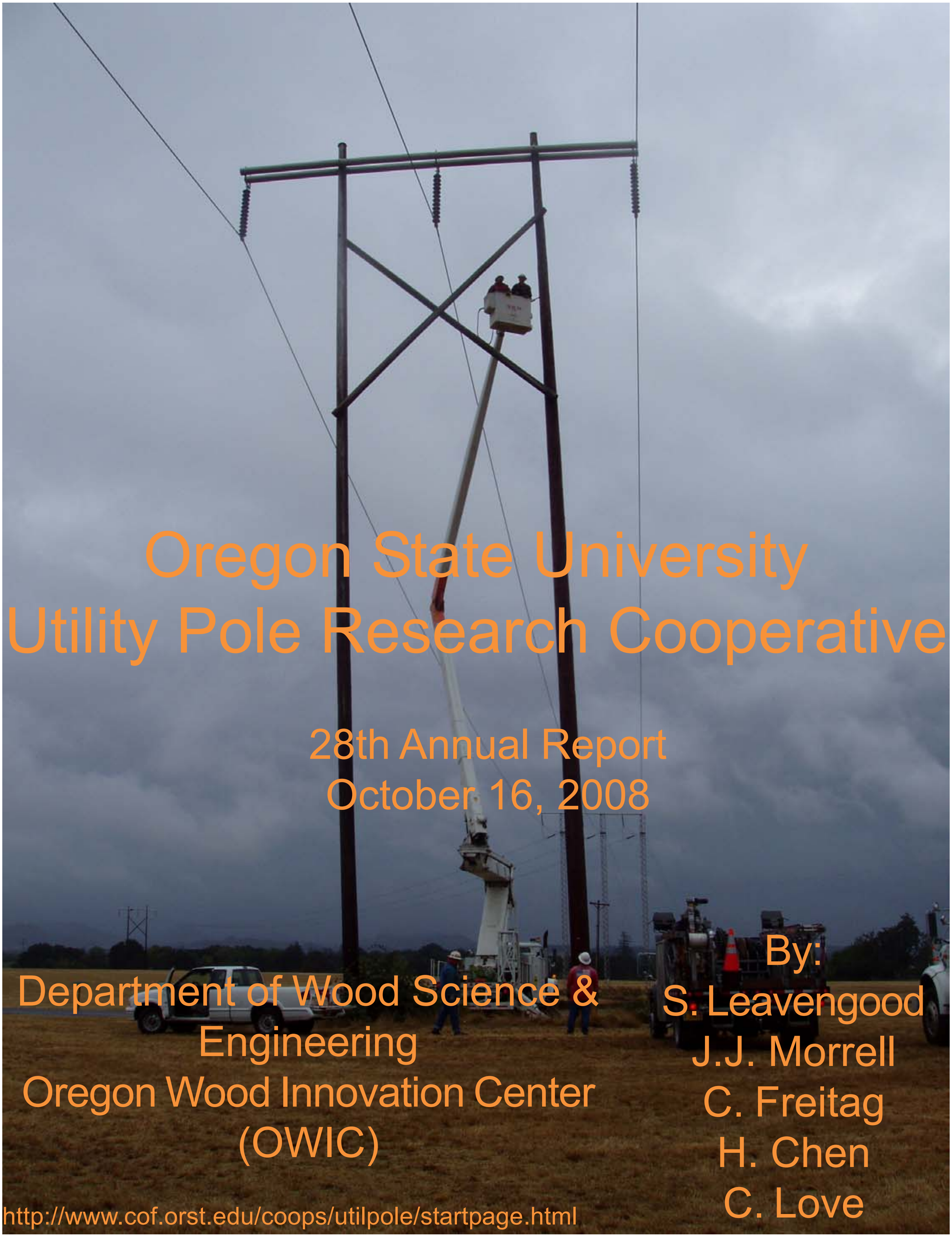


Oregon State University
Utility Pole Research Cooperative

28th Annual Report
October 16, 2008

Department of Wood Science &
Engineering
Oregon Wood Innovation Center
(OWIC)

By:
S. Leavengood
J.J. Morrell
C. Freitag
H. Chen
C. Love

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

Cooperators

Bonneville Power Administration
Dr. Wolman, GMBH
Genics Inc.
Intec Services Inc.
ISK Biocides
Osmose Utilities Services Inc.
Pacific Gas and Electric
PacifiCorp
Pole Care Inc.
Pole Maintenance Co. (Copper Care Wood Preservatives Inc.)
Portland General Electric Company
Public Service of New Mexico
Puget Sound Energy Services
Utility Pole Technologies Inc.
Western Wood Preservers Institute
Fortis Alberta
American Transmission Company
Penta Council
Salt River Project
Arizona Public Service

PERSONNEL

ADVISORY COMMITTEE

Dave Asgharian, PacifiCorp
Chuck Wright, PacifiCorp
Robert Ochs, Bonneville Power Administration
Brent Elton, Genics Inc
Rand Smith, Pacific Gas and Electric Co.
Randy Gross, Copper Care, Inc.
Ted LaDoux, Western Wood Preservers Institute
Tom Jantzen, Fortis Alberta
Dr. Manfred Jung, Dr. Wolman GmbH
Andy Kudick, Intec Services Inc.
Dave VanBossuyt, Portland General Electric Company
David Reynolds, ISK BioSciences
Rich Ziobro, Osmose Holdings, Inc.
Doug Herdman, Osmose Holdings, Inc.
Vince Cruce, UPT, Inc.
Helen Turner, Puget Sound Energy
Norman Sedillo, Public Service Company of New Mexico
John Wilkinson, Penta Council
Gerald Rhode, American Transmission Company
Larry White, Salt River Project
Yancy Gill, Salt River Project
Mike Woodward, Arizona Public Service
Art Peralta, Southern Cal Edison

RESEARCH

Principle Investigator:

Jeffrey J. Morrell, Professor, Department of Wood Science & Engineering, Oregon State University

Faculty Research Assistants:

Hua Chen, Department of Wood Science & Engineering, Oregon State University
Camille Freitag, Department of Wood Science & Engineering, Oregon State University
Connie Love, Department of Wood Science & Engineering, Oregon State University

Graduate Students:

Yohanna Cabrera, M.S., Dept. of Wood Science & Engineering, Oregon State University
June Mitsuhashi, M.S., Dept. of Wood Science & Engineering, Oregon State University
Anita Ragan, M.S., Dept. of Wood Science & Engineering, Oregon State University
Christoph Schauwecker, M.S., Dept. of Wood Science & Engineering, Oregon State University

Table of Contents

Objective I

Objective II

Objective III

Objective IV

Objective V

Objective VI

Executive Summary

The Coop continues to operate under the 2007 proposal and is active in six Objectives. We will briefly review progress under each objective.

Objective I: The Coop continues to assess the field performance of various internal remedial treatments. We have sampled Douglas-fir transmission poles 15 years after treatment with dazomet alone or amended with copper sulfate. The results show that residual methylisothiocyanate (MITC) levels have declined to the point where retreatment is recommended and the test has been discontinued. The test did show that dazomet provided sustained MITC release for 10 years and that the presence of copper resulted in more rapid MITC release. Tests with powdered and rod forms of dazomet show that MITC remains present at effective levels 8 years after treatment and also indicate that there is little or no difference in performance between the two formulations. Similarly, field trials of dazomet as a loose powder and in cardboard tubes showed little difference in release rate 2 years after application.

Studies to assess the efficacy of fused boron rods indicate that fungitoxic levels remain in the heartwood of poles 12 and 15 years after treatment. These results were surprising, but indicate that, while boron takes longer to reach effective levels after application, the chemicals remain in the heartwood for long periods thereafter. Tests of a fluoride/boron rod 15 years after application indicate that none of the zones contain fungitoxic levels of either boron or fluoride. The formulation tested was much less dense than the traditional fused rod. The product is used on a 5 year cycle in Australia and, based upon our results, this cycle would be appropriate for softwood poles in North America as well, although higher dosages might be advisable.

A small scale study to assess the effect of rod dosage on boron or fluoride movement in Douglas-fir heartwood was also completed. This study was undertaken to determine why we often see no increase in chemical levels in poles treated with higher dosages of rod. Higher rod dosages had no effect on moisture content surrounding the treatment holes, suggesting that moisture sorption by rods was not the cause for the limited chemical movement. Further tests are planned.

We have also established a large scale field trial of all internal remedial treatments. This test includes 14 internal treatment systems and will be sampled for the first time this coming spring. The test was established to put to rest concerns that our internal field tests have never compared all available treatments at the same time.

Finally, we have completed the final sampling of poles with voids treated above ground with various rods and fumigants. The goal was to determine if voids affected movement of the treatments. Chemicals did move around the voids, but distribution tended to be more variable in poles treated with water diffusible rods. This may reflect moisture variations since chemical levels in poles treated with dazomet rods, a system that is less dependent on moisture for movement, tended to be more uniform.

Objective II: There was no activity under this Objective, although we continue to monitor above ground decay in aging utility poles. This activity is described in Objective III.

Objective III: We continue to actively pursue methods for improving the performance of utility poles. Efforts to include through-boring in the ANSI standards are in process. All of our data has been submitted to the ANSI committee for review and we have prepared a proposed appendix for ANSI 05.1. In addition, we completed a small project to assess the feasibility of through-boring laminated cross arms for improved treatment with either pentachlorophenol (penta) or ammoniacal copper zinc arsenate (ACZA). These arms would be used in high decay hazard areas. Treatment was markedly improved with through-boring at either a 150 or 300 mm interval. The results indicate that through-boring represents a simple method for improving treatment of these arms.

Field tests of fire retardant treated poles were also conducted this year. All three treatments that were evaluated reduced the depth of charring and extent of cross sectional loss. A fiberglass wrap system evaluated for the first time tended to ignite and twist off the poles, while the two external coatings applied 3 years earlier experience some bubbling. We will assess these systems after 5 years to determine how long the barriers continue to provide fire protection.

Tests to assess the ability of end-plates to control splitting of Douglas-fir cross arms have now entered the ninth wet/dry cycle. End-plates have produced noticeable reductions in both the width and number of checks present on the ends of the arms.

Our assessment of internal decay patterns above ground in Douglas-fir poles continues. We have dissected and imaged a number of transmission poles. We have then assembled this data to produce three-dimensional images of pole voids. We have found a consistent association between woodpeckers and dampwood termites, even 30 to 40 feet above the groundline. Woodpecker holes apparently provide an attractive nesting site for these insects. Our results highlight the need to fill woodpecker cavities as soon as possible after they are produced to reduce the associated moisture entry.

We have also completed an evaluation of internal decay in the above ground regions of a series of older Douglas-fir transmission poles in Western Oregon. The sampling indicated that upward of 25 % of poles in some lines had considerable internal decay above ground. These results differ from previous surveys of distribution poles in the same region. The results may reflect the larger size of the poles, which leads to a greater tendency for checks to extend beyond the treated zone.

Objective IV: Field trials of external preservative pastes and bandages continue in a line near Douglas, Georgia. Copper levels in most systems have declined between 1 and 3 years. As expected, most of the copper is near the surface where it can protect the wood against renewed fungal attack. Boron levels increased between 1 and 2 years in poles treated with three of the four systems tested. Boron levels increased further with CuRap 20 and the CuBor bandage system, but declined slightly with CuBor paste. Fluoride levels remain elevated in Cop-R-Plastic treated poles, but have declined slightly in poles treated with PoleWrap. Fluoride remains above the threshold in both systems. Distribution of the boron and fluoride has become more uniform between 1 and 3 years, reflecting the water solubility of these components.

Objective V: Stake tests of copper naphthenate treated western redcedar continue to show the excellent performance provided by this chemical. Stakes treated to the lower retentions have continued to slowly decline, but stakes treated to the current retention levels remain sound. Field assessment of 20 year old copper naphthenate treated Douglas-fir poles indicate that the poles were performing well. No evidence of surface decay was found on any of the poles inspected. X-ray fluorescence analysis of residual copper in the poles indicated that most contained acceptable levels of copper. The results indicate that copper naphthenate continues to perform well on western wood species.

Objective VI: Field assessment of preservative migration from Douglas-fir poles is continuing. We have completed our exposures of pentachlorophenol treated poles, but have examined methods for capturing runoff in the water. Sawdust appears to be potent material for capturing the penta. Attempts to use kenaf were unsuccessful as this material captured little or no penta. We will continue to assess other sorbent materials. In practice, mats containing the sorbent materials would be placed beneath temporary pole storage areas. These would capture any penta in the runoff and the mats could be reused or, eventually burned in a licensed facility. Our data suggested that sawdust columns absorbed the penta in meters of rainfall. In addition, we have continued sampling our ACZA poles in the runoff system. The results continue to show that the poles lose small amounts of metal during every rainfall event. As with the penta, the amounts were predictable and this would allow utilities to plan their storage practices to limit accumulation in a single storage area.

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 formulations. 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.

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,

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

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

solid methylisothiocyanate (MITC) and dazomet. Both chemicals are solid at room temperature, reducing the risk of spills and simplifying cleanup of any spills that occur. MITC was commercialized as MITC-FUME, while dazomet has been labeled as Super-Fume, UltraFume and DuraFume. 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 15 years, first as a glass encapsulated material and later in aluminum ampules. In both cases, the cap was punctured and the tube was inserted, open end down, into the treatment hole. As with any encapsulated material, the time required for the chemical to move from the tubes and into the surrounding wood has important effects 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. These trials continued for 14 years. Initially, MITC released rapidly from tubes in pole stubs at warmer temperatures, but tended to remain in the tubes for many years at 5 C. This test was discontinued in 2008, although some of the tubes stored at 5 C still contained chemical residue.

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, 12 and 15 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 3.3 m zone was omitted from the 15 year sample because no chemical had been detected at this level at either 10 or 12 years. The outer, heavily treated zone was discarded, and then the outer and inner 25 mm of each core was removed (Figure I-1) 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.

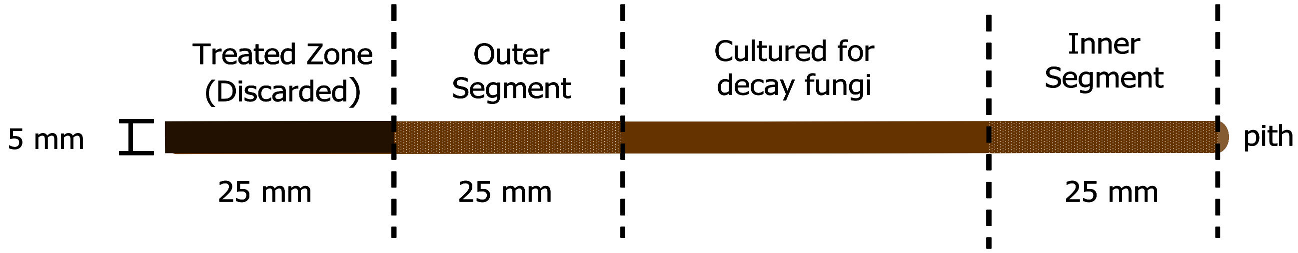


Figure I-1. Representation of increment core showing inner and outer 25 mm segments analyzed for fumigant content.

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 1 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 1 m 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.

Treatment of poles with 200 or 400 g of dazomet alone produced more variable MITC levels 1 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.

Table I-2. Residual MITC (ug/g ODW) levels at selected locations in Douglas-fir poles 1 to 15 years after treatment with metam sodium or dazomet alone or amended with 1% copper sulfate (w/w). Numbers in bold are above the lethal threshold for MITC of 20 ug/g ODW.

Chemical treatment	Dose	Year	MITC content (ug/g of wood)[a]															
			0.3				1.3				2.3				3.3			
			inner		outer		inner		outer		inner		outer		inner		outer	
Dazomet	200 g	1	8	(21)	2	(7)	5	(9)	13	(23)	0	0	0	0	1	(4)	1	(2)
		2	18	(20)	**29**	(37)	8	(11)	7	(16)	4	(6)	1	(4)	4	(8)	4	(7)
		3	**51**	(44)	**50**	(63)	19	(21)	**38**	(36)	8	(5)	9	(7)	2	(4)	2	(3)
		4	**25**	(15)	**39**	(31)	8	(4)	9	(11)	0	(1)	0		0		0	
		5	**31**	(31)	**37**	(26)	10	(5)	7	(6)	0	(1)	0	(1)	0		0	
		7	**38**	(20)	**35**	(30)	11	(7)	7	(8)	0		0		0		0	
		10	**134**	(178)	**68**	(75)	**48**	(17)	**44**	(25)	20	(11)	10	(9)	7	(9)	6	(7)
		12	**43**	(35)	**32**	(19)	14	(8)	6	(5)	2	(4)	1	(2)	0		0	
		15	14	(18)	5	(7)	11	(12)	6	(9)	**25**	(26)	14	(18)				
Dazomet plus copper	200 g	1	12	(27)	14	(31)	**26**	(38)	**42**	(65)	0	0	1	(5)	2	(5)	0	0
		2	**72**	(100)	**50**	(74)	13	(18)	8	(13)	7	(19)	4	(9)	6	(13)	10	(21)
		3	**182**	(215)	**203**	(272)	**63**	(70)	**47**	(52)	10	(13)	9	(17)	1	(4)	0	0
		4	**110**	(86)	**103**	(86)	**25**	(20)	11	(16)	1	(2)	0	(2)	0	0	0	0
		5	**110**	(92)	**59**	(101)	**28**	(21)	10	(10)	3	(4)	1	(2)	0	0	0	0
		7	**80**	(73)	**77**	(87)	**22**	(14)	**21**	(18)	5	(4)	4	(5)	0	0	0	0
		10	**114**	(111)	**112**	(90)	**55**	(35)	**57**	(56)	**30**	(20)	19	(14)	15	(12)	11	(9)
		12	**70**	(66)	**45**	(62)	13	(5)	7	(7)	4	(4)	2	(4)	0	0	0	
		15	6	(10)	6	(14)	9	(12)	6	(8)	5	(9)	2	(4)				
Dazomet	400 g	1	5	(9)	**22**	(49)	16	(31)	**56**	(86)	1	(4)	0	0	0	0	1	(3)
		2	**45**	(47)	**110**	(108)	5	(5)	1	(3)	1	(2)	1	(3)	1	(2)	4	(10)
		3	**102**	(97)	**137**	(207)	**107**	(106)	**69**	(105)	15	(15)	6	(8)	3	(6)	3	(6)
		4	**59**	(35)	**84**	(54)	11	(8)	7	(6)	0	0	0	0	0	0	0	0
		5	**42**	(23)	**38**	(31)	12	(8)	7	(6)	1	(2)	0	0	0	0	0	0
		7	**60**	(31)	**59**	(27)	15	(7)	12	(6)	1	(2)	0	(2)	0	0	0	0
		10	**139**	(128)	**103**	(80)	**58**	(20)	**51**	(36)	19	(7)	13	(8)	10	(7)	2	(4)
		12	**67**	(56)	**76**	(106)	11	(9)	6	(6)	3	(6)	1	(3)	1	(3)	0	
		15	20	(28)	10	(16)	19	(21)	15	(17)	19	(22)	14	(23)				
Dazomet plus copper	400 g	1	**25**	(41)	**25**	(76)	**31**	(46)	**64**	(139)	0	0	0	0	0	0	0	0
		2	**100**	(93)	**69**	(126)	7	(8)	3	(5)	2	(5)	3	(5)	3	(5)	4	(6)
		3	**435**	(613)	**501**	(787)	**149**	(162)	**132**	(185)	11	(11)	6	(8)	1	(2)	1	(2)
		4	**121**	(82)	**130**	(116)	9	(10)	7	(10)	1	(2)	0	(1)	0	0	0	0
		5	**108**	(89)	**54**	(70)	13	(14)	9	(10)	14	(48)	6	(21)	0	0	0	0
		7	**70**	(89)	**51**	(30)	10	(8)	10	(7)	1	(2)	1	(2)	1	(4)	0	0
		10	**79**	(43)	**53**	(29)	**40**	(22)	**46**	(46)	11	(10)	10	(7)	8	(8)	3	(7)
		12	13	(9)	16	(19)	5	(9)	6	(19)	4	(14)	0		0		0	
		15	5	(7)	5	(9)	2	(3)	0		1	(3)	0	(1)				
Metam sodium	500 mL	1	**21**	(43)	**30**	(61)	**57**	(82)	**38**	(46)	1	(3)	0	0	1	(3)	0	0
		2	**53**	(47)	**26**	(28)	15	(17)	8	(16)	4	(7)	3	(5)	3	(6)	3	(5)
		3	**48**	(34)	**64**	(106)	**51**	(122)	**25**	(31)	12	(9)	5	(5)	7	(15)	2	(6)
		4	15	(16)	14	(11)	7	(8)	4	(7)	1	(3)	1	(2)	0	0	0	0
		5	8	(8)	7	(6)	6	(6)	2	(4)	0	(1)	0	(1)	0	0	0	0
		7	3	(5)	2	(4)	1	(2)	1	(2)	0	0	0	0	0	0	0	0
		10	8	(15)	3	(7)	1	(4)	1	(3)	0	0	0	0	0	0	0	0
		12	1	(4)	1	(2)	1	(3)	1	(2)	0	(2)	0		0	(2)	0	(1)
		15	0		0		0		0		0		0					

[a] Numbers in parentheses represent one standard deviation.

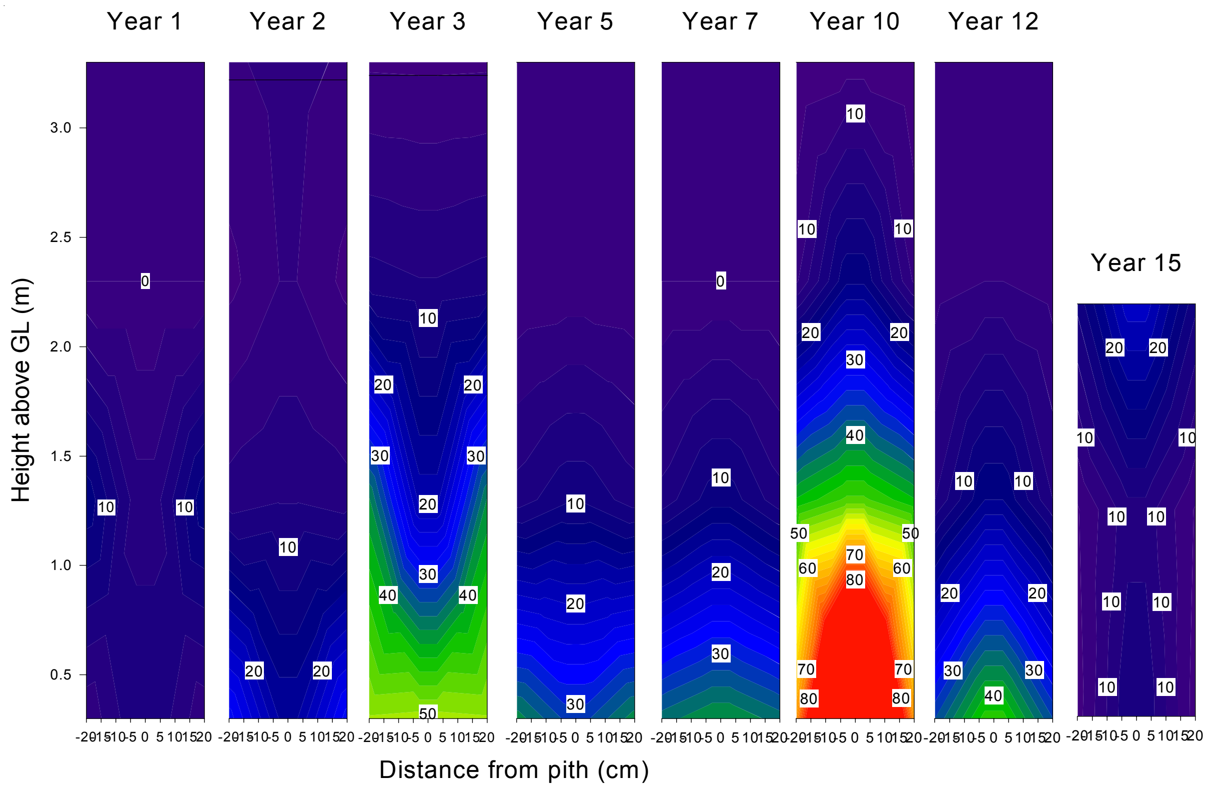


Figure I-2. Residual MITC levels in pentachlorophenol treated Douglas-fir transmission poles treated with 200 g of dazomet and monitored over a 15 year period. Dark blue indicates MITC levels below threshold. Light blue and all other colors indicate MITC levels above the lethal threshold.

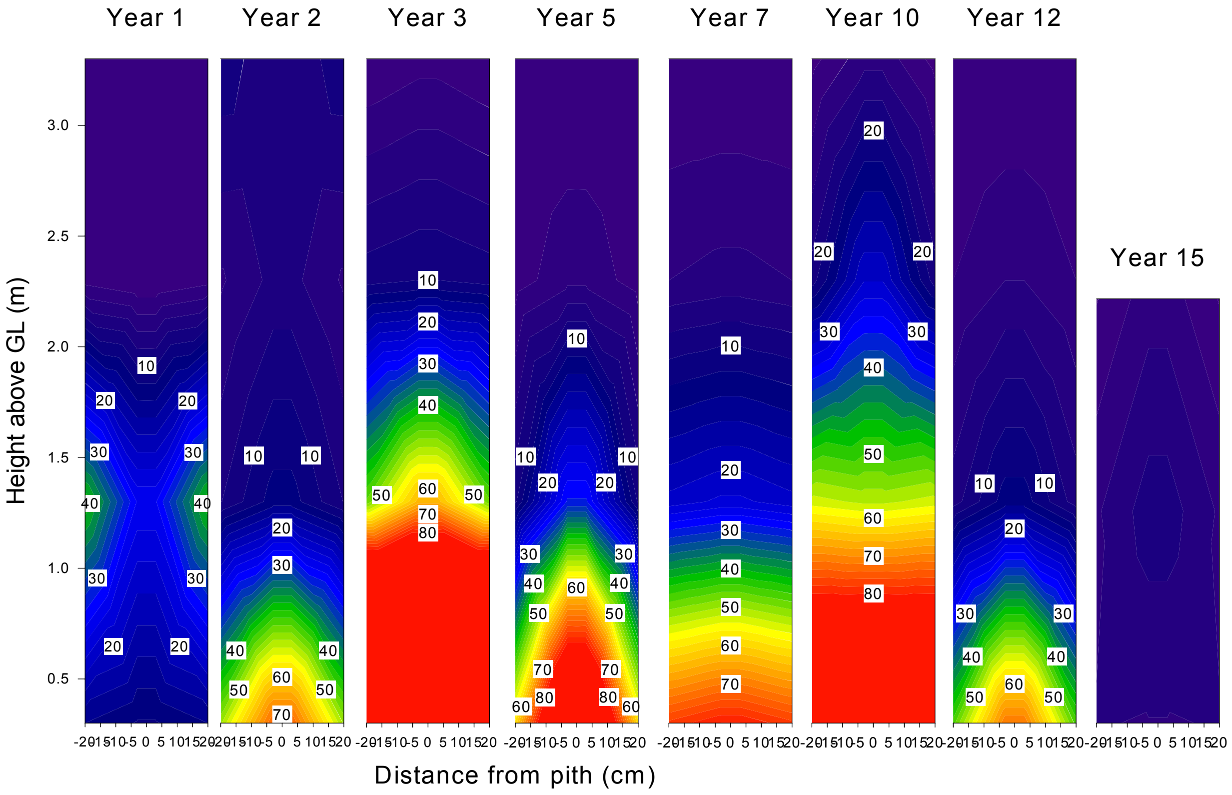


Figure I-3. Residual MITC levels in pentachlorophenol treated Douglas-fir transmission poles treated with 200 g of dazomet plus copper sulfate and monitored over a 15 year period. Dark blue indicates MITC levels below threshold. Light blue and all other colors indicate MITC levels above the lethal threshold.

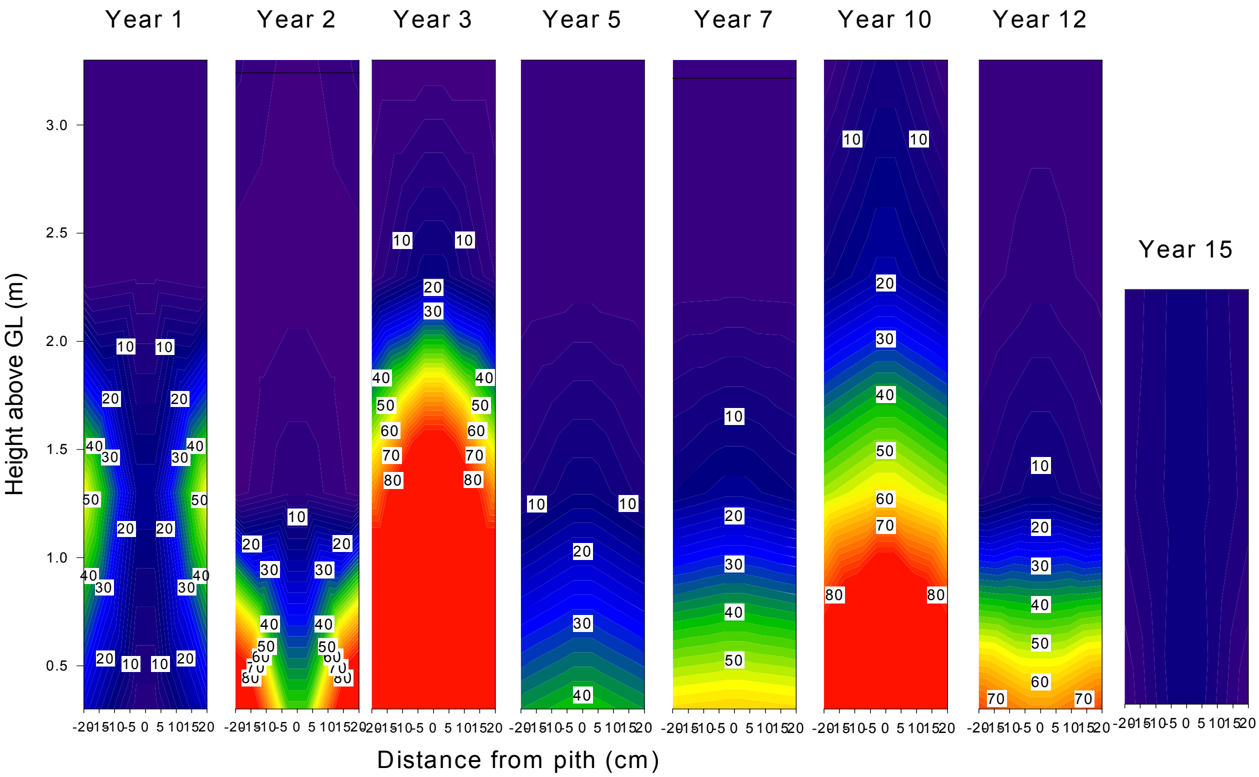


Figure I-4. Residual MITC levels in pentachlorophenol treated Douglas-fir transmission poles treated with 400 g of dazomet and monitored over a 15 year period. Dark blue indicates MITC levels below threshold. Light blue and all other colors indicate MITC levels above the lethal threshold.

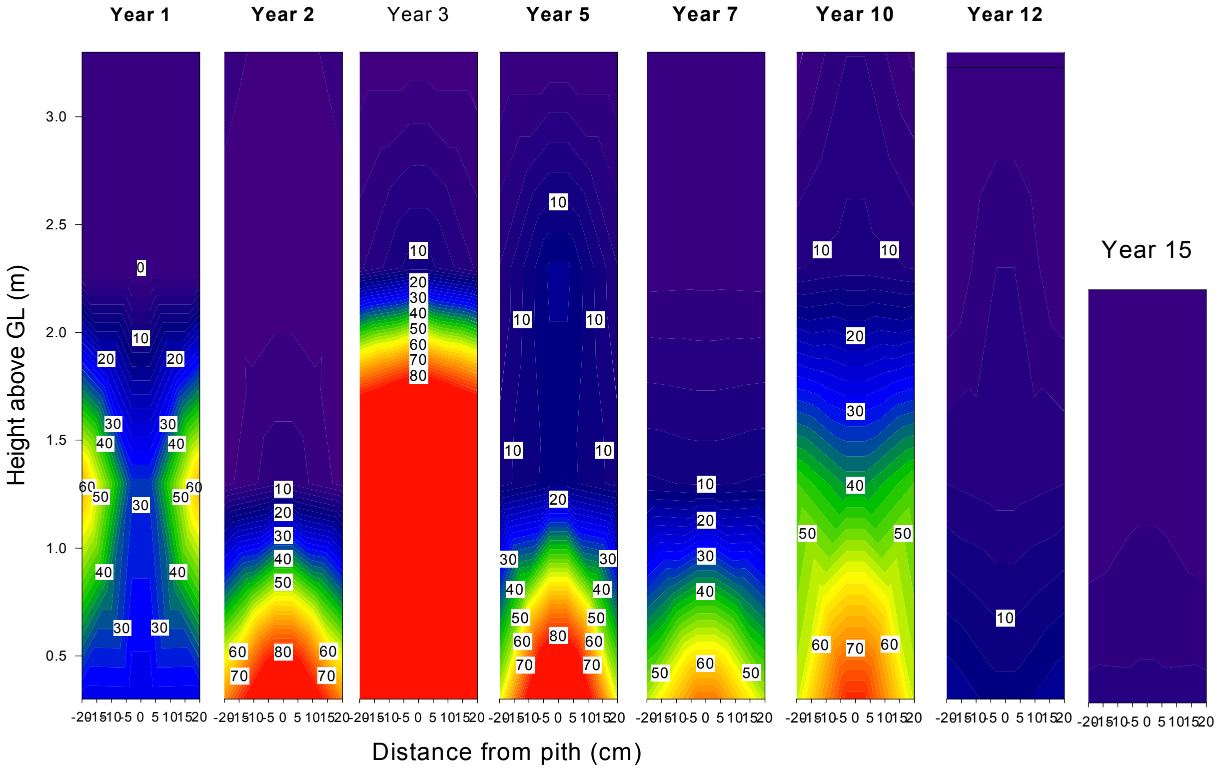


Figure I-5. Residual MITC levels in pentachlorophenol treated Douglas-fir transmission poles treated with 400 g of dazomet plus copper sulfate and monitored over a 15 year period. Dark blue indicates MITC levels below threshold. Light blue and all other colors indicate MITC levels above the lethal threshold.

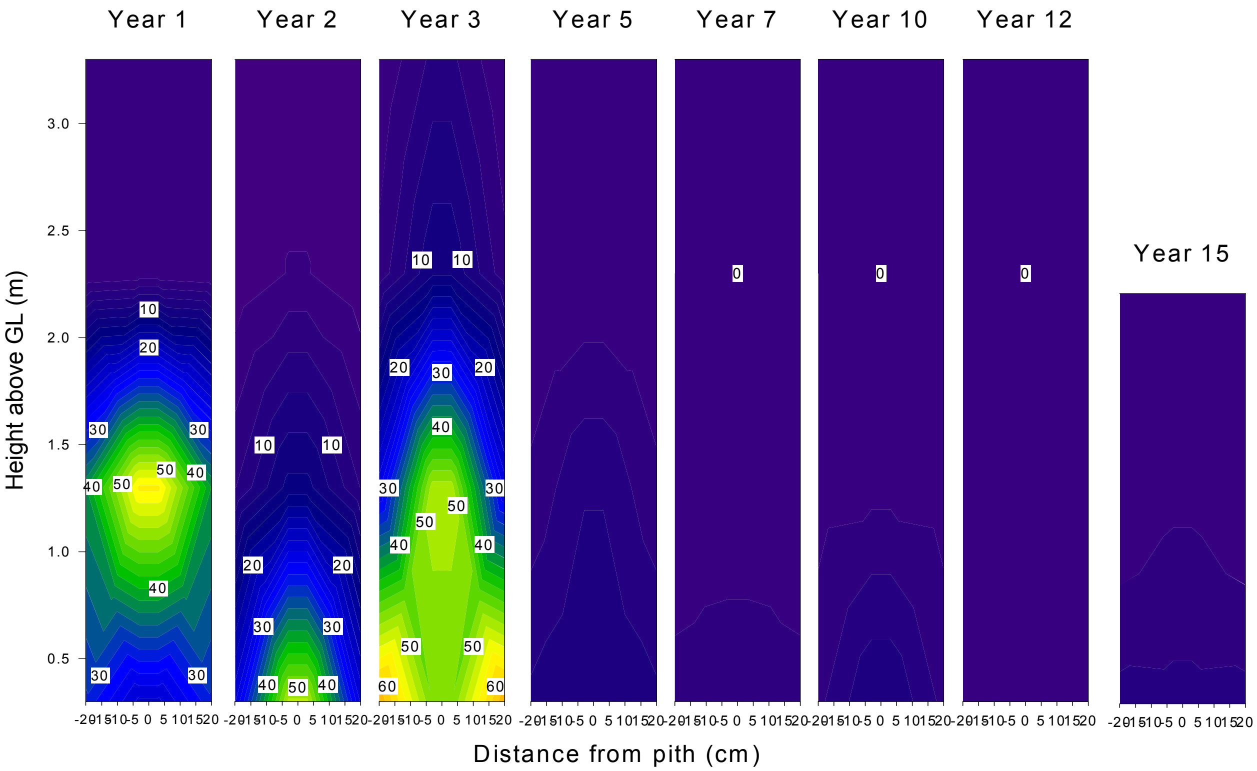


Figure I-6. Residual MITC levels in pentachlorophenol treated Douglas-fir transmission poles treated with 500 ml of metam sodium and monitored over a 15 year period. Dark blue indicates MITC levels below threshold. Light blue and all other colors indicate MITC levels above the lethal threshold.

Sampling of poles 15 years after treatment revealed that most of the wood contained no detectable MITC and when MITC was present, the levels were less than half of our target threshold of 20 ug. The results indicate that the treatment has lost it efficacy and this study has been terminated. Regardless of initial dosage or the use of copper additives, the results suggest that treatment cycles between 10 and 12 years would be prudent for this system. These cycles are consistent with most utilities across North America.

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

Table I-3. Percentage of increment cores containing decay and non-decay fungi 1 to 15 years after application of metam sodium or dazomet to Douglas-fir pole sections.

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	15 yr	2 yr	3 yr	4 yr	5 yr	7 yr	10 yr	12 yr	15 yr
Metam sodium	500 ml		0^{47}	0^{10}	0^{5}	0^{13}	0^{27}	0^{40}	3^{28}	0^{17}	0^{54}	0^{13}	0^{3}	0^{10}	0^{30}	0^{20}	0^{28}	0^{33}	8^{58}
dazomet	400 g		0^{14}	0^{7}	0^{0}	0^{0}	0^{27}	0^{0}	0^{0}	0^{27}	0^{0}	0^{23}	0^{0}	0^{0}	0^{13}	0^{0}	0^{0}	0^{47}	0^{0}
dazomet	400 g	+	0^{27}	0^{7}	0^{20}	0^{0}	0^{27}	0^{0}	0^{7}	0^{20}	0^{0}	0^{13}	0^{7}	0^{0}	0^{27}	0^{0}	0^{0}	0^{20}	7^{7}
dazomet	200 g		7^{20}	0^{27}	0^{0}	0^{0}	0^{33}	0^{7}	0^{0}	0^{20}	0^{0}	0^{33}	0^{0}	0^{7}	0^{40}	0^{0}	0^{0}	0^{33}	0^{7}
dazomet	200 g	+	0^{0}	0^{0}	0^{0}	0^{7}	13^{13}	0^{20}	0^{0}	0^{60}	0^{0}	13^{0}	0^{20}	0^{0}	7^{40}	0^{20}	0^{0}	7^{50}	0^{0}
				2.3 m								3.3 m							
				2 yr	3 yr	4 yr	5 yr	7 yr	10 yr	12 yr	15 yr	2 yr	3 yr	4 yr	5 yr	7 yr	10 yr	12 yr	15 yr
Metam sodium	500 ml		- -	0^{10}	0^{7}	0^{10}	3^{40}	13^{27}	0^{21}	0^{33}	17^{42}	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^{0}	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^{13}	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}	7^{33}	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^{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 Vapam. Superscripts represent pecentage 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 as a soil fumigant. 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 could 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. Each hole received either 53.3 g of powdered dazomet alone, 35.2 g of dazomet rod plus 6.7 g of copper naphthenate, 52.8 g of dazomet rod alone, 52.8 g of dazomet rod amended with 6.7 g of copper naphthenate, 52.8 g of dazomet rod amended with 6.7 g of water, or 490 g of metam sodium. When amendments were added, they were poured into the holes after the addition of the fumigants. Each treatment was replicated on five poles.

