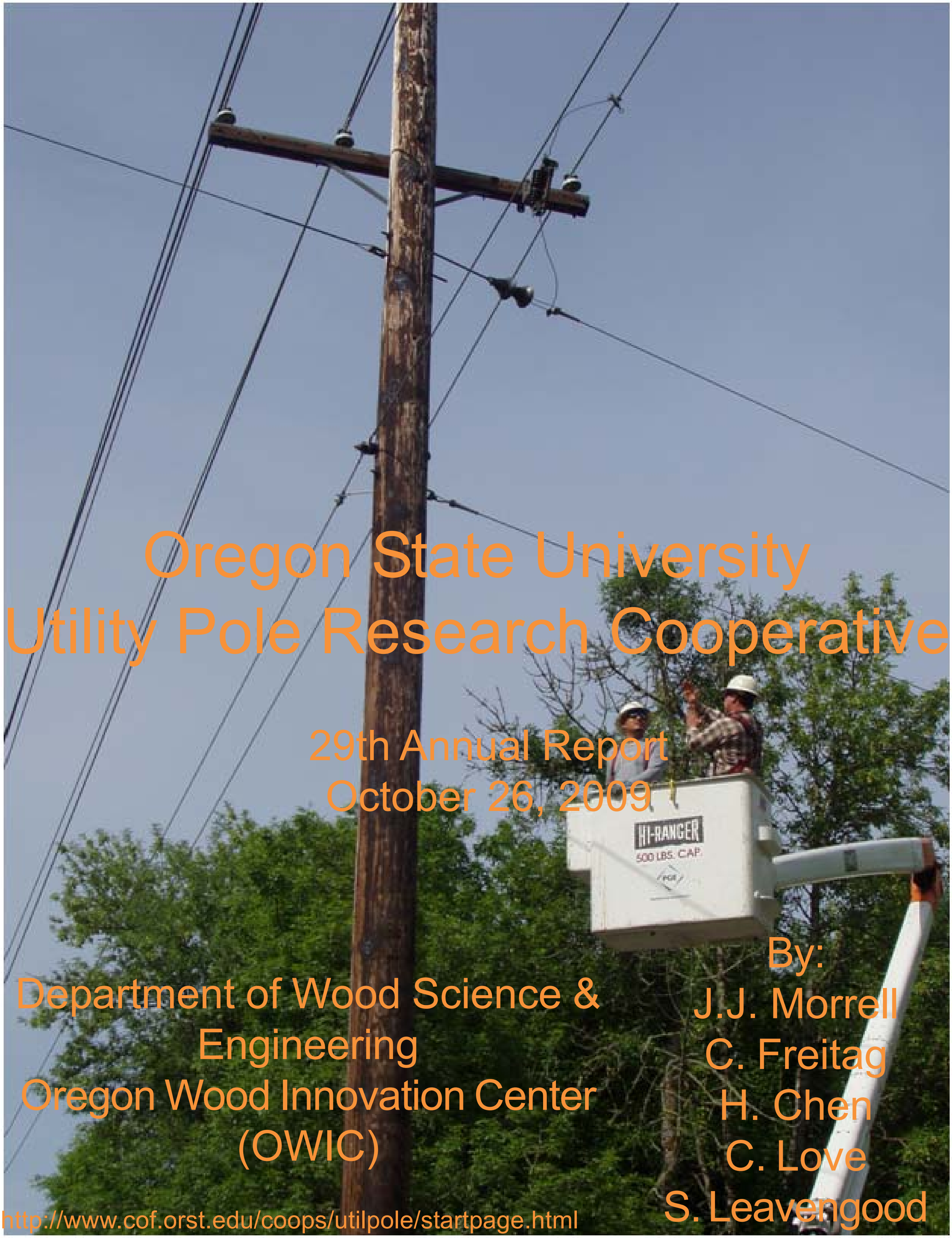

Oregon State University
Utility Pole Research Cooperative

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

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Bonneville Power Administration
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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
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Table of Contents

Executive Summary

The UPRC continues to make progress under six Objectives. This year, we were also fortunate to have three new members joint the coop, bringing us up to 21 members. This renewed interest has allowed us to expand our activities into several new areas. The progress will be summarized under each objective. Under Objective I we continue to assess the properties of various internal remedial treatments. We are assessing dazomet with copper amendments as well as tests with paper and plastic tubes to contain the chemical prior to treatment. Copper naphthenate appears to be equivalent to copper sulfate as an accelerant for degrading dazomet to methylisothiocyanate. Paper tubes do not appear to slow MITC release from dazomet while the plastic tubes slow the release to a slight extent. Both systems reduce the risk of spills during application.

Further assessment of our 15 year boron rod test has allowed us to examine thresholds for wood protection with this chemical. Boron levels above what we have termed the threshold for protection against internal fungal attack were generally protective although some fungi were isolated from a composite sample containing these levels of boron. Boron levels above what we term the level for external protection were much more effective, although we did isolated one fungus from a core where the boron concentration in the composite sample was above this level. The results indicate that boron continues to provide protection 15 years after application.

The large scale field trial of all internal remedial treatments was assessed 18 months after installation. The results showed that the fumigants were moving well through the wood, while the water diffusibles were moving, but to a much lesser extent. These trials are at a very early stage, but the results so far are consistent with previous work and the test should provide extremely useful comparative data as it matures.

Under Objective II, we have assessed the performance of copper/diffusible paste coated bolts for protection against decay in field drilled holes. The results continue to show limited movement of both the copper and the boron or fluoride. Based upon previous field trials with boron, we believe that this shallow copper barrier coupled with a slightly deeper boron or fluoride protected zone should help limit the risk of decay in field drilled holes.

Under Objective III, we continue to examine an array of issues. We performed full scale tests on poles that had been through-bored, radial drilled or deep incised. The through-bored poles were tested with the holes perpendicular to the loading direction to answer questions raised by the ASC 05 Committee. The results showed no significant differences between the three groundline treatments, but we are still analyzing the data. We also used the upper sections of the same poles to assess the effects of groundline inspection holes on flexural properties. These tests showed that drilling three or six 7/8 inch diameter holes at groundline had no significant effect on flexural properties compared with the non-bored controls.

Examination of moisture levels in poles receiving groundline barriers revealed that moisture contents in poles with barriers were similar to those without barriers during the winter; however, the barrier seemed to retard drying during the summer. As a result, the moisture conditions in the barrier-protected poles tended to be higher. Longer exposures to higher moisture levels might produce an environment that is more conducive to decay. Further assessment will be required to determine if this poses a real risk to the poles. Field trials of the effects of caps on pole moisture content clearly show that caps sharply reduce the moisture content of the wood beneath. This presence of an effective cap should reduce the risk of top decay.

Fire retardant tests are also continuing. This past summer, we evaluated a copper lined barrier treatment which appeared to show some promise for reducing charring of poles. In addition, we evaluated the fire resistance of poles treated with pentachlorophenol formulated using either concentrate and then diluted with # 2 diesel or from solid blocks solubilized with an oil containing biodiesel as a co-solvent. There were no substantial differences in fire resistance between the two systems.

Tests of end-plates for Douglas-fir cross arms continue to show that the plates reduce check development in arms subjected to repeated wet/dry cycles. These plates appear to be useful for arms used in drier areas where the wood is subjected to repeated wet/dry cycles.

Data analysis of internal voids in the above ground portions of 25 year old Douglas-fir poles is continuing. We have collected scan data from poles with a variety of voids and will continue to assemble these into 3-dimensional images that can be used to help engineers visualize the level of damage associated with woodpecker damage. These images can, in turn, be used to determine how to assess the effects of woodpecker damage on pole properties.

We continue to assist members with assessing their systems. This past year, we helped inspect poles within the Fortis Alberta system. MITC levels in the poles varied widely, with levels in 1/3 of the poles being below the threshold for fungal protection. Levels of boron from groundline wraps also varied widely. Further inspections are planned.

Under Objective IV, we have performed a re-analysis of several groundline tests after questions arose about our method for copper analysis. We concluded that we had been using too little wood in our tests and that a dilution method we used was not suitable. We have re-analyzed all of the samples we had retained from early tests and re-designed our sampling procedures for future tests. The results showed that copper levels were higher than previously reported.

Under Objective V, we continue to assess the performance of copper naphthenate treated stakes. The results indicate that all of the copper treated stakes are beginning to experience decay. The treatment remains protective at the current use levels. Stakes that had been weathered prior to treatment continue to experience more decay than stakes cut from freshly harvested western redcedar. These tests are continuing and we continue to seek poles that can be assessed over time.

Tests on the potential for migration of preservatives from poles in storage are continuing under Objective VI. This past year, we examined the potential for three groundline liners to capture drippage from penta treated poles. The results showed that the barriers could sorb a considerable quantity of oil, but only one had any ability to remove penta from contaminated water. Unfortunately, this barrier was the least effective at sorbing water. The results suggested that the primary benefit of the barriers tested was to capture whole oil. We also continue to monitor metal losses from ACZA treated pole sections in our outdoor tank. The results showed that metal levels were initially high, then declined to low, steady levels with continued rainfall. The initial, higher levels were likely due to surface deposits, while the continued detections reflect slow solubilization of metals. The results are comparable to those with the penta treated poles and indicate that pole storage can be managed by the utilities.

Finally, we have appended the draft update of the Wood Pole Maintenance Manual under Objective VII. This manual was last updated in 1996. We would very much appreciate comments from the coop members. It would also be helpful if members could provide information on other materials and tools for inclusion in the appendix. We are also planning to update the video in the coming year.

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 systems. 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.

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.

UPRC research identified two alternatives, solid methylisothiocyanate (MITC) and dazomet. Both chemicals were solid at room temperature, reducing the risk of spills and simplifying cleanup of any spills that occur. MITC was commercialized as MITC-FUME, while dazomet has been labeled as Super-Fume, UltraFume and 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 16 years, first as a glass encapsulated material and later in aluminum ampules. In both cases, the cap was punctured and the tube was inserted, open end down, into the treatment hole. As with any encapsulated material, the time required for the chemical to move from the tubes and into the surrounding wood has important implications on efficacy. As a part of our initial evaluations of MITC-FUME, we established small scale trials to assess the rates of MITC release under varying temperature conditions. We assessed MITC movement release over 14 years. MITC released rapidly from tubes in poles at warmer temperatures, but tended to remain in the tubes for many years at 5C. The test was discontinued in 2008, although some of the tubes stored at 5C still contained chemical.

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 produced effective levels of MITC in wood over time, and this chemical 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 a field trial on transmission-sized poles. This trial was evaluated over a 15 year period, but was discontinued in 2008 because MITC levels had declined below the detection limit in most poles.

3. Performance of Dazomet With or Without Copper-based Accelerants

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

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

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

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

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

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

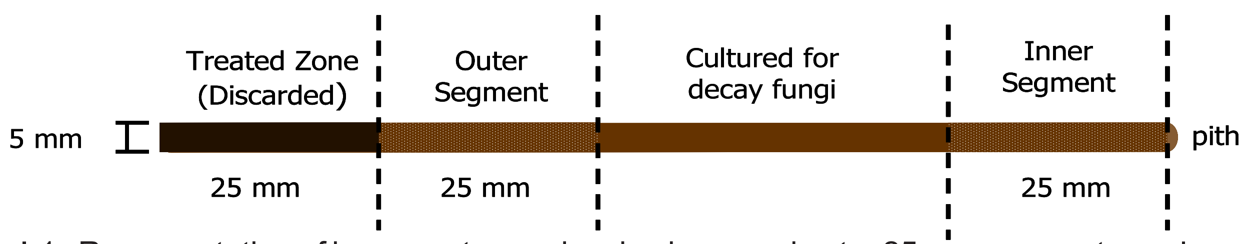

Figure I-1. Representation of increment core showing inner and outer 25 mm segments analyzed for fumigant content.

As with our other tests, the threshold for MITC is considered to be 20 ug or more of MITC/oven dried gram of wood. MITC levels tended to be greater in the inner zones, reflecting the tendency of the treatment holes to encourage chemical movement to the pole center. MITC levels in poles receiving no supplemental treatment reached the threshold level 0.3 m above ground 1 year after treatment (Figure I-2). MITC levels increased slightly over the next 4 years in these poles, but appeared to stabilize at levels well above the threshold by 4 years after treatment. MITC levels in these poles declined to just at or below the threshold after 8 years and below that level after 10 years. Levels were again above the threshold 12 years after treatment, but only at 0.3 m above groundline. Chemical levels at locations above this height were extremely low, suggesting that the treatment effect was confined to a relatively narrow zone around the application point (Table I-2).

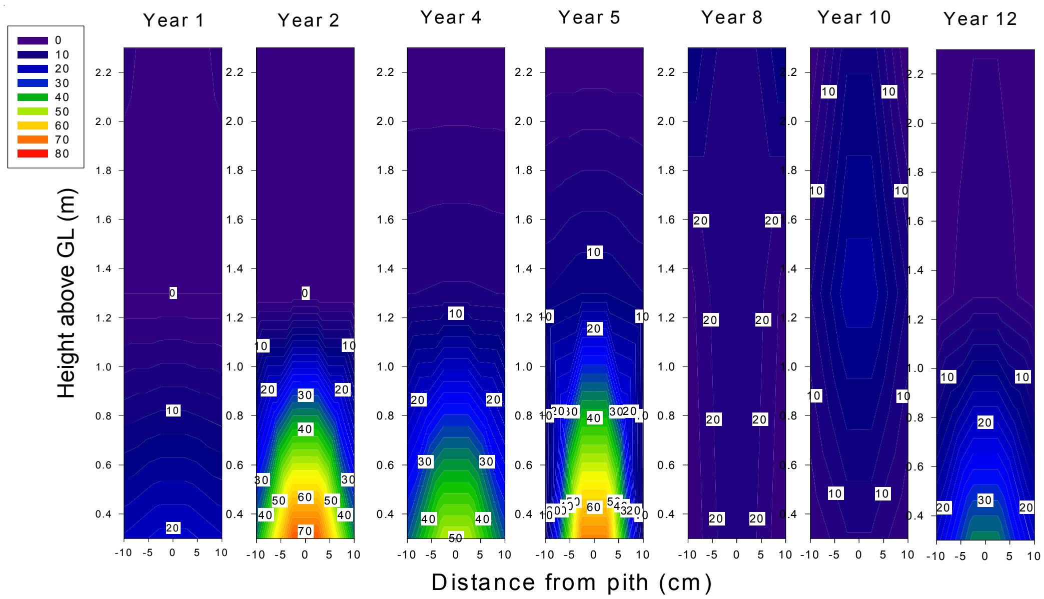

Figure I-2. Distribution of residual MITC in Douglas-fir pole sections 1 to 12 years after treatment with 200 g of dazomet. Dark blue indicates MITC levels below the threshold. Light blue and all other colors indicate MITC levels above that level.

Table I-2. Residual MITC in Douglas-fir pole sections 1 to 12 years after treatment with dazomet with or without copper sulfate or copper naphthenate.

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

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

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

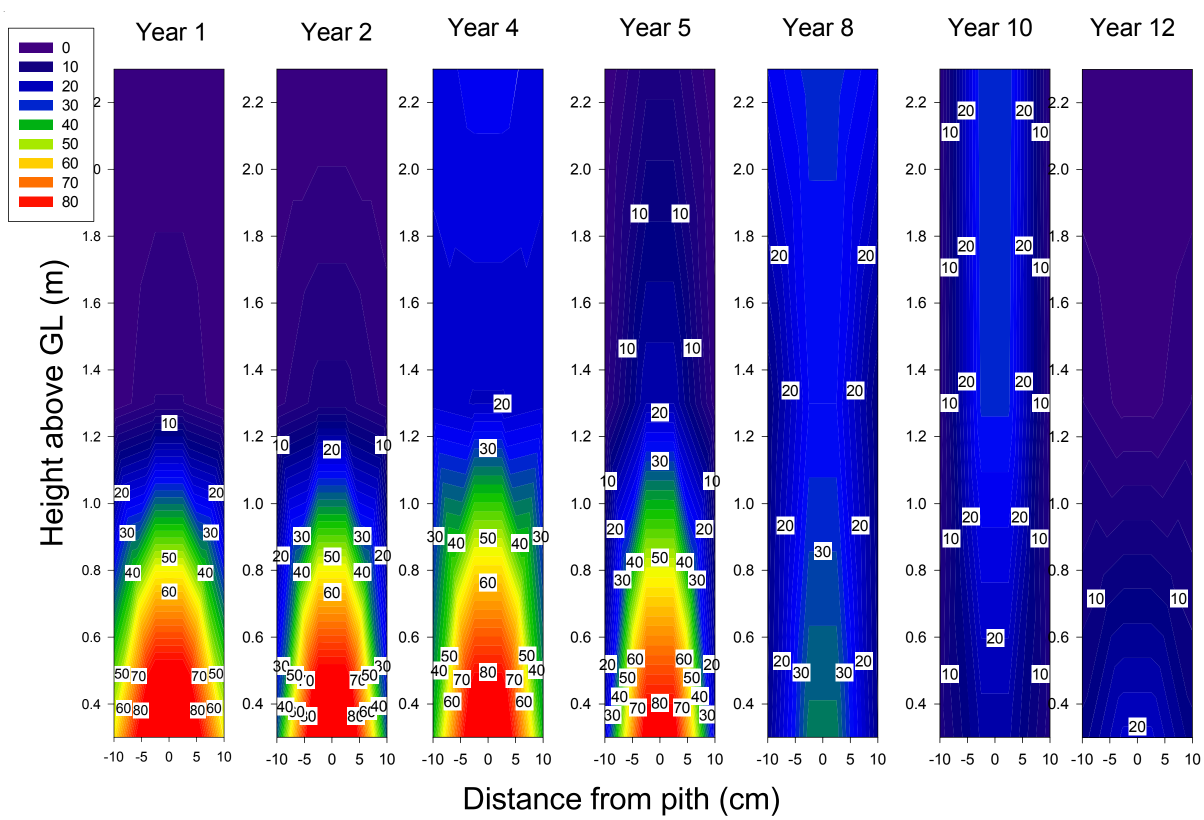

Figure I-3. Distribution of residual MITC in Douglas-fir pole sections 1 to 12 years after treatment with 200 g of dazomet plus 20 g of copper sulfate. Dark blue indicates MITC levels below the threshold. Light blue and all other colors indicate MITC levels above that level.

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

Isolation of decay fungi from the inner zones of the poles 1 year after treatment were limited except from poles treated with dazomet amended with copper compounds. Fungi continue to be isolated from the above ground zones of these poles, but the isolations were sporadic and suggest that isolated fungal

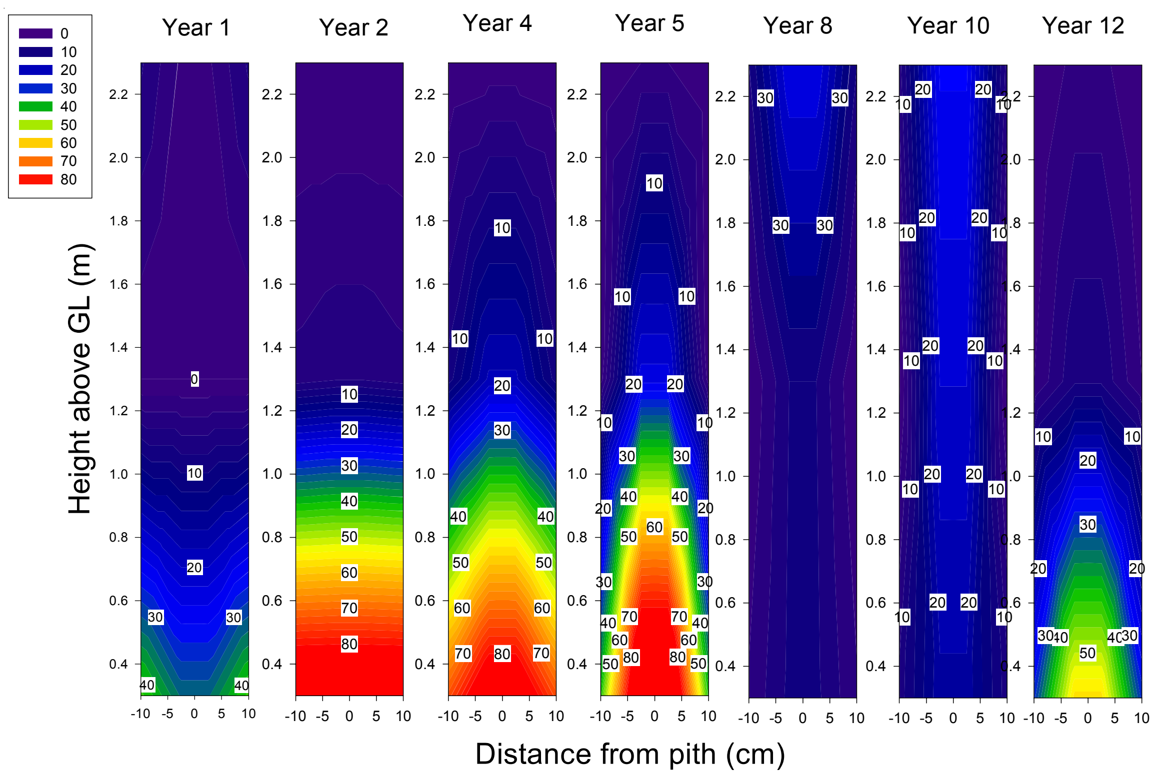

Figure I-4. Distribution of residual MITC in Douglas-fir pole sections 1 to 12 years after treatment with 200 g of dazomet plus 20 g of copper naphthenate. Dark blue indicates MITC levels below the threshold. Light blue and all other colors indicate MITC levels above that level.

colonies were present in the above ground zones of the poles (Table I-3). We suspect that the fungi present after 1 year were probably present at the time of treatment. The relatively low levels of chemical1.3 and 2.3 m above groundline likely limited the potential for control in these zones. Decay fungi were isolated at various locations along the poles at 1.3 m and above the groundline, but there was no consistent pattern. In addition, no decay fungi were isolated from any cores this past year (Table I-3). These results suggest that treatment patterns and the zone of protection are more limited with these controlled release formulations than they are with liquid formulations that are applied at much higher doses. As a result, some adaptation of treatment patterns may be necessary where decay control is desired above the groundline; however, one advantage of these treatments over liquids is the ability to more safely apply the chemical above the groundline.

4. Performance of Dazomet in Powdered and Rod Forms in Douglas-fir Pole Sections

Date Established:	March 2000
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @GL (avg., max., min.)	84, 104, 65 cm

Dazomet was originally supplied in a powdered formulation which was intended for application to agricultural fields where it could be tilled into the soil. Once in contact with the soil, the dazomet would rapidly react to release MITC, killing potential pathogens prior to planting. The drawbacks to the use of powdered formulations for treatment of internal decay in wood poles include the risk of spillage during application, as well as the potential for the presence of chemical dusts that can be inhaled. In our early trials, we produced dazomet pellets by wetting the powder and compressing the mixture into pellets, but these were not commercially available. The desire for improved handling characteristics, however,

Table I-3. Percentage of increment cores containing decay and non-decay fungi 1 to 12 years after application of dazomet with or without copper sulfate or copper naphthenate.

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

[a]Values represent the average of nine cores containing decay fungi. Superscripts represent average of non-decay fungi in the same cores.

encouraged the development of dazomet rods. These rods simplified application, but we wondered whether the decreased wood/chemical contact associated with the rods, might reduce dazomet decomposition, thereby slowing fungal control.

Pentachlorophenol treated Douglas-fir pole sections (206-332 mm in diameter by 3 m long) were set to a depth of 0.6 m at the Corvallis test site. Three steeply angled holes were drilled into each pole beginning at groundline and moving upward 150 mm and around 120 degrees. The holes received either 160 g of powdered dazomet, 107 g of dazomet rod plus 100 g of copper naphthenate, 160 g of dazomet rod alone, 160 g of dazomet rod amended with 100 g of copper naphthenate, 160 g of dazomet rod amended with 100 g of water, or 490 g of metam sodium. Each treatment was replicated on five poles. This trial was not sampled this year, but will be evaluated next year at the 10 year point.

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 commercially applied for almost 10 years; however, one concern with this system is the risk of spilling the granules during application. In previous tests, we explored the use of dazomet in 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 plastic bottles. The content of one bottle was then applied to each of the three holes in each of 10 poles. The holes in 10 additional poles received a 400 to 450 mm long by 19 mm diameter paper tube containing 60 g of dazomet. The granular treatment received more dazomet because volume in the hole was not lost due to the paper tube. 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 7g of 18% copper naphthenate (2% metallic Cu) in mineral spirits (Tenino Copper Naphthenate). As mentioned previously, the addition of copper naphthenate at concentrations higher than 1% is a violation of the product label and not allowed for commercial applications. The holes were plugged with tight fitting plastic plugs. A second set of poles was treated one year later with an improved tube system using these same procedures. The newest tubes were constructed of biodegradable perforated plastic which will degrade over time and will not require removal before re-treating the poles.

MITC distribution was assessed 1, 2, and 3 years after treatment by removing increment cores from three locations around the pole 150 mm below groundline, at groundline as well as 300, 450 and 600 mm above groundline. The 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 non-treated 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-4).

MITC levels were generally above the threshold within one 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-5 to I-7). Chemicals levels tended to be higher in the inner zones but the differences were often slight. Chemical levels were more variable 600 mm above

Table I-4. Residual MITC in pentachlorophenol treated Douglas-fir pole sections 1 to 3 years after application of dazomet granules loose or in two types of tubes, and with or without copper naphthenate.

