Oregon State University
Utility Pole Research Cooperative

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

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Fortis Alberta
Genics Inc.
Intec Services Inc.
ISK Biocides
McFarland Cascade
Pacific Wood Preserving Companies
Osmose Utility 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
Southern California Edison
Salt River Project
The Pentachlorophenol Working Group
Utility Pole Technologies Inc.
Western Wood Preservers Institute

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EXECUTIVE SUMMARY

This has been an exceptionally productive year in a number of areas. We also have been fortunate to have Pacific Gas & Electric and Brooks Manufacturing join the Coop, bringing us to 23 members. We very much appreciate the willingness of existing members to help encourage others to join the Coop.

Under Objective I, we have completed a number of long-term studies on dazomet and fused borate rods illustrating their potential for long term protection although they differ slightly in their initial chemical migration patterns. We are also exploring re-treatment options with dazomet-treated poles to better understand the potential regulatory, safety and efficacy impacts of residual material. We have evaluated the boron rod /glycol test after 10 years and find that the addition of supplemental glycol and even water had a long lasting effect on residual boron levels in the wood.

The large scale field trial of internal remedial treatments is now 30 months old. We continue to find elevated levels of fumigants and boron/fluoride in the poles; however, MITC levels in the metam sodium treatments have begun to decline. In general, the results mirror those found in our previous trials, but the large scale trial allows us to directly compare performance of the available treatments.

We have also installed an internal remedial treatment test with fewer chemicals in the Rocky Mountain Power service area to assess the performance of internal treatments in drier regions.

There was no activity under Objective II and we will discuss whether further work is needed related to field drilled bolt holes and above-ground surface protection of non-treated wood.

We have a diverse array of activities under Objective III. We have performed additional full scale bending tests on poles with various groundline boring patterns. Poles were left non-bored, radial drilled or were through-bored with holes oriented either perpendicular or parallel to the loading direction. In our initial trials, through-boring using holes up to 0.5 inches in diameter had no significant negative effect on pole flexural properties, but questions were raised about hole direction in relation to loading. In the most recent test, we loaded through-bored poles perpendicular and parallel to the hole orientation. There was a significant reduction in MOR at groundline in through-bored poles as well as in radial-drilled poles. These results contradicted earlier studies and we are still seeking an explanation for the differences.

Full scale bending tests on poles with three or six groundline inspection holes showed that drilling inspection holes had no significant negative impact on flexural properties of what would be Class 6 poles. The results indicate that the inspection process does not negatively impact overall pole MOR at groundline. Although we recommend that inspectors use the same holes for repeated inspections, the results showed that drilling a second set of holes did not adversely affect MOR.

Polyurea coated cross arms were installed in Hawaii 12 months ago. Termite tests showed that the barriers could not protect non-treated wood, while coated and non-coated penta-treated blocks remained free of termite attack. Cross arms with and without end-plates have been subjected to 12 wet/dry cycles. Checking continues to be greater on non-plated arms, illustrating the benefits of end-plates for limiting splitting in service.

A field trial of an ultrasonic test device was performed on the above-ground portions of Douglas-fir poles. While the PoleScan device was generally able to detect large voids, the current system needs to be modified for above-ground use and we plan additional trials once this has been accomplished.

The evaluation of external groundline pastes and bandages under Objective IV is continuing in Georgia. We have re-analyzed some of our previous samples because of concerns that the x-ray fluorescence measurements were inaccurate. The new analyses resulted in much higher copper levels in the 3 and 5 year samples. Fluoride levels in samples containing fluoride based pastes have begun to decline, although they are still above the threshold for fungal protection. We are in the process of re-analyzing samples to confirm these results.

We also installed a field trial of selected external preservative pastes in the Arizona Public Service/Salt River Project service territories to assess the performance of these systems under dry conditions.

External barriers have been proposed for situations where treated wood is used in sensitive environments. These systems were originally developed in South Africa to improve pole performance, but have been employed by some Pacific Northwest utilities. Field tests suggest that these barriers initially slow pole wetting and they also moderate subsequent wetting and drying. The effects of these changes on decay development are unclear, and we have installed a larger trial of more recently developed barriers to assess the effect of barriers on both moisture behavior and chemical migration from the wood.

Assessment of copper naphthenate continues under Objective V. Stake tests of copper naphthenate treated western redcedar continue to show that this treatment is performing well. A second test examining the effects of biodiesel as an additive to # 2 diesel has produced some disturbing results. Biodiesel is currently being added to #2 diesel to reduce odors. Soil block tests indicated that adding 10 to 30 % biodiesel had serious negative effects on resistance to attack by the copper tolerant fungus, *Postia placenta*. Soy, canola and recycled biodiesel were all tested and each produced a negative effect on performance. The results suggest that biodiesel should not be used as an additive in these systems with copper naphthenate.

The evaluation of metal migration from ammoniacal copper zinc arsenate (ACZA) treated pole sections is nearing completion. Metals were consistently found in rainwater runoff from the poles, but the levels steadily declined over time. The data were used to predict the amount of metal runoff from poles stacked in different configurations that presented varying surface areas exposed to direct rainfall. The results indicated that copper levels would increase by less than 2 ppm in a low rainfall climate and 4 to 6 ppm in a wetter climate over a four year period in the upper 6 inches of soil with no further migration. Normal soil copper levels average 25 ppm, indicating that the levels of copper build-up are small and would typically be even lower as the copper was diluted by the surrounding soil. The results can be used to predict the impact of pole storage.

OBJECTIVE I

DEVELOP SAFER CHEMICALS FOR CONTROLLING INTERNAL DECAY OF WOOD POLES

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

A. Develop Improved Fumigants for Control of Internal Decay

While there are a variety of methods for internal decay control used around the world, fumigants remain the most widely used systems in North America. Initially, two fumigants were registered for wood, 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. Utility Pole Research Cooperative (UPRC) research identified two alternatives, solid methylisothiocyanate (MITC) and dazomet. Both chemicals are solid at room temperature, reducing the risk of spills and simplifying cleanup of any spills that occur. MITC was commercialized as MITC-FUME, while dazomet has been labeled as Super-Fume, UltraFume and DuraFume. An important part of the development process for these systems has been continuing performance evaluations to determine when retreatment is necessary and to identify any factors that might affect performance.