The poles were sampled 1 to 8 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.

MITC levels in the inner assay zone 0.3 m above the groundline in poles receiving dazomet were all above the 20 ug threshold 1 year after treatment and have remained well above the level for the intervening 8 years (Figures I-7 to I-12, Table I-4). MITC levels in the outer zone at the same locations were also above the threshold except for the 2 year sample. MITC levels after 8 years ranged from 70 to 211 ug in the inner zone to 88 to 119 ug in the outer zone. The results indicate that MITC remains well above the protective level 8 years after treatment. There also appeared to be no consistent difference in MITC levels between rod and powdered dazomet, nor did there appear to be a consistent effect from the addition of copper. MITC levels in the inner zones of metam sodium treated poles were above the threshold up to 3 years after treatment and for 1 to 3 years in the outer zone, but levels fell off sharply thereafter. MITC remains detectable in metam sodium treated poles, but the levels are no longer protective. These results are consistent with previous studies with this chemical.

MITC levels 0.8 m above groundline were below the threshold in the inner zones for the first year after treatment with either dazomet or metam sodium. MITC levels rose above the threshold in the second year and remained above that level for the next 7 years for dazomet treated poles. MITC levels in metam sodium treated poles declined below the threshold 3 years after treatment and remain detectable, but low. Chemical levels in the outer zones 0.8 m above groundline as well as in the inner and outer zones 1.3 m above groundline tended to be much more variable with no consistent effect of dosage, copper addition or form of dazomet on MITC levels. The results were similar for metam sodium and suggest that the effects of the fumigant are limited to 0 to 0.8 m above the point of application. These results are somewhat at odds with older work suggesting fumigant movement up to 3.0 m above the point of application; however, these results must be viewed with some caution since they used much higher dosages of chemical and used bioassays in place of chemical analysis.

The results indicate that there is little difference in the performance of powdered and rod forms of dazomet.

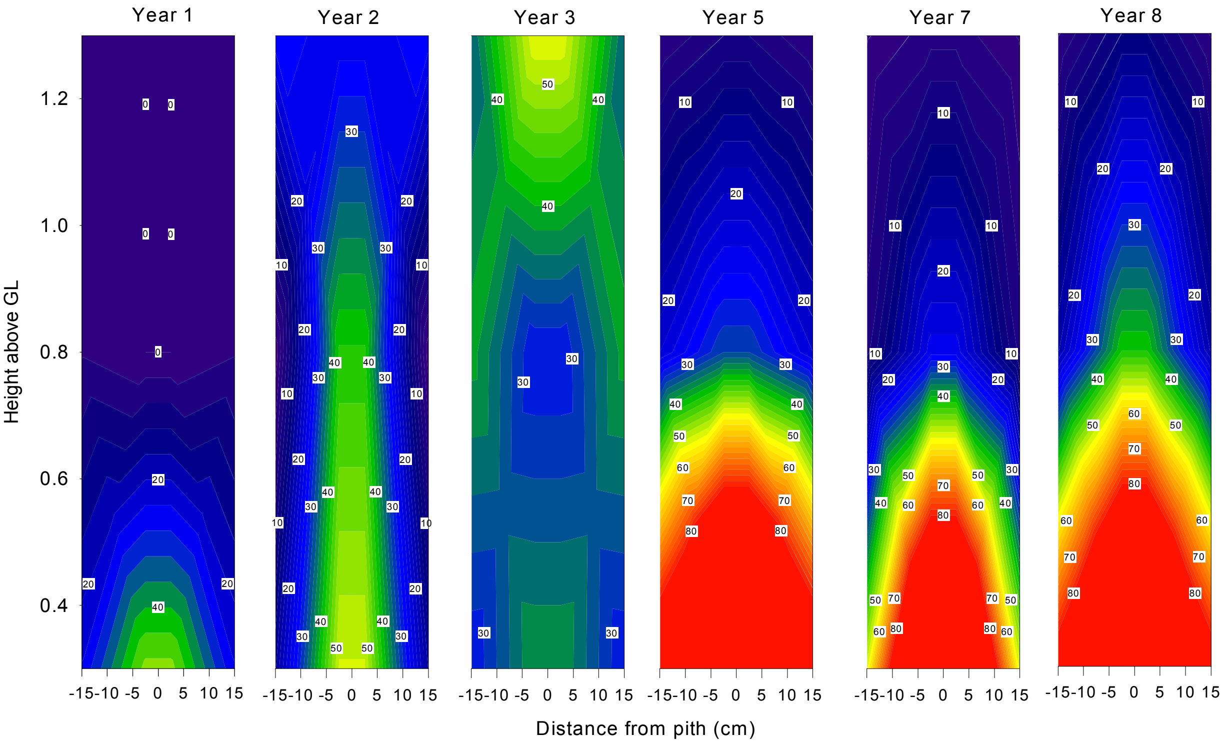


Figure I-7. MITC levels in pentachlorophenol treated Douglas-fir pole stubs 1 to 8 years after treatment with 160 g of powdered dazomet. Dark blue indicates MITC levels below the threshold for fungal attack. Light blue and other colors indicate MITC levels above the lethal threshold.

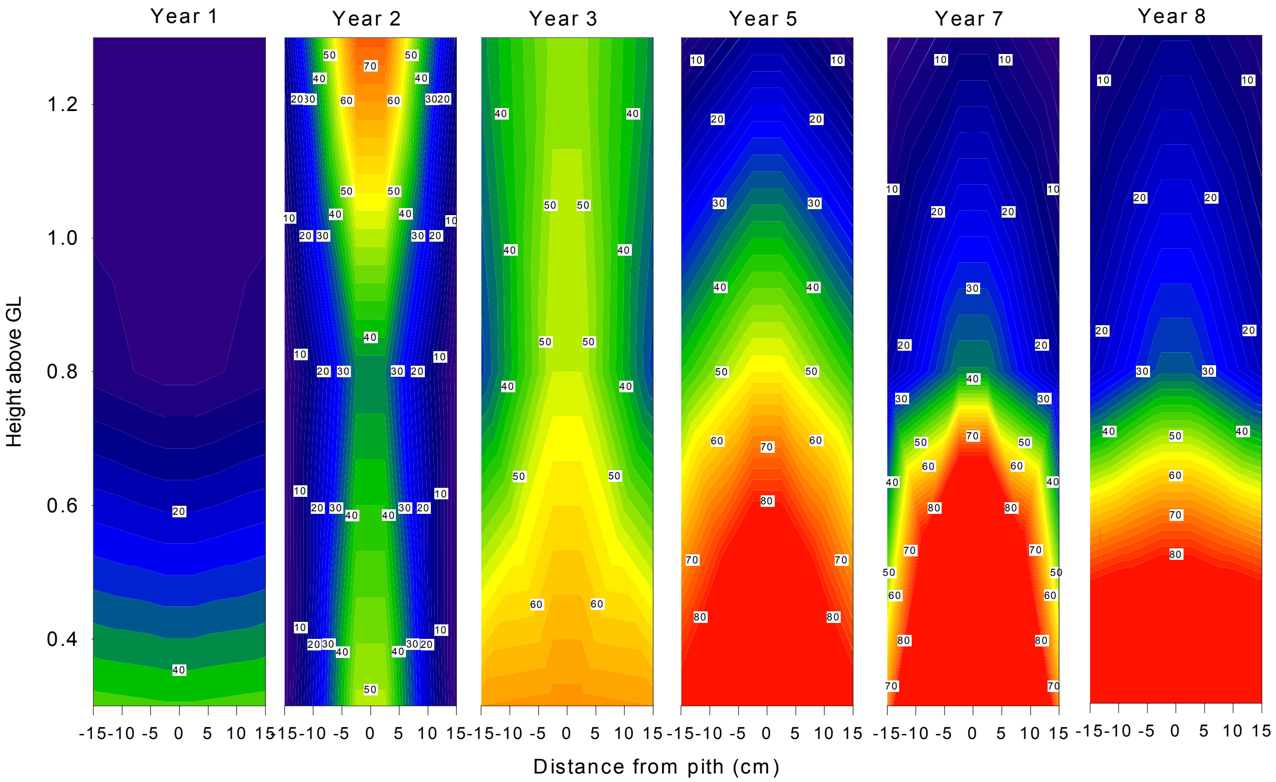


Figure I-8. MITC levels in pentachlorophenol treated Douglas-fir pole stubs 1 to 8 years after treatment with 6 dazomet rods plus 20 g of copper naphthenate. Dark blue indicates MITC levels below the threshold for fungal attack. Light blue and other colors indicate MITC levels above the lethal threshold.

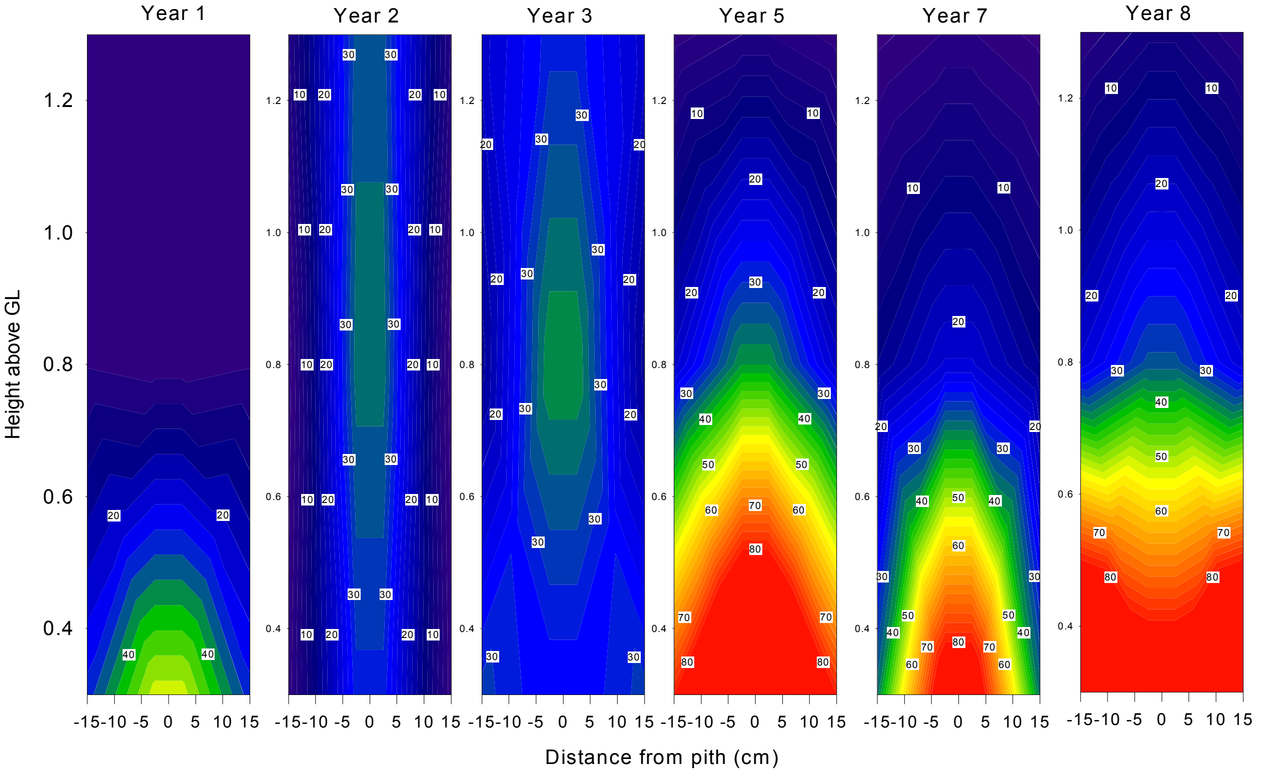


Figure I-9. MITC levels in pentachlorophenol treated Douglas-fir pole stubs 1 to 8 years after treatment with 9 dazomet rods. Dark blue indicates MITC levels below the threshold for fungal attack. Light blue and other colors indicate MITC levels above the lethal threshold.

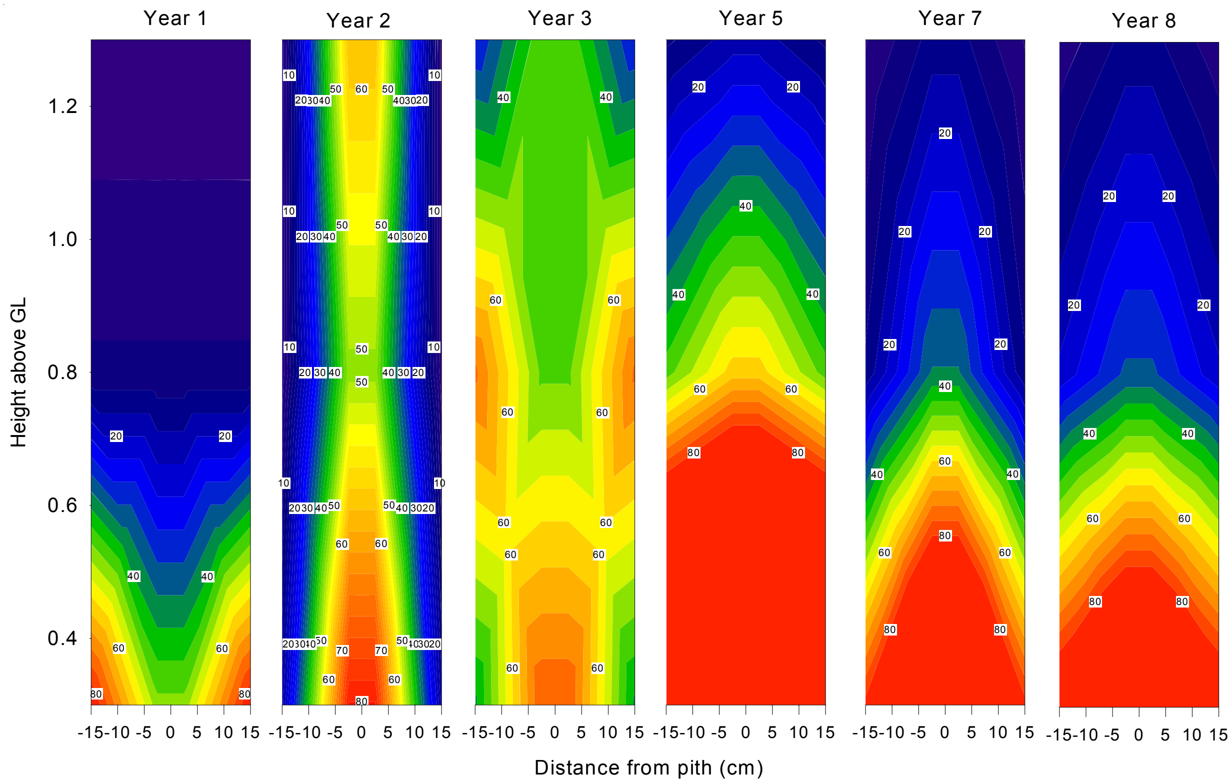


Figure I-10. MITC levels in pentachlorophenol treated Douglas-fir pole stubs 1 to 8 years after treatment with 9 dazomet rods plus 20 g of copper naphthenate. Dark blue indicates MITC levels below the threshold for fungal attack. Light blue and other colors indicate MITC levels above the lethal threshold.

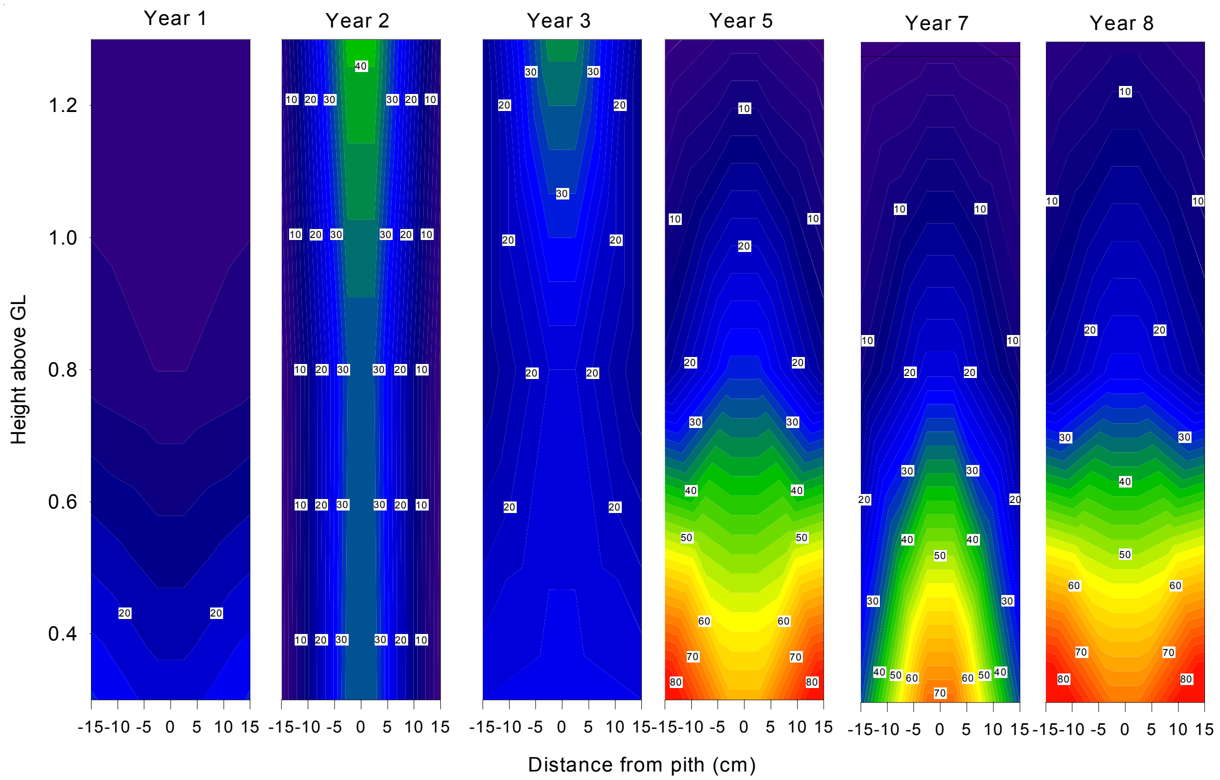


Figure I-11. MITC levels in pentachlorophenol treated Douglas-fir pole stubs 1 to 8 years after treatment with 9 dazomet rods plus 20 g of water. Dark blue indicates MITC levels below the threshold for fungal attack. Light blue and other colors indicate MITC levels above the lethal threshold.

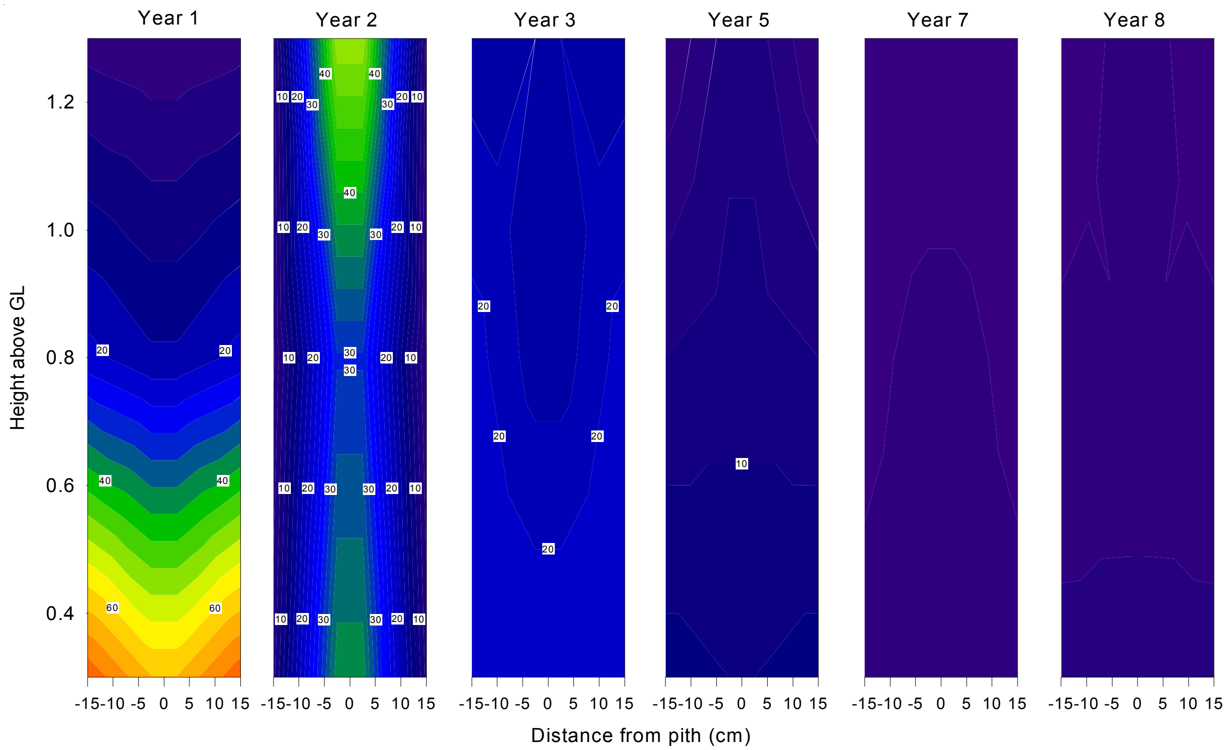


Figure I-12. MITC levels in pentachlorophenol treated Douglas-fir pole stubs 1 to 8 years after treatment with 490 ml of metam sodium. Dark blue indicates MITC levels below the threshold for fungal attack. Light blue and other colors indicate MITC levels above the lethal threshold.

Table I-4. Residual MITC in Douglas-fir pole sections at selected distances above the groundline 1 to 8 years after treatment with dazomet rods or powder alone or amended with copper naphthenate or water compared with MITC levels of metam sodium treated poles.

Treatment	Dosage/ Pole	Supplement/ Hole	Year sampled	Residual MITC (ug/g wood)[a]					
				0.3 m		0.8 m		1.3 m	
				inner	outer	inner	outer	inner	outer
Dazomet Powder	160 g	None	1	**50** (35)	**24** (23)	6 (17)	4 (8)	0 (0)	0 (1)
			2	**52** (70)	16 (55)	**42** (54)	1 (3)	**25** (31)	**27** (41)
			3	**38** (41)	**28** (44)	**28** (28)	**39** (65)	**54** (98)	**34** (51)
			5	**145** (99)	**97** (81)	**32** (19)	**22** (20)	8 (11)	4 (7)
			7	**132** (45)	**53** (49)	**25** (23)	7 (9)	5 (6)	2 (5)
			8	**132** (74)	**88** (52)	**42** (57)	18 (8)	12 (16)	4 6
Dazomet Rods (6)	107 g	6.7 g copper naphthenate	1	**44** (57)	**46** (44)	2 (4)	6 (8)	0 (0)	0 (0)
			2	**51** (70)	0 (2)	**36** (51)	1 (3)	**73** (101)	14 (28)
			3	**67** (81)	**66** (102)	**52** (98)	**31** (46)	**49** (67)	**37** (71)
			5	**118** (53)	**85** (52)	**56** (38)	**42** (73)	16 (11)	5 (11)
			7	**211** (324)	**67** (58)	**36** (18)	17 (11)	11 (10)	2 (4)
			8	**118** (70)	**115** (116)	**33** (12)	20 (9)	14 (7)	6 4
Dazomet Rods (9)	160 g	None	1	**54** (95)	**30** (30)	2 (4)	4 (7)	0 (2)	1 (3)
			2	**29** (37)	3 (6)	**35** (53)	1 (3)	**33** (46)	6 (11)
			3	**26** (36)	**31** (43)	**38** (51)	15 (20)	**29** (34)	**21** (49)
			5	**113** (56)	**80** (66)	**38** (29)	**21** (11)	6 (11)	3 (7)
			7	**91** (63)	**35** (28)	**22** (12)	14 (13)	4 (9)	1 (3)
			8	**93** (47)	**119** (102)	**33** (22)	**22** (15)	9 (12)	4 8
Dazomet Rods (9)	160 g	6.7 g copper naphthenate	1	**49** (63)	**85** (88)	9 (16)	9 (16)	1 (2)	0 (2)
			2	**80** (104)	17 (45)	**49** (64)	4 (9)	**62** (75)	5 (11)
			3	**76** (101)	**39** (53)	**47** (55)	**73** (115)	**47** (52)	**28** (48)
			5	**175** (197)	**159** (139)	**62** (88)	**46** (87)	18 (30)	11 (21)
			7	**125** (70)	**82** (51)	**36** (45)	13 (12)	14 (19)	4 (5)
			8	**114** (81)	**92** (80)	**33** (28)	**21** (15)	13 (17)	5 7
Dazomet Rods (9)	160 g	6.7 g water	1	**22** (21)	**29** (35)	4 (6)	6 (10)	0 (0.0)	1 (2)
			2	**33** (47)	1 (2)	**32** (34)	1 (5)	**41** (41)	6 (11)
			3	**25** (23)	**24** (28)	**22** (31)	14 (26)	**37** (45)	14 (27)
			5	**63** (28)	**87** (104)	**29** (14)	15 (18)	5 (7)	1 (3)
			7	**71** (37)	**32** (29)	**23** (16)	10 (11)	3 (5)	1 (3)
			8	**70** (22)	**89** (74)	**25** (11)	15 (9)	7 (8)	4 6
Metam Sodium	490 ml	None	1	**64** (43)	**75** (73)	17 (18)	**22** (27)	1 (2)	2 (4)
			2	**37** (49)	7 (11)	**30** (27)	4 (7)	**50** (78)	5 (10)
			3	**22** (19)	**22** (22)	17 (18)	**21** (20)	18 (15)	17 (19)
			5	12 (11)	13 (10)	9 (9)	8 (10)	7 (8)	2 (5)
			7	3 (6)	3 (5)	3 (6)	1 (3)	0 0	0 0
			8	5 (8)	5 (7)	2 (4)	2 (4)	3 (6)	0 1

[a] Numbers in parentheses represent one standard deviation.

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

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

This test was not sampled this year and will next be sampled in 2009.

5. Performance of Dazomet in Granular and Tube Formulations

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

Dazomet has been successfully applied for almost 5 years; however, one concern with this system is the risk of spilling the granules during application. In previous tests, we explored the use of dazomet in pellet form, but this does not appear to be a commercially viable product. As an alternative, dazomet could be placed in degradable tubes that contained the chemical prior to application. The tubes would protect the material prior to application, but may also affect subsequent dazomet decomposition and release of methylisothiocyanate. In order to investigate this possibility, the following trial was established.

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

Seventy grams of dazomet was pre-weighed into 125 ml glass or plastic bottles. The contents of one bottle was then applied to each of the three holes in each of 10 poles. The holes in 10 additional poles received a 400 to 450 mm long by 19 mm diameter paper tube containing 60 g of dazomet. The tubes were gently rotated as they were inserted to avoid damage to the paper. The holes in one half of the poles treated with either granular or tubular dazomet were then treated with 10 -12 % (w/w) copper naphthenate (2% metallic copper per hole) in mineral spirits. The holes were plugged with tight fitting plastic plugs. The label states that a solution of 1% copper naphthenate can be added as an accelerant but we used an 18% copper naphthenate solution which is contrary to the label.

One year after the test was installed an additional treatment was added to the study. Two biodegradable perforated plastic-wrapped tubes, each containing 17.1 g of dazomet, were placed into each of three holes in five poles as described above, then supplemental copper naphthenate was added as above. These poles were also sampled in 2008 and the data reported as 1 year results.

MITC distribution was assessed 1 and 2 years after treatment by removing increment cores from three locations around the pole 150 mm below groundline, at groundline as well as 300, 450, 600 and 900 mm above groundline. The outer treated zone was removed and then the inner and outer 25 mm of each core were placed in ethyl acetate, extracted for 48 hours at room temperature and then the core was removed. The extract was analyzed by gas chromatography for MITC.

Traces of MITC (1 ug/g of wood) were detected in some untreated control poles, however, we believe this was due to handling in the lab. The levels were well below the threshold for protection and should not interfere with interpretation of the results (Table I-5).

MITC levels were generally above the threshold within 1 year after treatment 150 mm below ground, at groundline and up to 450 mm above the groundline regardless of formulation or the addition of copper naphthenate as an accelerant. (Figures I-13 to I-15). Chemical levels tended to be higher in the inner zones but the differences were often slight. Chemical levels were more variable 600 mm above groundline, reflecting the distance away from the treatment site. In general, the tube had no noticeable effect on chemical levels. Chemical levels in poles receiving the plastic tube system applied one year after installation of the original system tended to be lower than those for the systems applied a year earlier, but the amount of dazomet applied to each pole was substantially lower with this treatment. MITC levels were still generally above the threshold for protection with the plastic tubes, however.

No decay fungi were isolated from any of the treated poles, suggesting that all of the treatments were effective (Table I-6). Non-decay fungi were isolated from a number of treatments, but there appeared to be no specific pattern to the isolations. We will continue to monitor fungal levels in these poles over the remainder of the test to determine when chemical levels fall below the minimum for fungal growth.

The preliminary results indicate that placing dazomet in paper tubes does not adversely affect release rate into the surrounding wood.

Table I-5. Residual MITC in pentachlorophenol treated Douglas-fir pole sections 1 or 2 years after application of dazomet granules loose or in tubes alone or amended with copper naphthenate.

Treatment	Dosage (g/pole)	Supplement	Years after treatment	Residual MITC (ug/g of wood)[a]											
				-15 cm				0 cm				30 cm			
				Inner		Outer		Inner		Outer		Inner		Outer	
Granular	210	CuNaph	1	**108**	(56)	**53**	(87)	**114**	(66)	19	(23)	**79**	(38)	**45**	(56)
			2	**173**	(225)	**96**	(102)	**131**	(158)	**88**	(62)	**122**	(72)	**56**	(40)
		None	1	**144**	(111)	**48**	(64)	**108**	(49)	15	(24)	**63**	(21)	**32**	(44)
			2	**189**	(241)	**73**	(80)	**119**	(77)	**49**	(49)	**126**	(83)	**33**	(24)
Paper Tube	180	CuNaph	1	**133**	(99)	**66**	(97)	**158**	(111)	**53**	(59)	**81**	(40)	**53**	(59)
			2	**138**	(94)	**103**	(106)	**154**	(166)	**62**	(50)	**135**	(93)	**42**	(34)
		None	1	**108**	(59)	16	(31)	**112**	(108)	**21**	(32)	**72**	(52)	10	(12)
			2	**103**	(104)	**55**	(47)	**117**	(139)	**37**	(23)	**122**	(84)	**34**	(26)
Plastic Tube	103	CuNaph	1	**41**	(73)	16	(25)	**51**	(49)	19	(19)	**47**	(35)	**21**	(36)
Control	0	None	1	0	0	1	(5)	8	(31)	0	0	1	(3)	0	0
			2	0	0	0	0	1	(3)	0	0	0	0	0	0

Treatment	Dosage (g/pole)	Supplement	Years after treatment	Residual MITC (ug/g of wood)[a]											
				45 cm				60 cm				90 cm			
				Inner		Outer		Inner		Outer		Inner		Outer	
Granular	210	CuNaph	1	**47**	(27)	**39**	(33)	**27**	(17)	10	(14)	**21**	(34)	1	(3)
			2	**92**	(58)	**51**	(63)	**109**	(103)	**39**	(35)	**134**	(196)	**64**	(69)
		None	1	**34**	(13)	**27**	(42)	17	(28)	2	(5)	17	(43)	2	(5)
			2	**94**	(115)	**51**	(87)	**167**	(256)	**35**	(40)	**132**	(117)	**55**	(70)
Paper Tube	180	CuNaph	1	**39**	(21)	19	(20)	**22**	(13)	5	(7)	12	(25)	2	(4)
			2	**109**	(84)	**44**	(44)	**118**	(112)	**72**	(114)	**99**	(77)	**54**	(41)
		None	1	**51**	(34)	14	(24)	**20**	(11)	9	(15)	7	(16)	1	(4)
			2	**108**	(163)	**50**	(62)	**103**	(106)	**48**	(69)	**96**	(86)	**48**	(49)
Plastic Tube	103	CuNaph	1	**34**	(44)	17	(27)	**44**	(47)	10	(13)	**74**	(153)	**26**	(41)
Control	0	None	1	0	0	0	0	2	(7)	0	0	0	0	0	0
			2	0	0	0	0	1	(3)	0	0	0	0	0	0

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

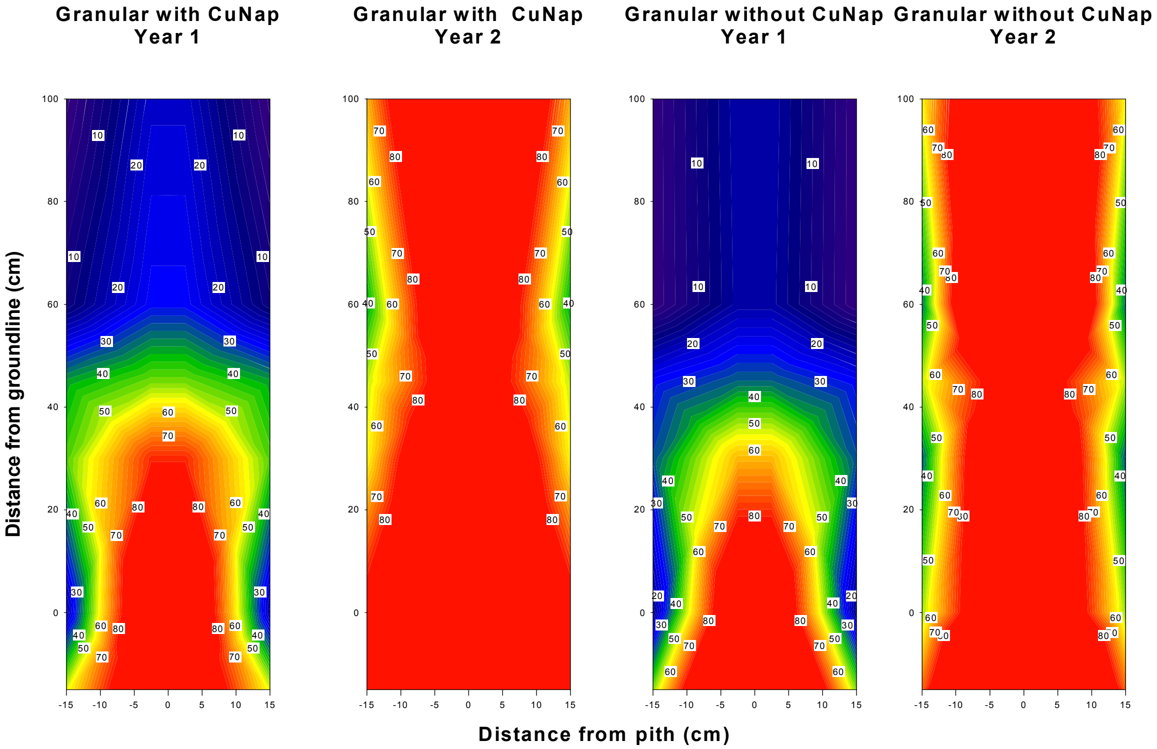


Figure I-13. MITC levels in pentachlorophenol treated Douglas-fir pole sections 1 and 2 years after treatment with granular dazomet with and without copper naphthenate. Dark blue indicates MITC levels below the threshold for fungal attack. Light blue and other colors indicate MITC levels above the lethal threshold.

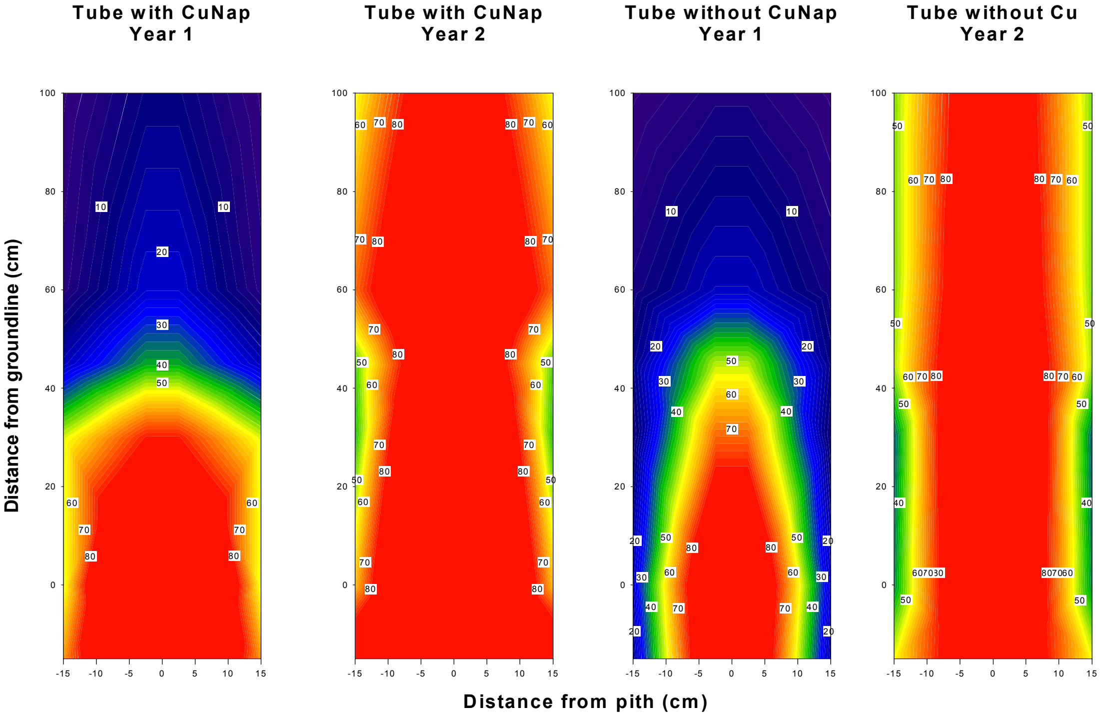


Figure I-14. MITC levels in pentachlorophenol treated Douglas-fir pole sections 1 and 2 years after treatment with granular dazomet in paper tubes with and without copper naphthenate. Dark blue indicates MITC levels below the threshold for fungal attack. Light blue and other colors indicate MITC levels above the lethal threshold.

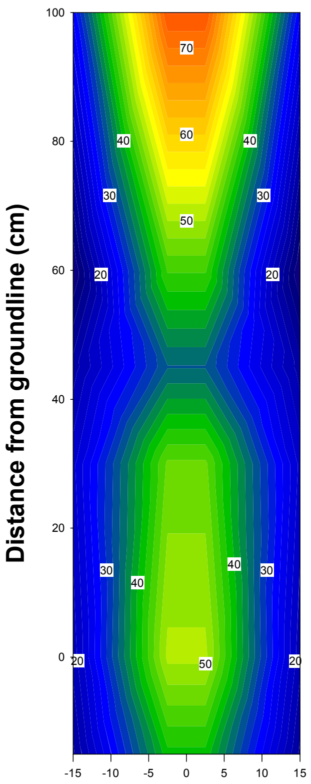


Figure I-15. MITC levels in pentachlorophenol treated Douglas-fir pole sections 1 year after treatment with granular dazomet in perforated plastic tubes plus copper naphthenate. Dark blue indicates MITC levels below the threshold for fungal attack. Light blue and other colors indicate MITC levels above the lethal threshold.

Table I-6. Frequency of isolation of basidiomycetes and non-decay fungi from Douglas-fir poles 1 to 2 years after application of dazomet granules loose or in two types of tubes and with or without copper naphthenate.

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

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

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 boron only or boron plus copper. These rods are produced by heating boron to its molten state, then pouring the molten boron into a mold. The cooled boron rods are easily handled and applied. In theory, the boron is released as the rods come in contact with water.

Fluoride has also been used in a variety of preservative formulations going back to the 1930's when fluor-chrome-arsenic-phenol was employed as an initial treatment. Fluoride, in rod form, has long been used to treat the area under tie plates in railroad tracks and has been used as a dip-diffusion treatment in Europe. Fluoride can be corrosive to metals, although this should not be a problem in the groundline area of a utility pole. 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

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.

This test was not inspected this year and will next be sampled in 2009.

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

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

Thirty pentachlorophenol treated Douglas-fir poles (283-364 mm in diameter by 2 m long) were set to a depth of 0.6 m at the Peavy Arboretum test site. Three 19 mm diameter by 200 mm long holes were drilled perpendicular to the grain beginning at groundline and moving around the pole 120 degrees and upward 15 cm. Each hole received either 1 or 2 boron rods (180 or 360 g of rod, respectively). The holes were then plugged with tight fitting wooden dowels. Each treatment was replicated on 10 poles.

