Oregon State University
Utility Pole Research Cooperative

25th Annual Report
October 25,2005

Department of Wood Science & Engineering

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

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Arch Chemicals

Bonneville Power Administration

Dr. Wolman, GMBH

Genics Inc.

Intec, Inc.

ISK Biocides Inc.

New York State Electric and Gas

Osmose Utilities Services, Inc.

Pacific Gas and Electric

Pacific Corp.

Pole Care, Inc.

Pole Maintenance Co. (Copper Care Wood Preservatives, Inc.)

Portland General Electric Company

The Southern Company

Utility Pole Technologies, Inc.

Western Wood Preservers Institute

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Table of Contents

Objective I

Objective II

Objective III

EXECUTIVE SUMMARY

The Co-op continues to examine issues related to improving the performance of wood poles under a number of Objectives.

Objective I: The Co-op continues to evaluate a number of trials of both gaseous and water diffusible internal remedial treatments under laboratory and field conditions. Field tests of dazomet show that this chemical has provided protection to Douglas-fir poles for far longer periods than that provided by liquid metam sodium. Tests with accelerants showed that dazomet decomposition was enhanced by using copper sulfate or copper naphthenate.

Field trials with water diffusible rods show that boron in boron/copper rods has moved to protective levels at or below the groundline where moisture levels are suitable for diffusion to occur, but there was much less consistent movement above the groundline. Copper moved for only a short distance from the point of application and does not appear to play a substantial role in the efficacy of this system. We continue to see a negative dosage effect with these rods, suggesting that excess chemical slows the rate of movement into the wood. We plan to explore this phenomenon over the coming year.

Trials of glycol-amended treatments with boron rods suggest that adding any liquid to the treatment at the time of application enhances movement. The results also show continued protective levels inside poles at groundline 10 years after rods plus liquid application.

Reexamination of previously collected fluoride data using newly developed minimum thresholds for this chemical indicate that protective levels of fluoride have developed in poles receiving fluoride rods. Further discussion of the threshold levels for all of the internal and external treatments is planned to help utilities better interpret our results.

Objective II: Field trials of a preservative-coated bolt for protecting field drilled bolt holes continue to show that the chemicals on these bolts move into the surrounding wood where they are available to provide protection against decay. Further monitoring is planned, but the approach appears to be a simple way to ensure bolt hole protection.

Objective III: Full scale testing of through-bored poles showed that this process had no significant negative effect on strength when holes 12.5 mm and smaller in diameter were employed. The holes appear to act as stress relievers and actually resulted in more uniform bending data. A presentation of the data to ANSI for development of a through-boring standard is planned.

Controlled testing of external barriers for limiting chemical migration from poles reveals that these systems can limit moisture ingress into poles, although failure to cap the bottom negates this value. The field monitoring is continuing.

Field assessments of the above ground portions of older Douglas-fir poles subjected to multiple maintenance cycles at groundline continues to show little change in the condition of the poles. The results indicate that decay near the pole top remains a problem, but that decay around the bolts and other penetrations has not increased markedly with time.

Follow-up tests on the condition of turned Douglas-fir crossarms removed from service in Western Oregon showed that these arms had considerable losses in properties over their 40-50 year service life. These results differ substantially from those found with sawn arms in the same wishbone configuration. We believe that increased checking on the round arms contributed to the reduced (but still excellent) life of these arms.

Objective IV: Field tests of external groundline preservative systems have been established in Georgia and New York. The Georgia trial was assessed after the release of this report. The results will be included in the next annual report.

Objective V: Copper naphthenate treated western redcedar continues to perform well in soil bed tests, mirroring the observed field performance of western species treated with this chemical.

Objective VI: Monitoring of pentachlorophenol treated poles in storage continues to show that small amounts of penta are released during each rainfall event. The concentration of chemical in the water is independent of rainfall amount, temperature, time between rainfall events or pole configuration. The results suggest that the risk of penta migration from poles in storage can be accurately predicted using exposed surface area and total rainfall. Stacking to reduce the amount of area exposed to direct rainfall would also reduce chemical release. Further monitoring is planned.

Objective I

DEVELOP SAFER CHEMICALS FOR CONTROLLING INTERNAL DECAY OF WOOD POLES

Remedial treatments continue to play a major role in extending the service life of wood poles. While the first remedial treatments were broadly toxic, volatile chemicals, the treatments have gradually shifted to more controllable treatments. This shift has resulted in the availability of a variety of internal treatments for arresting fungal attack (Table I-1). Some of these treatments are fungitoxic based upon movement of gases through the wood, while others are fungitoxic based upon movement of boron or fluoride in free water. Each system has advantages and disadvantages in terms of safety and efficacy. In this section, we discuss the active field tests of the newer formulations as well as additional work to more completely characterize the performance of several older treatments.

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

Trade Name	Active Ingredient	Conc. (%)	EPA Registration Number	Manufacturer
TimberFume	trichloronitromethane	96	3008-39	Osmose Utilities Services, Inc.
WoodFume ISK Fume	sodium n-methyldithiocarbamate	32.1	3008-33 1022-562-50534	Osmose Utilities Services, Inc. ISK Biocides
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 01448-00104-75341	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.

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 contact. UPRC research identified two alternatives, solid methylisothiocyanate (MITC) and dazomet. Both chemicals were solid at room temperature, reducing the risk of spills and simplifying cleanup of any spills that occur. MITC was commercialized as MITC-FUME, while dazomet has been labeled as Super-Fume, UltraFume and Dura-Fume. An important part of the development process for these systems have been continued performance evaluation to determine when retreatment is necessary and to identify 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 13 years, first as a glass encapsulated material and later in aluminum ampules. In both cases, the cap was removed 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 untreated 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 rubber stoppers, 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.

As noted previously, ampules stored at 32 C lost most of their chemical within 1 year (Figure I-1). Ampules stored outdoors lost chemical more slowly and there was a slight, but noticeably more rapid release rate for ampules in pole sections that were initially seasoned. Ampules stored at ambient conditions required 4 to 8 years to lose all of the initial chemical, although the vast majority of chemical was lost within the first 4 years after treatment.

Ampules stored at 5 C continue to lose chemical very slowly at rates that will require 25 to 30 years for the chemical to completely leave the ampule. MITC is an interesting chemical in that it sublimes directly from a solid to a gas at room temperature. Clearly, cooler temperatures retard this process. Conversely, decay fungi are only marginally active at 5C, making it unlikely that any significant decay would occur under these conditions. Thus, the slow release of MITC may be attractive from a practical aspect for poles exposed in cooler climates. The only concern about this prolonged

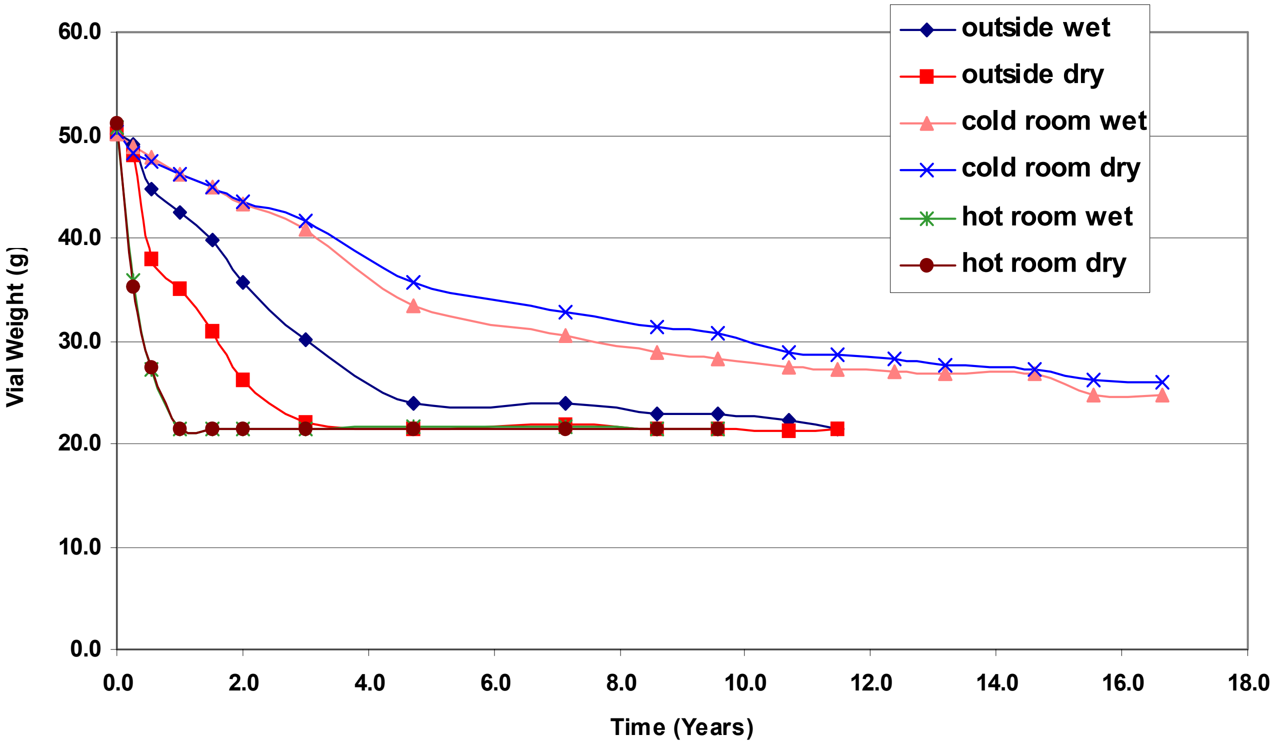


Figure I-1. MITC remaining in glass ampules installed in Douglas-fir pole sections exposed at 5 C, 32 C or ambient outdoor conditions.

release would be that the ampules continue to retain active ingredient for many years. This might become a concern were the pole to be involved in a vehicle accident, since the ampule could be ejected from the hole, or the chemical could be released if the pole were cut through with a chainsaw. However, prior tests by the manufacturers have shown that even cutting through an ampule in the wood results in little or no airborne exposure of workers to the chemical. In addition, there is only 2 to 4 g of chemical in the tubes stored under the cooler condition at this time. Thus, there are minimal risks posed by long term residual chemical in the tubes.

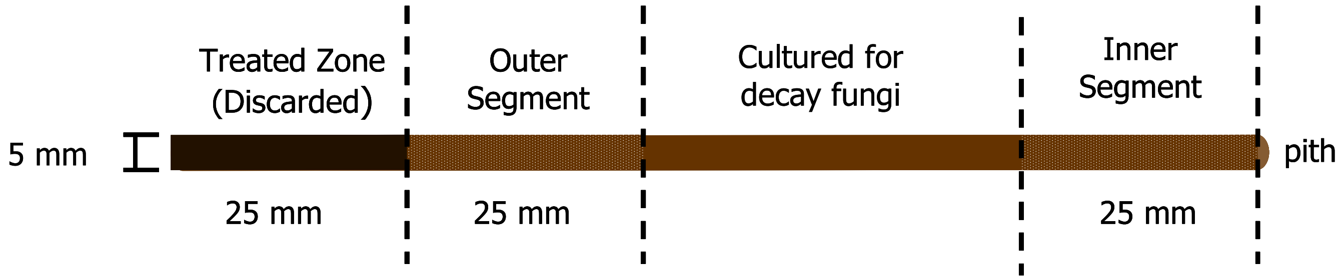
2. Performance of Copper Amended Dazomet in Douglas-fir Transmission Poles

Date Established:	June 1993
Location:	Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta, Class 1-75 to H2-85
Circumference @ GL (avg., max., min.)	144, 160, 132 cm

While chloropicrin, metam sodium, and MITC-FUME have all provided excellent protection, each has handling characteristics that are of concern to some users. In the late 1980's we began work with dazomet, a solid, crystalline chemical that decomposes in the presence of water to produce MITC and a host of other compounds. Preliminary trials suggested that the rate of decomposition was too slow to be of use for controlling wood decay, but continuing trials suggested that this chemical might have promise, particularly because of its ease of handling. In a series of laboratory and small-scale field trials, we showed that dazomet could produce effective levels of MITC in wood over time and also continued to produce MITC for far longer periods than was found with metam sodium. We also found that the presence of some copper in the system markedly improved MITC production. Following these successful small scale trials, we established the following test on transmission-sized poles.

Three steeply angled holes were drilled beginning at groundline and moving upward at 150 mm increments and around 120 degrees in Douglas-fir transmission poles (420 to 510 mm diameter). Drill shavings from each drill hole were retained. These shavings were briefly flamed and then placed on the surface of malt extract agar in plastic petri dishes. These chips were observed for evidence of fungal growth, which was then examined under a microscope for characteristics typical of basidiomycetes, a class of fungi containing many important wood decayers.

The poles were treated with either 200 or 400 g of dazomet with or without 1 % copper sulfate (w/w). The dosages were premixed and evenly distributed among the three treatment holes. An additional set of poles was treated with 500 ml of metam sodium, also distributed among three holes at the same locations as those drilled in the dazomet treatments. The treatment holes were plugged with tight-fitting wood dowels. Chemical movement and efficacy were assessed annually for the first 5 years after treatment, then 7, 10, and 12 years after chemical application by removing increment cores from three equidistant points around each pole 0.3, 1.3, 2.3, and 3.3 m above groundline. The outer, heavily treated zone was discarded, and then the outer and inner 25 mm of each core was removed (see below) 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 g 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 roles in chemical performance remain unknown.

Evaluations of previously collected data suggest that the MITC threshold for fungal protection in Douglas-fir poles is approximately 20 ug/oven dried g of wood. This level was selected on the basis of comparisons between fungal isolations and residual chemical levels in various field tests. Using this level as our guide, protective MITC levels were present within one year in poles receiving metam sodium and with either dazomet dosage amended with copper sulfate (Table I-2, Figure I-2 to I-6). MITC levels tended to be highest within one meter of the groundline, reflecting the concentration of the original application holes near that zone. MITC levels in metam sodium treated poles remained above the threshold in this zone for the first 3 years after treatment, then declined sharply after the fourth year. These results are consistent with the finding that wood from metam treated poles remains inhibitory to decay fungi in bioassays for 3 to 5 years after treatment. It also shows the relatively minimal fungicidal effect of metam sodium in comparison with other fumigants.

Table I-2. Residual MITC (ug/g ODW) levels at selected locations in Douglas-fir poles 1 to 12 years after treatment with metam sodium or dazomet. Numbers in bold are above the lethal threshold for MITC of 20 ug/g ODW.

Treatment	Height (m)	Position inner/outer		Year 1	Year 2	Year 3	Year 4	Year 5	Year 7	Year 10	Year 12
200g dazomet	0	inner	avg.	8	18	**51**	**25**	**31**	**38**	**134**	**43**
			SD	21	20	44	15	31	20	178	35
		outer	avg.	2	**29**	**50**	**39**	**37**	**35**	**68**	**32**
			SD	7	37	63	31	26	30	75	19
	1	inner	avg.	5	8	19	8	10	11	**48**	14
			SD	9	11	21	4	5	7	17	8
		outer	avg.	13	7	**38**	9	7	7	**44**	6
			SD	23	16	36	11	6	8	25	5
	2	inner	avg.	0	4	8	0	0	0	**20**	2
			SD	0	6	5	1	1	0	11	4
		outer	avg.	0	1	9	0	0	0	10	1
			SD	0	4	7	0	1	0	9	2
	3	inner	avg.	1	4	2	0	0	0	7	0
			SD	4	8	4	0	0	0	9	0
		outer	avg.	1	4	2	0	0	0	6	0
			SD	2	7	3	0	0	0	7	0
200g dazomet+ Cu	0	inner	avg.	12	**72**	**182**	**110**	**110**	**80**	**114**	**70**
			SD	27	100	215	86	92	73	111	66
		outer	avg.	14	**50**	**203**	**103**	**59**	**77**	**112**	**45**
			SD	31	74	272	86	101	87	90	62
	1	inner	avg.	**26**	13	**63**	**25**	**28**	**22**	**55**	13
			SD	38	18	70	20	21	14	35	5
		outer	avg.	**42**	8	**47**	11	10	**21**	**57**	7
			SD	65	13	52	16	10	18	56	7
	2	inner	avg.	0	7	10	1	3	5	**30**	4
			SD	0	19	13	2	4	4	20	4
		outer	avg.	1	4	9	0	1	4	19	2
			SD	5	9	17	2	2	5	14	4
	3	inner	avg.	2	6	1	0	0	0	15	0
			SD	5	13	4	0	0	0	12	0
		outer	avg.	0	10	0	0	0	0	11	0
			SD	0	21	0	0	0	0	9	0

Table I-2 (cont.). Residual MITC levels at selected locations in Douglas-fir poles 1 to 12 years after treatment with metam sodium or dazomet. Numbers in bold are above the lethal threshold for MITC of 20 ug/g ODW.

Treatment	Height (m)	Position inner/outer		Year 1	Year 2	Year 3	Year 4	Year 5	Year 7	Year 10	Year 12
400g dazomet	0	inner	avg.	5	**45**	**102**	**59**	**42**	**60**	**139**	**67**
			SD	9	47	97	35	23	31	128	56
		outer	avg.	**22**	**110**	**137**	**84**	**38**	**59**	**103**	**76**
			SD	49	108	207	54	31	27	80	106
	1	inner	avg.	16	5	**107**	11	12	15	**58**	11
			SD	31	5	106	8	8	7	20	9
		outer	avg.	**56**	1	**69**	7	7	12	**51**	6
			SD	86	3	105	6	6	6	36	6
	2	inner	avg.	1	1	15	0	1	1	19	3
			SD	4	2	15	0	2	2	7	6
		outer	avg.	0	1	6	0	0	0	13	1
			SD	0	3	8	0	0	2	8	3
	3	inner	avg.	0	1	3	0	0	0	10	1
			SD	0	2	6	0	0	0	7	3
		outer	avg.	1	4	3	0	0	0	2	0
			SD	3	10	6	0	0	0	4	0
400g Dazomet + Cu	0	inner	avg.	**25**	**100**	**435**	**121**	**108**	**70**	**79**	13
		inner	SD	41	93	613	82	89	89	43	9
		outer	avg.	**25**	**69**	**501**	**130**	**54**	**51**	**53**	16
		outer	SD	76	126	787	116	70	30	29	19
	1	inner	avg.	**31**	7	**149**	9	13	10	**40**	5
		inner	SD	46	8	162	10	14	8	22	9
		outer	avg.	**64**	3	**132**	7	9	10	**46**	6
		outer	SD	139	5	185	10	10	7	46	19
	2	inner	avg.	0	2	11	1	14	1	11	4
		inner	SD	0	5	11	2	48	2	10	14
		outer	avg.	0	3	6	0	6	1	10	0
		outer	SD	0	5	8	1	21	2	7	0
	3	inner	avg.	0	3	1	0	0	1	8	0
		inner	SD	0	5	2	0	0	4	8	0
		outer	avg.	0	4	1	0	0	0	3	0
		outer	SD	0	6	2	0	0	0	7	0
500ml metam sodium	0	inner	avg.	**21**	**53**	**48**	**15**	**8**	**3**	**8**	1
			SD	43	47	34	16	8	5	15	4
		outer	avg.	**30**	**26**	**64**	**14**	**7**	**2**	**3**	1
			SD	61	28	106	11	6	4	7	2
	1	inner	avg.	**57**	15	**51**	7	6	1	**1**	1
			SD	82	17	122	8	6	2	4	3
		outer	avg.	**38**	8	**25**	4	2	1	**1**	1
			SD	46	16	31	7	4	2	3	2
	2	inner	avg.	1	4	12	1	0	0	0	0
			SD	3	7	9	3	1	0	0	2
		outer	avg.	0	3	5	1	0	0	0	0
			SD	0	5	5	2	1	0	0	0
	3	inner	avg.	1	3	7	0	0	0	0	0
			SD	3	6	15	0	0	0	0	2
		outer	avg.	0	3	2	0	0	0	0	0
			SD	0	5	6	0	0	0	0	1

Treatment of poles with 200 or 400 g of dazomet alone produced more variable MITC levels one year after treatment. Protective levels were present at the groundline within the second year for the 200 g dosage, but levels further above the groundline were more variable. Doubling the dosage improved MITC levels after the first year and also produced increased MITC levels 1 m above the groundline. In addition, both dosages resulted in protective levels at groundline 12 years after treatment. This long term release rate is a secondary benefit of the use of this fumigant. While initial chemical levels were lower than those found with metam sodium, the longer release period from this treatment should produce more uniform protection against renewed fungal attack.

Over the longer term, we have seen a periodic increase in MITC levels near the groundline for both the 200 and 400 g dazomet treatments without any added copper (Figures I-2, I-4). The apparent fluctuations in MITC levels over time may reflect variations in moisture availability. Moisture is essential for dazomet decomposition to produce MITC and any increases in precipitation patterns should be accompanied by a later rise in MITC levels. This relationship is evidenced in the year 3 results, which followed a record setting rainfall year (1500 mm vs the normal 1000 mm); however, the sudden increase in MITC levels at year 10 followed a normal precipitation year.

The addition of copper to dazomet at the time of treatment produced marked increases in levels of MITC found one year after treatment. The copper enhancement of dazomet decomposition to MITC remained evident for 5 years after treatment, then the effect declined and MITC levels were similar in amended and non-amended treatments. In both cases, the residual MITC levels were well above those required for protection against renewed fungal attack. This copper effect appeared to occur for the first 10 years of the test. This past year, however, the MITC levels near groundline in the 400g dosage with amended copper were below the threshold for fungal protection, while MITC levels in the lower dosage were similar to those found in the non-copper amended treatment (Figures I-3, I-5). These results suggest that the enhancement effect of copper ultimately declines, although this decline occurs well beyond the traditional 10 year retreatment cycle.

Culturing increment cores from the poles revealed that decay fungi were periodically isolated from various locations over the course of the test, but there was no consistent increase in fungal frequency over the 12 year test. For example, decay fungi were isolated near the groundline in poles 5 years after treatment with 200 g of dazomet plus copper sulfate;

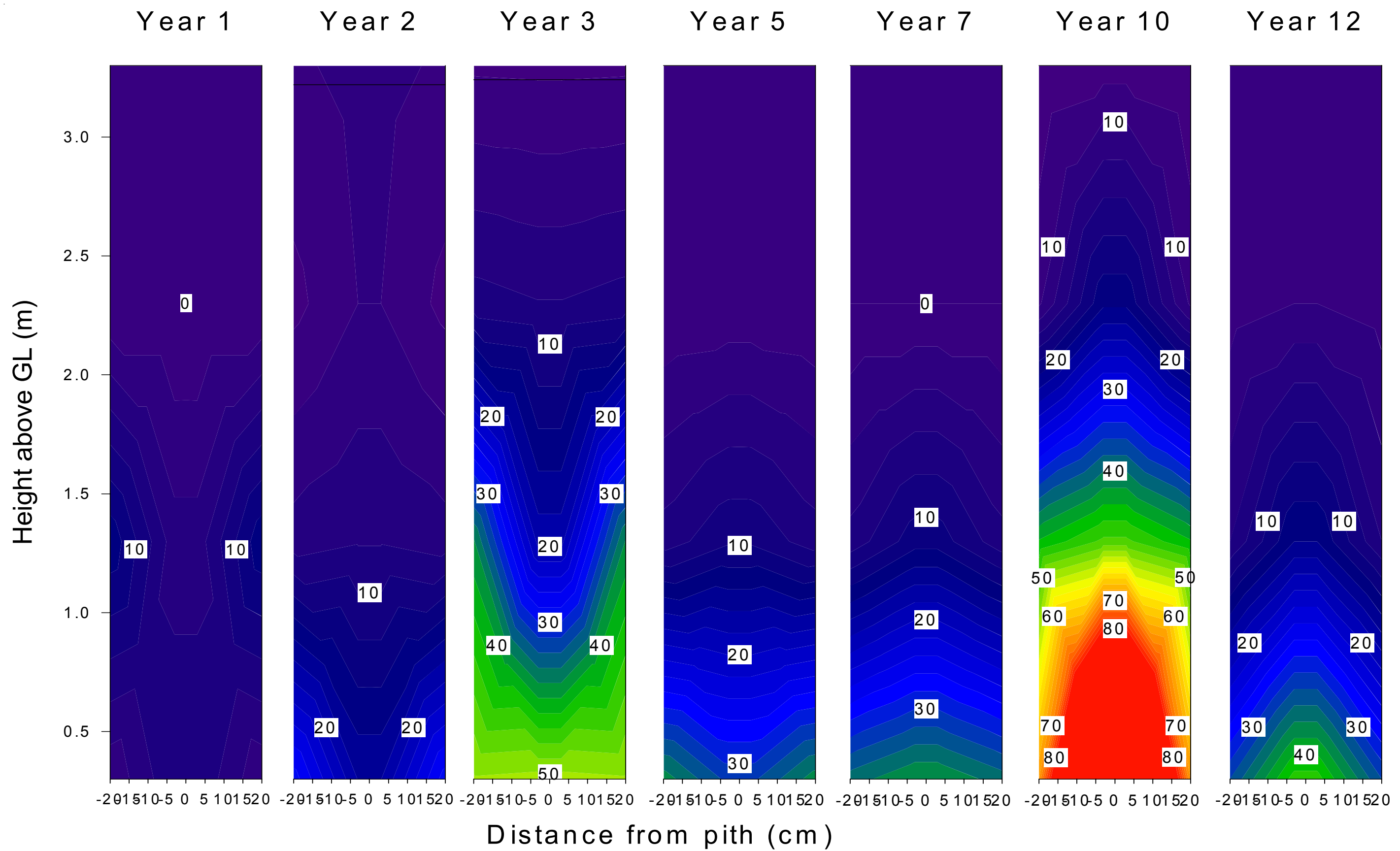


Figure I-2 Residual MITC (ug/g ODW) levels in Douglas-fir poles 1 to 12 years after treatment with 200 g of dazomet. Dark blue indicates MITC levels below threshold. Light blue and all other colors indicate MITC levels above the lethal threshold.

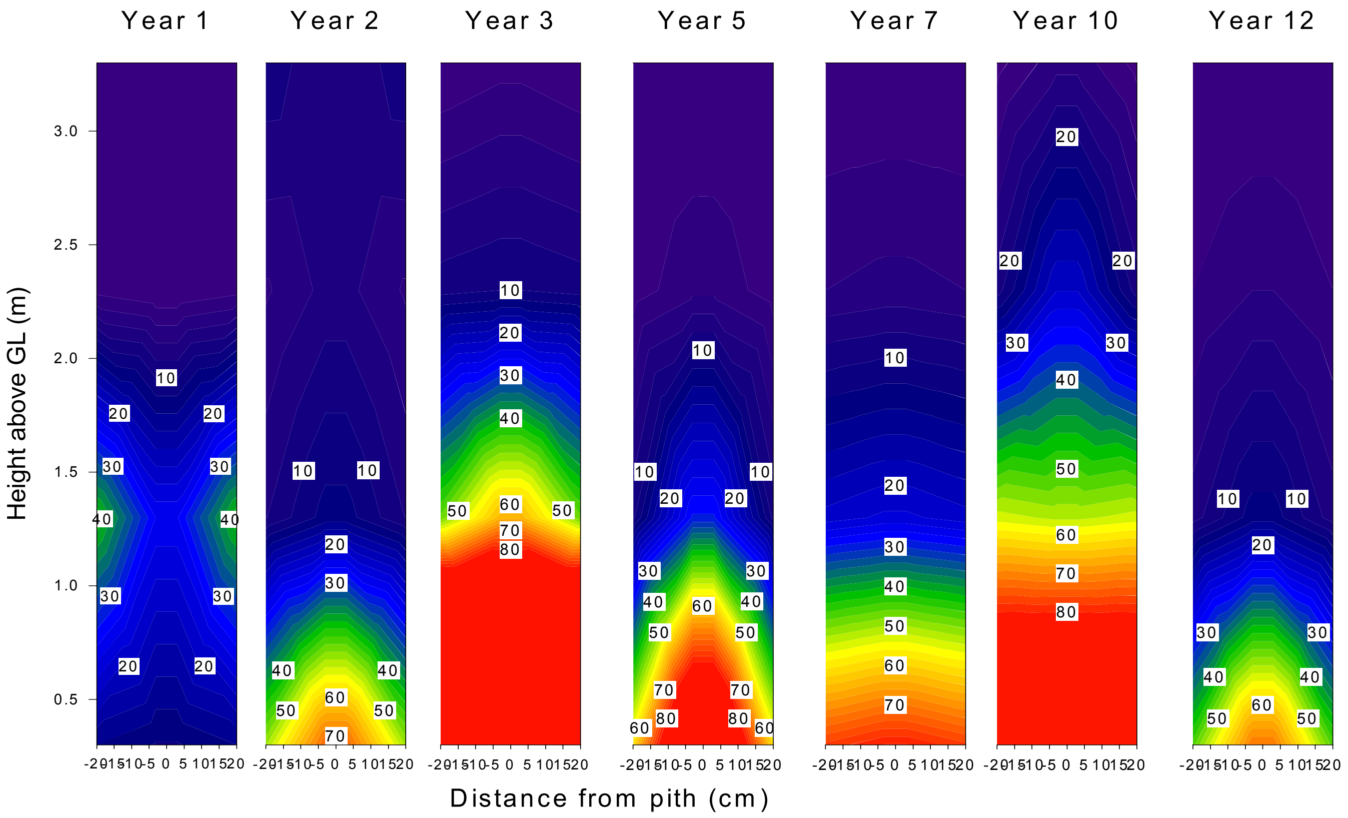


Figure I-3. Residual MITC (ug/g ODW) levels in Douglas-fir poles 1 to 12 years after treatment with 200 g of dazomet amended with 1 % copper sulfate. Dark blue indicates MITC levels below threshold. Light blue and all other colors indicate MITC levels above the lethal threshold.

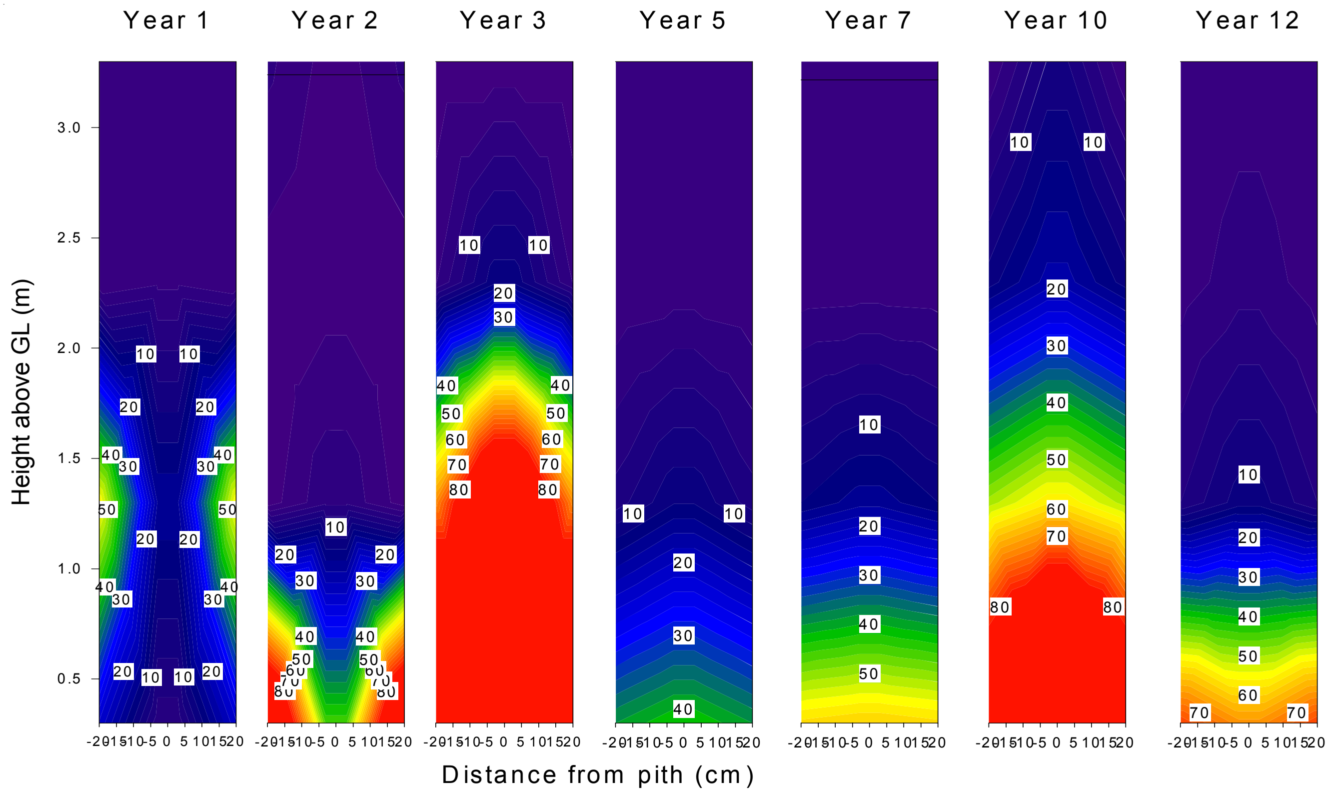


Figure I-4. Residual MITC (ug/g ODW) levels in Douglas-fir poles 1 to 12 years after treatment with 400 g of dazomet. Dark blue indicates MITC levels below threshold. Light blue and all other colors indicate MITC levels above the lethal threshold.

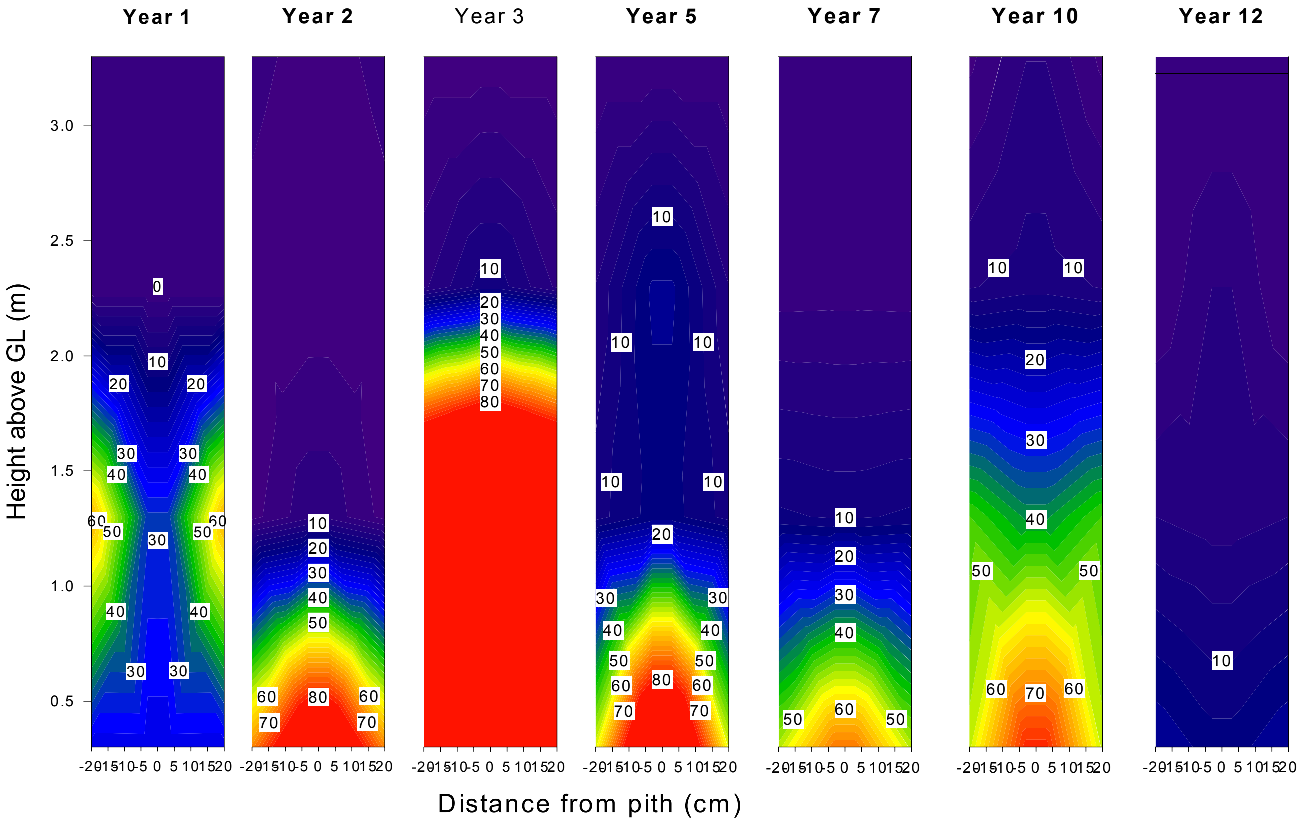


Figure I-5. Residual MITC (ug/g ODW) levels in Douglas-fir poles 1 to 12 years after treatment with 400 g of dazomet amended with 1% copper sulfate. Dark blue indicates MITC levels below threshold. Light blue and all other colors indicate MITC levels above the lethal threshold.

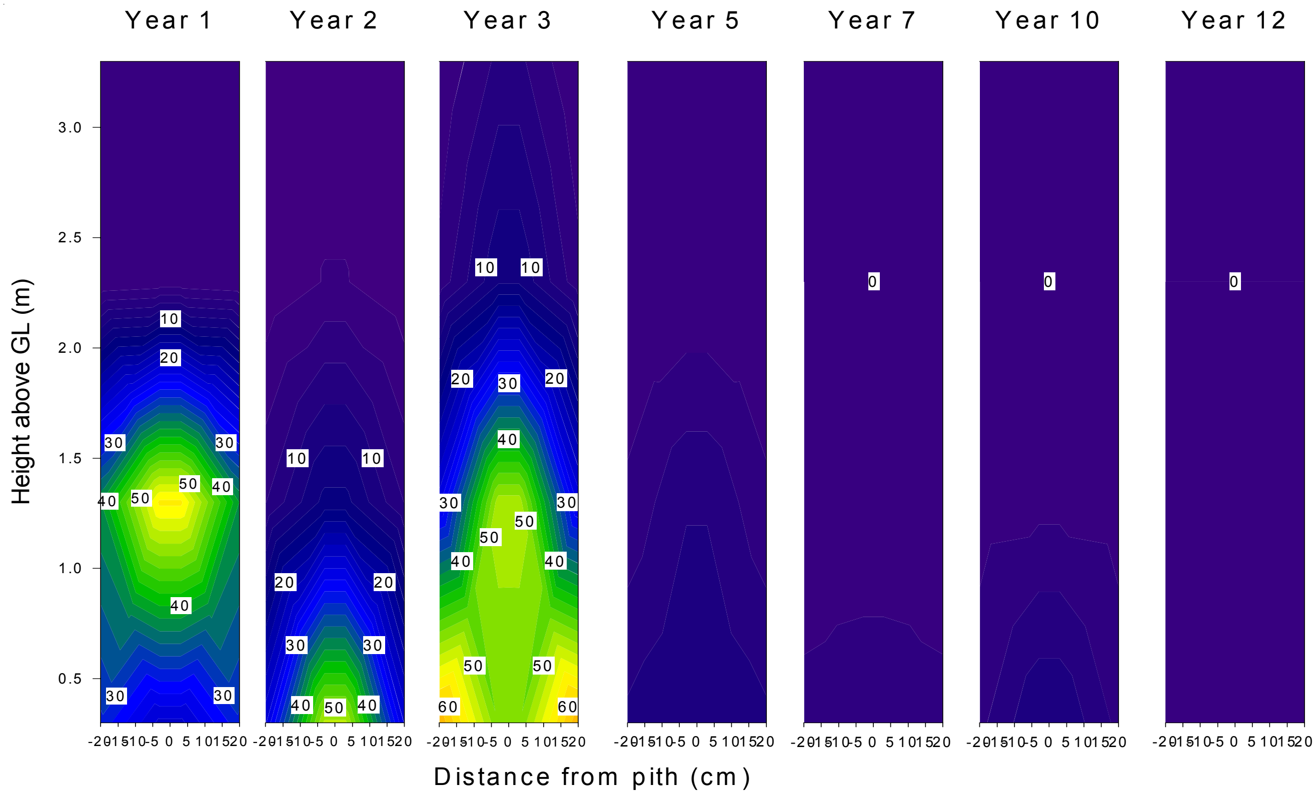


Figure I-6. Residual MITC (ug/g ODW) levels in Douglas-fir poles 1 to 12 years after treatment with 500 ml of metam sodium. Dark blue indicates MITC levels below threshold. Light blue and all other colors indicate MITC levels above the lethal threshold.

however, no decay fungi were isolated from this location 7 or 10 years after treatment. The inconsistent isolations indicate that the treatment remains largely protective (Table I-3).