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

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

1. The fungitoxic threshold of methylisothiocyanate

MITC is the presumed primary active ingredient of both metam sodium and dazomet and is also marketed in pure form as MITC-FUME. This chemical is highly effective against decay fungi and we have analyzed for MITC in all of our field tests using these fumigants in 1984. However, for many years after that, we had not identified a specific level of MITC that was effective in a pole. In order to determine that level, field test results from a number of previous tests were examined.

The fungitoxic threshold of MITC was determined by comparing isolations of decay fungi to MITC levels from the same increment core using data from a 1993 field test of dazomet with copper accelerants. Although this was completed in 2000, the data were not included in an annual report. Analysis of data from an additional four years of sampling from the same test confirmed the threshold to be 20 ug/g of wood. Data from the original MITC-FUME study at the Peavy Arboretum test site was also re-examined; the results verified the threshold level. The test was established in 1993 and sampled at 0, 2, 3, 4, 5, 7, 10, 12 and 15 years. The inner and outer 25 mm of each core were extracted and analyzed for MITC. The center section of the core was placed on malt extract agar and observed for evidence of fungal growth. The data set included 5312 MITC analyses and isolation attempts from 2660 core segments. The inner or outer segment was missing for 8 cores.

The higher, lower and average MITC levels from each core were associated with the presence or absence of a decay fungus from the same core (Fig 1-1). Over the 15 years of sampling, 43 decay fungi were isolated. Of these, 42 were from cores with MITC levels below 20 ug/g and one was isolated from a core with a low value of 40 and a high value of 221 ug/g wood. The average MITC level in cores associated with a decay fungus was 4 ug/g wood, while cores without decay fungi contained an average of 18 ug/g. The result was the same whether the higher, lower or average MITC value was used. Based upon these results, we selected 20 ug MITC/oven dried g of wood as a threshold for fungal protection.

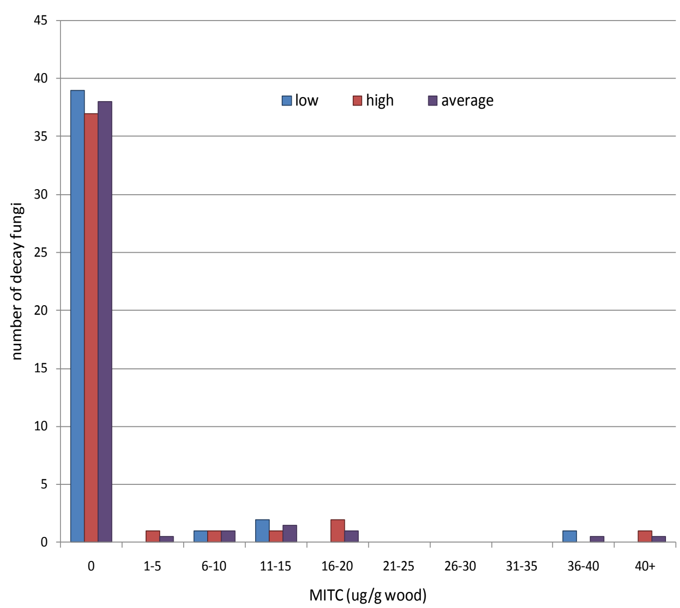
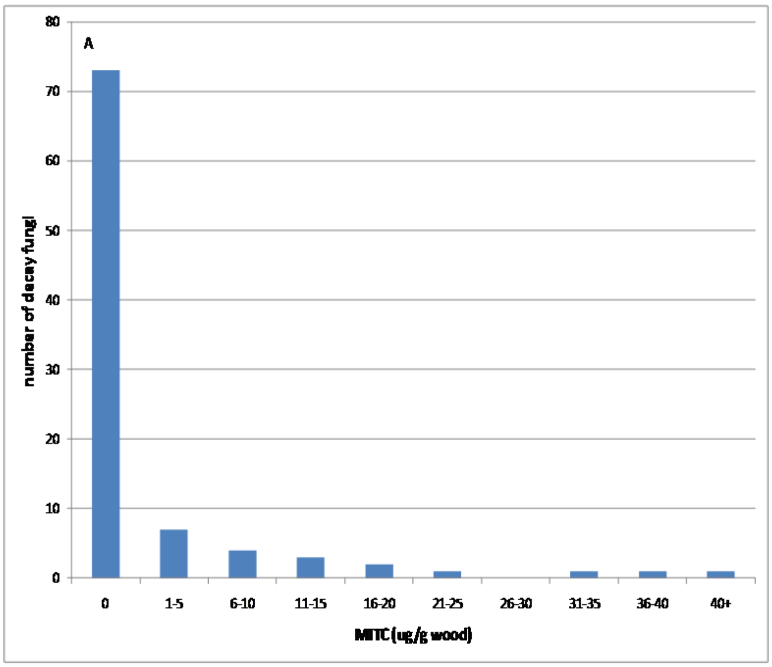


Figure I-1. High, low and average MITC values associated with decay fungi isolated from the same increment core removed from Douglas-fir poles 1 to 15 years after treatment with various MITC based internal treatments.

The proposed threshold value was verified using data from the original MITC-FUME test at the Peavy Arboretum test site. In this case only the lower of the two MITC values was used. There were 2682 isolation attempts from Douglas-fir yielding 93 decay fungi and 2420 from southern pine yielding 23 decay fungi. Decay fungi were isolated from 89 Douglas-fir cores with a lower MITC value of 20 ug/g of wood or less and from four from cores with MITC levels above the proposed threshold (Fig 1-2). Decay fungi were from 23 southern pine cores with lower MITC values over 20 ug/g of wood (Fig 1-2).