The poles were sampled 1, 3, 4, 5, 7, 10, 12 and 15 years after treatment by removing increment cores from sites located 150 mm below groundline as well as 75, 225, 450, and 600 mm above the groundline. The cores were divided into inner and outer segments which were ground to pass a 20 mesh screen, then extracted and analyzed for boron using the Azomethine H/Carminic Acid method. Boron levels were expressed on a kg/m^3 of boron as boric acid equivalent (BAE). Previous studies in our laboratory indicate that the threshold for protection of Douglas-fir heartwood against internal decay is approximately 0.5 kg/m^3 BAE.

Untreated control poles naturally contained low levels of background boron ranging from 0.01 to 0.11 kg/m^3 (Table I-7). These levels are well below the threshold for protection. Boron levels in the inner zones of

Table I-7 Boron levels in pentachlorophenol treated Douglas-fir pole sections 1 to 15 years after treatment with 180 or 360 g of fused boron rod.

Dosage	Sampling	Core	Boron (kg/m^3 BAE)[a]							
			Year 1	Year 3	Year 4	Year 5	Year 7	Year 10	Year 12	year 15
(g)	Ht (mm)	Section								
180	-150	inner	0.38	**1.81**	**2.39**	**1.85**	**1.54**	**2.16**	**3.33**	**0.50**
180	-150	outer	0.24	0.25	0.49	**1.14**	**0.70**	**1.32**	**0.94**	**0.62**
180	75	inner	**2.82**	**3.75**	**6.02**	**6.40**	**2.05**	**2.83**	**4.65**	**1.25**
180	75	outer	**0.65**	**1.10**	**1.16**	**2.32**	**3.38**	**1.84**	**2.28**	**0.82**
180	225	inner	**0.89**	**3.16**	**2.09**	**2.82**	**1.47**	**0.81**	**0.52**	**0.86**
180	225	outer	**0.98**	**0.58**	0.35	**1.10**	0.31	0.14	**1.70**	**0.96**
180	450	inner	**0.54**	0.22	0.21	0.17	0.15	0.00	0.28	0.05
180	450	outer	0.22	0.20	0.11	0.09	0.12	0.00	0.12	0.07
180	600	inner	0.18	0.24	0.19	0.41	0.08	0.00	0.11	0.02
180	600	outer	0.14	0.09	0.06	0.25	**1.80**	0.00	0.04	0.00
360	-150	inner	0.09	**0.76**	**0.62**	**0.60**	**1.00**	0.09	**1.94**	**2.29**
360	-150	outer	0.07	0.23	0.27	**3.00**	**1.42**	**3.94**	**0.82**	**1.62**
360	75	inner	**0.96**	**10.88**	**7.27**	**12.01**	**3.28**	0.11	**2.77**	**1.56**
360	75	outer	**0.59**	**0.61**	**1.33**	**3.93**	**0.85**	**0.89**	**1.39**	**3.01**
360	225	inner	0.48	**3.21**	**1.35**	**7.30**	**0.95**	**2.27**	**0.81**	**5.23**
360	225	outer	0.13	0.14	0.42	**4.34**	**0.77**	0.07	**3.30**	**2.57**
360	450	inner	0.04	0.11	0.08	**1.24**	0.21	0.00	0.50	**1.20**
360	450	outer	0.02	0.09	0.07	**0.83**	0.17	0.00	0.21	0.12
360	600	inner	0.05	0.39	0.21	0.16	0.10	0.00	0.13	0.27
360	600	outer	0.02	0.09	0.09	0.16	**1.02**	0.00	0.06	0.13
control	-150	inner	0.02	0.09	0.02	0.05	0.06	0.00	0.01	0.00
control	-150	outer	0.02	0.09	0.02	0.07	0.06	0.00	0.00	0.00
control	75	inner	0.02	0.06	0.06	0.03	0.05	0.00	0.02	0.00
control	75	outer	0.02	0.07	0.02	0.02	0.05	0.00	0.02	0.00
control	225	inner	0.01	0.08	0.02	0.05	0.05	0.00	0.05	0.00
control	225	outer	0.01	0.07	0.02	0.03	0.04	0.00	0.01	0.00
control	450	inner	0.03	0.06	0.02	0.03	0.03	0.00	0.04	0.00
control	450	outer	0.02	0.10	0.02	0.02	0.03	0.00	0.06	0.00
control	600	inner	0.02	0.08	0.02	0.27	0.08	0.00	0.06	0.01
control	600	outer	0.01	0.09	0.03	0.11	0.04	0.00	0.02	0.02

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

poles treated with 180 g of boron rod were at or above the threshold 150 mm below ground as well as 75 and 225 mm above the groundline throughout the test (Figure I-16). Levels in these inner zones were still 0.5 to 1.5 kg/m^3 15 years after treatment. Boron is traditionally viewed as extremely water soluble and likely to rapidly diffuse from treated wood in soil contact; however, it is likely that the oil treated shell limited the ability of boron to diffuse outward. Boron levels 450 and 600 mm above groundline were much lower and generally above the protective threshold over the course of the test. These sampling sites were well above the original treatment zone. Given the limited ability of boron to move upward, it is not surprising to see low boron levels in these zones.

Boron levels in the outer zones tended to be more variable 150 mm below ground as well as 75 and 225 mm above ground. These results are consistent with a tendency for the rods to direct chemical towards the pole center though the steeply drilled treatment holes. Despite this variability, boron levels were still above the threshold up to 225 mm above groundline 15 years after treatment.

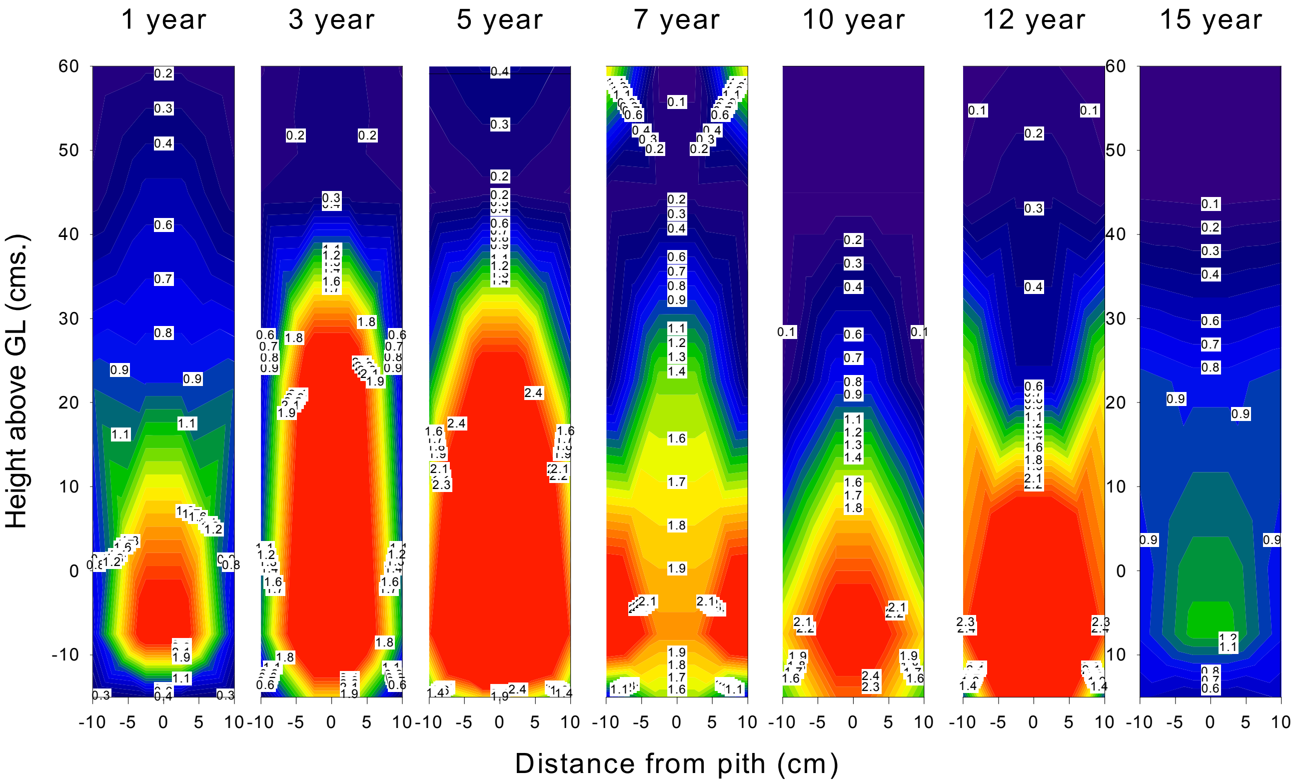


Figure I-16. Boron levels in pentachlorophenol treated Douglas-fir pole sections 1 to 15 years after treatment with 180 g of fused boron rod. Dark blue indicates boron levels below the threshold for fungal attack. Light blue and other colors indicate boron levels above the lethal threshold.

Boron levels in poles treated with 360 g of boron rod followed similar trends to those for the 180 g treatment, although the levels of boron detected were sometimes much greater, particularly in the inner zone 75 mm above groundline (Figure I-17). This area corresponded to the heart of the treated zone. We often observe the absence of dosage effect with boron rods and have attributed this lack of effect of lack of adequate moisture; however, there did appear to be some difference in boron levels between the two dosages 4 and 5 years after treatment. This effect disappeared thereafter.

The results indicate that boron continues to remain in the poles at levels capable of conferring protection against fungal attack 15 years after treatment.

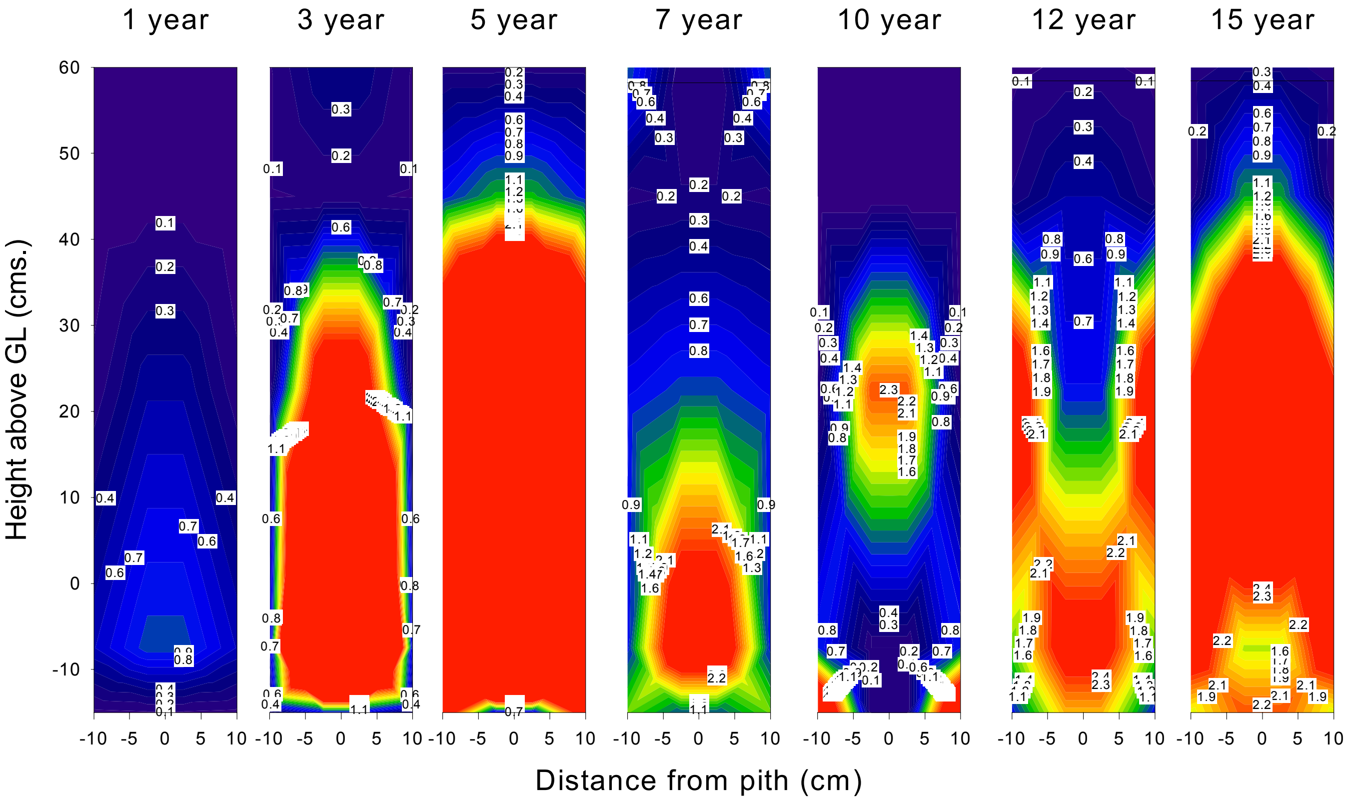


Figure I-17. Boron levels in pentachlorophenol treated Douglas-fir pole sections 1 to 15 years after treatment with 360 g of fused boron rod. Dark blue indicates boron levels below the threshold for fungal attack. Light blue and other colors indicate boron levels above the lethal threshold.

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

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 (260 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 poles were treated with varying levels of boron and glycol mixtures. Boron levels have been assessed over a 10 year period, and will next be sampled in 2010.

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

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 upward 150 mm and around the pole 90 or 120 degrees. A total of 70.5 or 141 g of boron/fluoride rod (3 or 6 rods per pole) was equally distributed among the three holes which were plugged with tight fitting wooden dowels. Each treatment was replicated on five poles.

Chemical movement has assessed 1, 2, 3, 5, 7, 10, 12 and 15 years after treatment 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 extracted in hot water and analyzed for boron content using the Azomethine-H method. In previous years, we have also analyzed the wood for fluoride; however, fluoride levels were extremely low 10 and 12 years after treatment and we saw little value in analyzing for this chemical at the 15 year point.

Boron was naturally present at low levels in non-treated controls, but the levels were at the limit of detection and would have little or no effect on limiting fungal attack (Table I-8). Boron levels in poles receiving three or six of the fluoride/boron rods varied widely. In many cases, boron levels were above the threshold for protection against internal decay 1 to 5 years after treatment in the inner zones, but levels tended to be lower in the outer zones during the same time period. Boron contents were uniformly below the threshold 60 mm above the groundline reflecting both the limiting ability of boron to move upward as well as the relatively small dosages applied to the poles

Hole spacing appeared to have little effect on long term boron distribution except with the 3 rod dosage for the first 5 years where chemical levels tended to be higher in poles using the 3 rod spacing (Figures I-18 to I-21). This effect disappeared, however, after that time suggesting that hole spacing did not markedly affect performance.

While boron levels at 12 years were sometimes elevated and were above the threshold for fungal attack at two locations, boron levels after 15 years were all uniformly low and many were near background levels.

The results indicate that the fluoride/boron rod treatments provided protective levels of boron for 5 to 7 years, and then declined to background levels. This time frame is consistent with their use in Australia where most utilities use a 5 year inspection cycle. The decline in boron levels to below threshold at 7 years does not mean that fungi will instantaneously invade the wood. Recolonization after remedial treatment appears to be a relatively slow process and it is possible that it would take 2 to 3 years for fungi to reinvade the poles. This performance would be similar to that seen with metam sodium where chemical protection is lost after 3 to 5 years, but fungi do not begin to reinvade at appreciable levels for 7 to 10 years.

Table I-8. Boron content at locations above and below the groundline in Douglas-fir poles 1 to 15 years after application of 3 or 6 fluoride/boron rods at 90 or 120 degree spacings.

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

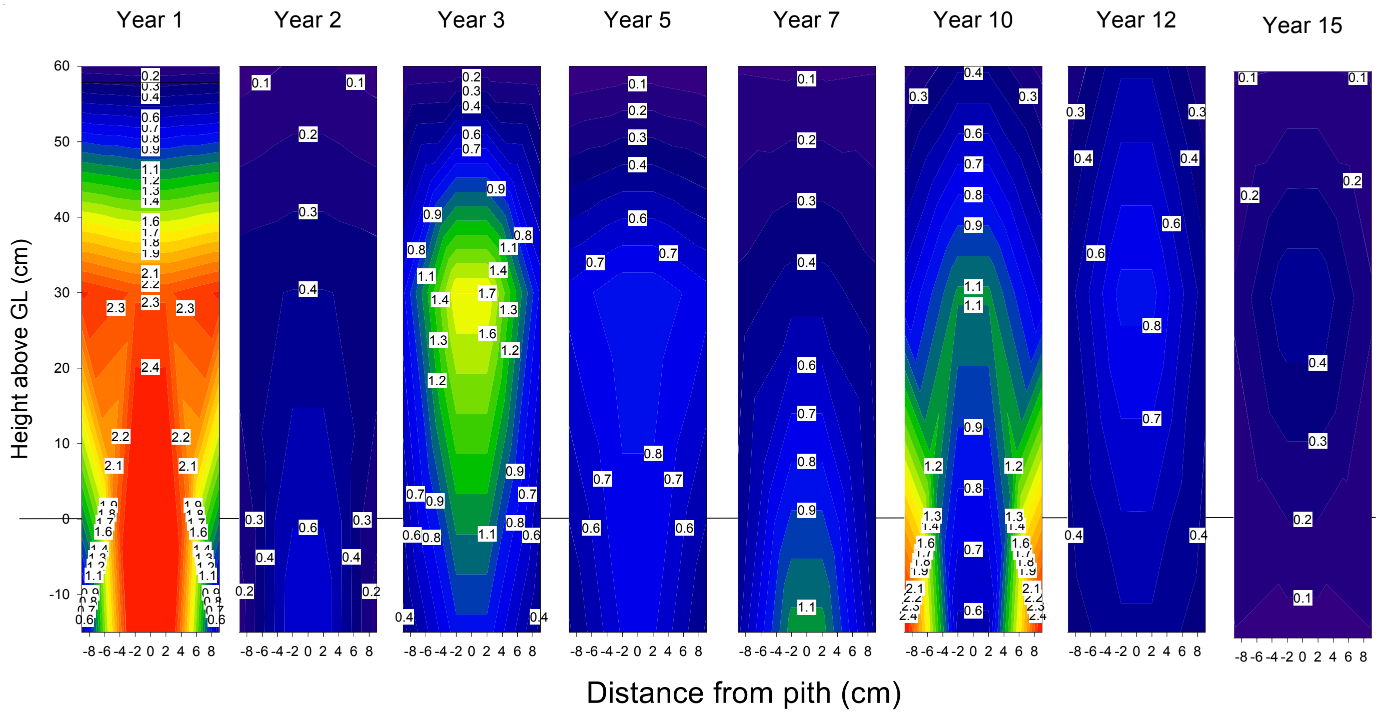


Figure I-18. Boron content in Douglas-fir pole sections 1 to 15 years after treatment with 3 fluoride/boron rods applied to holes at a 90 degree spacing. Dark blue indicates boron levels below the threshold for fungal attack. Light blue and other colors indicate boron levels above the lethal threshold.

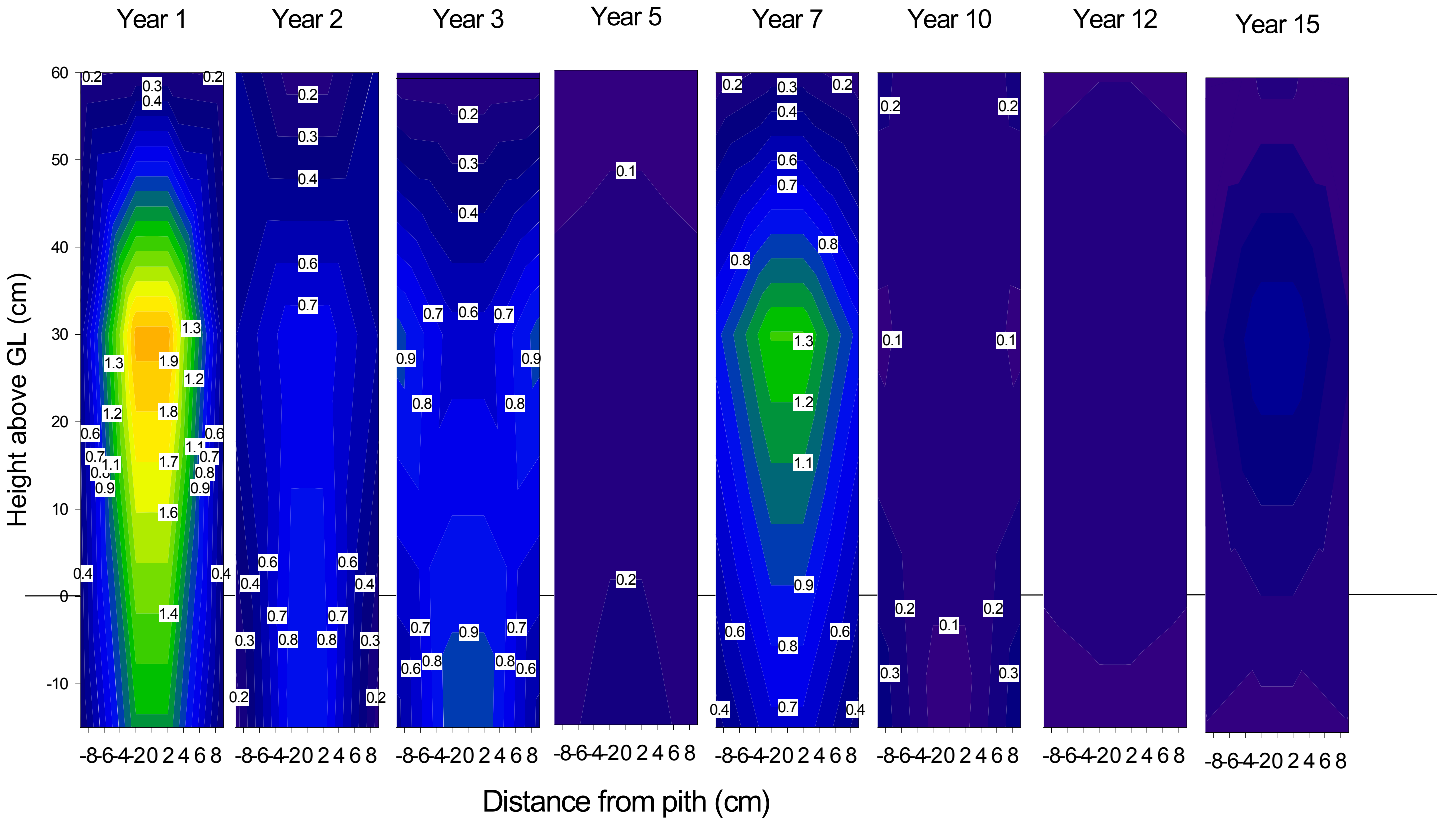


Figure I-19. Boron content in Douglas-fir pole sections 1 to 15 years after treatment with 3 fluoride/boron rods applied to holes at a 120 degree spacing. Dark blue indicates boron levels below the threshold for fungal attack. Light blue and other colors indicate boron levels above the lethal threshold.

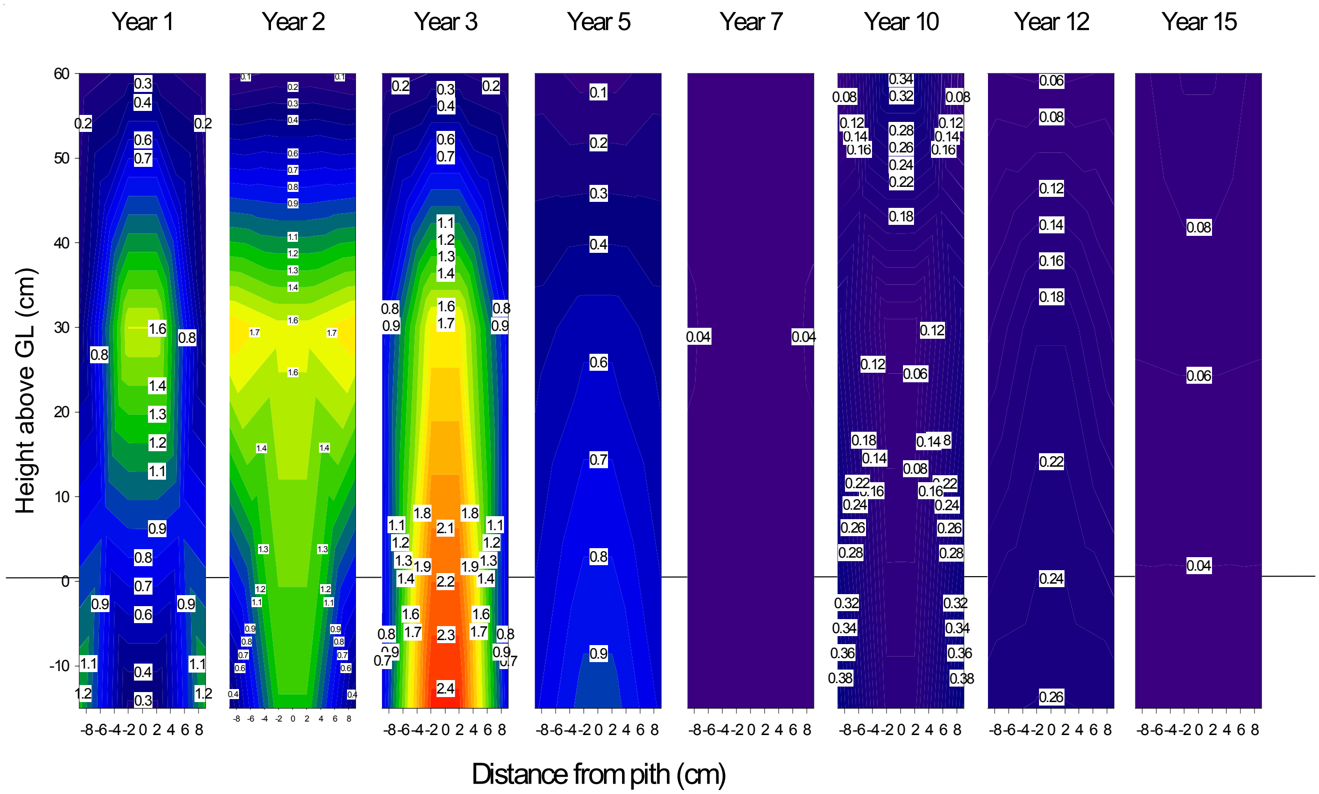


Figure I-20. Boron content in Douglas-fir pole sections 1 to 15 years after treatment with 6 fluoride/boron rods applied to holes at a 90 degree spacing. Dark blue indicates boron levels below the threshold for fungal attack. Light blue and other colors indicate boron levels above the lethal threshold.

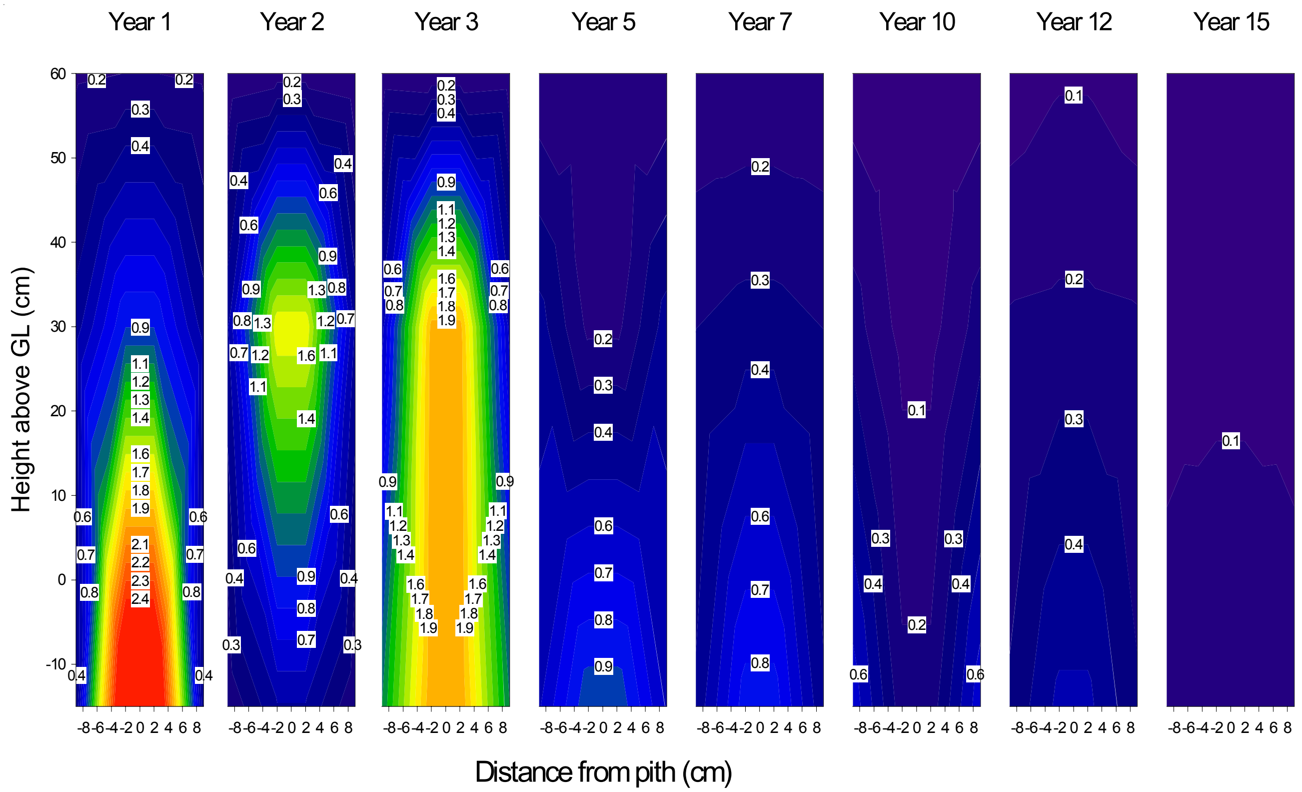


Figure I-21. Boron content in Douglas-fir pole sections 1 to 15 years after treatment with 6 fluoride/boron rods applied to holes at a 120 degree spacing. Dark blue indicates boron levels below the threshold for fungal attack. Light blue and other colors indicate boron levels above the lethal threshold.

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

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 (260-310 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.

The poles were sampled 1, 2, 3, 5, 7, and 10 years after treatment but were not sampled this past year. They are scheduled to be sampled in 2009.

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

Internal decay in large timbers and poles has long been a problem for wood used for utility poles, railroad ties and other structures. Ideally, the decay would be prevented by proper specifications that include pre-treatments to enhance initial wood treatment (Graham, 1983; Morrell, 1996); however, there are vast quantities of materials already in service that are at risk of decay. Arresting the damage once the material is in service poses a major challenge because the heartwood of most wood species is largely resistant to liquid treatment, even under pressure. Globally, two very different approaches have been taken for internal decay control. In North America, fumigants have been the most commonly used treatment for arresting internal decay (Morrell and Corden, 1986). These chemicals are applied as either liquids or solids that then volatilize to move through the wood for 1 to 3 m as gases. While these chemicals have been highly effective, an alternative approach has been employed elsewhere. Boron and fluoride are both water soluble compounds that can move with moisture in wood and systems based on one or both of these diffusible chemicals have been widely used in Europe and Australasia.

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 (Cockcroft and Levy, 1973, Becker, 1976). This chemical has also been used more recently for treatment of lumber in Hawaii to limit attack by the Formosan subterranean termite. Boron is attractive as a preservative because it has exceptionally low toxicity to non-target organisms, especially humans, and because it has the ability to diffuse through wet wood (Smith and Williams, 1967). Boron is available for remedial treatments in a number of forms, but the most popular are fused borate rods which are available as pure boron or boron plus copper. These rods are produced by heating boron to its molten state, then pouring the molten boron into a mold. The cooled boron rods are easily handled and applied. In theory, the boron is released as the rods come in contact with water.

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

Fluoride has also been used for many years in Europe and has seen some use in the United States for treatment of railway ties (Becker, 1973, 1976). Unlike boron, which can be produced in dense, relatively pure rod form, fluoride is usually applied as sodium fluoride in chalk-like rods. As with boron, however, this compound moves relatively well through wet wood of most species.

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

Douglas-fir heartwood blocks (50 by 100 by 150 mm long) were oven-dried (103ºC / 24 hours), weighed and then pressure soaked with water. The blocks were then weighed prior to being air-dried to 30, 60, or 90% moisture content (MC). Once each block achieved its target MC, it was dipped in molten paraffin to retard further moisture loss, and then stored at 5º C to allow for further equilibration.

A 9 mm diameter hole (20 mm deep) was drilled on the narrow face of each block and a single fused borate (6.45 g) rod or fluoride (4.6 g) rod was added. The treatment hole was sealed with duct tape and the blocks were incubated at room temperature for 7, 30, 90 and 180 days. At each time point, six blocks conditioned to a given MC were removed and sections were sawn immediately adjacent (0-5mm) to the original treatment hole as well as at 5-10 mm and 10-20 mm away from the treatment hole (Figure I-22). These sections were immediately weighed, oven dried, and weighed again to determine wood MC. The

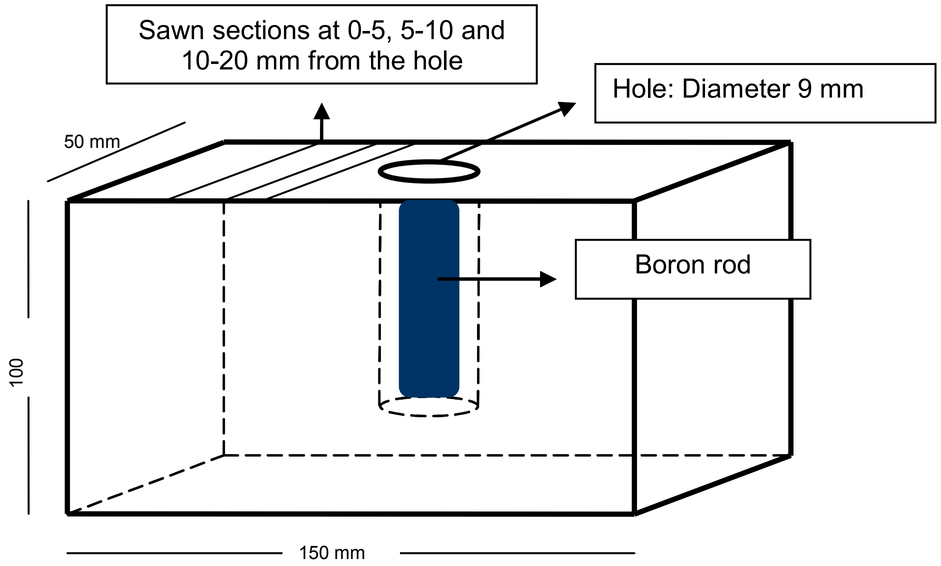


Figure I-22. Representation of a Douglas-fir heartwood block treated with a boron or fluoride rod.

wood was then ground to pass a 20 mesh screen. For wood treated with boron, the sawdust was extracted with hot water. The extract was analyzed for boron using the azomethine / H carminic acid method American Wood Preserves' Association Standard A2 Method 16 (AWPA 2006). Fluoride in fluoride rod treated blocks was analyzed by hot water extraction according to procedures described by Chen et al. (2005). The resulting extract was analyzed using a specific ion electrode according to AWPA Standard A2 Method 7 (AWPA, 2006). The moisture contents of the residual boron or fluoride rods in the treatment hole was also determined by weighing each rod, oven-drying the rod, and then re-weighing.

For the purposes of assessing chemical distribution, the threshold values presumed to be effective against internal decay were 0.050 % for fluoride and 0.098 % boric acid equivalent (BAE) (Freitag and Morrell, 2005).

Moisture contents of the blocks were generally lower than the target levels for all three moisture contents. The differences were slight at 30% MC, but became increasingly larger with higher MCs (Table I-8). Moisture contents immediately adjacent to the treatment hole at the time of cutting (0 days) for the 30, 60 and 90% blocks were 24.7, 49.6 and 79.6%, respectively. Moisture levels tended to be slightly higher 5 to 10 mm from the treatment site, but the differences were slight for the 60 and 90 % MC blocks. Moisture levels immediately adjacent to the treatment hole in the 30% MC blocks at the time of treatment were almost one fourth lower than those 5-10 or 10-20 mm from the surface, suggesting that drilling altered the moisture gradient in these blocks. However, moisture gradients tended to become uniform over time and there was little difference in moisture level 7 days after treatment.

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

Boron contents tended to increase with increasing initial MC as well as with incubation time (Table I-8). Boron levels immediately adjacent to the treatment hole tended to be well above the threshold for protection against internal attack even at 30% MC (Fahlstrom, 1964; Williams and Amburgey, 1987; Freitag and Morrell, 2005). Boron levels were above the threshold at all distances sampled in blocks conditioned to 60 or 90% MC within 7 days after treatment, but remained below threshold 5 to 20 mm away from the treatment site in the 30% MC blocks until the 90 day sampling point. Boron levels tended to follow consistent concentration gradients with distance away from the treatment hole. Chemical levels tended to be consistently higher in 60 and 90% MC blocks. Since free water is necessary for boron diffusion, this would suggest that sufficient moisture was present in the blocks to allow diffusion to occur at some point in the exposure period, even at the lowest moisture level tested. It is also clear that the rods do not sorb excessive moisture to the point where further movement of boron from the rods is inhibited. This finding still leaves us at a loss to explain the lack of a dose response when increasing amounts of boron are used.

Table I-8. Moisture and boron contents at selected locations away from the treatment zone in Douglas-fir blocks conditioned to 30, 60, or 90% moisture content and incubated for 0, 7, 30, 90 or 180 days at ambient temperature.

Incubation Time (days)	Assay Zone (mm)	Boron Content (BAE* %)[a] *Boric Acid Equivalent			Wood Moisture Content (%)		
		30%	60%	90%	30%	60%	90%
7	0-5	**0.94** (0.90)	**8.10** (3.73)	**12.28** (2.83)	25.3	45.2	68.9
	5-10	**0.47** (0.52)	**2.49** (2.55)	**5.25** (3.83)	23.7	38.3	60.8
	10-20	**0.15** (0.26)	**0.78** (0.22)	**2.45** (1.28)	24.2	42.2	62.0
30	0-5	**0.45** (0.27)	**4.70** (2.80)	**6.22** (4.55)	20.7	32.2	69.1
	5-10	**0.13** (0.08)	**2.38** (1.55)	**5.42** (3.20)	20.9	29.9	68.4
	10-20	0.04 (0.02)	**0.91** (0.86)	**3.47** (2.31)	21.8	31.1	70.3
90	0-5	**2.68** (4.42)	**9.19** (6.04)	**10.97** (3.13)	18.2	17.0	46.8
	5-10	**1.92** (4.08)	**4.33** (1.83)	**9.19** (2.61)	18.4	16.0	44.3
	10-20	**1.15** (2.63)	**1.46** (0.52)	**5.07** (1.72)	21.1	18.9	50.9
180	0-5	**0.90** (0.70)	**7.72** (4.07)	**8.39** (2.81)	16.3	14.6	56.1
	5-10	**0.51** (0.63)	**4.98** (2.67)	**6.94** (1.13)	14.9	14.1	55.1
	10-20	**0.09** (0.06)	**2.13** (1.59)	**4.44** (2.18)	16.9	14.5	53.3

[a] Values represent means of six blocks per time/moisture content. Boron values in bold fonts exceed the minimum threshold for protection against internal decay. Numbers in parentheses represent one standard deviation.

The moisture contents of the boron rods tended to increase over time after application to the wood (Table I-9). Rods in 60 and 90% MC blocks could not be removed after 90 and 30 days, respectively, because they had sorbed moisture to the point where they crumbled when touched. Clearly, the rods had sorbed moisture from the surrounding wood, but the overall effect on wood moisture content was negligible, even immediately adjacent to the hole.

Table I-9. Moisture content of fused boron rods inserted into holes in Douglas-fir blocks conditioned to 30, 60 or 90 % moisture content and incubated for 7 to 180 days.

Wood MC (%)	Boron Rod Moisture Content (%)			
	7 Days	30 Days	90 Days	180 Days
30	3.5	4.2	5.9	10.6
60	6.1	22.5	N/A	N/A
90	3.6	N/A	N/A	N/A

Fluoride levels in blocks at the various moisture contents were consistently lower than those found with boron (Table I-10). These lower levels reflect, in part, the lower initial dosage applied to the blocks. Fluoride levels in blocks at 30 % moisture content remained extremely low over the entire 180 day incubation period, even immediately adjacent to the treatment hole. Fluoride levels increased slightly in blocks at 60 % moisture content, but there appeared to be little difference in fluoride level with distance from the treatment site 90 or 120 days after treatment. Fluoride levels did appear to be much higher in blocks at 90 % moisture content and the levels rose steadily with incubation time. Fluoride levels, however, tended to show little evidence of a concentration gradient from highest near the treatment site to lowest further away.

