles and any slight decrease in above ground protection would probably take decades to emerge. As a result, retreatment of cedar still appears to be a feasible method for avoiding pole disposal and maximizing the value of the original pole investment.

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

The results with freshly sawn and treated western redcedar clearly show good performance of this system and these results were consistent with field performance of this preservative on western species. We continue to seek copper naphthenate treated Douglas-fir poles located in the Northwest so that we can better assess field performance of this system; however, we have had difficulty locating these poles within the cooperating utility systems. We will endeavor to locate additional poles this coming year.

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.

A. Assess the Potential for Preservative Migration from Pentachlorophenol Treated Poles in Storage Yards

In an ideal system, utilities would only receive poles as needed for specific activities; however, most utilities must stock poles of various sizes at selected depots around their system so that crews can quickly access poles for emergency repairs that result from storms or accidents. In previous studies we examined the potential for decay in these stored poles and made recommendations for either regular stock rotation of poles so that no single pole was stored for longer than 2 to 3 years, or for a system of periodic remedial treatment of stored poles to ensure that these structures did not develop internal decay during storage. These recommendations were primarily based upon long term storage, but there was little concern about the potential for any preservative migration during this storage period.

The potential for preservative migration from stored poles has received little attention, but could be a concern where large numbers of poles are stored for long periods. Preservative present on the wood surface could be dislodged or solubilized during rain events and subsequent heating in sun could encourage further oil migration to the wood surface. There is, however, little data on the potential for migration of preservative from poles in storage. Treating plants have less concern about this issue because surface water from their sites is already regulated and must be treated prior to discharge (or be shown to contain less than permissible levels). Pole storage facilities, however, are not currently regulated, nor are there recommendations or best management practices that might help utilities minimize the potential for chemical loss.

The purpose of this section was to assess the levels of preservative migrating from pentachlorophenol treated Douglas-fir poles sections subjected to natural rainfall in Western Oregon with the ultimate goal of developing recommendations for pole handling and storage by utilities.

Douglas-fir poles sections (250 to 300 mm in diameter by 1.0 m long) were air-seasoned and pressure-treated with pentachlorophenol in P9 Type A oil 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 end sealed with an elastomeric paint designed to reduce the potential for chemical loss from that surface, while the other end was left unsealed. 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. The poles were set 150 mm above the tank bottom to reduce the risk that the wood would be submerged and, therefore, have the potential to lose more chemical. The poles were then exposed outside the Richardson Hall laboratories where they were subjected to natural heating and rainfall. We allowed this system to operate for approximately 1 year, then we removed the poles, cleaned the system and reset the tank so that different pole surfaces were exposed.

Three pole configurations have been examined using this system (Figure VI-1). These configurations were designed to vary the surface area exposed directly to rainfall. We altered our design to produce varying amounts of exposed treated wood after it appeared that penta water solubility was the primary factor in runoff concentrations.

Figure VI-1. Photo showing the two six-pole configurations a) configuration 1, b) configuration 2, and c) the four-pole configuration evaluated in our small scale preservative migration chamber.

c.

Figure VI-1 (cont.). Photo showing the two six-pole configurations a) configuration 1, b) configuration 2, and c) the four-pole configuration evaluated in our small scale preservative migration chamber.

The tank was sampled whenever there was measurable rainfall by draining all of the water collected in the tank bottom as soon as possible after the rainfall event had concluded, or daily when storms continued for more than one day. In some cases, the rainfall, while measurable, did not result in collectible water samples because the conditions were so dry prior to rain that the falling moisture was either sorbed by the wood or evaporated. In addition, early in the process, it became obvious that debris (primarily leaves) was falling into the tanks between collections. Since these materials had the potential to sorb any chemical solubilized by the rainfall, we placed a large mesh screen around the tank to limit the potential for debris entering the tank, while still allowing rainfall to strike the wood.

We quantified penta in the runoff on a ug/mL of runoff basis, then used these values to assess the amount of runoff in ug/ml/cm^2 of exposed surface area. Exposed surface area was quantified by observing poles during several rainfall events. We noted that water did not always run around poles, but instead struck the pole surface, then dripped off the edges to strike the pole below. As a result, much of the pole surface was not in direct contact with the rainfall. We combined these surface area measurements with the surface area exposed on the non-sealed end of each pole to produce a total exposed area per tank, then divided this area by the total tank area. These values for Configurations 1, 2, and 3 were 79.5, 59.6 and 79.5 % of the total tank area, respectively. These values were then used to express runoff values on a ug/ml/cm^2 basis.

Penta levels in runoff from the stored poles in the original six-pole alignment ranged between 1 and 2.5 ug/ml of water over 62 rainfall events (Figure VI-2). Penta levels in the runoff from the first six rainfall events were lower than almost all other samples; however, there was a delay in analysis of these samples and we believe the lower levels were due to degradation or sorption of the penta during storage time.

The remaining samples were processed within 3 days of collection, limiting the potential for degradation or loss in storage. The relatively narrow range of concentrations suggests that penta solubilization in rainwater is relatively predictable. Penta levels in the runoff from 13 rainfall events for the realigned six-pole stack were slightly higher than those in the original six-pole stack (2.3 to 2.9 ug/ml of water) (Figure VI-2), but the differences were small. The penta levels in the four-pole array were similar to those found with the first two configurations, ranging from 0.8 to 2.6 mg/ml of water. The four-pole configuration exposed a slightly lower surface area to direct rainfall, but did not have excess area beneath the directly exposed samples on which the resulting runoff water could strike the wood.