Although there were occasional isolations from wood associated with higher MITC values, the



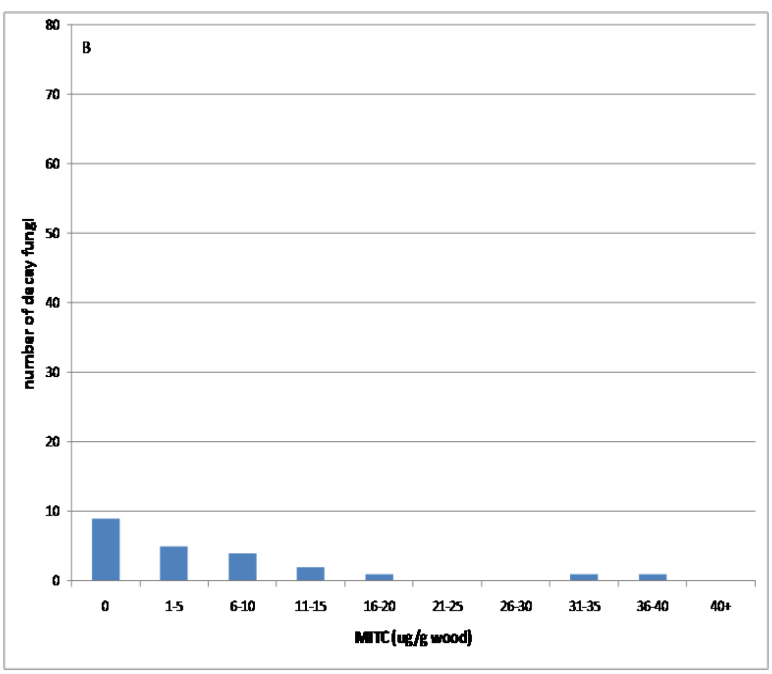


Figure I-2. Comparison between the lowest MITC value obtained from a core and the frequency of isolation of a decay fungus from A. Douglas-fir or B. southern pine poles treated with metam sodium or varying levels of MITC-FUME in the original MITC-FUME test.

threshold level of 20 ug/g of wood eliminated 95% of decay fungi. Fumigant levels in wood can vary markedly within short distances because of differences in wood permeability and moisture levels. As a result, we would expect some degree of variability in the incidence of fungi adjacent to higher chemical levels. The 20 ug/g threshold gives a reasonable degree of predictability for assessing residual protection and we have used this value to assess performance in all of our current tests.

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

MITC-FUME has been commercially available for over 14 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 for 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 5 C. The test was discontinued in 2009, although some of the tubes stored at 5 C still contained residual chemical.

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

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 1980s, the UPRC began work with dazomet, a solid, crystalline chemical that decomposes in the presence of water to produce MITC and a host of other compounds. Preliminary trials suggested that the rate of decomposition was too slow to be of use for controlling wood decay, but continuing trials suggested that this chemical might have promise, particularly because of its ease of handling. In a series of laboratory and small-scale field trials, we showed that dazomet could produce effective levels of MITC in wood over time and could continue 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 tests on transmission-sized poles. These trials were evaluated over a 15 year period, but have been discontinued because the MITC levels had declined below the detection limit at most sampling locations.

4. 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 generally used by utility personnel. One alternative to copper sulfate is copper naphthenate, which is commonly recommended for treatment of internal field damage to utility poles. There were, however, questions concerning the ability of copper naphthenate, a copper soap, to enhance decomposition in comparison with the copper salt.

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

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-3), of each core were placed into vials containing 5 ml of ethyl acetate, extracted for 48 hours at room temperature, and the resulting extracts were analyzed for residual MITC by gas chromatography using a Simadzu GC equipped with a flame photometric detector with filters specific for sulfur. MITC levels were determined by comparison with similar analyses of prepared standards. 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

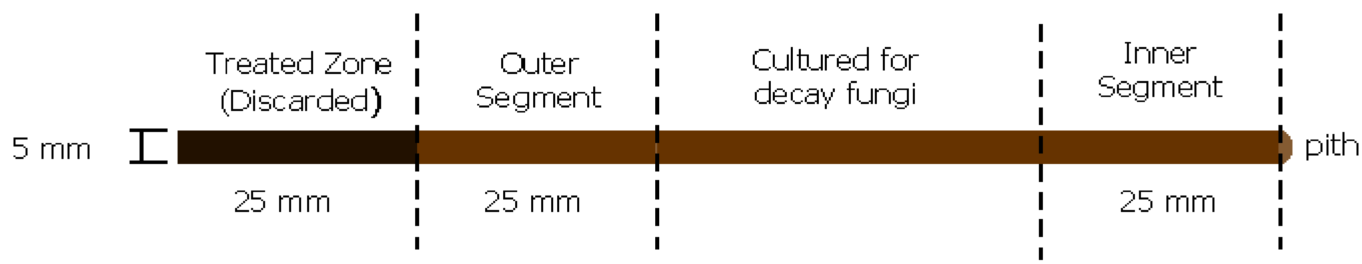


Figure I-3. Representation of increment core showing inner and outer 25 mm segments analyzed for fumigant content. The length of the segment cultured for decay fungi varies in length depending on the size of the pole.

important wood decayers.

These poles were not sampled in 2010.

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

Pentachlorophenol treated Douglas-fir pole sections (206-332 mm in diameter by 3 m long) were set to a depth of 0.6 m at the Corvallis test site. Three steeply angled holes were drilled into each pole beginning at groundline and moving upward 150 mm and around 120 degrees. The holes received either 160 g of powdered dazomet, 107 g of dazomet rod plus 100 g of copper naphthenate (2% as Cu), 160 g of dazomet rod alone, 160 g of dazomet rod amended with 100 g of copper naphthenate, 160 g of dazomet rod amended with 100 g of water, or 490 g of metam sodium. Pre-measured aliquots of the ammendments were placed into the treatment holes on top of the fumigants. Each treatment was replicated on five poles.

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

In evaluating the effectiveness of treatment, we have traditionally used a threshold for fungal protection of 20 ug of MITC/oven dried g of wood. This value is based upon an examination of previous fungal culturing and chemical analysis data from our many field trials. In general, MITC levels 1.3 m above the groundline were rarely above the threshold over the 10 year test although MITC was generally detectable at this level (Table I-2, Figures I-4 to I-9). MITC was also consistently detected 0.8 m above groundline. Levels in the outer zones at this height were also below

Table I-2. Residual MITC in Douglas-fir pole sections 1 to 10 years after treatment with metam sodium or combinations of dazomet in rod or powdered form and copper naphthenate or water.