Treatment	Dosage (g/pole)	Supplement	Years after treatment	Residual MITC (ug/g of wood)[a] -15 cm Inner		-15 cm Outer		0 cm Inner		0 cm Outer		30 cm Inner		30 cm Outer	
Granular	210	CuNaph	1	**108**	(56)	**53**	(87)	**114**	(66)	19	(23)	**79**	(38)	**45**	(56)
			2	**173**	(225)	**96**	(102)	**131**	(158)	**88**	(62)	**122**	(72)	**56**	(40)
			3	**180**	(64)	**91**	(143)	**132**	(56)	**66**	(59)	**83**	(31)	**60**	(42)
		None	1	**144**	(111)	**48**	(64)	**108**	(49)	15	(24)	**63**	(21)	**32**	(44)
			2	**189**	(241)	**73**	(80)	**119**	(77)	**49**	(49)	**126**	(83)	**33**	(24)
			3	**232**	(145)	**74**	(62)	**215**	(158)	**85**	(100)	**135**	(92)	**75**	(52)
Paper Tube	180	CuNaph	1	**133**	(99)	**66**	(97)	**158**	(111)	**53**	(59)	**81**	(40)	**53**	(59)
			2	**138**	(94)	**103**	(106)	**154**	(166)	**62**	(50)	**135**	(93)	**42**	(34)
			3	**284**	(249)	**137**	(93)	**278**	(112)	**137**	(107)	**101**	(38)	**89**	(53)
		None	1	**108**	(59)	16	(31)	**112**	(108)	**21**	(32)	**72**	(52)	10	(12)
			2	**103**	(104)	**55**	(47)	**117**	(139)	**37**	(23)	**122**	(84)	**34**	(26)
			3	**269**	(142)	**53**	(36)	**205**	(179)	**46**	(30)	**100**	(50)	**45**	(17)
Plastic Tube	103	CuNaph	1	**41**	(73)	16	(25)	**51**	(49)	19	(19)	**47**	(35)	**21**	(36)
			2	**104**	(53)	**48**	(67)	**129**	(121)	**97**	(158)	**64**	(45)	**118**	(222)
Control	0	None	1	0	0	1	(5)	8	(31)	0	0	1	(3)	0	0
			2	0	0	0	0	1	(3)	0	0	0	0	0	0
			3	1	(3)	0	0	0	0	0	0	1	(3)	0	0

Treatment	Dosage (g/pole)	Supplement	Years after treatment	Residual MITC (ug/g of wood)[a] 45 cm Inner		45 cm Outer		60 cm Inner		60 cm Outer		90 cm Inner		90 cm Outer	
Granular	210	CuNaph	1	**47**	(27)	**39**	(33)	**27**	(17)	10	(14)	**21**	(34)	1	(3)
			2	**92**	(58)	**51**	(63)	**109**	(103)	**39**	(35)	**134**	(196)	**64**	(69)
			3	**58**	(19)	**56**	(56)	**45**	(15)	**30**	(16)	**30**	(8)	14	(8)
		None	1	**34**	(13)	**27**	(42)	17	(28)	2	(5)	17	(43)	2	(5)
			2	**94**	(115)	**51**	(87)	**167**	(256)	**35**	(40)	**132**	(117)	**55**	(70)
			3	**87**	(31)	**61**	(54)	**63**	(35)	**35**	(29)	**46**	(39)	19	(16)
Paper Tube	180	CuNaph	1	**39**	(21)	19	(20)	**22**	(13)	5	(7)	12	(25)	2	(4)
			2	**109**	(84)	**44**	(44)	**118**	(112)	**72**	(114)	**99**	(77)	**54**	(41)
			3	**69**	(22)	**55**	(30)	**44**	(14)	**24**	(10)	**26**	(9)	9	(9)
		None	1	**51**	(34)	14	(24)	**20**	(11)	9	(15)	7	(16)	1	(4)
			2	**108**	(163)	**50**	(62)	**103**	(106)	**48**	(69)	**96**	(86)	**48**	(49)
			3	**61**	(20)	**31**	(8)	**40**	(14)	**21**	(7)	**26**	(13)	6	(6)
Plastic Tube	103	CuNaph	1	**34**	(44)	17	(27)	**44**	(47)	10	(13)	**74**	(153)	**26**	(41)
			2	**40**	(17)	**32**	(24)	**36**	(18)	19	(27)	18	(16)	3	(6)
Control	0	None	1	0	0	0	0	2	(7)	0	0	0	0	0	0
			2	0	0	0	0	1	(3)	0	0	0	0	0	0
			3	2	(3)	0	0	3	(11)	0	0	1	(2)	0	0

[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.

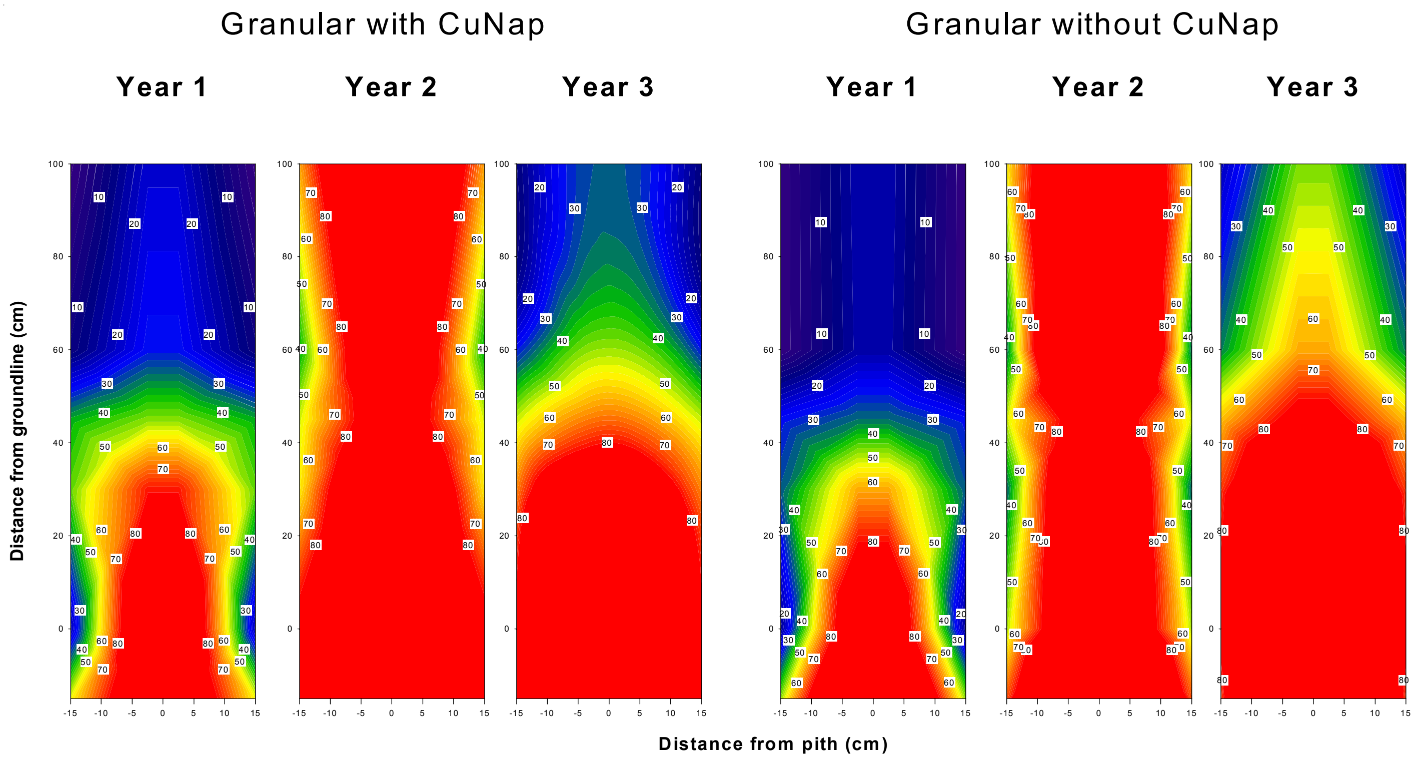

Figure I-5. MITC levels in pentachlorophenol treated Douglas-fir pole sections 1, 2, and 3 years after treatment with granular dazomet with and without copper naphthenate. Dark blue indicates MITC levels below the threshold for fungal attack. Light blue and other colors indicate MITC levels above the lethal threshold.

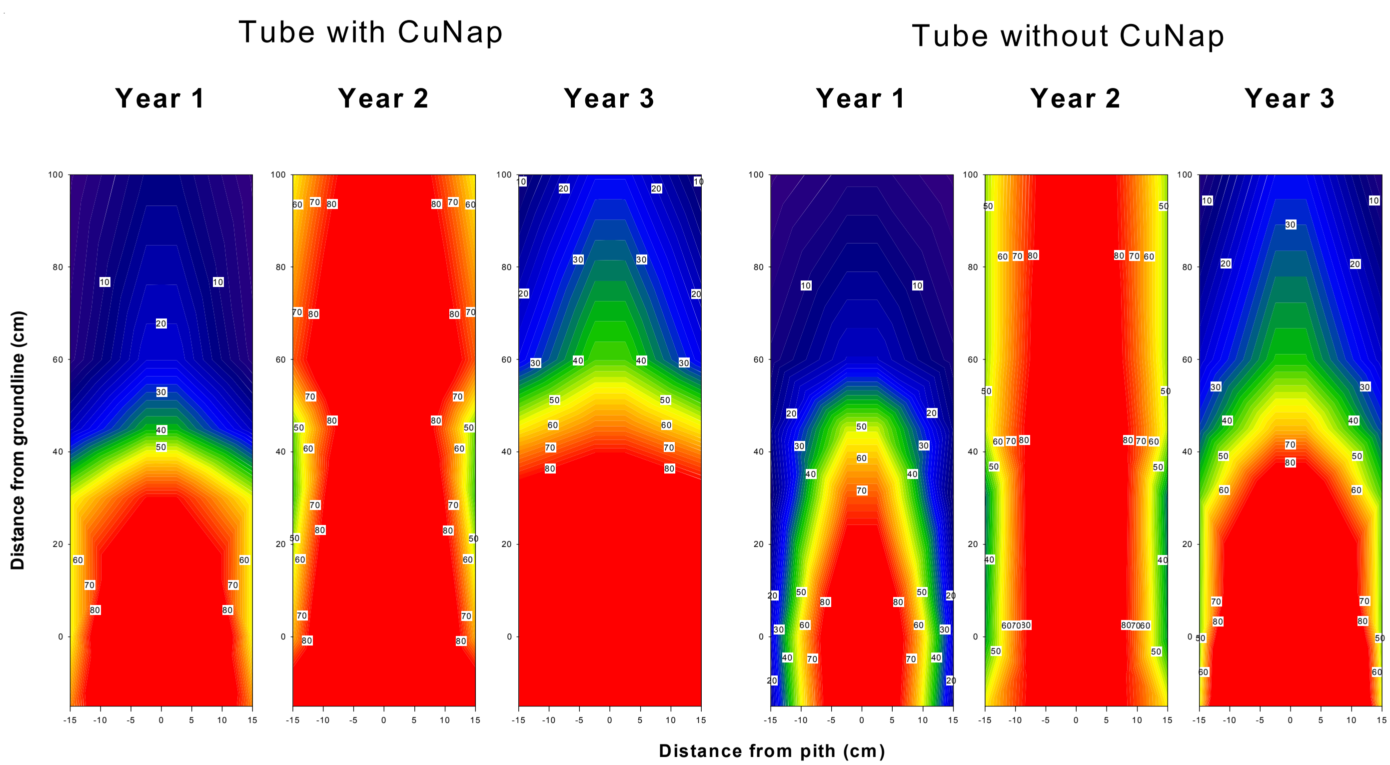

Figure I-6. MITC levels in pentachlorophenol treated Douglas-fir pole sections 1, 2, and 3 years after treatment with granular dazomet in paper tubes with and without copper naphthenate. Dark blue indicates MITC levels below the threshold for fungal attack. Light blue and other colors indicate MITC levels above the lethal threshold.

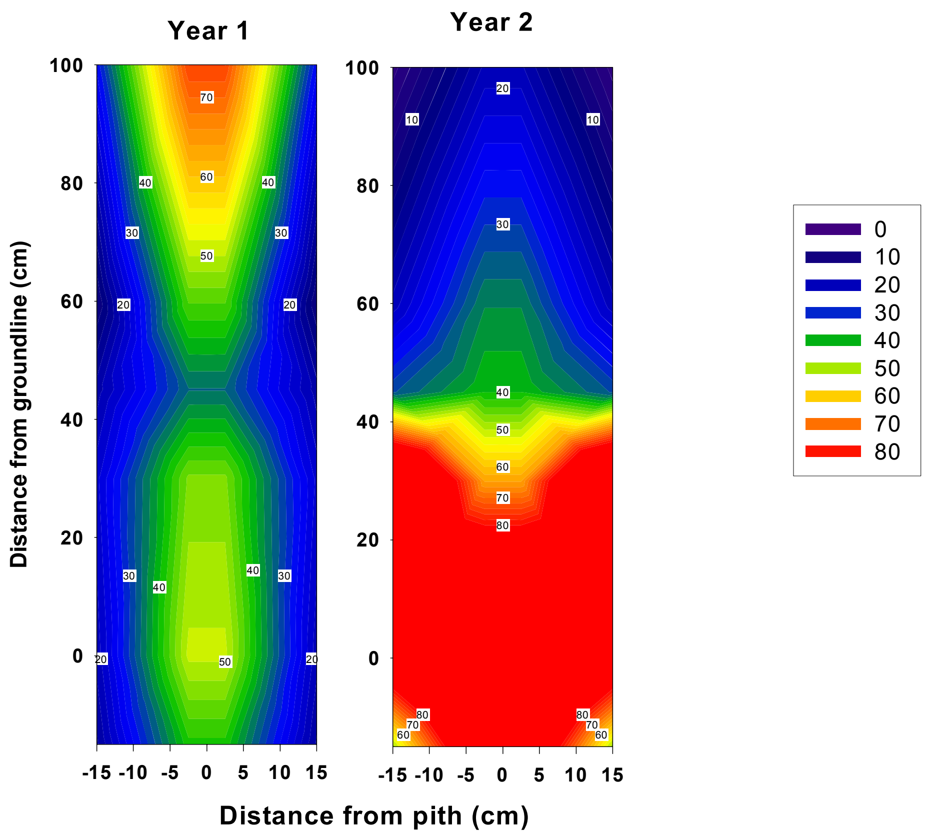

Figure I-7. MITC levels in pentachlorophenol treated Douglas-fir pole sections 1 and 2 years after treatment with granular dazomet in a newly designed plastic tube plus copper naphthenate. Dark blue indicates MITC levels below the threshold for fungal attack. Light blue and other colors indicate MITC levels above the lethal threshold.

groundline, reflecting the distance away from the treatment site, but levels in the inner zones of the poles were still above threshold at this height. In general, the presence of the paper 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 original system, but the levels were still generally above the threshold for protection. The lower MITC levels most likely reflect the lower dosage in the newer tubes as well as the later installation of the treatment. Poles treated with the plastic tubes received 103 g of dazomet, while those treated with the other system received 180 g.

No decay fungi have been isolated from any cores over the past three years (Table I-5). Non-decay fungi have been isolated from a number of poles, but there is no consistent relationship between fungal isolation and initial treatment. These results would be consistent with the relatively slow invasion of poles by fungi following initial preservative treatment.

The results at 3 years indicate that placing dazomet in tubes does not adversely affect release rate into the surrounding wood.

Table I-5. Frequency of isolation of basidiomycetes and non-decay fungi from Douglas-fir poles 1 to 3 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}
			3	0^{0}	0^{0}	0^{20}	0^{0}	0^{0}	0^{13}
		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}
			3	0^{0}	0^{0}	0^{0}	0^{7}	0^{7}	0^{13}
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}
			3	0^{0}	0^{0}	0^{0}	0^{7}	0^{0}	0^{13}
		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}
			3	0^{0}	0^{7}	0^{0}	0^{7}	0^{7}	0^{0}
Plastic Tube	103	CuNaph	1	0^{11}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}
			2	0^{0}	0^{0}	0^{6}	0^{0}	0^{0}	0^{6}
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}
			3	0^{7}	0^{13}	0^{13}	0^{13}	0^{0}	0^{13}

[a] Values represent the percent of fifteen attempts yielding fungal 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 either pure boron or boron plus copper. These rods are produced by heating boron to its molten state, then pouring the molten boron into a mold. The cooled boron rods are easily handled and applied. In theory, the boron is released as the rods come in contact with water.

Fluoride has also been used in a variety of preservative formulations going back to the 1930's when fluor-chrome-arsenic-phenol was employed as an initial treatment. Fluoride, in rod form, has long been used to treat the area under tie plates in railroad tracks and has been used as a dip-diffusion treatment in Europe. Fluoride can be corrosive to metals, although this should not be a problem in the groundline area. Sodium fluoride 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, 3 and 5 years after treatment by removing increment cores from locations 150 mm below groundline as well as at groundline, and 300 or 900 mm above this zone. The outer treated shell was discarded, and the remainder divided into the outer and inner 2.5 cm. Any wood remaining in the middle was plated on malt extract agar.

This test was inspected late this year and the year 8 data will be presented in the 2010 report.

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 15 cm below groundline as well as 7.5, 22.5, 45, and 60 cm above the groundline. The cores were divided into inner and outer segments which were ground to pass a 20 mesh screen, then extracted and analyzed for boron using the Azomethine H/Carminic Acid method. Boron levels were expressed on a kg/m^3 of boron as boric acid equivalent. 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.

At the last Annual Advisory Committee meeting, questions were raised about whether the boron levels found in the poles were actually protective (i.e. were we isolating fungi from the poles). To answer this question, we resampled the poles and used the cores to isolate fungi and assess residual boron levels. Because the 2.5 cm inner and outer zones from a single core do not yield enough sawdust for boron analysis these zones from three cores from the same height were combined. Then the inner and outer segments were averaged seperately. The remaining wood was plated individually. The occurance of a decay fungus in a core is therefore associated with aggragate inner and outer boron levels from the three cores.

Non-treated control poles naturally contained low levels of background boron ranging from 0.01 to 0.11 kg/m^3 (Table I-6). These levels are well below the threshold for protection. Boron levels in the inner zones of poles treated with 180 g of boron rod were at or above the threshold 150 mm below ground as well as 75 and 225 mm above the groundline throughout the test (Figure I-8). 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 below 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.

Table I-6. 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 (g)	Sampling Ht. (cm)	Core Section	Boron (kg/m^3 BAE)							
			Year 1	Year 3	Year 4	Year 5	Year 7	Year 10	Year 12	Year 15
180	-15	inner	0.38	**1.81**	**2.39**	**1.85**	**1.54**	**2.16**	**3.33**	**0.50**
		outer	0.24	0.25	0.49	**1.14**	**0.70**	**1.32**	**0.94**	**0.62**
	7.5	inner	**2.82**	**3.75**	**6.02**	**6.40**	**2.05**	**2.83**	**4.65**	**1.25**
		outer	**0.65**	**1.10**	**1.16**	**2.32**	**3.38**	**1.84**	**2.28**	**0.82**
	22.5	inner	**0.89**	**3.16**	**2.09**	**2.82**	**1.47**	**0.81**	**0.52**	**0.86**
		outer	**0.98**	**0.58**	0.35	**1.10**	0.31	0.14	**1.70**	**0.96**
	45	inner	**0.54**	0.22	0.21	0.17	0.15	0.00	0.28	0.05
		outer	0.22	0.20	0.11	0.09	0.12	0.00	0.12	0.07
	60	inner	0.18	0.24	0.19	0.41	0.08	0.00	0.11	0.02
		outer	0.14	0.09	0.06	0.25	**1.80**	0.00	0.04	0.00
360	-15	inner	0.09	**0.76**	**0.62**	**0.60**	**1.00**	0.09	**1.94**	**2.29**
		outer	0.07	0.23	0.27	**3.00**	**1.42**	**3.94**	**0.82**	**1.62**
	7.5	inner	**0.96**	**10.88**	**7.27**	**12.01**	**3.28**	0.11	**2.77**	**1.56**
		outer	**0.59**	**0.61**	**1.33**	**3.93**	**0.85**	**0.89**	**1.39**	**3.01**
	22.5	inner	0.48	**3.21**	**1.35**	**7.30**	**0.95**	**2.27**	**0.81**	**5.23**
		outer	0.13	0.14	0.42	**4.34**	**0.77**	0.07	**3.30**	**2.57**
	45	inner	0.04	0.11	0.08	**1.24**	0.21	0.00	0.50	**1.20**
		outer	0.02	0.09	0.07	**0.83**	0.17	0.00	0.21	0.12
	60	inner	0.05	0.39	0.21	0.16	0.10	0.00	0.13	0.27
		outer	0.02	0.09	0.09	0.16	**1.02**	0.00	0.06	0.13
Control	-15	inner	0.02	0.09	0.02	0.05	0.06	0.00	0.01	0.00
		outer	0.02	0.09	0.02	0.07	0.06	0.00	0.00	0.00
	7.5	inner	0.02	0.06	0.06	0.03	0.05	0.00	0.02	0.00
		outer	0.02	0.07	0.02	0.02	0.05	0.00	0.02	0.00
	22.5	inner	0.01	0.08	0.02	0.05	0.05	0.00	0.05	0.00
		outer	0.01	0.07	0.02	0.03	0.04	0.00	0.01	0.00
	45	inner	0.03	0.06	0.02	0.03	0.03	0.00	0.04	0.00
		outer	0.02	0.10	0.02	0.02	0.03	0.00	0.06	0.00
	60	inner	0.02	0.08	0.02	0.27	0.08	0.00	0.06	0.01
		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.

Boron levels in the outer zones tended to be more variable 150 mm below ground as well as 70 and 225 mm above ground. These results are consistent with a tendency for the rods to direct chemical toward 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.

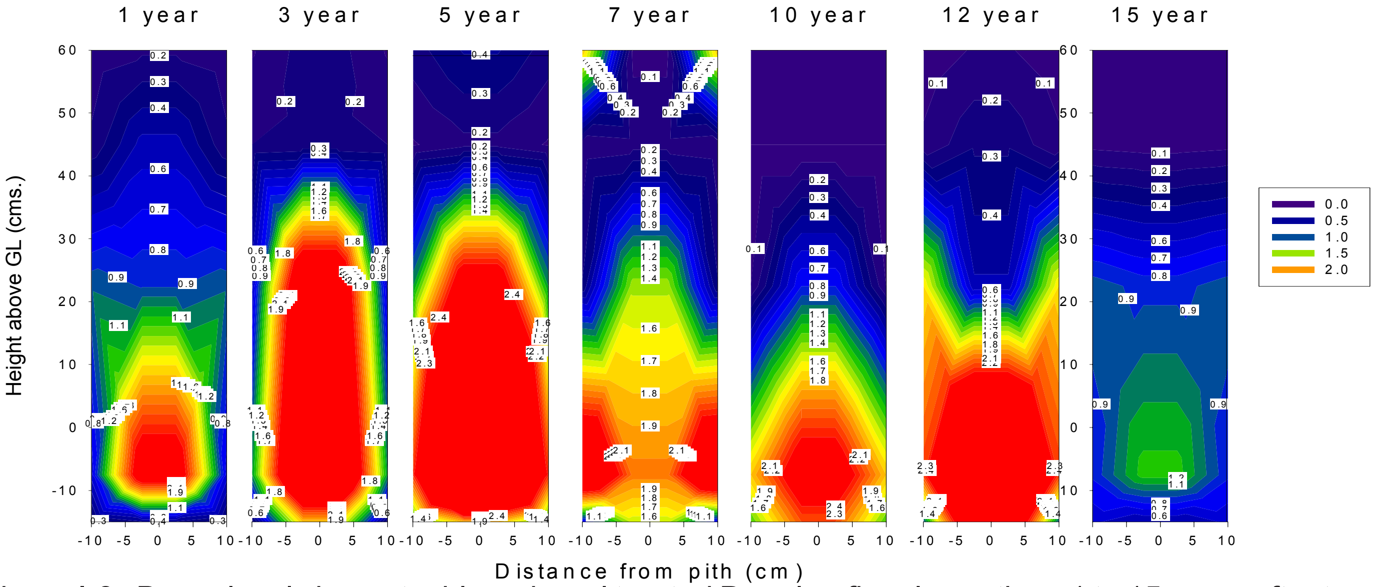

Figure I-8. Boron levels in pentachlorophenol treated Douglas-fir pole sections 1 to 15 years after treatment with 180 g of fused boron rod. Dark blue indicates boron levels below the threshold for fungal attack. Light blue and other colors indicate boron levels above the lethal threshold.

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-9). This area corresponded to the heart of the treated zone. We often observe the absence of a dosage effect with boron rods and have attributed this lack of effect to the lack of adequate moisture; however, there did appear to be some difference in boron levels between the two dosages early in the test. This effect disappeared after five years but appeared again 15 years after treatment.