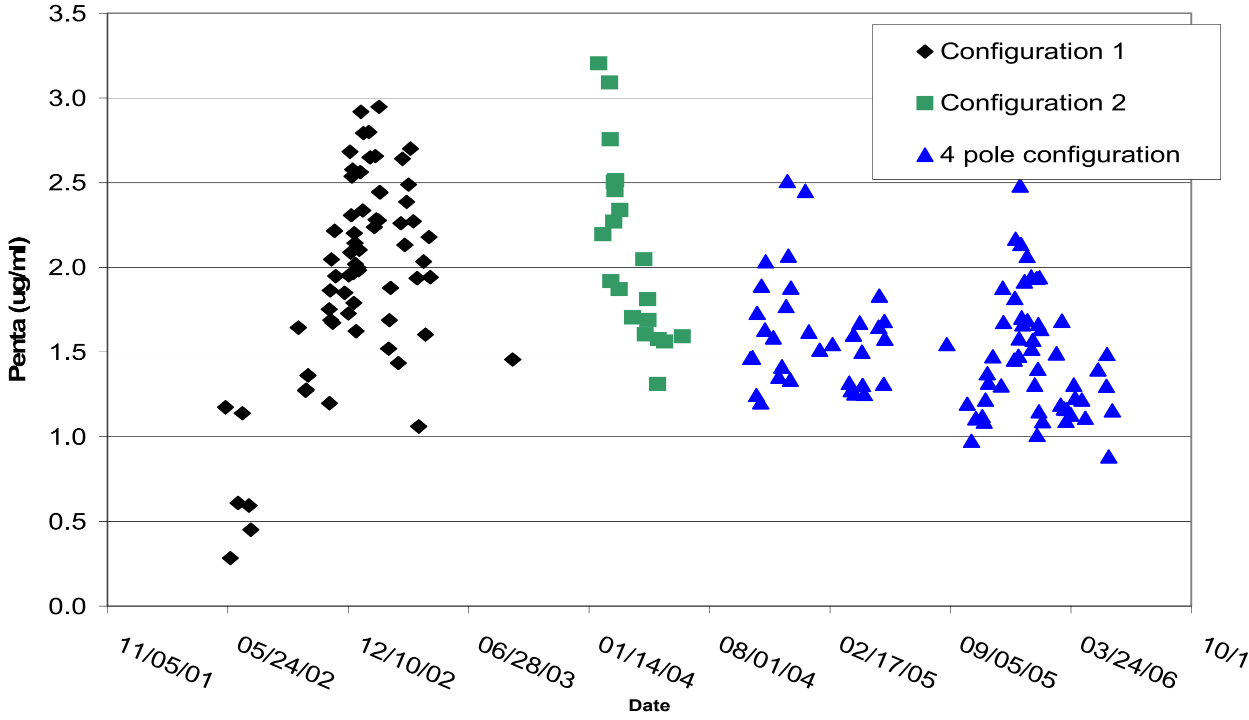


Figure VI-2. Penta concentrations as a function of sampling date in leachate collected from penta treated Douglas-fir poles following rainfall events over a 4.5 year exposure period showing data for three stacking configurations of poles.

Our data suggests that stacking poles to minimize the area exposed to rainfall is probably an effective approach to limiting preservative migration. Spreading poles out allows more rainfall to strike pole surfaces, solubilizing a proportionally higher total amount of penta. In addition, pole rotation (i.e. last in, first out inventory approaches) does not appear to affect losses which appear to be largely driven by the solubility of penta in water. It would take decades to deplete the penta on the pole surface given the elevated levels present in the wood. In previous studies, we have advocated for regular rotation of stored poles to avoid the development of deep checks and limit the potential for internal decay development during prolonged storage. We continue to recommend rotating stored poles so that they do not develop decay in storage.

The results clearly show that stacking configuration can make a major difference in the amount of water striking pentachlorophenol treated wood, but it was unclear how much difference that might make in terms of the amount of chemical leaving the poles and entering the soil beneath. This past year, we continued to sample runoff from poles treated with ammoniacal copper zinc arsenate; but we also undertook an assessment of the levels of penta that might develop beneath poles stored for varying periods of time under different rainfall regimes.

For the purposes of the assessment, we used a hypothetical group of 15 Class 4-40 foot long poles. The virtual poles were configured into three arrangements (Figure VI-3). The first was to have all 15 poles laid out so that they were touching, but not stacked upon one another. This represented the largest surface area exposed to direct rainfall. The second was to stack the poles in a triangle with five poles at the base and one fewer pole per level. The final configuration was a four pole wide stack with stickers between each row, with the final row only containing three poles. The total surface areas occupied by each stack can be found in Table V-1. Pole dimensions were based upon the ANSI 0.5 assumed values for poles of this class and length.