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

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

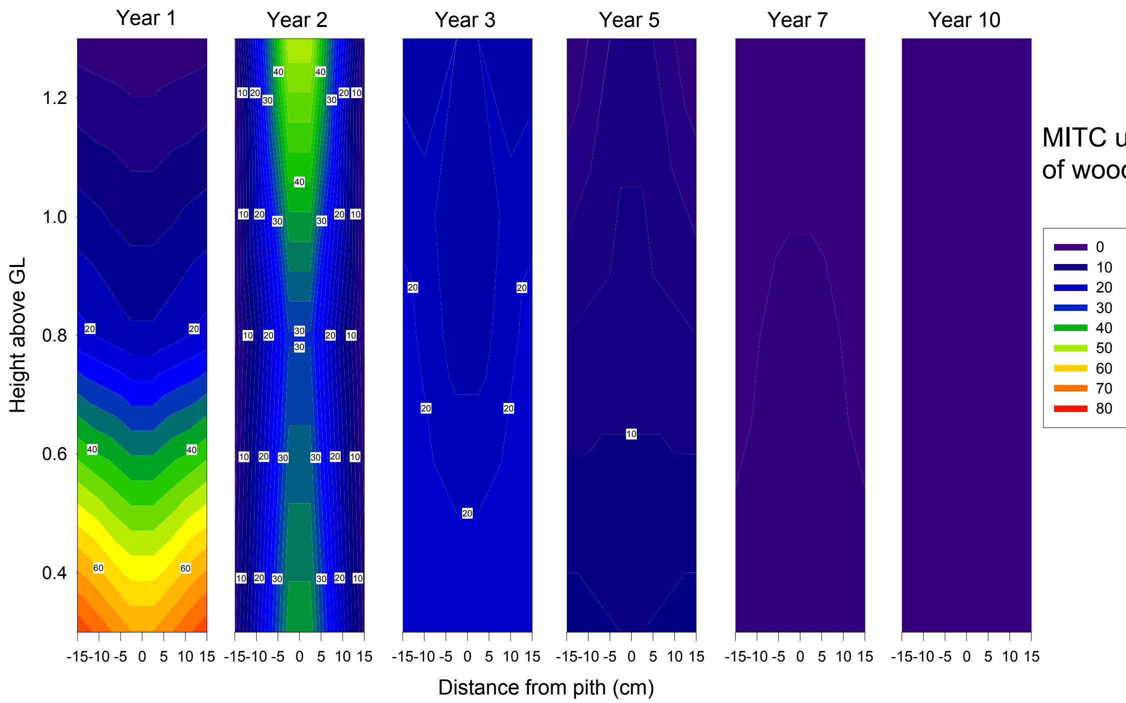


Figure I-4. Residual MITC in Douglas-fir poles 1 to 10 years after treatment with metam sodium.

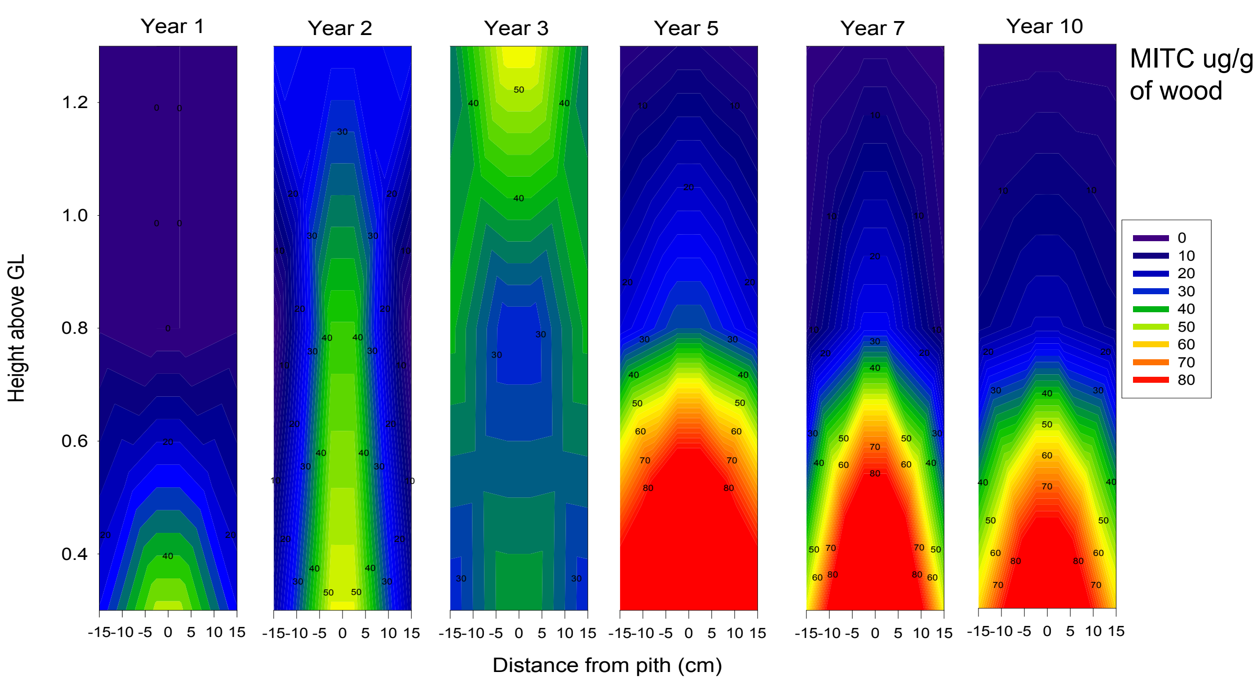


Figure I-5. Residual MITC in Douglas-fir poles 1 to 10 years after treatment with 160 g of powdered dazomet.