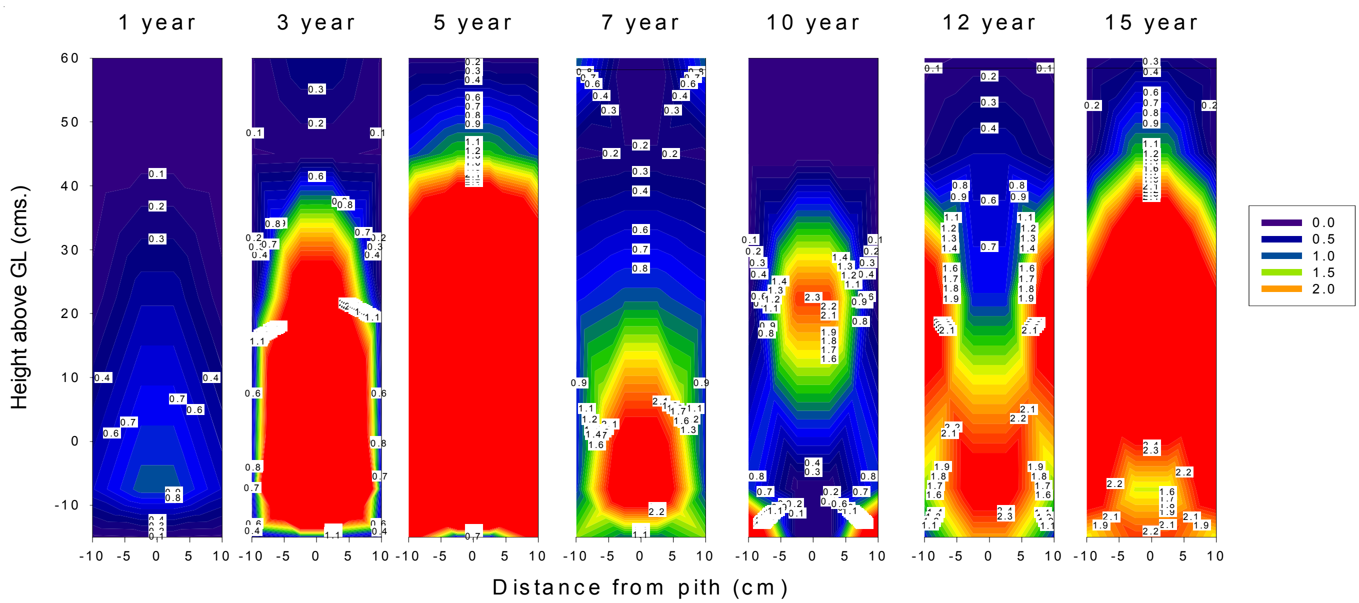

Figure I-9. Boron levels in pentachlorophenol treated Douglas-fir pole sections 1 to 15 years after treatment with 360 g of fused boron rod. Dark blue indicates boron levels below the threshold for fungal attack. Light blue and other colors indicate boron levels above the lethal threshold.

Fungal isolations varied among the various poles and with distance from the groundline (Table I-7). While no decay fungi were isolated from most samples with boron levels above the thresholds for protection against either internal or external decay, there were a few exceptions. Decay fungi were isolated from 18 of 67 cores where the boron level was below the fungal threshold, compared with 3 of 36 cores where the boron level was below the upper threshold (Figure I-10). Only one decay fungus was isolated from the 52 cores where the boron level was above the upper protective threshold. The results indicate that the risk of fungal decay is much lower where the boron levels are above either threshold, but they are particularly low when the level exceeds the upper threshold. The results confirm that protective levels of boron are present in most poles, especially in the areas closer to the groundline where moisture levels are likely to be higher.

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

Table I-7. Comparison between boron levels and fungal isolation frequency at selected distances from groundline 15 years after application of fused borate rods.

Pole #	Height (cm)	KCM (BAE)		# of isolations		% of cores	
		inner	outer	decay	non-decay	decay	non-decay
277	-15	0.00	0.06	1	2	33	67
	7.5	0.07	0.09	0	1	0	100
	22.5	0.15	0.07	0	2	0	100
	45	0.05	0.10	2	0	67	0
	60	0.08	0.10	1	2	33	67
278	-15	**0.78**	**1.43**	0	3	0	100
	7.5	**2.69**	**1.73**	0	2	0	67
	22.5	**2.07**	**3.91**	0	3	0	100
	45	**1.15**	**0.61**	0	3	0	100
	60	**1.01**	0.36	0	2	0	67
279	-15	**0.83**	**0.71**	0	1	0	33
	7.5	**1.24**	**2.28**	0	2	0	67
	22.5	**2.86**	**2.47**	0	3	0	100
	45	**0.58**	0.28	1	2	33	67
	60	0.11	0.25	2	0	67	0
280	-15	**1.21**	0.43	0	3	0	100
	7.5	**2.39**	**1.39**	0	2	0	67
	22.5	**3.69**	**1.74**	0	3	0	100
	45	0.19	0.13	1	1	100	100
	60	0.12	0.14	0	0	0	0
281	-15	**1.03**	**0.53**	1	2	33	67
	7.5	**1.08**	**0.52**	0	2	0	67
	22.5	**0.95**	**0.56**	0	1	0	33
	45	**0.73**	0.18	0	1	0	33
	60	0.37	0.15	1	3	33	100

Values in **bold** are above the lower threshold of 0.5 kg/m^3 BAE. Values in red are above the upper threshold of 1.2 kg/m^3 BAE.

Table I-7 (cont.). Comparison between boron levels and fungal isolation frequency at selected distances from groundline 15 years after application of fused borate rods.

Pole #	Height (cm)	KCM (BAE)		# of isolations		% of cores	
		inner	outer	decay	non-decay	decay	non-decay
282	-15	**0.51**	0.05	0	2	0	67
	7.5	0.14	0.18	0	0	0	0
	22.5	0.29	0.30	0	2	0	67
	45	0.20	0.19	0	3	0	100
	60	0.15	0.11	0	3	0	100
283	-15	0.24	0.13	0	1	0	33
	7.5	0.28	**0.53**	0	2	0	67
	22.5	0.20	0.47	0	1	0	33
	45	0.16	0.24	0	1	0	33
	60	0.13	0.22	0	1	0	33
284	-15	**0.72**	0.22	0	1	0	33
	7.5	**1.11**	**0.70**	0	0	0	0
	22.5	**0.53**	**0.68**	0	1	0	33
	45	**1.97**	**1.75**	0	2	0	67
	60	0.34	0.14	0	2	0	67
285	-15	**2.46**	**0.94**	0	1	0	33
	7.5	**3.37**	**1.27**	0	0	0	0
	22.5	**1.58**	**0.71**	0	1	0	33
	45	0.28	0.20	0	1	0	33
	60	0.15	0.14	0	1	0	33
286	-15	**1.05**	0.41	0	1	0	33
	7.5	**0.81**	0.35	0	0	0	0
	22.5	**1.34**	**0.55**	0	0	0	0
	45	0.42	0.24	0	2	0	67
	60	0.25	0.10	0	0	0	0
287	-15	**1.01**	0.12	0	0	0	0
	7.5	**2.49**	**1.41**	0	0	0	0
	22.5	**0.79**	0.00	0	1	0	33
	45	0.00	0.01	1	2	33	67
	60	0.17	0.00	2	1	67	33
288	-15	0.08	0.16	0	3	0	100
	7.5	0.25	0.30	0	3	0	100
	22.5	0.18	0.25	1	1	100	100
	45	0.31	0.14				
	60	0.21	0.03	0	1	0	50
289	-15	**6.72**	**4.09**	0	1	0	33
	7.5	**4.24**	**3.49**	0	1	0	33
	22.5	**2.07**	**2.31**	0	3	0	100
	45	**0.83**	0.20	0	1	0	33
	60	0.18	0.02	0	3	0	100

Values in **bold** are above the lower threshold of 0.5 kg/m^3 BAE. Values in red are above the upper threshold of 1.2 kg/m^3 BAE.

Table I-7 (cont.). Comparison between boron levels and fungal isolation frequency at selected distances from groundline 15 years after application of fused borate rods.

Pole #	Height (cm)	KCM (BAE)		# of isolations		% of cores	
		inner	outer	decay	non-decay	decay	non-decay
290	-15	**4.52**	**0.57**	0	3	0	100
	7.5	**5.43**	**12.97**	0	3	0	100
	22.5	**19.30**	**1.57**	0	1	0	33
	45	**1.38**	0.05	1	2	33	67
	60	0.09	0.02	1	3	33	100
291	-15	**1.99**	0.48	0	0	0	0
	7.5	**10.98**	**1.14**	0	2	0	67
	22.5	**15.63**	0.49	0	3	0	100
	45	**1.87**	0.13	0	1	0	33
	60	0.25	0.10	1	2	33	67
292	-15	**0.58**	0.33	1	2	33	67
	7.5	**0.87**	0.32	0	2	0	67
	22.5	**5.57**	0.12	0	1	0	33
	45	0.29	0.44	0	2	0	67
	60	0.21	0.09	1	3	33	100
293	-15	**3.01**	**0.66**	0	0	0	0
	7.5	**6.12**	**1.64**	0	0	0	0
	22.5	**20.62**	**0.84**	0	0	0	0
	45	**5.72**	0.24	0	1	0	33
	60	**1.75**	0.07	1	3	33	100
294	-15	**1.23**	0.20	0	1	0	33
	7.5	**8.07**	**4.16**	0	0	0	0
	22.5	**13.31**	**3.32**	0	0	0	0
	45	**6.01**	**0.55**	0	1	0	33
	60	**4.51**	**0.81**	0	1	0	33
295	-15	**1.47**	0.47	0	0	0	0
	7.5	**6.42**	**1.36**	0	1	0	33
	22.5	**6.46**	**0.82**	0	0	0	0
	45	**0.93**	0.44	0	1	0	33
	60	0.00	0.08	1	2	33	67
296	-15	**1.35**	0.43	0	3	0	100
	7.5	**4.61**	**2.16**	0	3	0	100
	22.5	**11.63**	**4.00**	0	1	0	33
	45	**2.10**	**0.76**	0	2	0	67
	60	**1.00**	0.15	0	0	0	0
297	-15	**1.51**	0.38	0	3	0	100
	7.5	**7.30**	**3.02**	0	2	0	67
	22.5	**8.34**	**6.58**	0	0	0	0
	45	**3.80**	**0.67**	1	2	33	67
	60	**0.99**	0.15	0	2	0	67

Values in **bold** are above the lower threshold of 0.5 kg/m³ BAE. Values in red are above the upper threshold of 1.2 kg/m³ BAE.

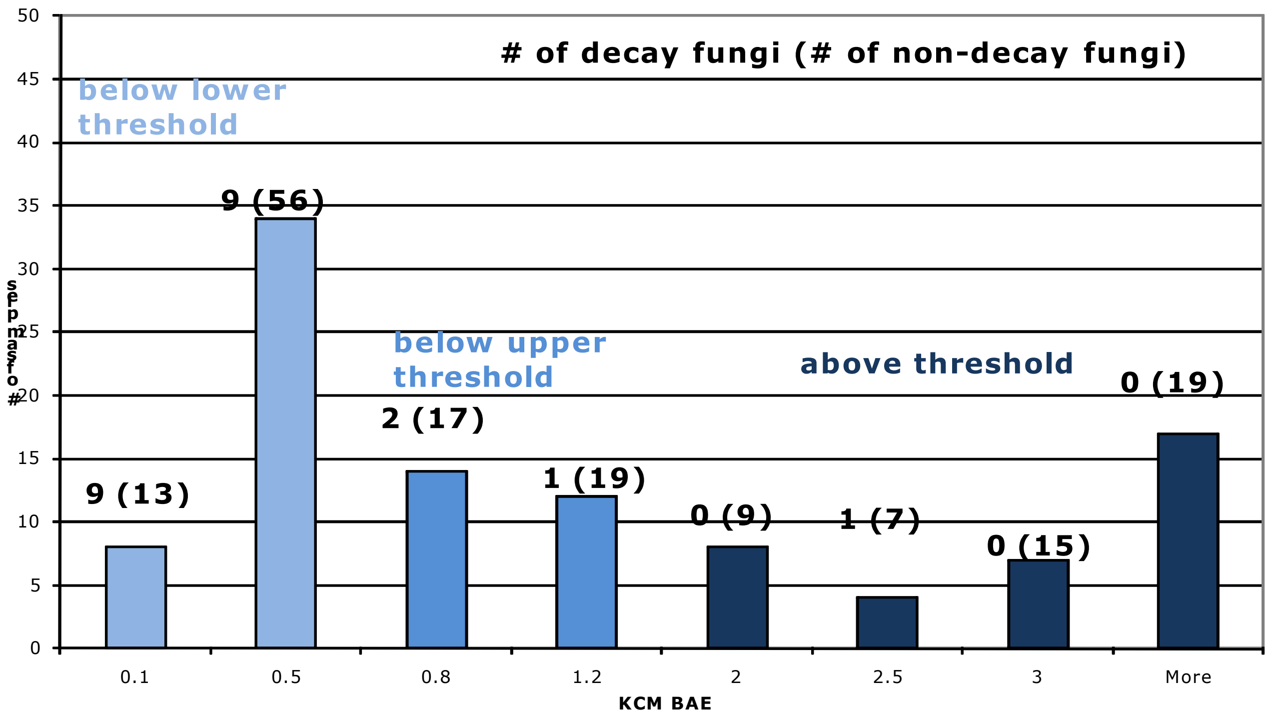

Figure I-10. Comparison between fungal isolation frequency and boron levels in cores removed from Douglas-fir poles 15 years after application of fused borate rods.

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 boron movement through dry wood that would normally not support diffusion (Bech-Anderson, 1987; Edlund et al., 1983).

Pentachlorophenol treated Douglas-fir pole sections (259 to 315 mm in diameter by 2.1 m long) were set to a depth of 0.6 m in the ground at the Peavy Arboretum test site. The poles were treated with varying levels of boron and glycol mixtures. Boron levels have been assessed over a 12 year period, and will next be sampled in 2010 at 15 years.

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

Chemical movement has been assessed 1, 2, 3, 5, 7, 10, 12 and 15 years after treatment and the final results published in the 2008 Annual Report.

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 (259-307 mm in diameter by 2.4 m long) were set in the ground to a depth of 0.6 m at the Peavy Arboretum test site. Three 19 mm diameter by 200 mm long holes were drilled beginning at groundline and moving around the pole 120 degrees and upward 150 mm. Each hole received either one or two sodium fluoride rods. The holes were then plugged with tight fitting wooden dowels. Eight poles were treated with one rod per hole and seven poles were treated with two rods per hole. After 3 years, five of the poles were destructively sampled. The remaining five poles from each treatment were sampled in subsequent years. The next sampling will be in 2010 at 15 years.

C. Full Scale Field Trial of All Internal Remedial Treatments

Date Established:	March 2008
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @ GL (avg., max., min.)	102, 117, 86 cm

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

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

Pentachlorophenol treated Douglas-fir pole stubs (280-300 mm in diameter by 2.1 m long) were set to a depth of 0.6 m. Three (for poles treated with diffusible rods) or four (for poles treated with fumigants) steeply sloping treatment holes (19 mm x 350 mm long) were drilled into the poles beginning at groundline and moving upward 150 mm and around the pole 120 degrees. The various remedial treatments (Table I-8) were added to the holes at the recommended dosage for a pole of this diameter, along with any additive, and then the holes were plugged with plastic plugs. The liquid copper naphthenate accelerant, approximately 10 % by weight, was added to the holes of the dazomet-containing products

(DuraFume, SUPER-FUME, UltraFume, Basamid, and Basamid rods) after the fumigant was placed in the holes, but before they were plugged. Again, the addition of higher concentrations of accelerant is a violation of the product label and is not allowed in commercial applications.

Table I-8. Characteristics of products included in full scale field trial of all internal remedial treatments.

Product Name	Dosage/pole	Additive	Common name	Active Ingredient
DuraFume	280 g	CuNaph	dazomet	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione
SUPER-FUME	280 g	CuNaph	dazomet	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione
UltraFume	280 g	CuNaph	dazomet	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione
Dazomet	280 g	CuNaph	dazomet	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione
Dazomet rods	264 g	CuNaph	dazomet	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione
MITC-FUME	120 g	none	methylisothiocyanate	methylisothiocyanate
WoodFume	475 ml	none	metam sodium	Sodium N-methyldithiocarbamate
SMDC-Fume	475 ml	none	metam sodium	Sodium N-methyldithiocarbamate
Pol Fume	475 ml	none	metam sodium	Sodium N-methyldithiocarbamate
Chloropicrin	475 ml	none	chloropicrin	trichloronitromethane
Impel rods	238 g (345 g BAE)	none	boron rod	Anhydrous disodium octaborate
FLURODS	180 g	none	fluoride rod	sodium fluoride
PoleSaver rods	134 g	none	fluoride rod	disodium octaborate tetrahydrate, sodium fluoride

Each treatment was replicated on five poles and five non-treated control poles were also included in the test.

Chemical movement in the poles was assessed 18 months 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 for fumigant treatments. The 900 mm sampling height was not included for diffusibles. The outer, preservative-treated shell was removed, and then the outer and inner 25 mm of each core was retained for chemical analysis using a method appropriate for the treatment. The fumigants were analyzed by gas chromatography. Chloropicrin is detected using an electron capture detector while the MITC based systems were analyzed using a flame-photometric detector. The remainder of each core was plated on malt extract agar and observed for fungal growth. Boron based systems were analyzed using the azomethine H/carminic acid method; while fluoride based systems were analyzed using neutron activation analysis.

Analysis of the MITC based and boron treated samples has been completed, while the fluoride based systems and chloropicrin are still in process. In order to simplify the discussion, we will discuss the results by chemical using the thresholds for chemical protection for each system. As noted earlier, the threshold is 20 ug/oven dried g of wood for fumigant based systems. Boron has a threshold of 0.5 kg/m^3 of wood for internal decay control.

MITC levels in dazomet plus copper naphthenate treated poles were 10 to 15 times the threshold in the inner zones150 mm below groundline 18 months after treatment (Table I-9; Figure I-11). As we have seen in previous studies, MITC levels tended to be lower in the outer zones at the same distance above groundline. Chemical levels were slightly lower but still 5 to10 times above threshold at groundline and 5 to 8 times above threshold 300, 450, and 600 mm above that level. MITC levels were two times the threshold inthe inner zone 1 m above groundline, but below in the outer zone. The results indicate that the dazomet/copper naphthenate treatment is performing well in the test.

MITC levels in the dazomet rod/copper naphthenate treatment were 9 to14 times threshold 150 mm below groundline and then declined to 4 to 8 times higher than threshold at groundline (Figure I-12). MITC levels declined slightly further above ground, ranging from 2 to 7 times threshold at the 300, 450 and 600 mm levels. MITC levels were above threshold in the inner zone 1 m above groundline, but below in the outer. As with the granular dazomet, the MITC from this system appears to be well distributed through the test poles at fungitoxic levels.

Table I-9. MITC levels in Douglas-fir poles18 months after application of various internal remedial fumigant treatments as determined by gas chromatography of extracts of increment cores.

Treatment	Residual MITC (ug/g of wood)[a]					
	-15 cm		0 cm		30 cm	
	inner	outer	inner	outer	inner	outer
Control	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Dazomet + CuNaph	**337** (266)	**158** (196)	**289** (322)	**102** (105)	**163** (112)	**151** (119)
Dazomet rods + CuNaph	**283** (260)	**181** (347)	**254** (166)	**51** (73)	**159** (66)	**95** (115)
DuraFume + CuNaph	**255** (164)	**126** (118)	**160** (87)	**83** (95)	**131** (81)	**82** (79)
MITC Fume	**1868** (1682)	**207** (219)	**24710** (88693)	**560** (1335)	**2085** (1906)	**372** (430)
Pol Fume	**147** (75)	**63** (49)	**515** (1310)	**65** (55)	**145** (89)	**105** (144)
SMDC-FUME	**152** (75)	**74** (55)	**168** (132)	**50** (22)	**135** (75)	**90** (77)
SuperFume Tubes + CuNaph	**173** (152)	**50** (77)	**121** (85)	**46** (46)	**91** (72)	**54** (47)
UltraFume + CuNaph	**174** (92)	**239** (324)	**175** (115)	**136** (183)	**168** (83)	**151** (208)
Wood Fume	**187** (125)	**91** (120)	**157** (106)	**74** (54)	**156** (107)	**103** (99)

Treatment	Residual MITC (ug/g of wood)[a]					
	45 cm		60 cm		100 cm	
	inner	outer	inner	outer	inner	outer
Control	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Dazomet + CuNaph	**148** (112)	**167** (205)	**107** (99)	**123** (206)	**47** (30)	19 (12)
Dazomet rods + CuNaph	**147** (55)	**118** (168)	**97** (53)	**53** (69)	**49** (36)	9 (21)
DuraFume + CuNaph	**132** (59)	**105** (109)	**99** (86)	**90** (134)	**45** (22)	**27** (37)
MITC Fume	**1574** (2239)	**360** (332)	**840** (673)	**283** (214)	**848** (764)	**235** (208)
Pol Fume	**134** (66)	**112** (96)	**113** (53)	**74** (51)	**75** (31)	**36** (26)
SMDC-FUME	**144** (112)	**71** (52)	**114** (89)	**61** (47)	**72** (51)	**24** (23)
SuperFume Tubes + CuNaph	**60** (22)	**60** (44)	**39** (17)	**38** (30)	**35** (72)	16 (19)
UltraFume + CuNaph	**112** (51)	**113** (134)	**98** (72)	**77** (65)	**59** (69)	**26** (20)
Wood Fume	**127** (79)	**85** (112)	**129** (62)	**100** (112)	**95** (48)	**46** (60)

[a]Numbers in bold represent MITC levels above the toxic threshold of 20 ug/g wood. Figures in parentheses represent one standard deviation.

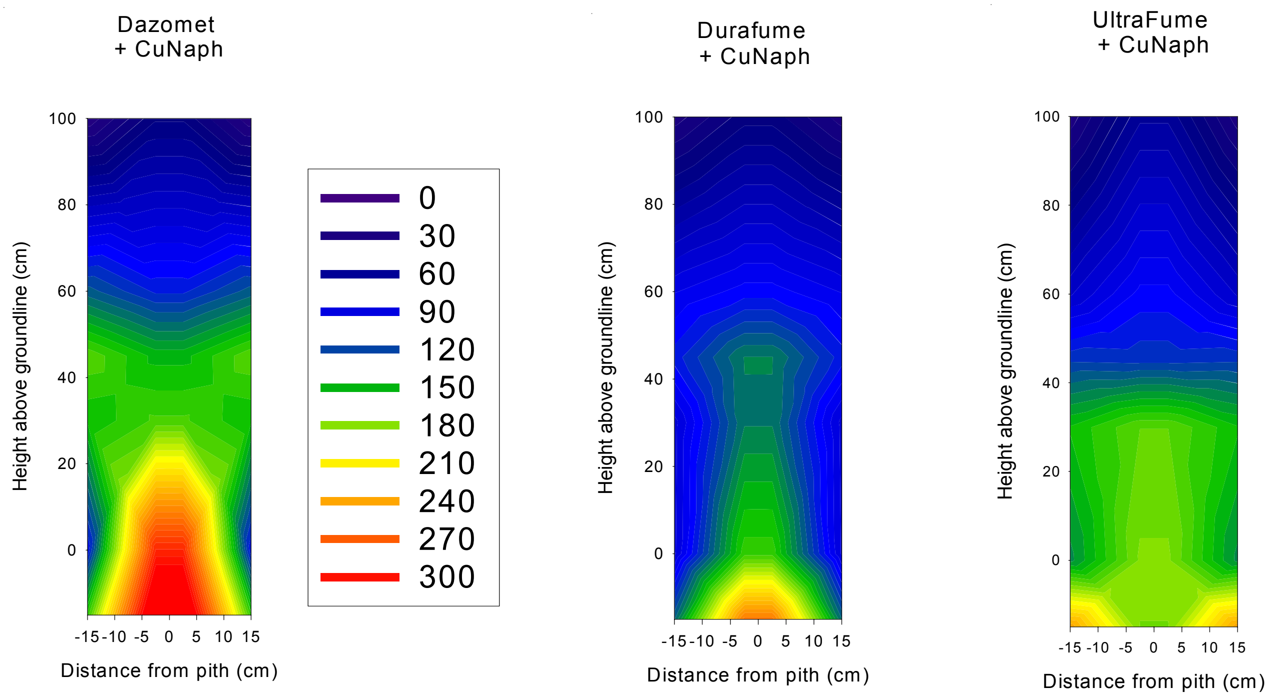

Figure I-11. Distribution of MITC in Douglas-fir poles sections 18 months after treatment with dazomet plus copper naphthenate, DuraFume plus copper naphthenate or UltraFume plus copper naphthenate. Dark blue indicates MITC levels below threshold, wholeall other colors indicate above-threshold values.

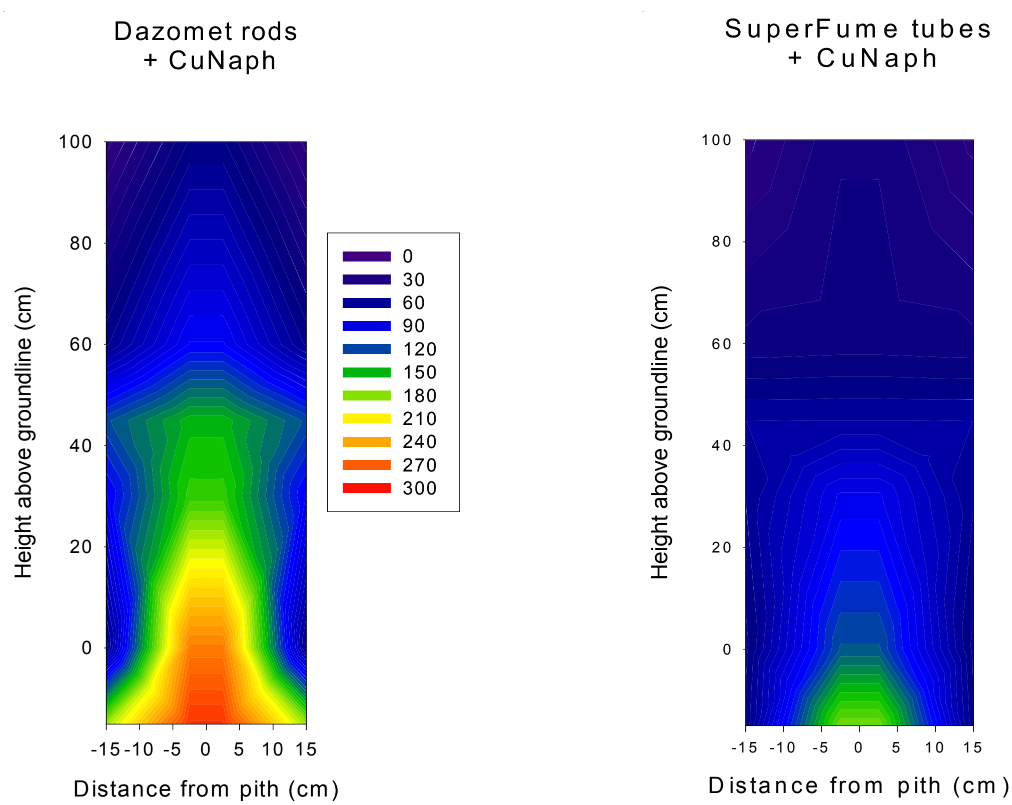

Figure I-12. Distribution of MITC in Douglas-fir poles sections 18 months after treatment with dazomet rods plus copper naphthenate or SUPER-FUME tubes plus copper naphthenate. Dark blue indicates MITC levels below threshold, while all other colors indicate above-threshold values.