Table I-10. Fluoride levels and final wood moisture contents in Douglas-fir heartwood blocks conditioned to 30, 60 or 90 % moisture content, then treated with a fluoride rod and incubated for 7 to 180 days.

Incubation time (days)	Assay zone (mm)	Fluoride content (%)						Wood moisture content (%)		
		30		60		90		30	60	90
7	0-5	0.03	(0.01)	**0.05**	(0.02)	0.05	(0.02)	25.7	43.7	68.7
	5-10	0.01	(0.01)	0.04	(0.02)	0.04	(0.01)	26.4	47.0	74.7
	10-20	0.01	(0.01)	0.03	(0.01)	0.04	(0.01)	27.7	48.6	80.0
30	0-5	0.02	(0.01)	**0.11**	(0.03)	**0.15**	(0.08)	23.2	31.9	69.9
	5-10	0.01	(0.01)	**0.08**	(0.03)	**0.13**	(0.06)	22.9	31.9	73.5
	10-20	0.01	(0.00)	**0.06**	(0.02)	**0.11**	(0.05)	23.9	34.7	77.9
60	0-5	0.01	(0.01)	**0.05**	(0.01)	**0.14**	(0.07)	17.6	16.4	61.3
	5-10	0.01	(0.00)	**0.05**	(0.01)	**0.15**	(0.07)	17.5	16.4	63.4
	10-20	0.00	(0.00)	0.04	(0.01)	**0.17**	(0.06)	19.7	19.2	70.7
120	0-5	0.02	(0.00)	**0.06**	(0.02)	**0.24**	(0.07)	15.5	13.5	47.5
	5-10	0.01	(0.00)	**0.06**	(0.02)	**0.32**	(0.11)	15.3	13.2	49.7
	10-20	0.01	(0.00)	0.05	(0.02)	**0.31**	(0.09)	15.6	14.0	51.6

[a] Values in bold are at or above the 0.05 % wt/wt threshold level for protection against internal fungal attack.

The reasons for this are unclear, although rod moisture contents might have influenced movement. Moisture contents of rods in blocks at 30 % moisture content were highest 7 days after treatment then declined with incubation period (Table I-11). Rods in blocks at 60 % MC followed similar trends, but they reached higher initial moisture loadings and contained much less moisture at the end of the test. Moisture levels were generally low in rods in blocks conditioned to 30 or 60 % moisture content, suggesting that moisture was not selectively sorbed by the rods in these materials. Moisture contents of rods in blocks at 90 % MC experienced steady increases over time, suggesting that moisture levels in the wood were not limiting in these blocks at the end of the test. The moisture behavior in fluoride rods differed markedly from that found with boron at the two lower moisture regimes although there was no apparent reason for any difference.

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

Table I-11. Moisture contents of fluoride rods 7 to 180 days after being inserted into holes drilled in Douglas-fir blocks conditioned to selected wood moisture contents.

Wood MC (%)	Fluoride Rod Moisture Content (%)[a]			
	7 days	30 days	60 days	90 days
30	3.8	3.2	1.3	0.6
60	5.3	5.8	0.2	<0.03
90	5.8	6.3	8.8	11.4

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

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

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

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

Pentachlorophenol treated Douglas-fir pole stubs (280-300 mm in diameter by 2.1 m long) were set to a depth of 0.6 m. Three or four (for fumigant treatments) steeply sloping treatment holes (19 mm x 350 mm long) were drilled into the poles beginning at groundline and moving upward 150 mm and around the pole 120 degrees. In some cases the holes were drilled too deep and the auger emerged from the opposite side of the pole. These poles were removed from the study and other poles were substituted. The various remedial treatments were added to the holes at the recommended dosage for poles of this diameter, along with any recommended additive, and then the holes were plugged with plastic plugs. Each treatment was replicated on five poles.

The proposed treatments include:

MITC- FUME
Chloropicrin
DuraFume
SuperFume
Ultra Fume
SMDC-Fume
Wood Fume
Pol Fume
Dazomet
Impel rods
FLURODS
Dazomet rods
PoleSaver rods
Control

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

The poles were treated in the spring of 2008 and will be inspected in the spring of 2009. The one year results will be reported in the 2009 Annual Report.

D. Effect of Voids on Movement of Remedial Treatments in Above-ground Locations of Douglas-fir Poles

Voids in poles pose an especially vexing problem to utilities. While large voids can generally be detected using conventional sound and bore techniques, arresting existing fungal attack and preventing renewed colonization can be difficult. This is particularly true when cavities are located some distance above the groundline. In most cases the void is connected to the surface through a check. As a result, the application of traditional internal liquid void treatments could result in chemical exposure to the applicator as well as contamination of the area surrounding the pole.

One alternative to the traditional liquid internal treatments is to apply either water or gas diffusible internal remedial treatments above and/or below the void and allow these materials to diffuse across the void. This reduces the risk of environmental contamination or worker exposure.

In previous trials, we created simulated voids in Douglas-fir pole sections and then treated below the voids with either MITC or chloropicrin. The results showed that both chemicals were capable of diffusing across the void at levels that would produce effective fungal control. While these data were promising, they were also criticized because they were not produced using natural voids. Efforts to locate test poles with suitable voids have proven difficult, owing to the inability to accurately assess the size of the void without extensive sampling that could alter subsequent chemical movement. In 2001, we obtained poles from the Portland General Electric system that had been removed from service. We used these poles to determine if sufficient moisture is present in the above-ground portions of Douglas-fir poles to allow for boron, fluoride, or copper diffusion or dazomet decomposition to methylisothiocyanate.

Twenty one Douglas-fir poles, two western redcedar poles, and one ponderosa pine pole in the Portland General Electric system were inspected. Six were found to have substantial above-ground decay pockets. Each pole was cut to a length of approximately 8 m and removed from the ground for transport to a site near Salem, Oregon.

While on the ground, each pole was thoroughly inspected to characterize the location and size of the void. The poles were divided into four groups of six poles each. Each group contained at least one pole with a void. The poles in each group were treated with three rods applied to three 20 mm diameter holes drilled above and below the void. Each pole received three rods applied to three horizontal holes drilled around the pole at the top and bottom of the void, or if no void was detected, the three holes were drilled 1 m apart. The materials evaluated were fused borate rods (Impel Rods), copper/boron rods (Cobra Rods), fluoride rods (FLURODS) and dazomet (Ultra Fume).

After treating, the poles were set in a spacing that permitted easy access around each pole. Two poles from each treatment group were removed 12 and 24 months after treatment. The treated section was cut from the pole and split lengthwise with wedges. Seven years after treatment the remaining poles were removed and each treated pole section was cut lengthwise with a portable band saw.

Each exposed pole surface was then sprayed with the appropriate indicator. Poles treated with the copper/boron rods had one exposed face sprayed with chrome azurol S, a copper indicator and the other with the boron indicator. The sprayed surfaces were photographed. Then the percentage of area between the two sets of treatment holes stained by the indicator was measured by counting squares in a 2.5 cm grid.

Poles treated with dazomet were sampled by removing increment cores from three equidistant locations around each pole 300 mm above and below the two treatment sites. The outer, treated shell was discarded, then the inner and outer 25 mm of the remaining core was placed into individual tubes containing 5 ml of ethyl acetate, and extracted for 48 hours. The resulting extract was analyzed for MITC by gas chromatography since there is no indicator for MITC. The extracted cores were oven-dried and weighed. MITC content in the poles was expressed on a ug MITC/oven-dried g of wood basis.

The first 6 months of the exposure were during the drier summer months when very little movement of chemical would be likely to occur. The remainder of the first year of exposure was an average rainfall period at the test site and we have continued to receive normal rainfall levels since that time. Although prior examination of the rods indicates that the materials have begun to diffuse into the wood, the percentage of pole area occupied by the chemicals remained limited 2 years after treatment. For example, boron was only detectable in 12 to 17 % of the area in poles treated with either the boron or copper/boron rods, respectively (Table I-12). Similarly, fluoride was only detectable in 2 to 8 % of the area in poles treated at the same time with the fluoride rods. Interestingly, copper was detectable in 7 to 20 % of the area treated with the copper/boron rod, a finding that contradicts copper analyses of poles treated with this formulation closer to the groundline (See Objective IV).

The analysis of samples removed 7 years after treatment showed that fluoride was present in 10 to 20 % of the section, representing a slight increase over the 2 year results. Boron levels ranged from 7 to 13 % of the surface area. These levels were similar to those found after 2 years for the Impel rods but slightly lower for the Cobra rods. The differences, however, remain slight.

Table I-12. Effect of voids on distribution of boron, fluoride or copper on exposed longitudinal sections cut from poles treated with various internal preservative rods.

Rod Treatment	Degree of Treatment (% of Area)								
	Year 1			Year 2			Year 7		
	Fluoride	Boron	Copper	Fluoride	Boron	Copper	Fluoride	Boron	Copper
Boron Impel	-	38	-	-	12	-	-	12	-
Boron Impel	-	50	-	-	12	-	-	13	-
Cobra	-	50	24	-	15	7	-	7	1
Cobra	-	28	33	-	17	20	-	8	1
FLUROD	44	-	-	8	-	-	10	-	-
FLUROD	3	-	-	2	-	-	20	-	-

MITC analysis of cores revealed that dazomet-treated poles had fungitoxic levels in the inner zones 1 year after treatment, but these levels had declined below the threshold 2 years after treatment (Table I-13). MITC was detectable in the other zones of the poles, but the levels were lower. Analysis of cores removed 7 years after treatment revealed that fungitoxic levels were still present in the inner zone of the cores removed 300 mm below the void. The remaining analysis indicated low levels of MITC, 0 to 6.1 ug/g of wood which would be too low to afford protection against renewed fungal attack.

The overall results still show that the rod treatments do not become uniformly distributed in the poles when applied above the groundline. The more variable distribution of moisture in these regions of the poles probably plays a major factor in this distribution. It may be possible that the chemical distribution coincides with the available moisture, which would also overlap with the areas where fungi might grow. If so, these treatments could still be effective in these above ground locations; however, we will need a much better understanding of seasonal moisture levels in poles before we could support this premise.

Table I-13. Effect of voids on distribution of methylisothiocyanate (MITC) content in Douglas-fir poles 1 to 7 years after treatment with dazomet.

Sampling Height (cm)	Residual MITC Content (ug/g of wood)					
	Year 1		Year 2		Year 7	
	inner	outer	inner	outer	inner	outer
-30	31.2 (25.1)	10.4 (17.2)	0	10.5 (25.6)	23.8 (26.5)	12.5 (17.0)
+30	31.5 (28.4)	8.9 (10.3)	3.6 (5.6)	18.5 (34.6)	3.9 (7.6)	6.0 (7.0)
+60	n/a	n/a	6.7 (7.4)	10.6 (15.3)	0	1.3 (3.2)
+120	n/a	n/a	6.8 (10.8)	10.1 (18.3)	6.1 (7.3)	0.9 (2.3)

LITERATURE CITED

American National Standards Institute (ANSI). 1995. ANSI Standard for wood poles. Specifications and dimensions. ANSI 05.1. ANSI, New York, NY. 126 pages.

American Wood Preservers Association. 2002. Standard C4-99. Poles: preservative treatment by pressure processes. In: AWPA Book of Standards. Granbury, TX.

American Wood Preservers' Association (AWPA). 2004. Standard A2. Analysis of waterborne preservatives and fire-retardant formulations. Method 16. Determination of boron in treated wood- using Azomethine H or carminic acid. In: AWPA Book of Standard, Selma, Alabama. Pages 241-243.

American Wood Preservers' Association (AWPA). 2006. Standard A2. Analysis of waterborne preservatives and fire-retardant formulations. Method 7. Determination of fluoride in wood and solutions. In: AWPA Book of Standard, Selma, Alabama. Pages 236-237.

Becker, G. 1976. Treatment of wood by diffusion of salts. International Research Group on Wood Preservation. Documents No. IRG/WP/358. Stockholm, Sweden.

Brooks, K.M. 1997. Literature review and assessment of the environmental risks associated with the use of ACZA treated wood products in aquatic environments. Western Wood Preservers Institute Vancouver, WA. 99 pages.

Becker, 1973. Fluorine compounds for wood preservation. J. Institute WoodScience 6(2):51-62.

Chen, H., R. Rhatigan, and J.J. Morrell. 2003. A rapid method for fluoride analysis of treated wood. Forest Products Journal 53(5):43-45.

Cockcroft, R. and J.F.Levy. 1973. Bibliography on the use of boron compounds in the preservation of wood. J. Institute of Wood Science 6(3):28-37.

Dickinson, D.J., P.I. Morris, and B. Calver. 1988. The secondary treatment of creosoted electricity poles with fused boron rods. International Research Group on Wood Preservation document No. IRG/WP/3485. Stockholm, Sweden. 3 pages.

Dietz, M.G. and E.L. Schmidt. 1988. Fused borate and bifluoride remedial treatments for controlling decay in window millwork. Forest Products Journal 38 (5):9-14.

Dirol, D. 1988. Borate diffusion in wood from rods and a liquid product: application to laminated beams. International Research Group on Wood Preservation document No. IRG/WP/3482. Stockholm, Sweden. 11 pages.

Edlund, M.L., B. Henningsson, A. Kaarik, and P.-E. Dicker. 1983. A chemical and mycological evaluation of fused borate rods and a boron/glycol solution for remedial treatment of window joinery. International Research Group on Wood Preservation document No. IRG/WP/3225. Stockholm, Sweden. 36 pages.

Morrell, J.J. 1996. Wood Pole Maintenance Manual: A guide to specification, inspection and maintenance. Research Contribution 14, Forest Research Laboratory, Oregon State University, Corvallis, Oregon.

Morrell, J.J. and M.E. Corden. 1986. Controlling wood deterioration with fumigant: a review. Forest Products Journal 36(10):26-34.

Morrell, J.J., M.A. Newbill, and C.M. Sexton. 1992. Remedial treatment of Douglas-fir and southern pine poles with methylisothiocyanate. Forest Products Journal 42(10):47-54.

Morrell, J.J., C.M. Sexton, and K. Archer. 1992. Diffusion of boron through selected wood species following application of fused borate rods. Forest Products Journal 42(7/8):41-44.

Morrell, J.J., C.M. Sexton, and A.F. Preston. 1990. Effect of wood moisture content on diffusion of boron from fused borate rods. Forest Products Journal 40(4):37-40.

Morrell, J.J. and P.F. Schneider. 1995. Performance of boron and fluoride based rods as remedial treatments in Douglas-fir poles. International Research Group on Wood Preservation Document No. IRG/WP/95-30070. Stockholm, Sweden. 11 pages.

Ruddick, J.N.R. and A.W. Kundzewicz. 1992. The effectiveness of fused borate rods in preventing or eliminating decay in ponderosa pine and Douglas-fir. Forest Products Journal 42(9):42-46.

Schneider, P.F., M.A. Newbill, and J.J. Morrell. 1993. Protection of pile tops using combinations of internal treatments and water-shedding caps. Document No. IRG/WP/93-30020. Stockholm, Sweden. 6 pp.

Smith, D. and A.I. Williams. 1967. Wood preservation by the boron diffusion process- the effect of moisture content on diffusion time. J. Institute of Wood Science 4(6):3-10.

Williams, L.T. and T.L.Amburgey. 1987. Integrated protection against Lyctid beetle infestations. IV. Resistance of boron treated wood (*Virola* spp) to insect and fungal attack. Forest Products Journal 37(2):10-17.

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

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

A. Evaluate Treatments for Protecting Field Drilled Bolt Holes

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

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.

The previous results have shown that the paste components move for short distances away from the bolts. We are still assessing the actual degree of penetration required for protection of field drilled holes; however, we suspect that a high degree of movement may not be necessary to protect the surface from spores or hyphae that enter into the hole. We have one set of these pole sections still in test and decided to skip sampling this year. We also have the bolts from last year’s samples and intend to assess the extent of corrosion.

Literature Cited

American Wood Protection Association. 2006. AWPA Standard A3 Standard methods for determining penetration of preservatives and fire retardants. Method 1. Method for determining penetration of boron-containing preservatives and fire retardants. AWPA Book of Standards, AWPA, Selma, Alabama.

American Wood Protection Association. 2006. AWPA Standard A3 Standard methods for determining penetration of preservatives and fire retardants. Method 2. Method for determining penetration of copper containing preservatives. AWPA Book of Standards, AWPA, Selma, Alabama.

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

Objective III

EVALUATE PROPERTIES AND DEVELOP IMPROVED SPECIFICATIONS FOR WOOD POLES

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

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

Over the past 4 years, we have performed an extensive series of laboratory and field trials to assess the effects of through-boring in the groundline on the properties of Douglas-fir poles. These studies have shown that through-boring with holes less than or equal to 0.5 inch (12.5 mm) in diameter has no significant negative effect on pole bending strength. This past year, we assembled all of the available data on through-boring and its effect on strength and submitted this information to the American National Standards Institute Sub-committee 05.1. In addition, we worked with Bonneville Power Administration, Southern California Edison, Portland General Electric and McFarland-Cascade to identify a single pattern that could be included in an ANSI standard.

The resulting pattern takes advantage of the information produced in the finite element analysis to move holes a minimum of 2 inches (50 mm) inward from the hole edge and uses the spacing patterns identified in both the finite element modeling and the subsequent field tests with a 0.5 inch (12.5 mm) diameter hole size (Figure III-1).

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

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

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

Through-boring Region: Pole shall be through-bored a minimum of 2 feet (0.6 m) above and below the expected groundline. This zone can be extended either up or downward depending on the decay risks. Zones extend downward up to 4 feet (1.2 m) below groundline in drier areas and upward 3 to 4 feet (1 to 1.2 m) in wetter areas.

Hole Size: Extensive testing has shown that hole sizes up to 0.5 inch (12.5 mm) in diameter can be used with no significant effect on pole bending strength. While smaller diameter holes can be used, they tend to lead to bit breakage and slower drilling.

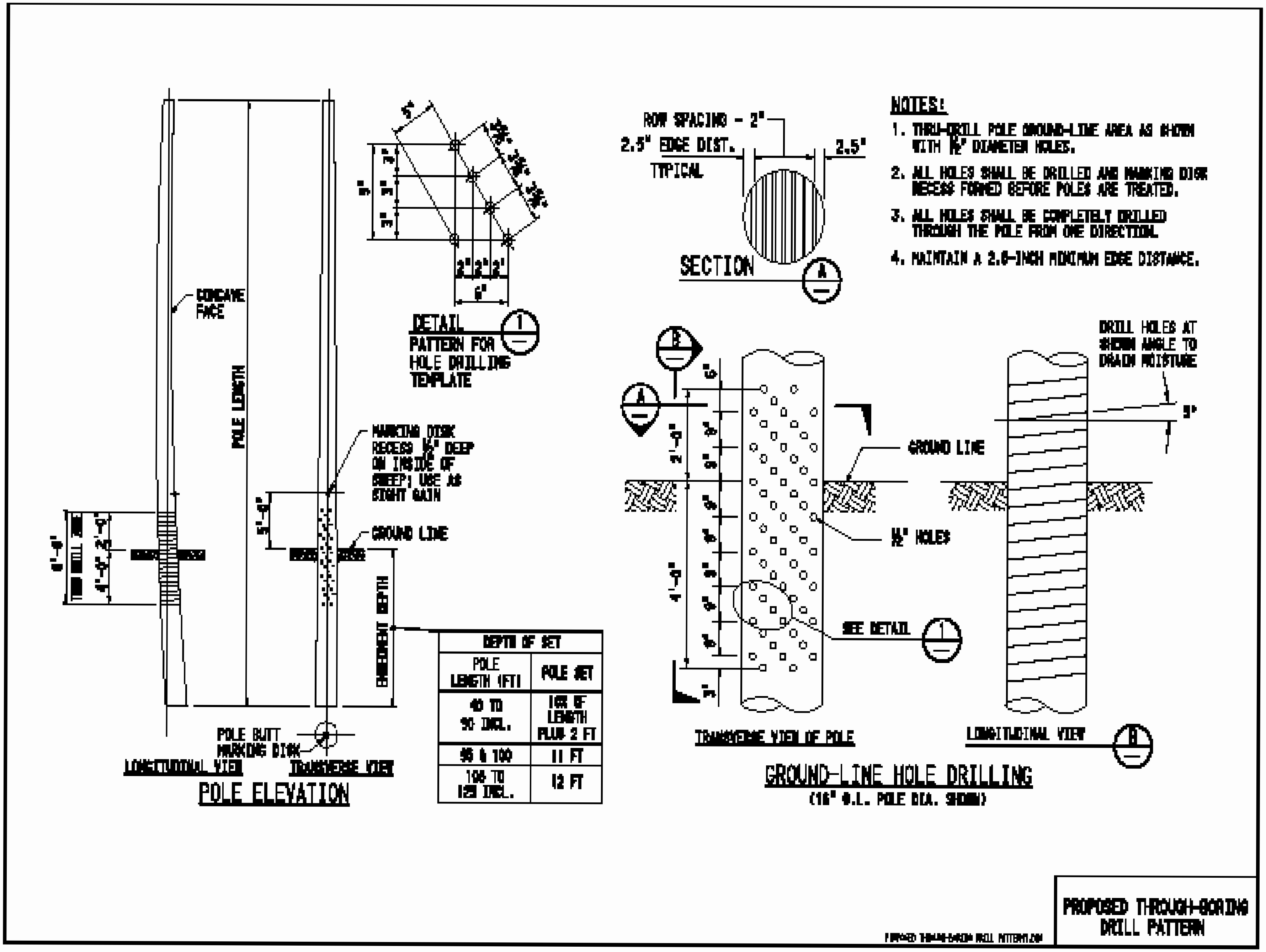


Figure III-1. Proposed pattern for through-boring of Douglas-fir poles.

Hole Locations: Holes shall be drilled on the pole face intended to be in the line direction. As shown in Figure III-1, holes shall be at least 2 inches (50 mm) inward from either edge of the pole. Holes shall be drilled with a slight downward slope to allow for drainage (3 to 5 degrees).

Treatment: The results of treatment shall be assessed by taking an increment core from the zone between two longitudinally spaced holes. Preservative penetration shall be assessed visually or by using the appropriate indicator. Penetration must be complete in the outer 2 inches (50 mm). Up to two annual rings may be untreated in the remainder of the core. Preservative retention in the through-bored zone shall be assessed in the usual 0.25 to 1 inch (6 to 25 mm) assay zone, but a second assay shall also be taken 2 to 3 inches (50 to 75 mm) inward from the surface. Retention in this zone shall be a minimum of one half of that in the outer assay zone.

The proposal for including through-boring as an appendix ANSI is under consideration by the ASC 05 committee. We have forwarded all of our data to the committee and expect this process to take another year or so.

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

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

C. Performance of Fire Retardants on Douglas-fir poles

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

As an alternative, poles can be periodically treated with fire retardants. Some of these materials are designed for short term protection and must be applied immediately prior to a fire. Other products are longer lasting, providing up to 10 years of protection. While fire retardant treatments have been available for decades, there is little published information on their efficacy or their longevity. In order to develop this information, the following test was initiated.

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

1. Osmose FireGuard
2. CuRap 20 as a below-ground treatment
3. J.H. Baxter Elastomeric Epoxy Roof Coating
4. Copper Care wrap
5. No treatment

The Copper Care product was a 100 mm wide flexible tape that was wrapped around the pole. This system only became available recently and was applied in the spring of 2008.

Poles were burned July 8, 2008, at the start of our dry season. The relative humidity at the time of burn was low and we had excellent conditions for ignition. Wire mesh cages, 2.4 m in circumference, were placed around each pole and 6.8 kg of dry straw was evenly distributed in the cage. The poles were individually ignited and allowed to burn until no visible flame remained. The degree of protection afforded by each treatment was assessed by first measuring the average depth of charring around the pole and then removing the charred wood prior to measuring the change in circumference.

In the 2006 test fire conditions were much better than the previous year. Charring ranged from 2.1 to 19.1 mm, with Fire Guard treated poles experiencing the least charring. This past year, charring ranged from 14.8 to 21.1 mm, with the largest amount of charring occurring on unprotected poles. The CuRap 20 treated poles were not tested this year. Charring on both the Elastomeric paint and Fire Guard treated poles averaged 14.8 mm indicating that the treatment limited, but did not completely protect the poles from burning (Table III-1). The surfaces of both coatings bubbled and cracked, suggesting some possible loss in adhesion over time.

In general, fire conditions in the 2005 test were not ideal, with relatively high humidity and an inadequate fuel load. Some poles ignited but the fire lasted no more than 20 minutes. Differences did emerge; however, in both circumference loss and char depth. Control poles and those treated below-ground with CuRap 20 experienced slightly higher losses in circumference than the other treatments. Poles treated with Fire Guard experienced no loss in circumference and only a slight degree of charring (0.8 mm) on the surface directly exposed to the fire. Char depth was lower for all of the treated poles compared with the untreated control.

Table III-1. Depth of charring and loss in circumference in Douglas-fir pole sections coated with various fire-retardant materials and subjected to a simulated field fire.

Treatment	Average Change in Circ. (cm)[a]			Average Depth of Charring (mm)		
	2005	2006	2008	2005	2006	2008
Control	-1.9	-3.6	-6.1	8.5	10.6	21.2
CuRap 20	-1.6	-5.5	not burned	1.3	19.1	not burned
Elastomeric Paint	0.4	-1.5	-4.6	1.1	5.8	14.8
FireGuard	2.8	-0.8	-4.7	0.8	2.1	14.8
Copper Care Wrap	NA	NA	-4.0	NA	NA	15.0

[a] Negative numbers indicate a loss in circumference after burning.
NA = Not available for testing until 2008.

The Copper Care wrap experienced a slightly higher degree of charring (15 mm), but the most important feature of this product was that the wrap edges tended to ignite, burn and then twist off the pole, exposing the treated wood beneath. This behavior would require reapplication of the barrier after each fire event. This might still be feasible if the treatment could be quickly applied ahead of an impending fire, but it would require substantial logistical planning.

As with charring depth, the average reductions in circumference and charring tended to be higher in the most recent fire test. Although it is possible that the protection afforded by the two coating treatments may be declining, conditions in 2008 were the most favorable of the three burns, leading to the most intense fire in the study. Therefore, care must be taken when interpreting these results because they are confounded by fire intensity. Additional burns will be required to determine if the protection afforded by the coatings is declining.

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

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

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

Thirteen pentachlorophenol treated Douglas-fir cross arm sections (87.5 mm by 112.5 mm by 1.2 m) long were end-plated on both ends then cut in half to leave one plated end and one non-plated end on each arm (Figure III-2). The objective was to compare checking with and without plates on comparable wood samples. The plates were developed by Brooks Manufacturing (Bellingham, WA). The arms were initially examined for the presence of checks. The arms were then immersed in water for 30 days before

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

being removed and assessed for check development. The total number of checks longer than 2.5 cm on each face was recorded, and the width of the widest check on each face was measured. The arm sections were air dried and measurements were made again. The arms were then returned to the water tank for an additional 30 days before the cycle was repeated. The arms were air dried in the first cycle, then the arms were kiln dried for the remaining 8 cycles.

Check measurements tended to vary over time, reflecting the tendency for different checks to open in different cycles (Table III-2). As a result, the average number of checks per arm was sometimes greater on non-plated ends, and then reversed at the end of the next cycle. Check width varied widely, even on opposite ends of the same arm. Check width and number of checks were elevated on non-plated samples at the start of the test, then declined over several cycles before beginning to increase. The number of checks on non-plated ends now averages 3.1 checks per arm for non-plated arms vs. 2.2 for the plated end.

The number of checks can be important in arm performance; however, bigger checks are more likely to be important because they can lead to splits or other defects that shorten service life. Check width at the end of the 9th dry cycle averaged 6.6 mm for non-plated samples vs. 3.4 mm for the plated end. Check width has increased substantially, from 3.6 mm after the 7th cycle to 6.6 at the end of the 9th cycle, suggesting that the non-plated end is experiencing more stress than the plated end. Check width in plated samples also increased from 2.1 to 3.4 mm in the same cycles, but the overall degree of checking is still lower in the plated samples.

The results indicate that the plates have reduced both the number and width of checks on the arms.

Table III-2. Number and width of checks on penta treated Douglas-fir cross arm sections with and without end plates.

Number of Wet/Dry Cycles	Check Frequency (#/arm)[a]		Maximum check width (mm)	
	No Endplate	Endplate	No Endplate	Endplate
1	0.48	0.12	0.81	0.81
2	1.00	0.52	1.10	1.40
3	0.24	0.16	1.00	1.30
4	1.00	0.96	1.20	1.10
5	0.56	0.80	3.00	1.50
6	2.00	0.36	2.50	2.00
7	2.24	2.00	3.60	2.10
8	2.00	1.44	7.0	2.20
9	3.04	2.24	6.60	3.40

[a] Values represent means of 25 arms per treatment.

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

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

Last year, we were fortunate to gain access to a series of Douglas-fir transmission poles that had been installed in 1982 in the Consumers Power system in Western Oregon (Figure III-3). The climate in their service area is moderate with warm, dry summers and mild winters. The average daily temperature range in January is 0 to 7 C, and in July from 10 to 27 C. The annual precipitation in the area is 993 mm, much of it coming in the windy winter months.

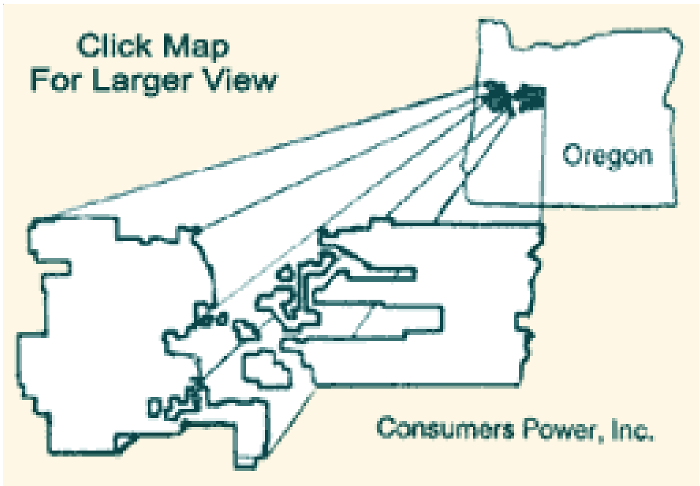


Figure III-3. Map of Consumers Power, Inc. development area in Oregon.

The poles studied were pentachlorophenol treated Class 1 to 2 poles between 19.5 and 24 m long. An above ground inspection revealed that approximately 25% of the poles in the line were decayed and needed replacement. A number of these poles also had evidence of buprestid beetle attack, suggesting that they had not been properly treated at the time of installation (i.e. they had not been sterilized). There is debate among treaters and utilities concerning the ability of the golden buprestid beetle to invade finished products. Generally, this beetle only attacks freshly fallen trees that retain their bark (Furniss and Carolin, 1977). When adult exit holes are found on poles, it is generally assumed that the larvae survived the treatment process, but some observers have suggested that the beetle could also infest in-service poles through checks that extended past the original treatment zone.

Several years ago, we surveyed Douglas-fir poles in the Bonneville Power Administration (BPA) system in the same region to determine the level of beetle incidence on their poles. BPA has an extensive heating requirement that should preclude beetle survival and we found little evidence that beetles survive the treatment process. Nor did we see evidence that buprestid beetles were invading in-service poles. However, we also could not disprove the possibility.

The marked pole sections removed from the field were cut into 2.4 m long sections, labeled and transported to our laboratory. These sections were then sliced longitudinally into 25 to 50 mm thick slabs on a portable sawmill. Slabs were marked so that we could track them through the process and selected slabs with visible defects were photographed.

Each slab from an individual pole was photographed sequentially using a camera mounted on a carriage above the slab. Images were collected at 30 cm intervals along the front and back of each slab. The images were transferred to photo imaging software and grouped, then the resulting composite was transferred to Reconstruct, a free editor (Fiala, 2005) where defects were traced and coded. Reconstruct allows us to montage and align the sections, reassemble the pole and produce three dimensional images of the defects. These images allow us to characterize and quantify the extent of a given defect. It is hoped that the results can be used to assess the effects of a given defect on pole properties when the defect is positioned at various sites along a pole.

The poles sampled to date have a number of visible defects including obvious internal decay (Figure III-4). Most notable is the presence of buprestid beetle attack in a number of locations as well as Pileated woodpecker (*Dryocopus pileatus)* attack on most of the poles.

Figure III-4. Example of a section through a Douglas-fir pole showing internal decay.

As we have cut the poles, we have first noted the extensive damage associated with woodpecker galleries. Often a single hole is connected to a decay pocket extending 0.9 or more meters downward from the opening (Figure III-5).

Figure III-5. Example of sections through a Douglas-fir pole showing a woodpecker hole on the surface and the extent of the internal damage associated with the hole.

Further examination also revealed additional evidence of damage. We often found evidence of buprestid beetle attack in the woodpecker affected sections. The beetle attack appears to precede woodpecker attack, suggesting that the birds excavated the poles in search of the beetle larvae. In addition, we have generally found dampwood termite (*Zootermopsis angusticollis* (Hagen)) galleries associated with these defects (Figure III-6).

Figure III-6. Example of a section through a Douglas-fir pole showing an association between golden buprestid galleries (circled areas) and dampwood termites.

The presence of dampwood termites was most surprising because the defects are located 6 to 12 m above the groundline. Dampwood termites, as their name implies, require very wet wood and we generally do not think pole moisture contents are suitable for colonization this far above ground. We suspect that the woodpecker openings allow for extensive moisture entry during our wet winter months and that these galleries are then invaded by dampwood termite reproductives that initiate colonies. If correct, we have a sequence that begins with a buprestid gallery, progresses through woodpecker excavation in search of the larvae and then finally termite attack through the now opened pole.

Assembling the sections cut from the slabs allows us to determine the extent of the damage. The first pole section reconstructed, taken from near the butt of the pole, was heavily decayed and nearly hollow for a high proportion of its length (Figure III-7). The reconstruction clearly shows the extent of damage. Two other pole sections, taken from higher on the same pole, (Figure III-8) had woodpecker attack and internal decay, but the extent of damage was somewhat smaller. The reconstruction shows the extent of the void in these three pole sections, making it clear why this pole was rejected. The decision to reject or restore a pole with this type of damage would be dependent on the pole configuration as well as the location and extent of the void. For example, a smaller void might be restorable on a pole with no attachments on a straightaway, but the incorporation of any guy wires or attachments could alter that decision.

Figure III-7. Illustration of reconstructed internal damage in a lower section a Douglas-fir utility pole after 25 years in service. The purple color represents internal damage and the longitudinal red portions represent fumigant treatment holes.

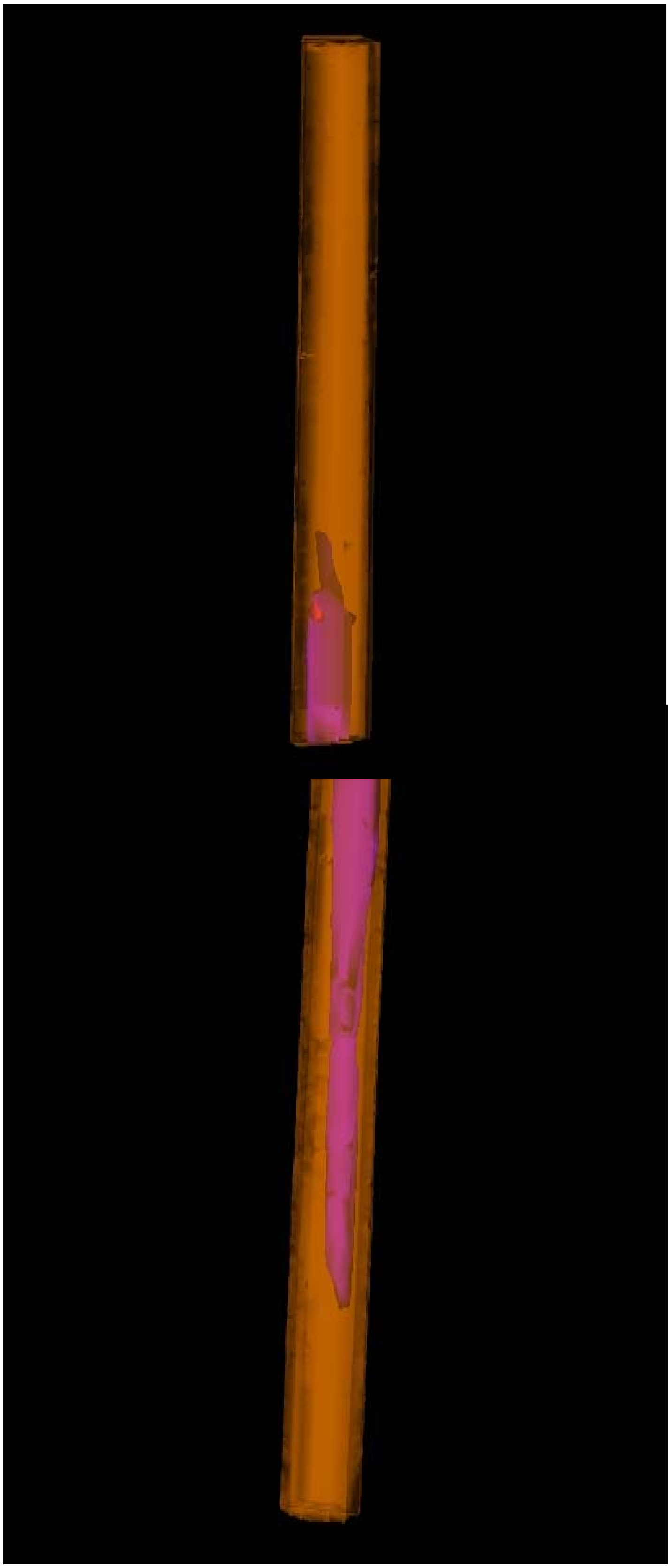


Figure III-8. Illustration of reconstructed internal damage in two pole sections taken from near the top of a Douglas-fir utility pole after 25 years in service. The purple color represents internal damage and the red portion in the top pole section indicates a woodpecker hole near the top of the void.

The other item that arose frequently in the sawing and reconstruction process was the association between termites and woodpecker galleries. We suspect these colonies were initiated as reproductives were blown into the wood pecker galleries. Once inside, the females found large quantities of wet, untreated wood. We found dampwood termite nests 10 to 12 meters up poles with no obvious attachment to the ground. While it is possible that the nests were initiated through female termites falling into checks where they attacked exposed, untreated wood, we suspect that the woodpeckers initiated the colonization process. In some cases, we also found buprestid beetle attack, suggesting that the woodpeckers might have been seeking the buprestids, then created conditions conducive to termite infestation. Clearly, woodpeckers have the potential to markedly alter the pole and any holes they create should be promptly repaired to limit moisture intrusion and avoid these issues.

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

F. Effect of Capping on Pole Moisture Content

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

Ten poles that had been removed from service were cut into 2.6 m lengths and set in the ground to a depth of 0.6 m. The poles were cut so that the top was at least 150 mm away from any pre-existing bolt hole. The original bolt holes on the pole sections were then plugged with tight fitting wood or plastic plugs to retard moisture entry.

Five of the poles were left uncapped while the remainder received plastic caps. Initial moisture contents were determined by removing increment cores 150 mm below the top of each pole prior to placing them in the ground. The outer treated zone was discarded, then the inner and outer 25 mm of the remainder of the core were weighed, oven-dried and reweighed to determine wood moisture content.

The effect of the caps on moisture content was assessed four months after treatment at the end of our rainy season. Increment cores were removed from just beneath the pole cap or at an equivalent location on the non-capped poles. The cores were processed as described above.

Moisture contents at the start of the test were 17.2 and 19.7% for the outer 25 mm of non-capped and capped poles, respectively, while they were 20.1 and 28.4% for the inner zones (Table III-4). The elevated levels in the inner zones of the capped poles were due to one very wet pole. Moisture contents at the 4 month point had declined in both the inner and outer zones of the capped poles, even though this was during our winter rainy season. Moisture contents in the non-capped pole sections were 25.2 and 19.1% in the inner and outer zones, respectively. While the increases were not major, they did show that the non-capped poles were wetter than capped poles after 4 months of rainy weather. We intend to continue monitoring these pole sections over the coming seasons to establish internal moisture trends associated with the caps.

Table III-4. Wood moisture contents immediately before, and 4 months after, installation of water shedding caps to Douglas-fir pole sections.