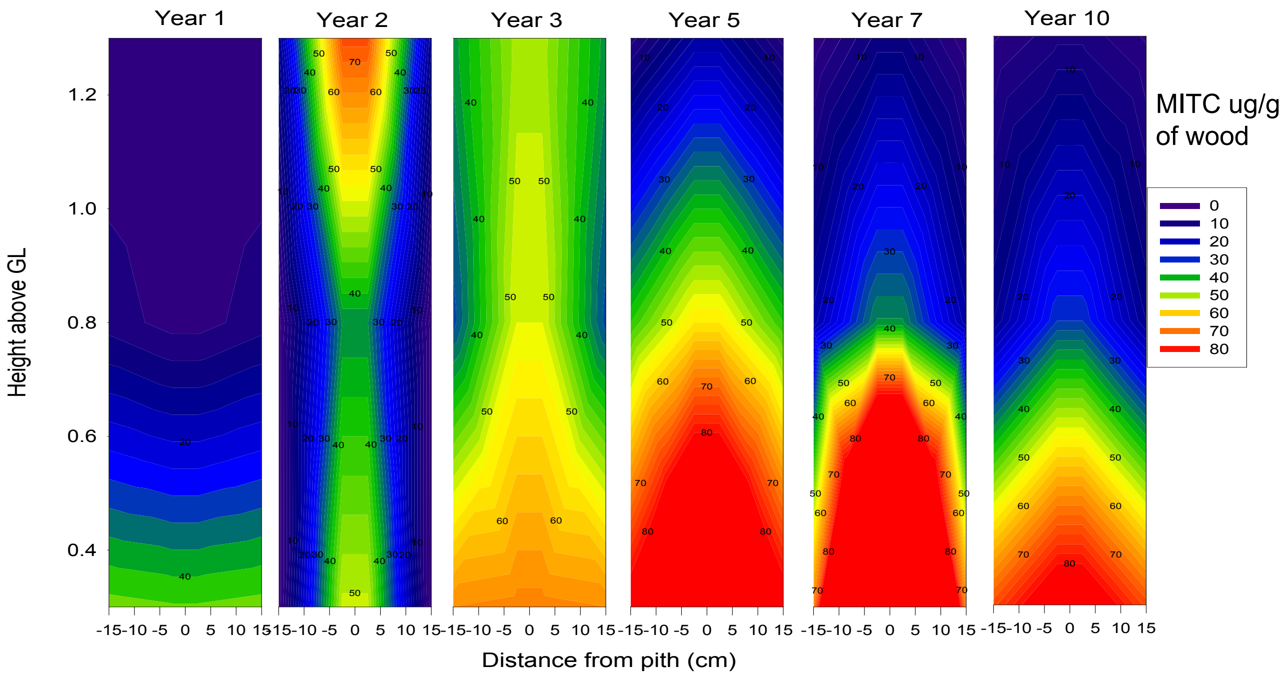


Figure I-6. Residual MITC in Douglas-fir poles 1 to 10 years after treatment with 6 dazomet rods (107 g) plus 100 g of copper naphthenate (2 % as Cu).

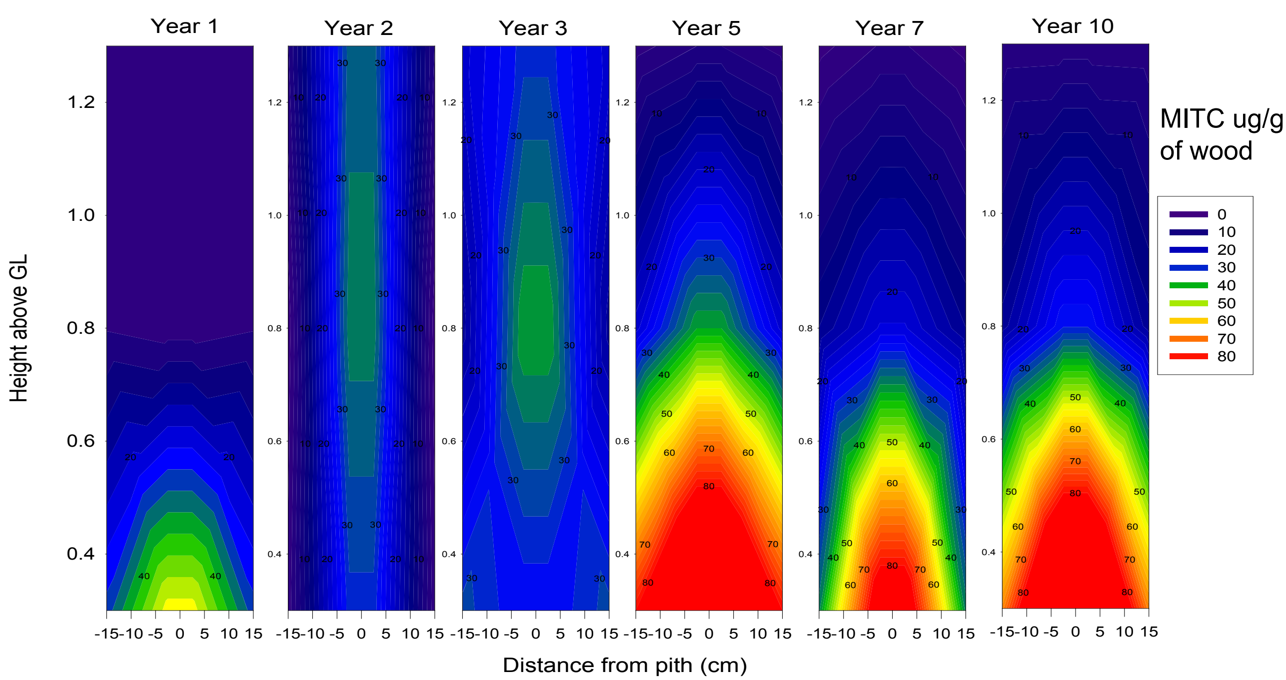


Figure I-7. Residual MITC in Douglas-fir poles 1 to 10 years after treatment with 9 dazomet rods (160 g).