MITC levels in the DuraFume plus copper naphthenate treated poles sections followed trends that were similar to the other two granular dazomet treatments. MITC levels were 6 to 12 times threshold 150 mm below groundline, then 4 to 8 times threshold at groundline, 300 mm and 450 mm above that level. The results indicate that there is little difference in MITC levels among the three systems at the 18 month sampling point.

MITC levels in poles treated with UltraFume plus copper naphthenate were 8 to 11 times threshold 150 mm below groundline and declined only slightly at groundline and 300 mm above that zone. MITC levels were 3 to 5 times threshold 450 and 600 mm above groundline and 1-2 times threshold 1 m above groundline. The SUPER-FUME levels appear to be slightly lower than those for the other two dazomet based systems, although the levels were still well above the threshold for protection. MITC levels in poles treated with SUPER-FUME in tubes plus copper naphthenate were 2 to 8 times threshold 150 mm below groundline, and 4 to 6 times threshold at groundline and 300 or 450 mm above those levels. MITC levels were slightly less than two times threshold 600 mm and in the inner zone 1 m above groundline. While the treatment resulted in fungitoxic levels of MITC 150 mm below to 600 mm above groundline, the overall levels present were lower than those found with granular and rod formulations of the same chemical.

MITC levels in MITC–FUME treated poles were 90 times the threshold in the inner zone 150 mm below groundline and 10 times that level in the outer zone (Figure I-13). The elevated MITC levels in the inner zone continued through groundline to 1 m above groundline. Levels in the outer zones at these same heights were also elevated, ranging from12 to 28 times the threshold value. The extremely high MITC levels in these poles reflect the application of pure MITC. In the case of both dazomet and sodium n-methyldithiocarbamate, the chemicals must decompose to release MITC. In this case, the MITC sublimesdirectly from a solid to a gas and can move rapidly into the wood. The results indicate that the MITC-FUME has produced exceptional levels of protection at all sampling locations18 months after treatment.

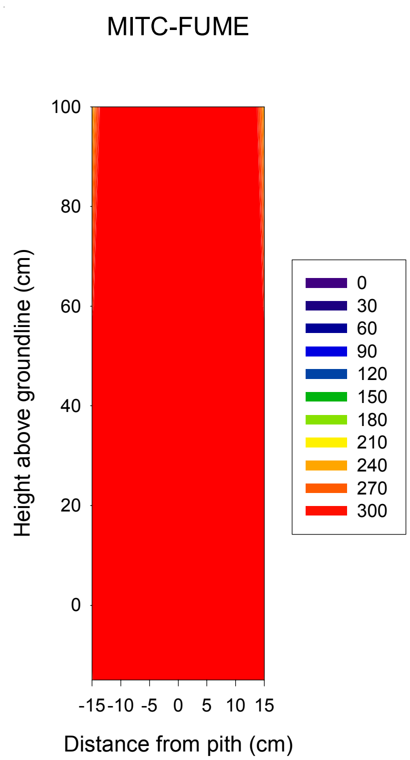

Figure I-13. Distribution of MITC in Douglas-fir poles sections 18 months after treatment with MITC-FUME. Dark blue indicates MITC levels below threshold, while all other colors indicate above-threshold values.

Pol-Fume, SMDC-Fume and WoodFume all contain sodium n-methyldithiocarbamate as the active ingredient and must decompose in the wood to release MITC. Previous studies have shown that the rate of decomposition is relatively low; however, these products have some attractive features including low cost and lack of strong volatile odors.

MITC levels in poles treated with Pol-Fume were 3 to 7 times threshold 150 mm below groundline, while levels were 3 to 25 times threshold at groundline (Figure I-14). Chemical levels were 5 to 7 times threshold 300 and 450 mm above groundline and 1 to 5 times threshold between 600 mm and 1m. Protective levels were found at all sampling locations. MITC levels in SMDC-Fume treated poles and poles treated with WoodFume followed trends that were very similar to those found for Pol-Fume, with protective levels at all heights 18 months after treatment.

The results indicate that the SMDC systems have all decomposed at levels capable of producing wood protection in a zone from 150 mm below groundline to 1 m above that line. These results are consistent with previous field trials.

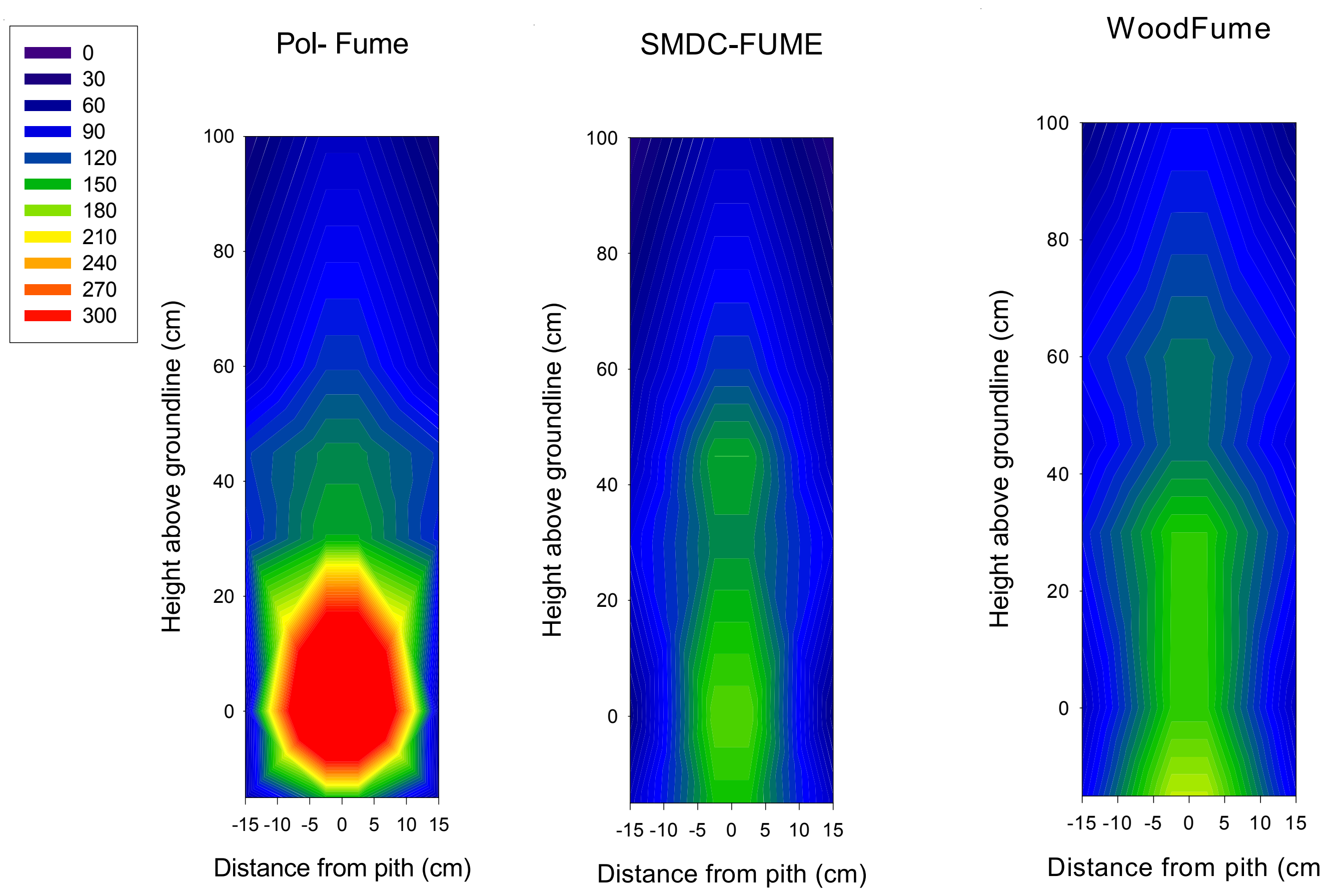

Figure I-14. Distribution of MITC in Douglas-fir poles sections 18 months after treatment with Pol-Fume, SMDC-Fume, or WoodFume. Dark blue indicates MITC levels below threshold, while all other colors indicate above-threshold values.

Sampling of poles treated with boron-based systems was limited to 150 mm below to 600 mm above the groundline because these systems are less like to migrate for long distances upward early in the test. Boron levels in both Impel and Pol Saver rod treated poles were at background levels 450 and 600 mm above groundline.

Boron levels were at or above threshold in the inner zones 150 mm below and at groundline for the Impel Rod treated poles, but below that level in the outer zone (Table I-10). Boron levels were above threshold in the outer zones of the same poles 300 mm above groundline (Figure I-15). In general, boron is not widely distributed in these poles at levels that would confer protection. These results are typical for water-based systems, which require longer time periods to become effective.

Poles treated with the fluoride-containing products, FLURODS and PoleSaver rods, were sampled in the same manner as the boron-treated poles. The analysis is ongoing and the results will be published in the 2010 Annual Report.

Table I-10. Boron levels at various distances above and below the groundline in Douglas-fir poles 18 months after application of Impel or Pol Saver rods.

Treatment	Residual Boron (Kg/m^3 BAE)[a]									
	-15 cm		0 cm		30 cm		45 cm		60 cm	
	inner	outer	inner	outer	inner	outer	inner	outer	inner	outer
Control	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Impel rods	**2.59** (1.44)	0.37 (0.35)	**7.68** (10.11)	0.16 (0.20)	0.02 (0.03)	**0.97** (2.17)	0.02 (0.03)	0.02 (0.03)	0.02 (0.04)	0.00 (0.01)
Pol Saver rods	**0.84** (0.11)	0.14 (0.24)	**7.50** (4.55)	**0.61** (0.74)	0.00 (0.00)	0.04 (0.08)	0.02 (0.04)	0.06 (0.06)	0.02 (0.03)	0.03 (0.04)

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

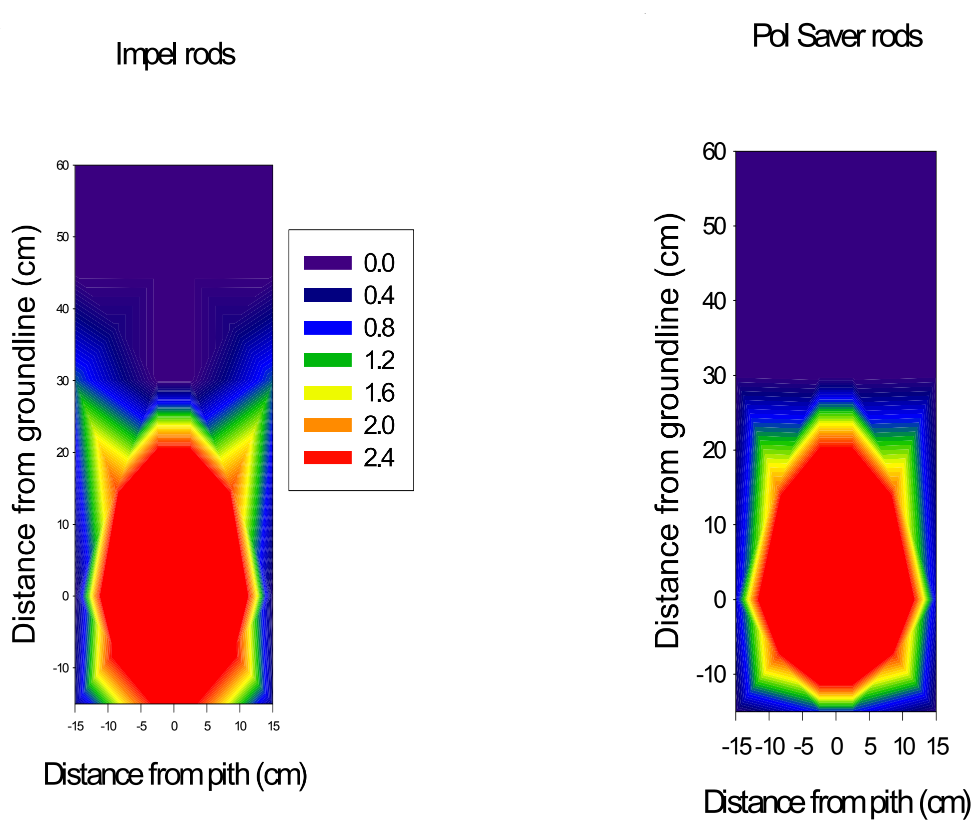

Figure I-15. Boron distribution in Douglas-fir poles 18 months after application of Impel or Pol Saver rods. Blue areas contain boron levels below the threshold, while areas with all other colors contain increasing levels of boron.

Boron levels in poles treated with Pol Saver rods were above threshold levels in the inner zones 150 mm below and at groundline as well as in the outer zone at groundline. This system also contains fluoride and these samples are still being analyzed. As with the Impel treatment, chemical levels are still too variable to be effective at this time, but we would expect continued diffusion to produce more uniform chemical distribution over time.

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Objective II

IDENTIFY CHEMICALS FOR PROTECTING EXPOSED WOOD SURFACES IN POLES

Preservative treatment prior to installation provides an excellent barrier against fungal, insect, and marine borer attack, but this barrier only remains effective as long as it is intact. Deep checks that form after treatment, 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 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, moisture naturally present 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. In the field trial pole sections were set and paste-coated bolts were driven into field drilled holes. At 1 to 8 years after treatment the pole sections were then split through the bolt hole and the degree of chemical movement was assessed using specific chemical indicators (AWPA, 2006 a-c). Penetration was measured as average and maximum distance up or down from the bolt.

Copper penetration longitudinally away from the bolt holes has been limited over the 8 year test (Tables II-1, 2). Average copper penetration for the Cop-R-Plastic treated rods was 2.7 mm after 8 years, while that around the CuRap 20 treated bolts was 3.8 mm (Figures II-1, 2). The copper in these systems was not designed to be mobile and the results reflect that limited ability to migrate.

Table II-1. Penetration of copper around chemically treated threaded galvanized rods inserted into Douglas-fir poles sections and exposed in the field for 1 to 8 years.

Treatment	Diffusion	Degree of Chemical Movement (mm)[a]					
		Copper					
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 6	Yr 8
Cop-R-Plastic	Average	<1	2.3 (1.3)	3.0 (0.8	2.3 (1.0)	2.3 (0.5)	2.7 (0.5
	Maximum	29.8 (28.8)	237.5 (64.0)	50.5 (47.5)	8.8 (3.2)	7.0 (5.6)	42.5 (32.9)
CuRap 20	Average	3.0 (1.2)	2.3 (0.5)	<1	1.0 (0.8)	8.3 (11.8)	3.8 (1.7)
	Maximum	20.5 (9.7)	110.3 (98.3)	51.3 (52.5)	7.3 (9.0)	18.0 (19.8)	21.8 (9.8)

[a]Numbers in parentheses represent one standard deviation.

Table II-2. Penetration of boron or fluoride around chemically treated threaded galvanized rods inserted into Douglas-fir poles sections and exposed in the field for 1 to 8 years.

Treatment	Diffusion	Degree of Chemical Movement (mm)[a]					
		Boron/Fluoride					
		Yr 1	Yr 2	Yr 3	Yr 4	Yr 6	Yr 8
Cop-R-Plastic	Average	<1	2.0 (2.8)	2.0 (1.8)	7.0 (4.7)	7.3 (3.1)	22.0 (18.9)
	Maximum	117.5 (138.7)	107.5 (73.7)	15.3 (16.9)	28.3 (18.0)	15.5 (5.4)	119.7 (33.9)
CuRap 20	Average	3.3 (0.5)	6.3 (3.4)	2.8 (2.2)	20.3 (16.1)	12.5 (6.7)	11.7 (8.7)
	Maximum	49.8 (10.5)	45.8 (28.5)	49.5 (55.1)	118.8 (69.4)	30.0 (29.5)	48.8 (47.5)

[a]Numbers in parentheses represent one standard deviation.

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

a.

b.

Figure II-1. Degree of a) copper and b) fluoride movement away from the sites in Douglas-fir pole stubs where Cop-R-Plastic coated galvanized threaded rods were installed 8 years earlier.

a.

b.

Figure II-2. Degree of a) copper and b) boron movement away from the sites in Douglas-fir pole stubs where CuRap 20 coated galvanized threaded rods were installed 8 years earlier.

The results, to date, show that the coated rods can deliver chemicals to a small area around the treatment hole. These results, coupled with previous trials of boron and fluoride sprays into field drilled bolt holes, suggest that treated bolts may represent one method for ensuring that field drilled wood is protected. This approach would allow utilities to specify specific treated bolts when other utilities (telecommunications and cable companies, for example) occupy portions of the pole and must field drill for attachments, allowing utilities to minimize the risk of decay in field drilled holes above the ground.

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

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Objective III

EVALUATE PROPERTIES AND DEVELOP IMPROVED SPECIFICATIONS FOR WOOD POLES

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

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

The proposed through-boring standard is under consideration by the ASC 05 committee. One question raised by the committee was whether there was an effect of loading of poles perpendicular to the through bored holes. Preliminary finite element modeling suggested that loading holes parallel to the hole direction was more detrimental and all of our tests had used a parallel to hole loading. In order to answer this question and move the through-boring proposal forward, we undertook a second test.

Freshly peeled, green Class 4-40 foot long poles were obtained from Oregon and Washington. The poles were immediately placed under sprinklers to maintain them in the green condition. This is important because ANSI tests are performed in the green condition to avoid the need for moisture content corrections. The poles were drilled using the same pattern employed in the original tests, except this time the holes were drilled perpendicular to the belly tag. Normally, the tag is placed in line direction and the original work was performed assuming that the holes should be placed on this face. The boring pattern was applied from 2 feet above ground to 4 feet below the theoretical groundline (6 feet from the butt in this case).

In addition to the through-bored poles, additional poles were either deep incised or radial drilled to a depth of 3.5 inches in the same zone. Each treatment was replicated on 30 poles. The poles were supplied as 40 foot sections, but each pole was cut into a 20 foot long section for testing.

The poles were tested in a modified 4-point bending method that forced the maximum bending stress to be in the region containing either the groundline preparation treatment holes while maintaining a nearly constant moment in the high moment zone so that the bending moment at failure could be accurately calculated. The test setup was a modification of that described by Crews et al. (2004).

The poles were tested as simply supported beams with two point loads applied near the assumed groundline. The end bearing points allowed the pole to rotate as well as move longitudinally. Wood saddles were used at the bearing points, as well as the points of loading. The U-shaped saddles measured 11-in. in length, and were made out of Douglas-fir so the point of contact between the two materials was of similar hardness.

Poles were shortened to a convenient length such that they had a reasonable span-depth ratio and were not shear critical. With those criteria, the poles were tested on four point bending where the length for the test specimen (L) was 144 inches with a minimum 1-ft overhang on each end (Figure III-1).

Figure III-1. Photograph showing a pole in the test set-up.

A 200-kip capacity hydraulic actuator mounted on a steel portal frame attached to the laboratory strong floor was used to apply the load to the poles. The load was displacement-controlled and the rate of loading was 0.01 in. /sec. This rate was estimated from the ASTM Standard D1036. An external load cell attached to the rod end of the actuator measured the force as it was applied to the pole. Deflection and force data were compiled continuously at 1 Hz during the test using National Instruments LabVIEW 6.1 operated through a personal computer.

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

The section modulus was determined at the point of failure from the butt using the groundline circumference data and assuming constant taper and uniform circular cross-section.

The maximum load was used to calculate the moment at failure assuming a prismatic member. The section modulus used as input for the modulus of rupture (MOR) values was the section of the pole at the failure location. All section modulus calculations were based on the gross pole section.

Modulus of elasticity (MOE) values were estimated from the load-displacement data in a range of approximately 10 to 30 percent of maximum load to ensure the data were from the linear portion of the curve. *P* is the load applied at the point of measured deflection (kips); Ä and *d* (in.) are the displacement and diameter measured at the failure point.

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

The data for these tests are still being processed; however, the preliminary results show that there were no significant differences in either maximum load or MOR between the three groundline treatment methods. The poles all largely failed within the groundline zone and the coefficients of variation were similar to or slightly lower than those found in the original study. The only difference noted to date was a slightly different failure mode for poles that are deep incised. While most poles tested in our apparatus failed in tension on the bottom face, deep incised poles tended to fail in shear (Figures III-2,-3). The poles still had the same flexural properties regardless of failure mode, indicating that none of the three methods for improving internal treatment at groundline negatively affect pole properties. The results mean that utilities can be comfortable using any of these methods to reduce their risk of internal decay at groundline. We expect to present the complete results in the next annual report.

Figure III-2. Example of a typical tension failure on a through-bored Douglas-fir pole.

Figure III-3. Example of a shear failure on a deep incised Douglas-fir pole.

B. Effect of Inspection Holes on Flexural Properties of Poles in Service

While a variety of non-destructive test methods have been developed for detecting internal insect attack and decay in poles, intrusive inspection is generally necessary to determine the cause and degree of damage. Many utilities are concerned about the potential for the inspection holes to, themselves, become damaging both from the removal of cross sectional area as well as from the potential to act as pathways for future fungal attack. Application of a remedial internal treatment can mitigate the risk of the holes acting as conduits for future fungal attack, but the potential effects on strength remain unknown. The upper halves of the poles used to assess the effects of groundline preparation provided a ready source of material to assess the effects of inspection holes on flexural properties. The poles were randomly allocated to four groups of 22-23 poles. The poles received the following treatments around the theoretical groundline (6 feet from the butt).

1. No holes
2. Three 5/8 inch diameter holes drilled at 6 inches below the groundline, 6 inches above the groundline and 18 inches above the groundline. The holes were approximately 15 inches long and drilled inward at a 45 degree angle. Each hole was 120 degrees around from the others.
3. Three 7/8 inch diameter holes drilled at 6 inches below the groundline, 6 inches above the groundline and 18 inches above the groundline. The holes were approximately 15 inches long and drilled inward at a 45 degree angle. Each hole was 120 degrees around from the others.
4. Six 7/8 inch diameter holes drilled in pairs beginning 6 inches below the groundline, 6 inches above the groundline and 18 inches above the groundline. The holes were approximately 15 inches long and drilled inward at a 45 degree angle. Holes at a given location from the groundline were drilled 120 degrees apart.

The first two drilling patterns were selected to simulate a first inspection of a pole, while the third was designed to simulate a re-inspection of the same pole at a later date. The Wood Pole Maintenance Manual does not recommend drilling additional holes in a re-inspection unless probing in the original inspection holes suggests that shell thickness has declined; however, some utilities routinely drill additional holes. These same utilities have then suggested that excess inspections would eventually lead to pole condemnation from inspection rather than decay. The poles were loaded to failure, defined as the point at which the pole could not continue to take increasing load. After failure, each pole was evaluated and the location of failure was recorded. Photographs were taken of each failure and notes were made of any significant features that might have contributed to the failure.

The section modulus was determined at the point of failure from the butt and groundline circumference data taken assuming a constant taper and uniform circular cross-section.

The maximum load was used to calculate the moment at failure assuming a prismatic member. The section modulus used as input for the MOR values was the section of the pole at the failure location. All section modulus calculations were based on the gross pole section.

The results indicate that drilling three or six steep angled holes into the groundline zone of a pole had no significant effect on modulus of rupture (Table III-1). The test apparatus placed the maximum stress in the area where the holes were drilled, indicating that inspection holes do not pose a significant threat to pole flexural properties. Despite the ability to drill additional holes, we would still recommend re-using inspection holes wherever possible.

Table III-1. Effect of inspection holes on flexural properties of Douglas-fir pole sections.

Boring	Reps	Variance (psi)	% of Control	P Value
None	23	1001866	100	-
Three 5/8“	23	1007758	97.5	0.314
Three 7/8”	22	1453834	95.3	0.198
Six 7/8“	23	491340	97.1	0.252

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

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

In 2007 an additional set of penta-treated Douglas-fir pole stubs were encased in the newest generation of Biotrans liner and set into the ground at our Peavy Arboretum research site (Figure III-5). The poles were each sampled prior to installation to determine chemical penetration and retention and baseline moisture content. Five poles received a Biotrans liner that extended 150 mm above groundline; five received a Biotrans liner that extended 300 mm above groundline and eleven poles were left unlined.

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

Moisture contents were similar among the control and barrier treatments at the start of the test (Table III-2). Moisture contents 6 months after installation rose in the outer three zones for both the control and barrier poles. This sampling coincided with the middle of our wet season and the results reflect elevated soil moisture conditions at that time. This test site has a water table near the surface during the winter, creating exceptional conditions for wetting of unprotected wood. Moisture levels 12 months after

Figure III-5. Example of external barrier assessed on Douglas-fir poles.

Table III-2. Effect of pole barriers on internal moisture contents of Douglas-fir poles.

Treatment	Months After Installation	Segment (mm from pole surface)			
		0-13	13-25	25-50	50-75
Biotrans 150 mm	0	39.5 (10.0)	35.1 (7.4)	34.0 (11.8)	33.5 (10.5)
	6	57.8 (19.0)	48.1 (10.5)	37.6 (2.6)	37.7 (5.5)
	12	48.7 (13.9)	35.6 (10.3)	35.7 (14.6)	34.6 (16.1)
Biotrans 300 mm	0	38.5 (7.7)	32.2 (3.9)	32.2 (8.1)	40.3 (24.3)
	6	67.1 (18.3)	49.5 (5.7)	38.8 (3.0)	35.5 (3.2)
	12	45.1 (20.7)	34.6 (9.8)	33.3 (7.0)	33.1 (6.7)
Unlined Control	0	34.4 (3.5)	28.9 (2.7)	27.2 (3.2)	29.1 (3.3)
	6	54.3 (14.9)	47.1 (7.4)	42.1 (7.9)	43.7 (10.8)
	12	20.2 (4.9)	28.7 (15.7)	28.8 (8.3)	29.5 (4.3)

installation were sharply lower in all four zones of the control poles, reflecting the very dry soil conditions typical of the site in the dry season. Moisture contents in the BioTrans Liner-protected poles declined slightly from their winter highs, but were still higher than those for the controls. The slower decline in moisture content in the BioTrans Lined poles may reflect the limited ability of moisture to move out of the poles, but it also likely reflects the fact that these liners completely seal the pole and do not have a hole at the bottom to allow for drainage. Elevated moisture beneath the top of the liner may not be important given the limited availability of oxygen in this zone. The moisture levels at the top of the liner, however, may be suitable for decay and inspection procedures may need to be changed to ensure that this zone is inspected, even if this zone is above the groundline.