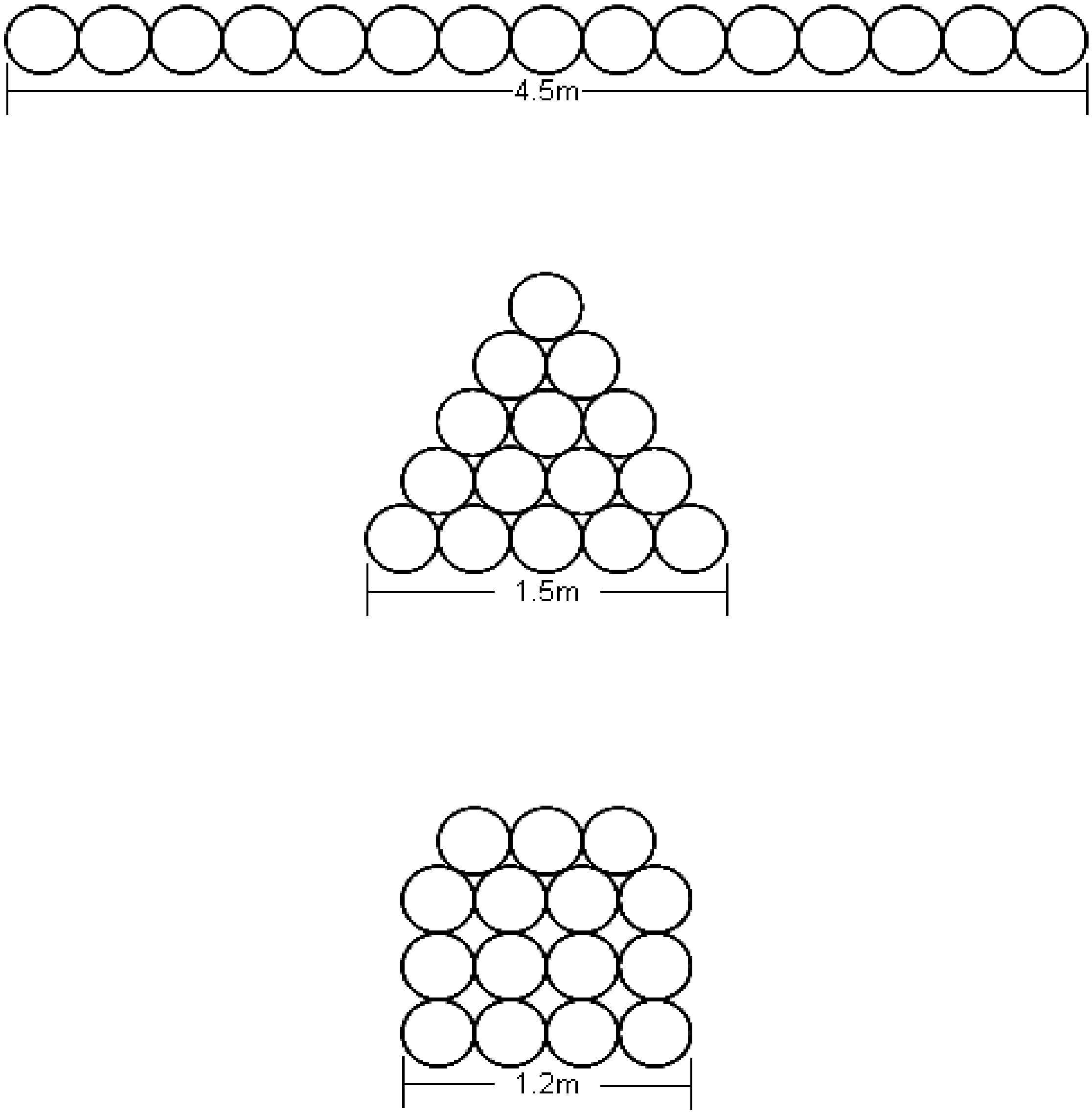


Figure VI-3. Configurations of 15 Class 4 forty foot long poles used to model predicted penta concentrations in soil beneath the poles as a result of rainwater runoff. Poles were configured as 15 individual poles, poles in a triangular stack and poles in four courses with stickers in between each course.

We made an assumption that any rainfall striking the wood would be saturated with penta. From previous tests, the upper levels of penta in runoff water tended to be approximately 3 ug/ml. This figure was used throughout the assessment as the concentration of penta in any water striking the poles.

The assessments were performed using rainfall totals of 15, 30, 45, and 60 inches per year (0.45, 0.90, 1.35, and 1.8 m/yr). Although we have observed periods where rainfall strikes the poles, but does not runoff because it is absorbed by the wood, we have conservatively assumed that any rainfall will leave the wood carrying chemical.

The total pole surface area exposed to rainfall and the total annual rainfall were then used to calculate a total water volume for each stacking configuration (Table VI-1).

Table VI-1. Total amount of rainfall that would fall on 15 Class 4 forty foot long poles arrayed in three different configurations.

Total Annual Rainfall (m)	Total rainfall per configuration (l)		
	Stack (14.4 m^2)	Triangle (18 m^2)	Arrayed (54 m^2)
0.375	54.0	67.5	202.5
0.750	108.0	135.0	405.0
1.125	162.0	202.5	607.5
1.500	216.0	216.0	810.0

The total water volume was then multiplied by the 3 mg/l concentration to estimate the amount of penta that would migrate from the poles in each of the three configurations. (Table VI-2)

Table VI-2. Total amount of penta that would migrate from 15 Class 4 forty foot long poles arrayed in three different configurations.

Total Annual Rainfall (m)	Total amount of penta migrating per configuration (mg)		
	Stack (14.4 m^2)	Triangle (18 m^2)	Arrayed (54 m^2)
0.375	162.0	202.5	607.5
0.750	324.0	405.0	1215.0
1.125	486.0	607.5	1822.5
1.500	648.0	810.0	2430.0

Values reflect an assumption that any water leaving the poles will contain at least 3 mg of pentachlorophenol per liter.

Finally, the depth to which the penta penetrated was assumed to be either 0.075 or 0.15 m (3 or 6 inches). These levels appeared to be practical for areas beneath stored poles in prior studies. Although there is ample evidence that many organisms in native soils are capable of degrading penta and that penta can be chemical degraded in some soils, we used a worst case assumption that none of the penta leaving the poles would be either physically or biologically degraded. Soil in the 0.075 or 0.150 m deep area was then calculated on a volume basis and concentrations that would develop in the soil were estimated based upon assumed soil densities of 1620 to 2160 kg of soil per cubic meter.

As expected, penta levels in the soil beneath the various pole configurations rose steadily over a 3 year period (Table VI-3, Figure VI-4). Concentration in soils where penta migration was confined to the upper 75 mm ranged from 94 to 1879 ppb, while those levels ranged from 47 to 938 when the soil layer was increased to 150 mm thick. A recent soil survey of a contaminated Bonneville Power Administration site

Table VI-3. Predicted penta concentrations in 75 or 150 mm of soil with densities between 1620 and 2160 kg per cubic meter beneath 15 Class 4 forty foot long poles arrayed in three different configurations and subjected to four different rainfall levels over a 4 year period.

Total Annual Rainfall (m)	Penta Concentration in Soil of a given depth (ppb)					
	Stack (14.4 m^2)		Triangle (18 m^2)		Arrayed (54 m^2)	
	75 mm	150 mm	75 mm	150 mm	75 mm	150 mm
0.375 m	94 to 125	47 to 63	282 to 375	141-189	352-469	176-235
0.750 m	188 to 250	94 to 125	564 to 750	282-375	704-938	352-470
1.125 m	282 to 375	141 to 188	843 to 1125	423-564	1056-1407	528-704
1.500 m	376 to 500	188 to 250	1125-1500	564-750	1404-1876	704-938

Values reflect an assumption that any water leaving the poles will contain at least 3 mg of pentachlorophenol per liter and all penta will remain in a soil layer either 75 or 150 mm thick. Values are expressed on a ug of penta per kg of soil basis.