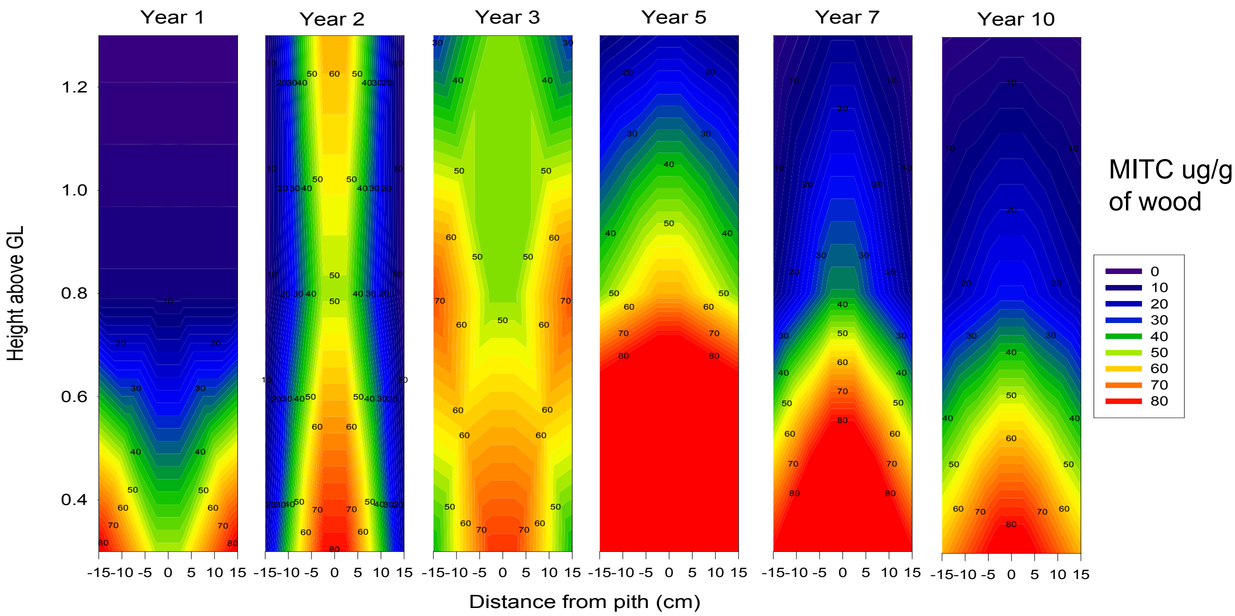


Figure I-8. Residual MITC in Douglas-fir poles 1 to 10 years after treatment with 9 dazomet rods (160 g) plus 100 g of copper naphthenate.

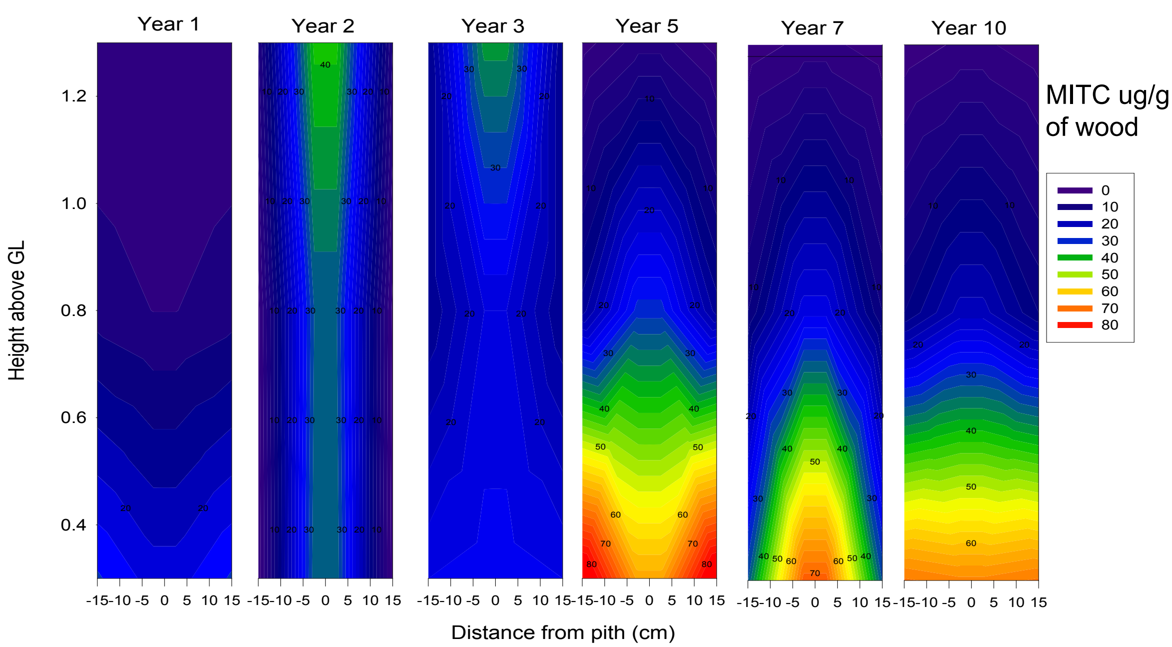


Figure I-9. Residual MITC in Douglas-fir poles 1 to 10 years after treatment with 9 dazomet rods (160 g) plus 100 g of water .

the threshold, but those in the inner zone at this height were above or very near the threshold for all dazomet treatments regardless of whether copper was added. MITC levels 0.8 m above groundline in metam sodium treated poles were only above the threshold 1 to 3 years after treatment. MITC levels at this same sampling height then fell off sharply illustrating the tendency for metam sodium to provide a large burst of initial activity followed by a sharp drop in residual protection.

MITC levels 0.3 m above the groundline in metam sodium treat poles were well above the threshold one year after treatment, particularly in the inner zone, but then declined sharply thereafter. The MITC levels at groundline were somewhat lower than those found in other tests, although the reasons for the lower levels are not clear.

MITC levels in poles treated with dazomet were also above the threshold regardless of the addition of either copper or water. Interestingly, the dazomet rod with water treatment appeared to result in the lowest MITC levels in the inner zone, while the two copper naphthenate treatments with rods produced the highest MITC levels. MITC levels in all dazomet treatments remained well above the threshold for fungal protection 10 years after treatment. The results indicate that formulating dazomet in rod form had no negative effect on performance.

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

6. Performance of Dazomet in Granular and Tube Formulations

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

Dazomet has been successfully applied for almost 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 encase the chemical prior to application. The tubes would contain the material prior to application, but may also affect subsequent dazomet decomposition and the release of MITC. In order to investigate this possibility, the following trial was established.

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

Seventy grams of dazomet was pre-weighed into 125 ml glass bottles. The content of one bottle was then applied to each of the three holes in each of 10 poles. The holes in 10 additional poles received a 400 to 450 mm long by 19 mm diameter paper tube containing 60 g of dazomet. The tubes were gently rotated as they were inserted to avoid damage to the paper. The holes in one half of the poles treated with either granular or tubular dazomet were then treated with 7 g of 2 % copper naphthenate (as 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 degradable perforated plastic which will break down over time and 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 of the core 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 extract was removed and analyzed by gas chromatography for MITC. The remainder of each core was placed on 1.5 % malt extract agar and observed for evidence of fungal growth. Any fungal growth was examined for characteristics typical of basidiomycetes, a class of fungi containing many important wood decayers.

These poles were not inspected in 2010, but will be sampled in 2011 at the five year point.

6. MITC Content of Residual Dazomet in Treatment Holes

Many field inspectors have noted the presence of a considerable volume of powder in poles previously treated with dazomet, even 10 to 12 years after application. We have also noted similar residual material in our original test poles, although these were not exposed in soil contact where elevated moisture levels might be expected to result in more complete dazomet decomposition.