We will continue to monitor these poles along with some monitoring of older BioTrans lined poles in the State of Washington to develop long term data on seasonal internal moisture fluctuation in barrier protected poles.

D. Performance of Fire Retardants on Douglas-fir poles

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

As an alternative, poles can be periodically treated with fire retardants. Some of these materials are designed for short term protection and must be applied immediately prior to a fire, while others are longer lasting and provide 1 to 3 years of protection. While these fire retardant treatments have been available for decades, there is little published information on their efficacy or their longevity. In order to develop this information, the following test was initiated.

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

1. Osmose Fire-Guard
2. CuRap 20 as a below-ground treatment
3. J.H. Baxter Elastomeric Epoxy Roof Coating
4. Copper Care wrap- no copper
5. Copper Care wrap with copper lining
6. No treatment

The Copper Care product was a 100 mm wide flexible tape that was wrapped around the pole. This system was applied last spring. The Copper Care wrap with copper was applied this past summer.

Poles have generally been burned in the fall at the end of our dry season. 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 (Figure III-6). 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 (Figure III-7).

In the 2006 test, charring ranged from 2.1 to 19.1 mm, with Fire Guard treated poles experiencing the least charring. In 2008, charring ranged from 14.8 to 21.1 mm, with the largest amount of charring occurring on unprotected poles. 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-3). The surfaces of both coatings bubbled and cracked, suggesting some loss in adhesion over time. The CuRap 20 treated poles were not tested in either 2008 or 2009. The Copper Care wrap experienced a slightly higher degree of charring (15 mm), but the most important feature of this product

Figure III-6. Example of a pole section with straw in cage prior to ignition.

Figure III-7. Example of char around a pole following a fire test.

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.

Table III-3. 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	Installation Year	Average Change in Circ. (cm)[a]				Average Depth of Charring (mm)			
		2005	2006	2008	2009	2005	2006	2008	2009
Control	2004	-1.9	-3.6	-6.1	-7.2	8.5	10.6	21.2	8.2
CuRap 20	2004	-1.6	-5.5	not burned	not burned	1.3	19.1	not burned	not burned
Elastomeric Paint	2004	0.4	-1.5	-4.6	not burned	1.1	5.8	14.8	not burned
Fire Guard	2004	2.8	-0.8	-4.7	not burned	0.8	2.1	14.8	not burned
Copper Care	2008	not installed	not installed	-4.0	-7.0	not installed	not installed	15.0	7.6
Copper Care Barrier	2009	not installed	not installed	not installed	-1.9	not installed	not installed	not installed	2.0

[a]Negative numbers indicate a loss in circumference after burning.

In the 2009 test, we assessed unprotected control poles plus the remaining pole that had received the copper care wrap along with a newer wrap that had a copper liner.

Conditions were somewhat less suitable for burning this year compared with the 2008 conditions. Although the test was preceded by 2 weeks of hot dry weather, periodic rainfall over the summer had limited the degree of drying. The circumference loss and average depth of charring were only 7.2 cm and 8.2 mm, respectively in the current test, compared with 6.1 cm and 21.2 mm the previous year. Charring and circumference losses on the Copper Care bandage without the copper barrier were similar to those found with the untreated control. As in the previous year, the wrap ignited and then unraveled from the pole, helping to fuel the fire on the wood surface. The results confirm the previous test.

Charring and circumference losses on the copper lined wrap were much lower than those for either the untreated control or the Copper Care wrap. While the external coating also burned off this material to expose the copper liner, the wood beneath experienced only slight charring that was similar to that experienced by the Fire Guard treated poles in the 2006 test. The results indicate that the copper acted as a reasonable barrier against ignition. While it might be possible to use a copper barrier alone, this material would likely be prone to vandalism by metal thieves. The sheathing disguises the copper, making it less susceptible to damage.

The results indicate that the copper lined barrier is promising as a fire preventative on the poles. The test will continue to be monitored to assess the long term efficacy of each system.

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

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

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

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

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

We used small scale tests to assess the flammability of poles treated with pentachlorophenol in two solvents conforming to the current AWPA Standard P9 Type A.

Ten non-treated, eight foot long Douglas-fir posts (6 inches in diameter) were obtained from Pacific Wood Preserving, cut into 2 foot long sections and end-sealed to retard preservative flow. The sections from a given pole were weighed and then allocated to four different treatment groups. One group of 10 sections was left untreated to serve as controls. The other three groups were sent to treating plants in Nevada, Oregon, and Washington for pressure treatment with pentachlorophenol in diesel. The instructions were to treat the posts in a charge for poles. The sections were then returned to OSU where they were weighed to determine gross solution uptake, then sampled to assess preservative penetration and retention by removing increment cores from one face of each section. Preservative penetration was visually assessed on each core, then the outer 0.25 to 1.0 inches was removed from each core from a given post. These segments were combined from a post, ground to pass a 20 mesh screen and then analyzed for pentachlorophenol by x-ray fluorescence spectroscopy.

Post sections were treated with the following systems:

Pentachlorophenol concentrate diluted in #2 diesel (A or B)
Pentachlorophenol diluted in #2 diesel (A)
Pentachlorophenol diluted in #2 diesel (A) and coated with polyurethane
Pentachlorophenol block diluted in FP9-HTS

The post sections were subjected to fire using a modified weed burner. A regulator was attached to the system to restrict the flow of fuel and reduce the size of the flame, and then the apparatus was placed in a stand so that the fire was in direct contact with an area approximately 10 by 60 mm wide on each pole (Figure III-8). Preliminary testing suggested that a fire exposure of approximately 15 minutes produced a degree of charring similar to that found in our most severe field fire test in 2008.

At the conclusion of the exposure, the sample was allowed to burn for an additional 10 minutes, and then extinguished. After cooling, the damage was assessed by measuring the total area charred, the maximum depth of char and the average char depth in the affected area. The results were used to determine if oil source affected flammability of the resulting treated wood.

Non-treated pole sections lost approximately 2% weight as a result of the fire exposure, representing a 7.3 % loss in cross sectional area (Table III-4). Exposure of treated sections to fire resulted in higher

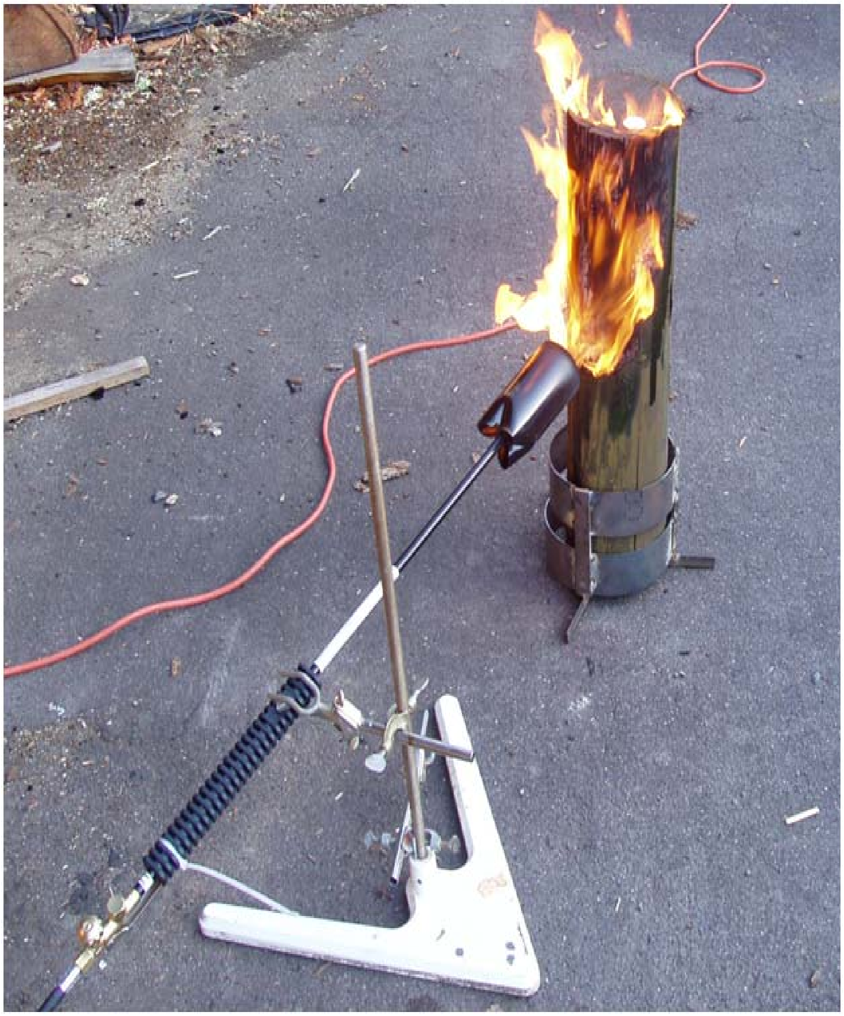

Figure III-8. Apparatus used to evaluate fire resistance of post sections treated with pentachlorophenol in various P9 Type A solvents.

Table III-4. Weight and circumference loss on post sections treated with pentachlorophenol in selected P9 Type A solvents and subjected to a simulated burn.

Treatment	Weight Loss (%)	Cross Sectional Loss (%)
Control (non-treated)	2.4 (0.2)	7.3 (4.1)
Penta concentrate diluted in #2 diesel (A or B)	11.9 (24.4)	9.3 (8.4)
Penta diluted in #2 diesel (A)	4.7 (2.0)	7.8 (2.6)
Penta diluted in #2 diesel (A), coated with polyurethane	4.0 (1.0)	7.3 (2.9)
Penta in FP9-HTS	7.0 (6.1)	7.3 (3.2)

weight losses regardless of oil source; however, we believe that most of this weight loss was due to loss of oil rather than wood loss. Pole sections in one treatment (penta concentrate) appeared to suffer a much higher weight loss; however, the value was skewed by several poles that experienced much greater damage. The remaining pole sections lost 4 to 7% weight. Cross sectional losses were all similar to those for the nontreated control, suggesting that, despite the loss of weight, the depth of char did not differ. These results are consistent with our very original fire tests where we observed that oil treated poles tended to burn for long periods, but experienced minimal charring. Furthermore, testing of wood beneath the char in the previous tests indicated that the treated wood retained its efficacy against fungal attack. The results suggest that there is little practical difference in the risk of fire damage to poles treated with pentachlorophenol in conventional and biodiesel amended P9Type A oils.

We are still completing this analysis and will provide the fire intensity data in the next annual report.

F. 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. End-plates 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 and then cut in half to leave one plated end and one non-plated end on each arm (Figure III-9). The objective was to compare checking with and without plates on comparable wood samples. The plates were developed by Brooks Manufacturing (Bellingham, WA). The arms were initially examined for the presence of checks. The arms were then immersed in water for 30 days before being removed and assessed for check development. The total number of checks longer than 2.5 cm on each face was recorded, and the width of the widest check on each face was measured. The arm sections were air dried and measurements were made again. The arms were then returned to the water tank for an additional 30 days before the cycle was repeated. The arms were air dried in the first cycle, then the arms were kiln dried for the remaining nine cycles.

The differences in degree of checking between the arms were slight for the first few drying cycles and checking was actually slightly greater in some arms with an end-plate early in the test (Table III-5). Continued moisture cycling, however, has gradually shown that check width and frequency have both become larger on the arm end without the end-plate. The results suggest that both the frequency and size of checks can be limited by end-plating. These results parallel those found with end-plating on railway sleepers. In the case of the sleepers, the need for anti-splitting devices is much greater because of the tendency of many hardwood species to split as they season; however, the principle is the same. These plates would be especially useful in very dry areas or in areas subjected to extreme wet/dry cycles. In both cases, the build-up of internal stress can lead to deep check development that can compromise cross arm connectors.

Figure III-9. Example of an end-plate on a penta treated Douglas-fir cross arm.

Table III-5. Number and width of checks on penta treated Douglas-fir cross arm sections with and without end plates and subjected to repeated wet/dry cycles.

	Average Number of Checks				Widest Check			
	Wetting Cycle		Drying Cycle		Wetting Cycle		Drying Cycle	
Cycle	No End Plate	End Plate	No End Plate	End Plate	No End Plate	End Plate	No End Plate	End Plate
1	2.32	0.36	0.48	0.12	1.00	1.50	0.81	0.81
2	0.20	0.08	1.00	0.52	0.31	1.00	1.10	1.40
3	0.00	0.08	0.24	0.16	0.00	1.10	1.00	1.30
4	0.04	0.08	1.00	0.96	0.64	1.50	1.20	1.10
5	0.04	0.08	0.56	0.80	0.70	1.80	3.00	1.50
6	1.92	0.32	2.00	0.36	0.81	0.89	2.50	2.00
7	1.40	0.52	2.24	2.00	0.71	1.40	3.60	2.10
8	0.96	0.12	2.00	1.44	1.90	1.90	7.00	2.20
9	0.92	0.52	3.08	2.24	3.00	1.20	6.60	3.40
10	1.52	1.05	3.84	2.20	4.00	1.10	5.90	2.60

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

G. 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.

Three years ago, 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-10). 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.

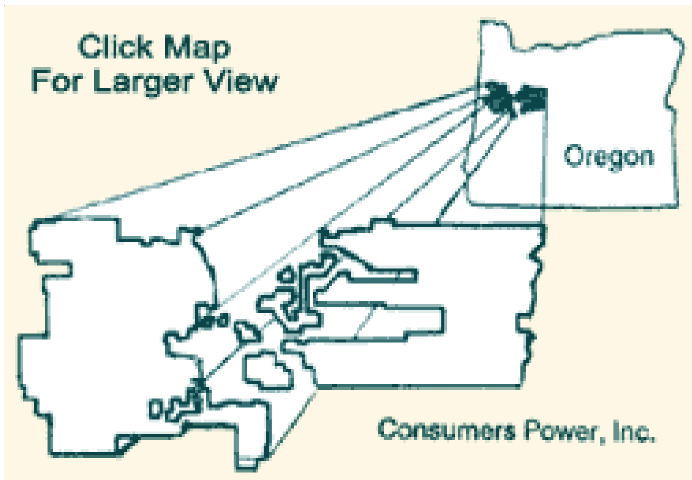

Figure III-10. Map of Consumers Power, Inc. development area in Oregon.

The poles 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-11). Most notable was the presence of buprestid attack in a number of locations as well as Pileated woodpecker (*Dryocopus pileatus*) attack on most of the poles.

Figure III-11. 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 3 or more feet downward from the opening (Figure III-12).

Further examination also revealed additional evidence of damage. We often found evidence of buprestid beetle attack in the woodpecker affected sections. The beetle attack appeared 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-13).

Figure III-12. 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.

Figure III-13. 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 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 allowed us to determine the extent of the damage. The first pole reconstructed was heavily decayed and nearly hollow for a high proportion of hits length. The reconstruction clearly showed the extent of damage, making it obvious why this was a reject pole (Figure III-14). The other pole also had woodpecker and internal decay, but the extent of damage was much smaller. The reconstruction shows the extent of the void. The decision to reject or restore this pole would be more dependent on the pole configuration as well as the location of the void. For example, this 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-14. Illustration of reconstructed internal damage in a Douglas-fir utility pole after 25 years in service.

We continue to see an association between termites and woodpecker galleries and 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 these materials. 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).

H. 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) that 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 2.5 m lengths and set in the ground to a depth of 0.6 m. The poles were cut so that the top was at least 150 mm away from any pre-existing bolt hole. The original bolt holes on the pole sections were then plugged with tight fitting wood or plastic plugs to retard moisture entry. Five of the poles were left uncapped while the remainder received Osmose plastic caps. Initial moisture contents were determined by removing increment cores 150 mm below the top of each pole (Figure III-15). 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 4 months after treatment at the end of our rainy season and again 12 months after installation. 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 and 19% for the outer 25 mm of uncapped and capped poles, respectively, while they were 20 and 28% for the inner zones (Table III-6). 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 sampling took place during our winter rainy season. Moisture contents in the non-capped sections rose to 25.2 % and 19.1 % in the inner and outer zones, respectively. While the increases were not major, they did show that

Figure III-15. Example of a capped pole used to assess the effects of capping on wood moisture content.

the non-capped poles were wetter. Moisture contents in non-capped pole sections 12 months after installation were 37.5% in the inner zone and 25.6% in the outer zone, while those in the same zones in capped poles averaged 14.2% and 16.4%, respectively. Clearly, capping has a marked effect on moisture content. Over time, we would expect the lower moisture content to reduce the risk of both preservative depletion and internal decay development. We will continue monitoring these pole sections over the coming seasons to establish internal moisture trends associated with the caps.

Table III-6. Wood moisture contents in Douglas-fir pole sections immediately and 4 or 12 months after installation of water shedding caps.

Treatment	Wood Moisture Content (%)					
	0 Months		4 Months		12 Months	
	inner	outer	inner	outer	inner	outer
Caps	20.1	17.2	25.2	19.1	14.2	16.4
No cap	28.4	19.7	19.0	18.3	37.5	25.6

G. Assessing the Condition of Western Redcedar and Lodgepole Pine Poles in Alberta, Canada

Remedial treatments clearly extend service life, but one of the 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.

Last year, we inspected additional poles in Alberta to determine residual chemical levels in poles. The poles were a mixture of western redcedar, lodgepole pine and western larch that had been treated with penta, creosote or CCA. The poles had been remedially treated with a copper naphthenate based external preservative wrap, metam sodium or boron rods at various times. This past year, we completed additional sampling of poles in this utility system

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 treated zone as well as the inner and outer 25 mm of the untreated zone. The treated zones were analyzed for penta or CCA by x-ray fluorescence spectroscopy. The non-preservative treated segments from fumigant treated poles were placed into tubes which were shipped back to OSU. Upon arrival, the tubes 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 fluoride, boron or copper depending upon the remedial treatment. Any remaining wood was cultured for the presence of decay fungi. Although fungi grew from many of the cores, none were identified as decay fungi.

At total of 44 poles were inspected (Table III-7). Two poles were creosote treated, six were treated with CCA and the remainder were treated with pentachlorophenol. Twenty one of the penta poles were lodgepole pine, while the remainder were western redcedar. Both of the creosote poles were western redcedar, as were two of the CCA treated poles. The poles ranged from Class 1 to 7, but the vast majority of poles were Class 5 and 35 feet long. The poles had been installed between 1958 and 2004.

All of the penta and creosote treated poles had been remedially treated with metam sodium. The CCA poles had received no remedial treatment. Nine of the penta treated poles (7 WRC/2 LPP) had been externally treated with CuBor, five had been treated with a fluoride containing paste (all WRC), and thirteen had been treated with Cobra Wrap (9 LPP/4 WRC).

Penetration and retention analyses were only performed on nine poles selected by Fortis personnel (Table III-8). Penetration in both CCA and penta treated lodgepole pine poles ranged from 20 to 62 mm, easily meeting the 19 mm required for treatment of this species. Penetration was lower in western redcedar, but this species has a very thin band of treatable sapwood. Retentions in the penta treated lodgepole pine ranged from 6.9 to 11.9 kg/m^3.

MITC levels in the poles varied quite widely, ranging from non-detectable to up to 627 ug/g of wood. MITC was not detected in either the inner or outer zones in only three poles (Table III-9). The target threshold for this treatment is 20 ug/g of wood. Using this threshold as a guideline, 12 of 38 samples from the outer zone were above the threshold, while 23 of 48 from the inner zone were above that level. There appeared to be only a slight species effect, with 6 of 23 WRC poles and 6/15 LPP achieving the threshold in both the inner and outer zones. The results suggest that the protective effect of these treatments has declined in many poles and that retreatment may be warranted in the next 2 to 3 years.

Table III-7. Characteristics of utility poles inspected in Alberta, Canada.

OSU #	IPID	Year	Species	Primary Treatment	Class	Length	Year Treated	Fumigant	Wrap	Ret
1	1011840812	1979	WRC	Penta	1	35	2005	metam sodium	CuBor	
2	1011840811	1979	WRC	Penta	2	35	2005	metam sodium	CuBor	
3	1011840614	1962	WRC	Penta	5	35	2005	metam sodium	CuBor	
4	1011840617	1962	WRC	Penta	6	35	2005	metam sodium	CuBor	
5	1011840624	1962	WRC	Penta	5	35	2005	metam sodium		
6	1011840626	1990	LPP	Penta	5	45	2005	metam sodium		Penta
7	1011840643	1992	LPP	CCA	4	40				CCA
8	1011840632	1974	WRC	Penta	5	35	2005	metam sodium	CuBor	
9	1011840634	1978	LPP	Penta	5	35	2005	metam sodium	CuBor	
10	1011840633	1978	LPP	Penta	6	35	2005	metam sodium	CuBor	
11	1011811957	1978	WRC	Penta	5	35	2005	metam sodium	CuBor	
12	1011811956	1978	WRC	Penta	5	35	2005	metam sodium	CuBor	
13	1011811960	1958	WRC	Creosote	6	35	2005	metam sodium		
14	1011811961	1958	WRC	Creosote	5	35	2005	metam sodium		
15	1011242148	1985	LPP	Penta	6	35	2005	metam sodium		Penta
16	1011242156	1985	LPP	Penta	6	35	2005	metam sodium		Penta
17	1020397580	1999	LPP	CCA	5	35				CCA
18	1017694558	2001	WRC	CCA	6	35				CCA
19	1017694555	2001	WRC	CCA	5	35				CCA
20	1020222779	2004	LPP	CCA	5	40				CCA
21	1011570906	1963	LPP	Penta	5	35	04F/05W	metam sodium	Cobra	
22	1011570907	1963	LPP	Penta	5	35	04F/05W	metam sodium	Cobra	
23	1011570908	1963	LPP	Penta	5	35	04F/05W	metam sodium	Cobra	
24	1011570911	1963	LPP	Penta	5	35	2004	metam sodium		
25	1011570924	1973	LPP	Penta			04F/05W	metam sodium	Cobra	
26	1011570927	1963	LPP	Penta	5	35	04F/05W	metam sodium	Cobra	
27	1011570928	1963	LPP	Penta	5	35	04F/05W	metam sodium	Cobra	
28	1011570940	1963	LPP	Penta	5	35	04F/05W	metam sodium	Cobra	
29	1012012417	1965	LPP	Penta	5	35	04F/05W	metam sodium	Cobra	
30	1012012418	1967	WRC	Penta	5	35	04F/05W	metam sodium	Cobra	
31	1012012419	1967	WRC	Penta	5	35	2004	metam sodium		
32	1012012420	1967	WRC	Penta	5	35	2004	metam sodium		
33	1011857569	1984	WRC	Penta	4	40	2004	metam sodium		
34	1011570941	1963	LPP	Penta	5	35	04F/05W	metam sodium	Cobra	
35	1012005632	1988	WRC	Penta	6	35	2004	metam sodium		
36	1012005631	1963	WRC	Penta	5	35	04F/05W	metam sodium	Cobra	
37	1012012395	1992	LPP	CCA	5	35				CCA
38	1012012421	1968	WRC	Penta	5	35	04F/05W	metam sodium	Cobra	
39	1012012426	1980	WRC	Penta	5	35	04F/05W	metam sodium	Cobra	
40	1011984430	1977	WRC	Penta	5	35	2007	metam sodium	Fluoride	
41	1011984428	1962	WRC	Penta	5	35	2007	metam sodium	Fluoride	
42	1011984432	1977	WRC	Penta	7	35	2007	metam sodium	Fluoride	
43	1011689120	1977	WRC	Penta	5	35	2007	metam sodium	Fluoride	
44	1011689121	1977	WRC	Penta	5	35	2007	metam sodium	Fluoride	

Table III-8. Preservative penetration and retention in selected lodgepole pine and western redcedar poles.

OSU #	IPID	Year	Species	Primary Treatment	Class	Length	Penetration (mm)[a]		Primary treatment Retention (Kg/m^3)[b]
							average	std dev	
7	1011840643	1992	LPP	CCA	4	40	27	(4)	10.54
17	1020397580	1999	LPP	CCA	5	35	23	(3)	12.43
20	1020222779	2004	LPP	CCA	5	40	49	(10)	9.86
37	1012012395	1992	LPP	CCA	5	35	20	(1)	6.72
18	1017694558	2001	WRC	CCA	6	35	7	(2)	2.21
19	1017694555	2001	WRC	CCA	5	35	12	(2)	6.61
6	1011840626	1990	LPP	Penta	5	45	62	(16)	6.90
15	1011242148	1985	LPP	Penta	6	35	42	(4)	9.34
16	1011242156	1985	LPP	Penta	6	35	53	(5)	11.86

[a]Average of six cores. [b]Combined analysis of six cores. Lodgepole pine assay zone 2.5-19 mm. Western redcedar assay zone 0-13 mm.

Table III-9. Residual MITC in lodgepole pine and western redcedar poles fumigated with metam sodium in 2004 or 2005.