The 12 year results indicate that dazomet provides a slower initial protection, but that MITC remains in the poles at effective levels for far longer periods than would be found with metam sodium. The addition of copper to the dazomet markedly improves MITC release rates, producing a treatment that is initially comparable to metam sodium, but provides a far longer period of protection against renewed fungal attack.

Table I-3. Frequency of isolation of basidiomycetes and non-decay fungi from Douglas-fir poles 1 to 12 years after application of metam sodium or dazomet alone or amended with 1 % copper sulfate (w/w).

Treatment	Dose	$CuSO_4$	Isolation Frequency %[a]														
			Distance above GL														
			0.3 m								1.3 m						
			0 yr	2 yr	3 yr	4 yr	5 yr	7 yr	10 yr	12 yr	2 yr	3 yr	4 yr	5 yr	7 yr	10 yr	12 yr
metam sodium	500 ml		0^{47}	0^{10}	0^{5}	0^{13}	0^{27}	0^{40}	3^{28}	0^{17}	0^{13}	0^{3}	0^{10}	0^{30}	0^{20}	0^{28}	0^{33}
dazomet	400 g		0^{14}	0^{7}	0^{0}	0^{0}	0^{27}	0^{0}	0^{0}	0^{27}	0^{23}	0^{0}	0^{0}	0^{13}	0^{0}	0^{0}	0^{47}
dazomet	400 g	+	0^{27}	0^{7}	0^{20}	0^{0}	0^{27}	0^{0}	0^{7}	0^{20}	0^{13}	0^{7}	0^{0}	0^{27}	0^{0}	0^{0}	0^{20}
dazomet	200 g		7^{20}	0^{27}	0^{0}	0^{0}	0^{33}	0^{7}	0^{0}	0^{20}	0^{33}	0^{0}	0^{7}	0^{40}	0^{0}	0^{0}	0^{33}
dazomet	200 g	+	0^{0}	0^{0}	0^{0}	0^{7}	13^{13}	0^{20}	0^{0}	0^{60}	13^{0}	0^{20}	0^{0}	7^{40}	0^{20}	0^{0}	7^{50}
				2.3 m							3.3 m						
				2 yr	3 yr	4 yr	5 yr	7 yr	10 yr	12 yr	2 yr	3 yr	4 yr	5 yr	7 yr	10 yr	12 yr
metam sodium	500 ml		- -	0^{10}	0^{7}	0^{10}	3^{40}	13^{27}	0^{21}	0^{33}	0^{10}	0^{3}	0^{13}	0^{50}	7^{7}	0^{0}	25^{67}
dazomet	400 g		- -	0^{7}	0^{25}	0^{20}	0^{27}	0^{7}	0^{7}	0^{36}	0^{14}	0^{25}	7^{7}	7^{33}	0^{27}	0^{13}	0^{40}
dazomet	400 g	+	- -	0^{13}	0^{7}	0^{7}	0^{33}	0^{7}	0^{7}	0^{47}	0^{7}	0^{13}	0^{0}	0^{33}	7^{0}	0^{13}	0^{33}
dazomet	200 g		- -	0^{27}	0^{14}	7^{33}	0^{33}	0^{27}	0^{13}	0^{7}	0^{40}	0^{0}	7^{27}	0^{33}	0^{40}	0^{7}	0^{20}
dazomet	200 g	+	- -	0^{27}	0^{0}	0^{7}	0^{27}	0^{7}	0^{0}	27^{27}	0^{0}	0^{13}	0^{7}	0^{27}	0^{0}	0^{0}	10^{27}
a) Initial samples were shavings from the treatment hole. Values from other years represent 15 samples/treatment for dazomet and 30 for metam sodium. Superscripts represent percentage of nondecay fungi.																	

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

Pentachlorophenol treated Douglas-fir pole sections (206-332 mm in diameter by 3 m long) were set to a depth of 0.6 m at the Corvallis test site. Three steeply angled holes were drilled into each pole beginning at groundline and moving upward 150 mm and around 120 degrees. The holes received either 160 g of powdered dazomet, 107 g of dazomet rod plus 100 g of copper naphthenate, 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 one to five 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 inner and outer 25 mm of each core was extracted in ethyl acetate and the extract was analyzed for MITC by gas chromatography as previously described. The remainder of each core was then cultured for decay fungi as previously described.

MITC levels 0.3 m above groundline were all well over the 20 ug threshold one year after treatment regardless of chemical treatment (Table I-4; Figure I-7 to I-12). The addition of copper compounds to the dazomet treatments had little effect on MITC levels in the inner zones one year after treatment, but MITC levels appeared to be slightly

Table I-4. Residual MITC in Douglas-fir pole sections at selected distances above the groundline 1 to 5 years after treatment with metam sodium, dazomet powder, or dazomet rods with or without supplemental copper.

Treatment	Dosage	Additive	Year Sampled	Residual MITC (ug/g wood)[a]					
				0.3 m		0.8 m		1.3 m	
				inner	outer	inner	outer	inner	outer
Dazomet Rod	160 g	none	Year 1	**50** (35)	**24** (24)	6 (17)	4 (8)	0	0
			Year 2	**52** (70)	16 (55)	**42** (54)	1 (3)	**25** (32)	**27** (41)
			Year 3	**38** (41)	**28** (44)	**28** (28)	**39** (65)	**54** (98)	**34** (51)
			Year 5	**145** (99)	**97** (81)	**32** (19)	**22** (20)	8 (11)	4 (7)
Dazomet Powder	107 g	100g Cu naphthenate	Year 1	**45** (57)	**46** (44)	2 (4)	6 (8)	0	0
			Year 2	**51** (70)	1 (2)	**36** (51)	1 (3)	**73** (101)	14 (28)
			Year 3	**67** (81)	**66** (102)	**52** (98)	**31** (46)	**49** (67)	**37** (71)
			Year 5	**118** (53)	**85** (52)	**56** (38)	**42** (73)	16 (11)	5 (11)
Dazomet Powder	160 g	none	Year 1	**54** (95)	**3**0 (30)	2 (4)	4 (7)	0	1 (3)
			Year 2	**29** (37)	3 (6)	**35** (53)	1 (3)	**33** (46)	6 (12)
			Year 3	**26** (36)	**31** (43)	**38** (51)	15 (20)	**29** (34)	**21** (49)
			Year 5	**113** (56)	**80** (66)	**38** (29)	**21** (11)	6 (11)	3 (7)
Dazomet Powder	160 g	100g Cu naphthenate	Year 1	**49** (63)	**85** (88)	9 (16)	9 (16)	1 (2)	1 (2)
			Year 2	**80** (104)	17 (45)	**49** (64)	4 (9)	**62** (75)	5 (11)
			Year 3	**76** (101)	**39** (53)	**47** (55)	**73** (115)	**47** (52)	**28** (48)
			Year 5	**175** (197)	**159** (139)	**62** (88)	**46** (87)	18 (30)	11 (21)
Dazomet Powder	160 g	100 g water	Year 1	**22** (22)	**29** (35)	4 (6)	6 (10)	0	1 (2)
			Year 2	**33** (47)	1 (2)	**32** (34)	1 (5)	**41** (41)	6 (11)
			Year 3	**25** (23)	**24** (28)	**22** (31)	14 (26)	**37** (45)	14 (27)
			Year 5	**63** (28)	**87** (104)	**29** (14)	15 (18)	5 (7)	1 (3)
Metam Sodium	490 ml	none	Year 1	**64** (44)	**75** (74)	17 (18)	**22** (27)	1 (3)	2 (4)
			Year 2	**37** (49)	7 (11)	**30** (27)	4 (7)	**50** (78)	5 (10)
			Year 3	**22** (19)	**22** (22)	17 (18)	**21** (20)	18 (15)	17 (19)
			Year 5	12 (11)	13 (10)	9 (9)	8 (10)	7 (8)	2 (5)

[a] Values represent means of 15 analyses per treatment. Figures in parentheses represent one standard deviation. Figures in bold type represent levels above the lethal threshold for MITC.

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. 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. At present all levels in poles receiving this treatment are below the minimum for fungal attack. MITC levels 0.3 m above groundline in poles 5 years after various dazomet treatments remained extremely high with most levels being at least three times the minimum 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. Chemicals 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 have continued after 3 years. 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 described under Objective I–3 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 would have diffused into a larger area, resulting in correspondingly lower chemical levels per unit area.

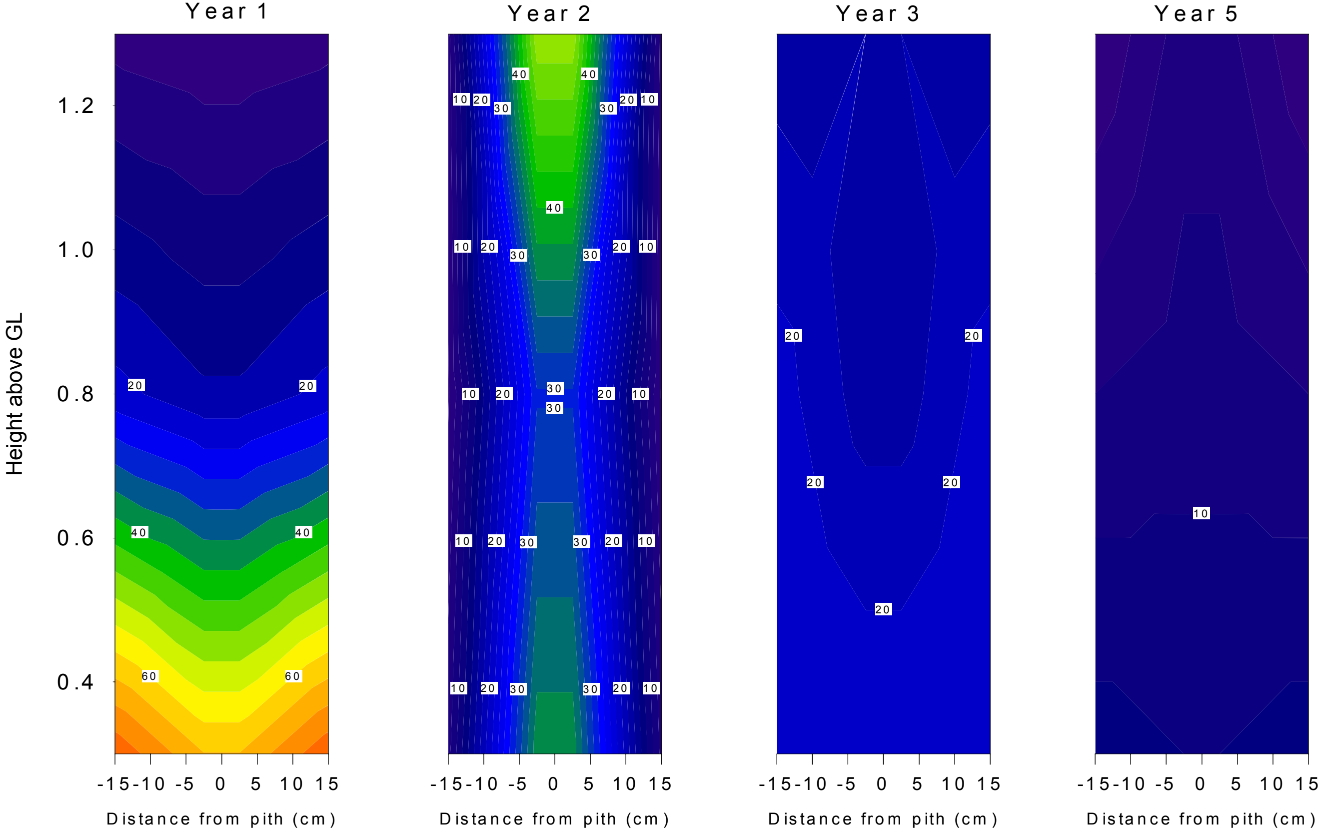


Figure I-7. Residual MITC in Douglas-fir poles 1 to 5 years after treatment with 490 ml of metam sodium. Dark blue indicates MITC levels below threshold. Light blue and all other colors indicate MITC levels above the lethal threshold.

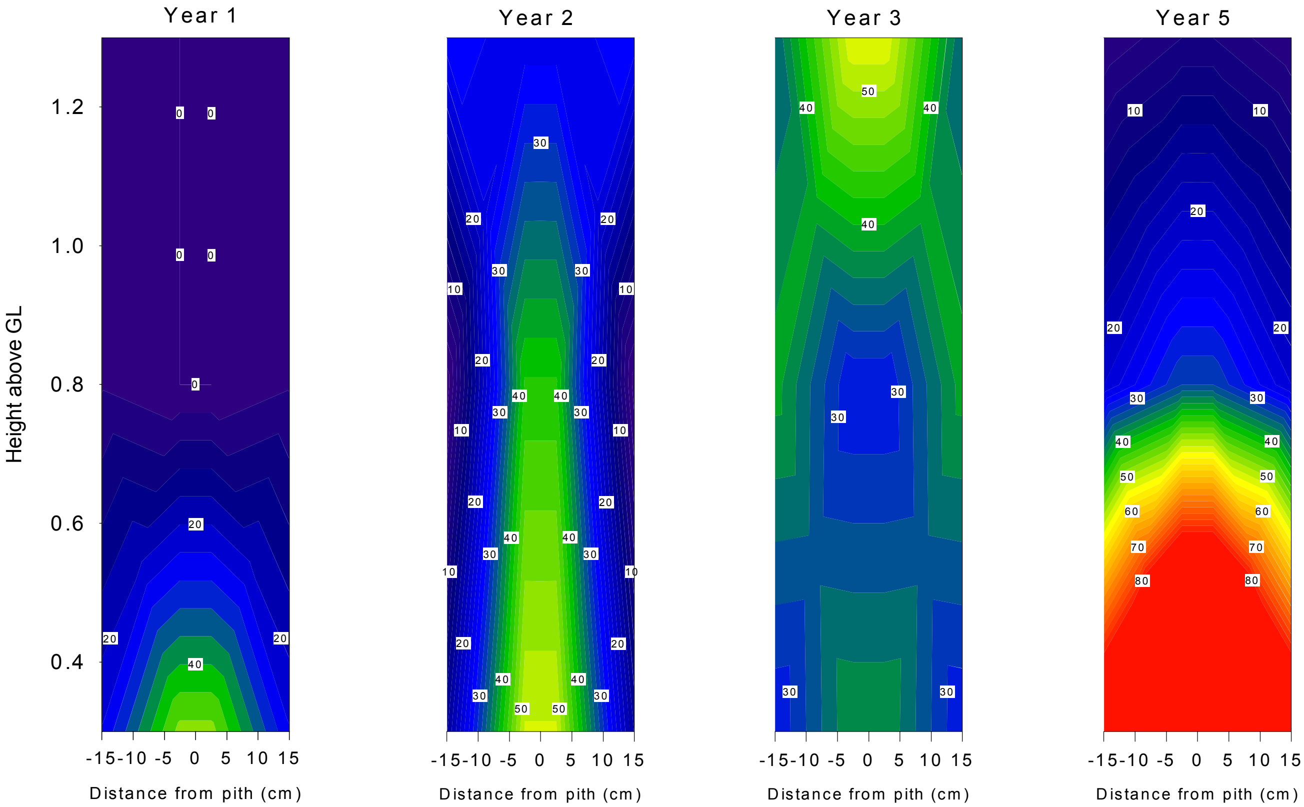


Figure I-8. Residual MITC in Douglas-fir poles 1 to 5 years after treatment with 160 g of powdered dazomet. Dark blue indicates MITC levels below threshold. Light blue and all other colors indicate MITC levels above the lethal threshold.

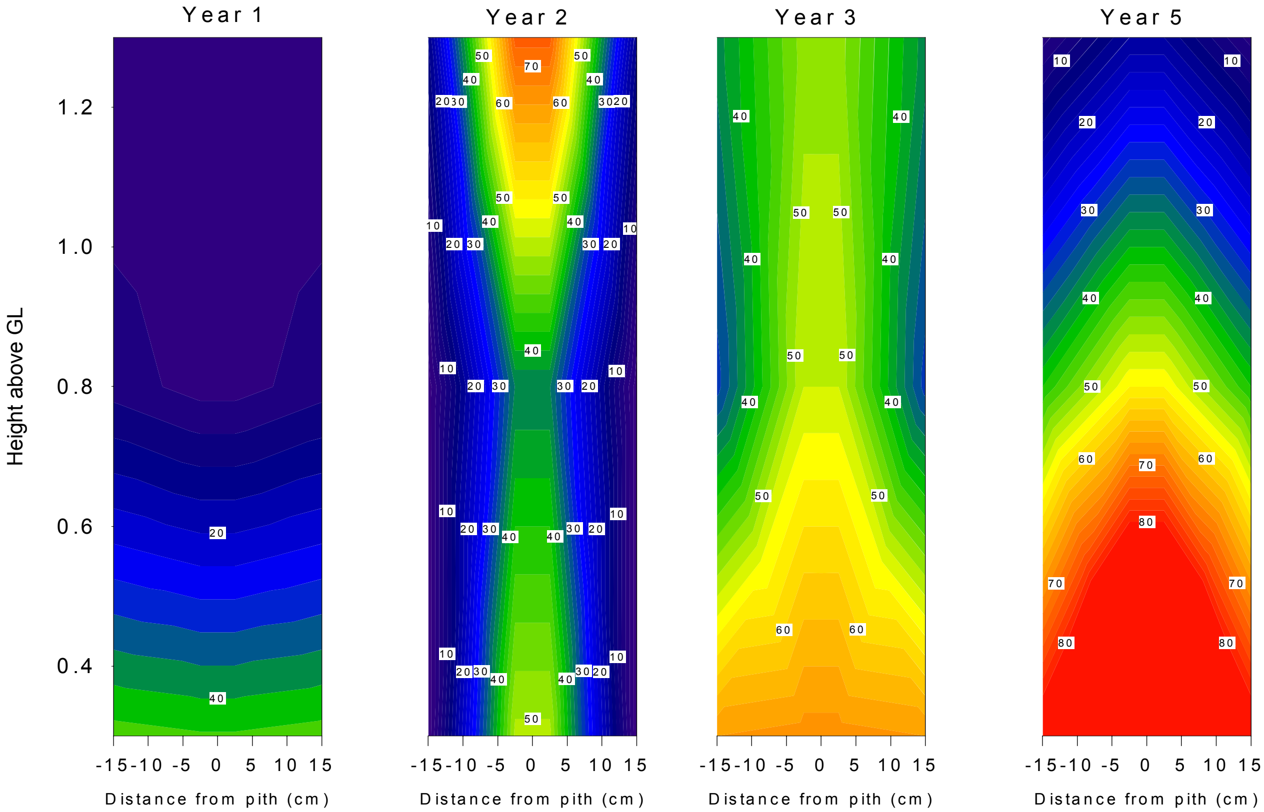


Figure I-9. Residual MITC in Douglas-fir poles 1 to 5 years after treatment with 107 g of dazomet rod plus 100 g of copper naphthenate. Dark blue indicates MITC levels below threshold. Light blue and all other colors indicate MITC levels above the lethal threshold.

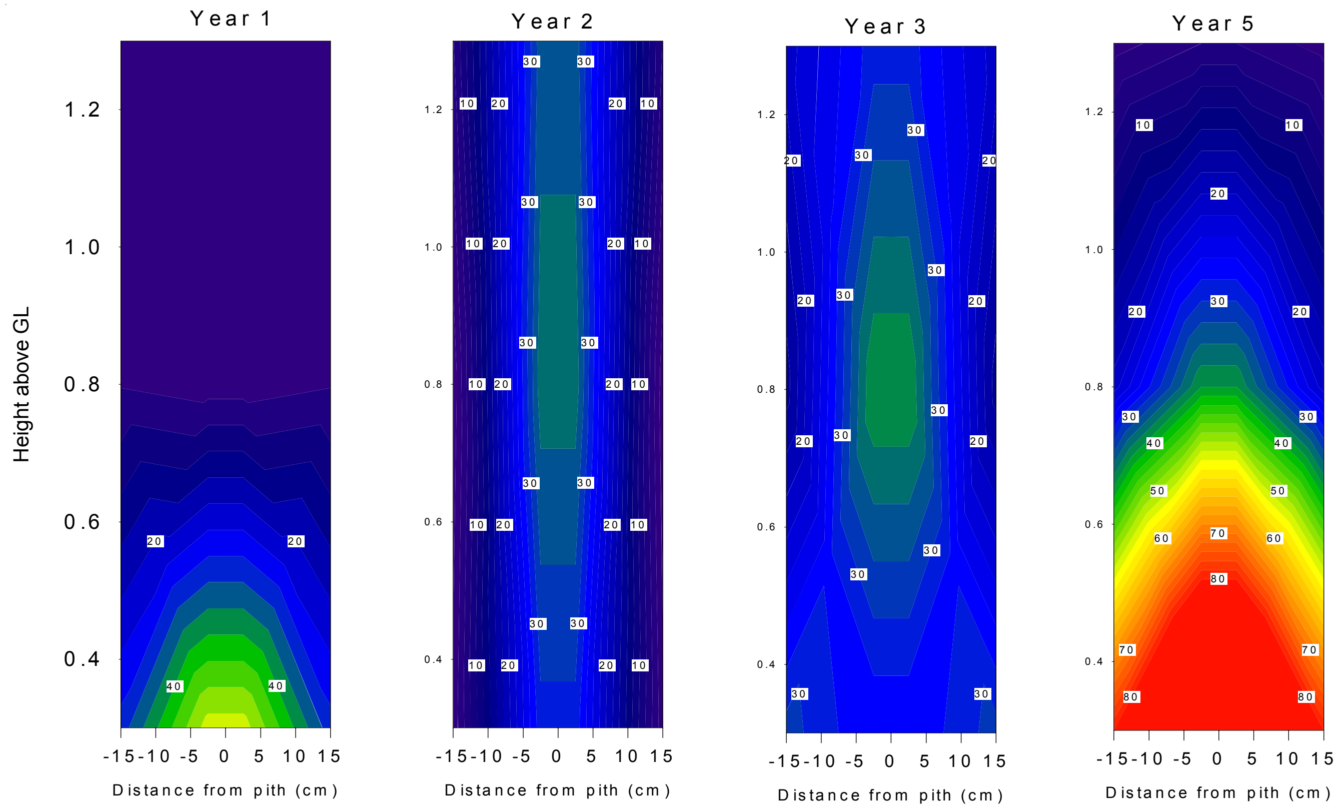


Figure I-10. Residual MITC in Douglas-fir poles 1 to 5 years after treatment with 160 g of dazomet rod alone. Dark blue indicates MITC levels below threshold. Light blue and all other colors indicate MITC levels above the lethal threshold.

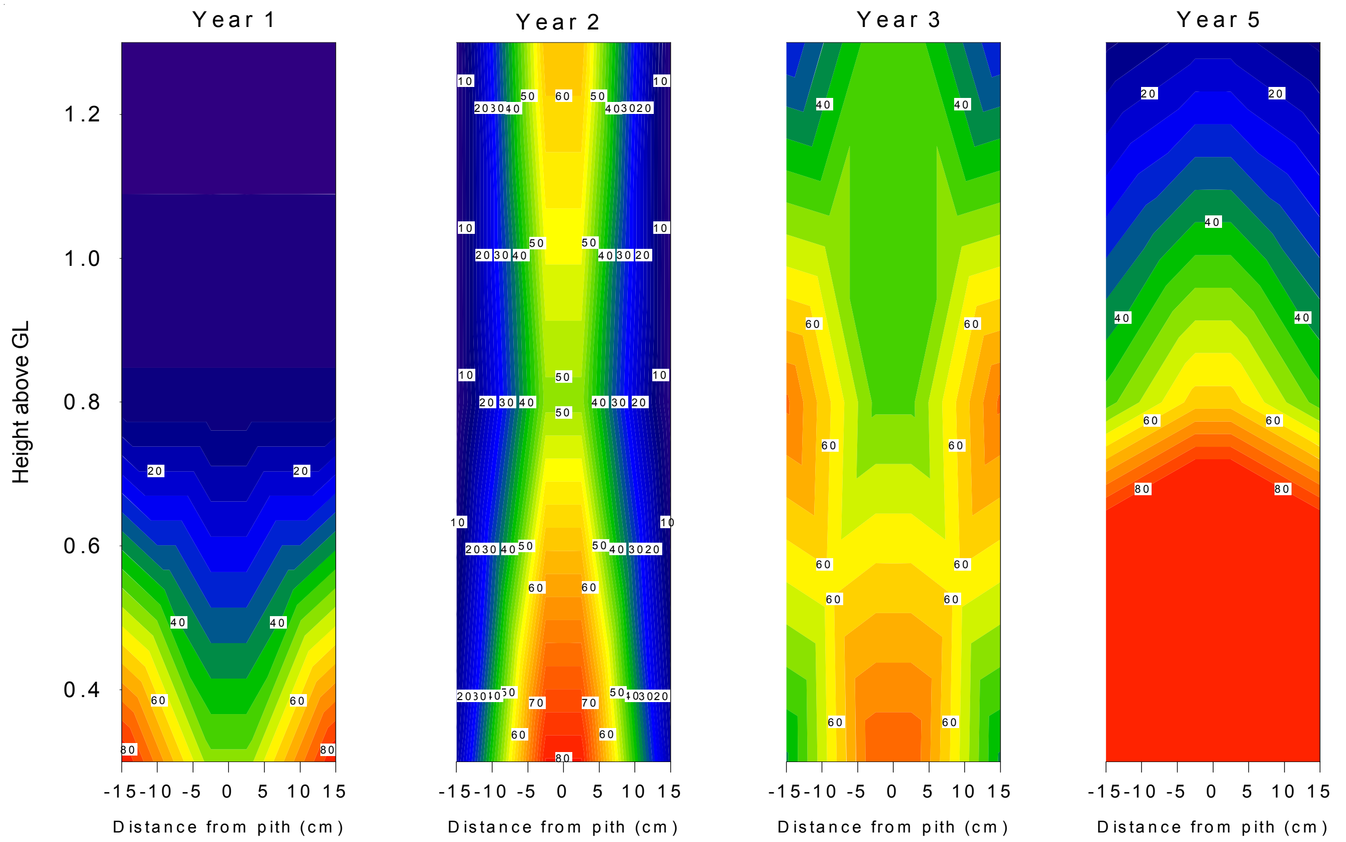


Figure I-11. Residual MITC in Douglas-fir poles 1 to 5 years after treatment with 160 g of dazomet rod with 100 g of copper naphthenate. Dark blue indicates MITC levels below threshold. Light blue and all other colors indicate MITC levels above the lethal threshold.

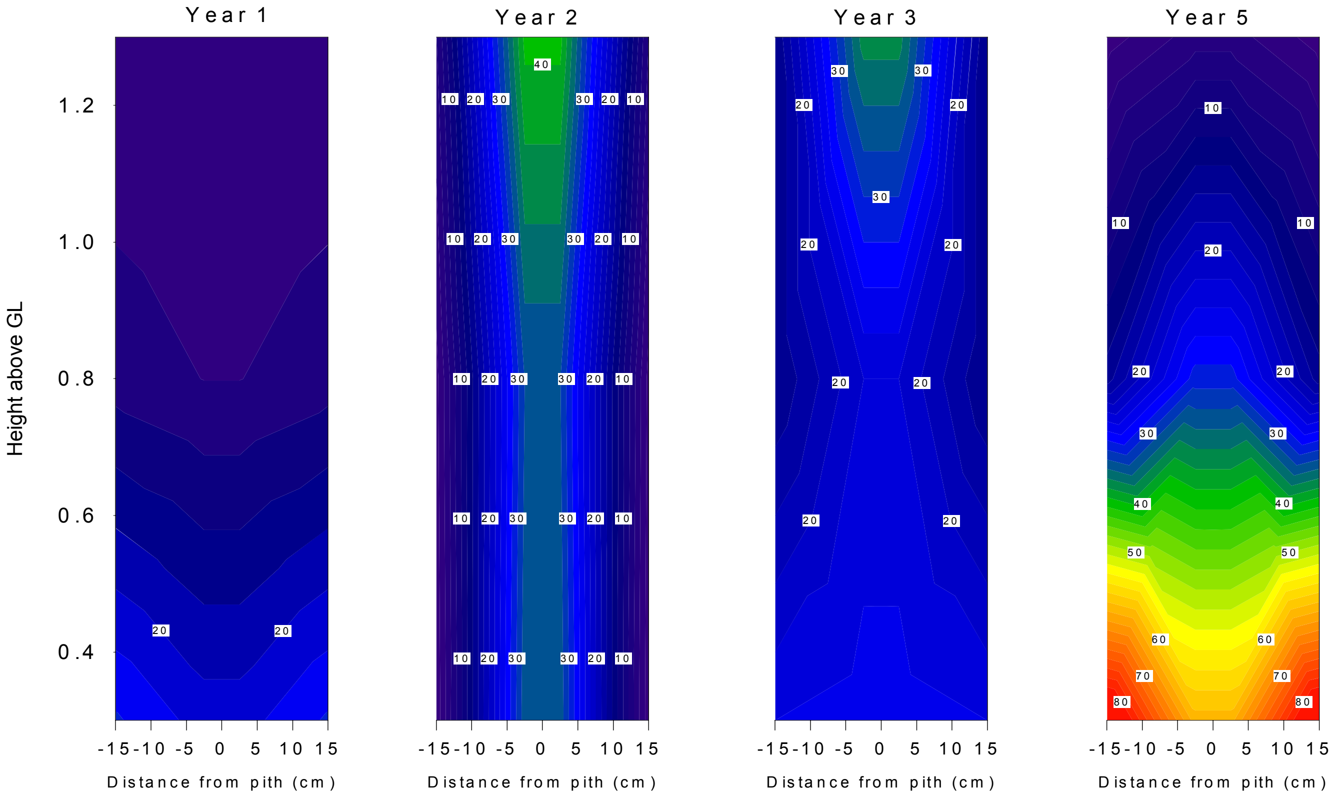


Figure I-12. Residual MITC in Douglas-fir poles 1 to 5 years after treatment with 160 g of dazomet rod with 100 g of water. Dark blue indicates MITC levels below threshold. Light blue and all other colors indicate MITC levels above the lethal threshold.

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. Chemical levels 1.3 m above groundline were protective 2 and 3 years after treatment, but had fallen below the protective threshold 5 years after treatment.

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. Conversely, the powdered formulation is more likely to sorb copper naphthenate making more of it 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 minimums for fungal growth.

Table I-5. Percentage of increment cores containing decay and non-decay fungi 1 to 5 years after application of metam sodium or dazomet to Douglas-fir pole sections.

Treatment	Dosage	Additive	Isolation Frequency (%)[a]											
			0.3 m				0.8 m				1.3 m			
			Yr 1	Yr 2	Yr 3	Yr 5	Yr 1	Yr 2	Yr 3	Yr 5	Yr 1	Yr 2	Yr 3	Yr 5
Dazomet rod	160 g	none	0^{7}	0^{7}	0^{0}	0^{0}	0^{7}	0^{27}	0^{7}	0^{0}	0^{20}	0^{47}	0^{0}	0^{20}
Dazomet Powder	107 g	100 g Cu naphthenate	0^{0}	0^{33}	0^{0}	0^{0}	0^{0}	0^{27}	0^{0}	0^{7}	0^{0}	0^{7}	0^{0}	0^{7}
Dazomet Powder	160 g	none	0^{13}	0^{13}	0^{0}	0^{0}	0^{0}	0^{47}	0^{0}	0^{13}	0^{0}	0^{53}	0^{0}	0^{40}
Dazomet Powder	160 g	100 g Cu naphthenate	0^{0}	0^{7}	0^{0}	0^{0}	0^{0}	0^{27}	0^{0}	0^{13}	0^{7}	0^{20}	0^{0}	0^{7}
Dazomet Powder	160 g	100 g water	0^{7}	0^{20}	0^{13}	0^{0}	0^{7}	0^{13}	0^{7}	0^{0}	0^{0}	0^{53}	0^{13}	0^{27}
Metam sodium	490 ml	none	0^{20}	0^{33}	0^{7}	0^{0}	0^{13}	0^{20}	0^{7}	0^{0}	0^{13}	0^{13}	0^{7}	0^{7}

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

4. 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 g 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 2 % copper naphthenate 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, of each core were placed into vials containing 5 ml of ethyl acetate, extracted for 24 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.

As with our other tests, the threshold for MITC is consdered to be 20 ug or more of MITC/oven dried g 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 no supplemental treatment barely reached the thresh-old level 0.3 m above ground 1 year after treatment (Figure I-13). 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 7 years. Chemical levels above this zone were extremely low, suggesting that the treatment effect was confined to a relatively narrow zone around the application point (Table I-6).

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 four year test period (Figure I-14). 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 7 years after chemical application. These results clearly support the application of copper sulfate at the time of dazomet treatment to increase the initial release rate.

MITC levels in pole sections receiving copper naphthenate appeared to experience less of an initial boost in release rate than poles receiving copper sulfate following treatment; however, chemical levels rose sharply 2 years after treatment and have remained elevated and similar to those for the copper sulfate treatment (Figure I-15). 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.

MITC levels in all three treatments were similar 7 years after treatment, suggesting that initial enhancement in decomposition provided by both copper compounds eventually declined and did not appear to negatively influence long term performance of the chemical.

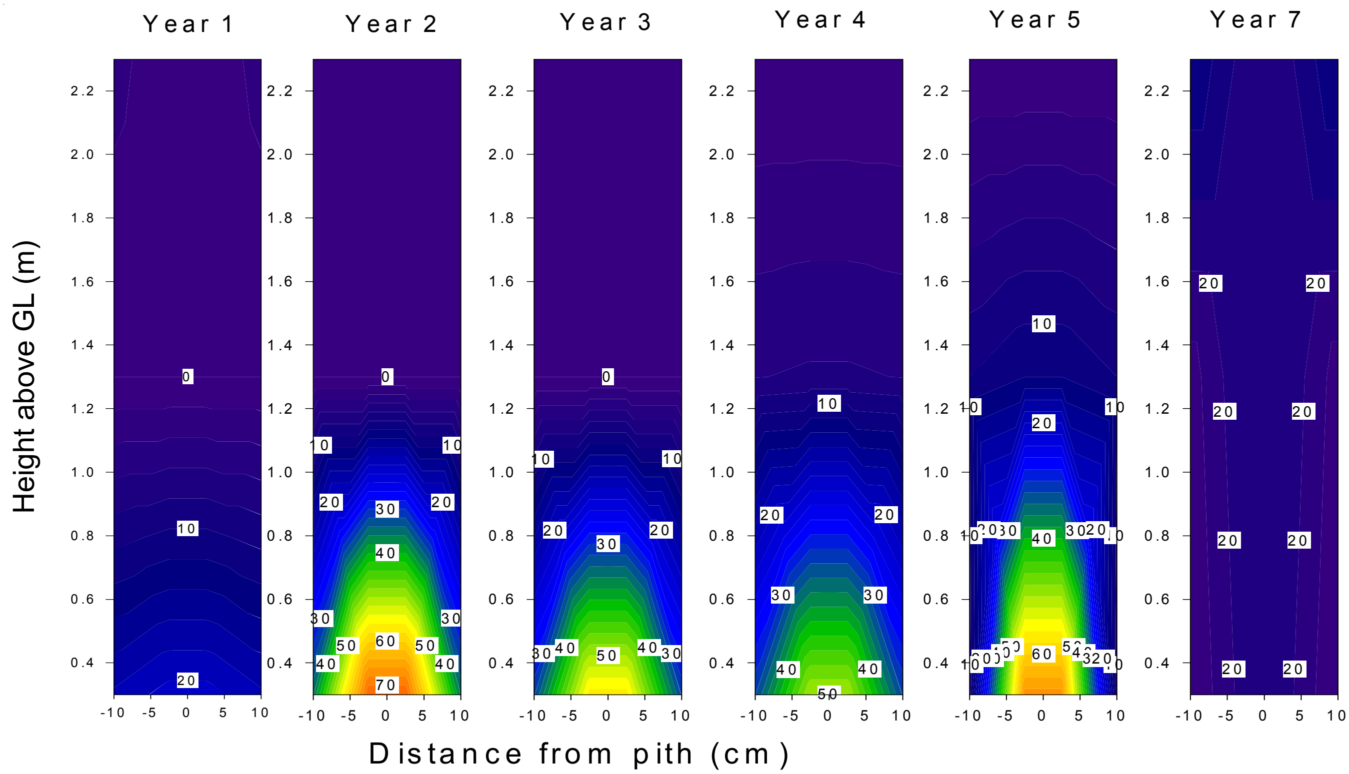


Figure I-13. Distribution of residual MITC in Douglas-fir poles 1 to 7 years after treatment with 200 g of dazomet. Dark blue indicates MITC levels below threshold. Light blue and all other colors indicate MITC levels above the lethal threshold.

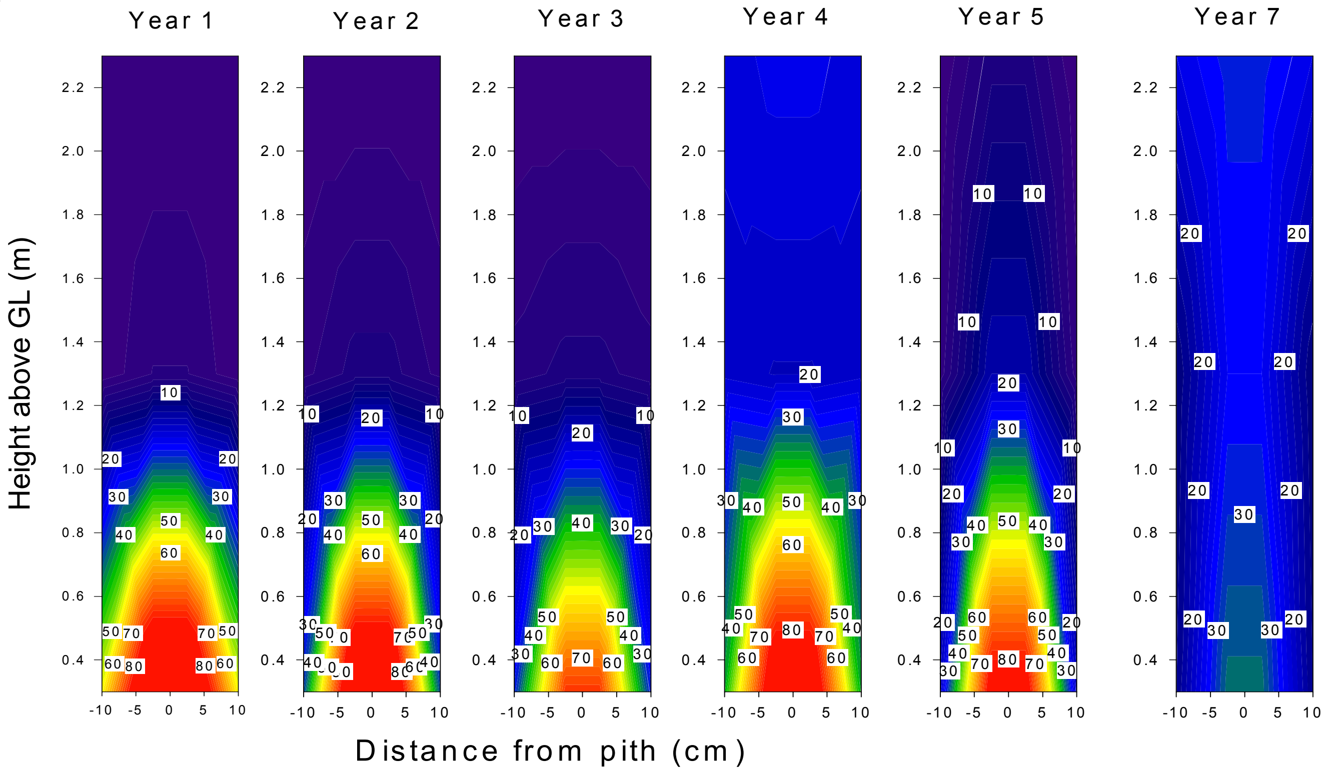


Figure I-14. Distribution of residual MITC in Douglas-fir poles 1 to 7 years after treatment with 200 g of dazomet plus 20 g of copper sulfate. Dark blue indicates MITC levels below threshold. Light blue and all other colors indicate MITC levels above the lethal threshold.