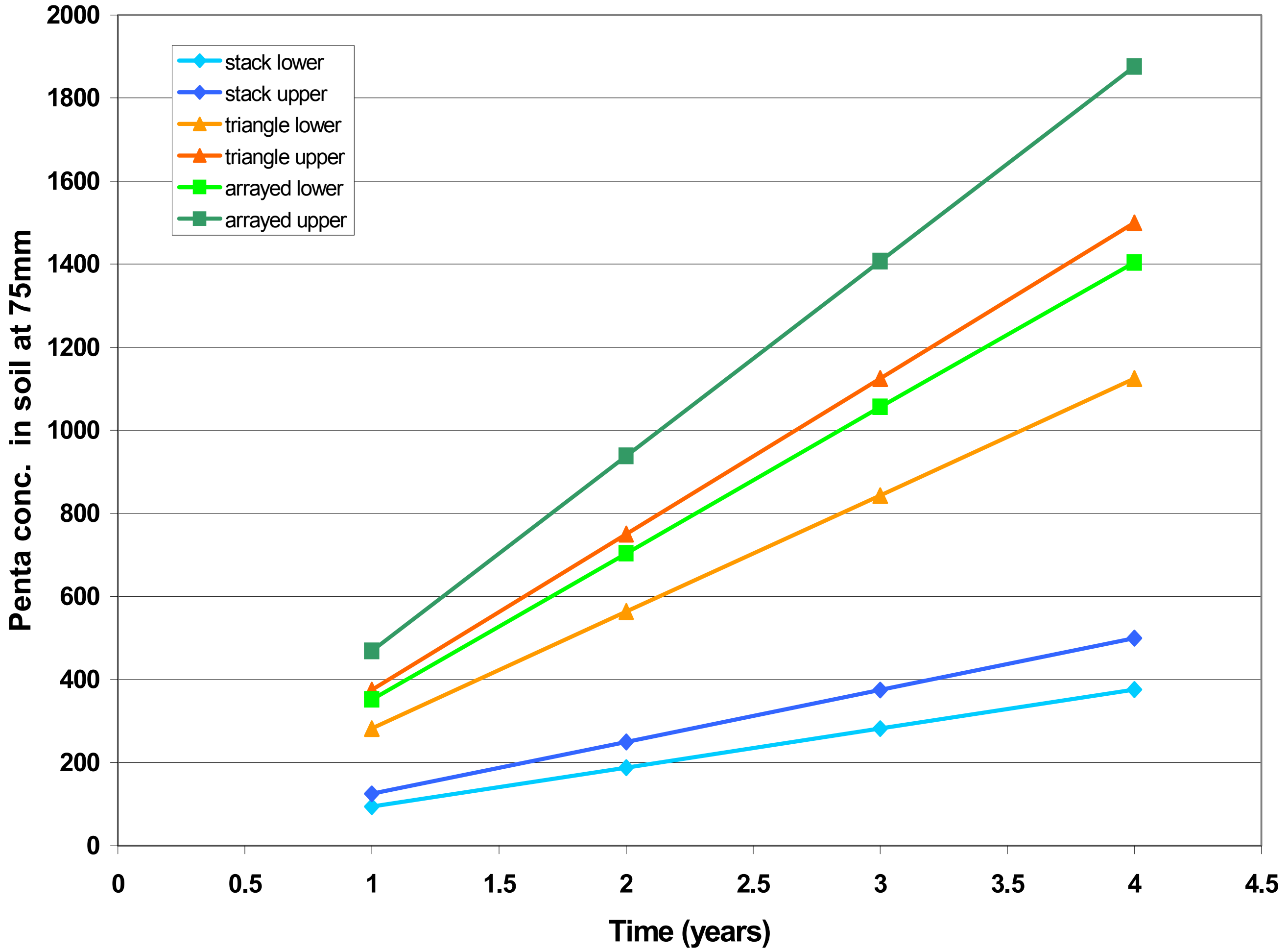


Figure VI-4. Predicted penta concentrations over a 3 year period in soils beneath poles stored in three configurations that varied total area exposed to rainfall.

used 1 mg of penta per kg of soil as an actionable level. Using this level as a guide, we can see that only the highest rainfall levels with the more widely spaced pole configurations would experience this level of contamination and then only in a 75 mm zone. While this could be a concern where poles were stored for many years, the primary concern for many utilities is temporary storage of poles being staged for field construction. In these cases, poles would be stored for much shorter periods and would therefore be subjected to much lower rainfall totals that would further reduce any potential impacts.

At sites where poles are stored for longer periods, it may be possible to adapt the site to contain any migrating chemical. For example, pole storage sites are often graveled to allow for all-weather equipment access. In these cases, it might be possible to install a layer beneath the gravel to trap any penta in the water runoff. This past year, we have explored the potential for using low cost materials such as clays and wood particles to trap penta from water runoff.

In these preliminary trials, test materials were mixed with water containing a known amount of penta. The resulting mixture was allowed to stand for 1 hour then the penta concentrations were determined. Most materials failed to remove an adequate amount of penta from the water; however, wood particles were surprisingly effective at reducing concentrations and further trials are underway to better understand how such a filter system might function. One approach would be to create mesh mats containing wood particles of the desired species and dimension that would be rolled out prior to gravel application. The mats would trap penta while slowly degrading.

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

While the penta results indicated that migration of preservative from oil-borne systems was relatively easily predicted, it was unclear whether these results would translate to poles treated with water based preservatives. In order to assess this potential, the following trial was established.

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 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 end sealed with an elastomeric paint designed to reduce the potential for chemical loss from that surface, while the other end was left unsealed.

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. The poles were set 150 mm above the tank bottom to reduce the risk that the wood would be submerged and, therefore, have the potential to lose more chemical. The poles were then exposed outside the Richardson Hall laboratories where they were subjected to natural heating and rainfall.