OSU #	IPID	Year	Species	Primary Treatment	Class	Length	Year Treated	MITC (ug/g oven dry wood)[a]	
								outer 2.5 cm	inner 2.5 cm
21	1011570906	1963	LPP	Penta	5	35	2004	0.0	14.2
22	1011570907	1963	LPP	Penta	5	35	2004	13.0	**35.2**
23	1011570908	1963	LPP	Penta	5	35	2004	9.9	12.7
24	1011570911	1963	LPP	Penta	5	35	2004	**23.9**	**38.5**
25	1011570924	1973	LPP	Penta			2004	**24.3**	**34.9**
26	1011570927	1963	LPP	Penta	5	35	2004	2.3	10.0
27	1011570928	1963	LPP	Penta	5	35	2004	0.0	7.5
28	1011570940	1963	LPP	Penta	5	35	2004	0.0	6.1
29	1012012417	1965	LPP	Penta	5	35	2004	2.6	6.9
30	1012012418	1967	WRC	Penta	5	35	2004	0.0	0.0
31	1012012419	1967	WRC	Penta	5	35	2004	0.0	0.0
32	1012012420	1967	WRC	Penta	5	35	2004	0.0	0.0
33	1011857569	1984	WRC	Penta	4	40	2004	0.0	15.2
34	1011570941	1963	LPP	Penta	5	35	2004	0.0	16.3
35	1012005632	1988	WRC	Penta	6	35	2004	9.7	12.0
36	1012005631	1963	WRC	Penta	5	35	2004	**22.7**	**24.3**
38	1012012421	1968	WRC	Penta	5	35	2004	3.0	16.8
39	1012012426	1980	WRC	Penta	5	35	2004	7.7	**54.7**
40	1011984430	1977	WRC	Penta	5	35	2004	14.4	**67.7**
41	1011984428	1962	WRC	Penta	5	35	2004	13.0	**23.1**
42	1011984432	1977	WRC	Penta	7	35	2004	8.8	**75.4**
43	1011689120	1977	WRC	Penta	5	35	2004	0.0	**67.9**
44	1011689121	1977	WRC	Penta	5	35	2004	0.0	**38.6**
1	1011840812	1979	WRC	Penta	1	35	2005	18.2	**27.2**
2	1011840811	1979	WRC	Penta	2	35	2005	**50.8**	**57.6**
3	1011840614	1962	WRC	Penta	5	35	2005	**39.1**	**90.8**
4	1011840617	1962	WRC	Penta	6	35	2005	6.3	10.5
5	1011840624	1962	WRC	Penta	5	35	2005	8.0	**33.2**
6	1011840626	1990	LPP	Penta	5	45	2005	**101.4**	**627.1**
8	1011840632	1974	WRC	Penta	5	35	2005	19.5	**33.1**
9	1011840634	1978	LPP	Penta	5	35	2005	4.2	**93.4**
10	1011840633	1978	LPP	Penta	6	35	2005	**25.5**	**40.8**
11	1011811957	1978	WRC	Penta	5	35	2005	**24.3**	**75.7**
12	1011811956	1978	WRC	Penta	5	35	2005	17.5	18.2
13	1011811960	1958	WRC	Creosote	6	35	2005	**53.1**	**48.9**
14	1011811961	1958	WRC	Creosote	5	35	2005	**30.5**	**66.4**
15	1011242148	1985	LPP	Penta	6	35	2005	**77.6**	**84.6**
16	1011242156	1985	LPP	Penta	6	35	2005	**134.3**	**68.0**

[a]Bold values are above the fungitoxic threshold of 20 ug/g

Boron analyses of wood from poles receiving CuBor paste were performed on composite materials collected from three poles in order to have enough material for the assay. Boron levels generally followed a downward gradient from the surface inward (Table III-10). None of the levels were above the threshold for boron for soil contract at this time.

Copper analyses are still underway and will be presented in the next annual report.

Table III-10. Residual boron levels in western redcedar and lodgepole pine poles remedially treated with CuBor.

Pole #	Boron Content (kg/m BAE^3)[a]				
	0-6 mm	6-13 mm	13-25 mm	25-50 mm	50-75 mm
1, 2, 8	0.238	0.184	0.176	0.062	0.046
3, 4 ,9	0.451	0.265	0.275	0.204	0.097
10, 11, 12	0.177	0.172	0.112	0.103	0.057

[a]Values represent means of composited materials from the three poles.

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Objective IV

PERFORMANCE OF EXTERNAL GROUNDLINE PRESERVATIVE SYSTEMS

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

For many years, the pastes used for this purpose incorporated a diverse mixture of chemicals including pentachlorophenol, potassium dichromate, creosote, fluoride and an array of insecticides. The 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 had declined to the point where they could 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/Wolman Wrap with Cu/F/B
BASF/Wolman Wrap with Cu/B
Genics Cobra Wrap
Genics Cobra Slim (an experimental wrap)
Triangle Laboratories Biological Treatment

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

Since the time of the test installation, the Cobra Slim, which was an experimental product, has been removed from the market. The chemical has been kept in the test because it can provide useful information about the effects of the bandage material on performance; however, the material used for the backing differs with that used in the commercial system.

The poles were sampled 2, 3, 5 and 7 years after treatment by removing increment cores from selected locations below groundline. The cores were cut into two different patterns, depending on the remedial treatment chemical involved. For copper based systems, the cores from a given treatment were cut into zones corresponding to 0-6, 6-13, and 13-25 mm. These assays zones were kept nearer the surface in recognition of the limited ability of copper to move into the wood.

The samples from poles treated with systems containing either boron or fluoride were divided into zones corresponding to 0-13, 13-25, 25-50 and 50-75 mm from the surface, in recognition that these chemicals are capable of moving rather deeply into the wood with moisture. Two sets of cores were removed from poles treated with systems containing both copper and a water diffusible component. In addition, at the time of treatment and one year after treatment, wood from each pole was cultured for the presence of fungi by placing small chips cut from each pole on plates of malt extract agar and observing for evidence of fungal growth. Any fungi were examined under a microscope and identified using the appropriate keys.

Last year, we undertook a re-examination of our copper analysis procedures. The small volume of wood collected from each pole made it difficult to use x-ray fluorescence spectroscopy for copper analysis. In order to overcome this problem, we developed a procedure where we diluted our samples with untreated sawdust. We then factored this dilution factor into our copper results. We performed a preliminary trial that appeared to show that this technique produced acceptable agreement with traditional analysis of larger volumes of wood. During a discussion about the results of our Georgia field test, we decided to re-examine this premise. Fortunately, we had retained most of the sawdust samples from prior years so that we could re-analyze the diluted sawdust by XRF and then have these samples digested and analyzed by ion coupled plasma spectroscopy. The results showed that our dilution technique substantially under-estimated the amount of copper present in samples. As a result, we rewrote much of the report on the Georgia test. We also reanalyzed all of the samples for the New York test. Fortunately, we had individual pole retains of all samples except those from 5 years after treatment which had been combined for each treatment. In the re-analysis, we analyzed the diluted samples by XRF, then digested the sample and analyzed by ICP. In a separate analysis, we analyzed combined samples without dilution and then analyzed these by ICP. The latter process indicated that XRF was accurate provided we had a sufficient quantity of wood (about 2g of sawdust). In the future, we will analyze combined samples from all poles in a treatment. While this prevents us from assessing treatment variations between poles, it will allow us to provide a more accurate measure of copper levels in a given zone. We are also examining different XRF cup holders that may allow us to assess smaller volumes of wood.

Copper levels in the outer two zones of most treatments tended to be higher when the wood was analyzed by ICP, although the results were not always markedly different (Figure IV-1, 2). For example, copper levels in the outer zone of the Cobra Wrap treated poles was higher by ICP at year 2, but did not differ after that in the same zone.

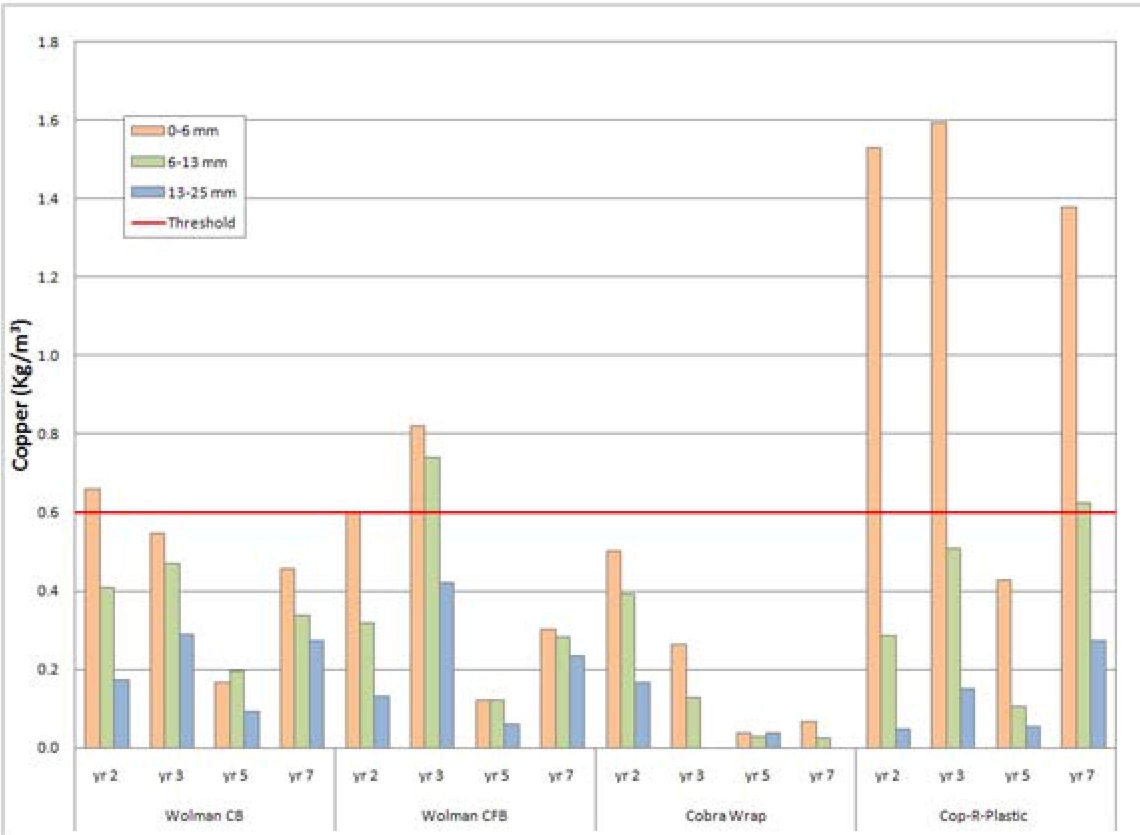


Figure IV-1. Copper levels in poles treated with various copper-based external preservative systems and sampled 2 to 7 years after treatment as determined by x-ray fluorescence spectroscopy.

The copper results for this trial all generally increased as a result of the reanalysis (Figure IV-2). As expected, copper levels were highest in the outer 6 mm, reflecting the limited water solubility of these systems and their role as external barriers. Despite the overall increases in copper levels as a result of the reanalysis, copper levels in the Wolman CB and CFB only reached the threshold in years 2 and 3, copper levels in year 7 were 2/3 of the threshold for CB and approximately one half the threshold for CFB 7 years after treatment. Copper levels in the Cobra wrap system approached, but did not reach the threshold 2 years after treatment and then steadily declined as the test progressed. Copper levels in the Cop-R-Plastic treated poles were above the threshold 2 years after treatment and have remained above that level in the outer zone at each sampling except at 5 years after treatment. Copper levels in the next zone (6 to 13 mm) inward from the surface remain surprisingly similar to those in the outer zone for most treatments, suggesting some movement inward over time. Copper levels generally declined in the innermost zone samples, but even these levels were 1/3 to 2/3 of the threshold at times during the test. The results illustrate that the copper components are moving for short distances into the wood at levels that are near or above the threshold in the outer zone.

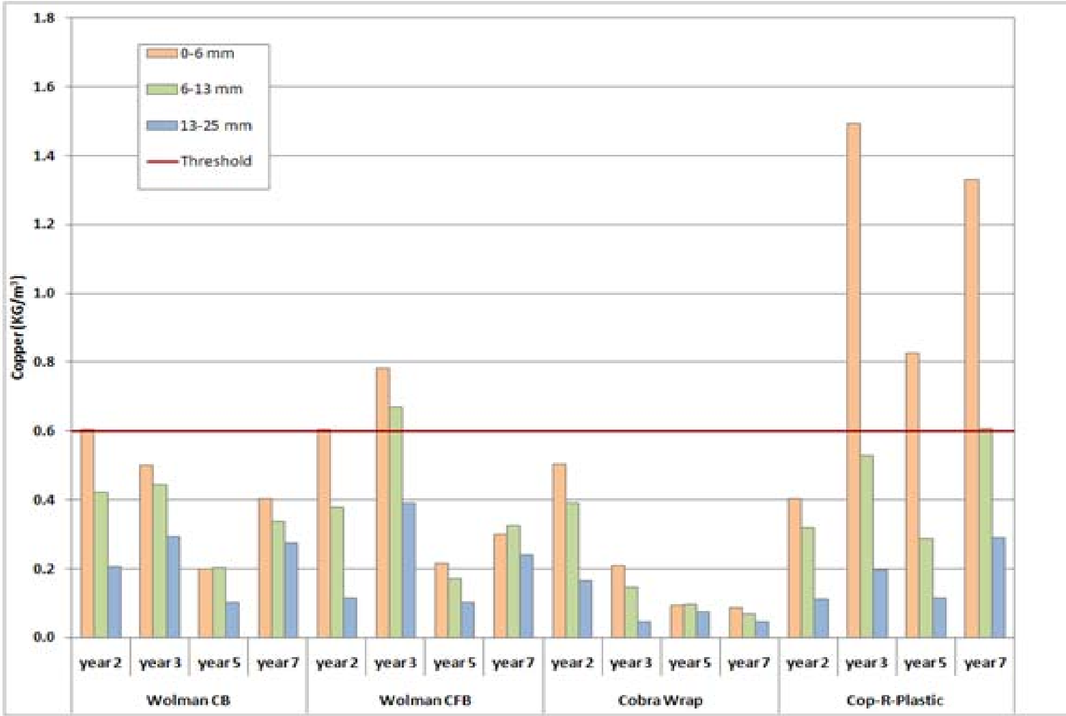


Figure IV-2. Copper levels in poles treated with various copper containing external preservative systems and sampled 2 to 7 years after treatment as determined by ICP.

Boron was a component of both Wolman systems. Boron levels in the CB system approached the threshold 2 years after application, then declined slightly at 3 years and then sharply at years 5 and 7 (Figure IV-3). Boron levels from the surface to 75 mm inward were fairly uniform reflecting the tendency for this compound to diffuse through the wood. The boron levels were well above the threshold for protection against internal fungal attack. Boron levels in CFB treated poles tended to be lower than those found in CB treated poles and did not exceed the threshold at any location or time point. As with the CB system, boron levels declined steadily between years 2 and 5, but rose slightly in year 7.

Fluoride levels tended to follow a steady gradient from the surface inward for all three systems tested (Figure IV-4). Fluoride levels were extremely low in the BASF CFB system and much higher in the Cop-R-Plastic and Pole Wrap treated poles. Levels had declined substantially in all three systems between three and five years after treatment, but as with boron, rose again after seven years. Fluoride levels in the Cop-R-Plastic and Pole Wrap treated poles had fallen below the soil contact threshold, but had risen to near or above this level after 7 years. The reasons for this increase are unclear but may reflect different sampling sites as well as changes in localized soil conditions that favored renewed movement.

One interesting performance feature of the systems evaluated was the tendency for self-contained wraps to produce lower chemical loadings. These systems have advantages in terms of ease of application and are often used by utility line crews when moving poles or setting poles in concrete. However, it is sometimes difficult to obtain the same degree of physical contact between the wood and the bandage that can be produced with a brush-on paste. The paste can be forced into checks and voids, improving the likelihood that chemical will diffuse into the wood. It is far more difficult to obtain continuous contact with the pole using a bandage, although the soil surrounding the structure should eventually exert pressure that brings the preservative in contact with the pole surface. Both systems have their merits and utilities must weigh ease of application against total amount of chemical delivered when deciding which system to use.

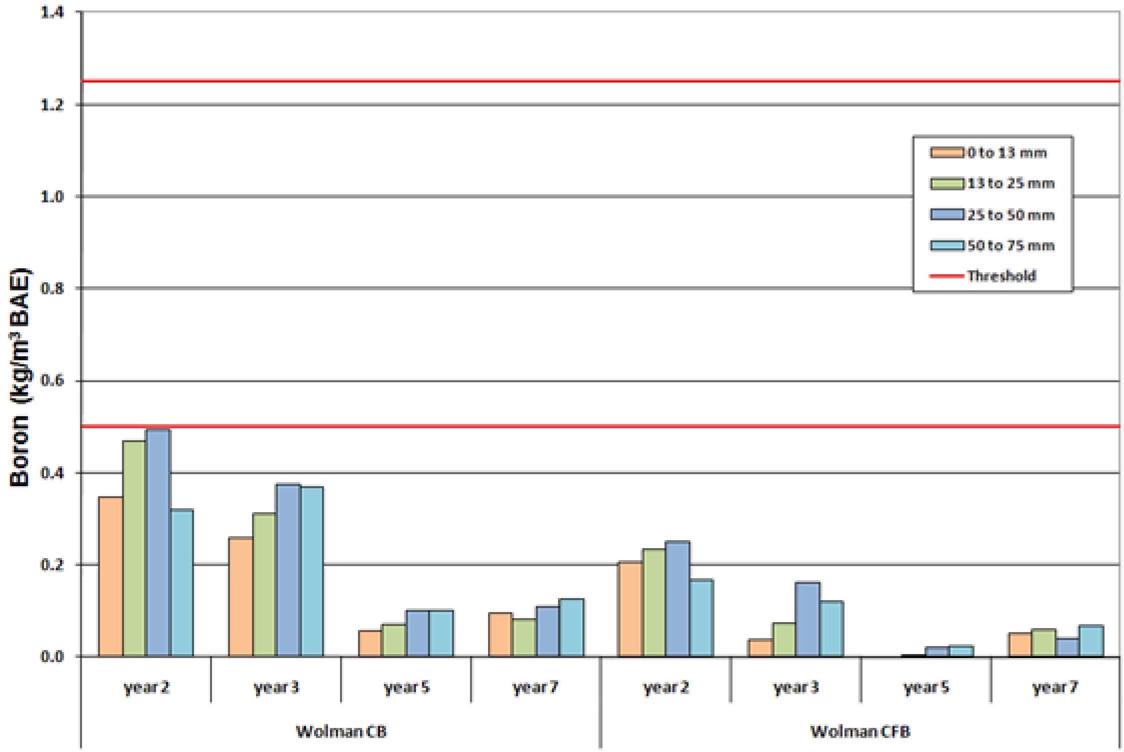


Figure IV-3. Boron levels in poles treated with boron containing external preservative systems and sampled 2 to 7 years after treatment.

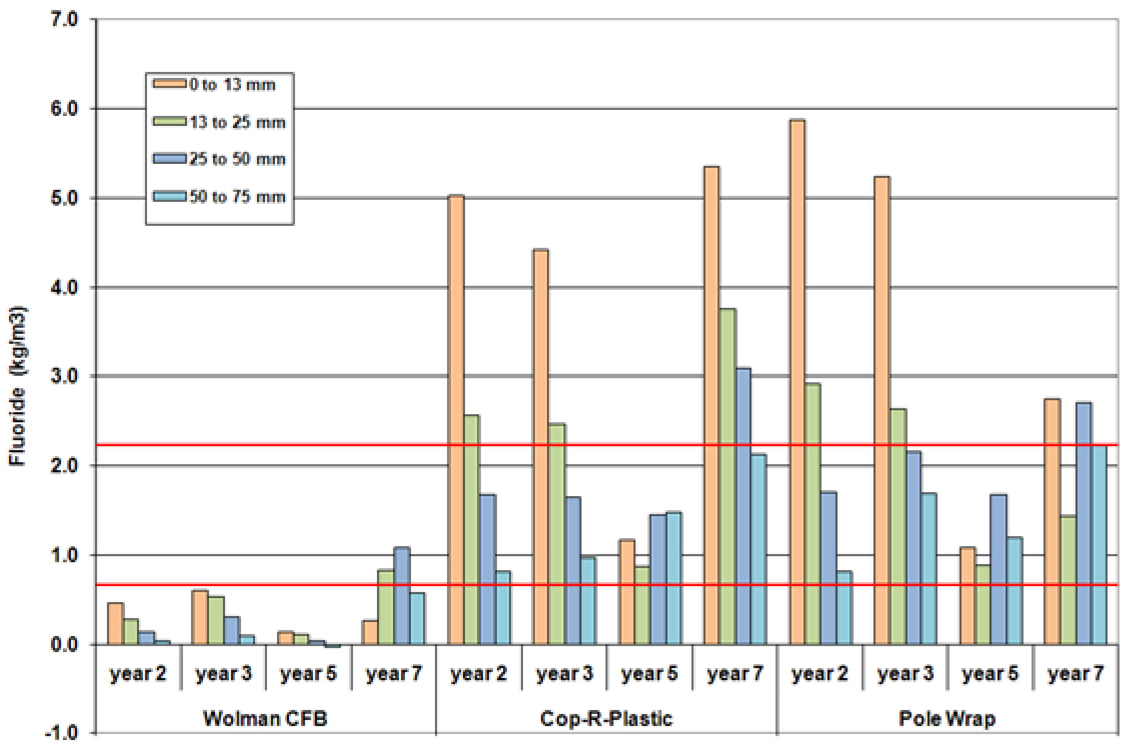


Figure IV-4 Fluoride levels in poles treated with fluoride containing external preservative systems and sampled 2 to 7 years after treatment.

The results also show that chemical levels in these poles have declined more sharply than in previous external preservative tests, including some on southern pine. Chemical levels rose after seven years in many instances.

It is important to note that the declines in chemical content do not mean that fungi will immediately begin to attack the wood. Instead, we would expect to see a continued decline in chemical levels coupled with a gradual reinvasion by fungi from the surrounding soil. This test is not scheduled to be sampled again.

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 performed under truly high decay hazards. In this section, we describe procedures used to establish a test of currently registered formulations in the Georgia Power system.

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

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

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

Proposed Treatment	Distance from Surface (mm)	Fluoride Level (kg/m^3)
Cop-R-Plastic	0-25	1.18 (1.77)
	25-50	0.46 (0.35)
	50-75	0.53 (0.36)
Pole Wrap	0-25	0.96 (0.89)
	25-50	0.54 (0.25)
	50-75	0.62 (0.28)

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

The treatments in this test were:

CuBor (paste and bandage)
CuRap 20 (paste and bandage)
Cobra Wrap
Cop-R-Plastic
PoleWrap (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.

Application rates on a given pole were determined by weighing the container and brush applicator before and after treatment. The differences represented the amount of chemical applied to a pole. Treated areas were then covered with materials recommended by the manufacturers and the soil was replaced around the pole.

Table IV-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.

This test will be sampled in November 2009. The results will be presented in the 2010 Annual Report.

E. Develop Thresholds for Commonly Used External Preservative Systems

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

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

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

We have not planned any additional tests at this time, although we continue to seek improved methods for assessing thresholds.

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).

Three years ago, 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 4.0 kg/m^3 continue to provide excellent protection after 232 months, while the conditions of the stakes treated to the lower retentions continued to decline this past year. Stakes treated to the two lowest retentions have declined below a 6.0 rating suggesting that decay has begun to affect the wood. Ratings for the intermediate retention declined to just above 6.0, indicating that the treatment had begun to lose some of its efficacy.

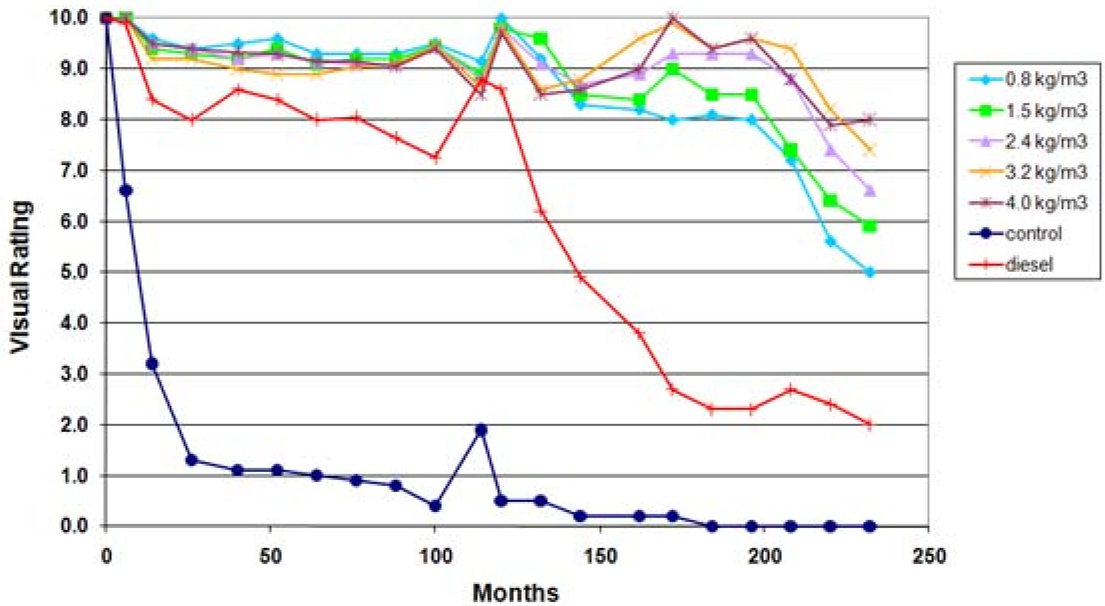


Figure V-1. Condition of freshly sawn western redcedar sapwood stakes treated with selected retentions of copper naphthenate in diesel oil and exposed in a soil bed for 232 months.