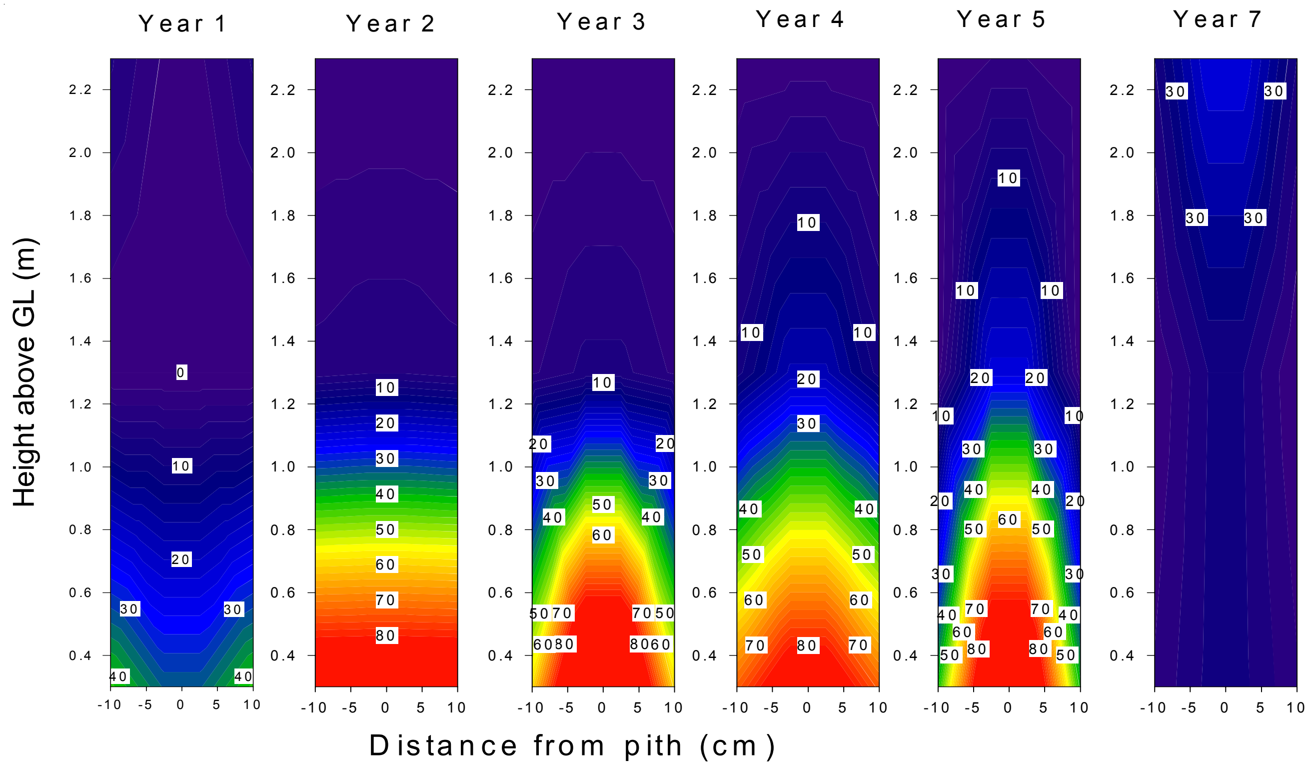


Figure I-15. Distribution of residual MITC in Douglas-fir poles 1 to 7 years after treatment with 200 g of dazomet plus 20 g of copper naphthenate. Dark blue indicates MITC levels below threshold. Light blue and all other colors indicate MITC levels above the lethal threshold.

Table I-6. Residual MITC in Douglas-fir pole sections 1 to 7 years after treatment with 200 g of dazomet supplemented with copper sulfate or copper naphthenate.

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

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

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-7). 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-7. Isolation frequency of decay and non-decay fungi from Douglas-fir pole sections 1 to 7 years after treatment with 200 g of dazomet alone or amended with copper naphthenate or copper sulfate.

Copper Treatment	Distance above GL (m)	Percent of Cores With Fungi[a]					
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Yr 7
None	0.3	0^{11}	0^{0}	0^{0}	0^{11}	0^{0}	0^{0}
	1.3	0^{11}	0^{33}	0^{33}	0^{33}	0^{0}	0^{11}
	2.3	0^{11}	0^{33}	0^{0}	0^{56}	0^{100}	0^{56}
20 g Copper sulfate ($CuSO_4 \cdot 5H_2O$)	0.3	0^{11}	0^{0}	0^{0}	0^{11}	0^{0}	0^{0}
	1.3	22^{33}	44^{56}	11^{11}	22^{33}	0^{67}	0^{22}
	2.3	0^{44}	0^{33}	0^{33}	11^{33}	0^{89}	0^{44}
20 g Copper naphthenate (2% Cu in mineral spirits)	0.3	33^{33}	0^{0}	0^{0}	0^{0}	0^{0}	0^{11}
	1.3	0^{22}	0^{0}	0^{0}	0^{0}	11^{11}	0^{0}
	2.3	0^{44}	0^{67}	0^{22}	0^{67}	0^{78}	0^{33}

[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.

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 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. Sodium fluoride is also 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 4 or 8 copper/boron rods or 4 boron rods. The holes were then plugged with tight fitting plastic plugs. Chemical movement was assessed 1, 2, and 3 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, 2.5 cm of treated shell was discarded, and the core was divided into inner and outer halves. The cores from 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.

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-16). 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 120 degree 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. These results suggest that the boron is diffusing well from the rods at or below groundline, but is facing challenges in the above ground zones. Boron levels in the outer zones tended to be lower and were only approaching the lower threshold at groundline 2 years after treatment.

Boron levels in the poles treated with 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. The results indicate that the boron from the fused borate 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 for the first 2 years after treatment, 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. Boron levels in the below ground and groundline inner assay zones did increase markedly 3 years after treatment, although the levels were still only similar to those found with the lower dosage treatment. Boron levels in outer zones at the same locations were still below those found with the 4 rod dosage. The results continue to indicate that more rods may not necessarily be an advantage for fungal control.

Copper levels in poles treated with 4 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-17). Copper was barely detectable away from these zones. Copper levels in the 8 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.

Cultural results of wood removed from the boron and copper/boron rod treated poles suggests 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-8). Decay fungi were also isolated from the upper height in the poles receiving 4 boron/copper rods, but no decay fungi were isolated from 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.

a.

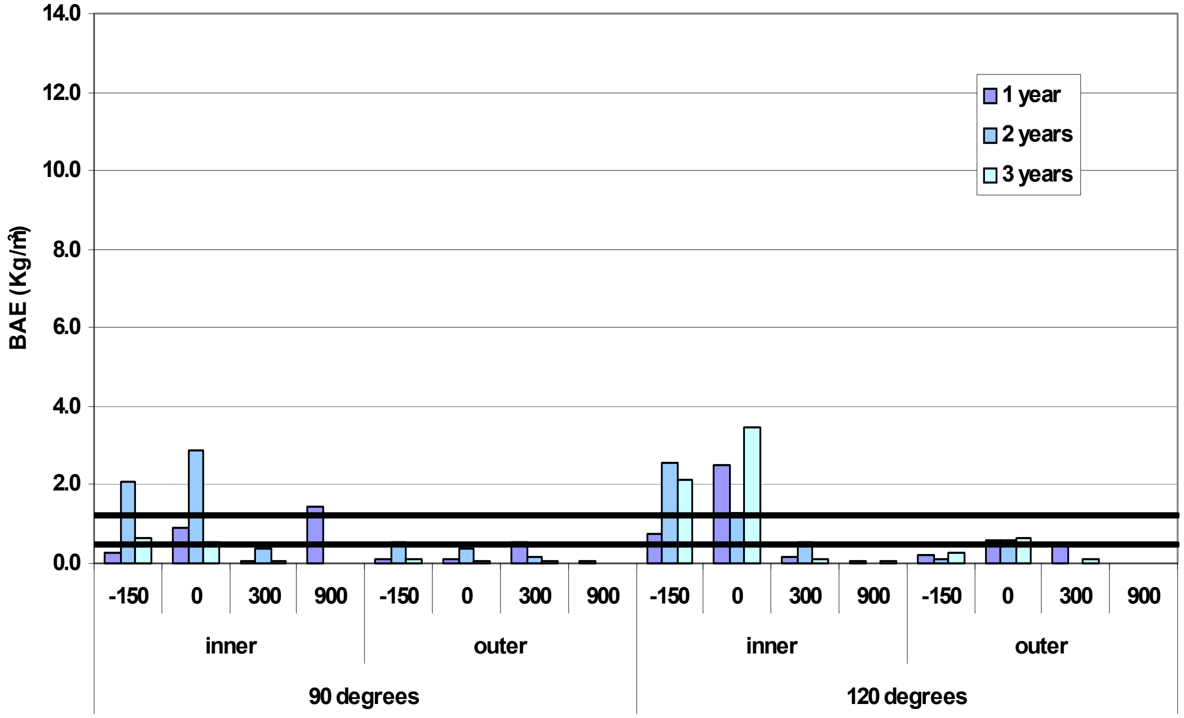
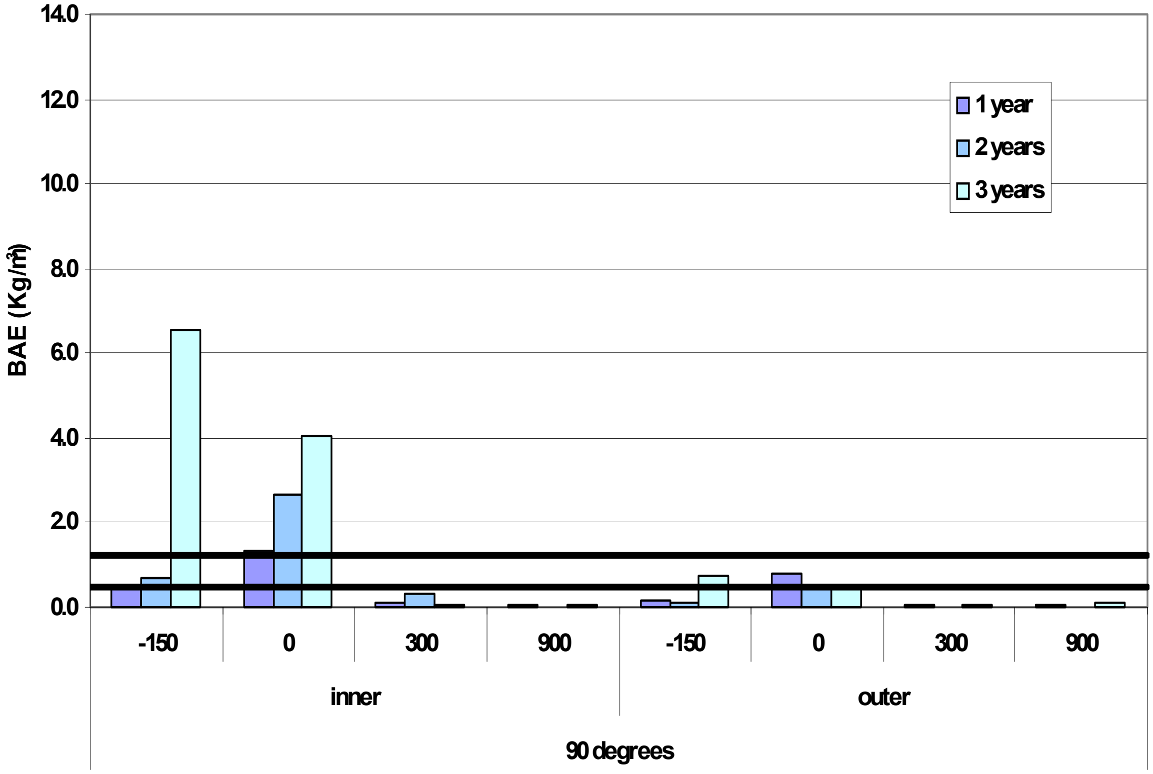


Figure I-16. Residual boron in Douglas-fir poles 1, 2, and 3 years after treatment with a) 4 copper/boron rods, b) 8 copper/boron rods, or c) 4 boron rods. Lower and upper threshold levels for boron are 0.5 and 1.2 kg/m^3 BAE, respectively.

b.



c.

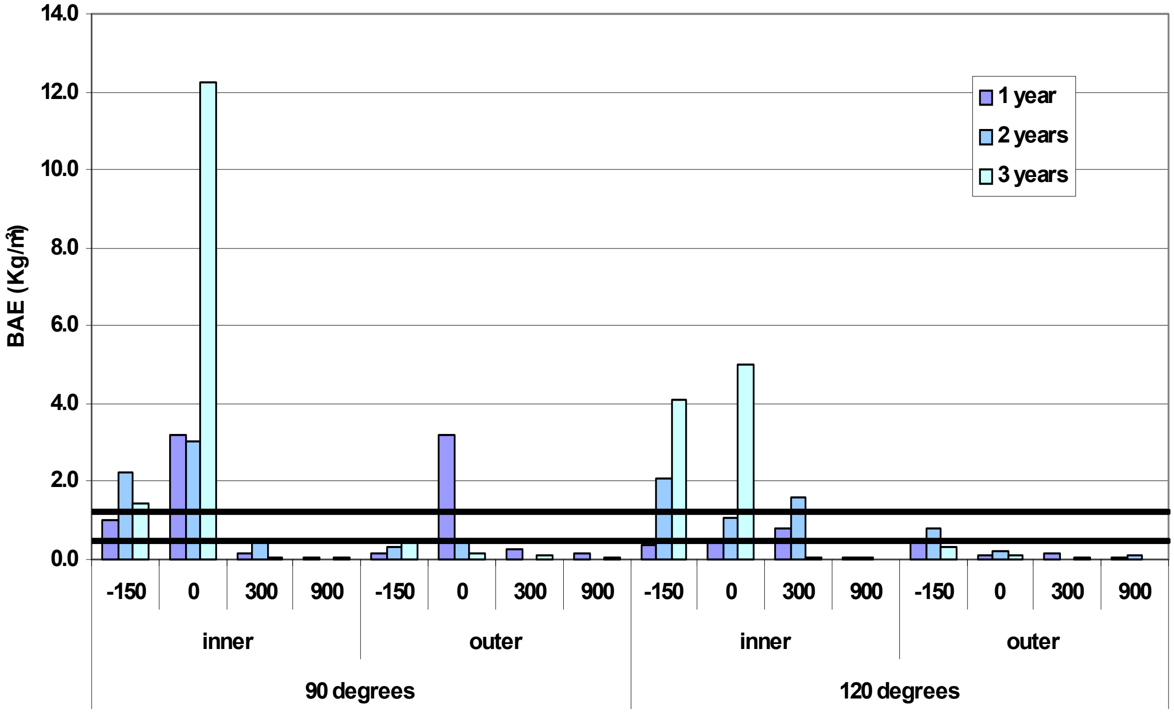
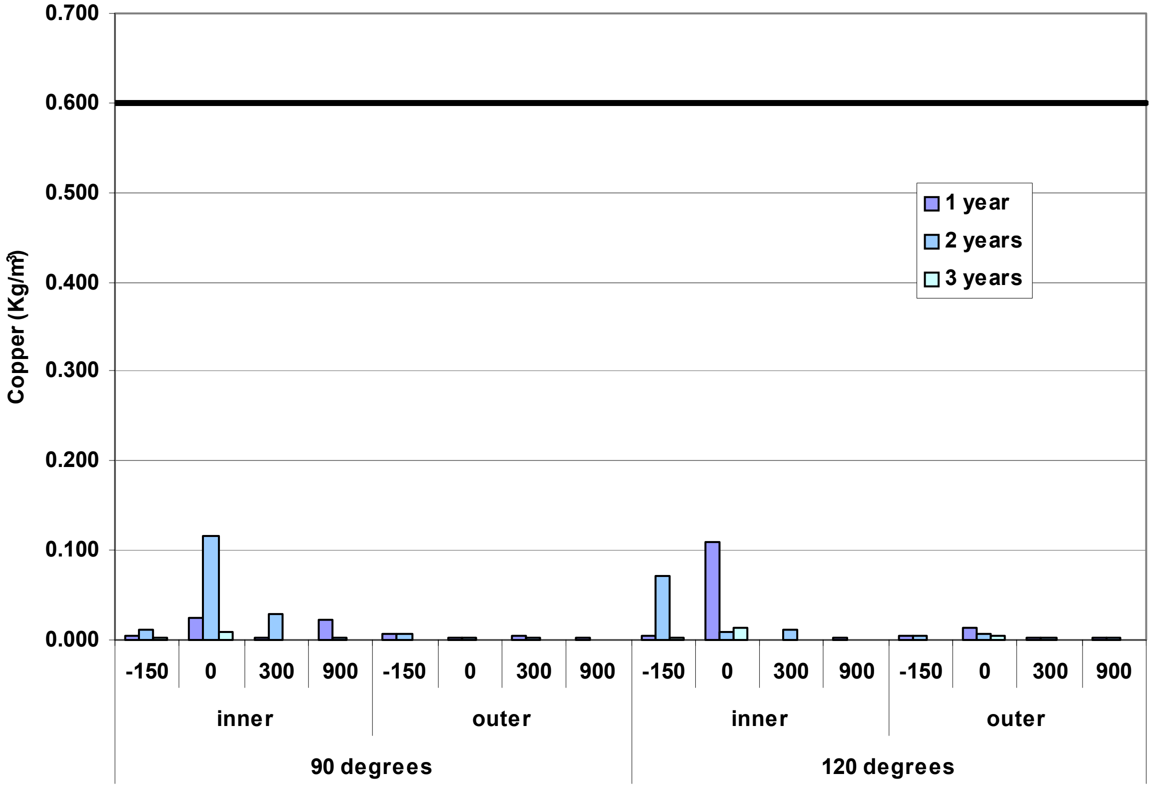


Figure I-16 (cont.). Residual boron in Douglas-fir poles 1, 2, and 3 years after treatment with a) 4 copper/boron rods, b) 8 copper/boron rods, or c) 4 boron rods. Lower and upper threshold levels for boron are 0.5 and 1.2 kg/m^3 BAE, respectively.

a.



b.

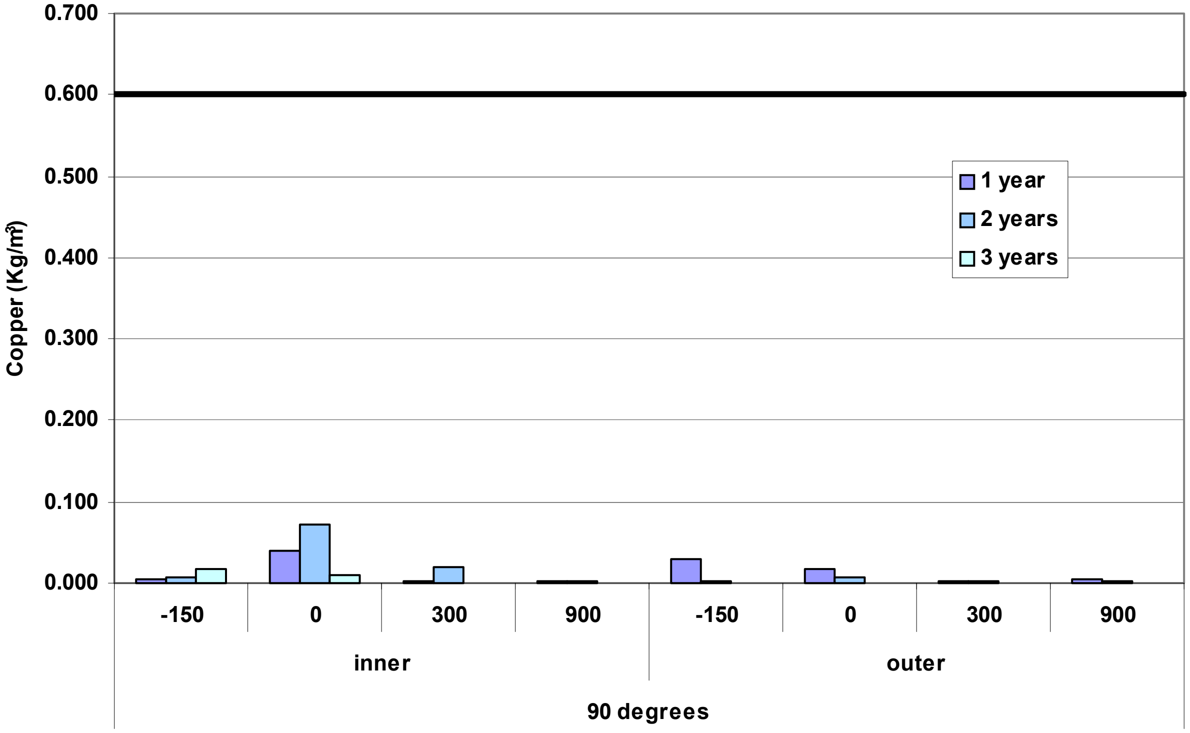


Figure I-17. Residual copper in Douglas-fir poles 1, 2 and 3 years after treatment with a) 4 or b) 8 copper/boron rods. The toxic threshold level for copper is 0.6 kg/m^3.

Table I-8. Isolation frequency of decay and non-decay fungi from Douglas-fir pole sections 1 to 3 years after treatment with boron or boron/copper rods in two different spacing patterns.

Treatment Spacing	Ht Above GL (mm)	Cores Containing Decay Fungi (%)[a]								
		4 Boron/Cu Rods			4 Boron Rods			8 Boron/Cu Rods		
		1 yr	2 yr	3 yr	1 yr	2 yr	3 yr	1 yr	2 yr	3 yr
90°	-150	0^{7}	0^{33}	0^{27}	0^{7}	0^{20}	0^{40}	0^{7}	0^{7}	0^{27}
	0	0^{10}	0^{20}	0^{10}	0^{10}	10^{10}	10^{50}	0^{0}	0^{0}	0^{10}
	300	0^{20}	0^{10}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{20}	0^{0}
	900	0^{7}	7^{0}	7^{13}	0^{0}	7^{0}	13^{7}	0^{7}	0^{7}	0^{0}
120°	-150	0^{40}	0^{33}	0^{47}	0^{0}	7^{13}	7^{33}	-	-	-
	0	0^{0}	0^{20}	0^{30}	0^{0}	0^{10}	20^{40}	-	-	-
	300	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{30}	-	-	-
	900	0^{13}	0^{0}	7^{7}	0^{20}	0^{0}	0^{7}	-	-	-

[a] Values represent means of 15 (-150 mm below GL) or 10 cultures per treatment. Superscripts denote non-decay fungi.

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 1 or 2 boron rods (180 or 360 g of rod, respectively). The holes were then plugged with tight fitting wooden dowels. Each treatment was replicated on 10 poles.

The poles were sampled 1, 3, 4, 5, 7, 10, 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. The outer, treated shell on each core was removed and discarded, then the remainder of each core was divided into inner and outer halves. Core segments for a given height and position (inner/outer) were combined for a given treatment and ground to pass a 20 mesh screen. The resulting sawdust was hot water extracted and analyzed using the azomethine-H method for boron which was expressed on a kg/m^3 BAE basis. As with the previous test, we used the lower threshold value as our target level.

As expected, background boron levels in untreated control poles were extremely low, ranging from 0.01 to 0.27 kg/m^3 (Table I-9). Boron levels in poles receiving either 180 or 360 g of rod were extremely low 45 and 60 cm above groundline over the course of the test, reflecting the limited ability of boron to diffuse upward (Figure I-18 and 19). Boron levels in the remaining locations tended to vary. Boron levels in the inner zones were initially low, then rose to levels well above the threshold 5 years after treatment. Concentrations then declined by the seventh year after treatment, then increased slightly 10 years after treatment. Boron levels remained well above the threshold 15 cm below groundline as well as 7.5 cm above groundline in the inner zone 10 years after treatment. Analysis of the outer zones from these same poles revealed that boron levels tended to remain lower over the earlier parts of the test, but did not have the concentration fluctuations noted in the inner assay zones. The reasons for this difference are unclear. Boron levels remained above the lower threshold both 15 cm below ground and 7.5 cm above ground 10 years after treatment.

Table I-9. Residual boron levels in inner and outer zones of increment cores removed from Douglas-fir poles 1 to 12 years after treatment with 180 or 360 g of boron rod.

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

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

Inspection of these same locations 12 years after treatment revealed that above-threshold boron levels were present 15 cm below groundline as well as 7.5 cm and 22.5 cm above groundline in poles receiving 180 g of borate rod. Boron levels were also above the threshold in these same locations for poles receiving the 360 g treatment, but there were no consistent differences between the two dosages.

The lack of a substantial treatment effect with higher loadings of boron rod remains a perplexing phenomenon, but one that appears to be consistent among our various field trials. This effect can be seen when boron levels are plotted in distribution maps for both dosages (Figures I-18 and I-19). There is a slight effect after 5 years, then after twelve years it appears to be more advantageous to use the lower dosage. This treatment effect merits further study.

The results indicate that borate rods are capable of delivering protective boron levels to the interior of Douglas-fir poles for up to 12 years although the zone of protection around the treatment area tends to be smaller than that found with volatile fumigants.

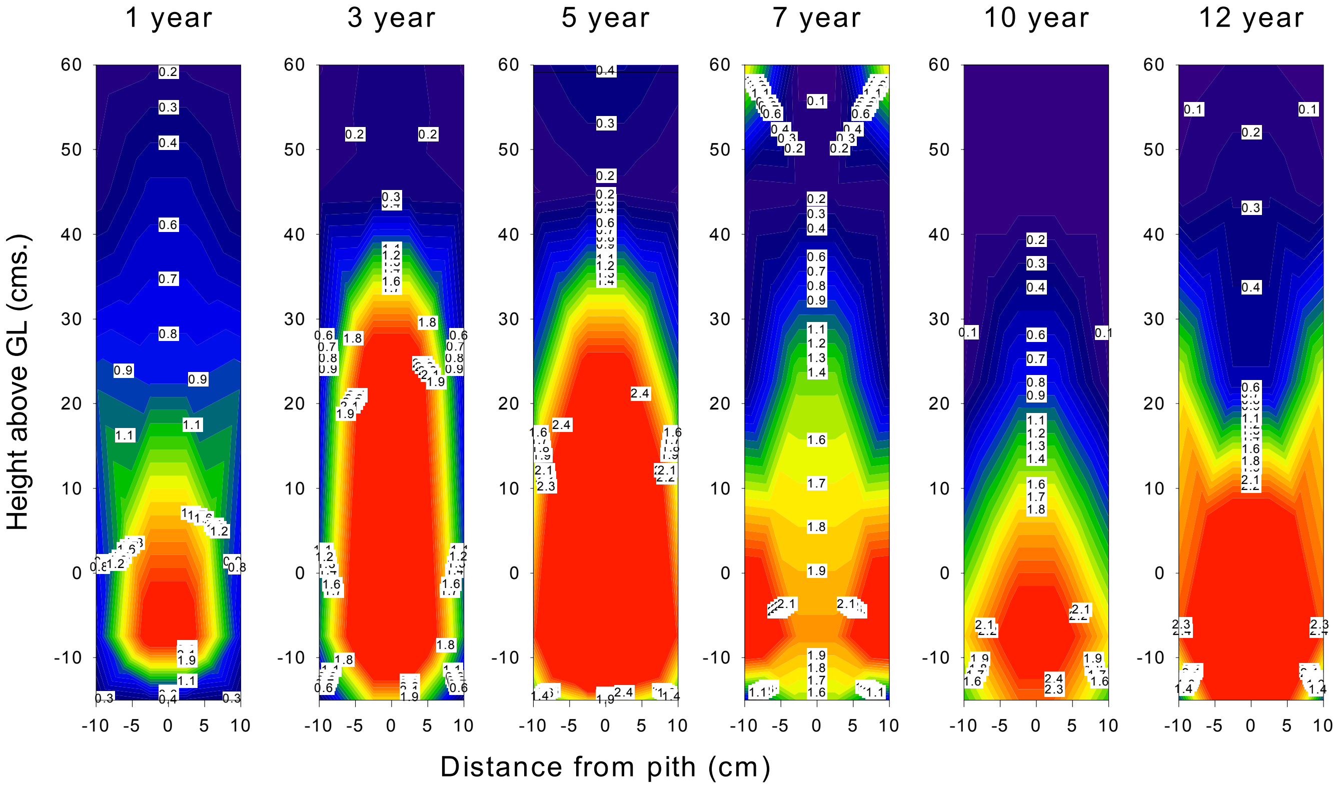


Figure I-18. Boron distribution in Douglas-fir pole sections 1 to 12 years after treatment with 180 g of fused boron rod. Dark blue indicates boron levels below threshold. Light blue and all other colors indicate boron levels above the lethal threshold.

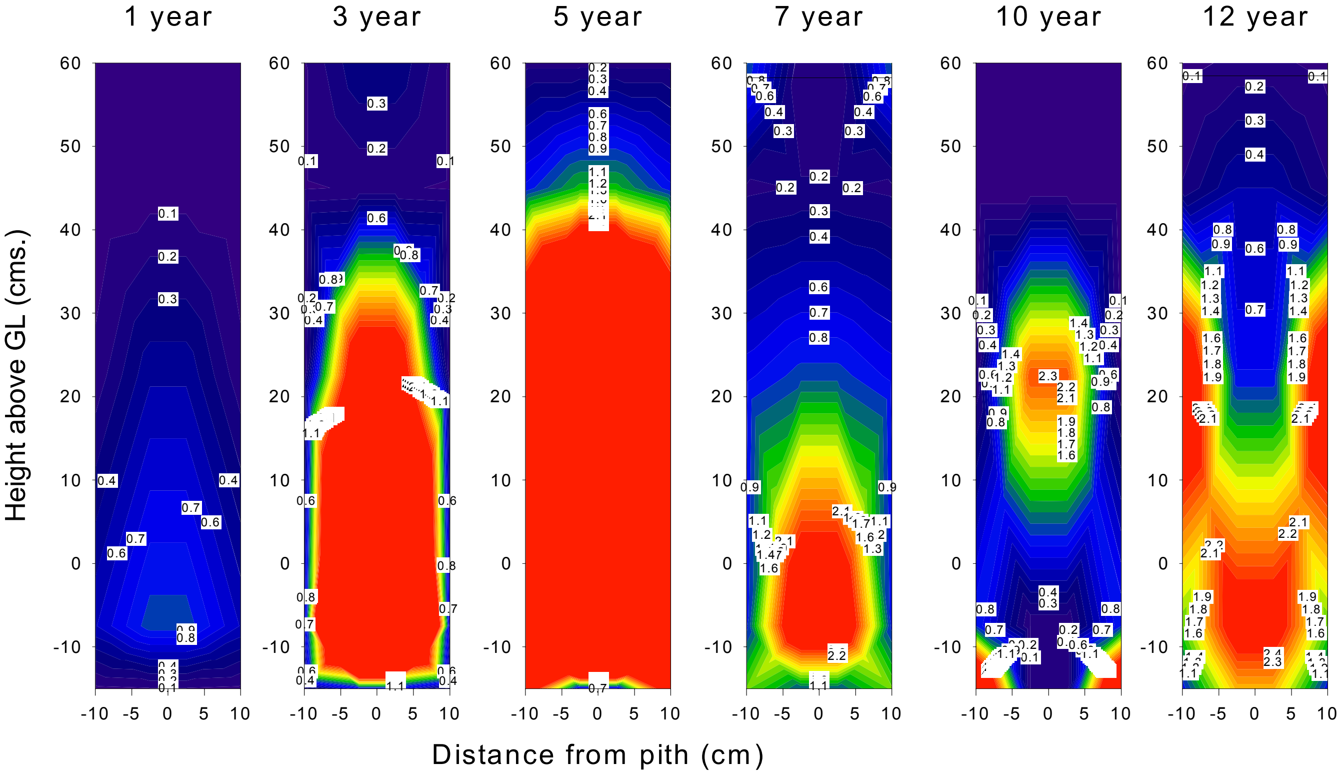


Figure I-19. Boron distribution in Douglas-fir pole sections 1 to 12 years after treatment with 360 g of fused boron rod Dark blue indicates boron levels below threshold. Light blue and all other colors indicate boron levels above the lethal threshold..

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 20 mm diameter holes were drilled at a 45 ° downward sloping angle in each pole, beginning 75 mm above the groundline, then moving 90 ° around and up to 230, 300, and 450 mm above the groundline. An equal amount of boron (227 g Boric acid equivalent) was added to each pole, but was delivered in different combinations of boron, water, or glycol (Table I-10). The borate rods were 100 mm long by 12.7 mm in diameter and weighed 24.4 g each. An equal weight of boron rod composed of one whole rod and a portion of another, were placed in each hole followed by the appropriate liquid supplement or were left dry. The holes were then plugged with tight fitting wooden dowels. Each treatment was replicated on five poles.

The pole sections were sampled 1, 2, 3, 5, 7, and 10 years after treatment by removing increment cores 180 ° apart from 30 cm below the groundline and cores from three equidistant locations around the pole 15 and 30 cm above the groundline. The treated portion of the cores was discarded, then the remainder of each core was divided into zones corresponding to 0-50 (O), 51-100 (M), and 101-150 (I) mm from the edge of the treated zone. The zones from the same depth and height from a given treatment were combined and ground to pass a 20 mesh screen. The resulting sawdust was then extracted and analyzed using the azomethine-H method.

Boron continues to be detectable in virtually all pole sections 10 years after treatment. As in previous boron tests, chemical levels were lower in poles receiving only the borate rods after one year (Table I-11). 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 in all treatments were at effective levels near the groundline except for the rod alone treatment, reflecting the presence of moisture in this zone. The low levels in rod only treatments suggests that elevated moisture in the groundline zone might have hastened boron losses (Figure I-20). Boron levels in poles receiving Boracol 20 tended to be lower than those receiving the Boracol 40 supplement (Figures I-21 and I-22). These results suggest that the liquid boron can provide long term improvement to residual boron levels and that the higher concentration of boron in the supplement does have a lasting effect on treatment efficacy.

The addition of Boracare also produced a lasting improvement in boron levels in comparison with the rod alone treatment (Figure I-23). The long-lasting improvement in boron levels appears to be related to the boron in the treatment and the added liquid. This is evidenced by the improvement afforded by addition of glycol alone to the boron rods as well as the benefits of adding a water-borne Timbor solution (Figures I-24 and 25). These effects suggest that the addition of some liquid at the time of boron rod application has both short term and longer lasting effects on treatment efficacy.

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-10. Combinations of boron treatments applied internally to Douglas-fir pole sections in 1995. All treatments deliver 227 g boric acid equivalent 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

Table I-11. Residual boron levels in Douglas-fir poles treated with various combinations of glycol, water, and various forms of boron.

Treatment	Height (cm)	Depth	Boron (Kg/m^3 BAE)[a]											
			Year 1		Year 2		Year 3		Year 5		Year 7		Year 10	
Rods alone	-30	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)
		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)
		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	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)
		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)
		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)
	15	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)
		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)
		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)
	30	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)
		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)
		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)
Rods plus Boracare	-30	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)
		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)
		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	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)
		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)
		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)
	15	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)
		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)
		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)
	30	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)
		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)
		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)
Rods plus Boracol 20	-30	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)
		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)
		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	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)
		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)
		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)
	15	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)
		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)
		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)
	30	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)
		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)
		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)

[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-11. (cont.) Residual boron levels in Douglas-fir poles treated with various combinations of glycol, water, and various forms of boron.

Treatment	Height (cm)	Depth	Boron (Kg/m^3 BAE)[a]											
			Year 1		Year 2		Year 3		Year 5		Year 7		Year 10	
Rods plus Boracol 40	-30	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)
		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)
		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	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)
		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)
		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)
	15	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)
		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)
		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)
	30	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)
		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)
		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)
Rods plus polyethelyne glycol	-30	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)
		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)
		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	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)
		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)
		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)
	15	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)
		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)
		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)
	30	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)
		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)
		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)
Rods plus Timbor	-30	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)
		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)
		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	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)
		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)
		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)
	15	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)
		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)
		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)
	30	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)
		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)
		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)

[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.

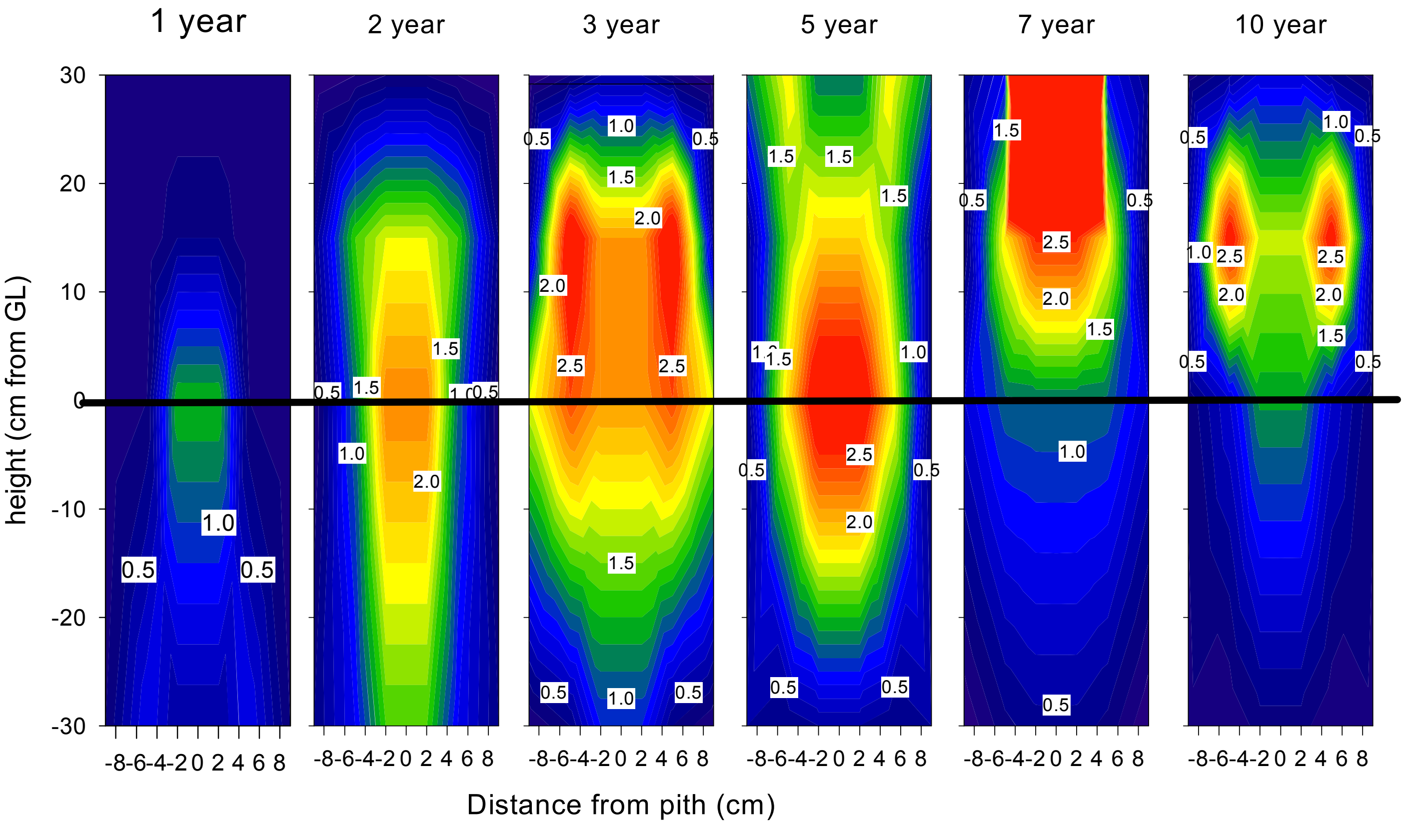


Figure I-20. Residual boron in Douglas-fir timbers 1 to 10 years after application of fused borate rod alone. Dark blue indicates boron levels below threshold. Light blue and all other colors indicate boron levels above the lethal threshold.