The tank was sampled whenever there was measurable rainfall by draining all of the water collected in the tank bottom as soon as possible after the rainfall event had concluded, or daily when storms continued for more than one day. In some cases, the rainfall, while measurable, did not result in collectible water samples because the conditions were so dry prior to rain that the falling moisture was either sorbed by the wood or evaporated.

Water samples were then analyzed for copper, zinc or arsenic by ion-coupled plasma spectroscopy. For the present, we have only assembled the data by rainfall date, total amount of water collected and days between rainfall collections.

As in the penta samples, metals were always detectable in runoff water following rainfall events (Figure VI-5). Arsenic was below the detection threshold at all collection points, however, we made no effort to concentrate materials prior to analysis so there is no way to say that arsenic was absent in the runoff. Copper levels in the runoff ranged from 15 to 90 ppm, but most rainfall contained 20 to 40 ppm of copper. Zinc levels tended to be much lower, ranging from 3 to 34 ppm, but most samples contained less than 10 ppm of zinc.

Metal levels did not appear to be related to time since exposure. For example, one might expect metal levels to decline over time as surface deposits from the original treatment process were removed; however, one of the highest readings occurred 9 months after exposure (Figure VI-5).

As with penta, neither the days between rainfall events nor the total amount of rainfall appeared to be related to the amount of zinc or copper in the runoff (Figures VI-5, 6). The results indicate that water striking the poles sorbs 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.

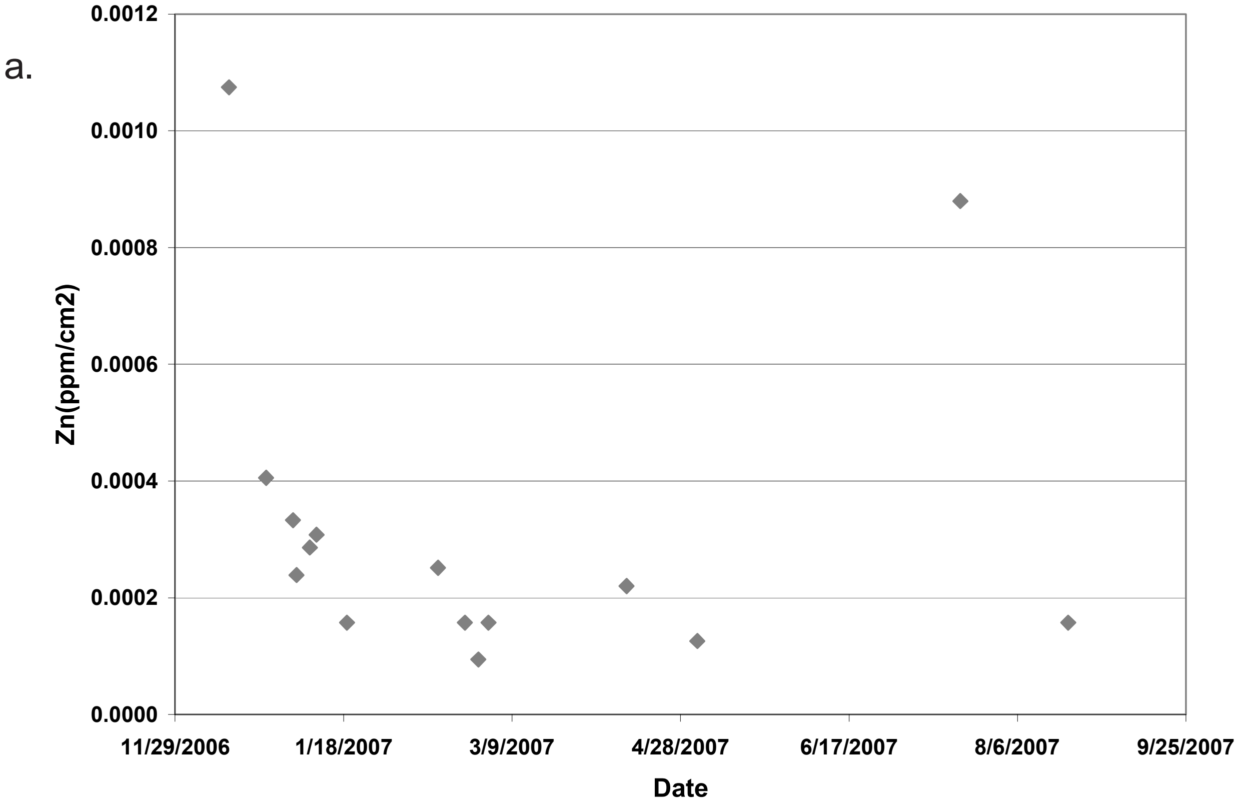


Figure VI-5. Zinc a) and copper b) levels in rainwater runoff from poles treated with ammoniacal copper zinc arsenate as a function of days between rainfall collections.