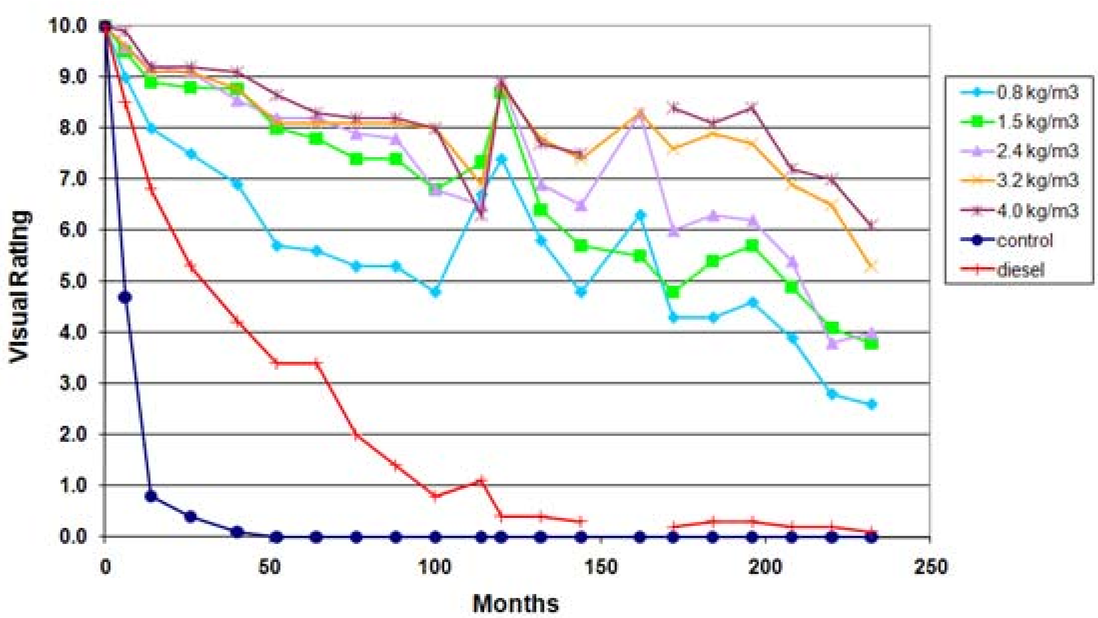


Figure V-2. Condition of weathered western redcedar sapwood stakes treated with selected retentions of copper naphthenate in diesel oil and exposed in a soil bed for 232 months.

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 below 4.0 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 between 5.0 and 6.0 and had experienced 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

No additional copper naphthenate treated poles were examined this past year. We will continue to seek out older poles treated with this chemical in order to develop a more complete performance data-base.

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 and Capture 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.

Over the past 4 years we have assessed the potential for preservative migration from penta treated Douglas-fir poles (Figure VI-1). The results have shown that penta is present in runoff water at fairly steady rates (Figure VI-2). In addition, we have attempted to develop predictive data concerning the amount of chemical that might move into soil beneath poles stored in various configurations (Figures VI-3, 4; Tables VI-1-3). Finally, we have explored the potential for developing simple methods for sorbing penta from pole runoff. We have assessed natural products such as kenaf and wood particles and found that wood particles are an excellent medium for capturing penta in runoff (Figure VI-5). The results have not yet been translated to field practical systems; however, some utilities have expressed interest in using commercially available barriers for placement under stored poles but there is little data on the ability of these systems to capture either the oil or the penta.

a.

b.

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.

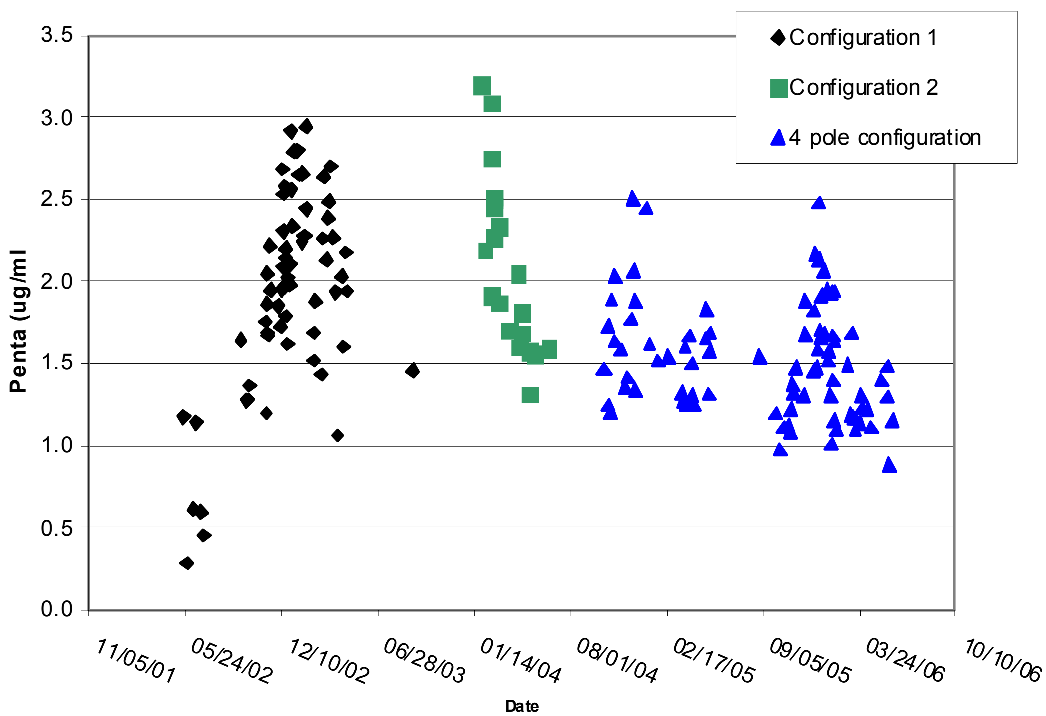


Figure VI-2. Penta concentrations as a function of sampling date in leachate collected from penta treated Douglas-fir poles following rainfall events over a 4.5 year exposure period showing data for three stacking configurations of poles.

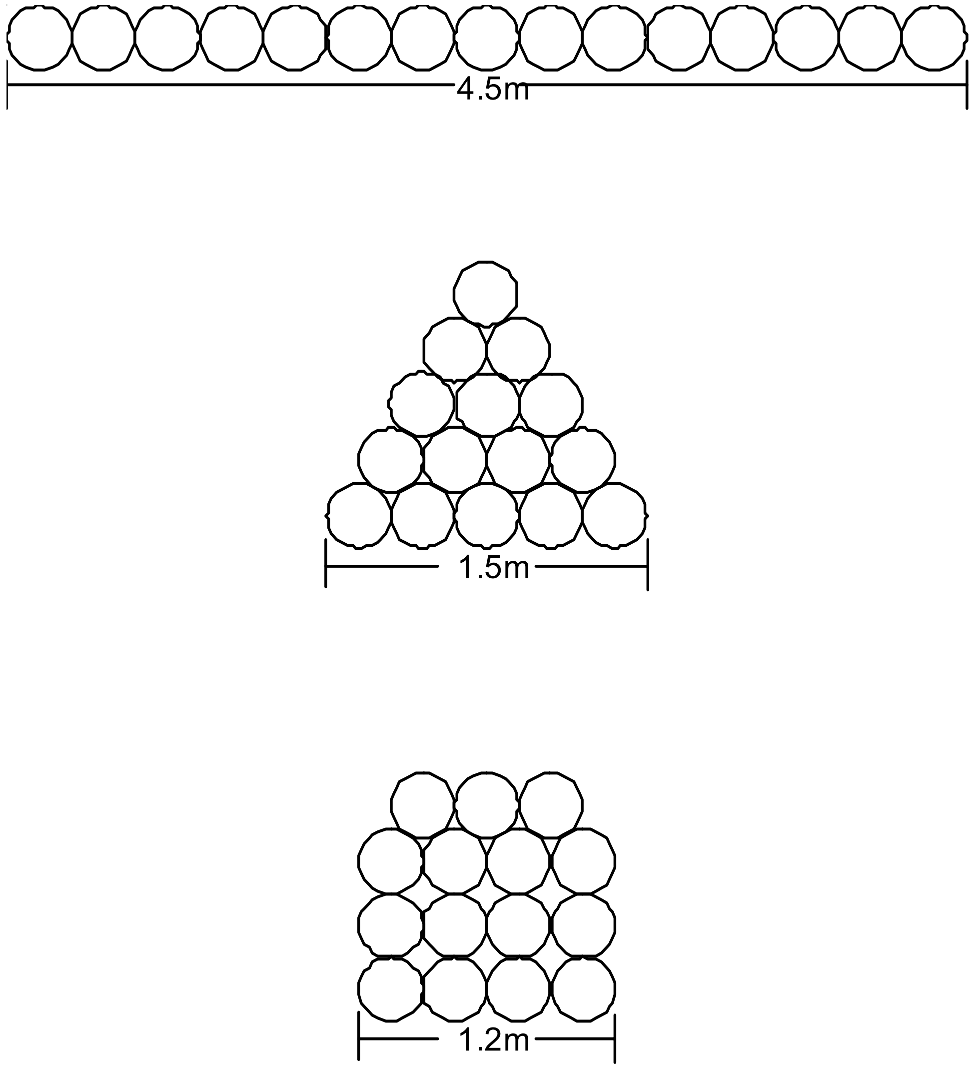


Figure VI-3. Configurations of 15 Class 4 forty foot long poles used to model predicted penta concentrations in soil beneath the poles as a result of rainwater runoff. Poles were configured as 15 individual poles, poles in a triangular stack and poles in four courses with stickers in between each course.

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

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.			

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.						

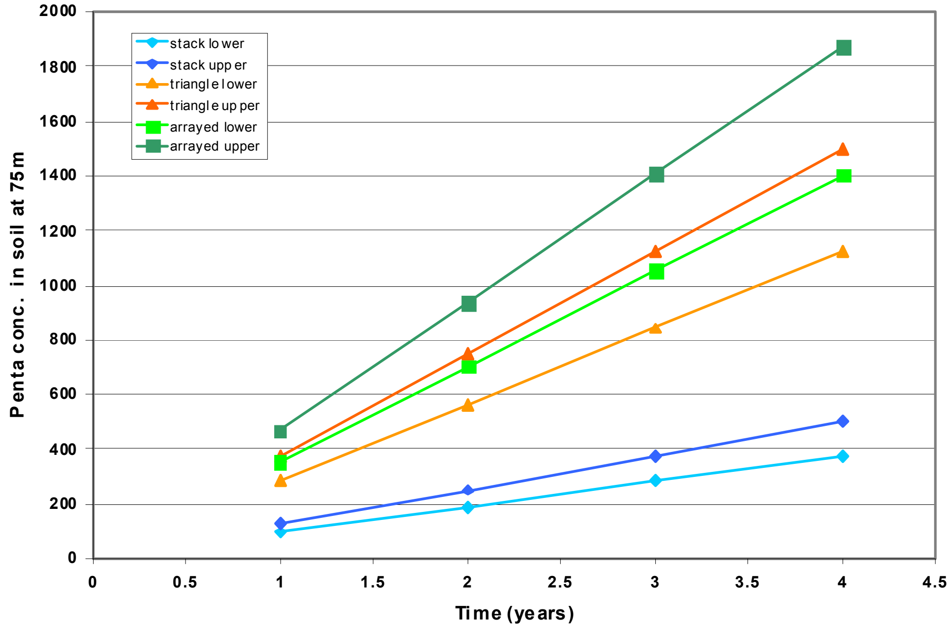


Figure VI-4. Predicted penta concentrations over a 3 year period in soils beneath poles stored in three configurations that varied total area exposed to rainfall.

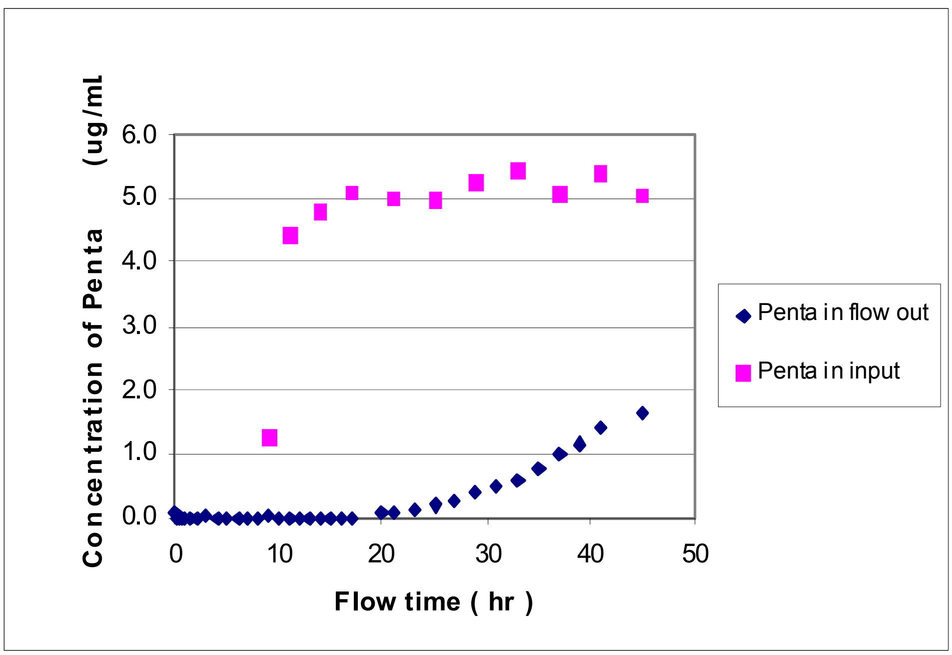


Figure VI-5. Pentachlorophenol content of water before and after passing through a wood particle packed column. Column flow rate was 1.8 mL/minute.

We undertook the following project to help develop data to assist a coop member in identifying the most suitable barrier for storing poles on a major line reconstruction project. Barrier systems were supplied by Bonneville Power Administration (Figure VI-6). The first was a woven mat material. The second was a three part system consisting of the same woven mat, a layer of another woven material and an impermeable layer. The third consisted of a landscape fabric, a woven mat and a clear plastic film barrier. The three materials were tested for their ability to sorb whole oil as well as for their potential for removing penta from runoff water.

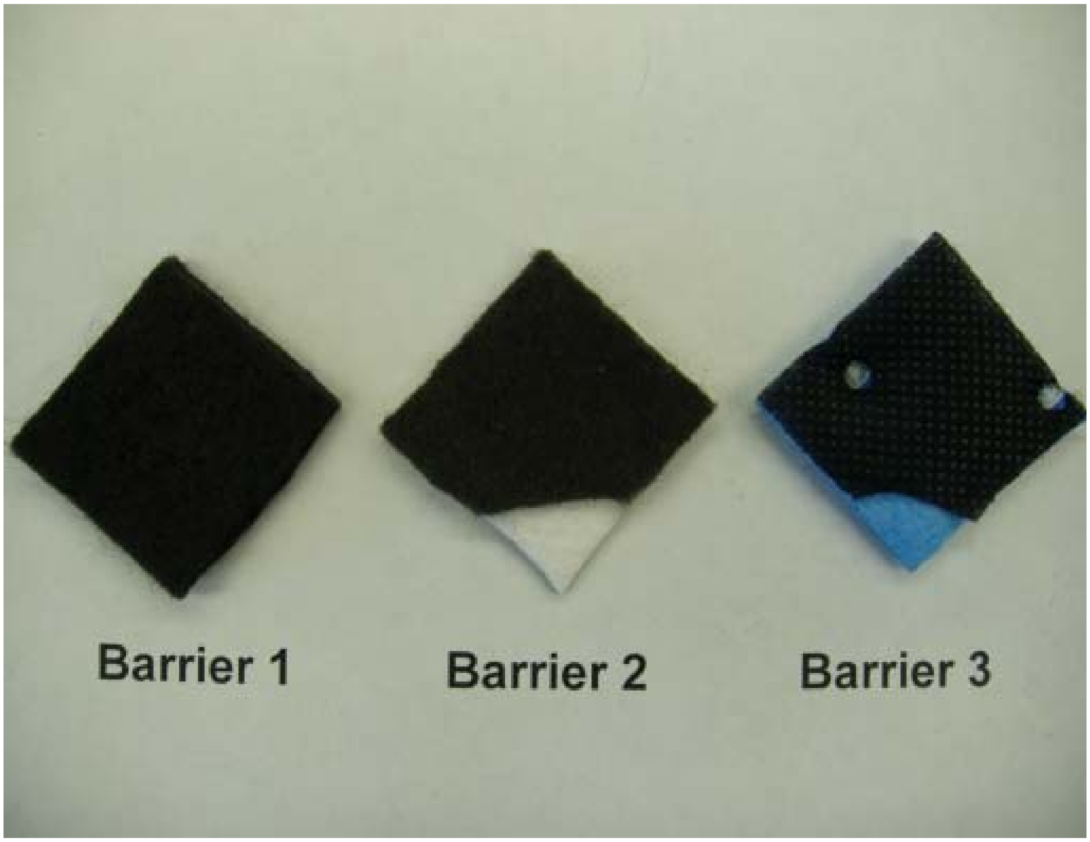


Figure VI-6. Mat materials examined for penta sorbancy.

The ability to sorb whole oil was assessed by adding oil, drop-wise, to a given section of barrier until the oil ran off the material. The weight of oil applied was then used to calculate an absorbance capacity per unit area of barrier. This capacity to sorb whole oil is probably a less useful property because proper treatment should minimize any risk of large scale oil loss from the poles.

The ability of the barriers to sorb penta from penta contaminated water was assessed by preparing a solution containing 5 ug/ml of penta. Small diameter discs (41 mm) were cut from each material. The materials were weighed then individual disks were placed into 100 ml glass beakers. A stainless steel cage was then fitted to the beaker to hold the mat in place and 40 ml of the 5 ug/ml penta solution was added. The mats were stored for 24 hours at room temperature (21-23 C) without stirring or they were incubated at the same temperature for 1 or 4 hours with stirring. The mats were then removed, allowed to drain and then weighed to determine net solution uptake. The residual solution in each beaker was then extracted to recover the penta. The difference between initial and final penta concentration was used to determine if a barrier selectively sorbed penta from the water.

Briefly the penta water samples were collected in 250 ml volumetric flasks through a 300 mL glass filtration unit. The filter was washed with 100% ethanol and then iso-octane to remove any residual penta and these rinsates were placed into the volumetric flask. The penta was then extracted from the aqueous phase by first adding 2.4 ml of 0.1 N sodium hydroxide to raise the pH to approximately 11. This converted the penta in the solution to pentachlorophenate anion. The solution was then extracted with isooctane to remove any residual petroleum residues, and then the water phase was acidified with hydrochloric acid. The pentachlorophenol was then extracted with iso-octane and the resulting mixture was analyzed for residual pentachlorophenol by high resolution gas chromatography on a Shimadzu 2010 GC equipped with a DB-5 capillary column (0.25 mm inner diameter by 30 m long).

Analytical conditions were as follows:
Injection Temp: 250 C
Column Temp: 40 C for 2 min, increase at 20 C/min to 260 C
Detector Temp: FID at 280 C
Carrier Gas: Helium (30 ml/min)

Penta was quantified by comparison with prepared standards.

Whole Oil Uptake: All three barriers sorbed considerable amounts of oil; however, the oil was easily dislodged when the material was squeezed (Table VI-4). In general, however, the amount of oil leaving the poles should be relatively small.

Table VI-4. Amounts of whole oil absorbed by three mat systems.

Barrier Type	Weight Increase (%)
Black (Barrier 1)	850
White (Barrier 2)	750
Blue (Barrier 3)	810

Solution Absorption: Barrier 1 had the greatest ability to absorb liquid from the solution, while Barrier 3 had the least (Figure VI-7). Barriers 1 and 2 had similar levels of absorbency. Interestingly, Barrier 3 is the most complex of the three systems, but the middle layer apparently lacked any ability to sorb solution.

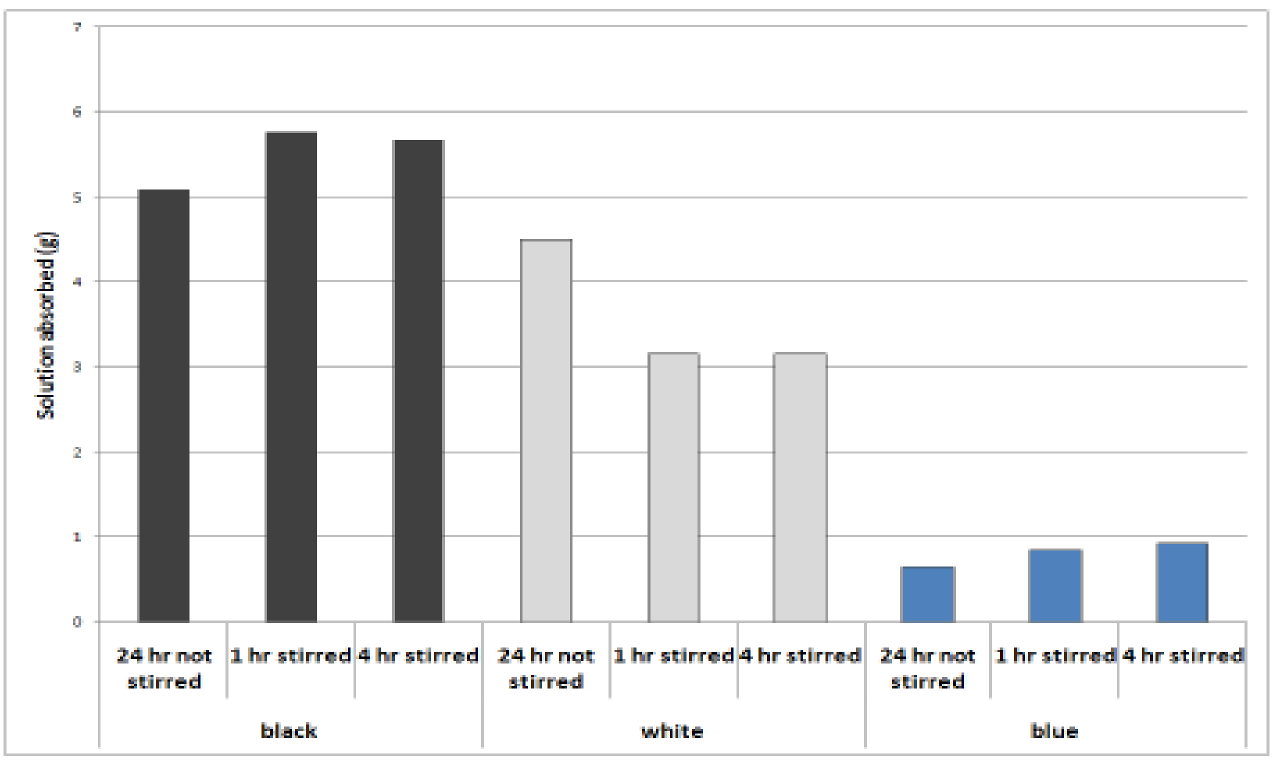


Figure VI-7. Ability of barrier mats to absorb an aqueous solution containing 5 ug/ml of pentachlorophenol.

There were only slight differences in uptake when mats were exposed for 24 hours without stirring and for shorter times with stirring. This suggests that most of the absorption occurs relatively quickly after immersion. This would be a positive attribute for limiting runoff, although Barriers 1 and 2 would have an advantage because they were able to absorb more liquid than Barrier 3.

Ability to Selectively Absorb Penta: An ideal mat system would allow water to pass through but capture any organic contaminants such as the penta. Barriers 1 and 2 both appeared to sorb penta at higher rates than they absorbed water (Figure VI-8). This selective absorption allowed Barrier 1 to remove 49.0 % of the penta and Barrier 2 to remove 31.3 % of the penta. Barrier 3 did not appear to selectively sorb penta. This material also had the lowest ability to absorb water. As a result, the overall amount of penta removed by this barrier was extremely low compared to the other two barriers, with only 18.6 % removal.

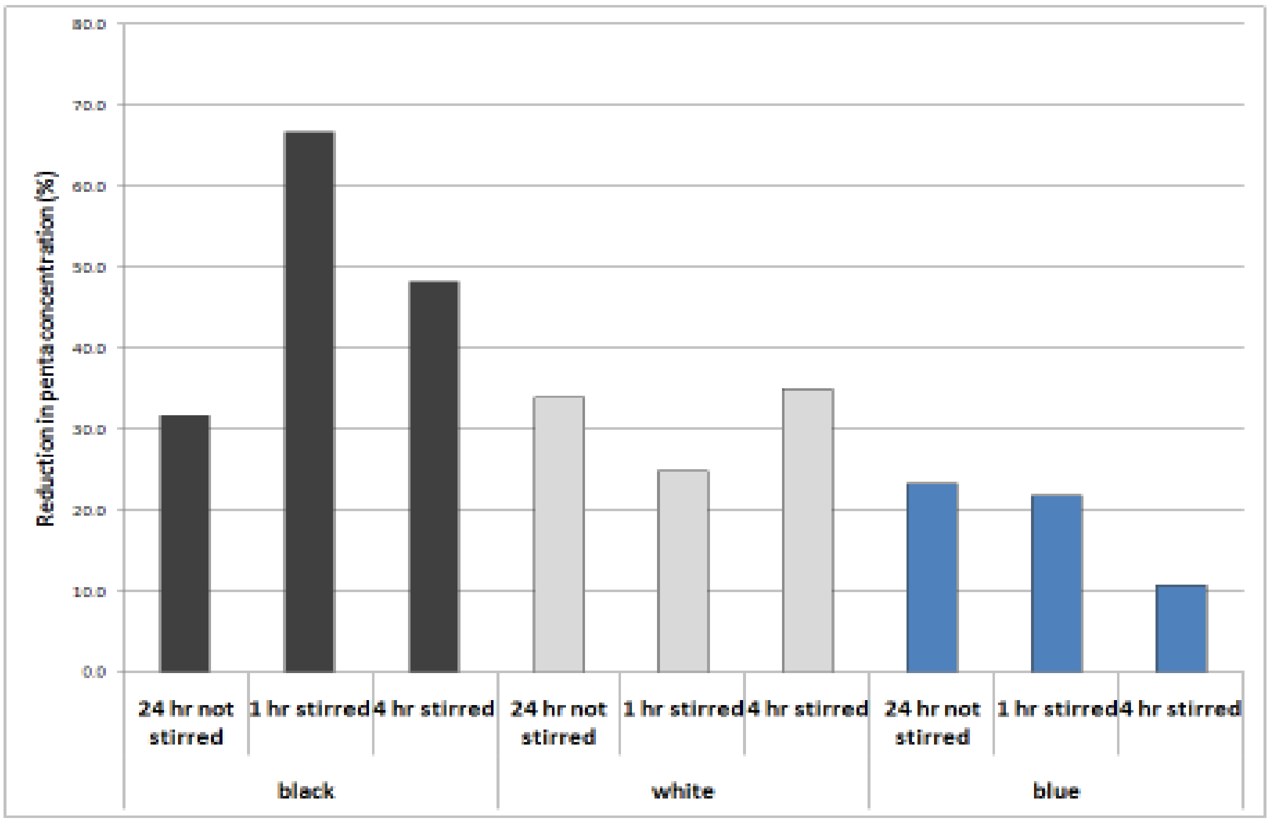


Figure VI-8. Reduction in pentachlorophenol concentration of an aqueous solution due to absorbtion by barrier mats (starting solution was 5.88 ug/ml).