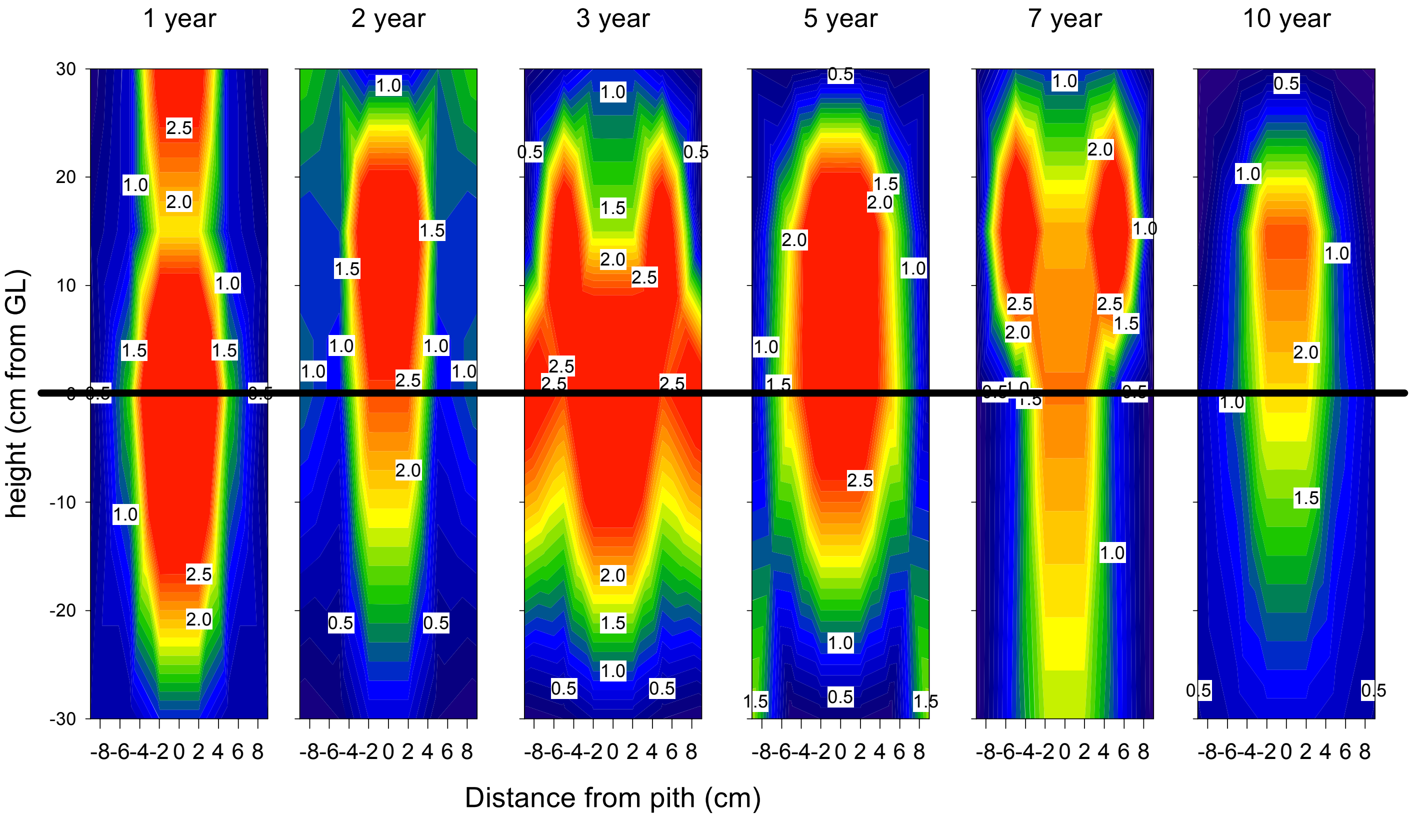


Figure I-21. Residual boron in Douglas-fir timbers 1 to 10 years after application of various combinations of fused borate rod and Boracol 20. Dark blue indicates boron levels below threshold. Light blue and all other colors indicate boron levels above the lethal threshold.

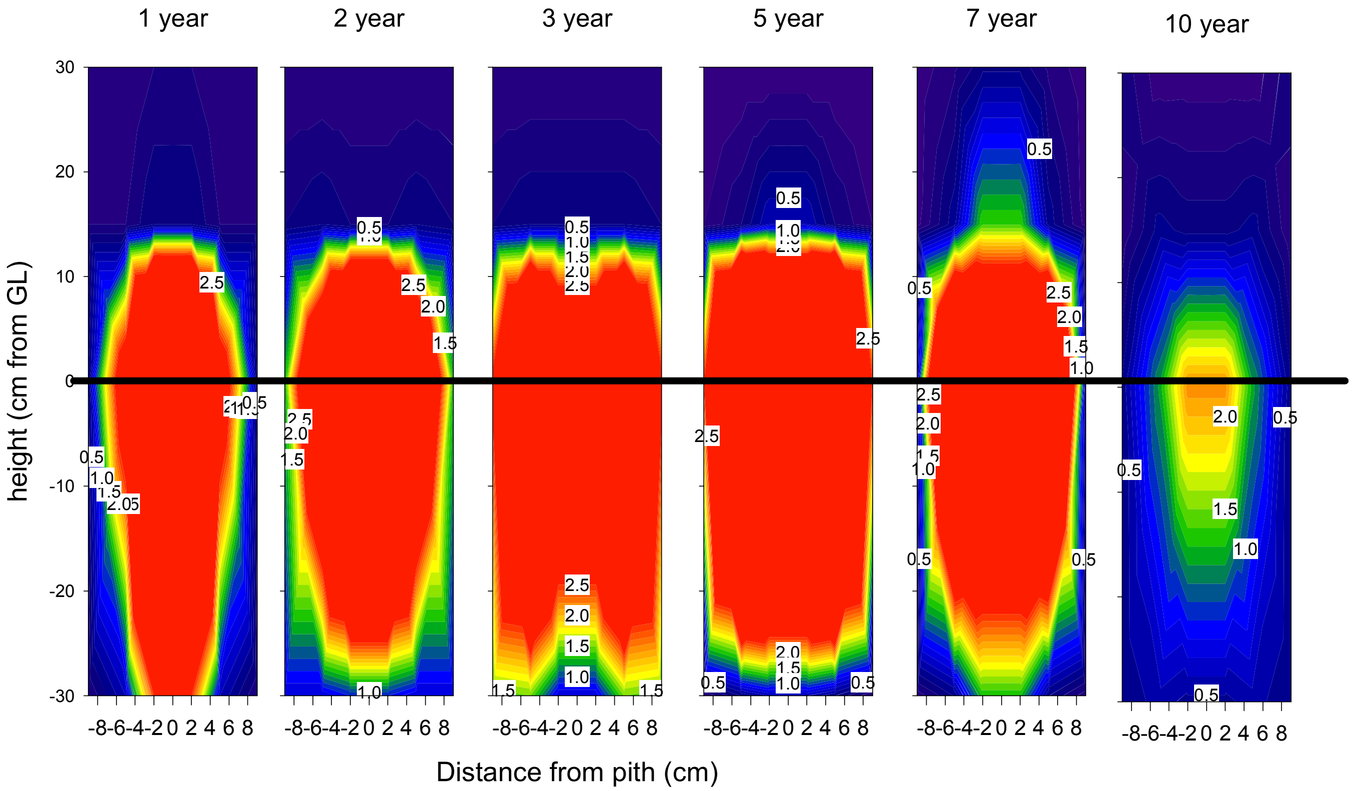


Figure I-22. Residual boron in Douglas-fir timbers 1 to 10 years after application of various combinations of fused borate rod and Boracol 40. Dark blue indicates boron levels below threshold. Light blue and all other colors indicate boron levels above the lethal threshold.

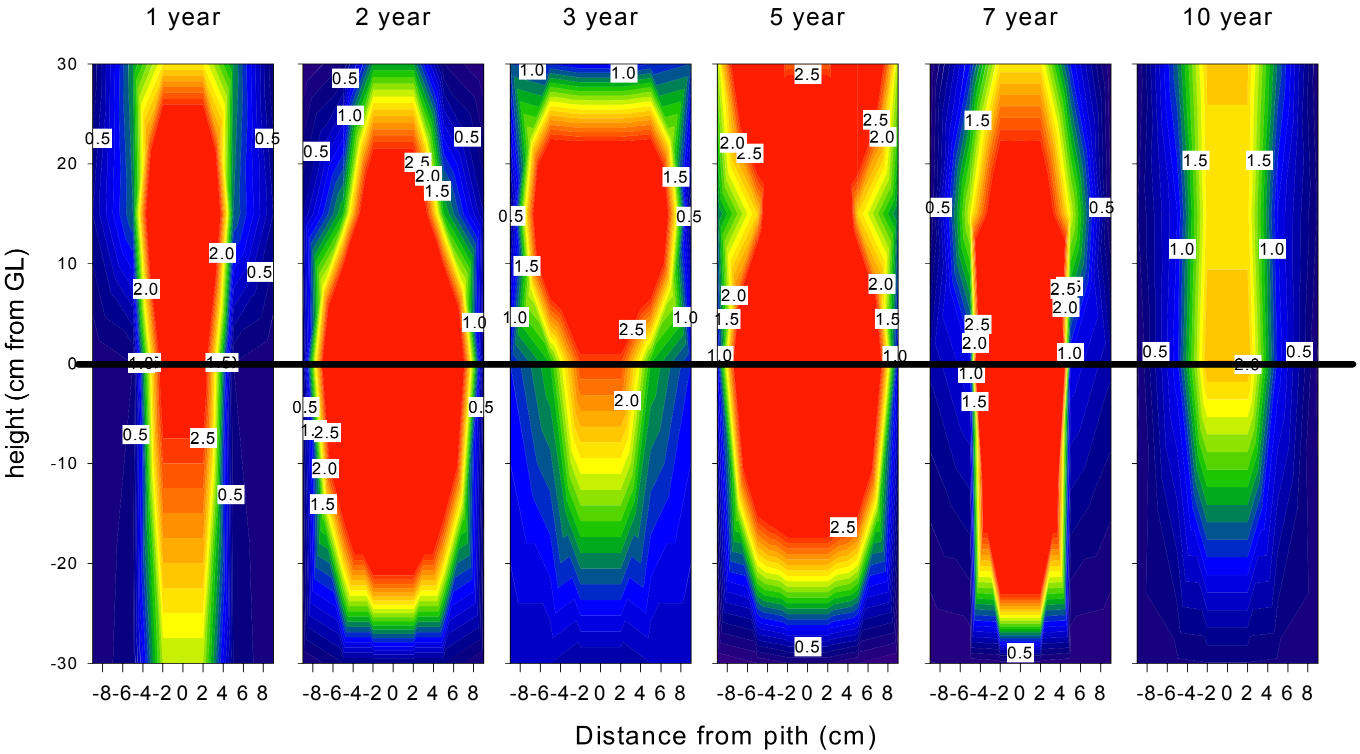


Figure I-23. Residual boron in Douglas-fir timbers 1 to 10 years after application of various combinations of fused borate rod and Boracare. Dark blue indicates boron levels below threshold. Light blue and all other colors indicate boron levels above the lethal threshold.

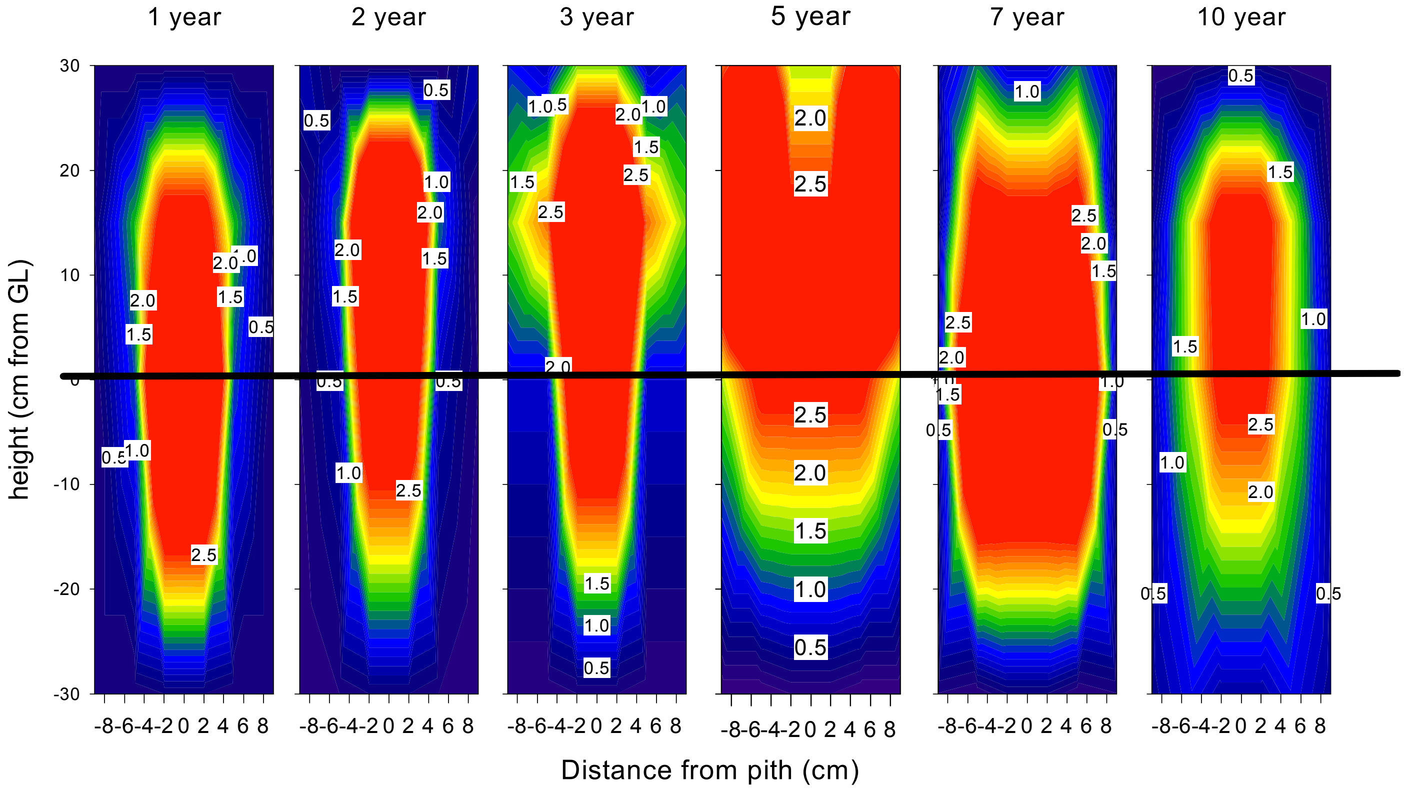


Figure I-24. Residual boron in Douglas-fir timbers 1 to 10 years after application of various combinations of fused borate rod and ethylene glycol. Dark blue indicates boron levels below threshold. Light blue and all other colors indicate boron levels above the lethal threshold.

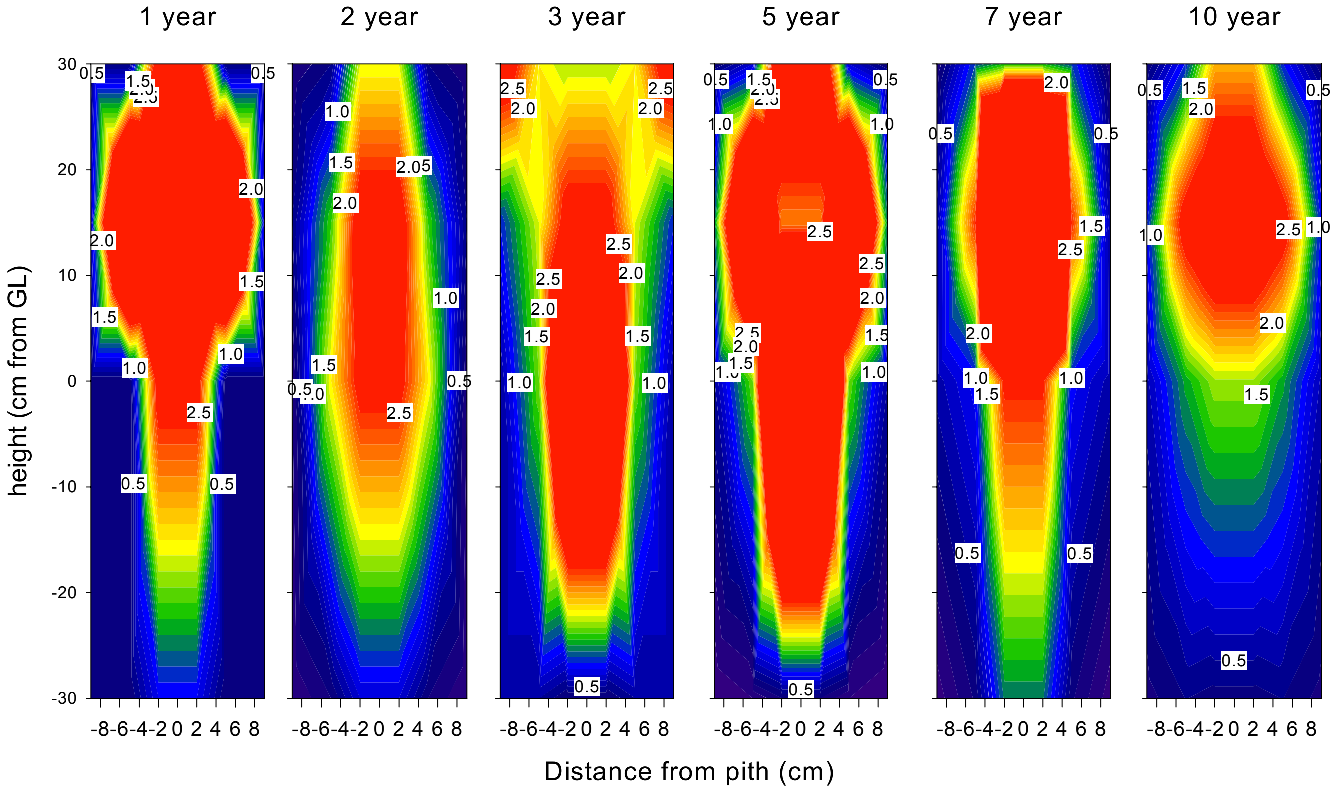


Figure I-25. Residual boron in Douglas-fir timbers 1 to 10 years after application of various combinations of fused borate rod and Timbor. Dark blue indicates boron levels below threshold. Light blue and all other colors indicate boron levels above the lethal threshold.

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 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 was assessed 1, 2, 3, 5, 7, 10 and 12 years after treatment by removing increment cores from three equidistant sites around each pole 30 cm below groundline, 30 cm above groundline and 60 cm above groundline. The outer 2.5 cm of the treated shell was discarded, then the inner and outer 2.5 cm of each core was retained. Core segments from a given zone for the same sampling height were combined for the five poles in each treatment. The cores were then ground to pass a 20 mesh screen and the resulting sawdust was thoroughly mixed before being divided into two equal portions. One portion was extracted in hot water and analyzed for boron content using the Azomethine-H method. The other portion was extracted in hot water, then the fluoride level was measured using a specific ion electrode.

In previous years, we have typically used a lower threshold for fluoride performance against internal decay fungi of 0.7 Kg/m^3, however, a series of laboratory studies suggest that the threshold for protection is actually lower, nearer 0.25 kg/m^3. Using this value as the lower threshold, we see that fluoride levels were initially elevated in both the 3 and 6 rod treatments in the below ground zones and exceeded the lower threshold in a number of locations (Figure I-26). Levels also tended to be higher in the 90 degree spacing at both dosages. Fluoride levels declined sharply after the first year, although they still approached the threshold below groundline and 30 cm above that zone in the 90 degree spacing treatment. The overall low levels of fluoride present in the wood over time make it unclear whether this component of the system plays a significant role in performance. Our previous tests suggest that fluoride is more active than boron; however, the levels detected in our test poles have never approached those that we would consider to be protective against fungal attack.

Boron levels in the 3 rod treatment were above the threshold below groundline and 300 mm above groundline one to five years after treatment in both the 90 and 120 degree spacings (Figure I-27 to I-30). Chemical levels then fell below the lower threshold at most locations. Chemical levels 600 mm above groundline were generally low throughout the test suggesting that upward movement from the rods was minimal. Boron levels were at or near background 12 years after treatment regardless of dosage or spacing pattern, suggesting that the original rod dosage has dissipated to background levels in the poles and is affording little or no supplemental protection (Table I-12).

The overall results after 10 to 12 years are consistent with the previous results. The fluoride, while potentially useful as a co-biocide, appears to move at low rates through the wood and its role in this system is questionable. Boron does appear to move well from the rods and remained at effective levels for 5 years after treatment at or near the groundline at the higher dosage. As with many internal remedial treatments, it would be expected that fungal reinvasion would not occur immediately after the chemical has depleted to levels below the threshold level. For example, metam sodium is only detectable in wood for 3 to 5 years after treatment, but the treatment provides 7 to 10 years of protection against renewed fungal attack. We might expect similarly slow rates of re-colonization with boron based treatments.

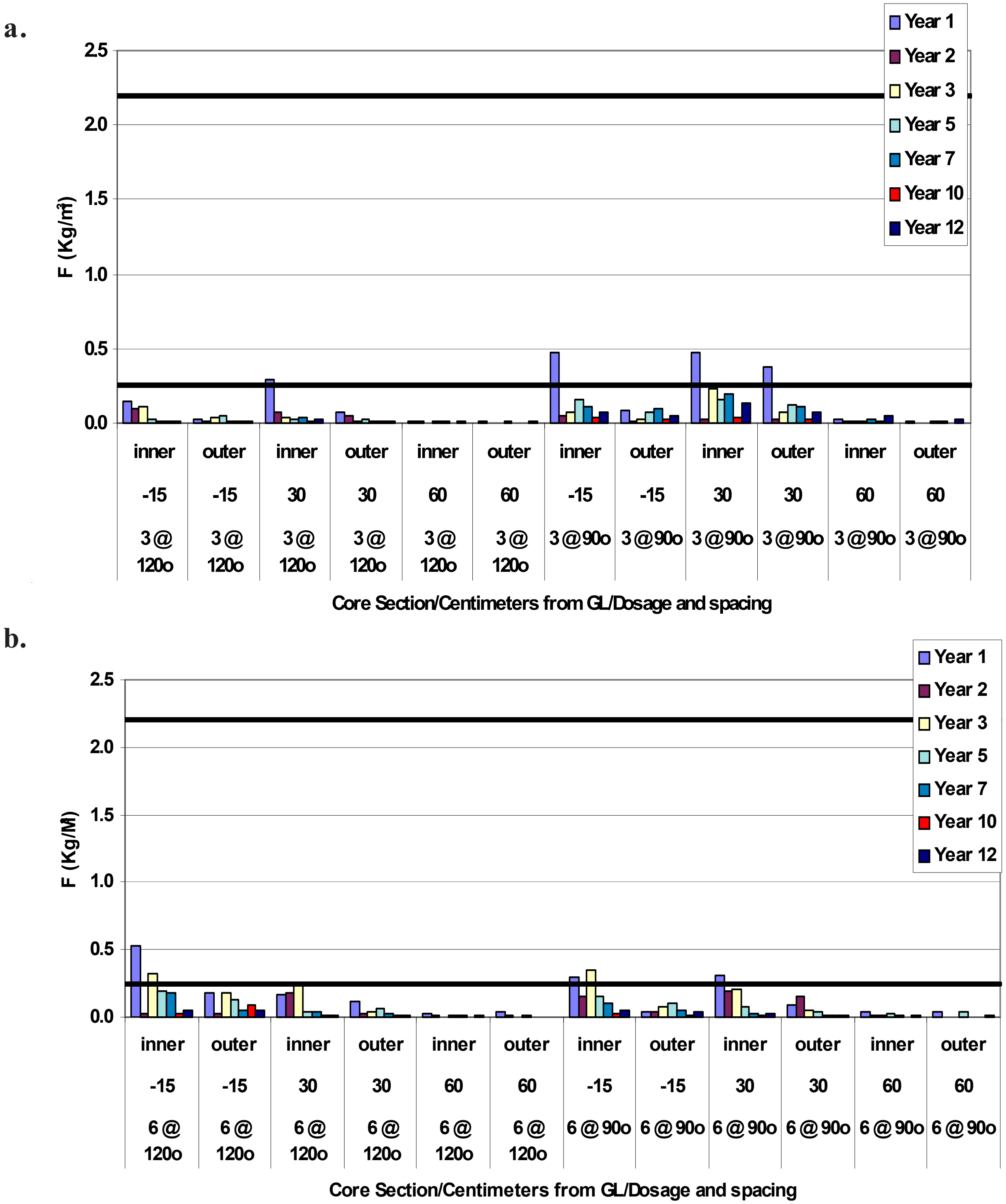


Figure I-26. Residual fluoride levels at selected distances from the groundline and wood surface (inner vs outer) in Douglas-fir pole sections 1 to 12 years after treatment with a) 3 or b) 6 fluoride/boron rods. Lower and upper threshold levels of fluoride are 0.25 and 2.20 Kg/m^3, respectively.

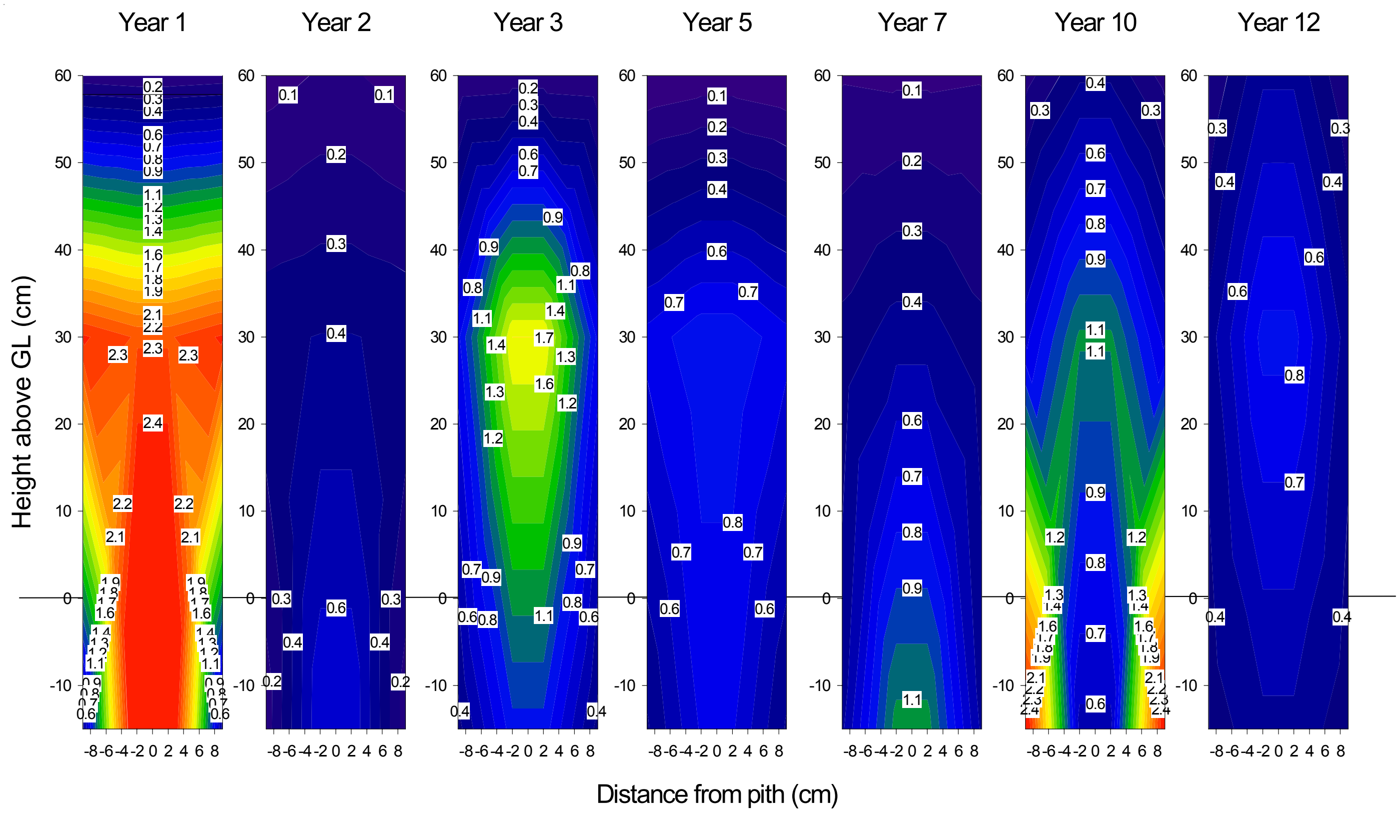


Figure I-27. Residual boron levels at selected distances from the groundline and wood surface in Douglas-fir pole sections 1 to12 years after treatment with 3 boron/fluoride rods installed at a 90 degree spacing. Dark blue indicates boron levels below threshold. Light blue and all other colors indicate boron levels above the lethal threshold.

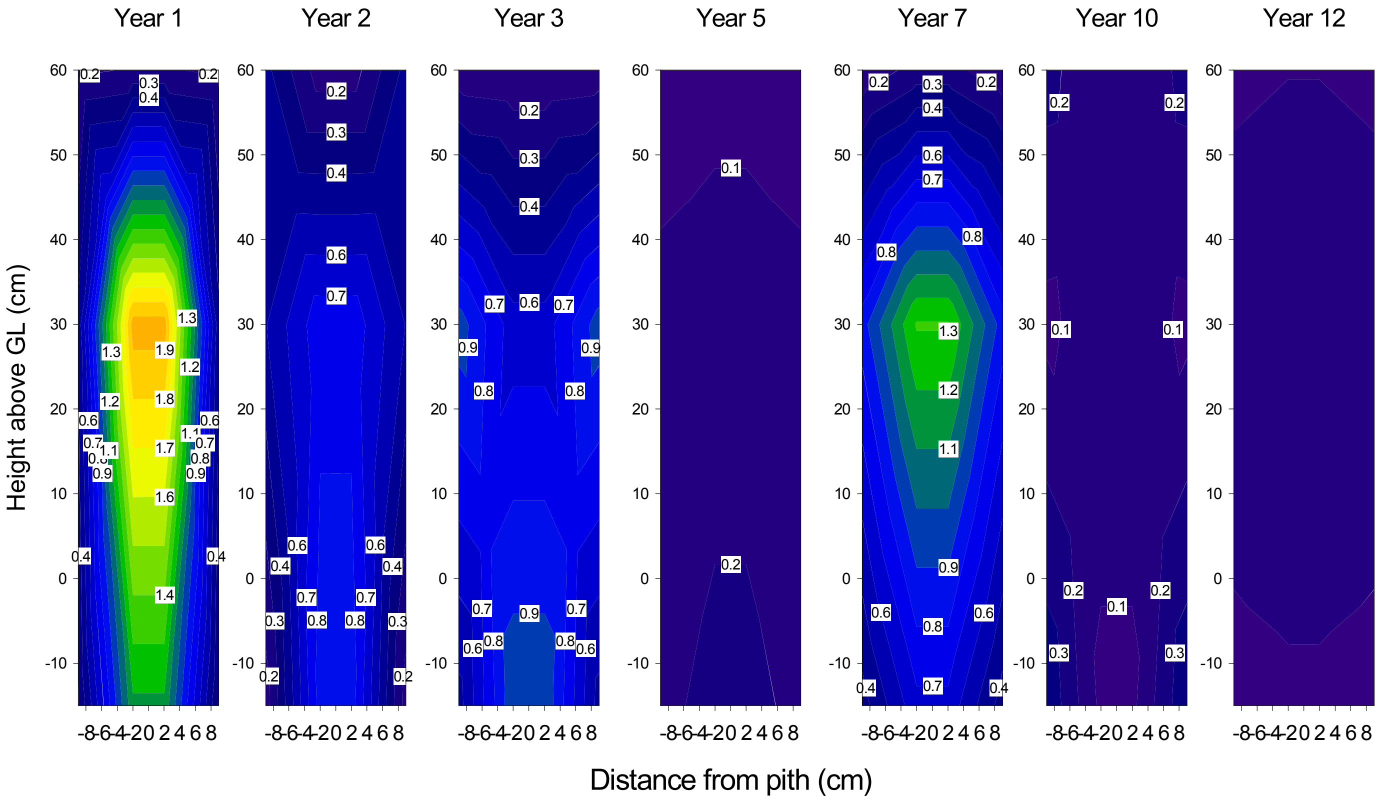


Figure I-28. Residual boron levels at selected distances from the groundline and wood surface in Douglas-fir pole sections 1 to12 years after treatment with 3 boron/fluoride rods installed at a 120 degree spacing. Dark blue indicates boron levels below threshold. Light blue and all other colors indicate boron levels above the lethal threshold.

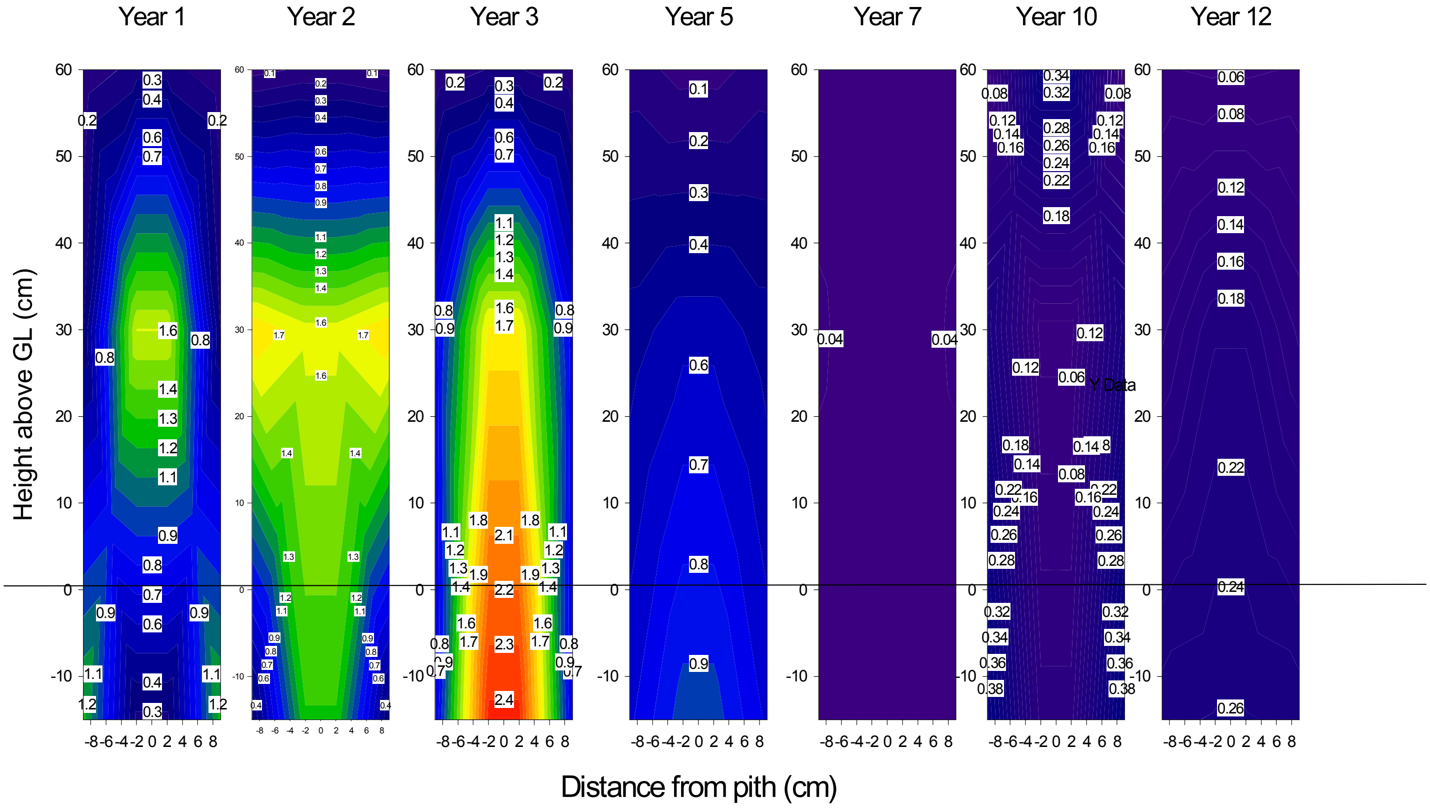


Figure I-29. Residual boron levels at selected distances from the groundline and wood surface in Douglas-fir pole sections 1 to12 years after treatment with 6 boron/fluoride rods installed at a 90 degree spacing. Dark blue indicates boron levels below threshold. Light blue and all other colors indicate boron levels above the lethal threshold.

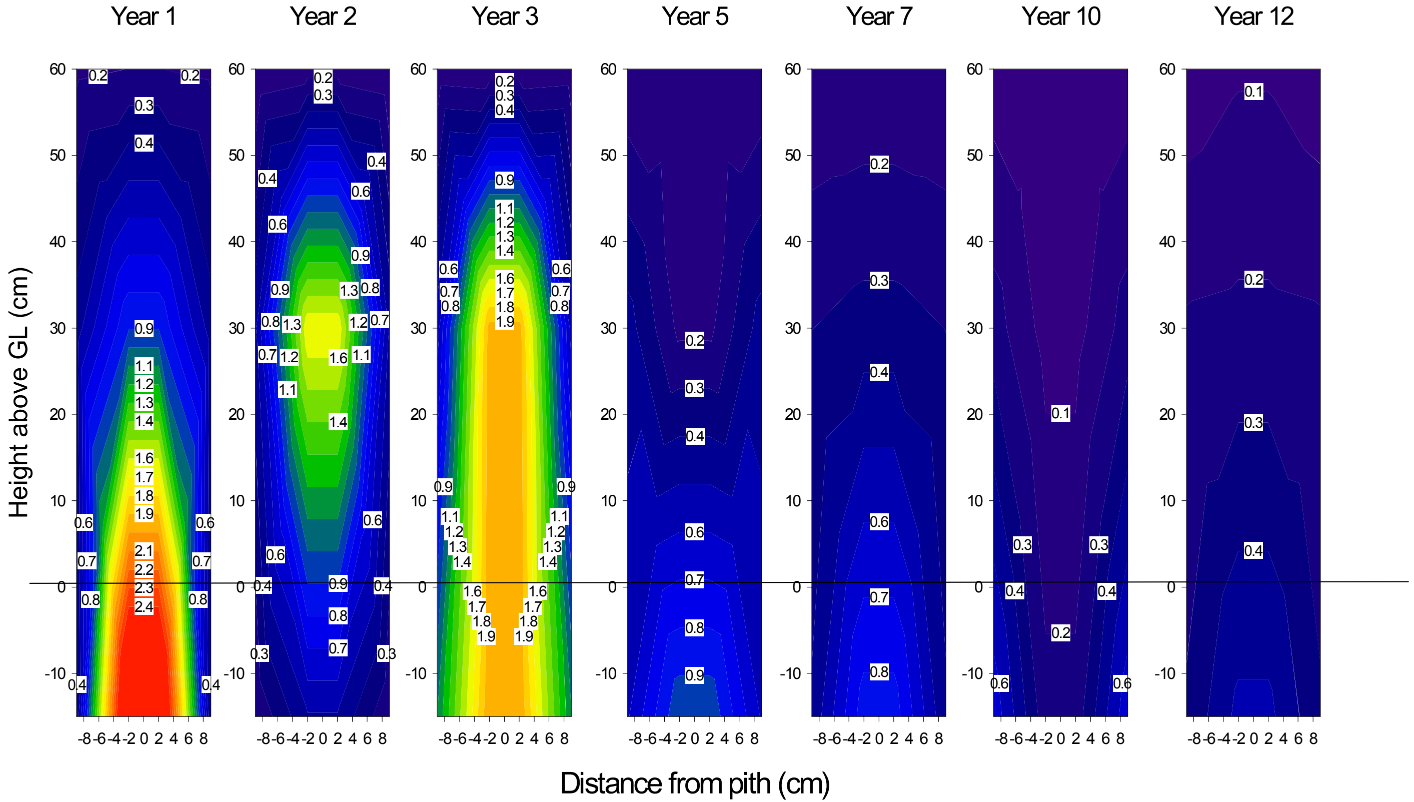


Figure I-30. Residual boron levels at selected distances from the groundline and wood surface in Douglas-fir pole sections 1 to12 years after treatment with 6 boron/fluoride rods installed at a 120 degree spacing. Dark blue indicates boron levels below threshold. Light blue and all other colors indicate boron levels above the lethal threshold.

Table I-12. Residual boron (as kg/m^3 BAE) in Douglas-fir poles 1 to 12 years after treatment with 3 or 6 boron/fluoride rods at 90 or 120 degree spacings.

Treatment	Height	Core	Boron (kg/m^3 BAE)[a]						
	(cm)	Section	Year 1	Year 2	Year 3	Year 5	Year 7	Year 10	Year 12
Control	-15	inner	0.04	0.03	0.05	0.00	0.19	0.00	0.10
		outer	0.05	0.03	0.07	0.00	0.11	0.00	0.09
	30	inner	0.05	0.02	0.08	0.00	0.46	0.00	0.21
		outer	0.16	0.05	0.08	0.00	0.22	0.00	0.19
	60	inner	0.04	0.04	0.05	0.00	0.11	0.00	0.11
		outer	0.03	0.02	0.07	0.00	0.10	0.00	0.09
3 @ 120^{o}	-15	inner	**1.17**	**0.85**	**0.98**	0.21	**0.67**	0.07	0.08
		outer	0.29	0.15	0.46	0.19	0.35	0.38	0.07
	30	inner	**1.95**	**0.77**	**0.65**	0.18	**1.31**	0.17	0.18
		outer	0.43	0.49	**0.95**	0.16	**0.85**	0.07	0.16
	60	inner	0.21	0.15	0.12	0.05	0.24	0.10	0.10
		outer	0.18	0.43	0.13	0.00	0.12	0.24	0.08
3 @ 90^{o}	-15	inner	**2.81**	**0.69**	**0.86**	**0.72**	**1.15**	**0.57**	0.47
		outer	0.45	0.14	0.36	0.38	0.47	**2.58**	0.34
	30	inner	**2.28**	0.40	**1.70**	**0.88**	0.45	**1.12**	**0.84**
		outer	**2.42**	0.38	**0.78**	**0.74**	0.33	**0.67**	0.44
	60	inner	0.11	0.11	0.13	0.03	0.08	0.38	0.48
		outer	0.13	0.05	0.11	0.00	0.09	0.16	0.20
6 @ 120^{o}	-15	inner	**2.99**	0.49	**2.00**	**0.99**	**0.86**	0.24	**0.53**
		outer	0.39	0.21	**1.11**	**0.59**	0.42	**0.67**	0.31
	30	inner	**0.90**	**1.69**	**1.95**	0.17	0.34	0.06	0.23
		outer	0.45	0.49	**0.56**	0.45	0.30	0.25	0.22
	60	inner	0.20	0.15	0.11	0.15	0.12	0.06	0.09
		outer	0.18	0.10	0.13	0.11	0.11	0.05	0.03
6 @ 90^{o}	-15	inner	0.27	**1.29**	**2.44**	**0.96**	0.02	0.13	0.26
		outer	**1.25**	0.30	**0.69**	**0.68**	0.02	0.40	0.25
	30	inner	**1.60**	**1.64**	**1.72**	**0.56**	0.02	0.05	0.20
		outer	0.30	**1.78**	**0.73**	0.45	0.04	0.25	0.13
	60	inner	0.25	0.12	0.21	0.06	0.03	0.35	0.06
		outer	0.12	0.06	0.12	0.15	0.03	0.05	0.06

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

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 was assessed on a blind sample basis by Osmose for the first 5 years using AWPA Standard A2 Method 7, then the last two samples at 7 and 10 years were performed by hot water extraction followed by specific ion electrode measurement of fluoride levels in the extract. Comparative 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-31). Fluoride levels further up the poles have remained below the threshold 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.