Questions have arisen from field inspectors about how to handle this material. If the material still consists of dazomet, then it could be left in the hole and additional dazomet plus accelerant could be added to regenerate the decomposition process. However, if this material represented only decomposition products, then it might have to be removed prior to adding more dazomet and this would constitute a potential handling issue as inspectors dealt with residual fumigant with varying levels of activity. In order to answer that question, we have removed residual dazomet from a number of poles that had received dazomet 3 to 15 years earlier. The material was removed from the holes and placed in Teflon lined glass vials. The residual MITC in the mixture was determined by extracting a portion of each sample with ethyl acetate in the same manner by which we currently analyze our wood. The resulting extract was then analyzed by gas chromatography. The residual solid material was then solubilized and analyzed by high performance liquid chromatography using an Environmental Protection Agency method. The resulting dazomet levels were quantified by comparison with prepared standards. These tests are in progress and will be presented in the 2012 Annual Reoprt.

B. Performance of Water Diffusible Preservatives as Internal Treatments

While fumigants have long been an important tool for utilities seeking to prolong the service lives of wood poles by limiting the extent of internal decay, some users have expressed concern about the risk of these chemicals. Water diffusible preservatives such as boron and fluoride have been developed as potentially less toxic alternatives to fumigants. (Table I-3).

Table I-3. Characteristics of diffusible internal remedial treatments for wood poles

Trade Name	Active Ingredient	Conc. (%)	Toxicity (LD_{50})	Manufacturer
Impel Rods Bor8-Rods	boron	100	>2000 mg/kg	Pole Care Inc. Osmose Utilities Services, Inc.
Pole Saver Rods	boron/fluoride	58/24	>2000 mg/kg	Preschem Ltd.
Flurods	fluoride	98	105 mg/kg	Osmose Utilities Services, Inc.
Cobra-Rods	boron/copper	97/3	10000 mg/kg oral 5000 mg/kg dermal	Genics Inc.

Boron has a long history of use as an initial treatment of freshly sawn lumber to prevent infestations by various species of powder post beetles in both Europe and New Zealand. This chemical has also been used more recently for treatment of lumber in Hawaii to limit attack by the Formosan subterranean termite. Boron is attractive as a preservative because it has exceptionally low toxicity to non-target organisms, especially humans, and because it has the ability to diffuse through wet wood. In principle, a decaying utility pole should be wet, particularly near the groundline and this moisture can provide the vehicle for boron to move from the point of application to wherever decay is occurring. Boron is available for remedial treatments in a number of forms, but the most popular are fused borate rods which come as pure boron or boron plus copper. These rods are produced by heating boron to its molten state, then pouring the molten boron into a mold. The cooled boron rods are easily handled and applied. In theory, the boron is released as the rods come in contact with water.

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

Both of these chemicals have been available for remedial treatments for several decades, but widespread use of these systems has only occurred in the last decade and most of this application has occurred in Europe. As a result, there is considerable performance data on boron and fluoride as remedial treatments on European species, but little data on performance on U.S. species used for utility poles.

1. Performance of Copper Amended Fused Boron Rods

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

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

Boron levels in pole sections were below the protective threshold level 1 year after treatment, but then gradually increased over the threshold in the next 2 years (Figures I-10 & I-11). Treatment levels appeared to drop slightly between 5 and 7 years after treatment, although they remained above the threshold in many cases. Boron levels tended to be highest at groundline and 150 mm below that zone, reflecting the tendency for the wood to be wetter in these regions. Moisture is obviously critical for boron movement. Boron levels also tended to be higher in the inner zones of increment cores, reflecting the positioning of the rods further inward in the treatment holes. Boron levels tended to be below the threshold 300 or 900 mm above groundline, reflecting the lower moisture regimes present in these zones.

Boron levels in poles receiving fused borate and fused borate plus copper rods appeared to differ little, suggesting that the copper in the latter system had little influence on either initial boron diffusion or subsequent retention in the wood.

Copper levels have been well below the protective threshold throughout the test. No copper was detected 7 years after treatment (Figures I-12).