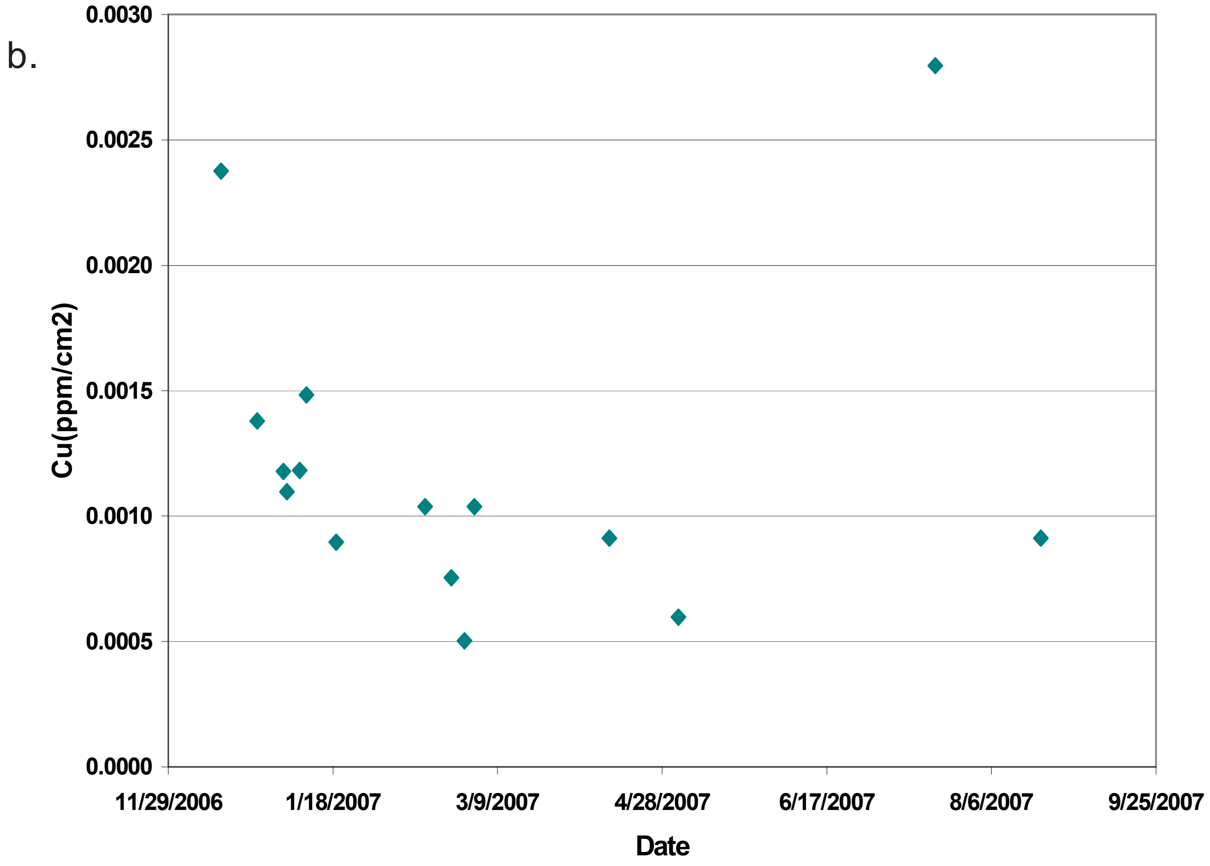
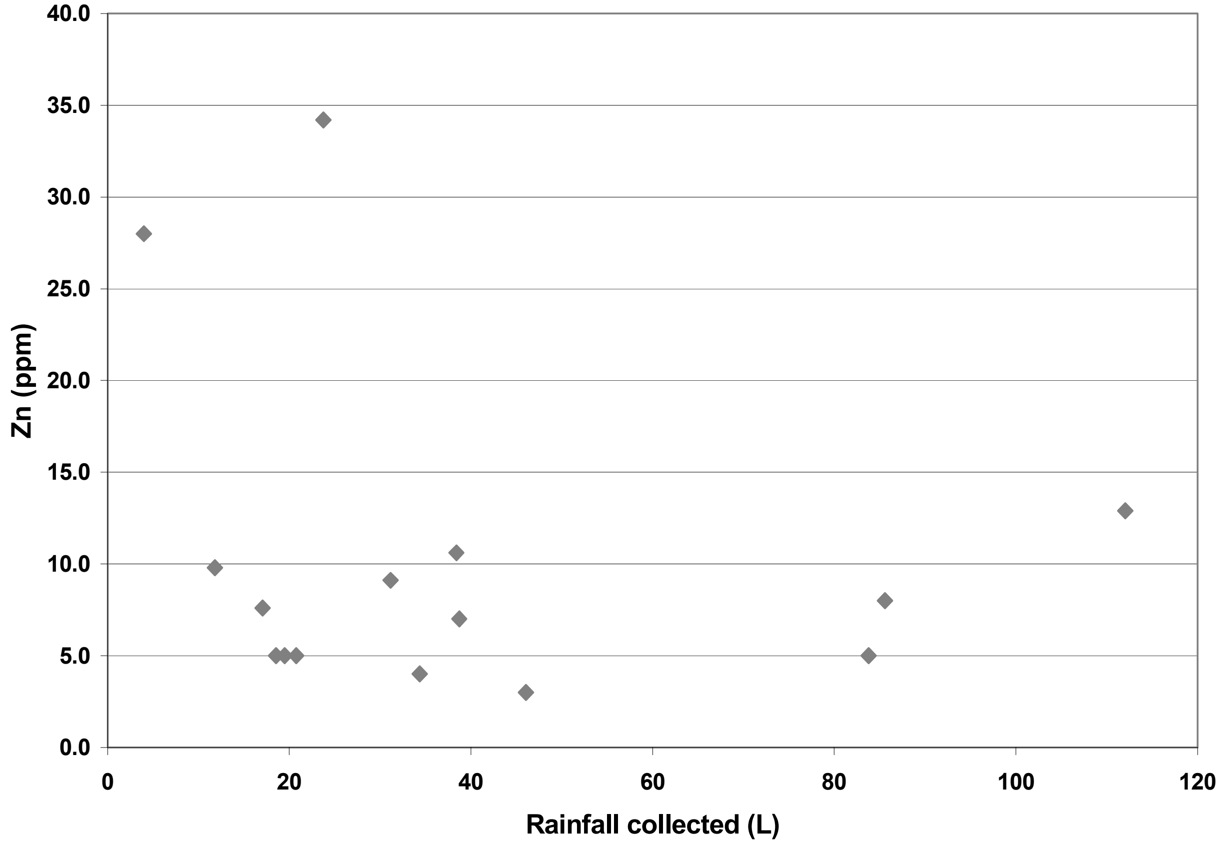


Figure VI-5 (cont.). Zinc a) and copper b) levels in rainwater runoff from poles treated with ammoniacal copper zinc arsenate as a function of days between rainfall collections.