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. 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.

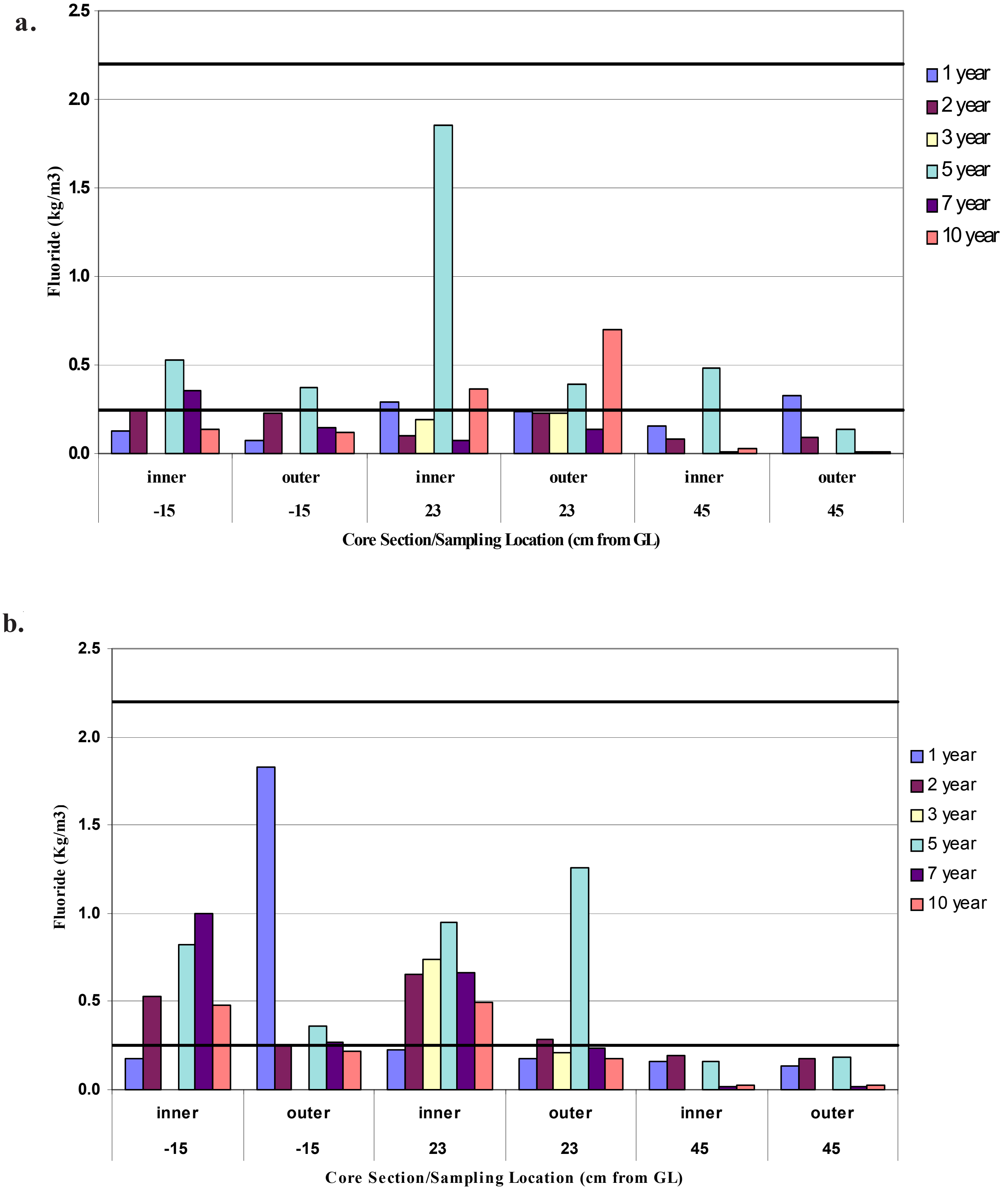


Figure I-31. Fluoride levels at selected heights above or below the groundline of Douglas-fir poles 1 to 10 years after application of a) 3 or b) 6 sodium fluoride rods. Lower and upper threshold levels for fluoride are 0.25 and 2.20 Kg/m^3, respectively.

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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 untreated 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 untreated western redcedar sapwood and for protecting untreated 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 personnel realize that this is highly unlikely to happen, providing little or no motivation for following the specification.

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

The 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.

Penetration of copper from bolts coated with only copper naphthenate was 2 mm one week after treatment and not detectable after 2 weeks of exposure (Table II-1). These results suggest that the copper was largely unable to move from the threaded rod into the wood. While limited movement might not pose a problem if the preservative created a sufficient barrier around the surface of the bolt hole, small checks or cracks could easily compromise this barrier. The inability of the copper to move into these cracks would largely negate the benefits of treatment. The inability to move with moisture into freshly opened checks also appeared to be one of the primary causes of failure for topically applied bolt hole treatments such as the pentachlorophenol in diesel oil treatment used in the original bolt hole test in Objective IIA of this report.

Bolts treated with the copper/boron paste also had minimal copper penetration 1 week after treatment, but the depth of penetration increased markedly with a second week of exposure. Boron distribution proved more variable. Initially, boron movement appeared to be substantial, but samples exposed for 2 weeks tended to have much shallower boron penetration. These results suggest that measurement errors influenced the initial results. The boron indicator is very sensitive and even small amounts of boron inadvertently smeared across the wood surface could lead to a positive result.

The preliminary tests suggested that the presence of a water diffusible component in the paste would be useful for providing deeper protection to the field damaged wood. For this reason, we established the subsequent field trial.

Table II-1. Degree of longitudinal penetration of copper or boron from rods coated with preservative paste and installed in Douglas-fir poles for one or two weeks.

Treatment	Exposure Period (weeks)	Chemical Penetration (mm)			
		Copper		Boron	
		Upward	Downward	Upward	Downward
Cop-R-Nap	1	2	2	-	-
	2	0	0	-	-
CuRap 20	1	2	2	36	42
	2	7	10	6	5

Galvanized rods (300 mm long by 12.7 mm in diameter) were coated along the center 200 mm with a layer of either 5 g of Cop-R-Plastic (copper/fluoride) or 3 g of CuRap 20 (copper/boron) (oven dry basis). Each rod received 100 mg or 60 mg elemental copper for the Cop-R-Plastic and CuRap 20 treatments, respectively. The rods were oven dried (54 C), and then painted with 2 coats of Plastidip (Figure II-1). One rod from each treatment was applied to each of 26 pentachlorophenol treated Douglas-fir poles sections that were exposed at the Peavy Arboretum test site. Selected poles were removed from the field one, two, three or four years after treatment and split lengthwise around the bolt hole. The average and maximum degree of diffusion of the each paste components was measured after the wood had been sprayed with the appropriate chemical indicator.

Figure II-1. Examples of galvanized rods coated with copper/boron (CuRap20) and copper/fluoride (Cop-R-Plastic) pastes.

The average degree of copper penetration away from the rods continues to be small, ranging from less than 1 mm to 4 mm, although the maximum penetration of copper approached 300 mm in some samples (Table II-2). Maximum copper penetration tended to be greater in the Cu/F system than in the Cu/B system for the first two years, however, these differences disappeared after three years. Maximum distance may reflect the ability of the liquid to move for long distances in the wood along openings such as checks or splits. At this point, there appears to be little difference in copper movement between the two copper naphthenate systems, one of which is oilborne and the other an amine-based waterborne system.

Average boron and fluoride diffusion were also somewhat limited 1 year after treatment. The degree of movement increased in the second year, but then failed to increase in the third year (Table II-2, Figures II-2, 3). We suspect that the continued slow rate of diffusion might reflect, in part, the presence of the spray-on plastic coating, which was applied to protect the chemical prior to application. The pastes tended to dry after application to the rods and were prone to

Table II-2. Degree of copper, boron, or fluoride diffusion from galvanized rods one to four years after installation in creosote-treated Douglas-fir pole sections.

Treatment	Diffusion	Chemical Movement (mm)							
		Copper				Boron/Fluoride			
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 1	Yr 2	Yr 3	Yr 4
Cop-R-Plastic	Average	<1	2.3 (1.3)	3.0 (0.8	2.3 (1.0)	<1	2.0 (2.8)	2.0 (1.8)	7.0 (4.7
	Maximum	30 (29)	238 (64)	51 (48)	9 (3)	118 (139)	108 (74)	15 (17)	28 (18)
CuRap 20	Average	3 (1)	2.3 (0.5)	<1	1.0 (0.8)	3.3 (0.5)	6.3 (3.4)	2.8 (2.2)	20.3 (16.1)
	Maximum	21 (10)	110 (98)	51 (53)	7 (9)	50 (11)	46 (29)	50 (55)	119 (69)

[a] Values represent means, while figures in parentheses represent 1 standard deviation.

flaking during handling. The plastic coating was designed to limit flaking and we presumed that this coating would be disrupted as the rod was driven into the hole allowing the chemicals to interact with moisture in the poles. We also presumed that the coating would decompose in the presence of the oil.

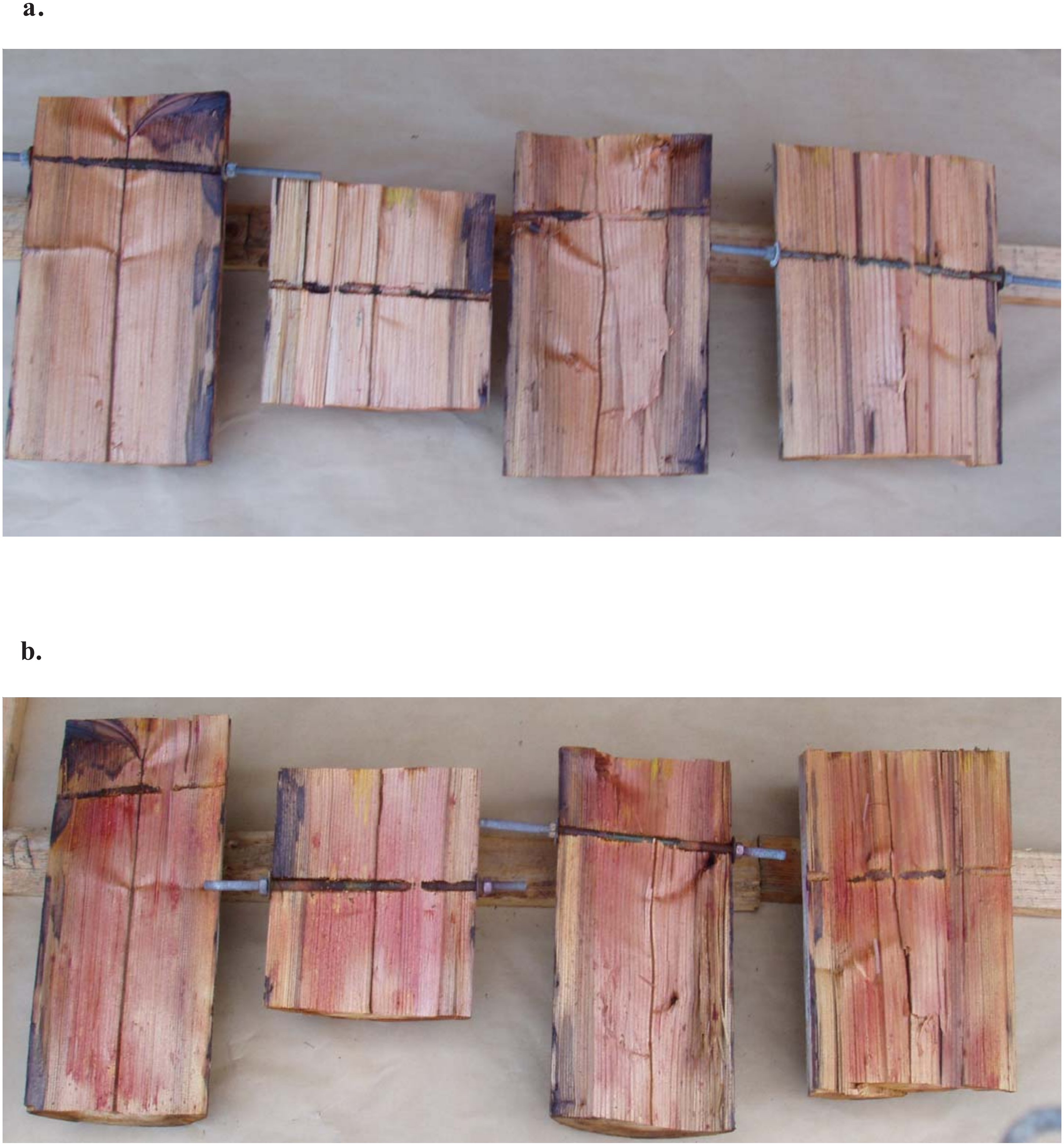


Figure II-2 Degree of a) copper [blue color] and b) fluoride [yellow color] movement away from the sites in Douglas-fir poles where Cop-R-Plastic coated galvanized rods were installed four years earlier.

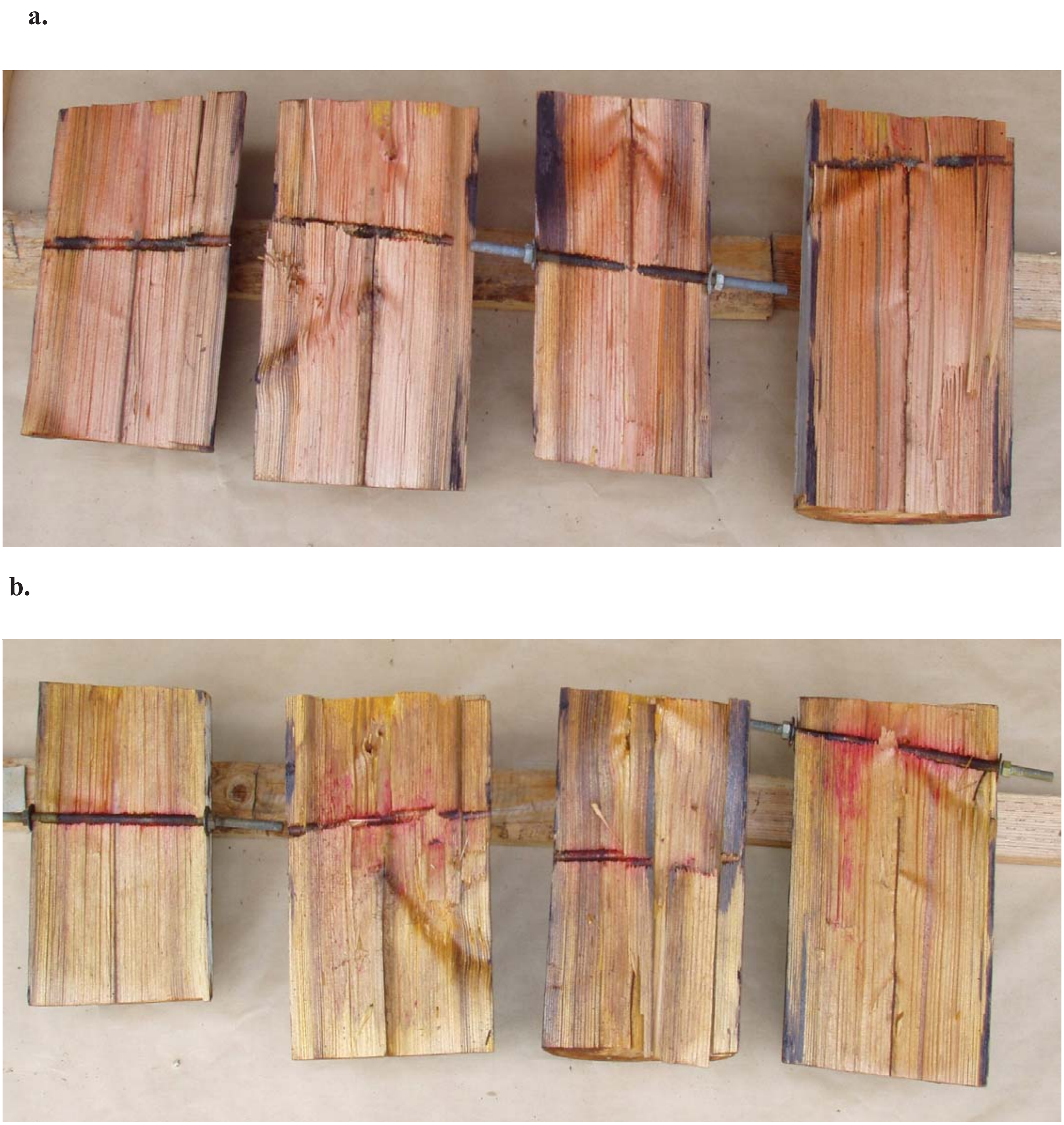


Figure II-3 Degree of a) copper [blue color] and b) boron [red color] movement away from the sites in Douglas-fir poles where CuRap 20 coated galvanized rods were installed four years earlier.

Boron and fluoride distribution in the poles were much improved 4 years after treatment. Average fluoride movement was 7 mm compared to 2 mm after 3 years, while average boron movement was 20 mm compared to 2.8 at 3 years. These results suggest that the water based materials are moving away from the metal rods, providing supplemental protection to the wood as checks or splits developed. The delayed release might be advantageous since it would prolong the useful life of any chemical in the bolt hole region.

The results 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 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 occupy portions of the pole and must field drill for attachments. This approach would allow 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.

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 would produce even greater investment savings for utilities. The goals of Objective III are to develop new treatment methods, explore the potential for new species, assess various inspection tools and explore methods for producing more durable wood poles.

A. Establishing a Through-Boring Pattern for Utility Poles

(This section represents a portion of the MS Thesis of Lori Elkins)

Through-boring is a highly effective method for improving preservative treatment of thin-sapwood species, developed in the 1960's, to reduce staggering losses from internal decay near the groundline. Through-boring has since gone on to be widely adopted by utilities using these species. While there are other methods such as deep incising, kerfing, or radially drilling that also improve groundline performance, the simplicity of through-boring has led to wider use of this process.

While through-boring is widely used, there is relatively little data on the effects of the bore holes on pole properties. The lack of data was of little concern for most utilities because there are literally millions of through-bored poles in service across North American. However, two Pacific Northwest utilities experienced catastrophic failures of through-bored poles during storm events. In both cases, the poles failed at the through-bored zone even though the poles were transmission sized and had maximum bending moments well above that zone. These failures led both utilities to investigate the background data supporting the use of through-boring as a part of their failure investigations. In both cases, the poles were subjected to extreme wind loads that were probably beyond the original design assumptions. In one case, 40 poles cascaded, including several steel poles and non-through-bored poles that were mixed in the line. Despite reassurances that the failures were not unexpected given the weather conditions, the investigation highlighted the need for more information on the effects of through-boring on pole properties.

Design values for wood poles reflect a decade's long development process that incorporates limited full scale bending tests of poles with tests of small clear beams of each species. The data are then used in combination with knowledge about the effects of various wood defects (knots, checks, etc) to develop acceptable recommended design values for each species. These values are then used with various safety factors in pole design. There are a variety of recent pole test data (Larson et al., 2004; Cerda and Wolfe, 2003; Wolfe et al., 2001; Wolfe and Moseley, 2000; Crews et al., 2004), but none of these have involved through-bored poles. It is straightforward to calculate an expected loss of bending strength due to the reduced section area from material removed, but these calculations alone do not appear to be good indicators of the effects of through-boring strength. A more precise estimate of through-boring effects requires assessing stress concentration factors that arise at hole boundaries and relating these stress concentrations to global pole performance as affected by the ground embedment.

The objective of this research was to assess the effects of through-boring on the bending strength of Douglas-fir utility poles. Finite-element analysis was used to examine various hole sizes and pattern attributes to establish a preferred through-boring pattern.

The results from finite-element modeling were used in conjunction with prior testing, stress concentration data, and data on preservative penetration with through-bored holes to develop an "ideal spacing" and hole pattern to use on utility poles. Evaluation of bending strength as affected by hole size was the primary test objective.

TECHNICAL BACKGROUND

Douglas-fir poles are the most common material for utility poles in the Northwestern United States. They are commonly through-bored because the heartwood is only moderately durable and is notoriously difficult to treat (Morrell and Schneider 1994). Through-boring allows for adequate preservative penetration to protect the poles from internal decay. Although, through-boring is more commonly used on larger transmission poles, Class 4 distribution poles were chosen for this study because the maximum stress is typically at or near the groundline for this type of pole. The groundline is coincident with the through-bored region, which is the critical region to assess the effect of through-bored holes. Larger poles, because of their height and taper, have stresses that are maximum some distance up the pole, away from the groundline (Figure III-1).

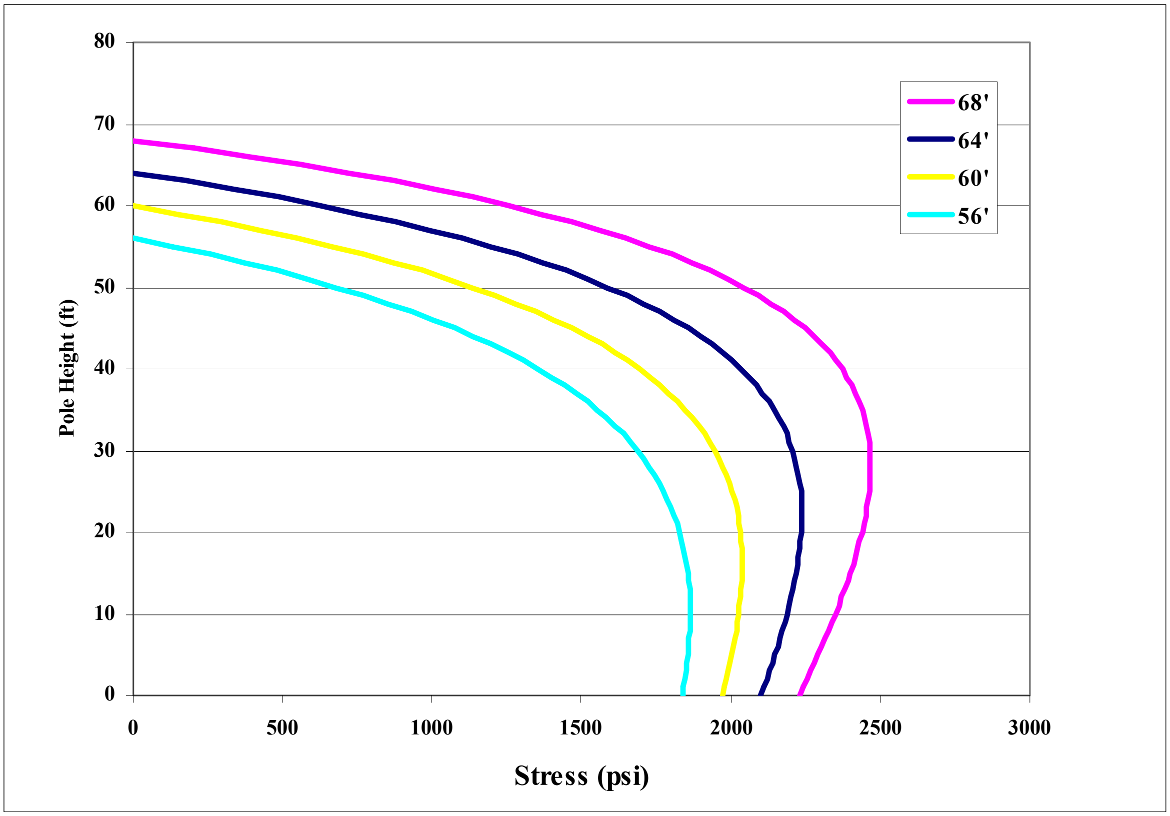


Figure III-1. Stress profile in poles of various heights.

Portland General Electric (PGE) introduced through-boring in 1959 with the Merz through-boring pattern (Brown and Davidson 1961). Their strength analysis was based on a static analysis with section modulus reduction and full-scale test results of 42, class 4, Douglas-fir poles tested by cable loading while embedded in the ground. The test results showed that poles with through-boring had strength reductions of less than 10 percent as compared to the controls. However, radial drilled poles were approximately 25 percent weaker than the controls even though the reduction of section was about equivalent to that of the through-bored poles. Other studies with through-bored poles were reported by Grassel (1969), Graham et al. (1969) and Newbill (1994), but the testing was limited and the use of varying test methods made it difficult to compare results. Hence, the literature on the effects of through-boring is sparse.

Many researchers have modeled wood bending members using the finite-element method. Wang (1987) modeled poles with a two-dimensional model but it did not produce reasonable results because it could not incorporate the complexity of the three-dimensional system. Pellicane and Franco (1994a, 1994b) modeled utility poles to assess maximum strength and failure modes. They used a three-dimensional model with linear elastic properties developed from tests of specimen poles and were able to reasonably predict the strength and failure mechanisms of poles with knots. Williams et al. (2000) and Falk et al. (2003) used a two-dimensional elastic model that was planar isotropic to model wood joists and planks to evaluate the effect of holes on the performance of recycled timbers. The finite-element mesh was refined in the area around the hole, but a complete discussion of mesh refinement is not available. Others have modeled holes in rectangular bending members with isotropic and orthotropic elastic properties, but there is limited literature for holes in beams with circular cross sections.

Stress concentration factors (SCFs) occur as a result of the disruption of stress flow in a member and are important because they often are attributable to member failure. Pilkey (1997) developed a SCF chart as a function of hole diameter in cylinders under bending stresses and found that SCFs of very small holes actually started increasing again with decreasing hole diameter. Stress analyses by Jessop et al. (1959), ESDU (1989), and Thum and Kirmser (1943) (cited in Pilkey [1997]) further showed that circular solids under bending had peak stresses occurring on the inside surface of holes. Wu and Mu (2003) used finite-element analysis to assess stress concentration factors for orthotropic cylinders with circular holes subjected to uniaxial tension or internal pressure (biaxial tension). The mesh for the orthotropic pipe was automatically generated with no discussion given referencing the mesh refinement or how it may affect the stress output. The study developed multiplicative factors for cylinders and for orthotropy to estimate SCFs from those derived for isotropic plates. They were able to match the finite-element results with those from closed-form functions for small holes where small d/D ratios exist (d=hole diameter and D=pipe diameter). However, the material of this study had an orthotropy ratio of only 2.2. Nonetheless, stress concentration factors can be a valuable tool for a comparative assessment of hole size and hole pattern. There appears to be limited literature on the stresses resulting from holes in solid cylindrical beams that are highly orthotropic, such as wood poles, where d/D is small.

Test methods for round poles have been reported by Brown and Davidson (1961), Wolfe and Moseley (2000), and Crews et al. (2004), along with two standardized methods widely used in the North America given in ASTM Standard D1036 (2005a). Brown and Davidson's (1961) ground-embedded test is not easily reproducible for a large number of tests while Wolfe and Moseley's test focused on using wood poles as timbers. The cantilever method of ASTM Standard D1036 fails to incorporate the effect of the foundation on the pole mechanics, which is critical to assessing through-boring effects on pole bending strength. The second standard test method, the 3-point bending test, has a sharply changing moment diagram over the critical groundline region. However, the 4-point bending test (Crews et al. 2004) appears to produce a stress distribution that would parallel that found in a pole in-service and this method was chosen as the basis for the testing method adopted for this study.

Development of Through-boring Pattern

Finite Element Modeling

The objectives for the computer modeling were:

1.To examine the stress concentrations created by different hole sizes;

2.To examine the effect of various longitudinal and lateral hole spacings as well as edge distances on bending strength and hole interaction;

3.To determine the effect of loading direction on bending stress with respect to the orientation of the through-bored holes.

A global elastic model of the tapered pole with through-bored holes was created. However, the stress analysis in the critical region was inadequate because the mesh was too coarse. As a result, a submodel was created so that sufficient mesh refinement would allow us to assess the stress concentration factors attendant to various combinations of hole size and hole spacing. The submodel was a 2-ft, tapered pole section, representative of the global pole at the groundline (Æ$_{\text{top}}$ = 5.50-in., Æ$_{\text{bottom}}$ = 5.74-in.).

ANSYS® solid element 95 was used with nodal translations fixed at the groundline. The fixed boundary condition prevented the submodel from translating as a rigid body or rotating at the base. Linear elastic properties were used based on Douglas-fir so that the model was planar isotropic with E_L = 1.72e6 psi and $E_{R/T}$ = 1.0e5 psi (USDA Wood Handbook 1999). The model coordinate system was setup with the Z-direction as the longitudinal material orientation and the X and Y directions as the averaged radial and tangential orientations.

The submodel was meshed automatically by ANSYS®. Our principal interest was that the mesh refinement would yield a compromise between stress output uncertainty and computational efficiency. We found this was a difficult balance to achieve but proceeded with using the finite-element analysis as one predictor of the strength effects of adding borings through a section. A typical mesh for a submodel is shown in Figure III-2.

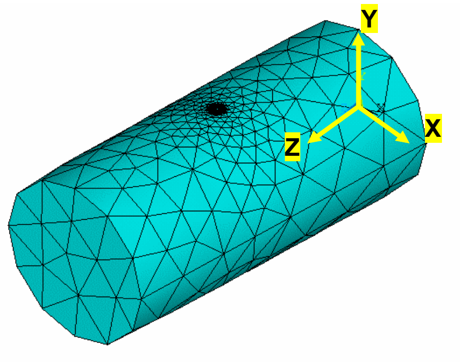


Figure III-2. Typical meshing around hole in submodel. Boundary conditions and loading not shown.

Hole size

The effect of hole size was addressed by developing models where hole size was varied in 1/4-in. increments, from 1/4-in. up to 1-1/4 in. while keeping other model variables and attributes constant. The difficulty of recreating meshes around the different hole sizes produced some variations in the stress distribution for hole size based on the mesh refinement. Finer meshes typically produced higher peak stress concentrations.

As a result, only general trends in SCFs were examined as a function of hole diameter. The smallest hole size typically had the largest SCF, but beyond this, no other distinct generalizations could be made given the variability in the modeling. No hole size emerged as "optimal" in terms of having the lowest peak stresses as was predicted by the stress concentration formula developed by Pilkey for cylinders in pure bending.

Hole spacing

The effect of longitudinal and transverse hole spacing was assessed by using a submodel with two borings removed near the centerline. The spacings of the two holes were varied as a function of hole radii to determine the effect of spacing on peak stresses. Generally, the finite-element analysis (FEA) output showed more closely spaced holes had lower peak stresses than did spacings at greater distances. Bending stresses for the 3/4-in. holes, were fairly uniform at longitudinal spacings of three and six times the hole radii, but stresses increased approximately 8 percent for spacings of nine and twelve hole radii.

The finite-element results confirmed previous reports that SCFs decrease due to the presence of nearby holes; however, this effect is small. The difference due to longitudinal spacing was nominal when multiple hole submodels were run with varied spacings. Hole placement had a larger influence on the maximum stress around the hole. Our results were similar to those by Falk et al. (2003) and Williams et al. (2000) showing that the location of holes in bending members was a critical issue.

Holes placed further out the pole diameter, in the higher stressed regions of the pole, exhibited higher SCFs. Therefore, submodeling was also used to examine the effect of edge distance on stresses. The increase in peak stresses was approximately linear as the hole was moved out the pole, away from the centroidal axis. However, there was a sharp increase in the peak stresses as the edge distance moved from 1.5-in to 1.0-in, suggesting that a 1.5-in edge distance should be maintained for through-boring. This trend was similar for the three different pole sizes that were submodeled; however, the inaccuracies inherent in drilling through large cross-sections suggest that a 2.0-in. minimum clear distance would help reduce the risk of inducing substantial negative effects on pole strength.

Load direction

Jessop et al. (1959) showed that members loaded in bending, perpendicular to the hole axis, have lower peak stresses then poles loaded parallel to the hole axis. This effect was reassessed with submodeling comparing the stress output from two hole spacing patterns; 2-in. x 3-in. and 1.5-in. x 5-in. over a fixed length of 15-in.

Loading perpendicular to the holes produced significantly lower peak stresses in tension and compression for both spacing patterns. Peak tension stresses for the longitudinal and transverse directions were 36 and 26 percent higher, respectively, when loaded parallel to the holes. Compression stress differences were even higher because of the maximum stress location. Loading perpendicular to the holes moved the peak compression stress to the groundline, instead of the hole edge.

Through-boring Pattern

Research by the Utility Pole Research Cooperative (Morrell 1998) at Oregon State University has shown that creosote penetration averaged 8.5-in. longitudinally (± 3.8-in.) and 0.72-in. transversely (± .16-in.) around single holes drilled into Douglas-fir heartwood. These values suggest that a longitudinal and transverse spacing of 5-in. and 1.5-in., respectively, repeated every 15-in. along the pole area to be bored, would provide the necessary coverage.

Literature, test results, and modeling were used to develop a final through-boring pattern for full-scale testing. The literature on SCFs for cylinders in bending and the limited prior full-scale tests both suggest that smaller holes may increase the stresses in a pole. Despite the limitations of the hole size modeling, the finite-element analysis also suggested that SCFs generally reached a minimum at some intermediate hole size, while very small hole sizes tended to have higher SCFs.

After careful integration of test data and the literature, the basic through-boring pattern was defined by hole size, hole spacing (longitudinal and transverse), and edge distance. It was decided that the effect of hole size would be established by tests of full-size poles, but hole spacing, edge distance, and loading direction could be specified from existing knowledge. Spacings were based on edge-to-edge distance, not center-to-center distance. The result of this spacing is that there are an increased number of holes for the smaller spacings but preservative penetration area stayed relatively constant. The basic through-boring pattern (Figure III-3) was a repeated staggered pattern with 5-in. longitudinal spacing, 1 1/2-in transverse spacing, and 2-in.edge distance. The holes were drilled parallel to one another. This hole pattern was applied to the poles over a 60-in. length, starting at 36-in. from the butt of the pole (-36-in. to +24-in.relative to the groundline on a 40-ft. pole).

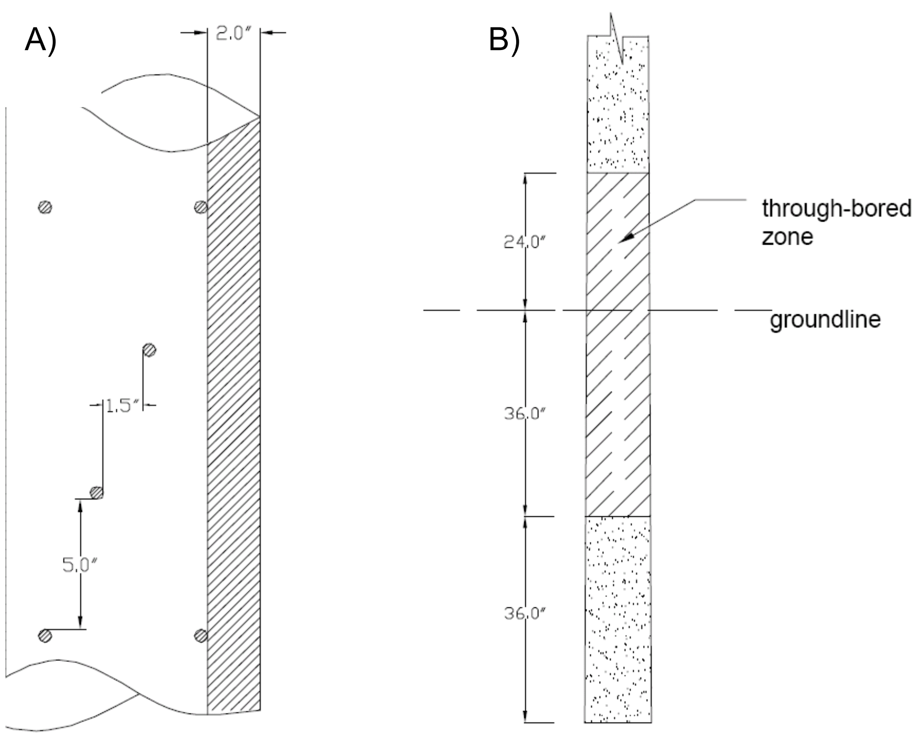


Figure III-3. Illustration of through-boring pattern showing a) hole spacing and b) through-boring zone on pole.

Experimental Methods

Experimental Design

The experiment used was a completely random design with hole size as the treatment source of variation. Five hole sizes were evaluated using the described through-boring pattern: 1/4-in, 1/2-in., 3/4-in., 1-in. holes, and no holes. Twenty-eight replicates (n=28) were tested for each treatment. Thus, 140 poles total were evaluated in the experiment.

Materials

Poles were shipped from a Weyerhaeuser yard, located near Wilbur, Oregon, to the J.H. Baxter & Co. plant in Eugene, OR for through-boring, then delivered to Oregon State University for testing. Although poles were not sourced from individual stands, nearly all poles came from within a 50-mile radius of the facility. Poles were received in four different loads, over the course of seven weeks.

At the Baxter plant, each pole was marked on the face side of the pole (the face side is termed the *reference side* for purposes of testing). The face of a pole is defined in ANSI 05.1 as the "concave side of greatest curvature". When through-boring poles, the standard practice is to drill the boring holes at a right angle to the face of the pole. Templates were constructed for the through-boring patterns with different hole sizes. A separate template was made for each treatment group because the center-to-center spacing of the holes changed with every hole diameter even though the clear spacing was constant. Each treatment group pole was hand drilled with an electric drill.

To limit strength variability due to moisture content, poles were tested in the green, freshly peeled condition. The "intersection moisture content", where mechanical properties begin to change as wood is dried, is 24 percent for

Douglas-fir.. Therefore, the poles for this study were tested untreated, in the green condition, with moisture contents above 24 percent, to minimize variability.

Test Apparatus

Two methods for testing poles are given in D1036 (ASTM 2005), the machine test method and the cantilever test method. Both methods were rejected as unsuitable for the purpose of this study because they did not create reproducible, in-use bending moment distributions. Direct embedment was considered, but it was deemed unsuitable because it was not reproducible between various laboratories or even due to seasonal differences. Instead, a modified 4-point bending method was developed that forced the maximum bending stress to be in the through-bored region while maintaining a nearly constant moment in the high moment zone so that the bending moment at failure could be accurately calculated. The test setup follows Crews et al. (2004). Its rationale is detailed further in Elkins (2005).

The poles were tested as simply supported beams with two point loads applied just inside the through-bored zone boundaries. The end bearing points allow the pole to rotate as well as move longitudinally. Wood saddles were used at the bearing points, as well as the points of loading, to minimize stress concentrations at these locations. The u-shaped saddles measured 11-in. in length, and were made out of Douglas-fir so the point of contact between the two materials was of similar hardness.

The top portion of the pole was not of concern for the purpose of assessing effects due to through-boring, so the pole was shortened to a convenient length for ease of testing. The length must represent a reasonable span-depth ratio so that the pole still behaves as a flexural element that is not shear critical. With those criteria, the length for the test span (L) was three times the embedment length (l) of the pole with a 1-ft overhang on each end (Figure III-4).