Treatment	Wood Moisture Content (%)			
	0 Months		4 Months	
	Inner	Outer	Inner	Outer
No Cap	20.1	17.2	25.2	19.1
Caps	28.4	19.7	19.0	18.3

G. Above-ground Assessment of Aging Douglas-fir Transmission Poles

There is no doubt that the average age of utility poles in America is increasing. This reflects the fact that a large part of the electric grid was installed in the 1950’s and 1960’s. Aggressive use of inspection and maintenance to detect and arrest decay problems before they necessitate replacement has sharply prolonged the useful life of these structures. Most of these maintenance activities have occurred at groundline, reflecting both the higher tendency for decay and insect attack to occur at this location and the easy access to this zone. New treatment practices and aggressive remedial treatments have largely controlled this decay and we are now seeing an increasingly older pole population. One outcome of this aging pole population is that we are now beginning to see decay manifest itself higher in the pole. Decay fungi have always been present in the upper regions of poles, but they tended to grow more slowly than at groundline. As a result, poles would fail at groundline long before above ground decay became an issue. At the same time, we are also seeing an increasing number of non-electrical users on poles attaching telecommunications equipment. This has resulted in more untreated holes for attachments, increasing the risk of decay development. As the pole population continues to age, it will be important to assess the risk of above ground decay.

We previously assessed the presence of decay fungi in Douglas-fir distribution poles in Western Oregon. Culturing and visual assessments of increment cores removed from various heights on poles in service for 40 to 60 years revealed that decay was relatively uncommon in these poles. When present, most decay was concentrated at the pole top or near attachments. The limited extent of decay in these poles could be the result of good initial treatment coupled with a specification that required pretreatment of all holes for attachments. We also suspect that pole size has an influence. Smaller poles are more likely to be better seasoned prior to treatment and any checks will therefore be more likely to be well treated. Since checks are the primary avenue of entry into the untreated wood at the pole center, these poles would be at a lower risk of developing above ground decay. While this does not preclude above ground decay in distribution poles, it does reduce the risk.

As we examined our data, however, we became concerned that these results might not be applicable to transmission poles. Transmission poles are less likely to be thoroughly seasoned prior to treatment and will be more likely to develop checks after treatment that extend beyond the treated shell. In addition, they contain a much higher proportion of untreatable heartwood. As a result, we might expect higher levels of above ground internal decay in these poles. This past summer, we were fortunate to be able to inspect a series of lines in the Portland General Electric system. The poles were located in Northwestern Oregon in sites ranging from the Coast Range to the foothills of the Cascade Mountains.

The poles were sampled by removing increment cores from various locations above the groundline (Table III-5). The sampling locations varied with pole configuration. Site selection was based upon

Table III-5. Sampling sites on Douglas-fir transmission poles inspected for above ground decay.

Location	Voltage	Configuration	# of Cores	Sampling locations
Beaver-Alston	230 kv	H-Frame	4	10 ft, below bottom brace, below top brace, below crossarm
Silverton-Mt Angel	57 kv	Single pole with underbuild	7	6 ft, midway, below braces on underbuild, below insulators in phase
Scotts Mill-Molalla	57 kv	Single pole with underbuild	7	6 ft, 15 ft, below neutral, below underbuild
Dayton-Yamhill	57 kv	Single pole wishbone with underbuild	7	6 ft, 12 ft, 20 ft, below neutral, below underbuild brace, below x-arm, below guy wire
Bethel-Round Butte	230 kv	H-frame, single or double braces	5	10 ft, 25 ft, below lower x-brace, top of lower x-brace, below upper x-brace,

proximity to a potential field drilled bolt hole or, in the case of the X-braces on the H-frames, to a location where decay would have a major effect on pole properties. The line crews were asked to note, where possible, shell depth as they removed the cores. The increment cores from each site were returned to OSU where they were examined for evidence of internal decay and then cultured on malt extract agar for the presence of fungi.

A total of five lines were inspected. The lines were selected to provide a range of exposure conditions from the wetter coast range, where wind driven rain might be expected to increase the risk of above ground decay, to the Willamette Valley, and finally extending upward into the foothills of the Cascades. The poles ranged in age from 17 to 59 years old.

The poles were visually inspected and sounded as the line personnel ascended the pole. In several instances, the inspector detected woodpecker holes and some evidence of internal voids. Inspections were terminated at this point because of safety concerns. As a result, the cultural data is somewhat skewed because samples were not obtained from these decaying poles. We have included data from all poles to provide a better representation of the systems inspected.

The Beaver to Alston line contained pentachlorophenol treated poles that were primarily installed in 1973-1974 (Table III-6). The poles were mostly Class 2 with a few Class 1 poles included. Pole heights ranged from 65 to 95 feet reflecting the need to cross mountainous areas. This line was located in the Coast Range and ran through heavily forested terrain. The line had been inspected at groundline in 1997-1998. Seven of the 48 poles inspected had evidence of woodpecker attack. Two other poles without woodpecker damage had evidence of internal decay. Preservative penetration ranged from 26 to 85 mm with an overall average of almost 46 mm indicating that the wood was well treated (Table III-7). Culturing of increment cores revealed that 4.9 % of the cores taken 3.3 m above groundline contained viable decay fungi, none of the cores removed below the bottom brace contained decay fungi, and 2.6 % of the cores removed below the cross arm contained decay fungi (Table III-8). These levels are relatively low, however, they do not include samples from the seven poles with woodpecker damage.

The Silverton to Mt Angel line contained pentachlorophenol treated poles that were installed in 1971 (Figure III-9). The poles were a mixture of Class 1 and 2 poles ranging from 65 to 70 feet long. The line had been inspected and remedially treated at groundline in 1997. Preservative penetration ranged from 44 to 91 mm and averaged 63 mm, again indicating that the poles were well treated when installed (Table III-7). Two of 33 poles contained woodpecker attack, one contained carpenter ants and three contained visible internal decay. Decay fungi were cultured from three of the 33 poles, one each with ants, woodpecker or advanced internal decay (Table III-8). Cores from the midpoint and just below the insulators contained decay fungi on these poles. Once again, the overall isolation levels remained low.

The Scott Mills to Molalla line contained pentachlorophenol treated poles ranging in size from Class 1 to 3 and 55 to 75 feet in height (Table III-10). The poles had been installed between 1951 and 1981. The lack of a large population of poles from a single year suggested that this line had experienced prior decay. Preservative penetration ranged from 37 to 93 mm with an average of 55 mm, again indicating good initial treatment (Table III-7). Of the 32 poles inspected, three contained evidence of advanced internal decay. There were no woodpecker damaged poles in this line. Decay fungi were isolated from two of the three poles where advanced decay was detected, but decay fungi were not isolated from any other poles (Table III-8). While some internal decay is present above ground, the results suggest that it is not widespread. Culturing provides a relative measure of future risk, since we can culture fungi before advanced decay becomes evident. The inability to culture from poles without visible decay suggests that the problem is not likely to become worse in this line in the immediate future.

Table III-6. Characteristics of poles in the Beaver to Alston line inspected in 2008.

				Penetration (mm)		Void detected	Decay fungi cultured
Pole #	Size	Class	Year	avg	std		
963			1974			bird	
967	80	1	1974	50	(6)		
970	95	2		36	(6)	bird	
971	95	2		55	(9)		
972				35	(15)		
974	no tag			45	(9)		
975	90	2		33	(5)		
976	80	2	1974	47	(1)	bird	
977	80	1	1974	33	(6)		
978	90	1	1974	26	(10)		
979	80	1	1974	46	(5)	bird	
980	80	2	1974	40	(8)		
1000	80	2	1973	38	(10)		
1001	80	2	1973	46	(5)		
1002				42	(18)		
1003	90	2		71	(3)		
6/1 1006	65	2	1974	36	(6)		
6/1 1007	65	2	1974	39	(9)		Y
1013	95			32	(21)		
1014	95			41	(2)		
1060	95			54	(13)		
1061	95			40	(16)	bird	Y
1062	95		1992	85	(32)		
1063				27		bird	
1064	95	1		39	(2)	termites	
1065	85	2		39	(4)		
1066	Not climbed, no cores					bird	
1067	75	2		53	(6)		
1068	75	2		51	(3)		
1069	65	2		41	(3)		
1070	65	2		38	(3)		
1071	75	2	1973	51	(3)		
1072	80	2	1973	47	(9)		
1073	75	2		48	(2)		
1074	75	2		54	(8)		
1075	92	2		45	(11)		
1076	90	2		42	(12)		
1077	70	2	1974	36	(23)		
1078	85	2		52	(11)		
1080				53	(4)		
10/8 1006	95	2		56	(7)		
10/8 1007	95	2		48	(3)		
10/8 1008	95	2		58	(17)		Y
2/2 961	85	1	1974	55	(11)		

Table III-7. Average depth of preservative penetration in increment cores removed from selected heights above groundline on Douglas-fir poles located in Northwestern Oregon. Core locations refer to sites listed for each line in Table III-5.

Core Location	Dayton-Yamhill		Scotts Mills-Mollala		Silverton-Mt Angel		Beaver-Alston		Bethel-Round Butte	
	other fungus	decay fungus	other fungus	decay fungus	other fungus	decay fungus	other fungus	decay fungus	other fungus	decay fungus
1	35.3	2.9	9.7	0.0	18.2	0.0	9.8	4.9	10.0	2.5
2	52.9	5.9	33.3	3.3	17.2	6.9	8.8	0.0	2.5	17.5
3	50.0	0.0	16.7	0.0	26.1	0.0	5.3	2.6	17.5	2.5
4	45.5	0.0	31.3	0.0	17.2	3.4			2.5	7.5
5	51.5	0.0	3.8	0.0	18.2	0.0			7.5	2.5
6	39.4	0.0	12.5	0.0	2.9	0.0				
7	30.3	0.0	27.3	3.0	32.4	0.0				

[a] Values in parentheses represent one standard deviation.

Table III-8. Percentage of increment cores removed from Douglas-fir transmission poles located in lines in Northwestern Oregon that contain either decay or non-decay fungi. Core locations refer to sites listed in Table III-5.

Core Location	Dayton-Yamhill		Scotts Mills-Mollala		Silverton-Mt Angel		Beaver-Alston		Bethel-Round Butte	
	other fungus	decay fungus	other fungus	decay fungus	other fungus	decay fungus	other fungus	decay fungus	other fungus	decay fungus
1	35.3	2.9	9.7	0.0	18.2	0.0	9.8	4.9	10.0	2.5
2	52.9	5.9	33.3	3.3	17.2	6.9	8.8	0.0	2.5	17.5
3	50.0	0.0	16.7	0.0	26.1	0.0	5.3	2.6	17.5	2.5
4	45.5	0.0	31.3	0.0	17.2	3.4			2.5	7.5
5	51.5	0.0	3.8	0.0	18.2	0.0			7.5	2.5
6	39.4	0.0	12.5	0.0	2.9	0.0				
7	30.3	0.0	27.3	3.0	32.4	0.0				

Table III-9. Characteristics of poles in the Silverton to Mt Angel line inspected in 2008.

				Penetration (mm)		Retention (KCM)		Void detected	Decay fungi cultured
						outer	inner		
Pole #	Size	Class	Year	avg	std	(0 - 0.25")	(0.25-1.0")		
116	75	2	1971	35	(18)	4.7	4.8		
131	75	2	1971	88	(29)	5.5	5.2		
133	75	2	1971	74	(42)	5.7	5.8		
134	70	2	1971	91	(43)	0.9	7.4		
136	75	2	1971	83	(39)	5.7	5.6		
166	70	2	1971	72	(44)	7.2	7.4		
1356	75	2	1971	45	(10)	7.0	4.5		
1357	65	1	1971	44	(7)	5.9	3.9	decay	
1717	70	2	1971	62	(26)	4.8	4.7		
2189	70	2	1971	51	(31)	6.4	4.4		
2192	70	2	1971	63	(29)	5.5	4.9		
2193	70	2	1971	60	(34)	3.4	3.1		
2194	70	2	1971	49	(32)	5.1	5.2		
2195	70	2	1971	67	(36)	7.2	6.3	decay	
3101	75	2	1971	58	(21)	4.4	4.4		
3103	60	0	1966	49	(18)	4.2	3.8		
3332	70	2	1971	64	(34)	5.0	4.6		
3341	75	2	1971	58	(18)	6.6	5.1		
3343	70	1	1971	57	(34)	4.3	4.0	bird	Y
3344	70	1	1971	77	(54)	5.3	5.4		
3345	70	1	1971	52	(32)	4.9	4.4		
3346	70	1	1971	66	(59)	6.5	4.3	ants	Y
3347	65	2	1971	53	(39)	3.9	3.3		
3348	65	2	1971	96	(35)	4.4	3.5		
3350	65	2	1971	52	(27)	5.9	6.3		
3351	65	1	1971	57	(19)	4.7	5.4		
3352	65	2	1971	79	(41)	5.9	6.8		
3354	65	2	1971	78	(50)	6.0	4.9		
3360	75	2	1971	61	(29)	0.8	6.8		
3362	70	1	1971	63	(38)	5.4	4.7	bird	
3368	65	2	1971	64	(48)	6.8	5.9		
3373	65	2	1971	64	(31)	4.9	6.0		
3374	65	1	1971			6.8	0.8	decay	Y

Table III-10. Characteristics of poles in the Scotts Mills to Molalla line inspected in 2008.

				Penetration (mm)		Retention (KCM)		Void detected	Decay fungi cultured
						outer	inner		
Pole #	Size	Class	Year	avg	std	(0 - 0.25")	(0.25-1.0")		
18	55	2	1964	71	(47)	4.4	3.8		
40	70	2	1973	50	(34)	3.8	3.7		
44	65		1975	43	(6)	3.6	3.9		
49	65	2	1975	57	(37)	4.3	4.8		
412	65	0	1979	52	(5)	5.0	7.0		
431	80	2	1973	76	(23)	5.1	5.3		
432	80	2	1973	43	(8)	6.0			
433	55	1	1953	53	(13)	2.4	0.8		
436	55	3	1951	30	(11)	2.2	1.2		
437	60	2	1976	56	(29)	4.0	5.1		
438	65		1983	93	(38)	0.8	7.5		
439	75		1973	73	(24)	4.2	4.2		
441	55	1	1953	75	(40)	2.4	0.9		
443	65	2	1981	57	(14)	4.3	6.3		
444	65	2	1972	60	(19)	3.3	3.9	decay	Y
448	65	2	1981	52	(20)	6.4	6.8		
451	65		1981	70	(31)	7.5	8.2		
454	65	0	1981	64	(31)	0.9	6.2		
748	55	2	1953	56	(4)	2.0	0.7		
787	65	2	1975	51	(32)	2.9	2.8		
789	65	2	1973	47	(5)	5.6	3.8		
795	65	2	1977	43	(12)	5.6	6.4		
863	75	2	1980	53	(26)	3.4	3.2		
868	60	1	1973	54	(26)	4.3	2.5		
870	60	1	1975	40	(8)	4.4	4.4		
873	65	2	1972	61	(15)	5.0	5.1		
885	60	1	1975	51	(16)	4.8	4.4		
892	60	2	1975	45	(11)	3.4	3.1	decay	
894	60	2	1975	43	(21)	3.2	2.0	decay	Y
916	55	3	1978	64	(32)	4.5	4.4		
918	55	1	1968	71	(34)	4.3	3.9		
919	60	1	1973	37	(15)	3.8	2.9		

The Dayton to Yamhill line contained creosote treated poles that were mostly installed in 1949, except for three of the 34 poles which were installed in 1962, 1968, and 1973 (Table III-11). The poles were primarily Class 2 and 3 and ranged from 55 to 70 feet long. Preservative penetration was excellent ranging from 31 to 67 mm and averaged 46 mm (Table III-7). One pole was damaged by woodpeckers while an additional five poles had obvious internal decay. Decay fungi were cultured from three of the five decayed poles, but no decay fungi were isolated from the poles without obvious decay (Table III-8). The fungi were primarily isolated from the lower portions of the poles, suggesting that they might have originally been associated with some type of groundline decay. As with the Scotts Mills line, these results suggest that there is no impending large increase in the incidence of internal decay above ground in these poles, but nearly 25 % of the poles inspected in this line have some evidence of above ground biological activity that merits further investigation.

Table III-11. Characteristics of poles in the Dayton to Yamhill line inspected in 2008.

				Penetration (mm)		Void detected	Decay fungi cultured
Pole #	Size	Class	Year	avg	std		
34	60		1949	43	(30)	bird	
35	60		1949	52	(20)		
37	60	3	1949	64	(27)		
39	60	3	1949	49	(34)		
53	55	2	1949	34	(8)		
55	55		1949	46	(7)		
62	55		1949	51	(36)		
63	55	3	1948	31	(7)		
64	55	3	1949	50	(33)		
69	55	3	1949	59	(24)		
72	60	3	1962	67	(22)		
77	70	2	1973	38	(6)	decay	
82	55	3	1949	45	(32)	decay	Y
110	60	2	1949	51	(39)	decay	
121	60		1949	48	(24)		
124	60	3	1949	42	(26)		
125	60	3	1949	37	(37)		
142	60		1949	37	(16)	decay	Y
156	60	2	1949	59	(38)		
158	65	2	1949	43	(12)		
338	55	2	1949	31	(8)	decay	Y
340	55	2	1949	52	(36)		
342	55	2	1949	63	(40)		
348	55		1949	39	(2)		
349	60	3	1949	31	(6)		
354	60	2	1968	55	(18)		
358	60	3	1949	57	(34)		
359	60	3	1949	45	(14)		
371	55	3	1949	36	(17)		
374	55	3	1949	41	(21)		
375	55	0	1949	43	(25)		
378	60	0	1949	40	(26)		
379	55	0	1949	53	(32)		
387	60	2	1949	41	(27)		

The Bethel to Round Butte line contained pentachlorophenol treated poles that had been installed in 1963 (Table III-12). The line contained a mixture of Class 1 and 2 poles ranging in height from 70 to 105 feet long. Preservative penetration ranged from 31 to 65 mm and averaged 43 mm (Table III-7). Almost a quarter of the poles in this line had visible internal decay, suggesting the need for a closer above ground assessment of this line. Decay fungi were isolated from eight of the nine poles with obvious decay, but were also isolated from three other poles where decay was not detected (Table III-8). Isolation frequencies of decay fungi from the poles ranged from 2.5 to 17.5 % of cores sampled. The highest levels were found 8 m above ground, but the presence of fungi along the length of these poles is cause for concern and suggests that this line also deserves more attention above the groundline.

Table III-12. Characteristics of poles in the Bethel to Round Butte line inspected in 2008.

				Penetration (mm)		Retention (KCM)		Void detected	Decay fungi cultured
						outer	inner		
Pole #	Size	Class	Year	avg	std	(0 - 0.25")	(0.25-1.0")		
452	70	2	1963	41	(12)		4.5		
454	70	1	1963	37	(9)		3.9		
455	70	1	1963	42	(8)	3.4	4.8		
459	95	2	1963	44	(12)	4.3	8.7	decay	Y
460	85	2	1963	47	(8)	5.2	6.2	decay	Y
469	100	2	1963	57	(7)	4.1	4.2		
470	100	2	1963	43	(11)	4.2	4.5		
495	90	1	1963	57	(15)		5.1	decay	Y
498	95	2	1963	35	(9)	6.2	4.6	decay	Y
502	90	2	1963	38	(16)	3.5	6.1		
511	95	2	1963	31	(4)	5.1	4.2		
513	85	2	1963	38	(13)	5.6	6.6		
514	85	1	1963	31	(4)	4.5	4.1		
515	95	1	1963	23	(10)	8.3	3.3	decay	Y
516	100	1	1963	37	(4)	7.0	4.4		
517	90	2	1963	65	(13)		4.8		
518	95	1	1963	39	(5)		3.0		
519	80	1	1963	96	(39)		4.0	decay	Y
520	85	2	1963	53	(7)		2.5	decay	Y
525	100	2	1963	35	(12)		4.3		
527	85	2	1963	38	(6)	3.3	4.5		Y
528	80	2	1963	58	(40)	6.3	6.3		Y
529	80	1	1963	31	(10)	4.9	4.7	decay	Y
531	90	2	1963	42	(3)	4.1	5.2		
532	90	2	1963	31	(6)		3.0		
535	100	1	1963	50	(10)		6.6		
536	100	1	1963	32	(5)		12.3		
538	85	2	1963	39	(8)		6.2		
539	80	2	1963	54	(4)		3.2		
547	90	1	1963	39	(15)		4.6		Y
548	90	1	1963	52	(8)		3.5		
573	95	2	1963	38	(6)		3.6	decay	
574	90	2	1963	48	(5)		5.2		
1653	90	2	1963	50	(8)		2.1		
1654	90	2	1963	37	(6)	6.7	5.3		
1656	85	2	1963	37	(10)	4.0	2.7		
1658	100	2	1963	35	(6)	4.9	5.4		
1660	90	2	1963	42	(10)	2.7	2.9		
1662	100	2	1963	50	(9)	5.9	4.6		
3443	105	2	1963	38	(13)	4.1	4.8		

Assays of residual penta in the poles from the Bethel to Round Butte line ranged from 2.7 to 8.3 kg/m^3 in the outer 6 mm and 2.1 to 12.3 kg/m^3 in the zone 6 to 25 mm in from the surface (Table III-12). The latter zone is the actual assay zone for new poles. The current retention requirement for penta is 9.6 kg/m^3; however, the presence of lower levels of penta on pole surfaces above ground is probably not a cause for concern because of the low risk of surface decay in this zone.

In general, the levels of decay in the transmission poles were higher than those found with the distribution poles previously sampled. The higher levels reflect, in part, the larger size of these poles and their greater tendency to check beyond the depth of the initial treatment. We did not find substantial levels of decay around the braces or conductors, suggesting that decay occurrence on these poles was relatively random. This lack of consistency makes it difficult to prepare a standard inspection pattern for line crews. In general; however, decay fungi were isolated more consistently from locations where advanced decay was present. This suggests that sounding remains a useful tool for line crews to identify areas of concern as they insect the pole.

The presence of woodpeckers in some lines also highlights the importance of early detection of this damage during annual line patrols. This will allow for expeditious repairs to avoid the termite and decay problems described in an earlier section of this Objective.

H. Through-boring to Improve Treatment of Glue-Laminated Douglas-fir Crossarms

Glue-laminated products are used in a variety of structural applications. In most cases, these applications are protected from wetting and the risk of decay is low. In other instances, the beams are subjected to condensation, such as near a swimming pool, or when wood is exposed outdoors. In these cases, the wood must be protected by pressure treatment with preservatives.

The American Wood Protection Association Standards for treatment of glue-laminated timbers currently require that pressure treatment produce a minimum of 15 mm of penetration into the material. This relatively shallow depth of treatment generally works well because laminated timbers are treated while very dry and therefore, are less likely to check in service. This is important because preservative treatment produces a barrier or envelope of protection. Deep checks that develop after treatment can compromise this barrier, allowing fungi to attack the untreated wood in the interior.

In some exposures, however, repeated wetting and drying of preservative-treated laminate timbers can result in the development of deep checks. An excellent example of this potential problem occurs when laminated timbers are used for cross arms. In most locations, the thin shell will provide excellent protection in this above ground exposure, however, problems can develop on the upper surfaces of these timbers. Checks that develop on the upper surfaces will tend to trap water and allow for the growth of fungi and plants. This growth traps additional moisture, creating ideal conditions for degradation. This damage can be difficult to detect from ground inspections, but the resulting decay can result in dramatic and unexpected failures.

The solution to this problem is to enhance initial treatment of the wood to increase the depth of the protective envelope. One approach to increase the depth of treatment is incising, but this process can only penetrate the wood to a limited depth and is already required for treatment of laminated timbers composed of Douglas-fir. More substantial improvements in treatment can be produced by drilling holes through the cross section of the timber, thereby exposing increased amounts of cross section to fluid flow. Preservative treatments flow to a much greater extent longitudinally than radially or tangentially and through-boring takes advantage of this wood characteristic.

Through-boring has been used for over four decades to enhance the treatment of round utility poles at groundline and is currently specified for treatment of glue-laminated poles. The process results in nearly complete treatment of the bored zone and has virtually eliminated internal decay at groundline. Mechanical tests indicate that through-boring has no negative effect on bending properties of poles and this practice is widely used for Douglas-fir poles in North America.

While through-boring has been widely effective for poles, there are no data for similar boring of arms. Clearly, any move to using this approach for enhancing the performance of glue-laminated cross arms would require testing to ensure that treatment can be achieved, as well as engineering calculations to determine the effects of the holes on arm strength. In this report, we describe the treatment trials undertaken to assess through-boring of Douglas-fir laminated timbers. This was a collaborative effort between Hughes Brothers (Seward, NB), EDM International (Fort Collins, Colorado) and OSU.

Douglas-fir laminated timbers were obtained from a local supplier. The timbers originally measured 131 mm by 188 mm by 3.6 m long and contained five laminates. Each beam was cut into 600 mm long sections which were randomly allocated to the following treatment groups:

No through-boring - ammoniacal copper zinc arsenate (ACZA) treatment
No through-boring - Pentachlorophenol (penta) treatment
Through-bored, 150 mm spacing - ACZA treatment
Through-bored, 150 mm spacing - penta treatment
Through-bored, 300 mm spacing - ACZA treatment
Through-bored, 300 mm spacing - penta treatment

The sections were end-coated with an elastomeric paint to retard longitudinal fluid penetration, then they were pressure treated with either ammoniacal copper zinc arsenate or pentachlorophenol in P9 Type A oil.

Following treatment, the beam sections were cut lengthwise on a band saw to expose the interior. The sections were photographed and the degree of preservative penetration was visually estimated. Because the primary goal of this test was to assess preservative penetration, no effort was made to quantify the retention, although the samples have been retained in the event that information is needed.

Preservative penetration into the non through-bored beams ranged from 30 to 60 % of the exposed section, depending on the treatment (Table III-13). There was some evidence of end-penetration in the timbers, which would not be present in longer specimens. ACZA tended to produce deeper penetration

Table III-13. Effect of through-boring on degree of preservative penetration in Douglas-fir glued laminated timbers treated with pentachlorophenol or ammoniacal copper zinc arsenate (ACZA).

Hole Spacing (mm)	Degree of Preservative Penetration (%)[a]	
	Pentachlorophenol	ACZA
No holes	40 (10)	53 (12)
300	90 (0)	88 (29)
150	97 (6)	90 (0)

[a] Values represent means of six replicates per treatment. Numbers in parentheses represent on standard deviation.

than pentachlorophenol. This improved penetration reflects the presence of ammonia, which acts to both swell the wood to increase permeability, and dissolve materials deposited on the wood pits, increasing fluid penetration. Both treatments left a considerable volume of untreated wood, reflecting the presence of high percentages of heartwood and the absence of incising on the beams, that would be susceptible to decay development as checks developed in service.

Penetration in the through-bored specimens was far greater than was found in the control samples (Figures III-9 to III-14). Penetration tended to be higher in the sections with holes at 150 mm spacing compared with those at the 300 mm spacing, but both patterns produced well treated sections. The advantage of the closer spacing would be more uniform treatment, however, this improved treatment would need to be weighed against the potential for reduced strength. There tended to be small skips or gaps in all of the through-bored timbers. These untreated zones are also present in many through-bored poles, and are generally not a concern because they are surrounded by deep zones of well treated wood. Even in the unlikely possibility that these skips in treatment were to become decayed, the relatively small area of damage should not adversely affect overall performance of the timber.

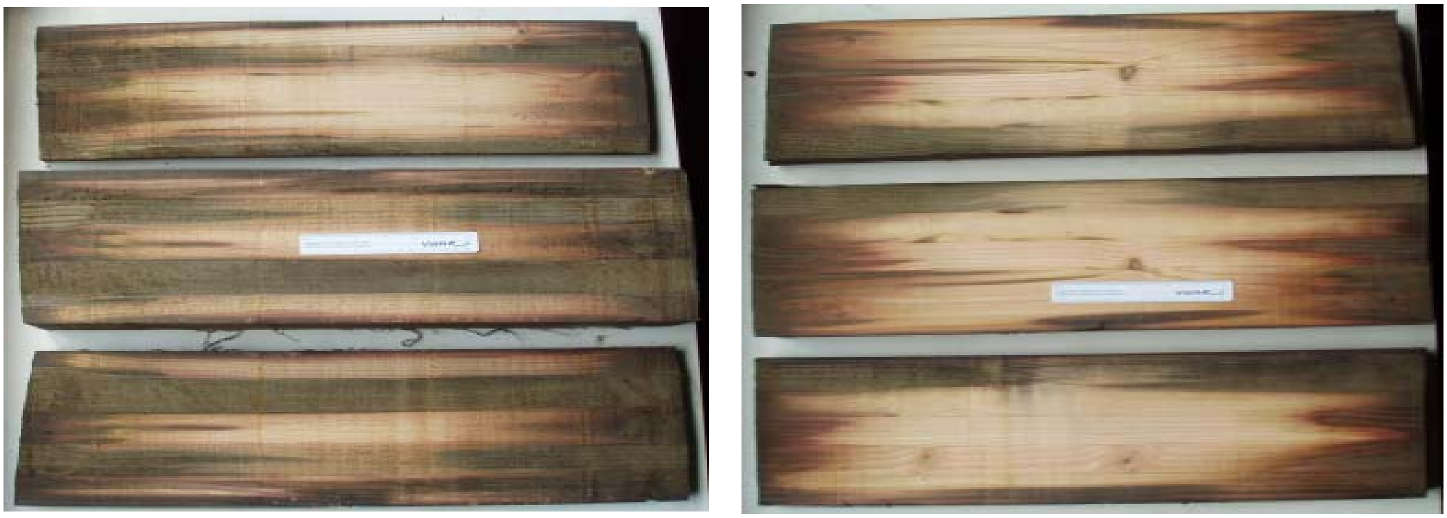


Figure III-9. Preservative penetration in laminated timber sections without through-boring and pressure treated with ACZA.

Figure III-10. Preservative penetration in laminated timber sections without through-boring and pressure treated with pentachlorophenol.

Figure III-11. Preservative penetration in laminated timber sections through-bored at 300 mm intervals and pressure treated with ACZA.

Figure III-12. Preservative penetration in laminated timber sections through-bored at 300 mm intervals and pressure treated with pentachlorophenol.

Figure III-13. Preservative penetration in laminated timber sections through-bored at 150 mm intervals and pressure treated with ACZA.

Figure III-14. Preservative penetration in laminated timber sections through-bored at 150 mm intervals and pressure treated with pentachlorophenol.

I. Assessing the Condition of Western redcedar and Lodgepole Pine Poles in Alberta, Canada

Remedial treatments clearly extend service life, but one of the most difficult decisions to make in designing a maintenance program is identifying when retreatment is required. Prolonging retreatment by even a few years can have significant effects on the cost of an inspection/treatment program, but extending the cycle by too much can result in increases in unexpected, costly failures that stretch the capabilities of a utility.

This past year, we inspected a series of poles near Calgary, Alberta to determine residual chemical levels in the poles. The poles were a mixture of western redcedar, lodgepole pine and western larch that had been treated with penta, creosote or CCA. Pole treatment dates ranged from 1954 to 1991 (Table III-14). The poles had been remedially treated with a copper naphthenate based external preservative wrap, metam sodium or boron rods at various times.

The poles were sampled by removing increment cores from selected locations above and below the groundline (depending on where the remedial treatment was applied). The cores were then divided into the treated zone, as well as the inner and outer 25 mm of the untreated zone. The segments from fumigant treated poles were placed into tubes which were flooded with ethyl acetate and allowed to stand for 48 hours. The resulting extract was analyzed by gas chromatography as described in Objective I. The remaining samples were ground to pass a 20 mesh screen and analyzed for either boron or copper. Any remaining wood was cultured for the presence of decay fungi.

We are in the midst of completing the analyses on these samples. The results will be reported in the next Annual Report.

Table III-14. Characteristics of utility poles inspected in Alberta, Canada.

OSU Pole #	IP ID	Species	Primary Treatment	Year Installed	Inspection History	Remedial Treatment
1	1268166	LPP	Creosote	1959	85, 92,99	Cobra wrap 1999, Vapam 2002
2	10525804	LPP	Creosote	1959	85, 92,99	Cobra wrap 1999, Vapam 2002
3	1268165	LPP	Creosote	1959	85, 92,99	Cobra wrap 1999, Vapam 2002
4	1052800	LPP	Creosote	1959	85, 92,99	Cobra wrap 1999, Vapam 2002
5	1268162	LPP	Creosote	1959	85, 92,99	Cobra wrap 1999, Vapam 2002
6	836751	LPP	CCA	1986		Vapam 2003
7	1210890	WRC	Penta	1974		Vapam 2003
8	209497	LPP	CCA	1990		none
9	6840983	WRC	Penta	1975		Vapam 2000
10	6178173	WL		1954	85, 91	Boron rods 1998, Vapam & CuNaph 2003
11	6481781	WL		1954	85,91	Boron rods 1997, vapam 2003
12	6329688	WRC	Penta	1978	2003	Vapam 2003
13	6633736	WRC	Penta	1975	2003	Vapam 2003
14	6330091	WRC	Penta	1978	2003	Vapam 2003
15	6785380	LPP	CCA	1989		
16	6530675	LPP	CCA	1991		
17	6834963	LPP	CCA	1991		
18	7139339	WRC	Penta	1988		Vapam 2003
19	7139558	LPP	Penta	1987	98, 03	Vapam 2003
20	6228026	WRC	Penta	1987	98, 03	Vapam 2008
21	6785224	WRC	Penta	1988	97, 03	Vapam 2003
22	7088821	LPP	Penta	1987		Vapam 2003
23	6785022	LPP	Penta	1987		Vapam 2003
24	7089146	WRC	Penta	1988		Vapam 2003
25	7089146	WRC	Penta	1987		Vapam 2003
26	6177585	LPP	Penta	1987		Vapam 2003
27	6481611	LPP	Penta	1987		Vapam 2003

OSU Pole #	IP ID	Analysis	Comments	Decay Fungi Cultured
1	1268166	fumigant, groundline wrap copper	roofed, butt-treated	
2	10525804	fumigant, groundline wrap copper	roofed	
3	1268165	fumigant, groundline wrap copper	roofed, at 6" fume hole, 1/2" punky wood, just past the pith, boron rods inserted into 6" and 12" inspection holes	
4	1052800	fumigant, groundline wrap copper	roofed	
5	1268162	fumigant, groundline wrap copper	roofed	
6	836751	fumigant, CCA penetration & retention	pole surface below GL looks very good	
7	1210890	Fume only, no dig		
8	209497	CCA penetration & retention	Class 5, 40 ft, Bell Pole	
9	6840983	Fume only, no dig		
10	6178173	fumigant, boron	butt-treated	
11	6481781	fumigant, boron	will be condemned, below-ground decay, did not finish sampling, 2 cores only	
12	6329688	Fume only, no dig		
13	6633736	Fume only, no dig		
14	6330091	Fume only, no dig		
15	6785380	CCA penetration & retention		Y
16	6530675	CCA penetration & retention		
17	6834963	CCA penetration & retention		
18	7139339	Penta penetration & retention	incised	
19	7139558	Penta penetration & retention		
20	6228026	Penta penetration & retention	incised	
21	6785224	Penta penetration & retention	Class 4, 40 ft, Bell Pole, incised	
22	7088821	Penta penetration & retention		
23	6785022	Penta penetration & retention		
24	7089146	Penta penetration & retention		
25	7089146	Penta penetration & retention		
26	6177585	Penta penetration & retention	7 cores	
27	6481611	Penta penetration & retention		

Literature Cited

American Wood Protection Association. 2006. Standard T1-06. Use Category System: Processing and Treatment Standard. Section 8.4. Poles. In: AWPA Book of Standards, Birmingham, Alabama. Pages 16-17.

American National Standards Institute (ANSI). 2002. American National Standard for Wood Poles – Specifications and Dimensions. ANSI 0.5 New York. 26 p.

Fiala, J.C. 2005. Reconstruct: a free editor for serial section microscopy. Journal of Microscopy 218 (1):52-61.

Furniss, R.L., and V.M. Carolin. 1977. Western Forest Insects. U.S. Department of Agriculture, Forest Service Misc. Pub. No 1339.

Graham, R.D. 1980. Improving the performance of wood poles. Proceedings American Wood Preservers' Association, 76:287-290.

Mankowski, M. E.N. Hansen, and J.J. Morrell. 2002. Wood pole purchasing, inspection and maintenance: a survey of utility practices. Forest Prod. J. 52(11/12):43-50.

Morrell, J. J. and P. F. Schneider. 1994. Through-boring of poles for improving treatment: distribution of preservative and effect on performance. Proceedings, American Wood Preservers' Association. 90:317-325.

Newbill, M.A., R, James, D. Asgharian, and J.J. Morrell. 1999. Full-length through-boring: Effect on pentachlorophenol penetration and retention and residual strength of Douglas-fir poles. Forest Prod. J. 49(1):73-76.

Newbill, M. A. 1997. Through-boring improves treatment and extends service life. Western Wood Preservers' Institute. Vancouver, Washington, Wood Pole Newsletter (21) 3-5.

Rhatigan, R.G. and J.J. Morrell. 2003. Use of through-boring to improve CCA or ACZA treatment of refractory Douglas-fir and grand fir. Forest Prod. J. 53(6):33-35.

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 from the surrounding soil.

For many years, the pastes used for this purpose incorporated a diverse mixture of chemicals including pentachlorophenol, potassium dichromate, creosote, fluoride and an array of insecticides. The reexamination 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

Date Established:	October 2001
Location:	Beacon, New York
Pole Species, Treatment, Size	Southern pine, penta, 4-35 to 2-55
Circumference @ GL (avg., max., min.)	104, 119, 80 cm

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

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

The poles were sampled in 2008 and the analyses are still in process. We will report the results in the 2009 Annual Report.

D. Performance of External Treatments for Limiting Groundline Decay on Southern Pine Poles in Southern 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 two decades, the UPRC has established a series of tests to evaluate the performance of external supplemental preservative systems on utility poles. Initially, tests were established on non-treated Douglas-fir pole sections. The tests were established on non-treated wood because the absence of prior treatment limited the potential for interference from existing preservatives, and the use of non-decayed wood eliminated the variation in degree of decay that might be found in existing utility poles. Later, we established tests on western redcedar, western pine and Douglas-fir poles in the Pacific Gas and Electric system near Merced, CA. The poles in this test had existing surface decay and were sorted into treatment groups on the basis of residual preservative retentions. Within several years, we also established similar trials in western redcedar and southern pine poles in Binghamton, New York and southern pine poles near Beacon, New York. In the 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 established in truly high decay hazard zones. 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 Georgia Power 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 label recommendations. In most cases, only one application rate, 1.6 mm, (1/16 inch) is allowed, but CuBor allowed for 1/16 to 1/2 inch (1.6 to 13 mm) paste thickness. After a consultation among the participants at the time the test was planned, it was agreed that all pastes would be applied at a single thickness. Since all of the other pastes could only be applied at 1.6 mm thickness, CuBor was applied at this thickness as well. While the same overall volume of paste was delivered to each pole (assuming similar circumference), density and copper content differences among the formulations created some variations in total copper applied. This can be best illustrated using the circumference of a Class 4 forty foot long pole and a 450 mm deep application zone. A 1.6 mm thick application rate delivers 4.24 kg of Cop-R-Plastic paste per pole, compared with 3.78 and 3.60 kg/pole for the CuRap 20 and CuBor treatments, respectively (Table VI-2) As a result, total copper levels delivered per pole for CuRap 20 and CuBor would be 89.4 and 84.7 % of those delivered in an equivalent Cop-R-Plastic treatment. This might have some effect on ultimate chemical movement, although the results with these and many prior tests suggest that other factors such as copper mobility and adhesion to the wood surface probably play a much greater role in the ability of copper to migrate into the wood.