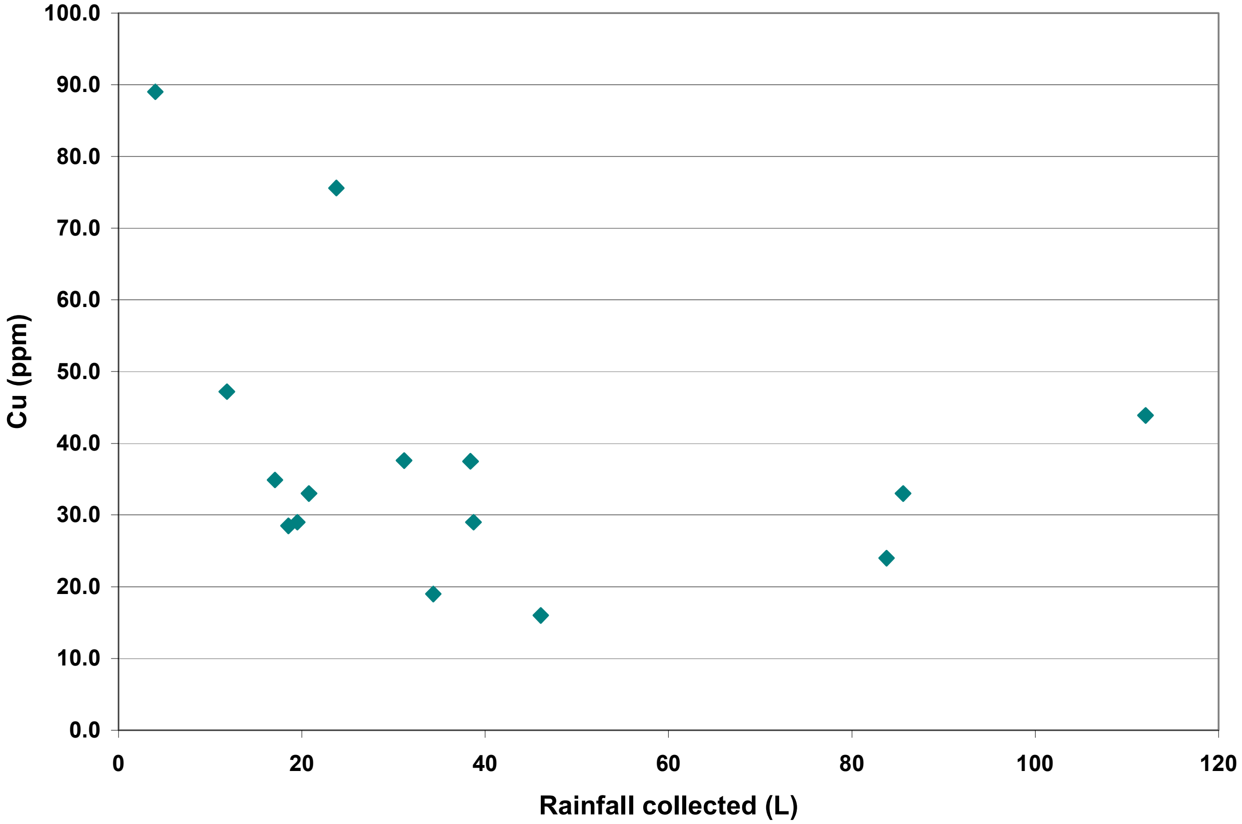


Figure VI-6. Zinc a) and copper b) levels in rainwater runoff from poles treated with ammoniacal copper zinc arsenate as a function of total rainfall collected.

C. Disposal of Utility Poles: A Survey of Utilities in the Pacific Northwest

A common concern among electric utilities is disposal of treated wood poles at the end of their useful life. While the U.S. Environmental Protection Agency routinely recommends re-use of treated wood products in applications similar to the original use, this is not always possible. Some poles are badly degraded and lack the structural integrity that would allow reuse, while others may be mechanically unsuitable for continued use. For decades, the common disposal pathway for these materials was to give away poles to adjacent landowners for re-use as fencing. Some utilities were concerned about this practice because there was little to prevent the new owner of the wood from misusing the product; for example, by burning it. The next solution was to require that those receiving used utility poles sign a waiver and receive a copy of the consumer information sheet for the chemical used to treat the wood, but it was generally accepted that these waivers would not completely protect the utility against misuse. Over time, utilities have experimented with a variety of alternative disposal methods including landfilling all poles, re-sawing poles of some species, burning poles for energy recovery and even disposal in a secure hazardous waste landfill.

A number of surveys in the 1980's and 1990's suggested that utilities worried about disposal, but the practices did not actually cost much and most utilities continued with age-old practices in disposing of old poles. We have not examined disposal practices in many years. As part of the upcoming Utility Pole Conference in Vancouver, WA, we had an opportunity to cooperate with the Northwest Public Power Association to survey their members on current disposal practices. The survey was sent electronically to all NWPPA utility members and the results were compiled by NWPPA for our analysis. The survey was loosely based upon the prior surveys, but added questions concerning alternative materials for poles.

Oregon State University

1. Total # of wood poles in your system: 6,716,858

2. Upper voltage limit where wood poles are used (check one)

20 %	67 kv
60 %	115 kv
27 %	230 kv
2 %	345 kv

3. Proportions of various wood species used in your system (in 10 % increments):

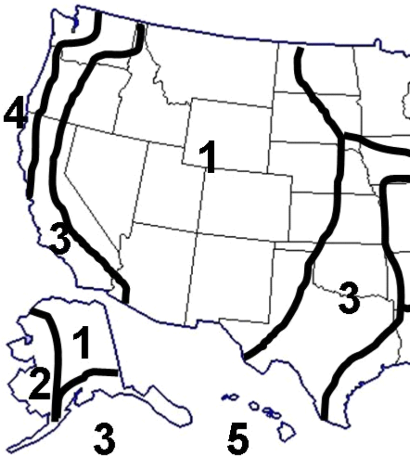
33.8 %	Western redcedar
52.8 %	Douglas-fir
8.3 %	Lodgepole pine
1.7 %	Southern pine
3.8 %	Other

4. Frequency of initial preservative treatments (in 10 % increments)

11.1 %	Creosote
81.8 %	Pentachlorophenol
5.0 %	Copper naphthenate
1.7 %	CCA
0.4 %	ACZA (Chemonite)