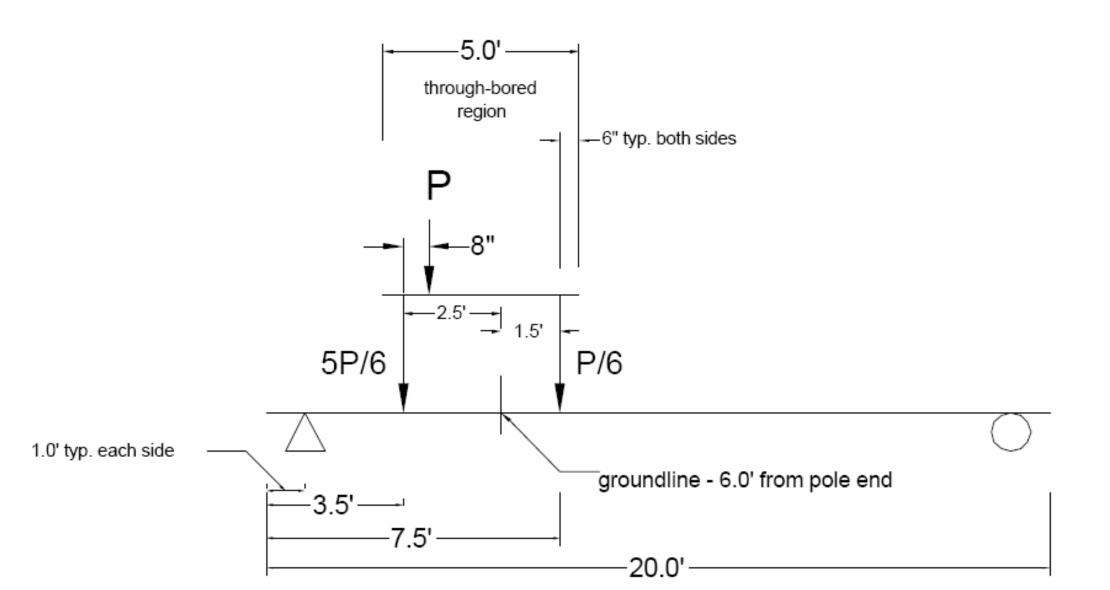


Figure III-4. Test set-up dimensions.

The embedment length for poles is typically 10 percent of the length plus 2-ft. In our tests we used a 40-ft pole, thus,

l (embed. length) = 0.10*pole length + 2 (2)

$l = .10*(40\text{ ft}) + 2\text{ ft} = 6\text{ ft}$

$L = 3*l + 2\text{ ft}$ (3)

$L = 3(6\text{ ft}) + 2\text{ ft} = 20\text{ ft}$ total length

The load was applied in the through-bored region to produce the service-like moment in this zone. The loading span was made 1-ft shorter than the length of the through-bored zone, which is typically 5-ft for Class 4 poles. The ratio between the two forces that would create a constant moment region was calculated to be 4.6:1, with the larger force applied closest to the butt end of the pole. We rounded the ratio to 5:1, to make an easy ratio for design and to introduce a small amount of shear at the groundline.

Testing Procedures

The poles were cut to length and strength-reducing defects, such as knots, were mapped in the through-bored region. The length of the trimmed pole as well as the circumference of the pole at the butt and tip ends were measured and the poles were weighed (±1 lb). The dynamic MOE of the poles were determined using the Director® tool (Carter Holt Harvey Ltd., New Zealand).

A center chalk line was snapped 90 degrees counterclockwise to the face of the pole (this was the side of the pole to which the drilling template was applied), and then the longitudinal and circumferential position and diameter of every knot greater than 1/2-in. was recorded. These knots were laid out on a grid and the eventual failure location was noted to visually represent the data.

Poles were hoisted into the testing jig and rotated so that the reference side of the pole was placed down in the testing jig. In this position, the 2.0-in. specified edge distance side of the pole was always on the tension side for the test.

The edge distance of one hole was measured on both the reference (tension) and non-reference (compression) sides. The measurements were taken as a linear offset from the closest edge of the hole to the horizontal plane created from the top or bottom of the pole as estimated from a level projection.

The maximum deflection of the poles was estimated to occur 7.5 feet from the end of the pole, directly under the point load above the groundline. The deflection measurement was taken at this maximum location with a string potentiometer. The base was rigidly clamped to the strong floor beneath the pole and the other end was tacked to the middle portion of the pole. Crushing between the pole and the reaction bearings was measured using a linearly variable differential transformer (LVDT). The LVDTs were secured to the base supports on both ends so that the support fixture and the LVDTs were free to rotate with the pole as the deflection near midspan increased. A flat surface was chiseled in the center of the poles at the support to provide a better contact surface for the measurement.

A 200-kip capacity hydraulic actuator mounted on a steel portal frame attached to the laboratory strong floor was used to apply the load to the poles. The load was displacement-controlled and the rate of loading was .01 inch/sec. This value was estimated from the ASTM standard for 3-point loading. An external load cell attached to the rod end of the actuator measured the force as it was applied to the pole. Deflection and force data were compiled continuously during the test using National Instruments LabVIEW 6.1 operated through a personal computer.

The poles were loaded to failure, defined as the point at which the pole could not continue to take increasing load. After failure, each pole was evaluated and the location of failure was recorded. Photographs were taken of each failure and notes were made of any significant features that might have contributed to the failure.

The section modulus was determined at the point of failure from the butt and groundline circumference data taken assuming a constant taper and uniform circular cross-section. In the cases of shear failures where an exact location was difficult to determine, the failure was assumed to occur at the groundline.

A full-section disk was removed adjacent to the failure zone for processing. The disk was used to determine oven-dry moisture content (MC), ring count, and heartwood diameter. Ring counts and heartwood measurements were taken in two directions, 90 degrees from one another, and the value was averaged. The disks were also used to estimate basic specific gravity (SG). Disk volume was estimated by taking two measurements for both diameter and thickness and averaging these values.

The maximum load was used to calculate the moment at failure assuming a prismatic member. The section modulus used as input for the MOR values was the section of the pole at the failure location. There was some discussion of whether it was appropriate to use the gross section or, in the case of a failure at a hole location, the net section modulus accounting for the material from the holes removed. Since the purpose of this study was to examine the effect of the holes on the strength of the pole as compared to controls, it is appropriate to use the solid section for section modulus so the comparisons will be equal. Using a net section modulus would introduce more subjectivity into the process, as there were many failures that occurred from a combination of holes and knots in nearby planes. Therefore, all section modulus calculations were based on the gross pole section.

Green modulus of elasticity (MOE) values were estimated from the load versus displacement data. MOE data were calculated from equation (4) and were averaged over a range of approximately 10 to 30 percent of maximum load to ensure the data were from the linear portion of the curve. P is the load applied at the point of measured deflection, Ä and d are the displacement and diameter measured at 7.5 ft from the butt end.

$$MOE = \frac{14236P}{\Delta d^4} \text{ ksi} \qquad (4)$$

Results and Discussion

One control pole was destroyed during setup, thus, 139 poles were tested in total. The missing data was ignored since it represented less than 5 percent of the total sample size and no attempt was made to fill in the missing data with an average value.

Many different pole parameters were measured and recorded in conjunction with this study. Most were not used to examine correlations between values but rather to ensure there were not variations within and between pole groups.

The poles had an average groundline circumference of 35 inch and an average taper over the 20-ft section of 0.22 inch/ft. The ANSI 05.1 standard gives a minimum groundline circumference for a Class 4 pole of 33.5 inch. The next larger class size, a Class 3, has a minimum circumference at groundline of 36inch. The poles delivered were graded prior to delivery by industry representatives and determined to be Class 4, ANSI poles that would have gone in service except for this study. There was no indication that these poles varied in any significant way below or above these standards.

The average weight of all poles was 547 lb. The mean average of any group did not vary from the global average by more than 2.6 percent. The same was true for the butt and tip end circumference measurements. All group mean circumference values were within the mean valueby less than 1.4 percent. No significant difference was noted between mean dimensions or weight for any treatment group at the 95 percent confidence level.

A 2 inch edge distance on the reference side was specified for the test pattern but the non-reference side was variable. For this reason, the reference side edge distance is the only consistent measure for comparison purposes. The two smaller hole treatment groups averaged a slightly higher edge distance; the 1/4-inch treatment group average edge distance was 2.08 inch, 4.0 percent greater than the specified edge distance, while the 1/2-inch group had an average edge distance of 2.03 inch. The largest variation from the test pattern was found in the 3/4-inch treatment group, which had an average edge distance of 1.80 inch, 10 percent less then specified. The 1-inch treatment group had an edge distance that was 1.96 inch

Some of the variation between the treatment group edge-distance data is to be expected as typical variation in drilling and pattern application. However, the 10 percent deviation of the 3/4-inch treatment group was significantly different that the specified 2.0 inch edge distance. Despite this, no reliable correction can be made for the variability in edge distances, as every edge distance in the pole was not measured. A representative hole was chosen in the middle of the through-bored region and measurements were taken on this one hole only. Furthermore, only the face where the drill entered the pole was measured. There may have been some offset as a result of the drilling through the cross section. For this reason, no correlation or corrective factors for edge distance were used.

The mean moisture content (MC) for all poles was 54 percent, with a range between 32 percent and 110 percent (Table III-1). All poles had MC's higher than the 24 percent intersection moisture content therefore, the assumption

Table III-1. Summary statistics for test poles by treatment groups (hole diameter).

TREATMENT GROUP	COMPARED TO GLOBAL MEAN		COMPARED TO CONTROL MEAN			
	Weight[a] (lb)	Δ (%)	Ref.[d] (in.)	Δ (%)	Rings[e]	Δ (%)
¼	532	2.64	2.08	-4.00	18.18	-7.07
½	547	-0.08	2.03	-1.50	15.79	7.01
¾	546	0.25	1.80	10.00	17.18	-1.18
1	550	-0.66	1.96	2.00	16.54	2.59
0	559	-2.23	0.00	N/A	16.98	N/A
	Butt C.[b] (in.)	Δ (%)	MC (%)	Δ (%)	Sapwood (%)	Δ (%)
¼	36.46	-0.20	49.10	15.18	41.07	1.65
½	36.70	-0.86	53.91	6.88	44.80	-7.28
¾	35.87	1.42	53.44	7.69	43.95	-5.24
1	36.14	0.68	57.29	1.04	46.35	-10.99
0	36.78	-1.08	57.89	N/A	41.76	N/A
	Tip C.[c] (in.)	Δ (%)	Rings/in.	Δ (%)	SG	Δ (%)
¼	32.21	-0.90	33.91	-3.04	0.43	-2.38
½	31.90	0.07	30.91	6.08	0.43	-2.38
¾	31.71	0.67	32.59	0.97	0.43	-2.38
1	31.96	-0.12	31.79	3.40	0.42	0.00
0	31.82	0.32	32.91	N/A	0.42	N/A

a. Gross weight
b. Butt circumference
c. Tip circumference of test section
d. Reference edge distance
e. Number of rings in outer 2 inch of pole diameter

that the strength properties did not vary as a function of MC was valid.

Specific gravity was only estimated in this study, but it showed very little variation between groups as all means were within 0.42-0.43. This is slightly lower than the 0.45 published value for green, coastal, Douglas-fir in the Wood Handbook, but it may reflect the relatively crude method used for estimating this value.

There were 4 distinct failure types: tension failure, shear failure, compression failure, and brash failure. Failure was most often attributable to a knot (or knot cluster) or through-bored holes, although it was also common to have multiple sources of failure. Knot related failures were typically tension failures that initiated at the knot. Failures that initiated at a hole were often a horizontal shear type failure starting at the edge of the hole combined with some tension failure. Compression failures usually occurred in combination with large holes on the compression side or severe grain deviation. Compression failures were characterized by distinctive compression wrinkles that developed from the crushing of the wood fibers. Brash failures were uncommon, but distinct. These were explosive failures where the pole broke almost completely through. The pole would drop to the ground, exposing a jagged fracture surface.

Generally, knots dominated pole failures at lower strengths and poles that failed at higher strengths were controlled more by holes (for those poles with through-boring applied). This trend can be seen in the box-plot representation of the data (Figure III-5). The MOR range for the through-bored poles was lower than the control group. At some point above the median value, the holes become critical and controlled the failures, causing poles to fail at lower strength than they might have if the holes had not been present. However, at breaking strengths lower than the median value, the through-bored poles had lower tail MOR values greater than those seen in the control group. This was particularly true for the smaller hole treatment groups. This suggests that the presence of the holes may help alleviate the peak stresses that arise around knots and allow greater strength gains to be achieved. This is consistent with the defense hole theory by Ting et al. (1998). It is logical to conclude that if the hole is larger than the critical knot, the hole has a detrimental effect on strength. This follows the results for the 1-in. diameter hole pattern, which had the only values lower than that of the control group.

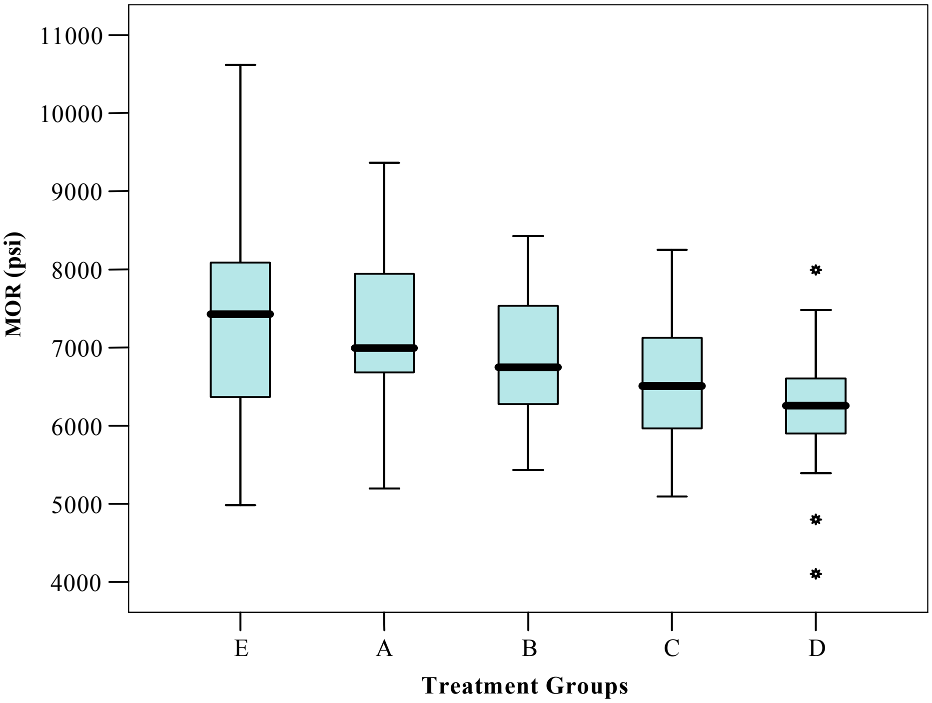


Figure III-5. MOR of Douglas-fir poles with through-boring holes of differing hole diameters. The boxed area represents 50 percent of each data set; the line through the shaded area is the median value. The bars represent the outer limits for the data except where there are outliers, which is only the case for the 1-in. treatment group. The outliers, represented by the stars are determined as those points that lie outside 1.5 times the inter-quartile range of the plot.

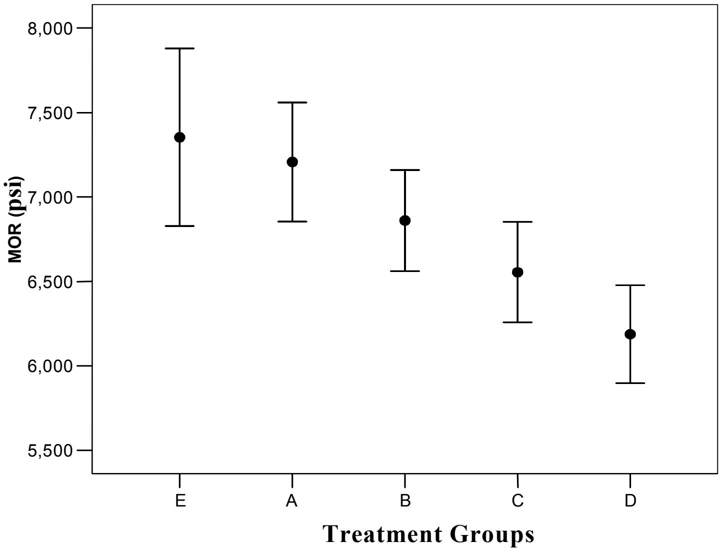
The MOR calculated for every pole (Table III-2) and its qualitative representation can be characterized by the measured dispersion. Data for the control group were more widely dispersed compared to the other treatment groups. This was true for the middle 50 percent region as well as the entire data range. The boxed area for each data set appeared to become more uniform and more compact with increasing hole size.

The MOR of coastal, Douglas-fir in the green condition (USDA 1999) is 7700 psi. This value is within 5 percent of the average for the control group which was 7353 psi. Size adjustment would bring the small clear test data into alignment with pole MOR data.

Table III-2. MOR summary statistics by treatment (hole diameter).

Hole Diameter (in.)	MOR (psi)	MOR COV (%)	Difference from control (%)	Difference between groups (%)
0	7353	18	N/A	N/A
1/4	7207	13	2	2
1/2	6860	11	7	5
3/4	6554	12	11	4
1	6187	12	16	6

When examining the averages of the five treatment groups (Figure III-6), the data showed a highly linear trend of reducing strength with increasing hole size, up to the maximum reduction of 16 percent mean bending strength loss for the 1-in. hole treatment group.



E = no hole
A = 1/4-in. hole
B = 1/2-in. hole
C = 3/4-in. hole
D = 1.0-in hole

Figure III-6. Summary of MOR data by treatment showing mean with 5 percent error bars.

The 1/4-in. and 1/2-in. treatment groups were not significantly different from the control group at the 5 percent significance level. If we further examine the difference in means at the 10 percent level, the two still remain significantly similar to the control. The mean for the largest hole size (1-in.) treatment group, was statistically different from both the control group and the 1/4-in. treatment group.

Average values are one indicator for examining the strength of wood but are not the parameter most often used in strength design. Due to the inherent large variability of most wood properties, wood design by the allowable stress method is based on a lower 5 percent parametric tolerance limit (PTL), rather than on mean values. The National Design Specification (NDS) (AF&PA 2001) uses this parameter as a starting point for establishing allowable design values for wood. The design standard for poles, however, ANSI 05.1, has nominal design values that are based on engineering judgment and values taken from full-size pole tests as well as small clear tests (USDA 2001), but may move to a more empirically based design.

The PTL value can be determined for the MOR if the test data has a normal distribution for each treatment group. A goodness of fit test to assess distribution normality is the Kolmogorov-Smirnov (KS) test (Steele et al. 1998). The data were hypothesized as normally distributed and the KS test could not reject the hypothesis of normality for all five groups. The PTL for all treatment groups can then be established as:

$$PTL = \overline{X} - K\sigma \tag{5}$$

Where K is the factor for one-sided tolerance limits as determined through linear interpolation from D 2915 (ASTM 2005b). The factor is based on the sample size, as well as the content and confidence level specified.

Examination of the values for the PTL for this set of test values at 95 percent content with 75 percent confidence shows that the higher variation of the control group compared to the other treatments has a pronounced effect on the magnitude of the PTL. The large dispersion of data in the control group lowers the value of the PTL, and may potentially decrease the design value for this pole compared to the others.

The PTL for the control group was 4844 psi while the 1/4-in. holes had a value of 5492 psi, for a difference of over 13 percent (Table III-3). The 1/4-in. and 1/2-in. holes had relatively similar lower limit values with the 1/2-in. being lower by 2 percent. The 1-in. hole was the only through-bored group with a higher PTL.

Table III-3. Lower 5 percent tolerance limit values for MOR data.

Hole Ø (in.)	PTL (psi)	Difference from control (%)	NTL (psi)	Difference from control (%)
0	4844	N/A	4983	N/A
1/4	5492	-13.38	5195	-7.25
1/2	5406	-11.62	5434	-12.19
3/4	5114	-5.59	5094	-5.17
1	4785	1.21	4104	15.27

We were also able to obtain the nonparametric tolerance limit (NTL) estimates for the data as prescribed by D2915 (ASTM 2005b). These values showed similar results as compared to the PTL except that the 1/2-in. hole size was higher than the 1/4-in hole group and the 1-in. hole size has a much lower value than was found for the PTL (Figure III-7).

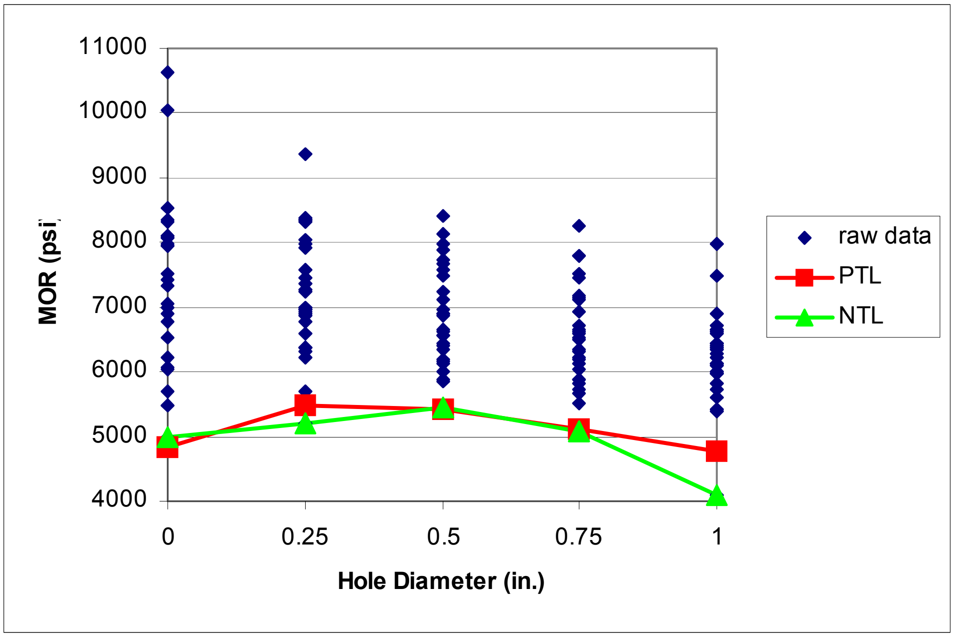


Figure III-7. 5 percent tolerance limit imposed on MOR scatter plot data.

Conclusions

The preferred through-boring pattern was a repeated staggered pattern of parallel holes drilled perpendicular to the longitudinal axis of the pole. The presence of through-boring holes appeared to produce less variation in pole MOR. The preferred hole diameter was 1/2 inch, and it was spaced 5 inch, and 1 1/2 inch, edge-to-edge in the longitudinal and transverse directions, respectively. A 2 inch edge distance was important for keeping holes out of high stressed regions. The results of our tests showed this through-boring pattern can be applied in a zone from -36inch to +24 inch about the groundline in a class 4 pole without a significant loss of bending strength.

The results show that through-boring should not adversely affect the design values for pole and that no adjustment factors for through-boring are necessary when using this pre-treatment process.

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

The groundline has long been recognized as the critical decay zone of poles in most regions of the country owing to the presence of elevated moisture levels and an abundance of wood degrading organisms. One approach to extending service life would be to protect this zone using synthetic barriers that restrict moisture and microbial access to the wood. A number of systems have been developed for this purpose. For example, the Port of Los Angeles experimented with a polyurethane coating to protect piling from marine borer attack, but these systems were never commercialized. Recently, however, the increasing concerns about the risk of preservative leaching from the poles into the surrounding soil have encouraged renewed interest in these systems, both for protecting the wood and limiting preservative migration. One system is currently used by a utility in Washington State and others are being considered. There are, however, limited reports on the ability of these systems to restrict moisture uptake. This past year, we initiated a test in cooperation with JH Baxter to examine moisture sorption characteristics in western redcedar poles protected with two of these barrier systems.

Western redcedar pole sections (200-250 mm in diameter by 2.4 m long) were treated with either pentachlorophenol or copper naphthenate in P9 Type A oil. The copper naphthenate was applied using a thermal process while the penta was applied using a pressure cycle. Additional poles were left unwrapped and non-treated to serve as controls. The poles were then wrapped with either the Biotrans barrier originally developed in South Africa or the UPC coating. The Biotrans materials were all applied with a closed end on the butt. This seal was not complete, but it should presumably restrict moisture sorption from the surrounding soil. The UPC samples were applied with the ends open. The samples were either exposed in water from their butts to just below the tops of the barrier or they were buried in soil to a similar depth in large tanks maintained at 23-25 C in our testing laboratory. The soil was regularly watered to maintain moisture conditions, but every effort was made to limit the potential for wetting above the groundline so we could assess the potential influence of soil or water contact on the lined zones of the poles.

Prior to setting, the moisture content of each pole was sampled at the butt, 80 cm, and 140 cm above the butt by removing increment cores from two sides of each pole. These cores were divided into zones corresponding to 0-13, 13-25, 25-50, and 50-75 mm from the surface. These cores segments were weighed, then oven dried and reweighed to determine wood moisture content. In addition, each pole was weighed. Moisture content was monitored 4 weeks after immersion or setting in soil by removing increment cores from locations adjacent to the original sampling sites. These cores were processed as described above. The poles were also weighed at this time to determine total moisture uptake.

Moisture contents of the samples at the time of immersion were fairly uniform, ranging from 16 to 24.8 % and there appeared to be little difference in moisture level with distance from the surface (Figures III-8 to III-16). Moisture levels were slightly elevated in some Biotrans wrapped poles 80 cm inches above the butt, but it was unclear why these particular poles had slightly higher moisture contents prior to moisture exposure.

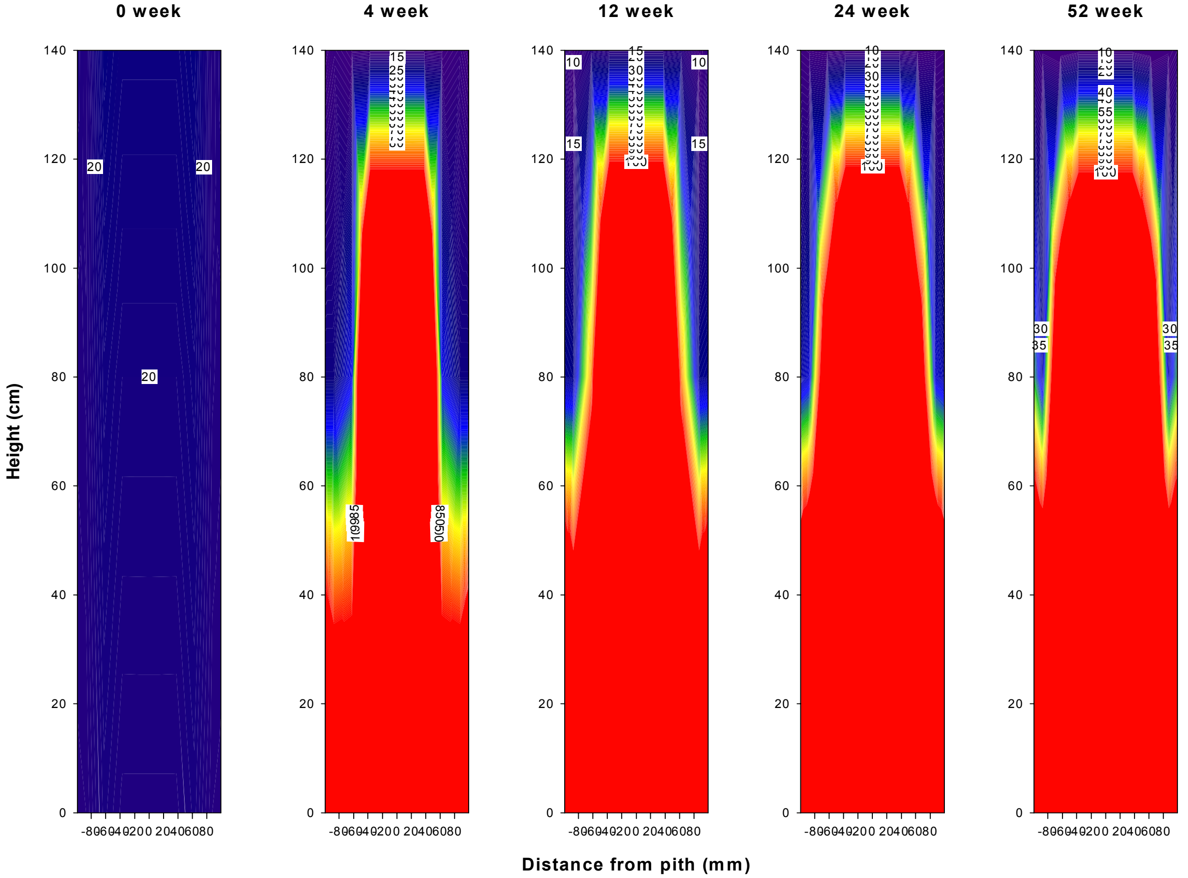


Figure III-8. Moisture contents of untreated western redcedar poles immersed in water for 0 to 52 weeks. Dark blue indicates moisture content below fiber saturation and red indicates moisture content above 80%.

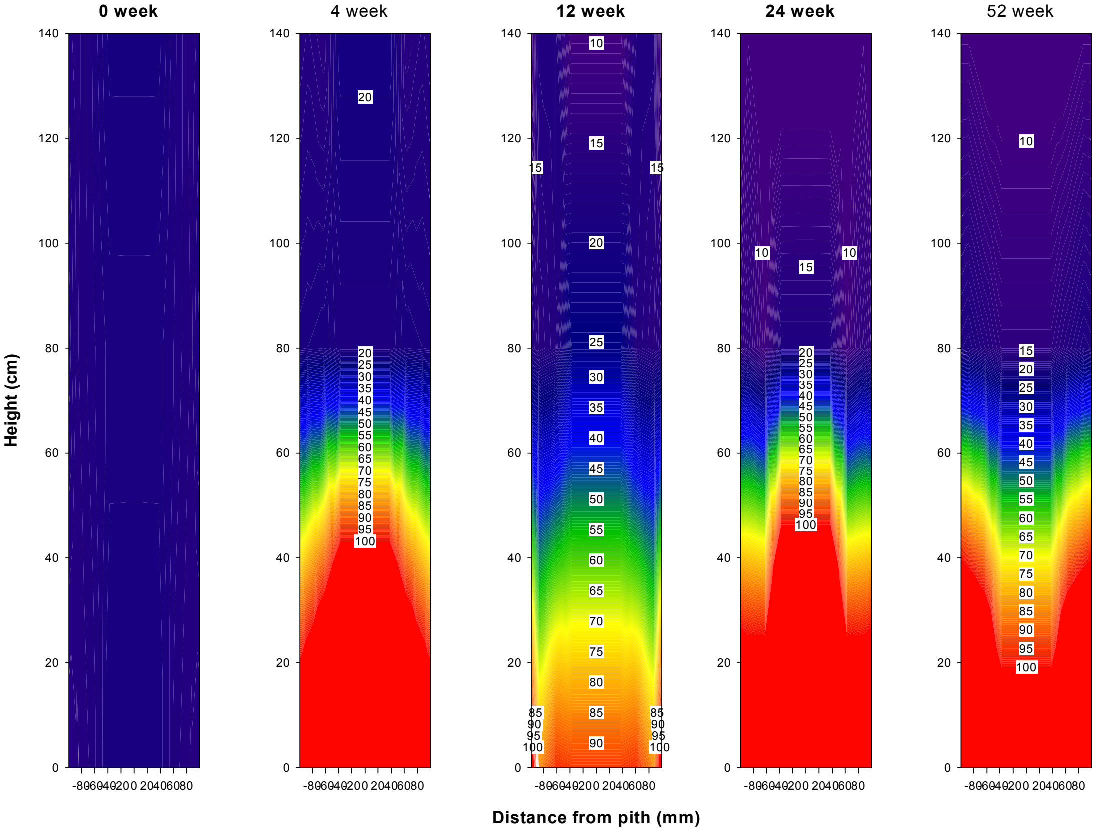


Figure III-9. Moisture contents of untreated western redcedar poles immersed in moist soil for 0 to 52 weeks. Dark blue indicates moisture content below fiber saturation and red indicates moisture content above 80%.

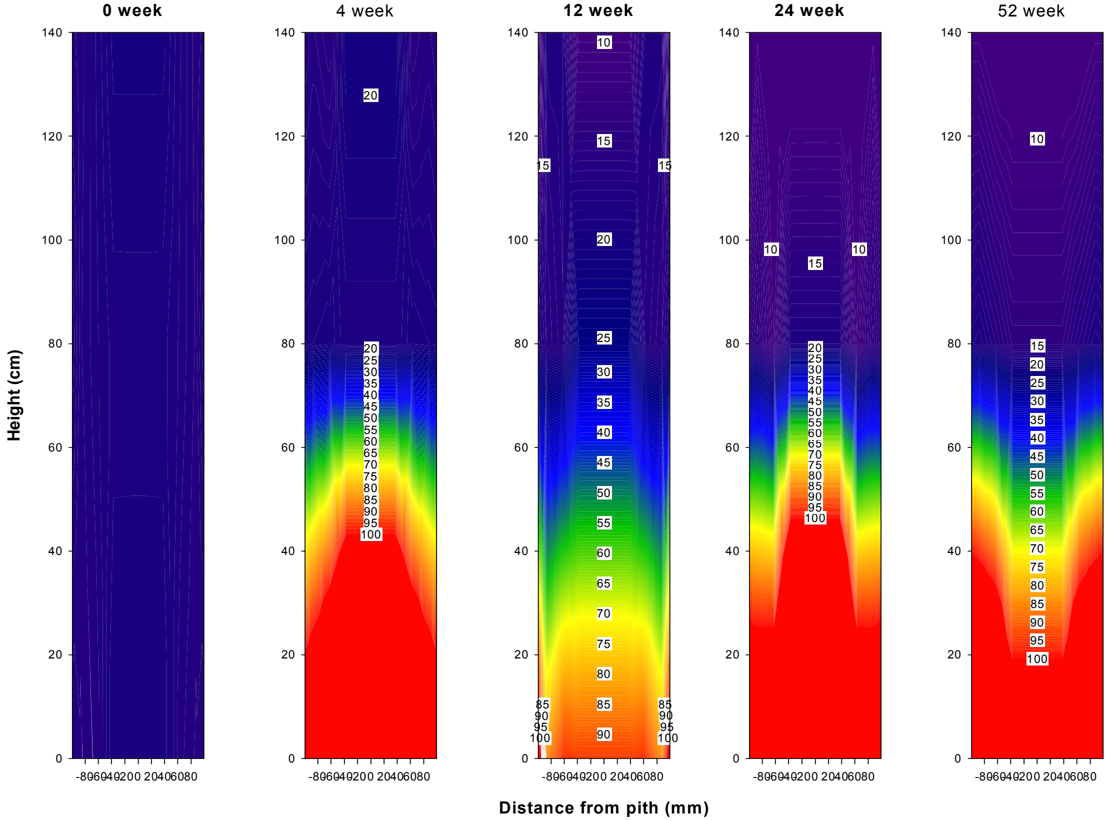


Figure III-10. Moisture contents of copper naphthenate treated western redcedar poles wrapped with a Biotrans liner from the butt to the groundline and immersed in water for 0 to 52 weeks. Dark blue indicates moisture content below fiber saturation and red indicates moisture content above 80%.

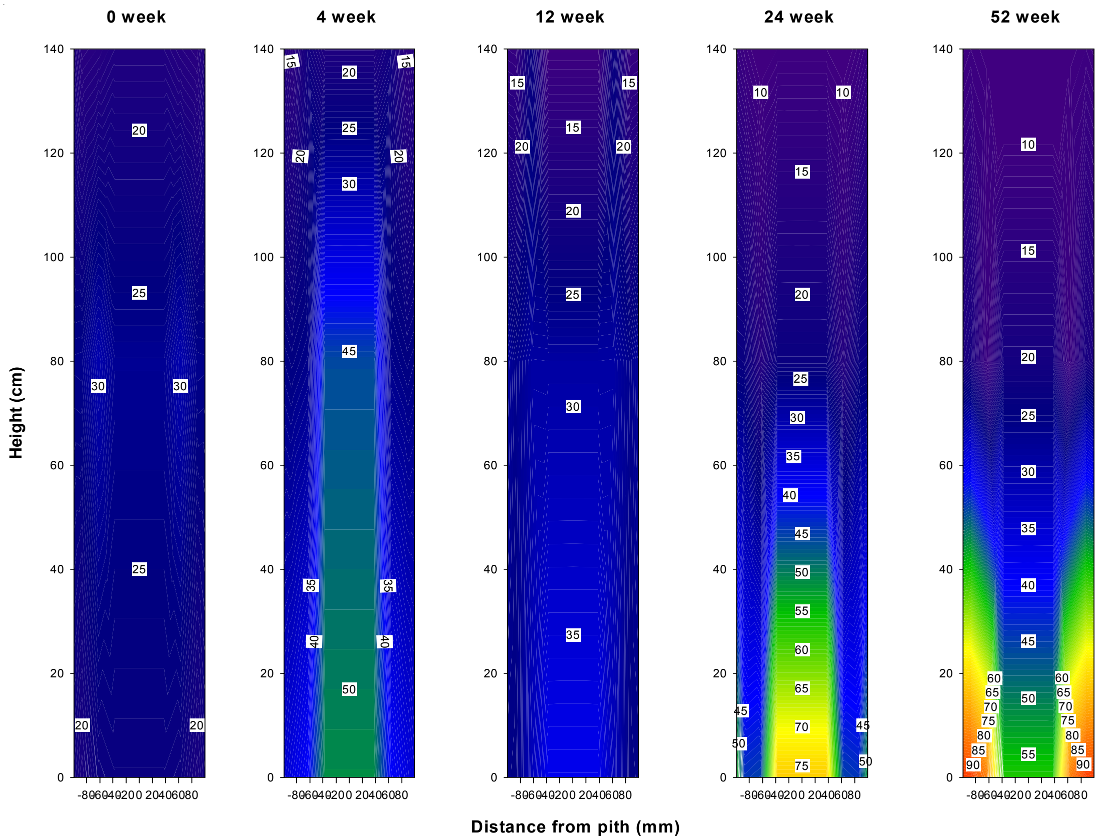


Figure III-11. Moisture contents of copper naphthenate treated western redcedar poles wrapped with a Biotrans liner from the butt to the groundline and immersed in moist soil for 0 to 52 weeks. Dark blue indicates moisture content below fiber saturation and red indicates moisture content above 80%.

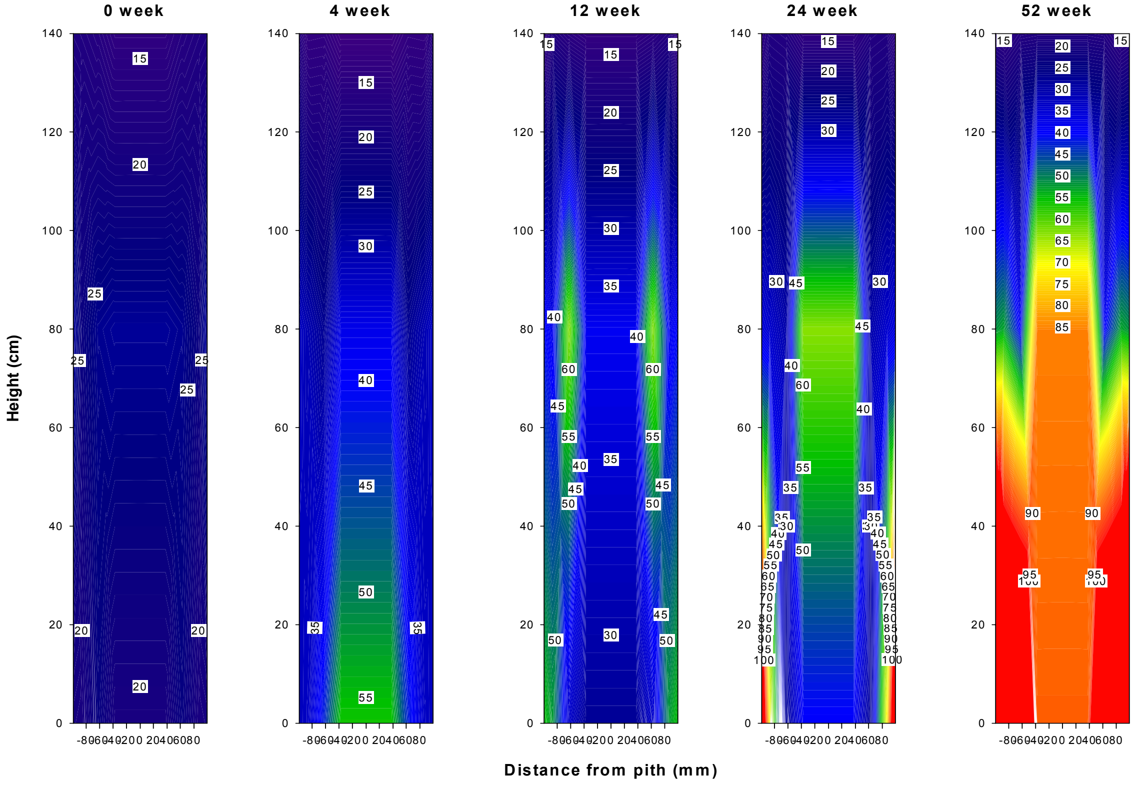


Figure III-12. Moisture contents of pentachlorophenol treated western redcedar poles wrapped with a Biotrans liner from the butt to the groundline and immersed in water for 0 to 52 weeks. Dark blue indicates moisture content below fiber saturation and red indicates moisture content above 80%.