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

Paste Product	Density (kg/liter)	Application Rate (kg/pole)	Metallic Cu (kg/pole)
CuBor	5.82	3.60	0.072
CuRap 20	6.12	3.78	0.076
Cop-R-Plastic	6.87	4.24	0.085

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

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

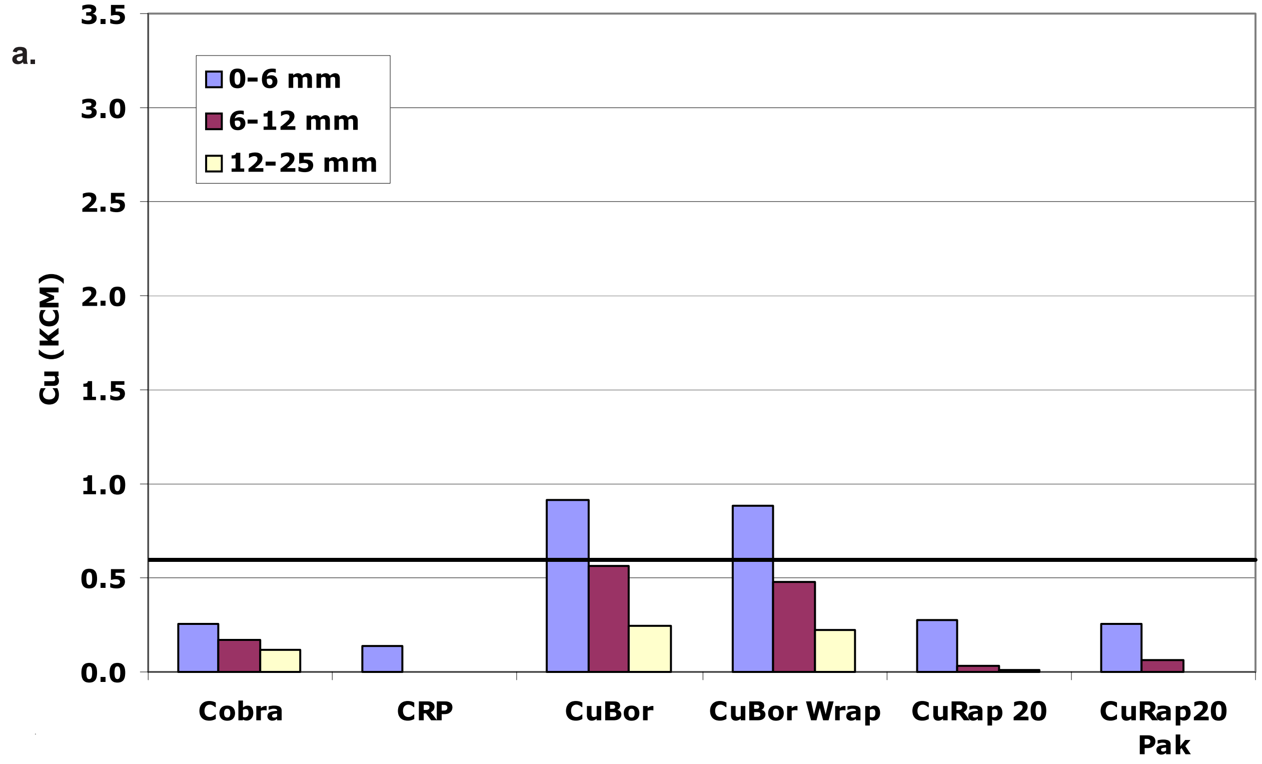
Several months after this test was installed, a number of questions were raised by various cooperators about aspects of the treatment including the application of a pasture wrap to the tops of some poles but not others, the possible interference of prior fluoride presence on the new treatment, and most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

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

For the purposes of this test, we have used the presumed threshold for copper in soil contact (0.6 kg/m^3 as Cu) as our target level; however, we recognize that this level ignores any contribution of the original treatment to wood protection. Thus, this discussion should be viewed as extremely conservative. We also consider the copper based components in these external preservative systems to have limited mobility in the wood. Thus, our analysis of copper primarily examines levels in the outer 6 mm where the copper forms a barrier against renewed fungal attack. This approach is supported by the sharp drop off in copper levels with distance from the wood surface.

In our initial copper analysis, the amount of wood dust produced by combining zones from increment cores from a given pole proved to be too small for XRF analysis. To overcome this problem, we created a procedure whereby untreated southern pine sawdust was used to dilute the wood dust from the test poles. This provided a sufficient quantity of material for XRF analysis and preliminary trials indicated that the results were strongly correlated with extraction and ICP analysis of the same wood. As a result of this preliminary trial, all samples for the first 3 years after installation were assayed using the dilution method. The results of the third year of the assay; however, were abnormally low and a discussion at the 2008 Coop Advisory Committee meeting led us to re-evaluate this method. Fortunately, we had retained the ground wood from most of the most recent assay as well as from the Beacon test poles. These samples were digested and then subjected to ICP analysis for copper and boron. These results were then compared with the XRF results for copper and the azomethine H results for boron.

The ICP analyses were consistently higher than those found by XRF (Figure IV-1). As a result, we have re-analyzed all the samples taken after 3 years. Copper values in the outer zones of all treatments except the Cobra system were well above the threshold for protection (0.6 kg/m^3 as Cu). Copper levels in the Cobra wrap treatment are just below the threshold in the outer zone at the three year point. These results led us to re-evaluate our analytical procedures. We performed additional tests on our residual dust and found that we had excellent agreement between XRF and ICP when we did not dilute samples (Figure IV-2). We have now changed our procedures and will combine all of the wood from a given assay zone for the poles in a single treatment (i.e. treated with a given groundline system) to ensure that we have a sufficient amount of wood for analysis. The disadvantage of this approach is that we will now have only two replicate analyses per treatment, but this is outweighed by the more accurate analysis. Unfortunately, we do not have the wood from the 1 or 2 year sample for this test. The uncertainty of the methodology used to analyze the 1 and 2 year samples leads us to discount these results. We had considered a correction factor; however, we have no samples from either of these years to verify the correction factor and believe the most prudent move is to use only the 3 year data for the copper from this test.



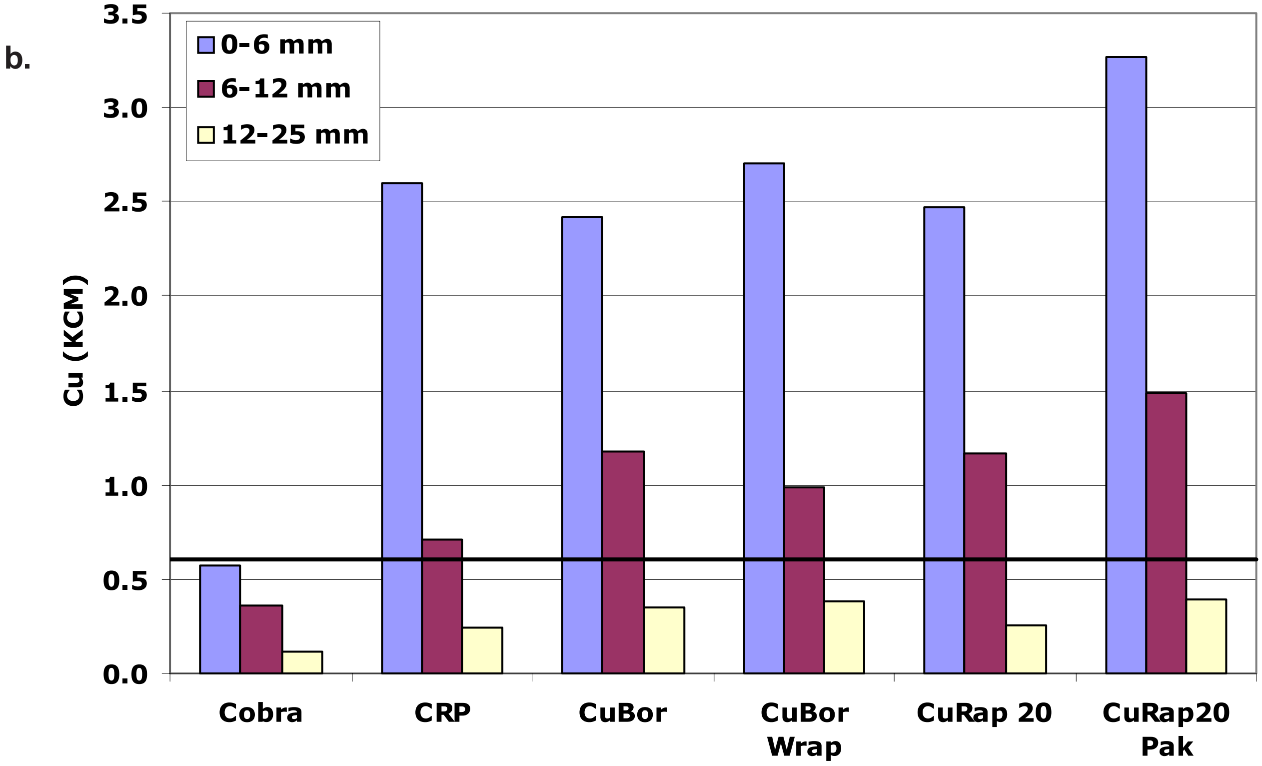


Figure IV-1. Residual copper levels at selected distances from the wood surface 150 mm below ground on southern pine poles 3 years after treatment with copper containing pastes or bandages as determined by a) x-ray fluorescence or b) ion-coupled plasma spectroscopy.

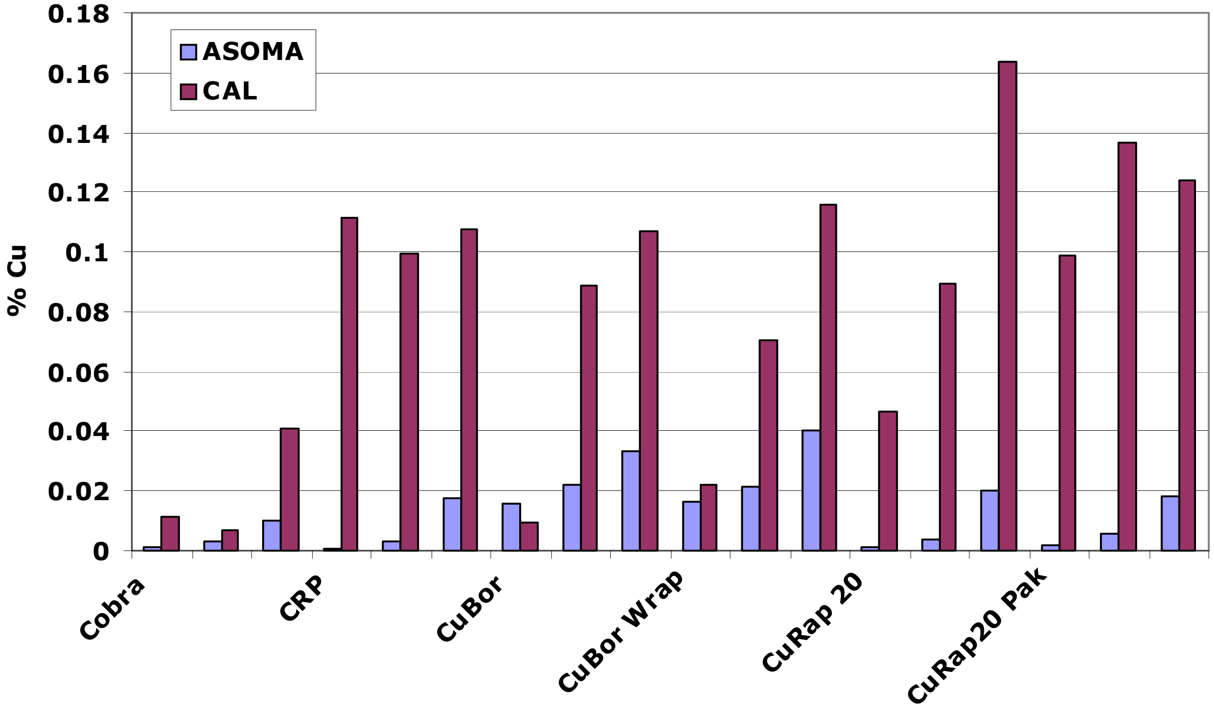


Figure IV-2. Comparison between ICP and XRF analysis for wood removed from poles 3 years after treatment with various supplemental groundline preservative systems. XRF was performed, then the wood was digested and analyzed by ICP.

Boron was a component of both the CuBor and CuRap systems applied as either pastes or bandages. We have used two thresholds for boron. The first is the upper limit in areas exposed to some level of leaching. This level is not really a ground contact threshold since boron rapidly migrates from wood with moisture, but it is difficult to provide a strict threshold for surface protection. The upper threshold used herein was developed using soil block tests against selected decay fungi. The lower threshold listed is the amount of boron needed to protect wood from internal decay. This threshold was produced by the Co-op.

Boron levels were above the upper threshold 1 year after application of CuBor, and then declined steadily over the next 2 years to levels just at the lower threshold (Figure IV-3). Boron levels in CuBor treated samples tended to become more uniform with depth over the 3 year sampling, reflecting the ability of this material to distribute with moisture. While there were some differences in boron levels near the surface for paste and bandages 1 year after treatment, the differences disappeared after 2 years and there appears to be little difference in boron levels with the two systems.

Boron levels in poles treated with CuRap 20 paste were below the threshold 2 years after treatment (there was no one year sample), then rose to just above the threshold 3 years after treatment. A similar trend toward increased boron levels in 3 year vs. 2 year samples was noted in the CuRap 20 bandage. These results suggest that boron is still migrating from the paste/bandage into the surrounding wood.

Boron levels by ICP were consistently lower than those found by the azomethine H method; however, comparative testing of spiked samples leads us to believe that the azomethine H results are more accurate and we have elected to use these results for boron.

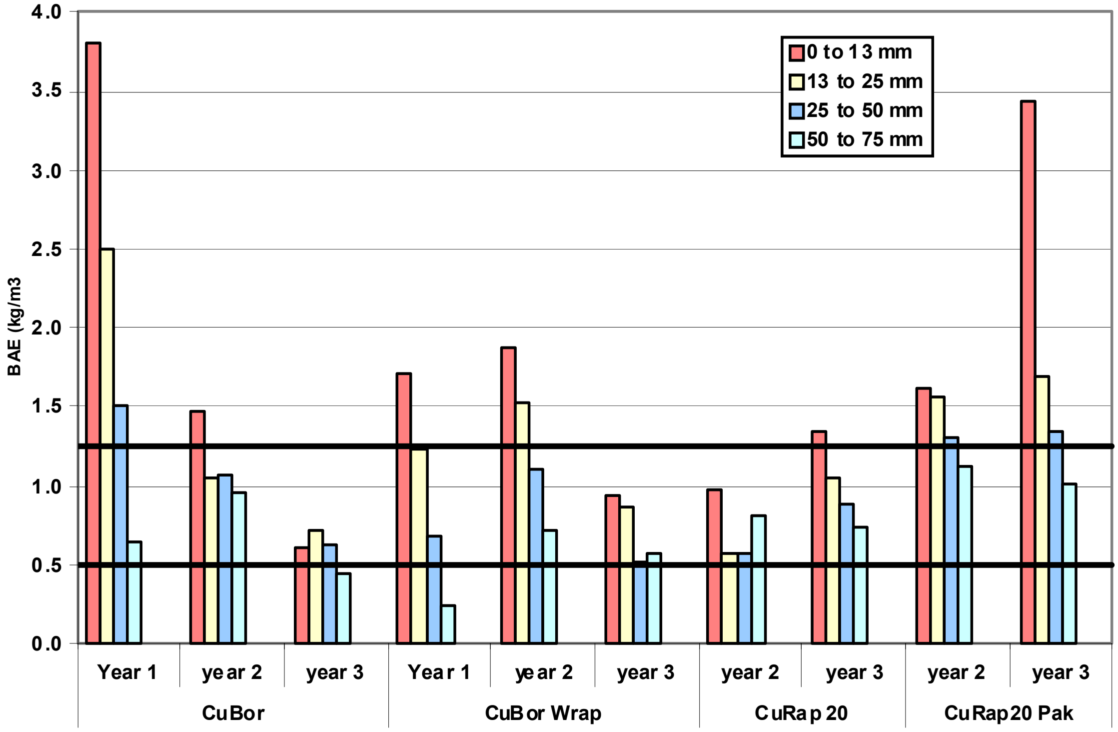


Figure IV-3. Residual boron levels at selected distances from the wood surface 150 mm below groundline on southern pine poles 1, 2 and 3 years after treatment with CuBor or CuRap 20 in paste or bandage form.

Fluoride was only present in the Cop-R-Plastic and Pole Wrap systems. As noted earlier, the test poles had received a prior fluoride treatment and initial sampling indicated that poles contained slightly less than 1 kg/m^3 of fluoride. Continued sampling of control poles shows that background fluoride levels remain within this range. Thus, total fluoride detected in the wood should actually be 1 kg/m^3 lower to account for this initial fluoride loading.

As with boron, we have listed two thresholds for fluoride. The upper threshold is that believed to protect wood against surface attack, while the lower is the threshold for protection against internal decay. Actual fluoride levels in poles treated with Cop-R-Plastic were well above the upper thresholds 1, 2, and 3 years after treatment, even when the initial background fluoride is subtracted (Figure IV-4). Fluoride levels were generally elevated from the surface to 75 mm inward, reflecting the ability of this chemical to diffuse with moisture. Fluoride levels in poles receiving PoleWrap were also above the upper threshold for the first 3 years of the test, although levels did decline somewhat sharply between 2 and 3 years. As with the Cop-R-Plastic, fluoride levels remain fairly uniform from the surface inward.

The results indicate that all of the preservative systems are performing as expected. Copper compounds have tended to remain near the surface, while boron and fluoride have become more evenly distributed. Copper and boron levels have begun to decline slightly while fluoride levels remain elevated. This test will not be sampled again until 2009, when the results should provide a better predictor of overall treatment performance.

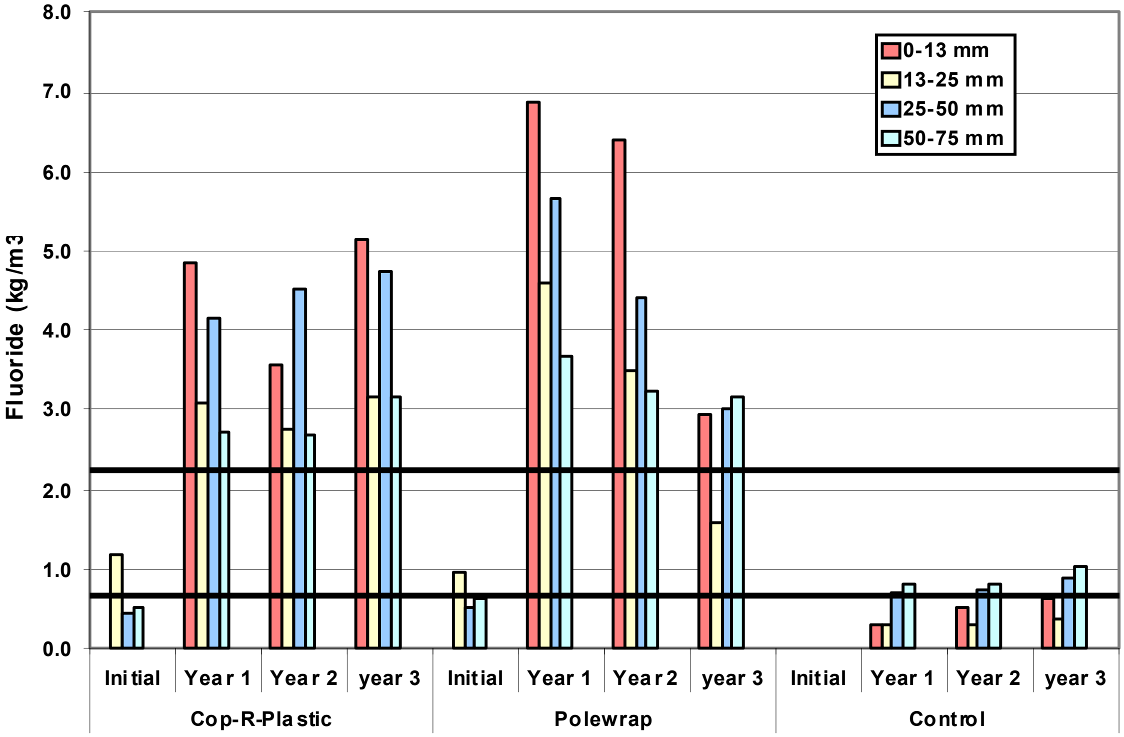


Figure IV-4. Residual fluoride levels at selected distances from the wood surface 150 mm below groundline on southern pine poles 1, 2 and 3 years after treatment with Cop-R-Plastic or PoleWrap.

Objective V

PERFORMANCE OF COPPER NAPHTHENATE TREATED WESTERN WOOD SPECIES

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

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

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

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

The stakes were conditioned to 13% moisture content, then weighed prior to pressure treatment with copper naphthenate diluted in diesel oil to produce target retentions of 0.8, 1.6, 2.4, 3.2, and 4.0 kg/m^3. Each retention was replicated on ten freshly sawn and ten weathered stakes. In addition, sets of ten freshly sawn and weathered stakes were each treated with diesel oil alone or left untreated to serve as controls.

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

Last year, we replaced the decay chambers, which had degraded to the point where they did not tightly seal. This often resulted in dryer conditions that were less conducive to decay. The new chambers created much more suitable decay conditions and this was evidenced by a drop in ratings for all treatments.

Freshly sawn stakes continue to outperform weathered stakes at a given retention level. (Figures V-1, 2). All of the freshly sawn stakes treated with copper naphthenate to retentions of 3.2 or 4.0 kg/m^3 continue to provide excellent protection after 220 months, although stake condition declined slightly this past year. Stakes treated to the two lowest retentions have declined below a 7.0 rating suggesting that decay has begun to affect the wood. Ratings for the intermediate retention had declined to just above 7.0, indicating that the treatment had lost some of its efficacy. The remaining stakes treated to the higher retentions were all near or above 8.0, suggesting that they continued to be resistant to fungal attack.

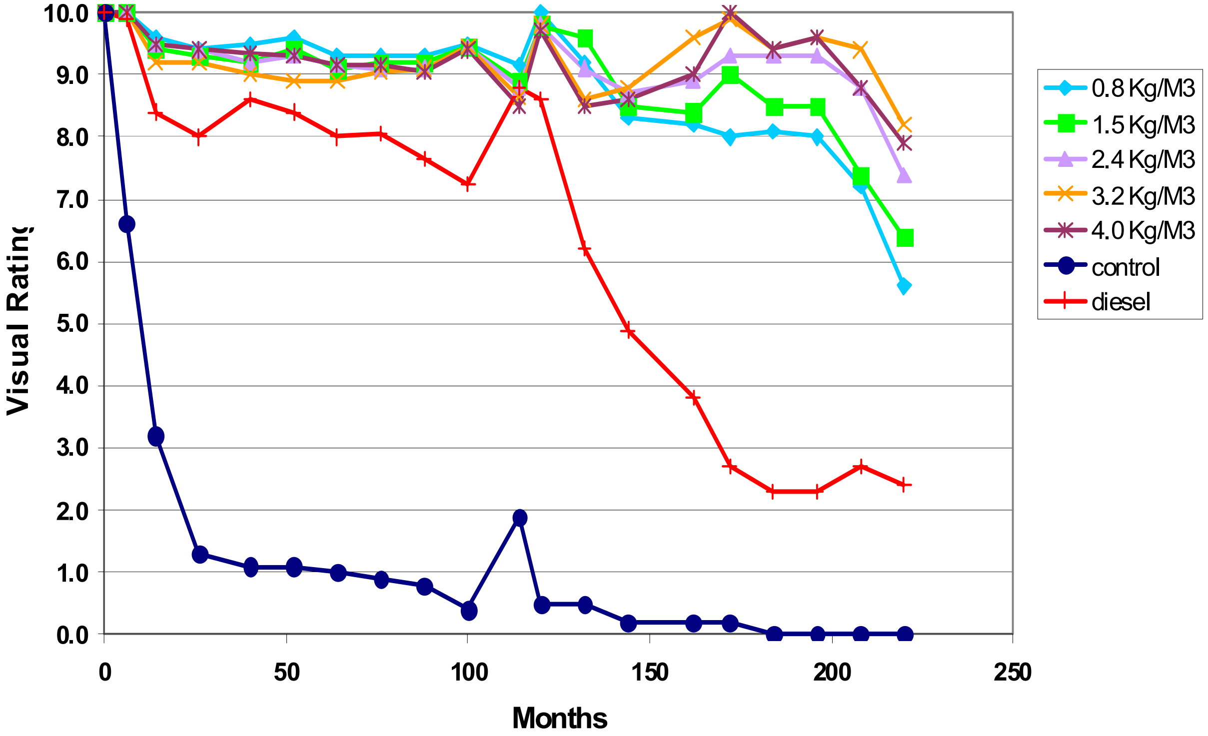


Figure V-1. Condition of freshly sawn western redcedar sapwood stakes treated with selected retentions of copper naphthenate in diesel oil and exposed in a soil bed for 220 months.

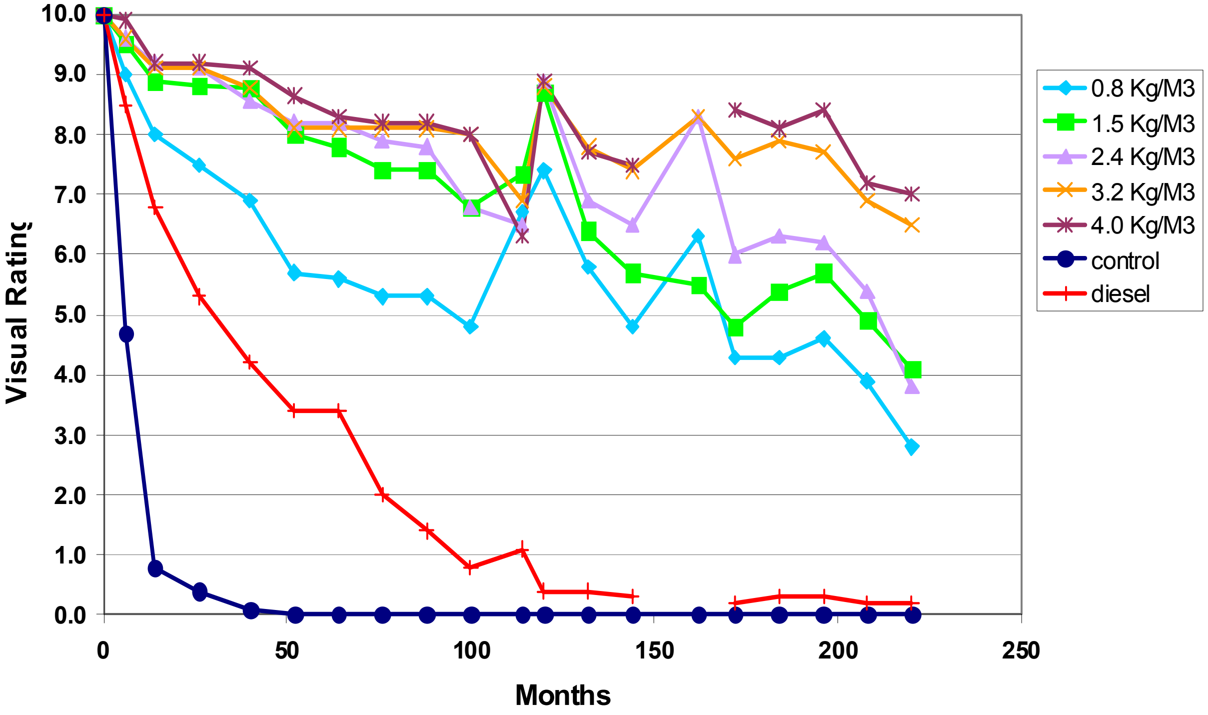


Figure V-2. Condition of weathered western redcedar sapwood stakes treated with selected retentions of copper naphthenate in diesel oil and exposed in a soil bed for 220 months.

Weathered stakes tended to exhibit much greater degrees of damage at a given treatment level and all experienced declines in ratings this past year. Weathered stakes treated to the three lowest retentions had ratings at or below 4.1 and the lowest retention had ratings below 3.0. Clearly, prior surface degradation from both microbial activity and UV light tended to sharply reduce the performance of the weathered material. Stakes treated to the two highest retentions had ratings near 7.0 indicating that they were beginning to experience visible decay.

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

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

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

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

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

Copper naphthenate has been incorporated in the Standards of the American Wood Protection Association for treatment of wood poles since the late 1980’s. In the late 1990’s, there were a number of dramatic failures of copper naphthenate treated southern pine poles. These failures were later found to be caused by the presence of excess moisture in the treatment systems as a result of the use of steam conditioning to season poles prior to treatment. This moisture led to uneven preservative treatment and the result was very early decay in poles throughout the Southern and Eastern United States.

At the same time, Douglas-fir poles treated with copper naphthenate experienced none of these issues, most likely because the process in the western region used Boulton seasoning and avoided the moisture accumulation issues associated with steam conditioning. Utilities in the western U.S., however, were concerned about the risk of early decay in their poles. In order to assess this risk, we undertook a large survey of copper naphthenate treated poles in Oregon and California in 1997-1998. The survey was limited, to an extent, by the fact that not many utilities specified this system in 1988 and 1992 when the poles we surveyed were installed. Despite this limitation, assessments were made on 66 poles in Or egon, 9 poles in the PG&E system and 16 poles treated with copper naphthenate in liquefied petroleum gas (Cellon). The results showed that copper levels remained high near the surface and there was no evidence of external decay in the limited time the poles had been in service.

It has been 10 years since we last investigated the condition of copper naphthenate treated Douglas-fir poles. This past year, we were fortunate to be able to assess 30 poles that had been installed in the Portland General Electric system in 1986 near Ballston in Yamhill County. The poles were treated by Niedermeyer Martin in 1983 at their now-closed Ridgefield plant and installed throughout the Willamette Valley of Western Oregon.

The poles in the current sample were inspected by removing increment cores in two patterns. In the first, cores were removed from just below groundline and 150 mm above the through-bored zone. In the second sampling pattern, the cores were removed from below groundline and from a zone approximately 150 mm above groundline so that both samples were taken within the through-bored zone. A total of six cores were removed from each location in each pole to produce enough wood for analysis.

The cores were segmented into zones corresponding to 0 to 13, 13-25, 25 to 51, 51-76 and 76 to 102 mm from the wood surface before being ground to pass a 20 mesh screen. The resulting dust was analyzed by x-ray fluorescence using standard curves prepared specifically for copper naphthenate treated wood. A total of 30 poles were sampled in the most recent inspection.

Copper levels in the 1998 test were assessed by removing increment cores from locations 150 mm below ground, 150 m above ground and 300 mm above the top of the through-bored zone. Cores from the through-bored zone were taken between the holes to avoid sampling directly above or below a through-boring hole. The cores in the original study were divided into zones corresponding to 0 to 13, 13 to 25, 25 to 38, 38 to 51, 51 to 64, 64 to76, and 76 to 102 mm from the wood surface. It was generally necessary to obtain 5 to 6 cores per position on a pole to produce enough wood for analysis. Wood from a given location above or below ground for each pole was combined and ground to pass a 20 mesh screen. The resulting sawdust was analyzed for copper by x-ray fluorescence analysis. The 1997-1998 analyses were performed using an ASOMA 8620 XRF analyzer, while the more recent assessments were performed using a Spectro-Titan analyzer using specific curves developed for copper naphthenate treated wood.

The results from the 1998 sampling are presented for comparative purposes only (Figure V-3 to V-12). They showed that copper was present at high loadings in a majority of the poles and there was no evidence of surface decay on any poles. Decay fungi were isolated from the interiors of two Cellon treated poles, but no decay fungi were present in any poles treated with copper naphthenate in conventional heavy oil. These results confirmed that the 10 year old copper naphthenate treated poles were performing well in a variety of conditions across the Western U.S.

Copper levels in the outer zones of poles sampled in 1998 averaged 1.1 kg/m^3 75 mm above groundline and 1.5 kg/m^3 300 mm above groundline in the Lacomb sample. Copper levels were slightly higher in the 13 to 25 mm zone, then steadily declined with distance from that zone. The higher copper levels 13-25 mm from the surface suggest that some surface depletion of copper has occurred. Although there is no evidence of any decay on the wood surface and copper levels on the surface remain well above the threshold for copper naphthenate performance, these results suggest that continued monitoring of these poles is warranted to ensure that copper levels remain stable.

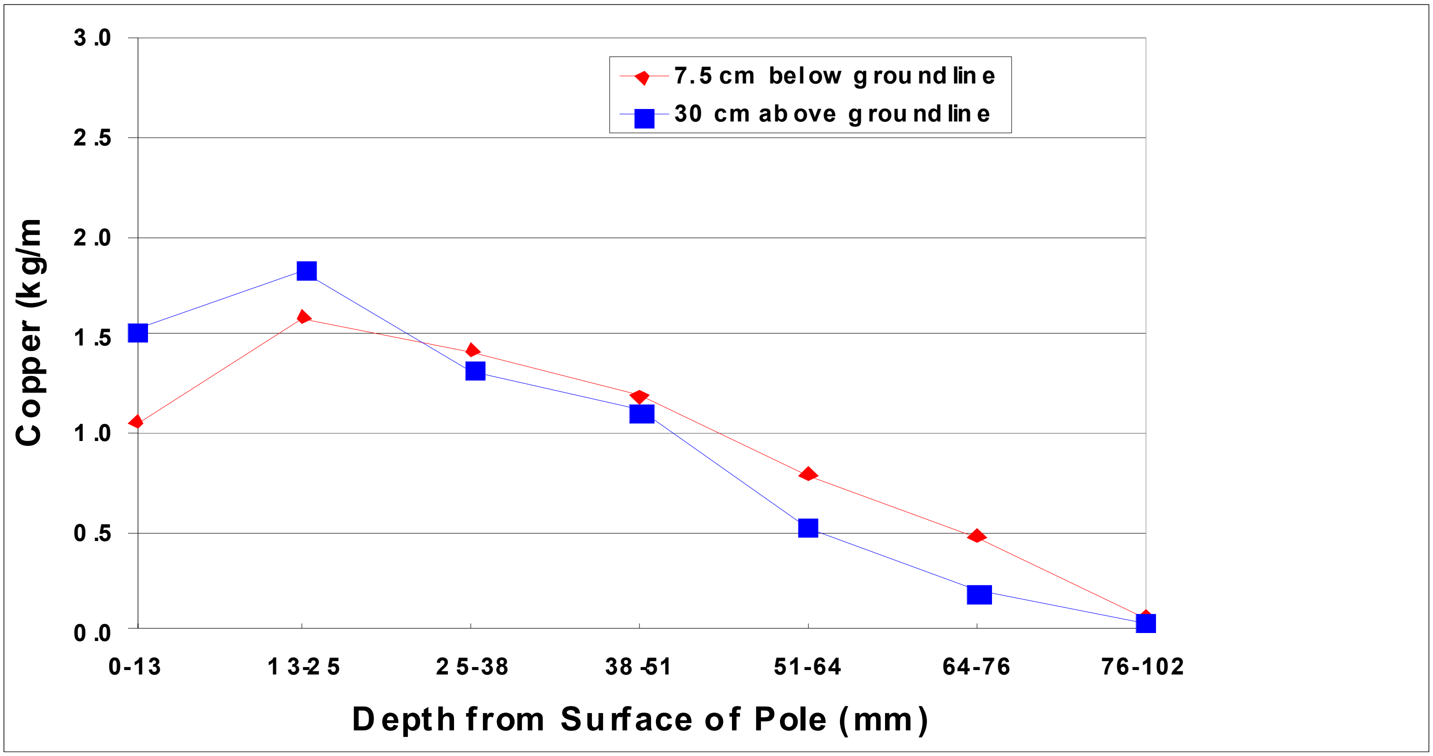


Figure V-3. Copper levels at selected distances from the wood surface in six radially-drilled copper naphthenate-treated Douglas-fir poles 10 years after installation in Lacomb, OR.

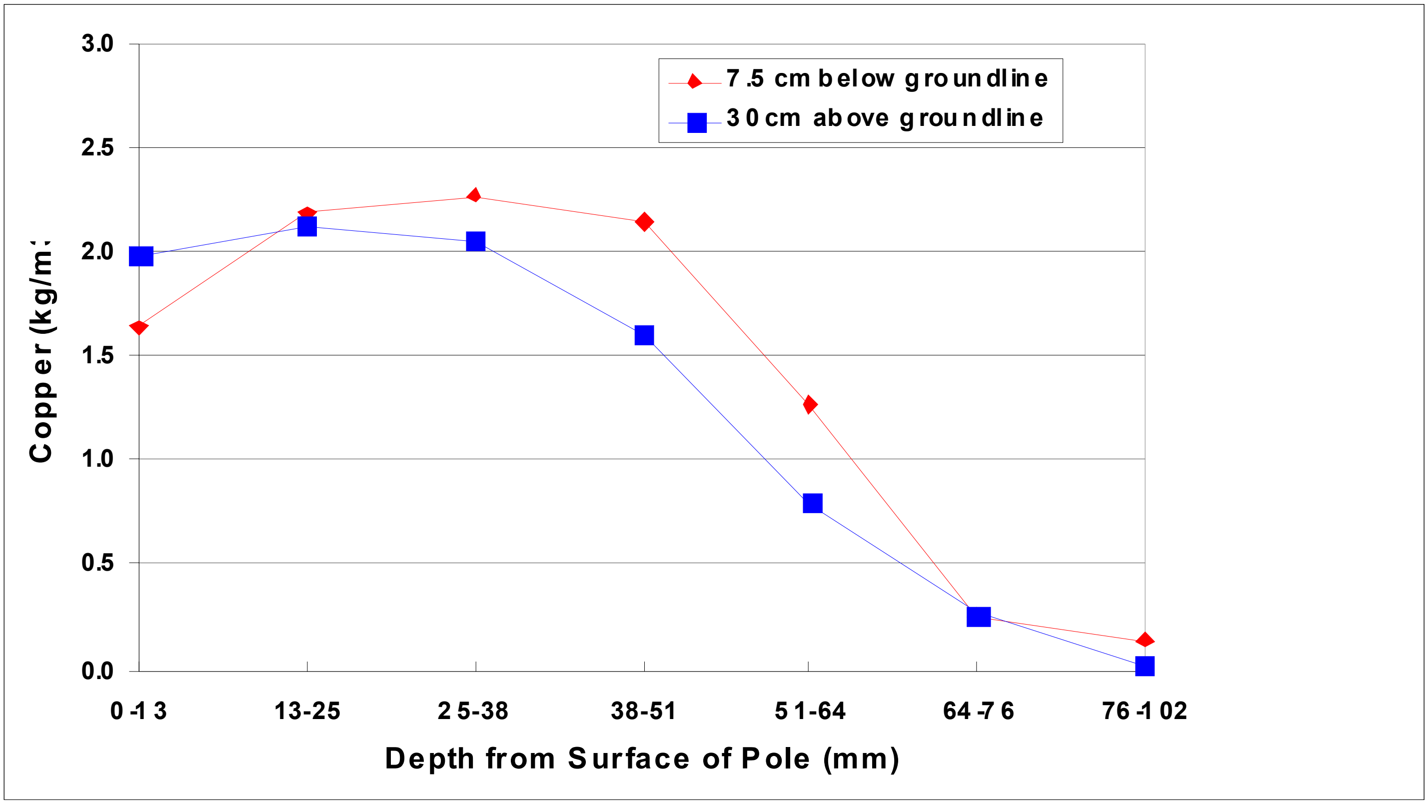


Figure V-4. Copper levels at selected distances from the wood surface in five radially-drilled copper naphthenate-treated Douglas-fir poles 10 years after installation in Peoria, OR.

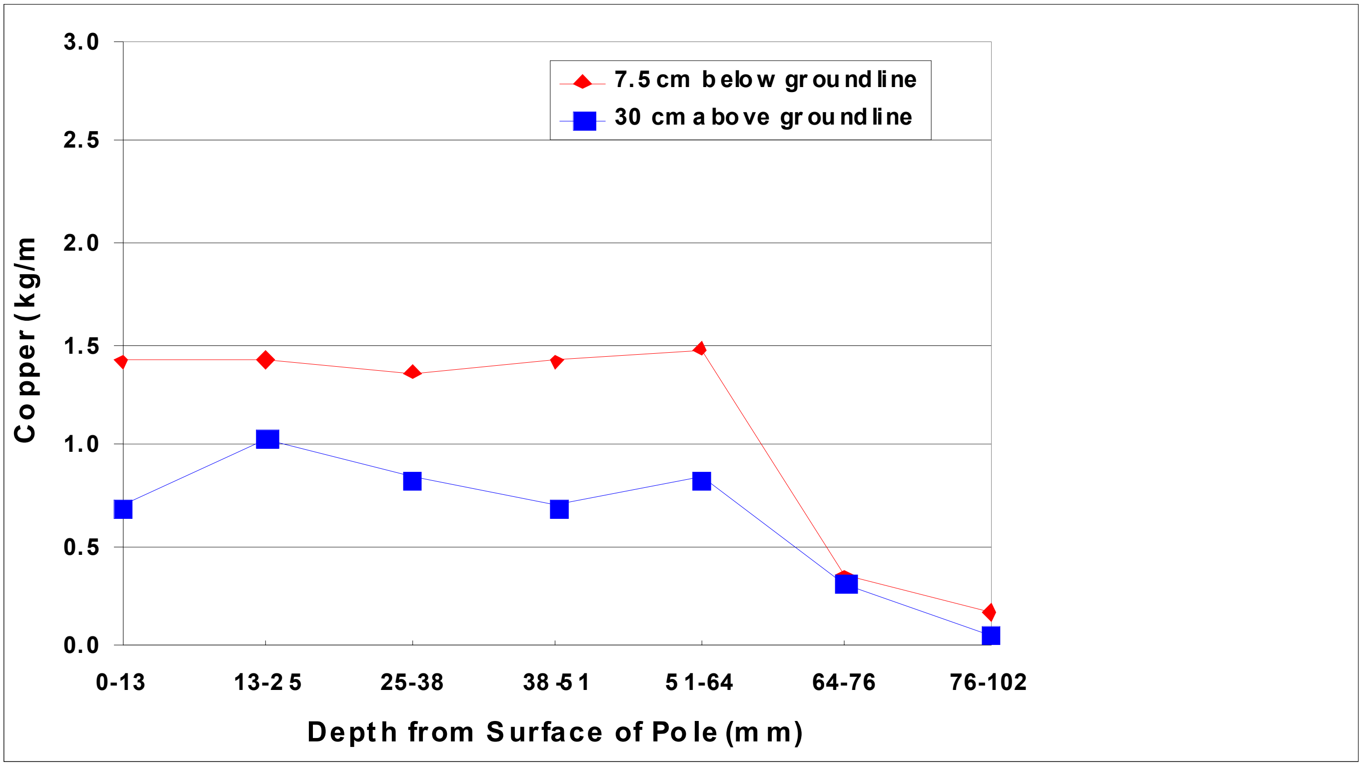


Figure V-5. Copper levels at selected distances from the wood surface in three radially-drilled copper naphthenate-treated Douglas-fir poles 10 years after installation near Tangent, OR.