Table VI-5. Relative uptakes of liquids by three different mat materials and the ability of each to selectively sorb penta from an aqueous solution.

Barrier	Solution uptake (g)	Penta in Residual Solution (%)
Black (Barrier 1)	5.51	49.0
White (Barrier 2)	3.60	31.3
Blue (Barrier 3)	0.81	18.6

[a]Values represent means of three samples. Uptakes are for a 4.1 cm disk of each material, while residual penta is based upon the original presence of 235.2 ug in 40 ml of water.

The three barriers all appear to be capable of sorbing considerable volumes of oil, although the sorbed materials were easily dislodgable. Only Barriers 1 and 2 appeared to selectively sorb penta from water, reducing the penta concentration by as much as 49%.

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

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

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

The tank was sampled periodically before the water level reached the poles. 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 (Figures VI-9 to VI-12).

Exposure was begun in the middle of the rainy season (December, 2007). Both zinc and copper levels were initially high, but then fell sharply for the remainder of the winter (Figure VI-9). After a 2 ½ month dry spell in the summer, zinc and copper levels were again high with the first rain and then declined over the winter. The first rain following the next seasonal dry spell resulted in a similar, but smaller spike in metal concentrations. Zinc levels remained somewhat elevated throughout the following winter, but copper levels fell to below 10 ppm.

There is a slight correlation between total volume of rainfall and metal concentrations (Figure VI-10), but it seems more likely that the high values in low total volumes are caused by the time of year the samples were taken. Summer rainfall tends to be brief, and a large percentage is absorbed by the wood. This may result in much higher metal concentrations from summer rain. A second factor might be degree of drying. While some drying occurs between rainfalls during the winter, the wood dries to a much greater extent during the summer. As a result, any moisture moving to the surface that carries metals is likely to deposit these elements at or near the surface where they will be available during the next rain event.

The lack of correlation between the number of days between collections and metal concentrations (Figure VI-11) can also be explained by looking at sampling season. Except for the zero samples (the first sample time), collections after dry spells tended to contain higher metal concentrations. The most notable exception to this was a sample after a 75 day interval which was low in both copper and zinc. This sample was taken in November and the previous sample in August had the highest level of copper and the second highest level of zinc. It is likely that any surface accumulation of metals from the summer had washed off in August and there had been little additional accumulation during the fall.

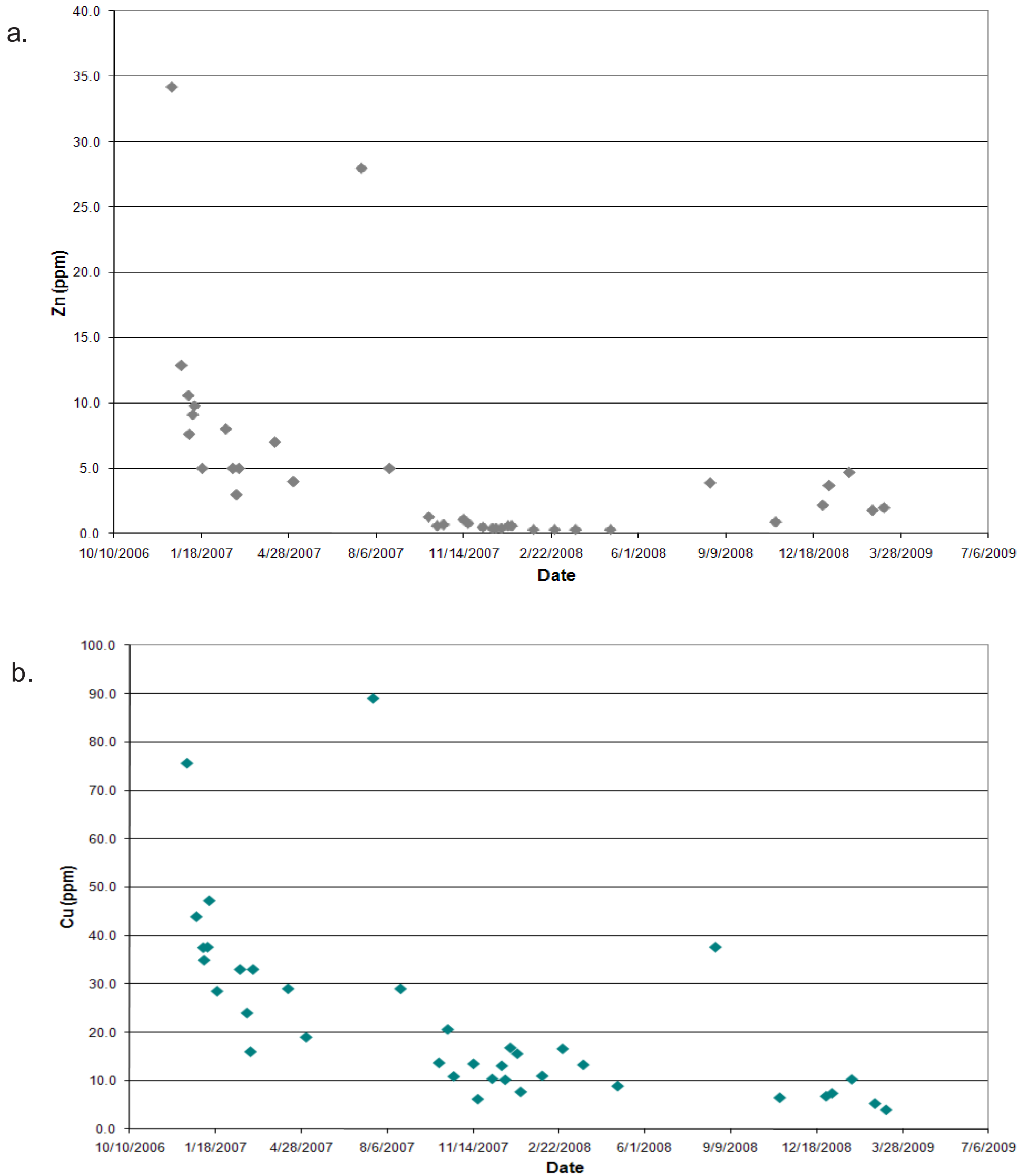
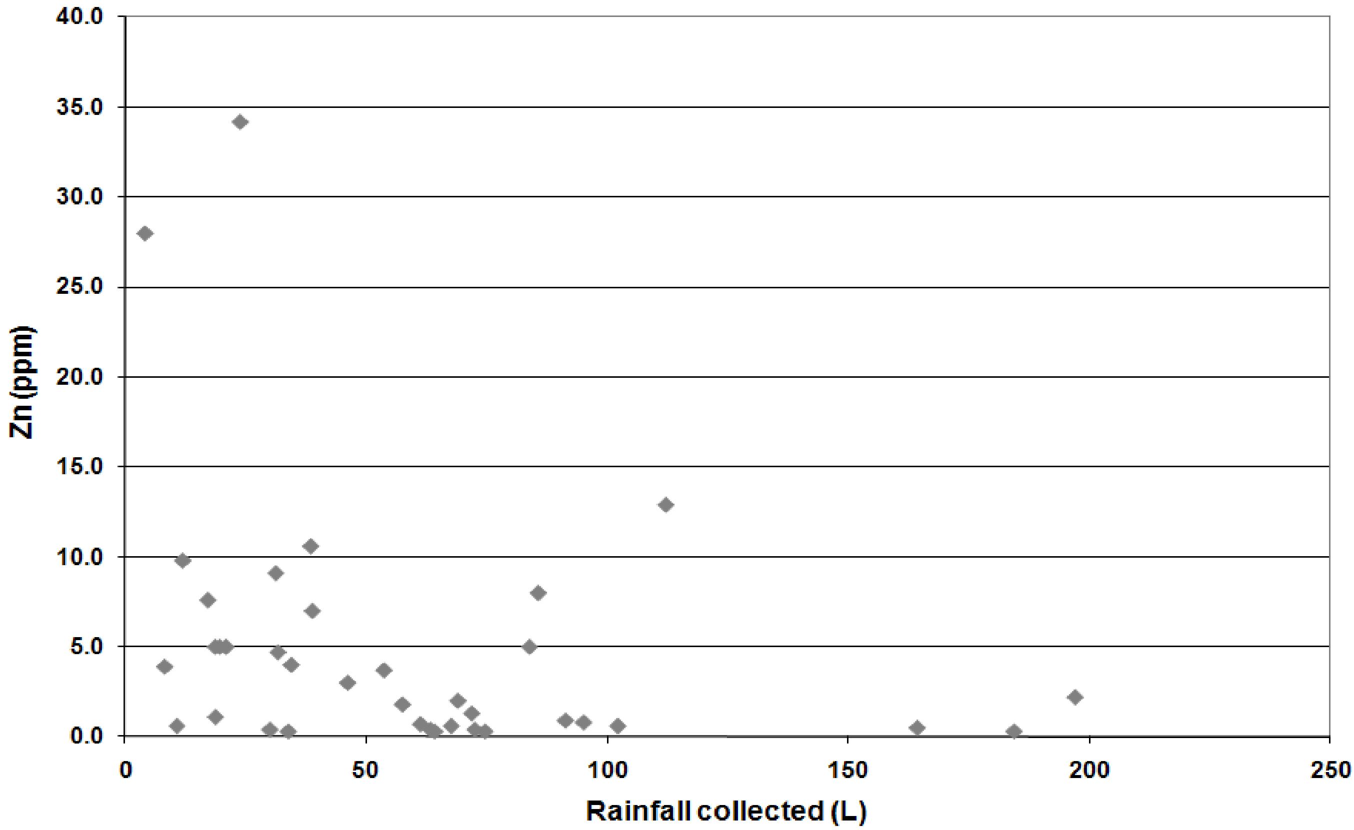


Figure VI-9. Zinc a) and copper b) levels in rainwater runoff from poles treated with ammoniacal copper zinc arsenate as a function of date of rainfall.

a.



b.

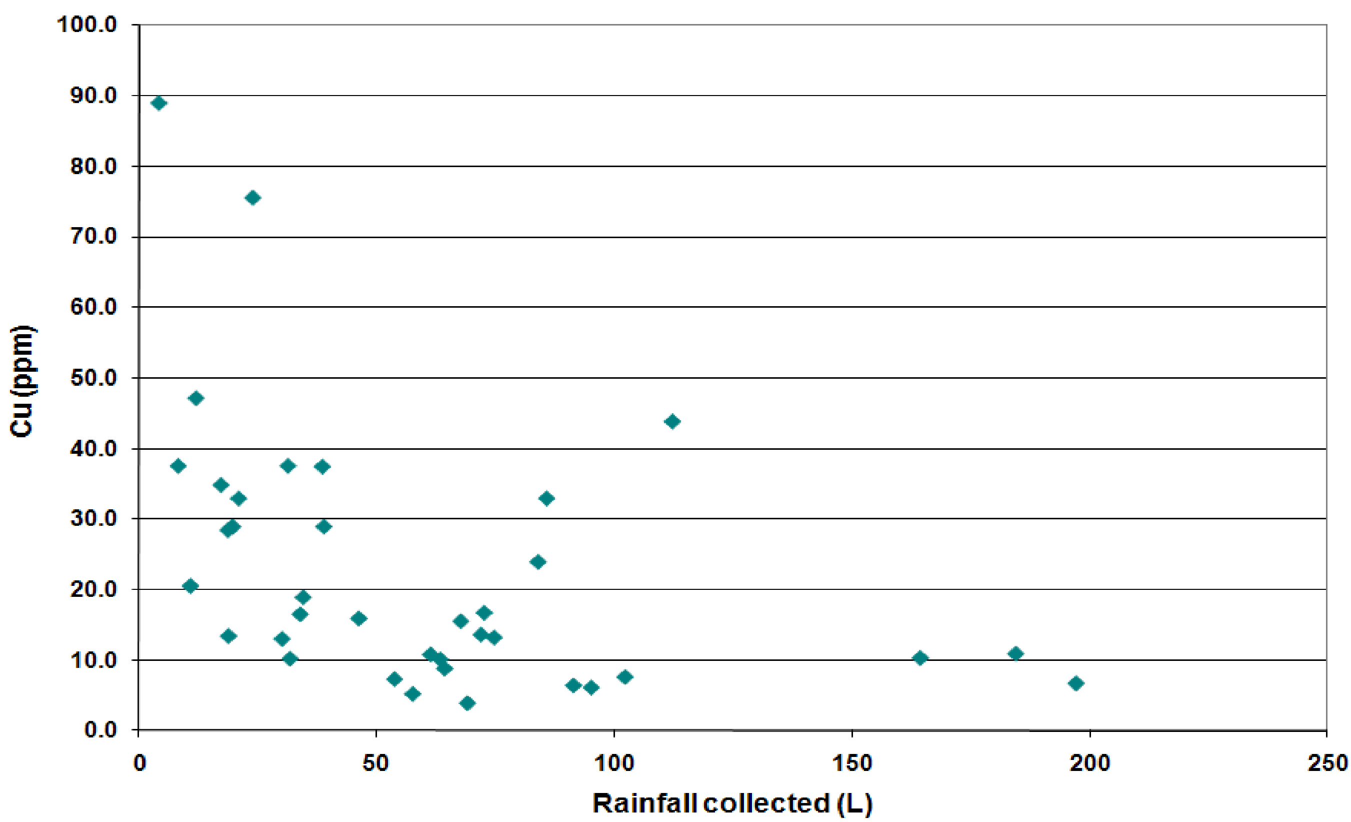
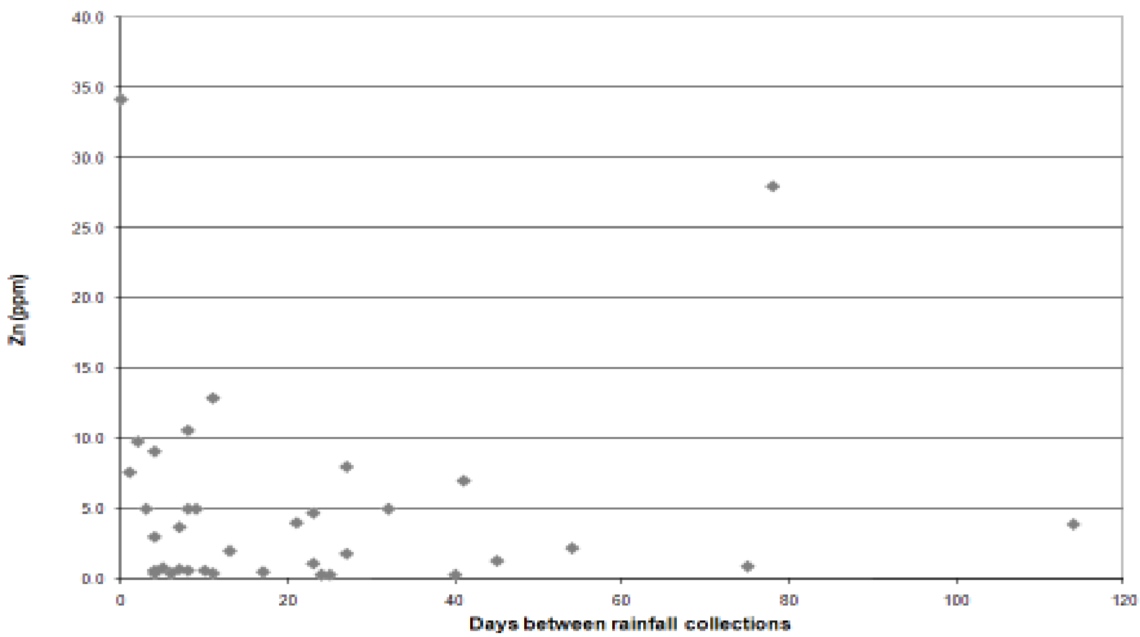


Figure VI-10. Zinc a) and copper b) levels in rainwater runoff from poles treated with ammoniacal copper zinc arsenate as a function of total rainfall collected.

The results indicate that water striking the poles sorbs a given amount of chemical, which appears to be independent of rainfall volume, but may vary by season. 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-12). 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.

a.



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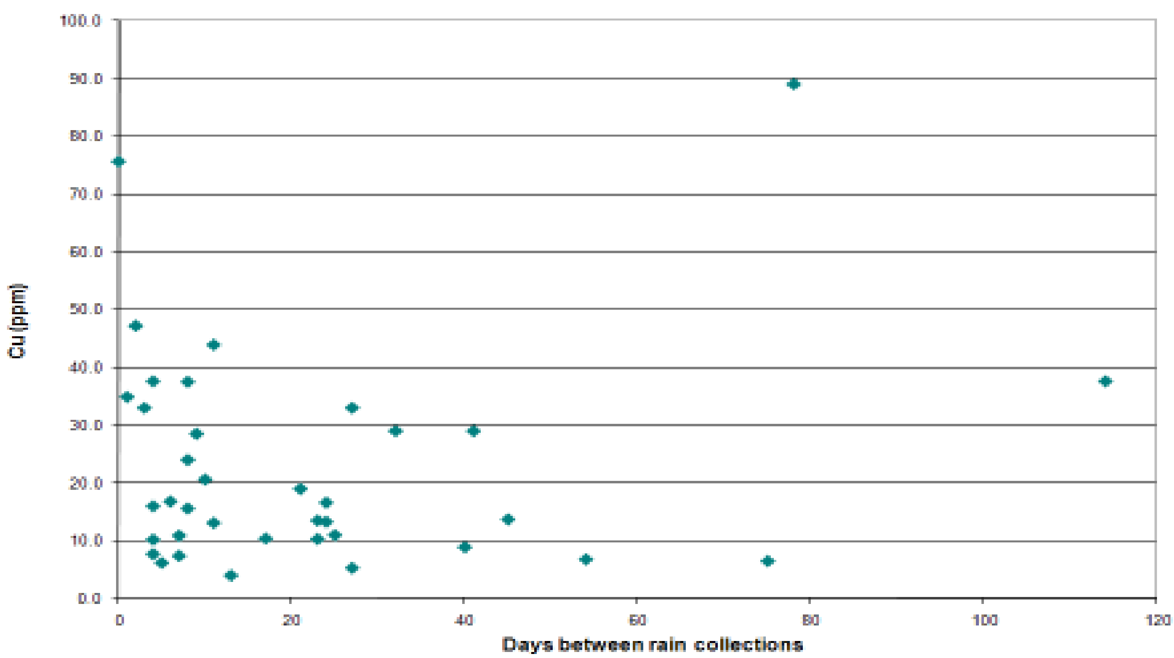
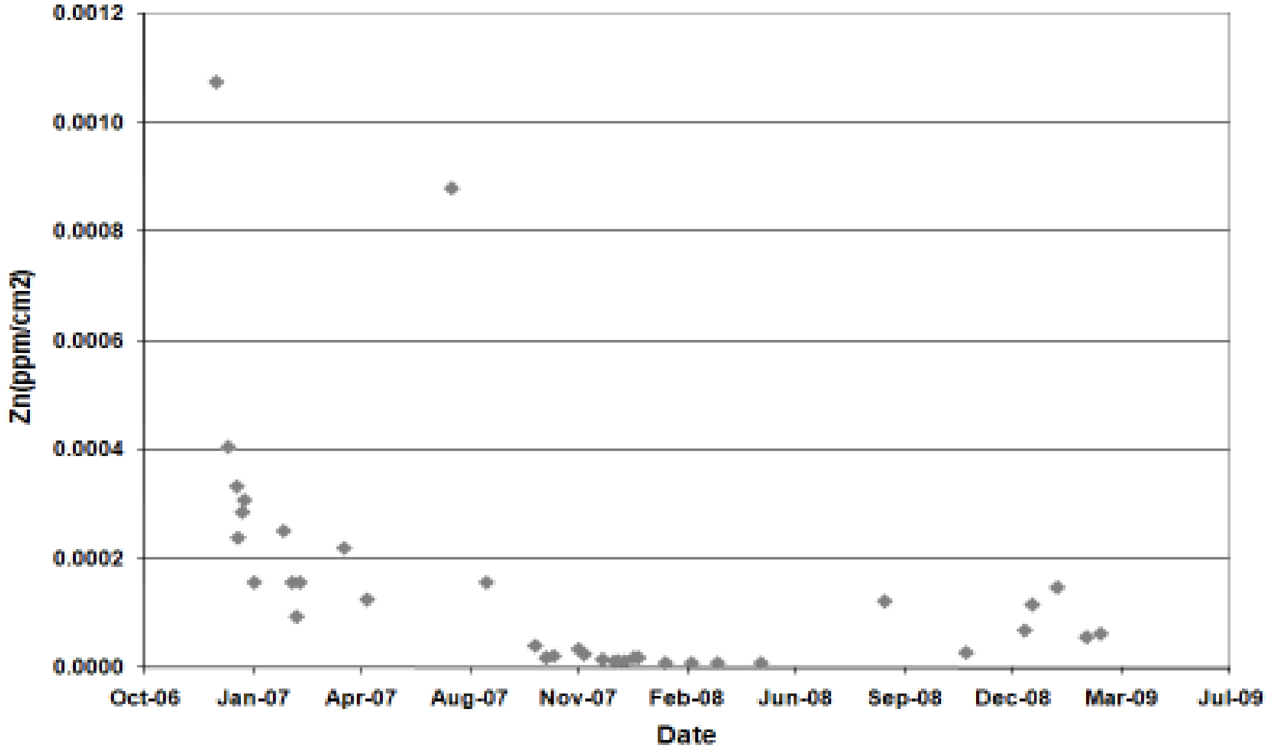


Figure VI-11. Zinc a) and copper b) levels in rainwater runoff from poles treated with ammoniacal copper zinc arsenate as a function of days between rainfall collections.

a.



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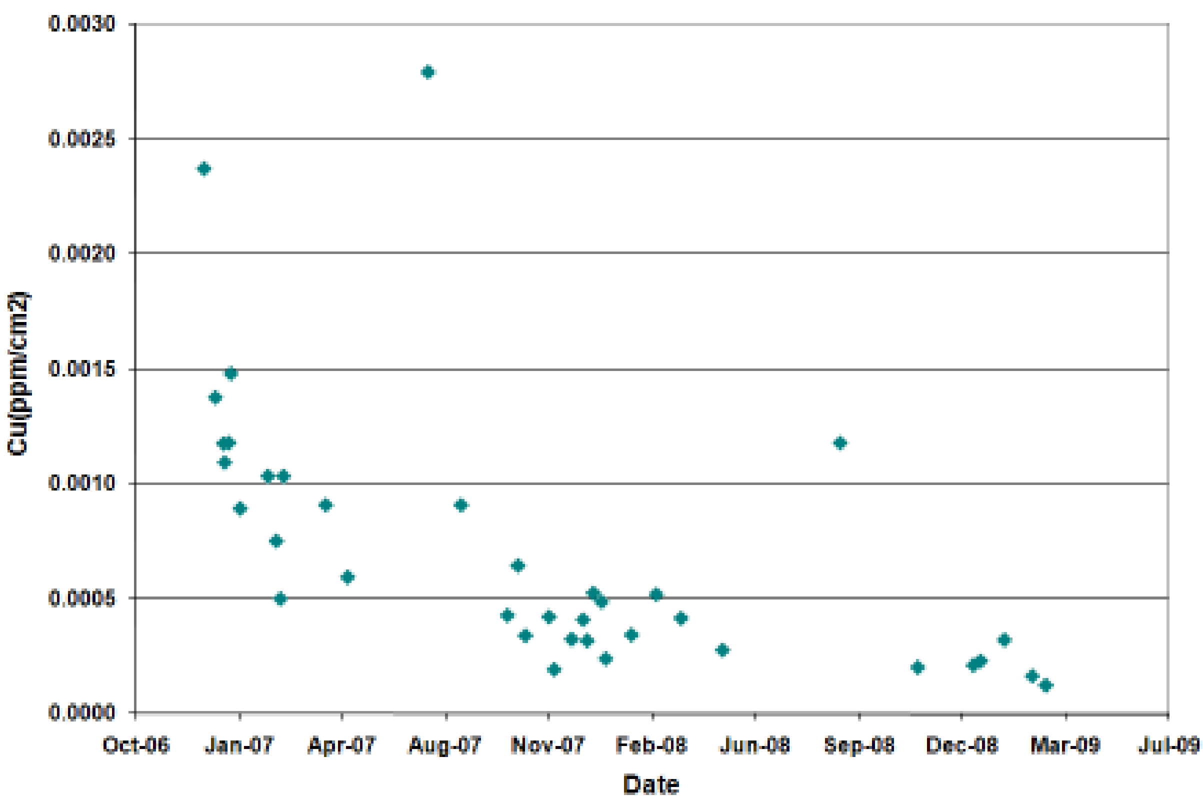

Figure VI-12. Zinc a) and copper b) levels in rainwater runoff from poles treated with ammoniacal copper zinc arsenate as a function of date of rainfall and pole surface area.

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