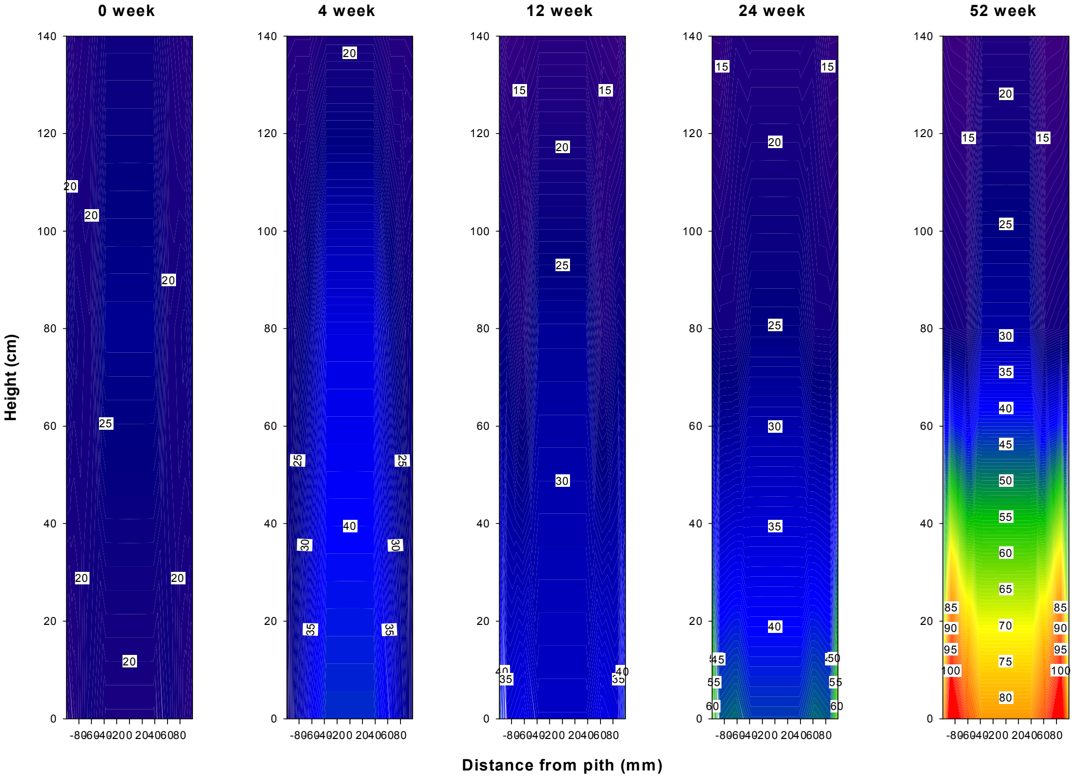


Figure III-13. Moisture contents of pentachlorophenol treated western redcedar poles wrapped with a Biotrans liner from the butt to the groundline and immersed in moist soil for 0 to 52 weeks. Dark blue indicates moisture content below fiber saturation and red indicates moisture content above 80%.

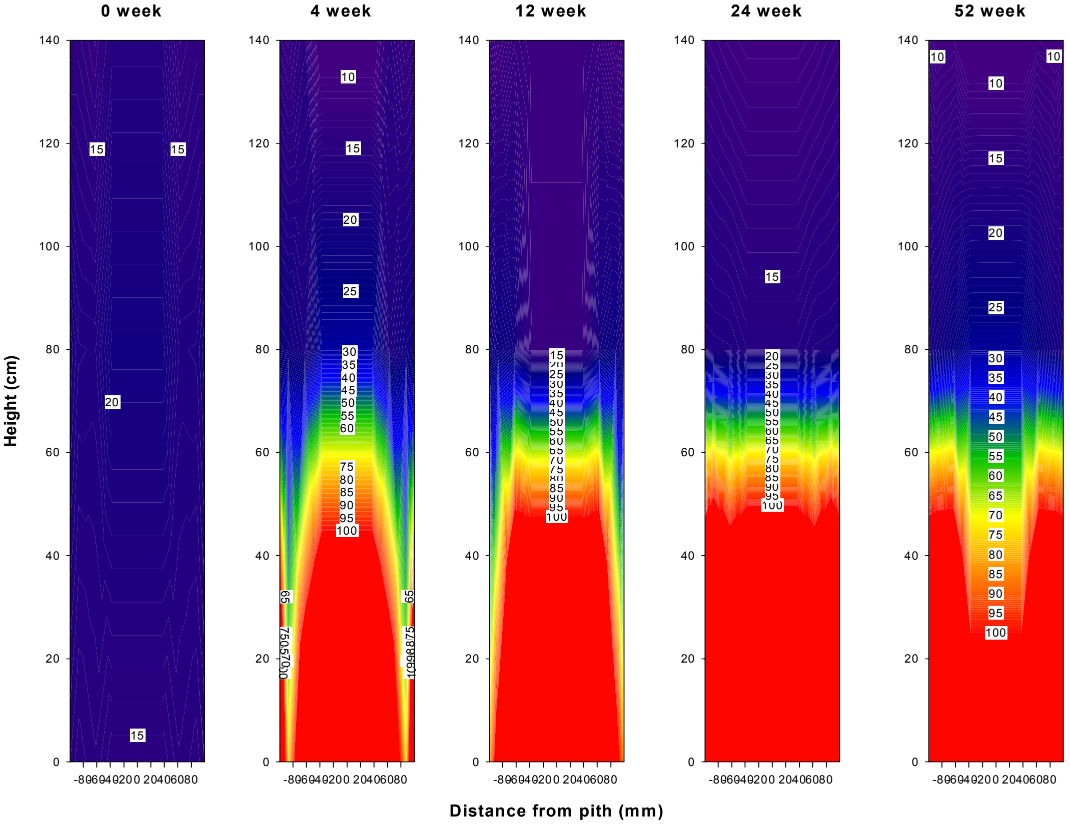


Figure III-14. Moisture contents of untreated western redcedar poles wrapped with a UPC liner from the butt to the groundline and immersed in moist soil for 0 to 52 weeks. Dark blue indicates moisture content below fiber saturation and red indicates moisture content above 80%.

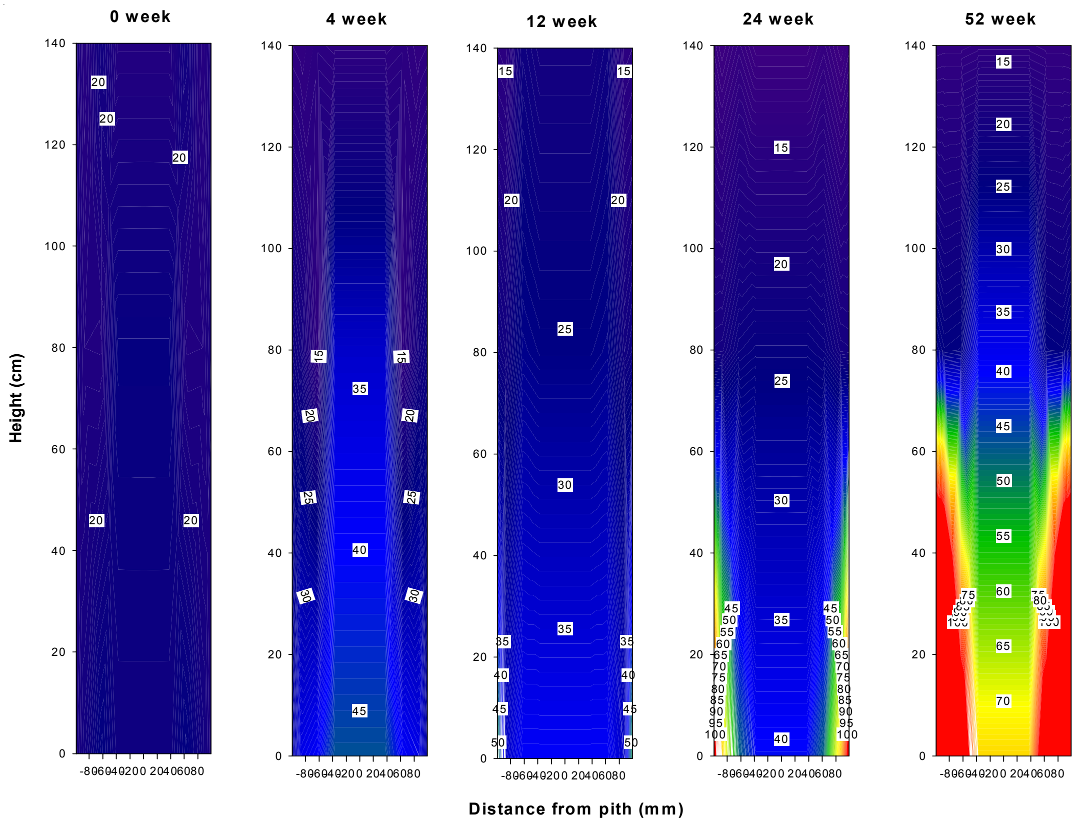


Figure III-15. Moisture contents of copper naphthenate treated western redcedar poles wrapped with a UPC liner from the butt to the groundline and immersed in water for 0 to 52 weeks. Dark blue indicates moisture content below fiber saturation and red indicates moisture content above 80%.

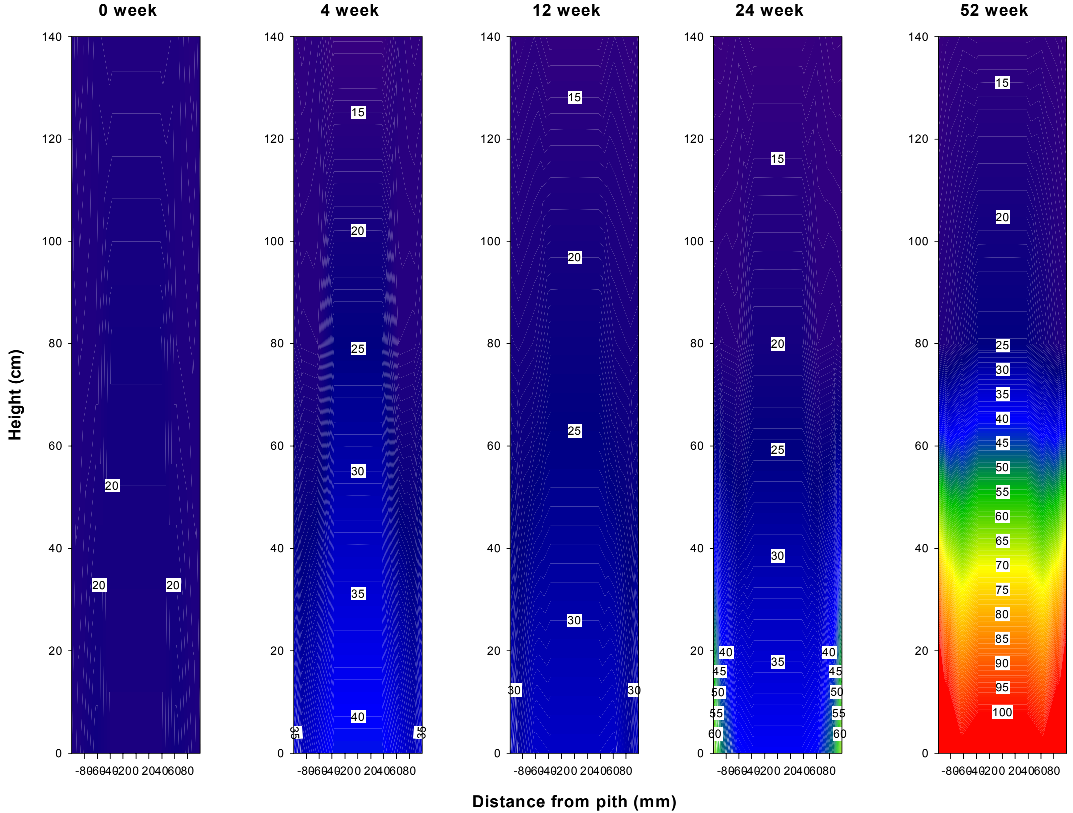


Figure III-16. Moisture contents of copper naphthenate treated western redcedar poles wrapped with a UPC liner from the butt to the groundline and immersed in moist soil for 0 to 52 weeks. Dark blue indicates moisture content below fiber saturation and red indicates moisture content above 80%.

Moisture contents of the non-wrapped western redcedar poles increase rapidly over the first 4 weeks of exposure in water and remained elevated for the entire 52 week test period (Figure III-8). Clearly, conditions in these poles were suitable for decay development, although the naturally durable heartwood of this species would initially limit attack. Untreated poles in soil exposures also experienced rapidly increasing moisture contents over the first 4 weeks, but the elevated moisture levels were confined to the zone from the butt to slightly above the groundline (Figure III-9). Furthermore, moisture levels above the zone did not increase over the next 48 weeks. These results highlight the importance of the groundline zone as a high decay hazard area.

Copper naphthenate treated poles wrapped with the Biotrans barriers experienced only slight increases in moisture content over the first 12 weeks of immersion (Figures III-10 & I-11), then both sets of poles experienced sharp rises in moisture content near the butt after 24 and 52 weeks of immersion. The effect was more noticeable in water immersed samples, but moisture contents in the soil immersed samples were still above 90 % near the butt. It is unclear why this moisture rise took so long to occur since the wraps had no evidence of damage. We also noted a similar rise in moisture content with the penta treated poles with the Biotrans liners with moisture levels that were even higher than those found with copper naphthenate treated poles (Figures III-12 and III-13). Some of the Biotrans wrapped poles had small gaps at the butt that could permit some moisture intrusion. We would expect, however, that this moisture intrusion would have occurred without any time delay. We will continue to monitor the moisture in these poles, but it does appear that the barriers are not as completely protective as originally believed.

Untreated cedar poles wrapped with the UPC coating and immersed in soil tended to rapidly gain moisture over the first 4 weeks of the test, then the moisture content stabilized much in the same way it did for the non-wrapped poles (Figure III-14). Once again, these barriers did not completely cover the butt of the poles and this clearly allowed water to move up and into the poles.

Exposure of copper naphthenate treated, UPC wrapped poles in soil or water produced a gradual increase in moisture content from the butt of the poles, but overall moisture levels remained below 35 % in the interior of the poles until 24 weeks of exposure (Figure III-15 and III-16). Moisture contents increased dramatically between 24 and 52 weeks, suggesting that the barrier have somehow been compromised over that time. Moisture levels after 52 weeks were similar to those found with the Biotrans barrier wrapped penta or copper naphthenate treated poles exposed in soil. Once again, it is unclear why moisture levels rose so dramatically over the second half of the exposure period, but the results do suggest that these barriers are not completely impermeable to moisture movement. The sudden increases in moisture content between 24 and 52 weeks have led us to consider sampling these systems at 18 months to better understand how these systems are functioning.

C. Above Ground Condition of Older Douglas-fir Poles in the Willamette Valley in Western Oregon

While internal groundline decay can largely be controlled through initial specifications that include through boring and regular inspections that incorporate some type of internal treatment, eventually, decay will also develop in some poles well above the groundline. Some utilities are now approaching their 3rd or 4th inspection cycles on poles that are 50 to 60 years old. At this point, weaker poles have been culled and internal decay has been arrested, but decay has gradually developed above the ground. Eventually, decay problems above the ground will begin to influence pole condition to the point where replacement becomes necessary, but determining when that will occur remains difficult and expensive.

In 1999, we undertook a project with an Oregon utility to characterize the extent of decay in older pentachlorophenol and creosote treated Douglas-fir poles. The inspection involved removing increment cores from locations along the pole length, then assessing these cores for depth of initial preservative treatment, presence of internal decay pockets and culturing for the presence of viable decay fungi. The results indicated that internal decay was present in many older poles, as were decay pockets, but the frequencies of both were much lower than might be expected. As a result, the utility was able to plan for additional maintenance cycles, producing additional savings.

The lines inspected in 1999 are now being considered for additional inspection and the utility wondered whether the incidence of internal decay had changed in the intervening 6 years. Thirty seven poles in the utility system were inspected by removing increment cores at groundline, midpoint of the energized zones and within 0.1m of the first connection, 0.1 m of any major attachments and within 0.3 m of the pole top. The cores were placed in plastic straws and returned to the laboratory for processing. The treated zone on each core was measured and then removed. The next 50 mm and each subsequent 50 mm were placed on malt extract agar and incubated at room temperature for 30 days. Any fungi growing from the wood were examined for characteristics typical of basidiomycetes, a class of fungi containing many important wood decayers.

Two poles in the original sample had been replaced in 2003, but the remaining poles sampled in 2005 had also been inspected in 1999. Five of the poles contained visible decay in 1999, but only one of the core samples collected in 2005 contained visible decay (Table III-4). The inability to find decay again reflects the sampling pattern along with the tendency for fungi to grow in pockets within the wood. Thus, the likelihood of collecting decayed wood from the poles is dependent on the size of the pockets. In most cases, the pockets in poles from the 1999 collection were very small, making it less likely that later sampling would detect the damage.

Isolations in 2005 revealed that 7 poles contained viable decay fungi while only one of these poles contained viable decay fungi in 1999. These results suggest that fungal attack is increasing within the poles, although the levels remain relatively low and the presence of internal decay remains at low levels. The poles in this test were generally well treated with preservative penetrations ranging from 29 to 63 mm, depending on proximity to cuts or bolt holes (Table III-5). In general, penetration was greater near attachments, reflecting the utility's requirement for pre-boring prior to treatment. This excellent pre-treatment undoubtedly contributed to the low levels of fungal attack found in these poles and highlights the benefits of avoiding field drilling.

D. Condition of Turned Douglas-fir Crossarms Removed from Service in Western Oregon

Decay at groundline remains the primary focus of most utility inspection and maintenance programs; however, vigilant programs have largely controlled decay in this zone through good initial specifications and aggressive remedial treatment programs. One development from this process is that poles that would formerly have been replaced after 30 or 40 years in service are now approaching 50 to 60 years of age. The additional 20 years of service has allowed issues above the groundline to emerge as potential maintenance problems. In previous reports, we have assessed the incidence of decay in the above ground regions of Douglas-fir poles in Western Oregon and last year we reported on the condition of older sawn crossarms. Western Oregon is an ideal site for decay development above the ground, owing to our mild winters with copious amounts of wind driven rain.

While we found decay in both components of the system, decay was surprisingly light in the crossarms. We attributed this to the orientation of the crossarms in a wishbone configuration. We speculated that the angled arms tended to shed water more quickly in contrast to a horizontal orientation that would tend to allow water to puddle in checks, creating ideal conditions for decay development. We are still looking for additional arms to test, but this year we were fortunate to receive 55 turned Douglas-fir arms that had been used in a similar wishbone configuration. The arms were 40 to 50 years old and were originally treated with pentachlorophenol (Table III-6). The cooperating utility had elected to remove all turned arms from their system because of several unexpected failures of these elements. This provided an opportunity to assess residual strength of the arms.

The arms were stored outdoors until testing, then tested in four point loading over a 111 inch span at a loading rate of 0.5 inches per minute. Load and deflection data were collected at 2 second intervals until failure and these data were used to determine modulus of elasticity (MOE) and modulus of rupture (MOR). Following testing, moisture content was determined in the failure zone using a resistance type moisture meter and the type of failure was determined.

Table III-4. Above ground condition of Douglas-fir poles with various treatments inspected in 1999 and 2005.

									1999	2005
Pole	Sampled	Map	Map	Nominal	Probable	Brand			Decay	Decay
Number	2005	#	ID	Treatment	Treatment	Year	Class	Ht	Fungi	Fungi
31	Y	15	C72-05A	C	C	1950	3	40	Y	
66	Y	21	C72-01	C	C	1948	3	40		Y
68	Y	1	C72-06B	P	C	1946	3	40	Y	
267	Y	29	C72-21C	P	P	1954	4	40		
268	Y	29	C72-21C	P	P	1950	4	40		
358		3	C72-06D	P	P	1949	4	35	Y	replaced 2003
539		16	C72-05A	C	C	1953	3	40		
549	Y	25	C72-11	C	P	1953	3	40		
637		20	C72-03	C	P	1951	3	40		
735	Y	23	C72-02	C	C	1950	3	40		
1119	Y	22	C72-01	C	C	1951	4	40		
1126	Y	22	C72-01	C	C	1950	4	40		
1149	Y	6	C72-03	P	P	1950	3	40		
1150	Y	6	C72-03	P	P	1950	3	40		
1176				C	C	1950	3	40	Y	
1204	Y	15	C72-05A	C	P	1951	4	40		
1308		17	C72-08D	C	C	1950	4	40		
1319		18	C72-16B	P	P	1950	3	40		
1365	Y	24	C72-11	C	S	1947	4	45		
1366	Y	24	C72-11	C	C	1947	4	40		Y
1369		24	C72-11	C	P	1947	4	40	Y	replaced 2003
1385	Y	4	C72-08C	C	C	1948	3	40		Y
1386	Y	4	C72-08C	C	C	1948	3	40	Y	Y
1387	Y	4	C72-08C	C	C	1948	2	40		
1437	Y	5	C72-09A	C	C	1950	4	40		
1453	Y	7	C72-12	C	C	1950	4	40		
1454	Y	7	C72-12	P	C	1950	3	40		
1455	Y	7	C72-12	C	C	1950	3	40		
1508	Y	8	C72-13	C	C	1952	3	40		
1509	Y	8	C72-13	C	C	1948	3	40		
1529	Y	26	C72-14	C	C	1950	3	40	Y	
1530	Y	26	C72-14	C	C	1950	3	40		Y
1624	Y	11	C72-20B	C	P	1960(1950)	4	40		
1671	Y	10	C72-21C	S	S	1946	4	40		Y
1672	Y	10	C72-21C	S	S	1946	4	40		
1674	Y	10	C72-21C	S	S	1946	3	40		
1699	Y	9	C72-23	C	C	1946	4	40		
1700	Y	9	C72-23	C	C	1950	4	40		
2033				C	C	1952	4	40		
2114	Y	13	C72-19C	C	C	1952	2	40		
2277	Y	12	C72-19C	P	P	1954	3	50		
2278	Y	12	C72-19C	P	P	1955(1954)	4	40		
2340	Y	2	C72-06C	P	P	1954	4	40		
2597	Y	14	C72-18A	P	P	1956	4	40		Y
ACA -1				S	S	1946-47				
5254	Y									

Table III-5. Degree of fungal infestation and average depth of preservative penetration along the length of Douglas-fir poles sampled in 1999 and 2005.

Sample Position on Pole	Cores Containing Decay Fungi		Cores Containing Non-Decay Fungi		Average Preservative Penetration (mm)	
	1999	2005	1999	2005	1999	2005
Groundline	0	0	31	27	44.5	35.7
Midpoint of energized zone	2	4	40	39	33.8	31.4
Within 0.1 m of first connection	5	0	47	29	34	29.4
Within 0.1 m of major attachment	1	1	42	25	51.9	34.9
Within 0.3 m of pole top	2	2	37	27	63.4	37.4
Total Cores Containing Fungi	10	7	197	147	--	--
Percentage of Cores With Fungi	2.3	1.9	45.4	39.7	--	--

MOE and MOR of the arms varied widely (Table III-7). These differences reflect the widely variable external conditions of the materials tested. In many cases, arms had large, deep checks and were badly weathered. While this did not always signify a weak arm, it did indicate some weakening near the surface. MOE's ranged from 0.41 to 2.51 million psi, while MOR's ranged from 1219 to 7919 psi. The current ANSI MOR design value for Douglas-fir is 8000 psi for poles. MOR's for all of the arms fell below this value and only 11 of 55 arms retained the required 67 % of their original design value. These results are in sharp contrast to those obtained for the sawn crossarms exposed in the same configuration. The reasons for these deviations are unclear, but they may reflect a tendency for the round arms to check more deeply, thereby opening untreated wood to possible decay. The results indicate that the utility was clearly justified in removing these arms from service. Although it may have been possible to retain the 11 stronger arms in the system, it is doubtful that the cost of inspecting all 55 arms in the air would have justified the inspection costs. The results illustrate the differences in performance that can occur with different wood configurations. We will continue to assess the condition of arms as they become available to us.

Table III-6. Dimensions, moisture contents, and failure modes of round Douglas-fir crossarms removed from service in Western Oregon and tested to failure in fourth point loading.

Crossarm #	Circ. Butt (in)	Circ. Tip (in)	Length (in)	Length CL to Butt (in)	M.C. %	Max Load (lb)	Defl. (in)	Failure
101	25.0	20.0	222	66.5	18	15860	2.75	tension at 6', compression at 3'
102	25.0	19.0	221	77	26	10049	1.6	tension at knot. Spiral grain.
103	27.5	19.5	221	65	22-23	8161	0.75	tension at knot
104	24.0	19.0	152	66	30+	8348	1.5	tension at knot
105	24.0	21.0	152	64.5	27	7514	1.75	tension
106	24.0	19.5	152	64.5	30+	7826	1.5	
107	25.0	21.5	223	69.5	21	9885	1	tension, 3.5 ft from butt, damage 10 ft from butt
108	25.5	19.0	182	67.8	30+	4653	1.2	tension at knot
109	22.0	20.5	151	64.5	24	3124	2	tension
110	23.0	20.0	152	65.3	30+	10069	2.5	tension
111	21.5	21.5	152	64	30+	7767	1.9	tension, decay at tip
112	23.0	20.0	151	65.5	22-27			sheer on butt
113	21.5	19.0	152	65.5	30+	7951	1.5	sheer, spiral grain.
114	23.5	21.5	152	65.5	30+	12839	1.4	tension
115	24.5	20.5	182	65.3	23	8896	1.5	shear and compression, void @ 9ft.
116	25.5	19.5	182	66.3	19	6740	1.1	mis-shapen arm, failed in tension
117	23.0	21.0	152	64.3	30+	2747	1.2	tension at knot
118	21.5	20.0	152	65	26	7211	1.5	sheer
119	24.0	21.0	146	67.8	30+	5690	2.3	tension
120	22.5	20.5	152	65.5	30+	7774	1.5	sheer
121	24.5	21.0	182	64.3	25	6411	1.7	sheer
122	23.5	18.5	152	67.5	24	6004	1.5	
123	27.5	18.5	219	65.5	28	14637	1.5	tension at a hole, went toward knots
124	24.0	17.0	152	64.8	24	7348	2.6	heavily weathered, possible decay. Failed in tension
125	25.3	20.3	182	66.5	26	7836	1.25	tension at knot
126	23.5	20.5	152	66	22	8845	2.5	tension
127	24.8	19.5	152	65.5	23	5099	1.4	tension at knots
128	24.5	21.0	152	65.3	24	7313	1.6	
129	22.0	17.5	152	64.8	22	6693	2	spiral grain, shear failure
130	22.0	20.8	182	64.8	29	4597	1.3	tension at knot, 6.5 ft from butt
131	23.0	18.0	166	67.8	20	6979	1.8	tension failure at knots
132	24.0	18.0	182	65.5	23	4531	1.4	tension failure at knots
133	26.3	18.0	152	65.3	25	6212	2.5	tension at knot
134	23.5	20.5	182	64.8	26	3676	1.1	sheer and tension at knot, probably mostly decayed
135	21.5	19.0	152	66.5	25	4664	1.9	sheer
136	20.0	18.0	182	67.5	19	3113	1	tension
137	23.0	20.0	182	68.3	16	9724	1.7	tension
138	23.0	20.0	182	66.8	19	9209	1.6	tension
139	24.5	20.5	182	67.5	26	3950	0.7	tension, lots of shake
140	23.5	19.0	182	66	22	7550	1.4	sheer, then tension
141	23.8	17.5	152	65.5	22	5292	2.7	tension at large knots
142	22.0	19.3	152	67	21	9560	1.8	tension at knot
143	22.0	18.5	182	67	21	6111	2.2	sheer
144	24.0	20.5	152	65	18	10391	1.6	sheer. Hardly weathered, very large arm.
145	23.5	20.0	152	65.5	19	4397	1	tension at knot
146	23.5	19.0	182	67	26	4282	1.6	tension at knot
147	23.0	20.0	152	66.5	22	8269	2.4	tension
148	25.5	18.5	152	63.8	15	10564	1.5	tension at knot
149	24.0	22.0	182	67.3	20	6649	1.45	sheer, then tension
150	23.5	18.5	182	63.5	23	6576	1.3	tension
151	22.8	19.0	182	65.5	23	7167	1.85	tension
152	22.0	21.0	182	65.5	38, 38, 22	5014	2.6	sheer at 3500 lb, excesive weathering/checks
153	23.0	19.8	182	68.5	21	6710	1.3	sheer, then tension

Table III-7. Modulus of elasticity and modulus of rupture of round Douglas-fir crossarms tested to failure in fourth point loading.

File Name	Center Deflection			Load Point Based		
	MOE	Slope	Break	MOR	MOE	Slope
	psi*10e6	(lbf/in)	(lbf)	(psi)	psi*10e6	(lbf/in)
D_101.TXT	1.4	7950.0	15860.6	7919.7	1.4	9050.3
D_102.TXT	1.5	7520.4	10048.8	5335.1	1.3	7701.3
D_103.TXT	1.5	10259.4	8161.0	3526.2	1.1	8708.2
D_104.TXT	1.5	6842.8	8348.4	4771.8	1.2	6235.5
D_105.TXT	1.0	5372.5	7514.0	3792.5	0.8	5130.1
D_106.TXT	1.0	4823.8	7825.9	4334.1	0.9	5163.7
D_107.TXT	2.1	13361.7	9885.3	4512.5	1.0	7317.5
D_108.TXT	1.0	5107.0	4653.3	2382.6	0.7	4447.2
D_109.TXT	0.4	1767.7	3123.8	1885.8	0.5	2271.5
D_110.TXT	1.6	7058.2	9999.7	5780.2	1.3	6602.2
D_110B.txt	1.3	5723.7	10069.0	5820.3	1.0	5340.8
D_111.TXT	1.4	6174.3	7766.7	4566.1	1.1	5806.5
D_112.TXT	1.1	4786.4	5839.8	3375.7	0.9	4867.2
D_113.TXT	1.7	6164.2	7951.0	5511.5	1.3	5458.2
D_114.TXT	2.5	13538.9	12839.4	6515.2	1.4	8918.9
D_115.TXT	1.2	6808.0	8895.9	4465.9	1.1	6752.8
D_116.TXT	1.1	5998.7	6740.1	3347.6	0.9	5943.1
D_117.TXT	0.5	2402.5	2246.7	1219.3	0.3	1940.4
D_118.TXT	1.7	6633.1	7211.3	4674.9	1.2	5231.6
D_119.TXT	0.9	4632.0	5690.3	2872.0	0.8	4941.3
D_120.TXT	1.2	5342.6	7774.0	4519.1	1.0	5273.2
D_121.TXT	1.1	5996.6	6411.1	3122.6	0.8	4921.8
D_122.TXT	2.0	8191.5	6004.0	3680.4	1.0	4856.3
D_123.TXT	2.0	12133.1	14636.8	6704.7	1.4	9630.8
D_123B.txt	0.9	5539.1	8723.1	3995.8	0.8	5759.2
D_124.TXT	1.1	4097.1	7348.0	4782.1	1.0	4306.1
D_125.TXT	1.1	6457.6	7836.3	3786.4	1.0	6316.5
D_126.TXT	0.9	4561.9	8844.6	4773.6	1.0	5654.5
D_127.TXT	1.2	6115.3	5098.9	2672.8	0.7	4017.4
D_128.TXT	1.1	6249.1	7312.6	3561.6	0.9	5781.9
D_129.TXT	1.6	5093.6	6693.1	4938.2	1.3	4744.4
D_130.TXT	1.2	5220.4	4596.6	2730.6	1.0	5154.7
D_131.TXT	1.3	5123.8	6998.3	4608.2	1.1	4672.8
D_132.TXT	1.0	4035.3	4531.3	2761.7	0.8	3874.4
D_133.TXT	1.0	5309.0	6212.2	3203.8	0.7	4349.9
D_134.TXT	0.8	3855.8	3676.1	1984.1	0.6	3470.9
D_135.TXT	0.9	3172.5	4664.3	3233.2	0.8	3466.0
D_136.TXT	1.3	3632.2	3112.8	2618.0	1.0	3265.9
D_137.TXT	1.4	6149.6	9723.5	5620.6	1.3	6763.6
D_138.TXT	1.5	6630.8	9209.0	5323.1	1.2	6020.1
D_139.TXT	1.0	5243.1	3949.6	1982.8	0.8	4787.9
D_140.TXT	1.6	7022.9	7550.0	4480.8	1.1	5417.3
D_141.TXT	0.9	3643.1	5292.4	3397.7	0.8	3602.5
D_142.TXT	1.8	6786.0	9559.9	6264.3	1.3	5579.4
D_143.TXT	1.2	4218.2	6111.5	4211.1	1.1	4623.6
D_144.TXT	1.6	8340.5	7809.4	4064.1	1.1	6339.3
D_144B.txt	1.5	7744.7	10391.2	5407.7	1.1	6726.2
D_145.TXT	1.4	6883.2	4397.0	2448.6	0.8	4614.7
D_146.TXT	0.7	3152.4	4281.6	2541.1	0.7	3621.7
D_147.TXT	1.3	6011.4	8269.0	4779.8	1.0	5242.2
D_148.TXT	1.9	9478.1	10564.0	5578.0	1.2	6841.3
D_149.TXT	1.1	6293.9	6648.6	3159.2	0.8	5618.1
D_150.TXT	1.3	5336.1	6575.9	4030.9	1.1	5152.8
D_151.TXT	1.6	6651.6	7167.4	4504.5	1.1	5149.1
D_152.TXT	1.1	4837.8	5014.0	2931.2	0.8	4232.2
D_153.TXT	1.3	5992.1	6709.6	3940.9	1.1	5428.7
D_154.TXT	0.6	3466.3	4311.5	2038.0	0.5	3418.7
D_155.TXT	1.2	6206.1	8113.4	4245.3	1.0	6062.7

E. Potential Iinfluence of Juvenile Wood on Pole Tip Strength

One property of wood poles that is particularly maddening to engineers is the variable nature of wood. Wood is a biological material whose properties can vary along the length of an individual tree as well as between trees. Wood can also vary depending upon tree age. Younger trees and the younger portions of older trees make wood that is very different than the wood produced by more mature trees. This younger wood, called juvenile wood, tends to be weaker, more prone to twisting or warping and has differential shrinkage properties than wood formed as the tree matures. In most cases, juvenile wood is only produced in the first 12 to 20 years of growth and is of little concern for utility engineers because poles are typically produced from older trees. However, engineers have expressed concerns about the potential influence of juvenile wood on smaller distribution poles, particularly near the tips where the proportion of juvenile wood is likely to be very high. While the highest stresses in a wood distribution pole typically occur at or near the groundline, weaker wood higher up could be a concern for heavily loaded poles.

As a result of the through-boring tests described in an earlier part of this objective, we obtained a large quantity of pole tips that could be used to assess the potential effects of juvenile wood on pole properties. We elected to use this material in the following test.

The original materials were Class 4, forty foot long poles. The lower 20 feet was tested to failure, while the remaining 20 feet was retained. We also retained a cross section cut from the groundline of these poles for later use. We selected all of the pole tips from poles that had not received any through-boring treatment along with 30 tips from other poles that had received one of the boring procedures at the groundline.

We had contemplated testing the 20 foot tip sections in the same manner as was done for the butt sections, however, that would have provided us with only a measure of pole properties at one cross section. Instead, we sought to characterize exterior wood strength along the pole length. Pole condition was assessed using longitudinal compression strength testing (LCS) of small plugs cut from each pole. In previous tests, we found that LCS was reasonably correlated with pole bending strength. It also allowed us to characterize wood properties along the length of the pole section in relation to the proportion of juvenile wood present.

Plugs (3/8 diameter by 1.5 inches long) were taken from three equidistant locations around each pole beginning at the butt and moving upward at 1 m intervals. The plugs were pressure soaked with water, and then tested in longitudinal compression using a specially designed jig. These data were then plotted and were used to calculate longitudinal compression strength of each plug. In addition, plugs will be cut from the section retained from the lower pole section.

Following plug sampling, 3 inch thick disks were cut from the butt and tip of each pole section. These sections, along with the cross section cut from the lower pole section were then used to determine the total number of annual rings present, the percent of juvenile wood, and the proportion of latewood in the outer 2 inches of the cross section. These tests are still underway and results will be provided in the next annual report.

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Objective IV

PERFORMANCE OF EXTERNAL GROUNDLINE PRESERVATIVE SYSTEMS

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

For many years, the pastes used for this purpose incorporated a diverse mixture of chemicals including pentachlorophenol, potassium dichromate, creosote, fluoride and an array of insecticides. The re-examination of pesticide registrations by the U.S. Environmental Protection Agency in the 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.

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

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

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

The pole sections in the field test of copper/boron and copper/boron/fluorides 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

The southern pine transmission poles in the Central Hudson Electric and Gas system were not sampled this past year. They are scheduled to be sampled in 2006.

D. Establishment of a Field Test on Southern Pine Poles in Coastal Georgia

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

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 preservative, 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.

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/m^3)
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 450 mm (18 inches) and any weakened wood was scraped away. The residual circumference of the pole was measured at groundline then the chemical was applied according to the manufacturer's 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.

Chemical movement from the pastes into the wood will be assessed in 5 poles per treatment one, two, three and five years after treatment by removing increment cores from approximately 150 mm below the groundline. A small patch of the exterior bandage and any adhering paste will be scraped away, then increment cores will be removed from locations around the pole. The cores will be cut into two different patterns. Chemicals containing copper-based biocides will be 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 will be combined and then ground to pass a 20 mesh screen. Copper will be assayed by x-ray fluorescence spectroscopy (XRF). Cores removed from poles treated with boron and fluoride containing systems will be cut into zones corresponding to 0-13, 13-25, 25-50 and 50-75 mm from the wood surface. These segments will be processed in the same manner as described for the copper containing cores. Boron will be analyzed by extracting the ground wood in hot water, then analyzing the extract using the azomethine-H method, while fluoride will be 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 effect of this wrap on subsequent paste performance is probably marginal, but we will set up some small scale tests at OSU over the winter to assess possible effects. 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.

The most important objection was that concerning the paste thickness. While most labels only specify a single thickness, the label for one treatment (CuBor) specifies a range of thicknesses. In addition, this particular system has a lower density. The decision to use a single thickness essentially resulted in both CuBor and CuRap 20 being applied at a lower active level than the Cop-R-Plastic. In the case of CuRap 20, this was inevitable since the label allows only a single thickness which is the same thickness used for Cop-R-Plastic; however, this did potentially reduce the amount of CuBor applied to the test poles. In all of our field tests, we have labored to develop fair methods for assessing different systems realizing that our data is heavily used in the market place. We are planning to sample these poles in November and, at the request of one cooperator, have elected to not sample the CuBor treated poles. We will, however, discus this topic more fully at the Fall Advisory committee meeting.

E. Effect of Moisture Content on Movement of Copper and Boron From CuBor 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. This past year, we examined the movement of CuBor in comparison with CuRap 20 through Douglas-fir sapwood blocks at 2 moisture contents.

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 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 4, 14, and 24 weeks after treatment by destructively sampling 5 blocks per paste thickness per chemical system. A set of blocks remains for a 48 week sampling.

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

Paste Thickness	CuBor			CuRap 20		
	Total (g)	Boron (g)	Copper (g)	Total (g)	Boron (g)	Copper (g)
1.6 mm	1.17	0.06	0.03	1.50	0.07	0.03
6.0 mm	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.

Boron levels in the outer 6 mm were above the threshold for boron protection in direct soil contact regardless of moisture content, formulation or paste thickness 4 weeks after treatment (Figure IV-1, a-d). Chemical levels declined sharply further inward for all treatment combinations and none of the levels even approached the lower boron threshold. The lower boron threshold is typically the value we use for protection of wood in non-soil contact (such as when boron is used in rod form for internal decay control), while the higher level is based upon previous laboratory and field data for boron in soil exposure. The lack of substantial boron movement further inward is perplexing since previous tests have shown excellent movement by this fungicide.