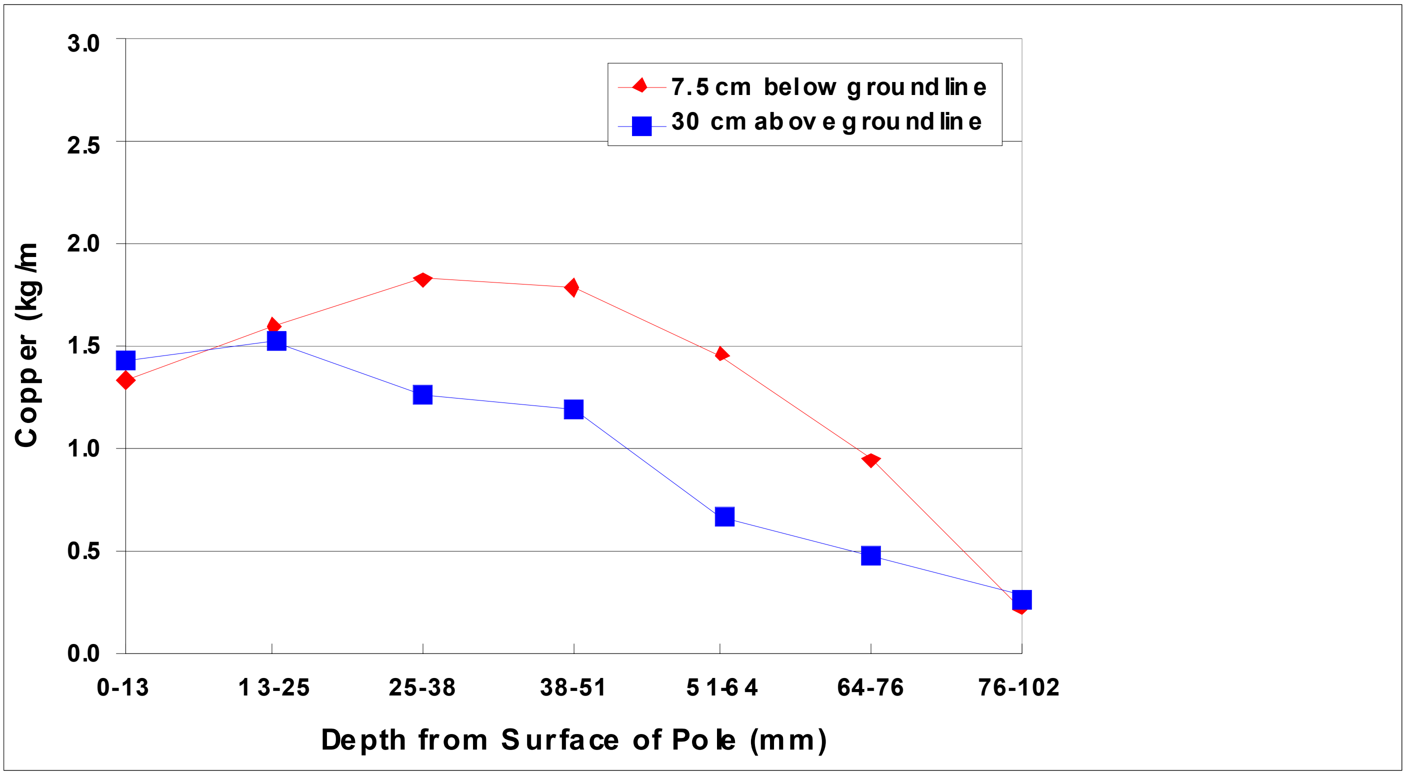


Figure V-6. Copper levels at selected distances from the wood surface in five radially-drilled copper naphthenate-treated Douglas-fir poles 10 years after installation near Scravel Hill, OR.

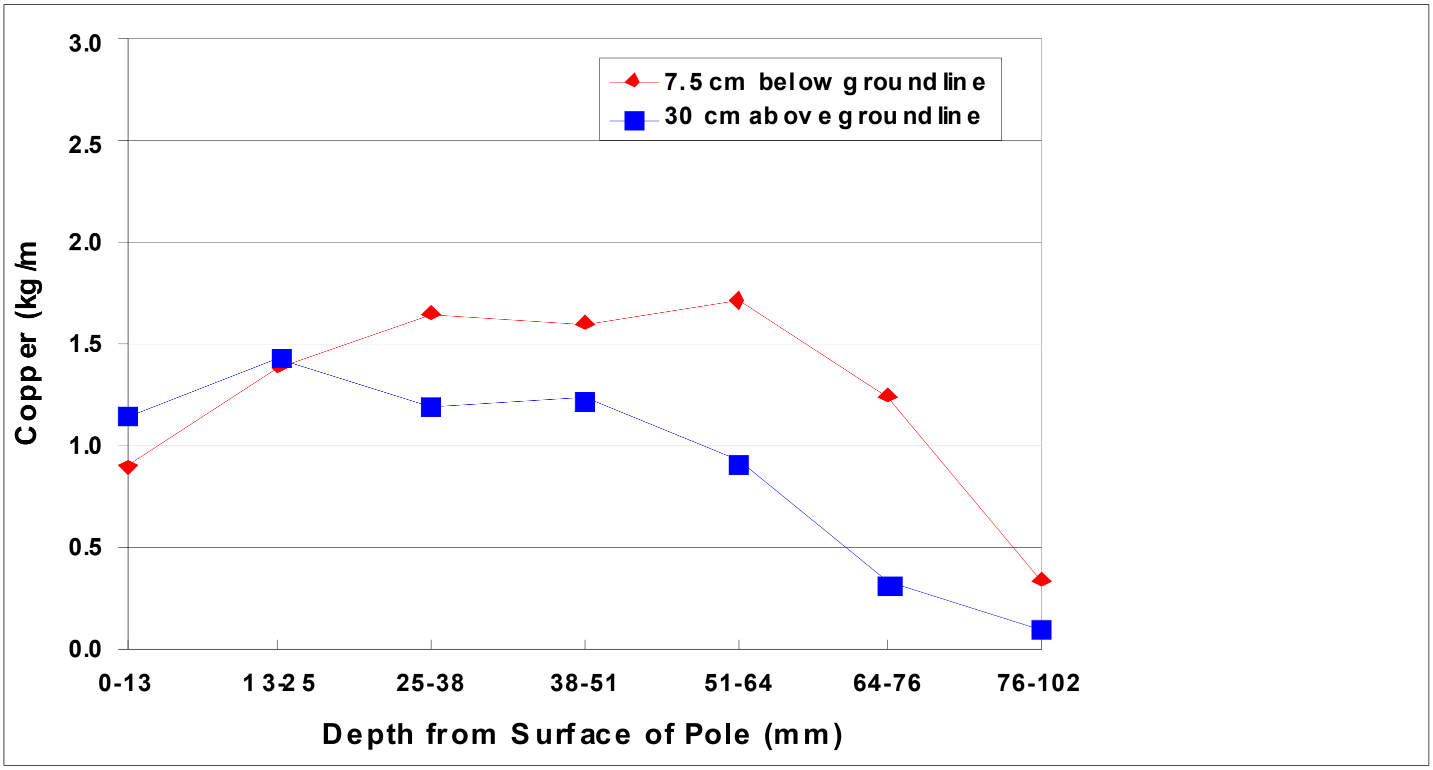


Figure V-7. Copper levels at selected distances from the wood surface in five radially-drilled copper naphthenate-treated Douglas-fir poles 10 years after installation near Draperville,OR.

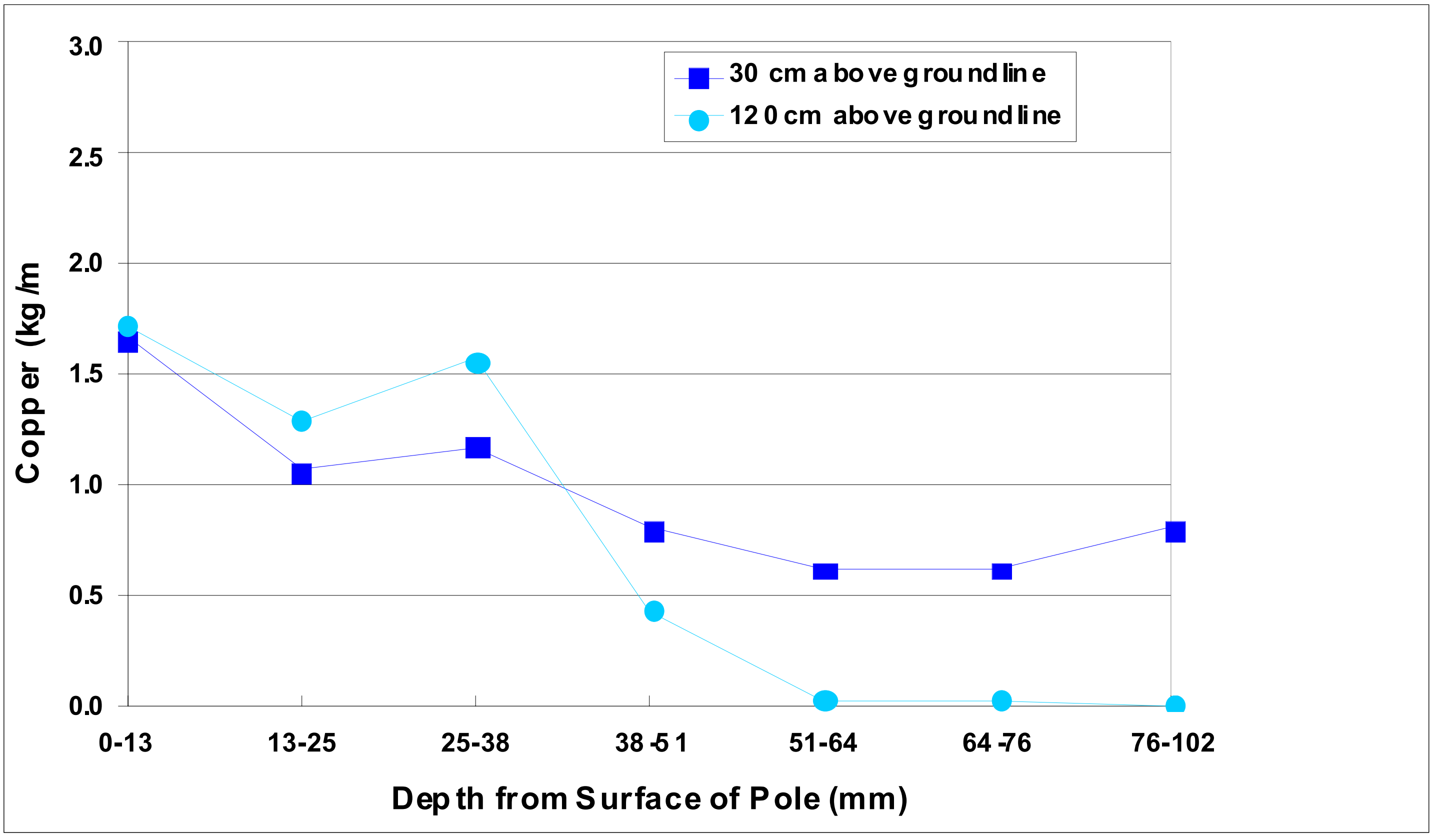


Figure V-8. Copper levels at selected distances from the wood surface in five copper naphthenate-treated Douglas-fir poles 10 years after installation near Cool, CA.

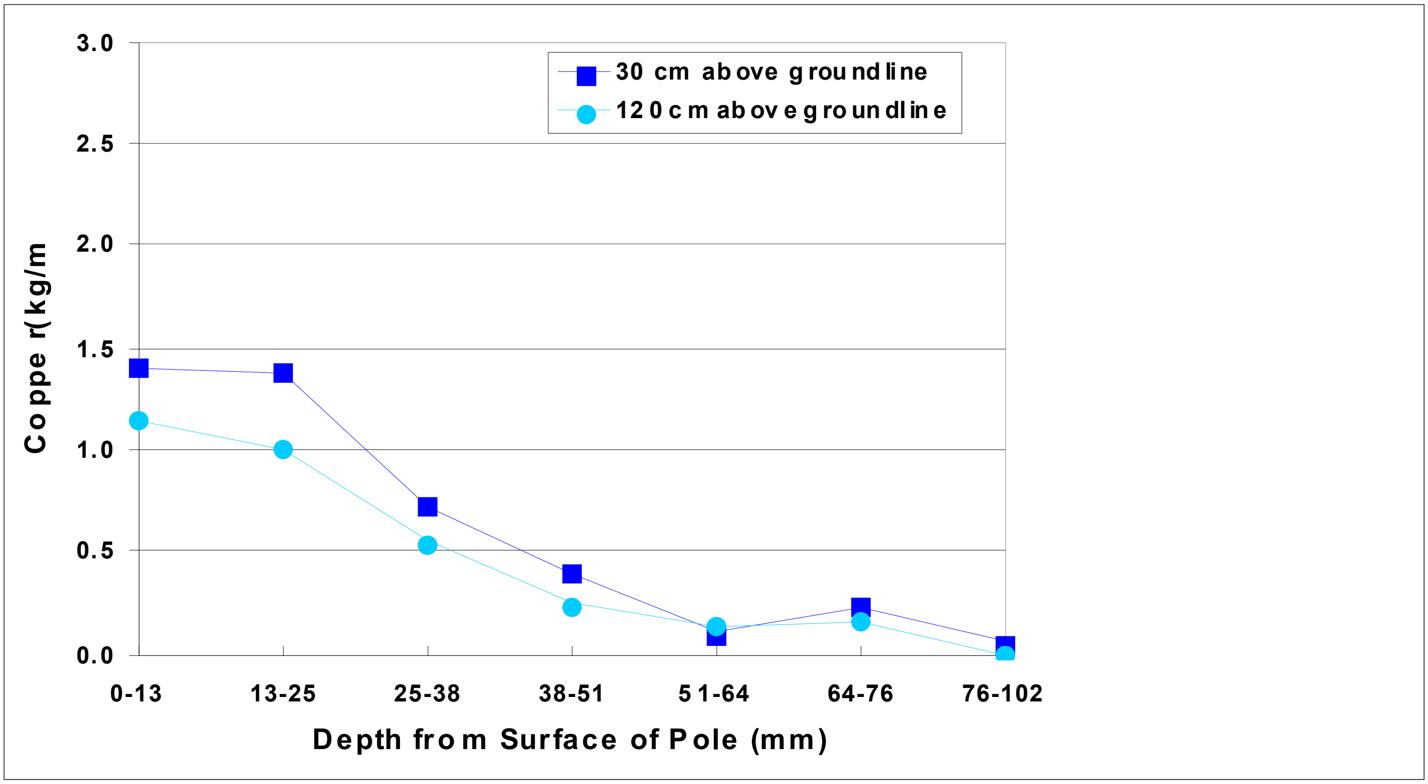


Figure V-9. Copper levels at selected distances from the wood surface in three copper naphthenate-treated Douglas-fir poles 10 years after installation near Nicholas, CA.

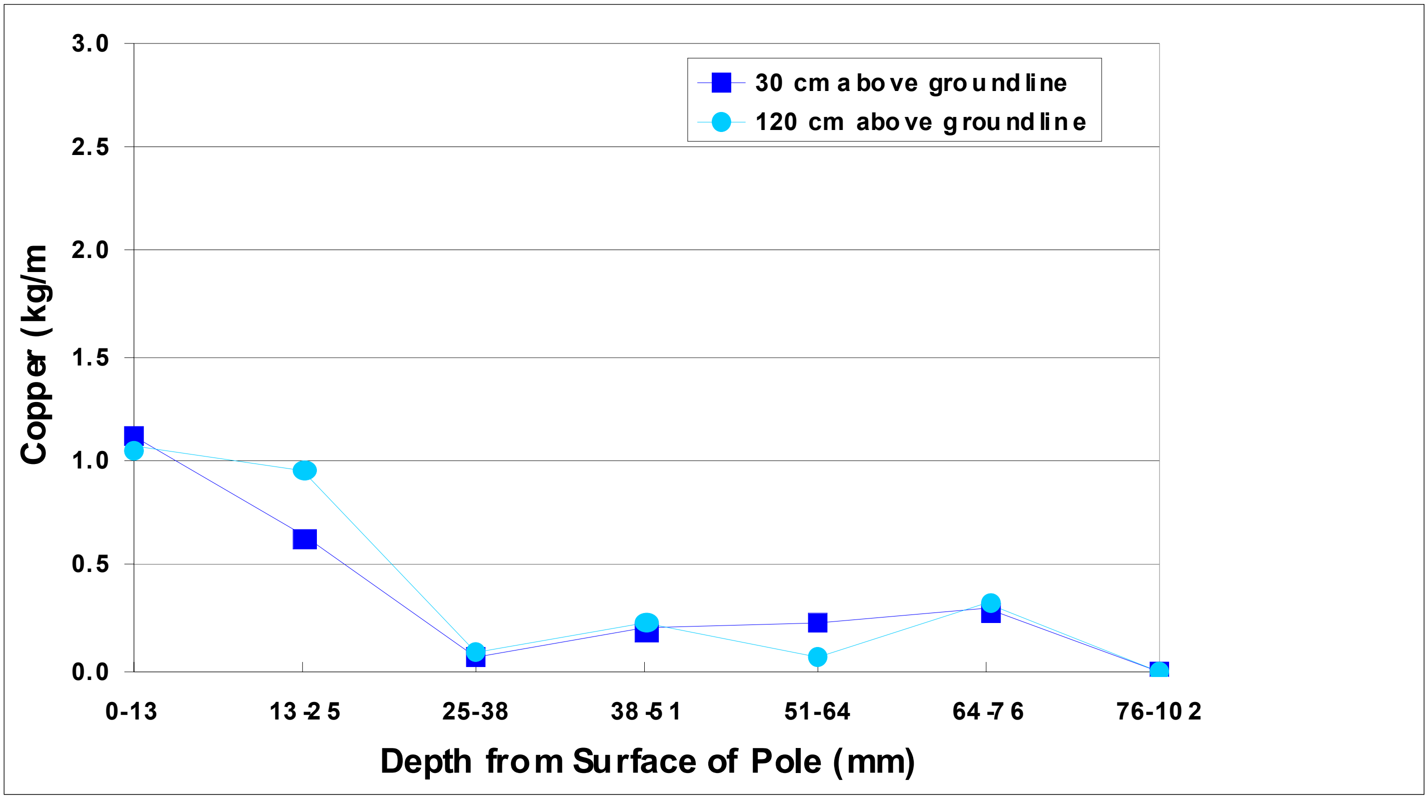


Figure V-10. Copper levels at selected distances from the wood surface in one copper naphthenate in oil-treated Douglas-fir pole 10 years after installation near San Ramon, CA.

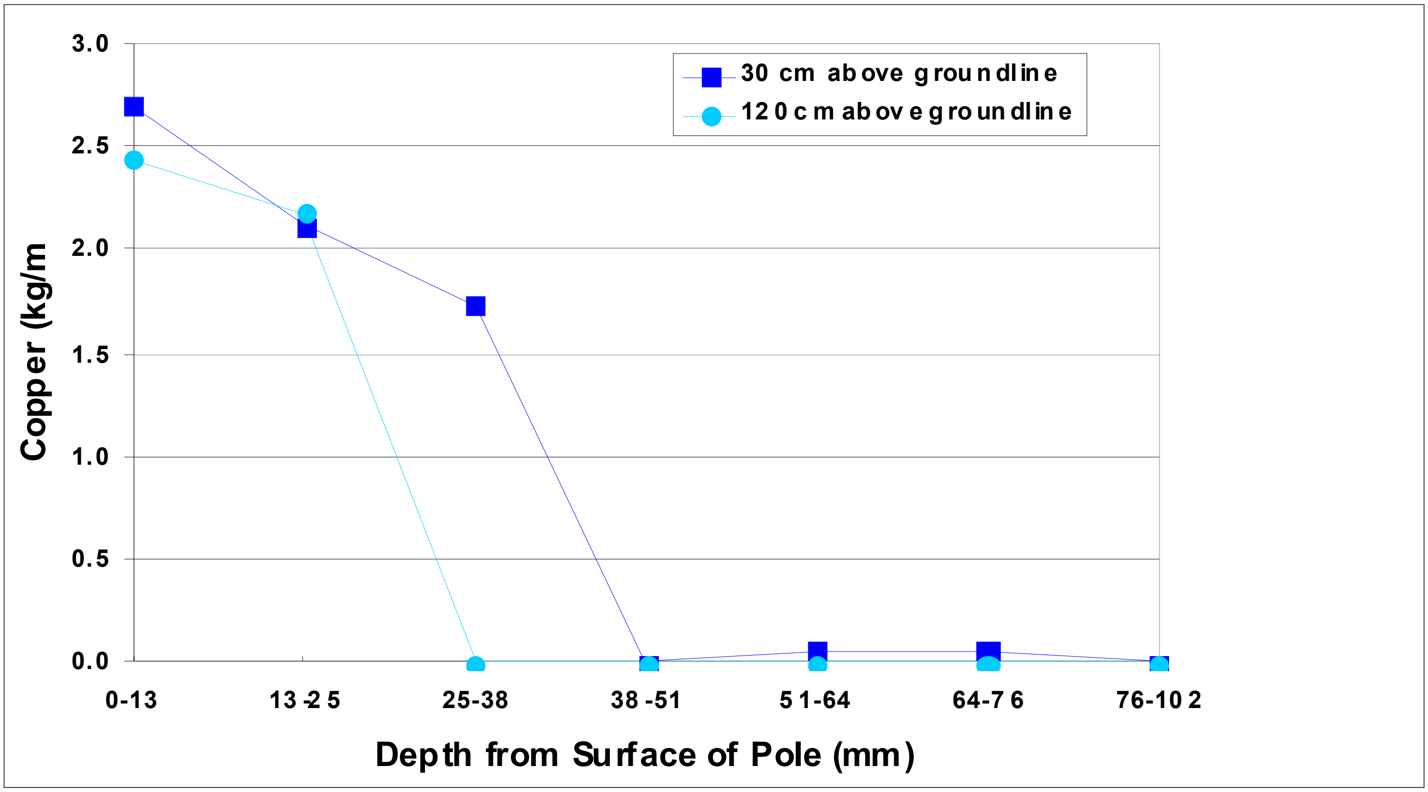


Figure V-11. Copper levels at selected distances from the wood surface in one copper naphthenate in liquified petroleum gas-treated Douglas-fir pole 10 years after installation in San Ramon, CA.

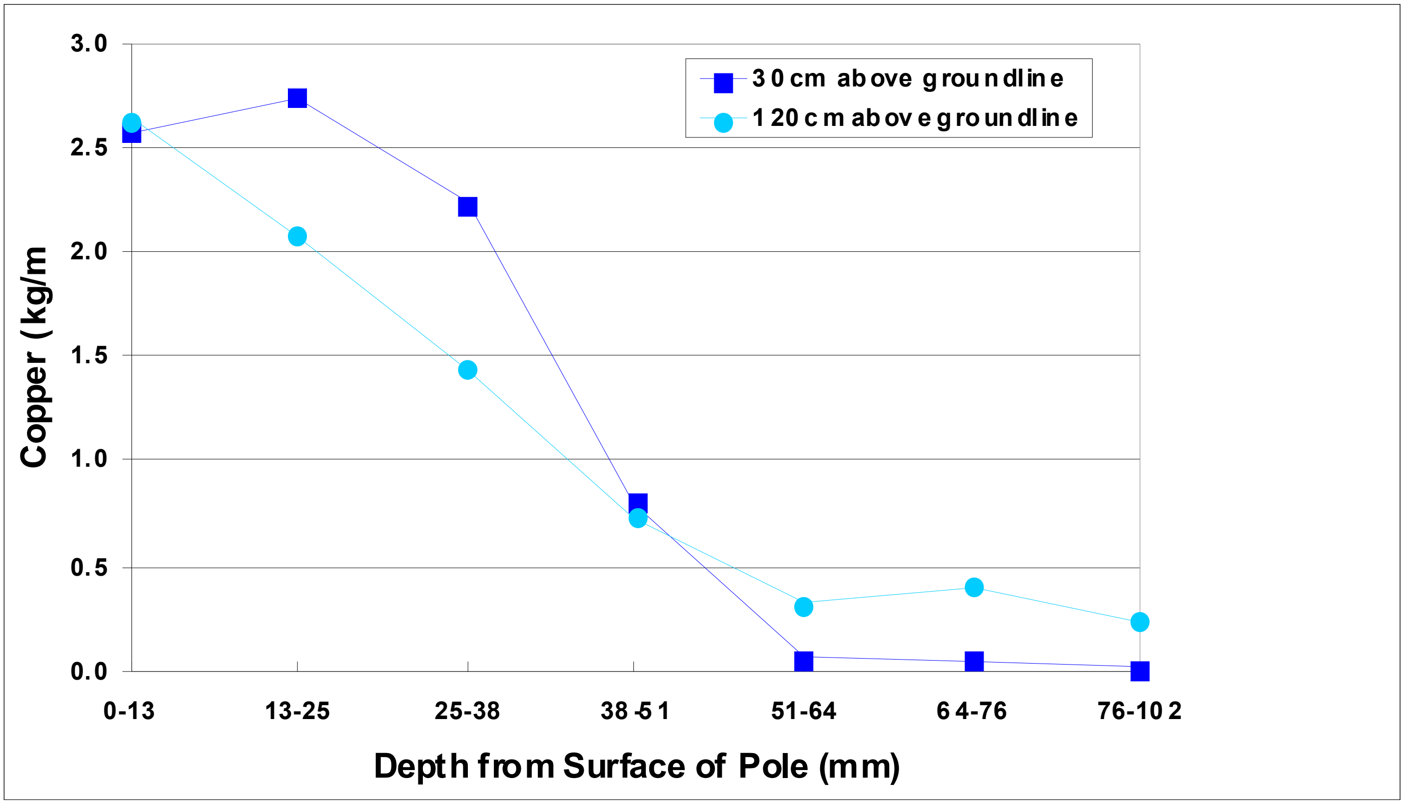


Figure V-12. Copper levels at selected distances from the wood surface in 15 copper naphthenate treated Douglas-fir poles 10 years after installation near Booneville, CA.

The current American Wood Protection Association Standards for treatment of wood poles with copper naphthenate calls for a retention of 1.52 kg/m^3 (as copper) in the zone extending from 6 to 25 mm from the surface for poles in a moderate decay zone. At the time these poles were treated, the target retention was still in flux and it is possible that these poles were instead treated to 1.2 kg/m^3. In the current survey, we did not use the exact AWPA Standard assay zone because we also wanted to determine the surface concentration of copper naphthenate. This required us to combine fractions to produce enough wood for analysis. As a result, it is not possible to directly compare assays with current retention requirements.

Copper levels were lower below the ground than above ground in the outer 13 mm of most poles sampled in 2008 (Tables V-1, 2, Figures V-13, 14). Two poles contained copper at the current standard for moderate decay exposure, while the remainder of the poles contained slightly lower copper levels. Copper levels on the outer surface of the poles were much higher 300 or 450 mm above the groundline than they were below groundline. Copper levels further from the surface were generally elevated regardless of height above ground on the pole, suggesting that a sufficient reservoir of copper naphthenate remains in the poles to provide additional protection.

While copper levels near the surface appear to have declined below ground, visual inspection and probing of the pole surfaces found no evidence of surface softening that would suggest soft rot development. The lack of decay development reflects, in part, the factor of safety applied to utility pole retentions. The general threshold for performance of copper naphthenate is 0.6 kg/m^3. While copper levels in several poles have approached that level, none have developed any noticeable problems. Given the current copper levels, however, it might be useful to revisit these poles in 3 to 5 years to assess both copper levels and the presence of decay.

Table V-1. Copper levels at selected distances from the surfaces of copper naphthenate treated Douglas-fir poles sampled 20 years after installation in Western Oregon using a sampling pattern of core removal from 150 mm below groundline and 300 mm above groundline.

	Assay zone (mm from the pole surface)									
Pole number	0-13		13-25		25-51		51-76		76-102	
	Distance from groundline (cm)									
	-15 cm	30 cm	-15 cm	30 cm	-15 cm	30 cm	-15 cm	30 cm	-15 cm	30 cm
16	0.659	0.808	0.805	0.749	1.196	1.040	1.494	1.379	1.229	1.764
17	0.484	1.752	0.786	1.893	1.232	1.975	1.554	0.280	1.365	0.000
18	0.523	1.504	0.792	0.911	1.002	1.085	0.966	1.077	0.636	1.357
19	0.852	0.736	1.056	0.891	1.343	1.021	1.103	0.974	1.002	0.613
20	1.555	1.169	1.645	1.232	1.496	0.477	1.686	0.000	1.160	0.033
21	1.086	0.739	1.341	1.318	1.238	1.184	1.719	1.672	1.286	1.601
1050	1.070	1.763	1.840	1.291	1.836	1.948	1.766	1.765	1.859	1.761
1576	1.410	1.905	1.846	1.747	1.673	1.541	1.793	1.890	1.406	2.001
1577	1.026	1.355	1.374	1.633	1.239	1.433	1.134	1.126	1.169	1.026
1580	0.840	1.158	1.323	1.500	1.173	1.223	1.611	1.380	0.490	1.627
1581	1.373	1.942	1.585	2.823	1.837	2.540	2.442	2.599	2.089	2.523
1582	0.680	0.596	0.895	0.753	0.937	1.105	1.413	1.536	1.197	1.432
1583	0.808	1.054	0.845	1.219	0.777	1.083	1.560	1.507	0.325	1.143
1584	0.518	1.486	0.986	1.549	1.052	1.824	1.356	1.260	0.932	1.304
1586	1.187	1.257	1.499	1.311	1.668	1.484	1.429	2.191	1.852	1.906
1587	1.075	1.362	1.789	1.524	1.660	1.053	1.811	1.189	1.067	1.272

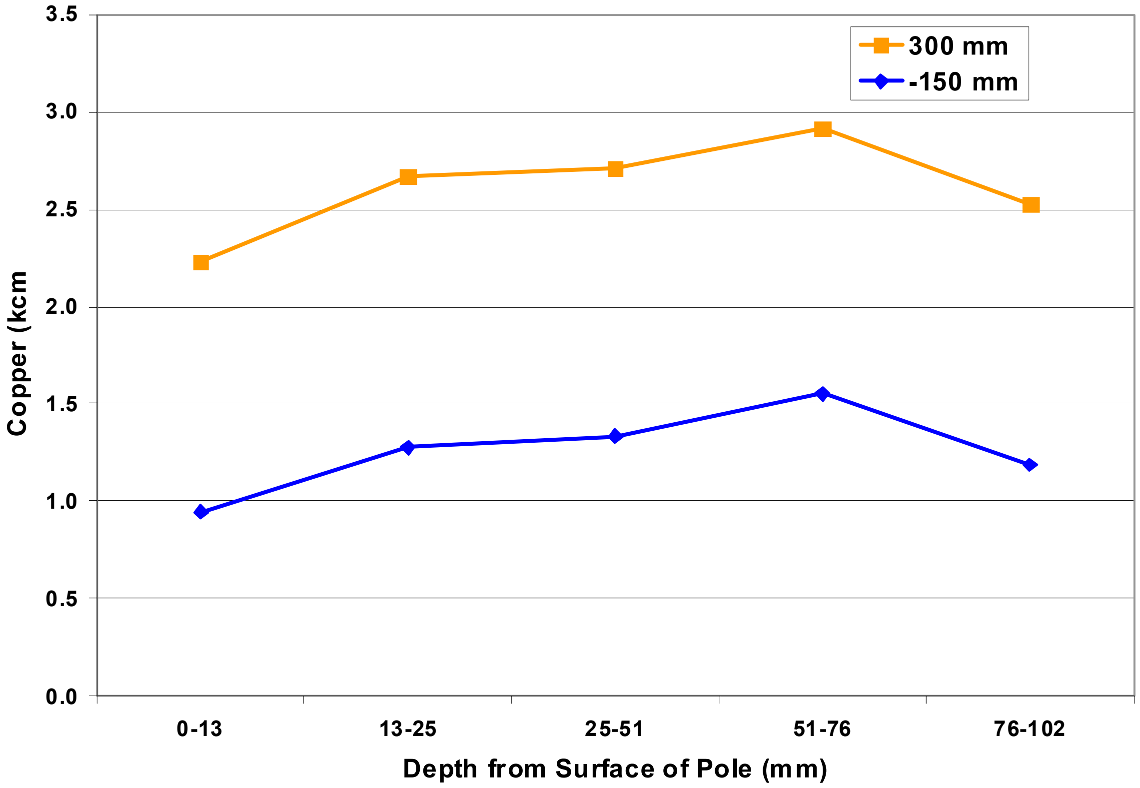


Figure V-13. Copper levels at selected distances from the wood surface in sixteen copper naphthenate-treated Douglas-fir poles 20 years after installation near Balston, OR.

Table V-2. Copper levels at selected distances from the surfaces of copper naphthenate treated Douglas-fir poles sampled 20 years after installation in Western Oregon using a sampling pattern of core removal from 150 mm below groundline and 450 mm above groundline.

	Assay zone (mm from the pole surface)									
Pole number	0-13		13-25		25-51		51-76		76-102	
	Distance from groundline (cm)									
	-15 cm	45 cm	-15 cm	45 cm	-15 cm	45 cm	-15 cm	45 cm	-15 cm	45 cm
225	1.272	1.742	1.343	1.747	1.106	1.543	0.788	1.300	0.566	1.780
226	1.157	1.013	1.709	0.908	2.055	0.759	1.544	0.000	1.776	0.000
235	1.029	1.005	1.323	1.082	1.964	1.150	1.265	0.299	1.292	0.099
236	0.444	1.012	0.802	0.813	1.173	1.059	1.182	0.166	1.676	0.231
323	0.312	1.078	0.590	1.447	1.155	1.103	1.338	0.271	1.443	0.078
1029	1.200	0.788	1.208	0.776	1.131	0.457	0.921	0.000	0.940	0.000
1031	1.031	1.867	2.040	2.218	1.726	1.017	2.994	0.000	2.801	0.000
1045	1.146	2.070	1.985	1.288	1.995	0.678	2.869	0.099	2.265	0.103
1049	0.786	0.972	1.086	1.511	1.309	0.787	0.633	0.000	0.541	0.000
1334	0.649	1.138	0.599	0.679	0.742	0.727	1.178	0.013	0.990	0.000
1594	0.571	0.940	0.893	0.773	0.967	0.591	0.628	0.085	0.742	0.103
1596	1.870	2.337	2.442	2.035	1.408	1.155	1.435	0.122	1.100	0.000
1597	0.867	1.423	1.220	1.466	1.626	1.157	2.177	0.260	1.317	0.077
1600	0.435	0.979	0.804	0.837	0.863	0.366	1.648	0.000	0.714	0.023

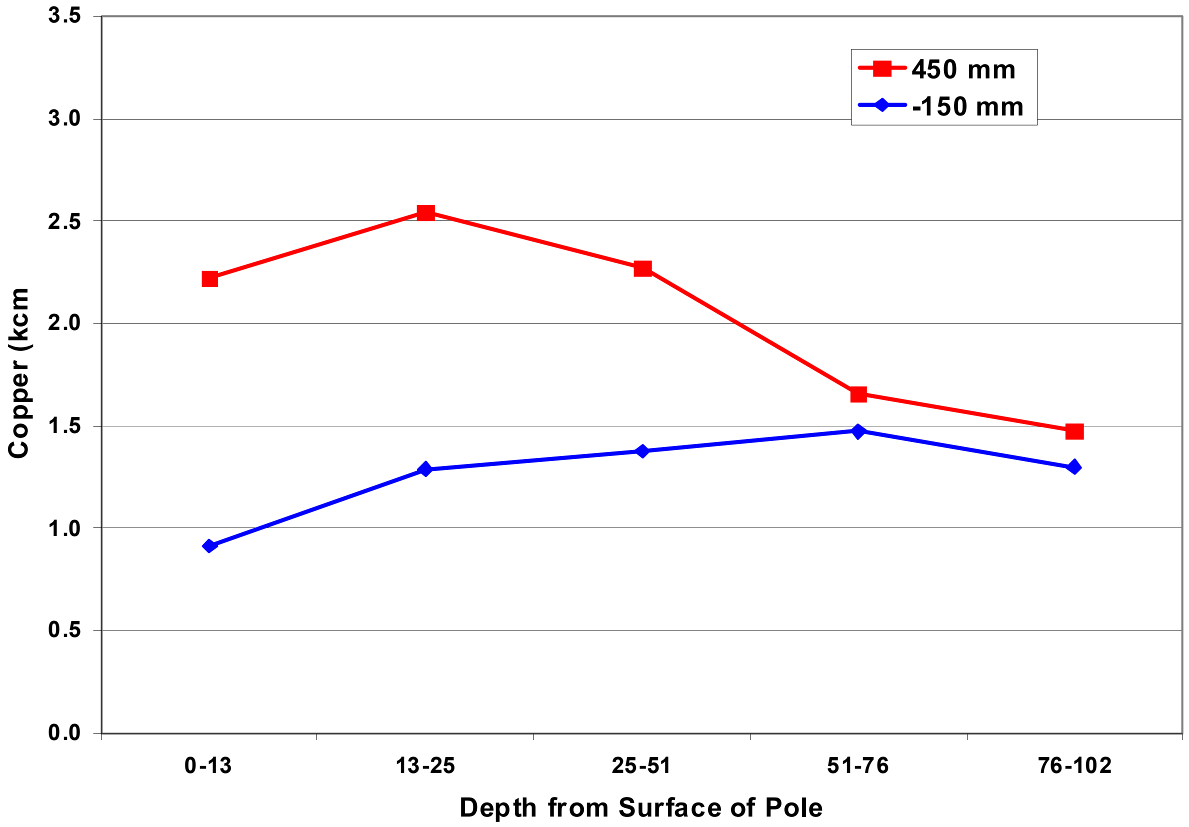


Figure V-14. Copper levels at selected distances from the wood surface in cores taken above and below groundline in fourteen through-bored copper naphthenate- treated Douglas-fir poles 20 years after installation near Balston, OR.

Objective VI

ASSESS THE POTENTIAL ENVIRONMENTAL IMPACTS OF WOOD POLES

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

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

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

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

The purpose of this study was to assess the levels of preservative migrating from pentachlorophenol treated Douglas-fir poles sections subjected to natural rainfall in Western Oregon with the ultimate goal of developing recommendations for pole handling and storage by utilities.Douglas-fir poles sections (250 to 300 mm in diameter by 1.0 m long) were air-seasoned and pressure-treated with pentachlorophenol in P9 Type A oil to a target retention of 9.6 kg/m^3 in the outer 6 to 25 mm of the poles. Treatment conditions followed the current Best Management Practices as outlined by the Western Wood Preservers' Institute. Following treatment, one end of each pole was end sealed with an elastomeric paint designed to reduce the potential for chemical loss from that surface, while the other end was left unsealed. The idea was to simulate a longer pole section where some end-grain loss was possible, but the amount of exposed end-grain did not dominate the overall surface area exposed. Six poles were then stacked on stainless steel supports in a stainless steel tank designed so that all rainfall striking the poles would be captured. The poles were set 150 mm above the tank bottom to reduce the risk that the wood would be submerged and, therefore, have the potential to lose more chemical. The poles were then exposed outside the Richardson Hall laboratories where they were subjected to natural heating and rainfall. We allowed this system to operate for approximately 1 year, then we removed the poles, cleaned the system and reset the tank so that different pole surfaces were exposed.