5. Please locate your approximate decay hazard zone on the map below:

Zone 1	25.9 %
Zone 2	1.9 %
Zone 3	40.7 %
Zone 4	29.6 %
Zone 5	1.9 %



6. Do you have a regular inspection/maintenance program?

Yes: 81 %
No 19 %

7. On average- how long between physical inspections of your wood poles?

17 %	0-5 year intervals
17 %	5-7 year intervals
23 %	7-10 year intervals
26 %	10-12 year intervals
4 %	12-15 year intervals
13 %	>15 year intervals

8. Estimated average service life of wood poles in your system:

9 %	20-30 years
23 %	30-39 years
32 %	40-49 years
26 %	50-59 years
6 %	60-69 years
4 %	>70 years

9. Total number of poles removed from service each year for all causes:
52,375

10. Approximate proportion of poles in your system removed for the following (52,375 poles):

56.0 %	Decay/insect/woodpecker attack
24.6 %	Road widening
13.5 %	Line upgrades
3.8 %	Car impacts
2.0 %	Other (Please specify)

11. Disposal method- please order from most to least common (place a N/A if not used)
    ______Pole give-aways
    ______Municipal solid waste facility
    ______Secure hazardous landfill
    ______Incineration/Cogeneration of energy
    ______Remanufacturing
    ______Other (please specify)

12. Have you ever had a landfill refuse to accept wood poles for disposal?
    If yes, why?

13. If you give poles away- do you provide the recipient with a consumer information sheet?

14. Estimated annual costs for disposal of wood poles in your system $467,000 (total)

15. Has disposal led you to consider alternative materials for poles?

13 %	Yes
80 %	No
8 %	Comment

Fifty eight utilities responded to the survey and these utilities had 6,516,858 poles in their systems. Respondents averaged 127,782 poles per utility, but the range was quite high with as few as 500 poles all the way up to 1.6 million poles.

The species used by utilities were Douglas-fir, western redcedar, lodgepole pine and southern pine. A majority of the poles in the systems were Douglas-fir (52.8 %) followed by western redcedar (33.8%). Only 8.3% of the poles were lodgepole pine, while 1.7% were southern pine. The latter poles most likely represent a utility on the eastern edge of the survey area where this species is more prevalent. A few utilities used only Douglas-fir (8 of 47 respondents) or western redcedar (3 of 47 respondents), but most used a mixture of poles in their systems.

Chemical preferences appear to be continuing to shift. A majority of the poles in the survey were treated with pentachlorophenol (81.8%), while only 11.1% were treated with creosote. Copper naphthenate treated poles represented 5.0% of the poles, followed by CCA (1.7%) and ACZA (0.4%). Creosote usage has declined for poles because of line personnel concerns about handling, although it remains a highly effective treatment. Copper naphthenate has been marketed as an effective penta replacement and, while its share continues to slowly grow, penta remains the dominant utility pole treatment in this region. ACZA is typically used to treat western wood species where a water-based system is desired and it has been marketed as being somewhat resistant to termites and carpenter ants; however, its market share remains exceedingly small.

Pole replacement rates also varied somewhat, with 52,375 poles replaced among the respondents, representing an annual replacement rate of 0.8% (not all utilities provided pole replacement rates). A majority of these poles (56%) were removed because of insect or fungal attack; however, a sizable number of poles were removed for road widening (24.6%) and line upgrades (13.5%), while a surprisingly small number of poles were removed from vehicular actions. The high proportion of poles removed for road widening and upgrades suggests that there is considerable potential for further reducing replacement rates by re-using some of these poles. Clearly, the availability of effective methods for accurately assessing pole quality prior to re-use would be essential for this process, but it would potentially only reduce the replacement rate to 0.50 % per year.

Most utilities disposed of their poles through give-aways (46.5%), but some utilities disposed of their used poles in municipal solid waste (MSW) facilities (26.8%) and a few used secure hazardous waste facilities. A majority of utilities that gave away poles (62.9%) required that the recipient receive a consumer information sheet.

The estimated annual cost for pole disposal ranged from 0 to $150,000 with a total of $467,050 among the 28 respondents. The average utility spent $16,680 dollars per year on disposal. Less than 20% of respondents (18.8%) had been refused the right to send their poles to a landfill. Of the eight that were refused access to an MSW facility, five of eight said it was because of the chemical, one because of the inability to handle the larger material and one because of the volume involved. The remaining 39 respondents had no difficulty using landfills, which is in accordance with currently accepted practices.

Utilities were strongly positive in terms of the effect of disposal on material choices. Nearly 80% of the respondents (79.5%) reported that disposal had not caused them to look at alternative materials.

The remaining parts of the survey examined utility maintenance practices and estimated pole service life. Over 80% of the respondents (81.3% of 48 responses) operated at least some form of maintenance and inspection program. Of those who responded positively, 17% inspected at 0-5 year intervals, 17% at 5-7 years, 23.4% at 7-10 years, 25.5% at 10-12 years, 4.3% at 12-15 years and 12.8% inspected at intervals greater than 15 years. The utilities responding in the 0 to 5 year interval most likely represent line patrols rather than a physical inspection. The majority of utilities appear to inspect at intervals of 12 years or less, which is in line with data suggesting that reject rates tend to climb substantially when intervals longer than this are used.

Utility personnel perceive that their poles have a range of estimated service lives. The majority of the 47 respondents believe that their poles last between 30 and 59 years, with the percentages for 30-39, 40-49 and 50-59 being 23.4, 31.9 and 25.5%, respectively. Some utilities believed that their poles lasted only 20-30 years (8.5%) while others felt that their poles lasted 60 or more years (10.7%). Given the current replacement rate outlined above and based upon previous surveys, the actual pole service life is between 60 and 80 years, including poles removed for reasons other than degradation.

The current survey indicates that most utilities continue to use traditional pathways for disposing of their used utility poles. The results also indicate that a majority of utilities have taken actions to implement programs that extend service life, thereby reducing the potential for pole disposal.

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