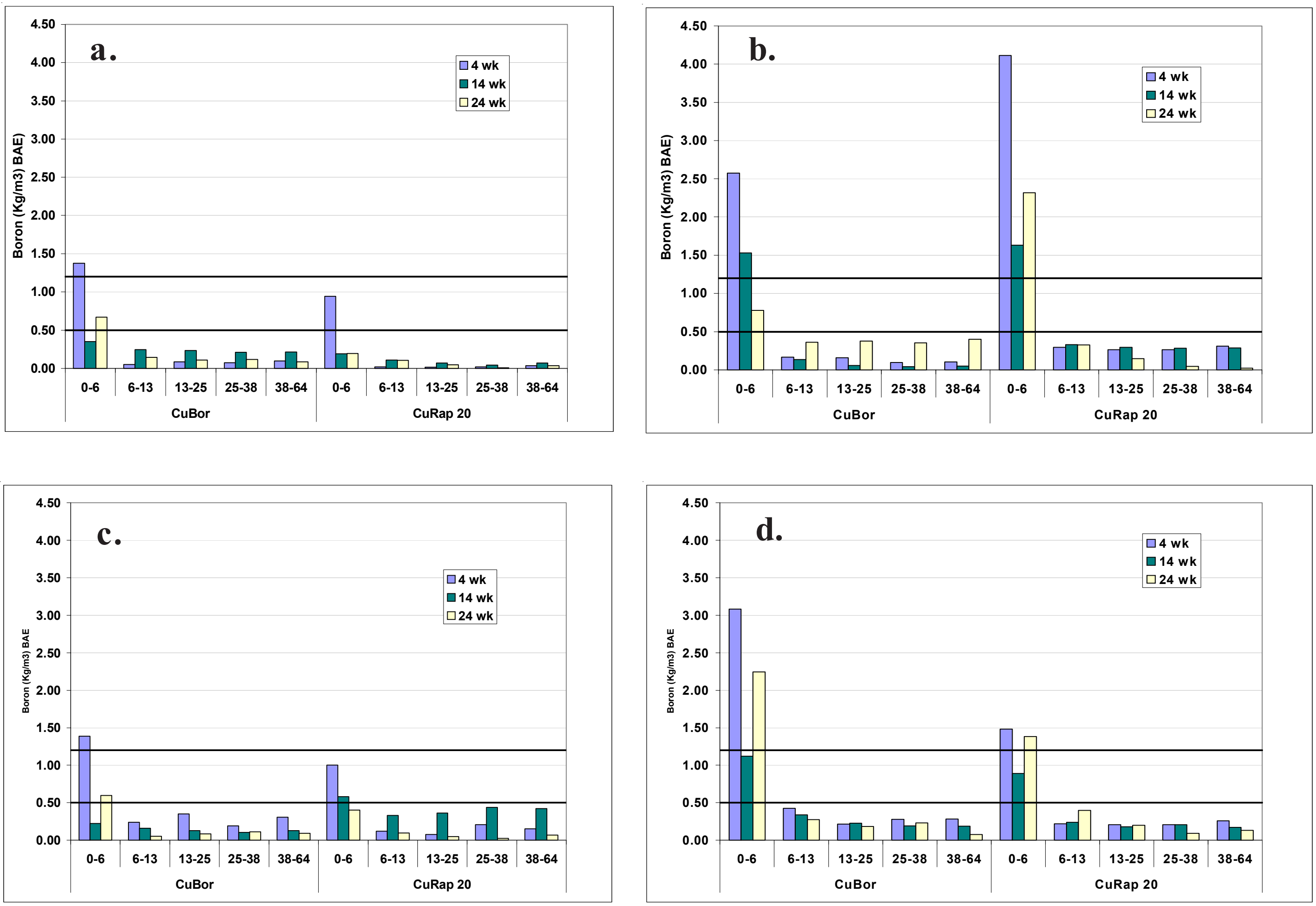

Figure IV-1. Residual boron levels at selected distances from the surface of Douglas- fir sapwood blocks at 30% (a, c) and 60% (b, d) moisture 4 to 24 weeks after application of 1.6 mm (c, d) or 6.0 mm (a, b) of two copper/boron pastes. The lower and upper threshold levels for boron are 0.5 and 1.2 kg/m^3, respectively.

Moisture content had a slight effect on boron movement with levels in 60 % MC blocks being consistently higher than those found with the 30 % MC blocks. This moisture effect was also evidenced by the slightly higher boron loadings in the inner zones of the 60 % blocks.

Paste thickness had little effect on CuBor concentrations in 30 % MC blocks, but did appear to have an inverse effect with CuRap 20 where boron levels tended to be slightly higher in the inner zones in samples receiving the thinner paste dosage. In both cases, the boron levels were well below the minimum internal threshold, making these differences of less practical importance. Paste thickness also appeared to have no consistent effect at 60 % moisture content. The apparent lack of a thickness effect may reflect the relatively short term nature of this test.

Copper was only detectable in the outer zones of the blocks 4 weeks after treatment (Figure IV-2, a-d). No copper was detectable further inward with any treatment. The lack of copper penetration is consistent with previous results with CuRap 20 which contains an amine soluble copper naphthenate. This system has some water solubility, but its primary function is to provide a surface barrier against renewed fungal attack. The CuBor results indicate that copper hydroxide in this system was also largely confined to the surface and was relatively immobile. The decline in copper levels between 4 and 24 weeks was perplexing and has led us to consider repeating this test.

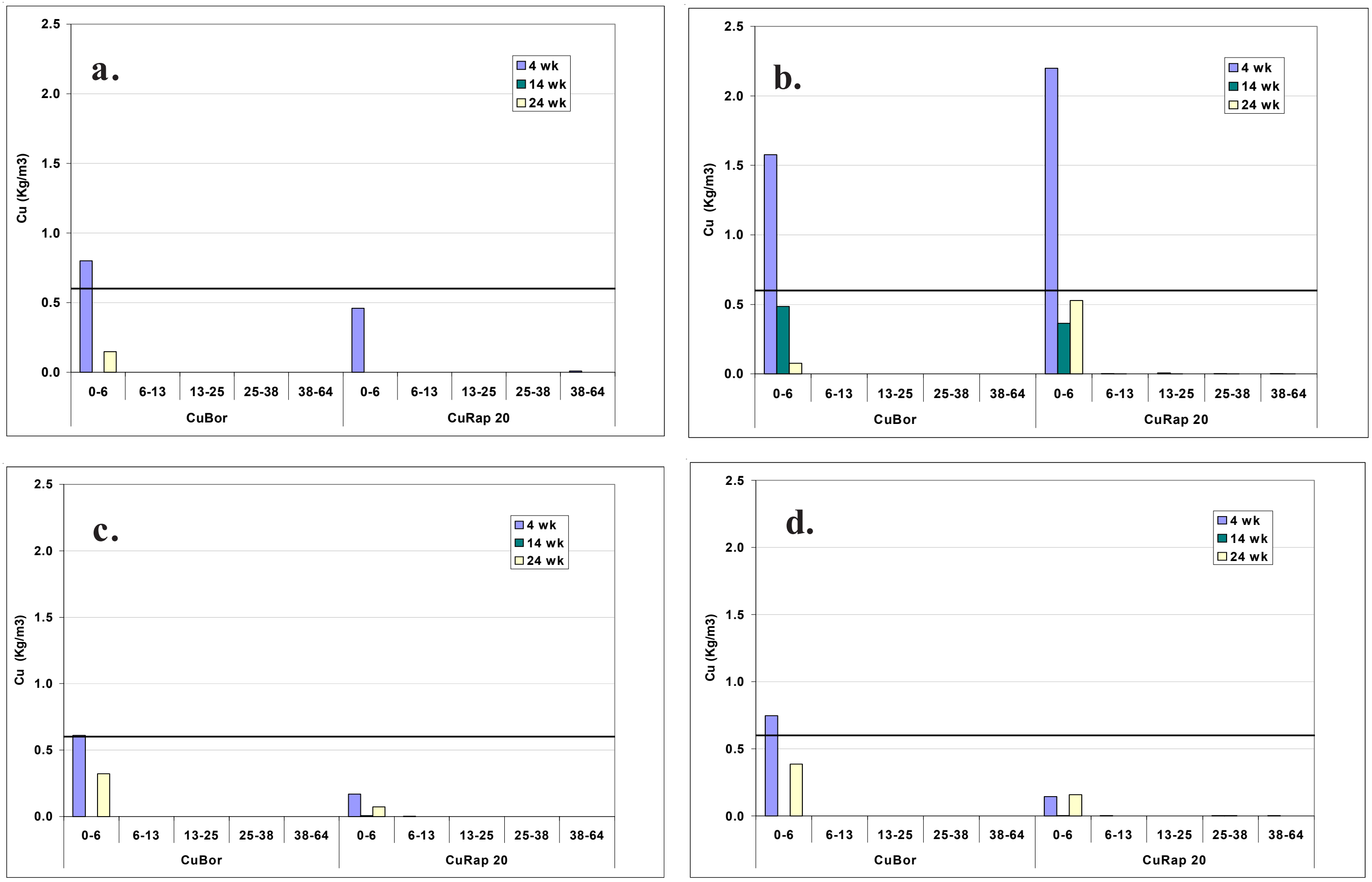

Figure IV-2. Residual copper levels at selected distances from the surface of Douglas- fir sapwood blocks at 30% (a, c) and 60% (b, d) moisture 4 to 24 weeks after application of 1.6 mm (c, d) or 6.0 mm (a, b) of two copper/boron pastes. The threshold level for copper is 0.6 kg/m^3.

Copper levels did tend to be higher in blocks receiving the higher dosage of chemical and when applied to wetter blocks. However, these differences were generally slight. The results suggest that the two systems behaved similarly in the small bock tests, although further testing will be necessary to resolve some of the anomalous results.

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 applications for 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 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 10 freshly sawn and 10 weathered stakes. 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).

The stakes cut from freshly sawn sapwood continue to out-perform those cut from weathered wood at each retention level (Figures V-1, 2). Weathering is generally a surface effect, the stakes also tended to have numerous small checks that increase the surface area for chemical loss and fungal attack. Ratings for stakes cut from freshly sawn lumber continue to average between 8.0 and 10.0 after 184 months of exposure, while stakes treated with diesel alone have declined sharply in the past 60 months. Untreated stakes are all destroyed. The initial diesel performance probably reflects the high loadings of solvent in these materials (80 to 90 kg/m^3). In actual practice, initial air pressure, post treatment steaming and other activities would reduce the amount of residual solvent slightly.

Weathered stakes had consistently lower ratings 184 months after treatment. Diesel treated weathered stakes were nearly completely decayed, while the untreated controls had failed after 5 years of exposure. Ratings for copper naphthenate treated weathered stakes ranged from 4.2 for the 0.8 kg/m^3 retention to 8.0 for the 4.0 kg/m^3 retention (Figure V-2). The difference in condition of the weathered stakes in comparison with similarly treated stakes cut from freshly sawn lumber emerged early in the test and illustrates the effects of weathering on performance.

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

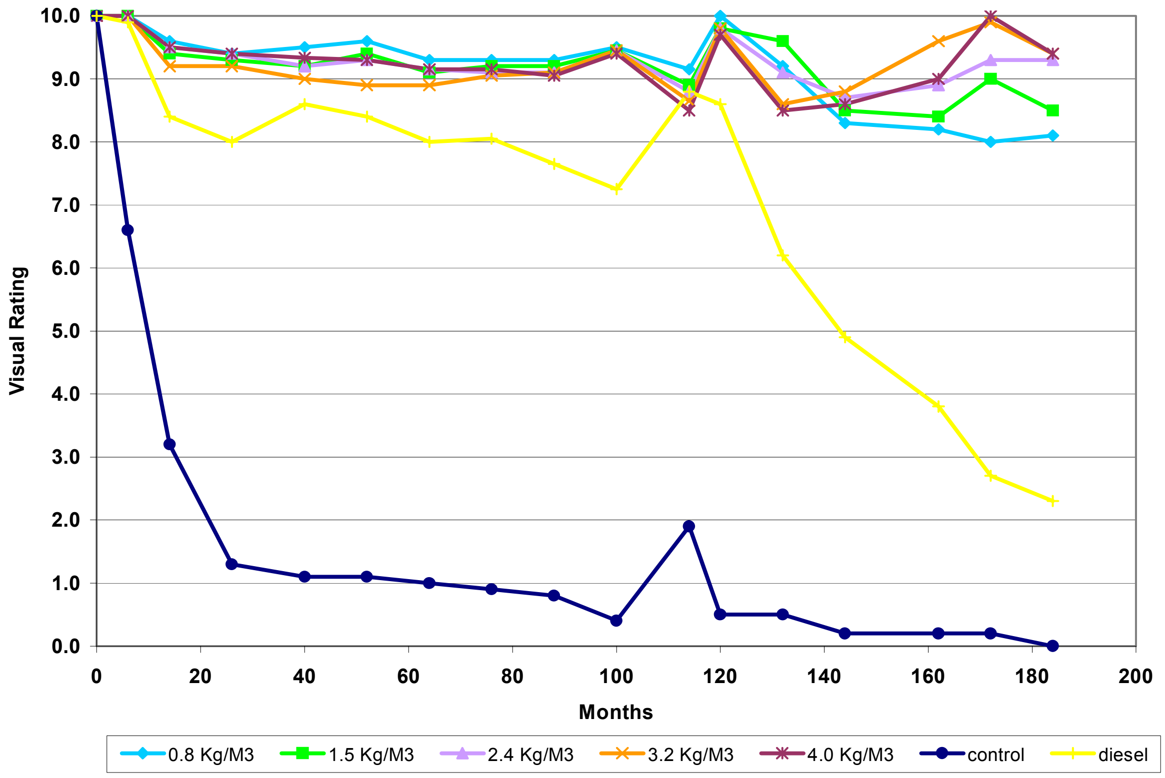

Figure V-1 Condition of freshly sawn western redcedar sapwood stakes treated with selected retentions of copper naphthenate in diesel oil and exposed in a soil bed for 184 months.

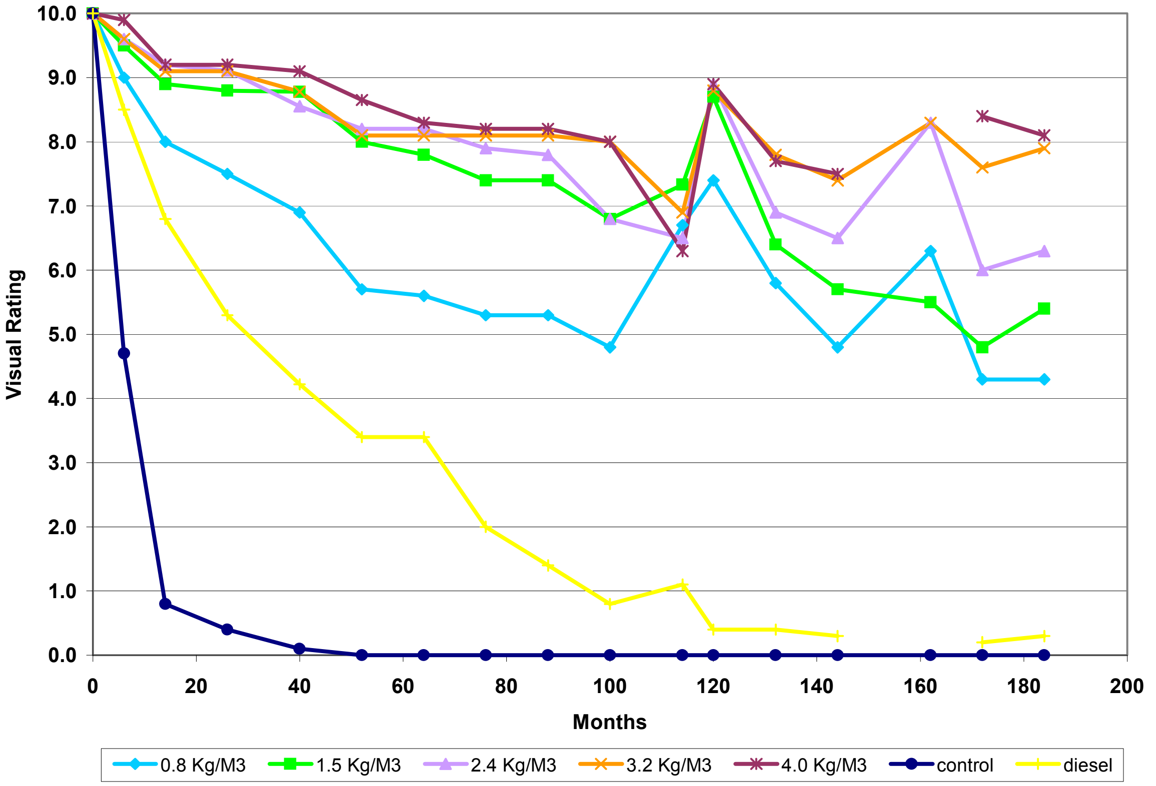

Figure V-2 Condition of weathered western redcedar sapwood stakes treated with selected retentions of copper naphthenate in diesel oil and exposed in a soil bed for 184 months.

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.

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. This next year, we plan to inspect 12 to 15 year old copper naphthenate treated Douglas-fir poles located in Northwest Oregon to better assess field performance of this system.

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 develop exposure data that can be employed by utilities to 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 two to three 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.

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 6 pole configurations a.) configuration 1, b.) configuration 2, and c.) the 4 pole configuration evaluated in our small scale preservative migration chamber.

c.

Figure VI-1 (cont.). Photo showing the two 6 pole configurations a.) configuration 1, b.) configuration 2, and c.) the 4 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, but still allow rainfall to strike the wood.

Tank sampling involved collecting all liquid and weighing this material. Approximately 230 ml of this material was then retained for penta analysis. Two extractions were required for the separation of PCP from an oil contaminated aqueous environment. The aqueous sample, or filter solid, was first adjusted to a high pH with sodium hydroxide to form pentachlorophenate anion in the aqueous phase. An extraction with iso-octane then removed the petroleum oil residues from the water phase, leaving the PCP in the aqueous phase. The water phase was then acidified, converting the pentachlorophenate back to pentachlorophenol. A second extraction with iso-octane now removed the PCP from the aqueous phase. This second extraction was analyzed for PCP content using high resolution gas chromatography with low resolution mass spectrometer detection system (HRGC-LRMS).

Reagents

a. DI water: Deionized water from Richardson Hall DI water line
b. Sodium Hydroxide: VWR, reagent grade
d. Hydrochloride acid: JT baker, Baker analyzed
e. Ethanol: McCormick, absolute-200 proof
f. Iso-octane: Fisher, Optima grade
g. Methanol: Fisher, HPLC grade
h. Pentachlorophenol: Aldrich, 98%
i. [$^{13}C_6$] labeled Pentachlorophenol: Cambridge Isotope Laboratories 99%, internal standard (IS)
j. P9A oil (Imperial): Shell, 124 process

Extraction from base: A 50 ìL portion of 200 ìg/mL IS was spiked into the two volumetric flasks. Then 2.4 mL 0.1N NaOH was added to each of the two flasks using an Oxford pipette yielding a pH of approximately 11. Water was added to bring the total volume to the bottom of the neck of the volumetric flask. The flasks were placed on a stirring plate. The stirring speed was increased until a vortex was obtained and continued for 1 minute. The flasks were then allowed to stand for 30 minutes, after which 2.4 mL of iso-octane was added to the #1 flask using a bottle top dispenser. Both flasks were stirred for one minute. The solvent layer was removed with a disposable glass pipette and discarded. The stirring and separation were repeated; except the stirring time was reduced to 30 seconds and 2.0 mL iso-octane was added. After the second separation, the weight of the two flasks was recorded. A 3 mL of aqueous solution was removed with an Oxford pipette.

Extraction from acid The solutions were acidified to a pH of approximately 3 by adding 3 mL of 0.5M H_2SO_4 to the flask with an Oxford pipette. The flask was stirred for 1 minute and allowed to stand for 30 minutes, then 2.4 mL of iso-octane was added. The flask was stirred for one minute. The extract was collected using a new glass pasture pipette and transferred to a 20 mL HRGC-LRMS vials. The procedure was repeated, except using 2.6 mL of solvent and 30 seconds stirring. The second extract was transferred to the same vial as the first and mixed.

HRGC-LRMS analysis: The HRGC-LRMS analysis was carried out on a Shimadzu HRGC-LRMS system class 5000 with injector AOC-17 and capillary column XTI-5 from Restek. This column is composed of fused silica with a 0.25 ?m thick film of 95% dimethyl, 5% diphenyl polysilarylene. The column dimensions were 0.25 mm ID X 30 m long.

HRGC parameters

Carrier gas: Helium grade 5.0
Flow rate: 1.2 mL/min
Split rate: 5
Injector temperature: 250°C
Detector interface temperature: 280°C
Temperature program: 2 min. hold, 35°C to 260°C at 25°C/min
Injection volume: 1 µL
Solvent wash: methanol

The National Institute of Science and Technology (NIST) Mass Spectral Library #107 software was installed on the system. The PCP standard (50 ìg/mL) and [$^{13}C_6$] PCP internal standard (50 ìg/mL) were scanned and identified by the Library search function of the HRGC-LRMS instrument. The retention time for PCP was 9.70 min. The selected ion for PCP quantitative analysis was m/z = 266, the reference ions were 264 and 268. The selected ion for the internal standard [$^{13}C_6$] PCP was m/z = 274, the reference ions were 276 and 172.

HRGC-LRMS auto-tuning was performed with perfluorotributlyamine. The calibration was carried out with PCP concentrations of 0.1, 0.2, 0.5, 1.0, 2.0, 5.0, 10.0, and 20.0 ug/mL; 2 ug/mL IS was added for each standard solution or sample. Five point calibration was employed, i.e., for each single batch a minimum of 5 consecutive standards were selected depending on the range of concentration of the samples.

Each sample was diluted to bring the PCP concentration into the selected calibration range. Linear regression software was chosen for the calculation of the calibration curve.

The volume of water collected was measured by weight. A density of 1.00 g/mL was used for water. The limit of detection (LOD) of this method was estimated to be 0.025 ng/mL cm^2. The LOD is defined according to Part 136, Appendix B, procedure (b) (Federal Register, 1984), as three times the standard deviation of replicate analyses of the analyte.

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 6 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 6 rainfall events were lower than almost all

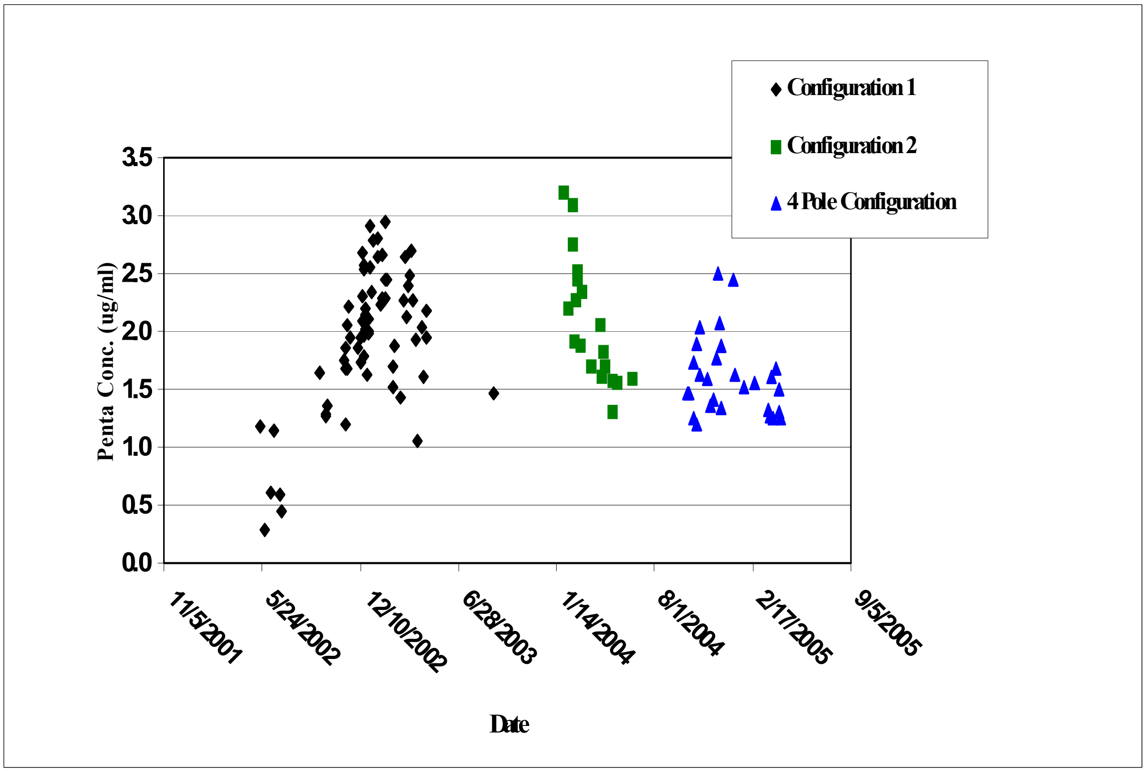

Figure VI-2. Penta concentrations as a function of sampling date in leachate collected from penta treated Douglas-fir poles following rainfall events over a 3.5 year exposure period showing data for three stacking configurations of poles.

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 6 pole stack were slightly higher than those in the original 6 pole stack (2.3 to 2.9 ug/ml of water) (Figure VI-2), but the differences were small. The penta levels in the 4 pole array were similar to those found with the first two configurations.

In addition to the apparent lack of concentration change with time or pole configuration, the total amount of rainfall did not appear to affect the runoff concentration for any of the three pole stack configurations. Instead, increased rainfall was associated with an overall increase in total penta migration, but the runoff concentrations did not vary (Figure VI-3). These results suggest that migration from the poles is a function of water contact with the pole and penta solubility in the rainwater. The similarity in runoff concentrations over time suggests that losses can be predicted based upon the rainfall amounts and total surface area exposed to direct rainfall to some limit (i.e. at some point penta concentrations would reach saturation and increasing pole surface area would not impact subsequent levels).

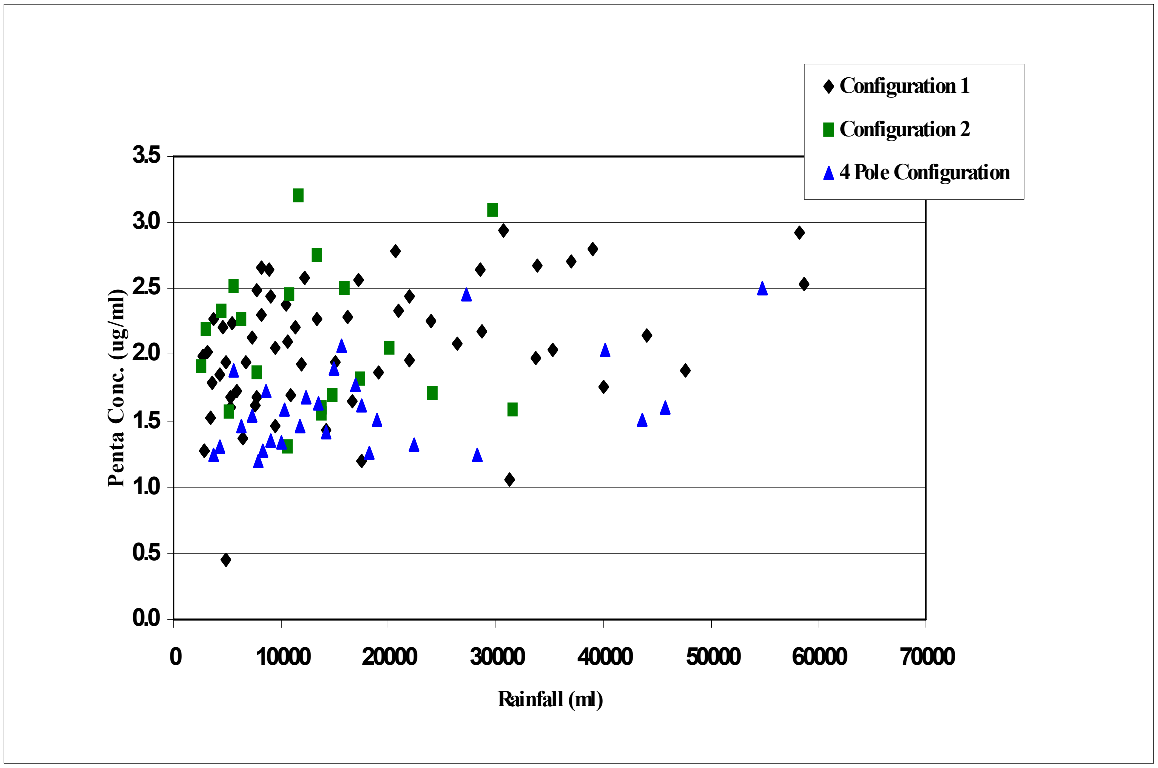

Figure VI-3. Penta concentrations as a function of total amount of rainfall collected in leachate from penta treated Douglas-fir poles following rainfall events over a 3.5 year exposure period showing data for three stacking configurations of poles.

Another factor that was assessed was whether time between rainfall events affected penta concentrations in the runoff. Long term storage in the absence of precipitation might allow chemical to migrate to the surface, where it would be more prone to migration. Once again, however, the time between rainfall events appeared to have little effect on runoff concentration (Figure VI-4). This effect is clearly illustrated by the final sampling of the 6 stack configuration in September 2003 where the previous measurable rainfall event was 5 months prior to the sampling, yet runoff concentrations were similar to those found in the wet season. These results suggest that penta migration from poles is affected more by the exposed surface area and total rainfall than other environmental factors such as temperature.The total area exposed

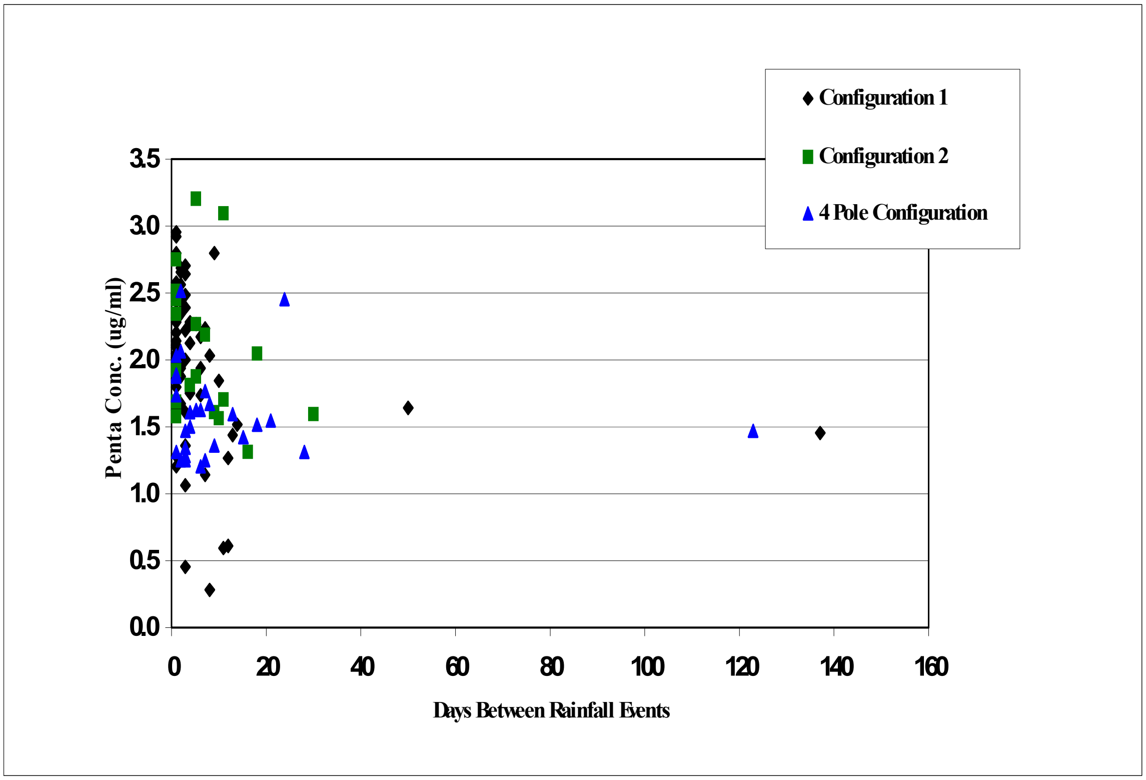

Figure VI-4. Penta concentrations as a function of intervals between collections (# of dry days) in leachate collected from penta treated Douglas-fir poles following rainfall events over a 3.5 year exposure period showing data for three stacking configurations of poles.

on the pole sections in the 6 pole configuration was approximately 6.21 square meters including the ends. A large proportion of this surface was on the underside of the poles and was not actually exposed to rainfall. While small streams of water flowed over these under-surfaces, the actual area exposed to potential rain contact was estimated to be approximately 5.3 square meters. If we convert our 6 short pole sections to 6 Class 4 forty-foot poles, we would multiply our total penta losses by approximately 12 to arrive at the amount of migration from these poles. We collected a total of 1910 mg of penta from all of the rainfall events. This would translate to a total of 22.9 g of penta for the poles over the past year. A typical Douglas-fir pole would contain approximately 2.89 kg of penta (calculated by considering 25 mm thick treatment zone and multiplying this volume by an assumed 9.6 kg/m^3 retention) and the 6 poles would contain 17.34 kg of penta. This translates to a loss of 0.13 % of the total available penta in the approximately 1.5 year exposure period.

An additional factor to consider in these calculations is the potential flow path of water on poles in solid piles. In our first two tests, the poles were stacked in tiers which tended to protect the lower poles from wetting. In a larger stack, this protective effect would be even greater. Thus, it may be possible to examine the potential for loss on the basis of the exposed upper portions of the stack rather than considering all the poles in an individual stack.

Evaluation of penta in the runoff on the basis of exposed pole area clearly showed that configuration can make a difference with regard to runoff per event (Figure VI-5 and VI-6). Factoring runoff on a total pole area basis produced a nearly 50 % reduction in concentration per ml of runoff per unit pole area. Our observations suggest that runoff is neither on all pole surfaces nor merely on the upper exposed faces. Precipitation runs along pole surfaces and the patterns of water flow change seasonally. For example, the first rainfalls after our dry summers tend to run to the pole edges then drip downward. In later rainfall events, the poles were wetter and, therefore less water repellent. The water at these times can run around the pole. It is difficult to tell whether this has any effect on maximum penta concentration in

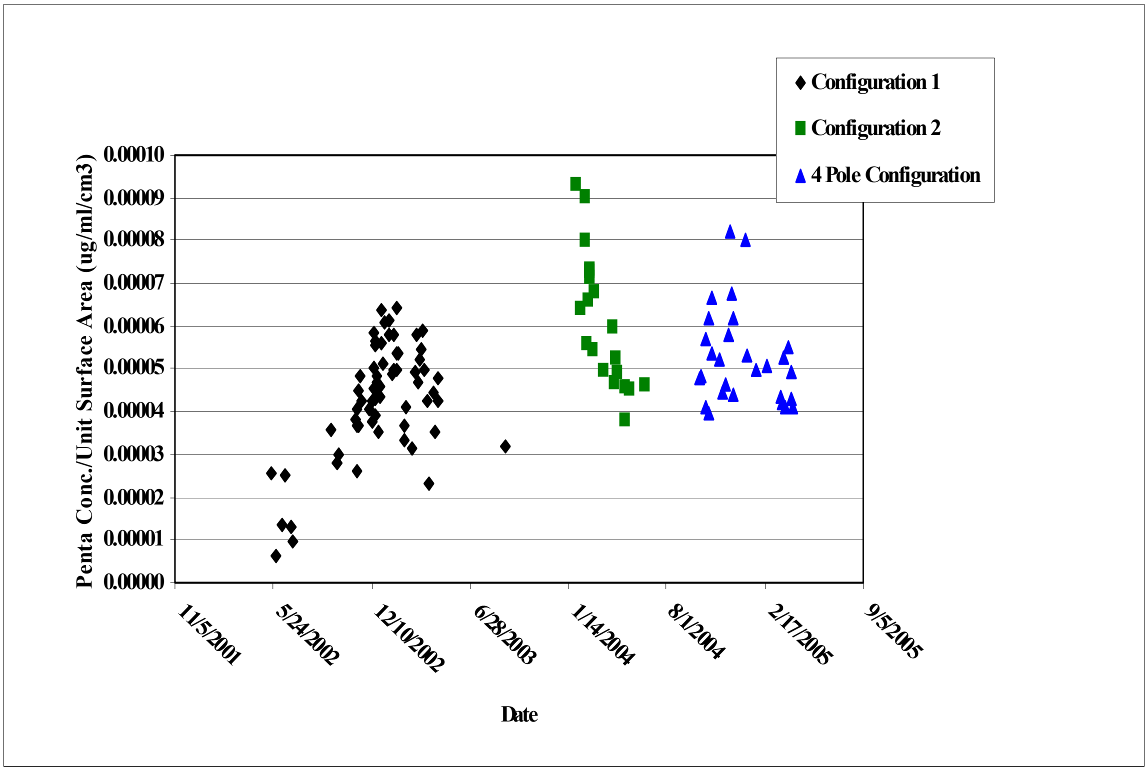

Figure VI-5. Concentration of pentachlorophenol in rainfall runoff from pentachlorophenol treated Douglas-fir poles sections stored in three stacking configurations as a function of total pole surface area.

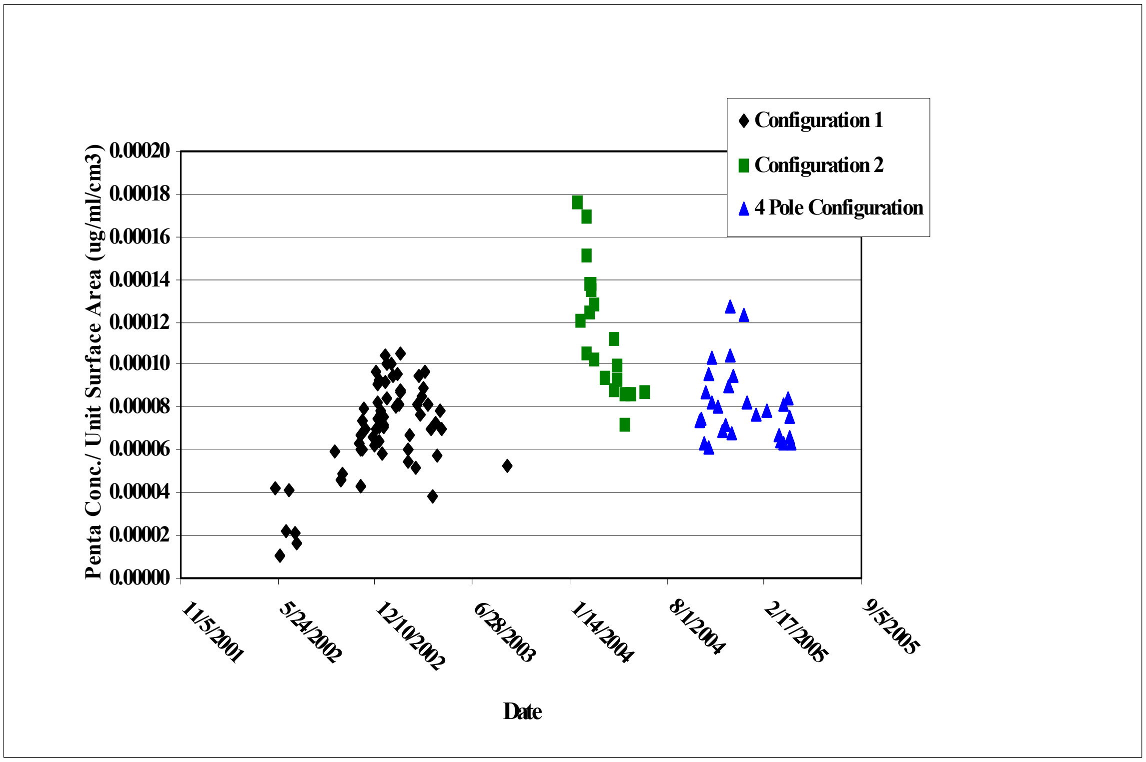

Figure VI-6. Concentration of pentachlorophenol in rainfall runoff from pentachlorophenol treated Douglas-fir poles sections stored in three stacking configurations as a function of only pole surface area exposed to direct rainfall.

the runoff; however, prior rainfall tests on penta treated lumber suggest that maximum penta concentrations in runoff water are achieved quickly and any additional wood/water contact does not measurably increase penta concentrations. As a result, using exposed wood surface area is probably a very conservative approach for estimating total penta in runoff from stored poles.

The initial evaluations clearly show that penta can migrate from stored poles, a finding supported by previous studies in aquatic environments. Unlike aquatic environments however, the migrating chemical winds up in the soil beneath the poles where it can be trapped and slowly degraded. There is also the potential for application of absorbent materials beneath the storage area to capture any migrating chemical. These materials could then be removed from the site once the operations are completed. As a result, the loss of chemical should have minimal impact on the surrounding environment. Our data also 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. 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. Our current findings should not affect that recommendation.

We will continue our tests using other poles and different storage configurations to better understand the primary factors that affect migration. These data will be used to develop more accurate storage recommendations to minimize potential releases of chemical into the environment.

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