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

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

c.

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

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

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

Penta levels in runoff from the stored poles in the original six-pole alignment ranged between 1 and 2.5 ug/ml of water over 62 rainfall events (Figure VI-2). Penta levels in the runoff from the first six rainfall events were lower than almost all other samples; however, there was a delay in analysis of these samples and we believe the lower levels were due to degradation or sorption of the penta during storage time. The remaining samples were processed within 3 days of collection, limiting the potential for degradation or loss in storage. The relatively narrow range of concentrations suggests that penta solubilization in rainwater is relatively predictable. Penta levels in the runoff from 13 rainfall events for the realigned six-pole stack were slightly higher than those in the original six-pole stack (2.3 to 2.9 ug/ml of water) (Figure VI-2), but the differences were small. The penta levels in the four-pole array were similar to those found with the first two configurations, ranging from 0.8 to 2.6 mg/ml of water. The four-pole configuration exposed a slightly lower surface area to direct rainfall, but did not have excess area beneath the directly exposed samples on which the resulting runoff water could strike the wood.

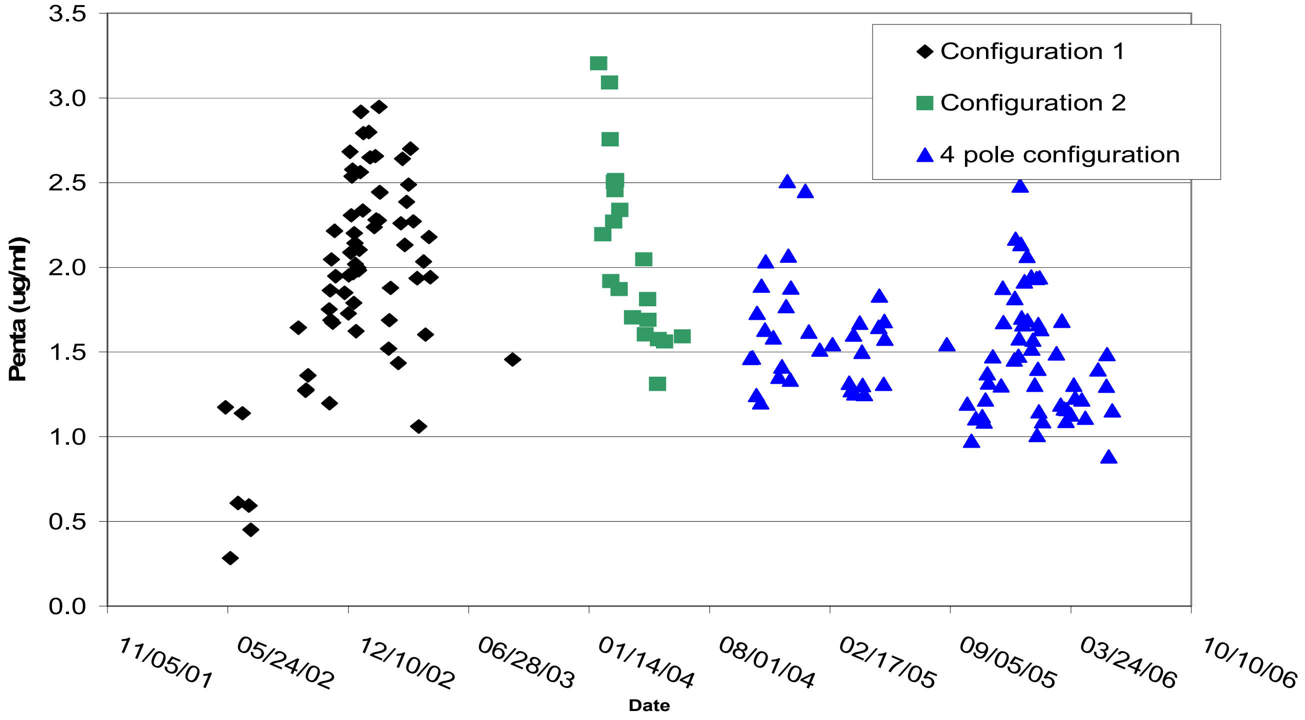


Figure VI-2. Penta concentrations as a function of sampling date in leachate collected from penta treated Douglas-fir poles following rainfall events over a 4.5 year exposure period showing data for three stacking configurations of poles.

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

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

For the purposes of the assessment, we used a hypothetical group of 15 Class 4-40 foot long poles. The virtual poles were configured into three arrangements (Figure VI-3). The first was to have all 15 poles laid out so that they were touching, but not stacked upon one another. This represented the largest surface area exposed to direct rainfall. The second was to stack the poles in a triangle with five poles at the base and one fewer pole per level. The final configuration was a four pole wide stack with stickers between each row, with the final row only containing three poles. The total surface areas occupied by each stack can be found in Table V-1. Pole dimensions were based upon the ANSI 0.5 assumed values for poles of this class and length. We made an assumption that any rainfall striking the wood would be saturated with penta. From previous tests, the upper levels of penta in runoff water tended to be approximately 3 ug/ml. This figure was used throughout the assessment as the concentration of penta in any water striking the poles.

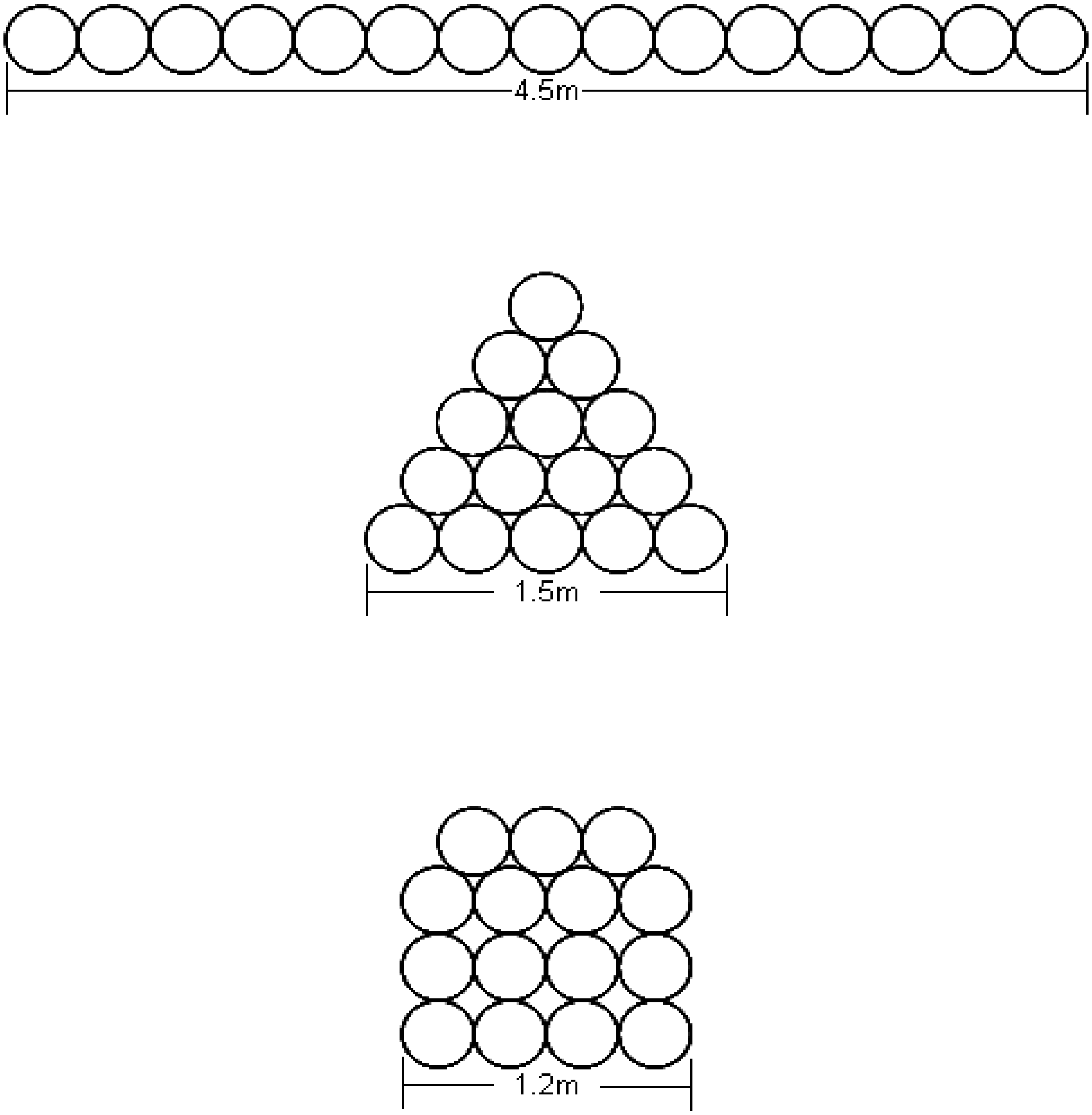


Figure VI-3. Configurations of 15 Class 4 forty foot long poles used to model predicted penta concentrations in soil beneath the poles as a result of rainwater runoff. Poles were configured as 15 individual poles, poles in a triangular stack and poles in four courses with stickers in between each course.

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

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

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

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

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

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

Total Annual Rainfall (m)	Total amount of penta migrating per configuration (mg)		
	Stack (14.4 m^2)	Triangle (18 m^2)	Arrayed (54 m^2)
0.375	162.0	202.5	607.5
0.750	324.0	405.0	1215.0
1.125	216.0	607.5	1822.5
1.500	648.0	810.0	2430.0
Values reflect an assumption that any water leaving the poles will contain at least 3 mg of pentachlorophenol per liter.			

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

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

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

Total Annual Rainfall (m)	Penta Concentration in Soil of a given depth (ppb)					
	Stack (14.4 m^2)		Triangle (18 m^2)		Arrayed (54 m^2)	
	75 mm	150 mm	75 mm	150 mm	75 mm	150 mm
0.375 m	94 to 125	47 to 63	282 to 375	141-189	352-469	176-235
0.750 m	188 to 250	94 to 125	564 to 750	282-375	704-938	352-470
1.125 m	282 to 375	141 to 188	843 to 1125	423-564	1056-1407	528-704
1.500 m	376 to 500	188 to 250	1125-1500	564-750	1404-1876	704-938
Values reflect an assumption that any water leaving the poles will contain at least 3 mg of pentachlorophenol per liter and all penta will remain in a soil layer either 75 or 150 mm thick. Values are expressed on a ug of penta per kg of soil basis.						

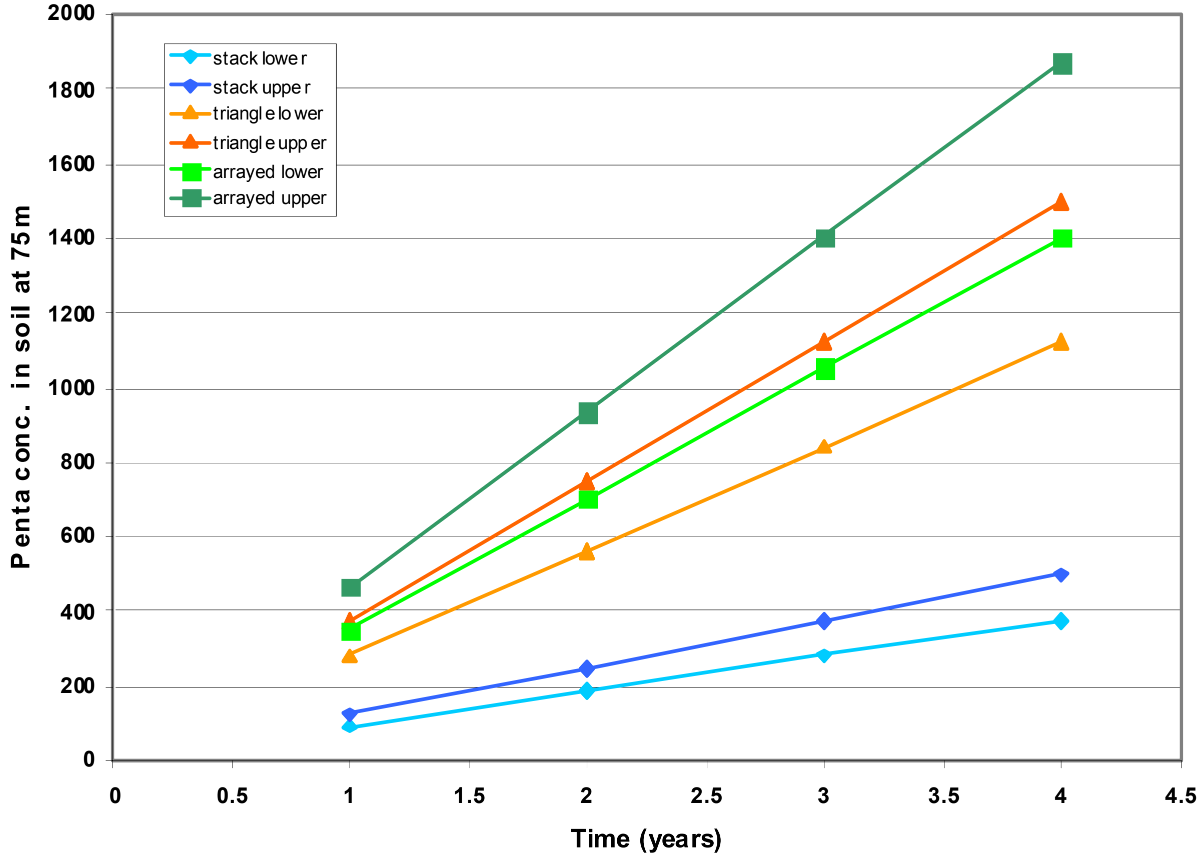


Figure VI-4. Predicted penta concentrations over a 3 year period in soils beneath poles stored in three configurations that varied total area exposed to rainfall.

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

While the results clearly showed that penta does migrate from poles into soils beneath stored poles, the levels remain low. Where concerns about this migration exist, it may be possible to adapt the site to contain any migrating chemical at sites where poles are stored for longer periods. For example, pole storage sites are often graveled to allow for all-weather equipment access. In these cases, it might be possible to install a layer beneath the gravel to trap any penta in the water runoff. This past year, we have explored the potential for using low cost materials such as clays and wood particles to trap penta from water runoff. Our preliminary trials indicate that simple, easily maintained traps are highly effective at removing penta from the runoff (Figure VI-5). Further studies are underway to more fully understand the relationship between absorbent type and penta.

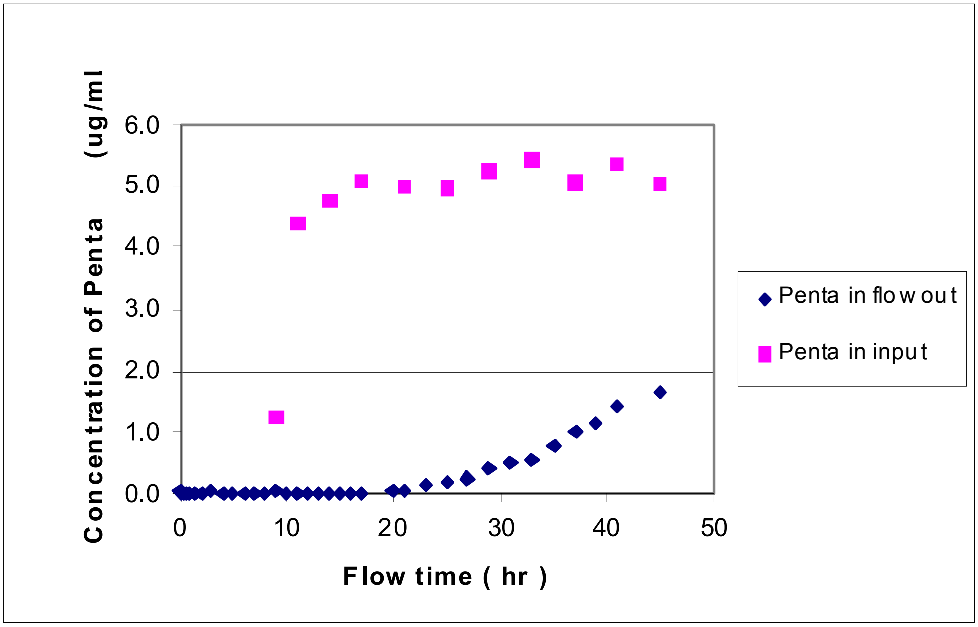


Figure VI-5. Pentachlorophenol content of water before and after passing through a wood particle packed column. Column flow rate was 1.8 mL/minute.

The results indicate that penta does migrate from poles in storage as a result of rainfall. The levels; however, are extremely low and should not pose a problem over several seasons of storage. In addition, the levels in the runoff are consistent and predictable, allowing for management strategies to mitigate any possible effects. Preliminary results suggest that simple sorbent materials such as sawdust can be extremely effective at removing penta from the runoff and may be useful for mitigating any potential effects.

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

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

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

The water in the tank was sampled before the level reached the poles during the rainy season and after individual rain events during the dry season by draining all of the water collected in the tank bottom. In some cases, the rainfall, while measurable, did not result in collectible water samples because the conditions were so dry prior to rain that the falling moisture was either sorbed by the wood or evaporated.

Water samples were then analyzed for copper, zinc or arsenic by ion-coupled plasma spectroscopy. The data were arrayed by date of collection, total rainfall, and days between rainfall events (Figure VI-6 to VI-8).

As in the penta samples, copper and zinc were always detectable in runoff water following rainfall events (Figure VI-6). Arsenic was below the detection threshold at all collection points, however, we made no effort to concentrate materials prior to analysis so there is no way to say that arsenic was absent in the runoff. Copper levels in the runoff ranged from 5 to 90 ppm, but most rainfall contained 10 to 40 ppm of copper. Zinc levels tended to be much lower, ranging from <1 to 34 ppm, but most samples contained less than 5 ppm of zinc. Although our initial observations were that metal levels in runoff did not appear to be related to exposure time, levels of both copper and zinc in runoff fell off sharply after 1 year of exposure. For example, copper levels declined by nearly 50 % in the second year, except for our most recent sample. Similarly, zinc levels declined to <1 ppm in the second year, although the most recent sample rose to nearly 5 ppm. One possible explanation for these declines is that the initial losses reflected migration of metals deposited on the wood surface. Although these poles were treated using the WWPI Best Management Practices, it is impossible to remove all surface deposits. Our results suggest that losses from these poles over a longer time declined sharply and differed markedly from those found with penta treated poles, where the concentration of penta in the runoff remained fairly constant for 3 or more years.

Evaluation of metal levels in runoff as a function of total rainfall amounts indicated that concentrations did not differ markedly with rainfall amount (Figure VI-7). This finding is consistent with the concept that total metals in runoff are related to solubility. Clearly, however, areas with higher rainfall will experience higher total metal losses.

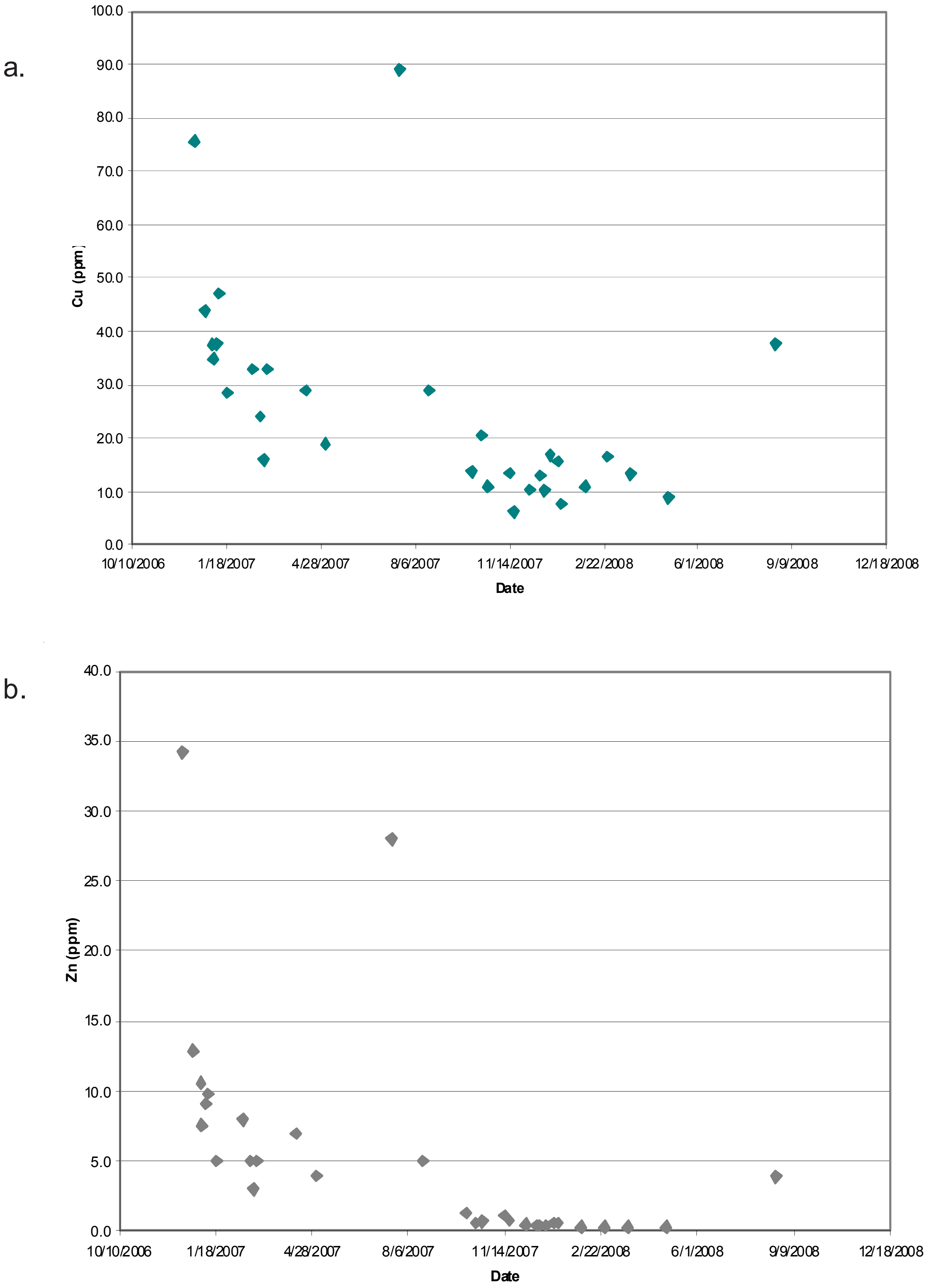
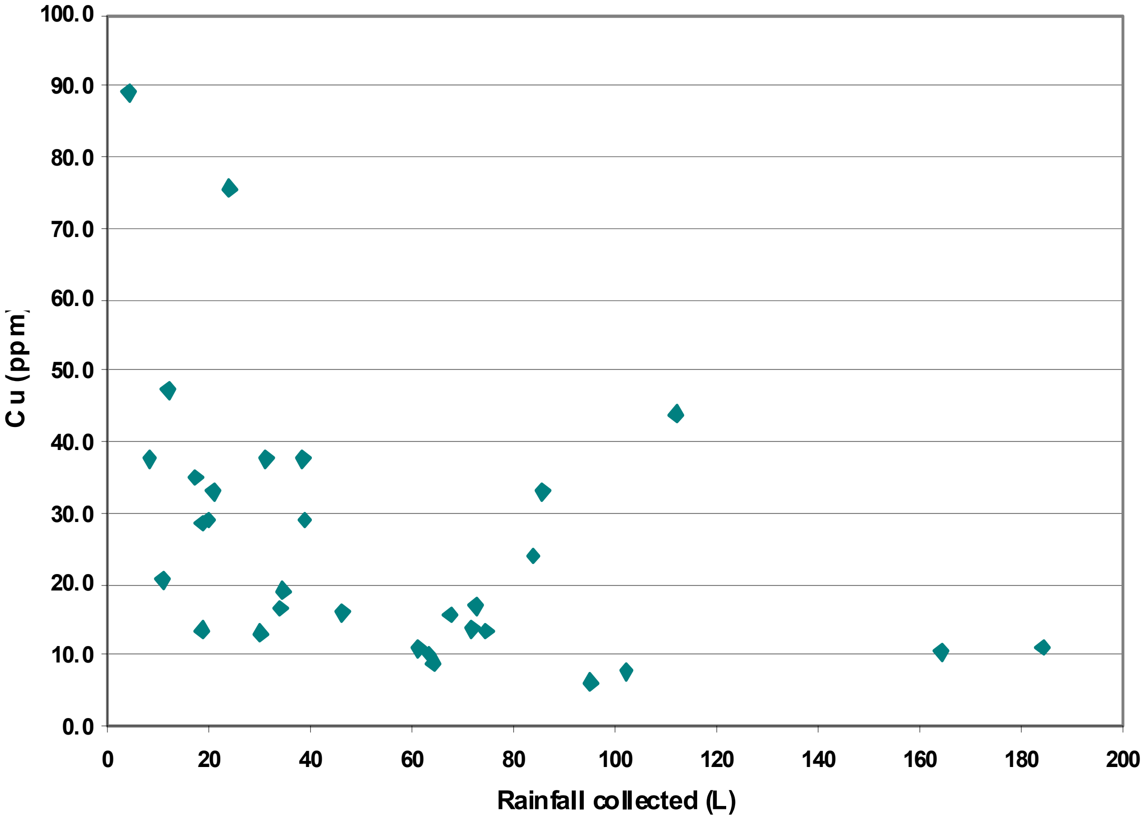


Figure VI-6. Copper (a) and zinc (b) levels in rainwater runoff from poles treated with ammoniacal copper zinc arsenate as a function of date of rainfall.

a.



b.

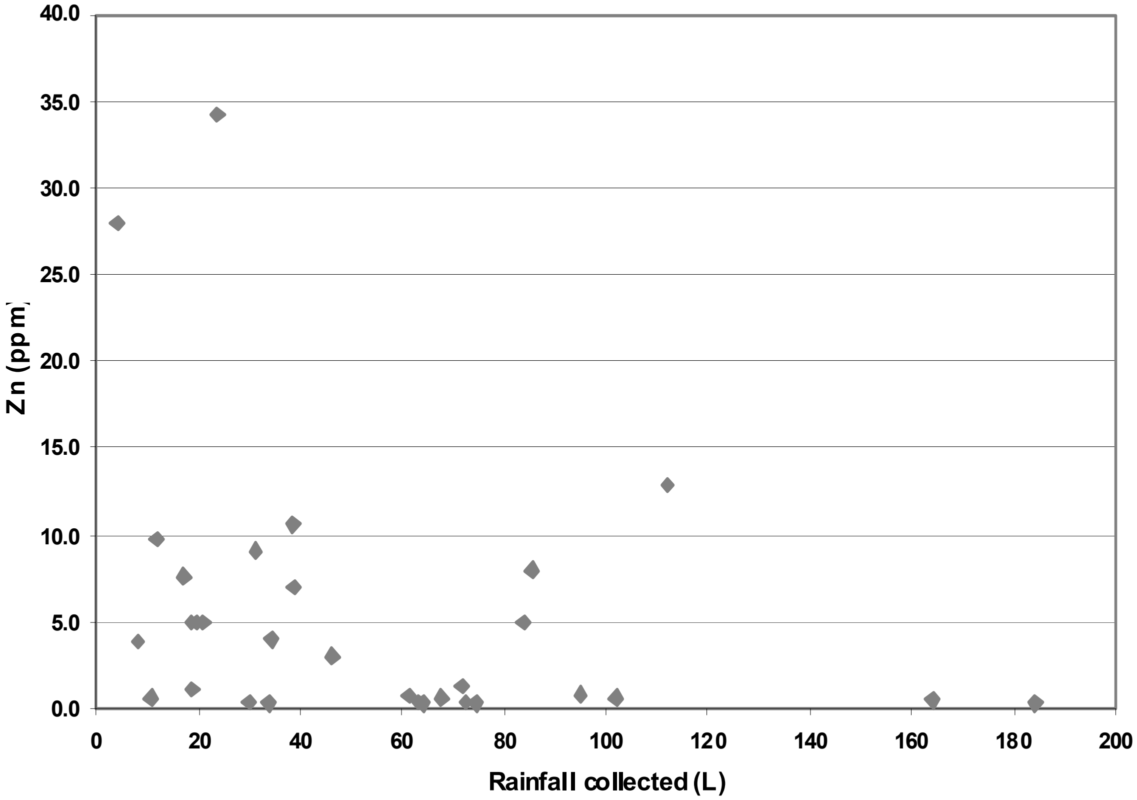


Figure VI-7. Copper (a) and zinc (b) levels in rainwater runoff from poles treated with ammoniacal copper zinc arsenate as a function of total rainfall collected.

As with penta treated poles, there appeared to be no consistent relationship between metal levels in runoff and time between rainfall events. With two exceptions, metal levels were fairly consistent even when rainfall events were separated from as few as one day to over one hundred days (Figure VI-8). These results indicate that drying between rainfall events does not bring an excess of metal to the wood surface. Coupled with the sharp drop in metal levels in the second year of exposure, the results suggest that metal levels will decline with prolonged storage and argues for longer term storage of specific poles to be used as emergency replacements. This strategy would have to be coupled with a program to apply some type of internal remedial treatment to guard against the development of internal decay fungi entering through checks exposed on the horizontally oriented poles.

The results indicate that water striking the poles sorbs a given amount of chemical, which appears to be independent of rainfall variables. As with penta, this suggests that it will be relatively easy to predict the rates of metal loss based upon exposed surface area. This creates the potential for creating relatively simple management tools for mitigating any possible risks associated with storage of ACZA treated poles. For example, it might be possible to examine the total surface area of wood exposed to initial rainfall to predict total potential runoff (Figure VI-9). This value could then be coupled with the upper concentration of zinc or copper in the water to predict the total amount of metal released at a given site. This information would allow planners to determine the feasibility of using a given site to store poles as well as when mitigation might have to be applied to a given site.

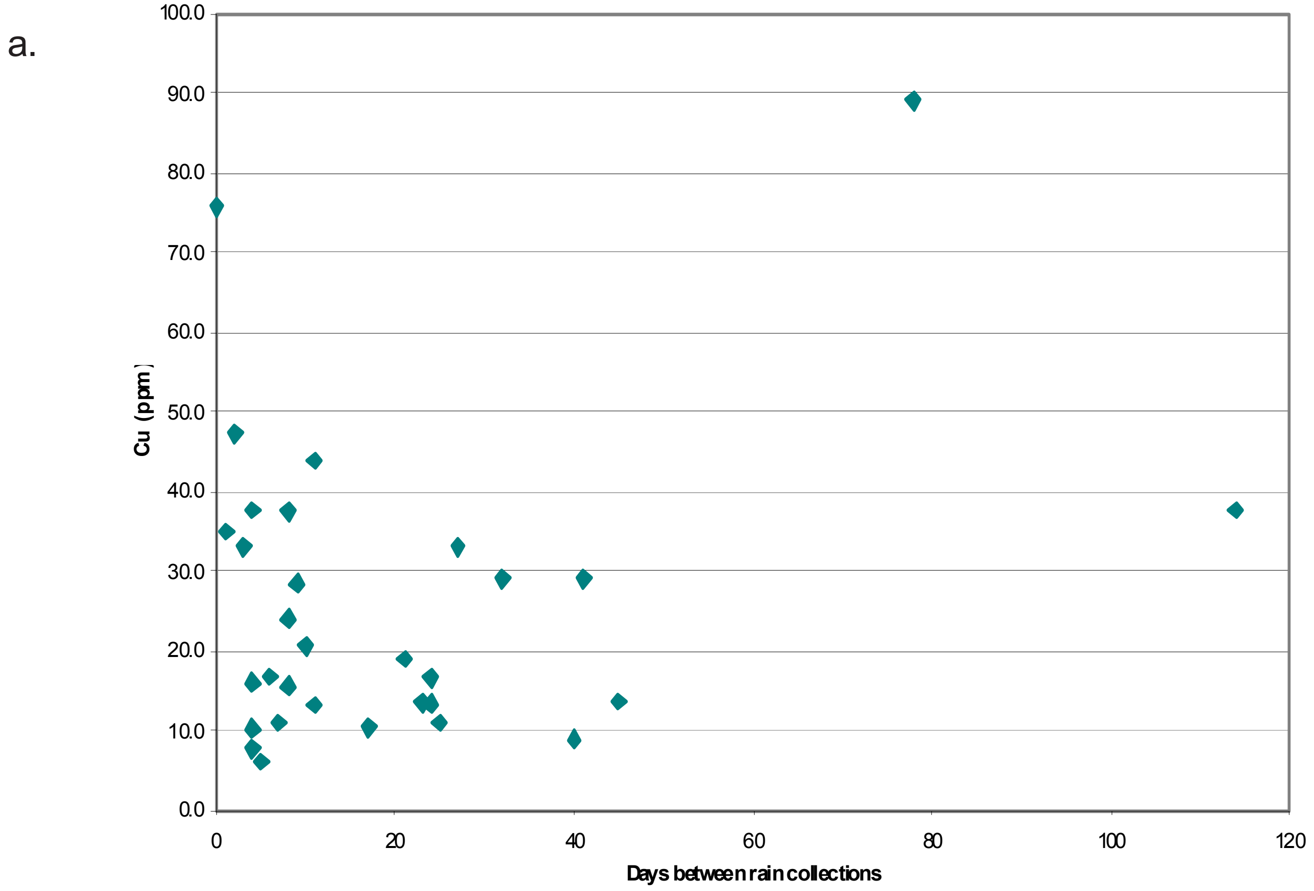


Figure VI-8. Copper (a) and zinc (b) levels in rainwater runoff from poles treated with ammoniacal copper zinc arsenate as a function of days between rainfall collections.

b.

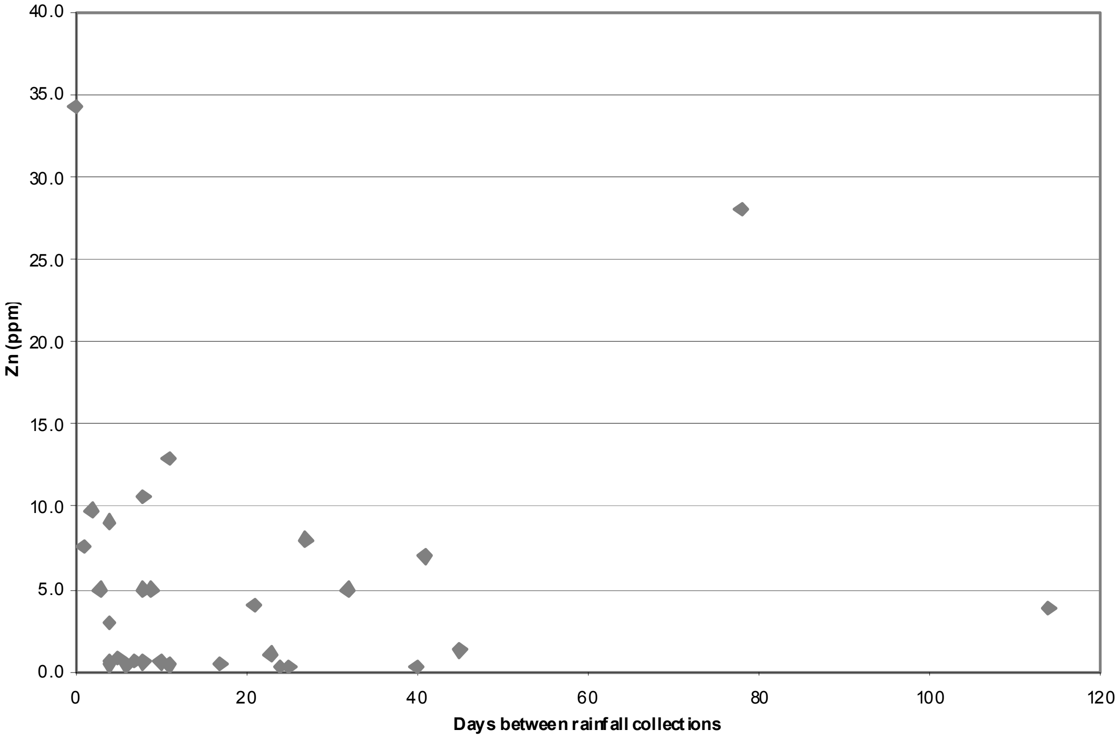


Figure VI-8 (cont.). Copper (a) and zinc (b) levels in rainwater runoff from poles treated with ammoniacal copper zinc arsenate as a function of days between rainfall collections.

a.

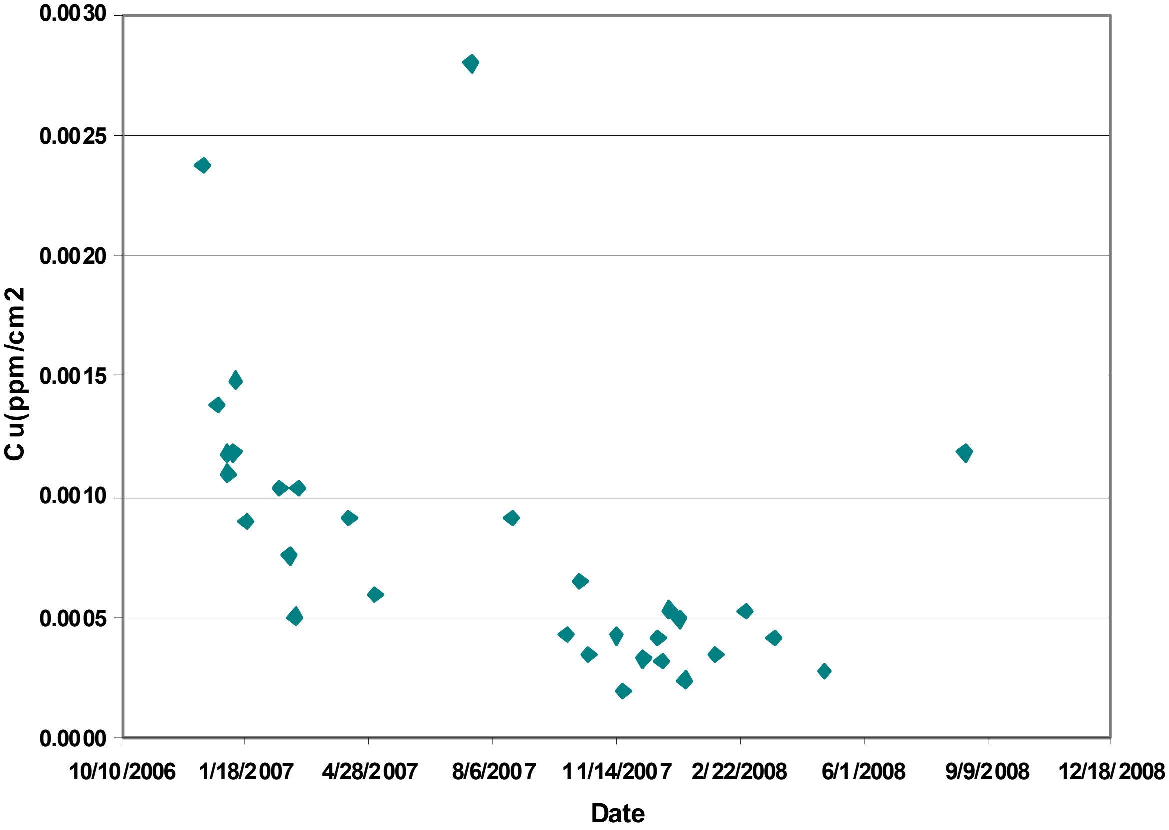


Figure VI-9. Copper (a) and zinc (b) levels in rainwater runoff from poles treated with ammoniacal copper zinc arsenate as a function of date of rainfall and pole surface area.

LITERATURE CITED

American Wood Protection Association. 1999a. Standard C1-99 All timber products— Preservative treatment by pressure processes. In: AWPA Book of Standards, Granbury, TX. Pages 23-32.

Mankowski, M.N., E.Hansen, and J.J. Morrell. 2002. Wood pole purchasing, inspection and maintenance: a survey of utility practices. Forest Products Journal 52(11/12):43-50.

Mortimer, W.P. 1991. The environmental persistence and migration of wood pole preservatives. Report for the Canadian Electrical Association, CEA, Montreal, Quebec, Canada..

Muraka, I.P., R. Malecki, B. Taylor, B. Hensel, and J. Roewer. 1996. Release, migration and degradation of pentachlorophenol around in-service utility poles. Proceedings American Wood Preservers' Association 92:180-187.

U.S. Department of Agriculture (USDA). 1980. The biologic and economic assessment of pentachlorophenol, inorganic arsenicals, and creosote, Volume I. Wood preservatives. USDA Technical Bulletin 1658-1. USDA, Washington, D.C. 435 pages.