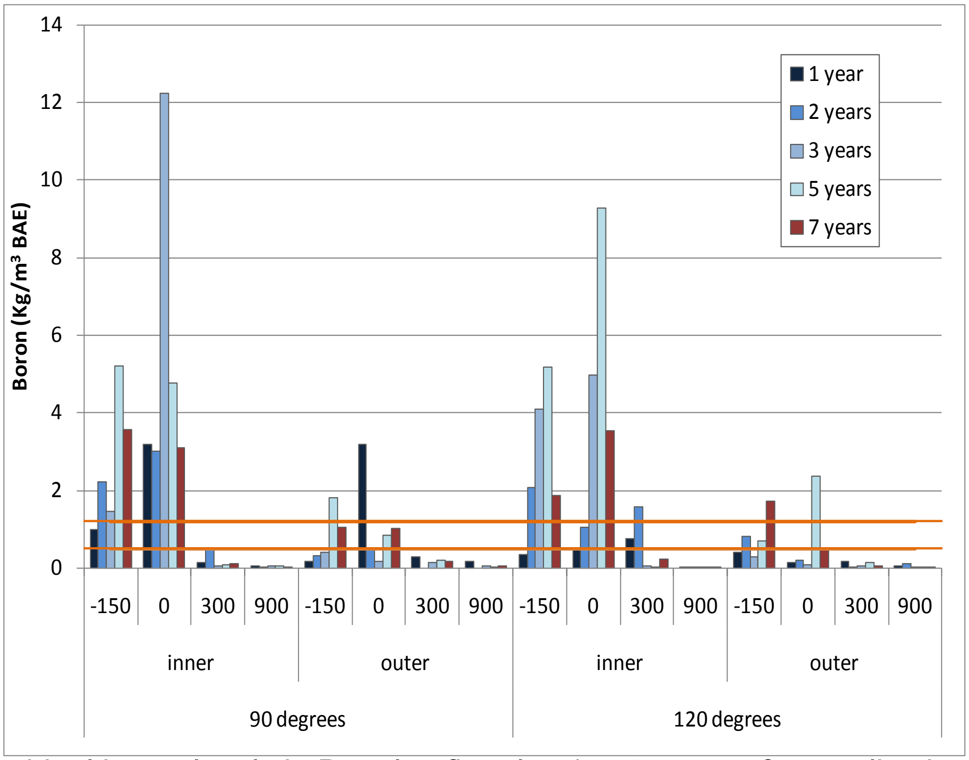
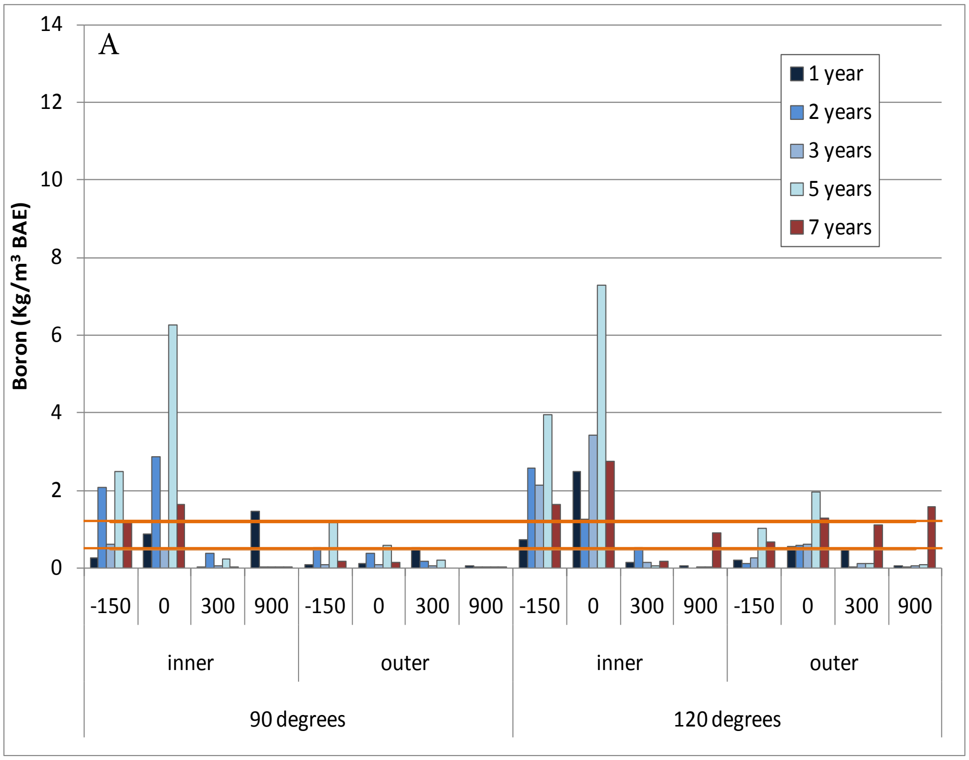


Figure I-10 Residual boron levels in Douglas-fir poles 1 to 7 years after application of 4 fused boron rods in treatment holes spaced at either 90 or 120 degree intervals around each pole.

Increasing the rod dosage from 4 to 8 rods per pole had only a slight effect on borate levels in the wood. The effect was mostly evident in the outer zones, particularly in poles treated using the 90 degree rod spacing. The increased boron levels in the outer zone likely occurred because the second rod sits higher in the treatment hole, providing direct contact between the wood and the rod in that zone. This would be less likely to occur in the lower dosage treatment because the rods would sit deeper in the hole and more toward the inner sampling zone.

Culturing of increment cores removed from the poles revealed the presence of some decay fungi in the poles, especially at groundline (Table I-4). Some decay fungi were isolated 300 or 900 mm above groundline, however, the overall low levels of boron in these zones suggest that the rod application would have little or no effect on fungal colonization in these zones. Fungal isolations near groundline tended to be more prevalent in poles receiving 4 fused borate rods using either the 90 or 120 degree spacing, although the isolation levels were very low. No decay fungi were isolated from poles treated with either 4 or 8 fused borate/ copper rods. The results suggest that both boron treatments are effectively limiting fungal colonization at and below groundline over the 7 year test period.

The results indicate that the boron from fused borate and fused borate plus copper rods is diffusing into Douglas-fir heartwood at rates capable of protecting against fungal attack. While there are some slight differences in chemical levels and in the presence of decay fungi, the results suggest that the systems provide similar protection.



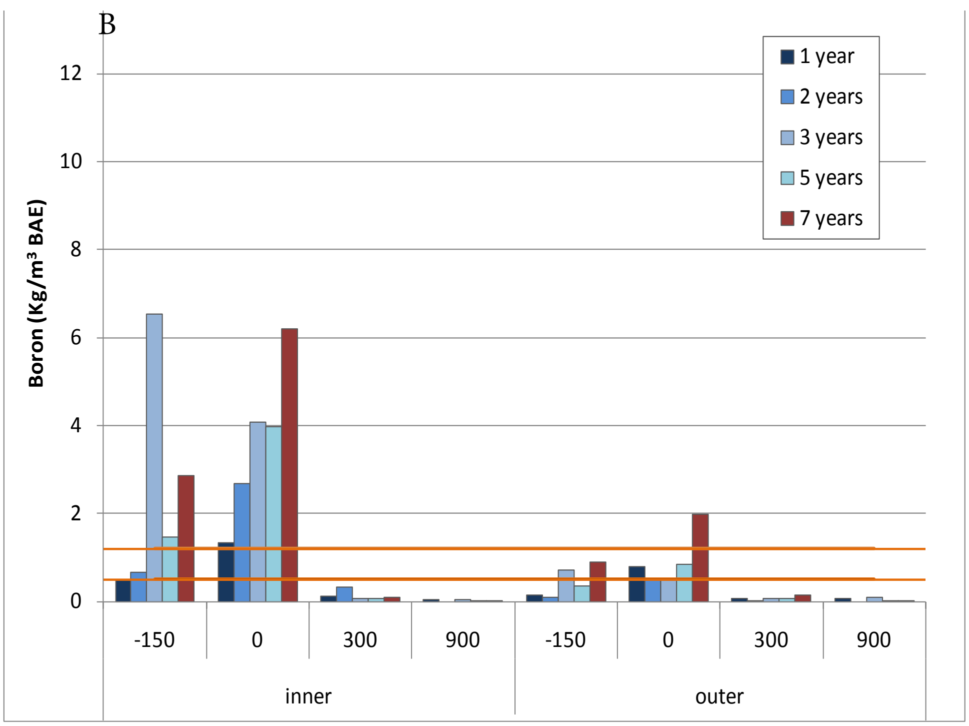
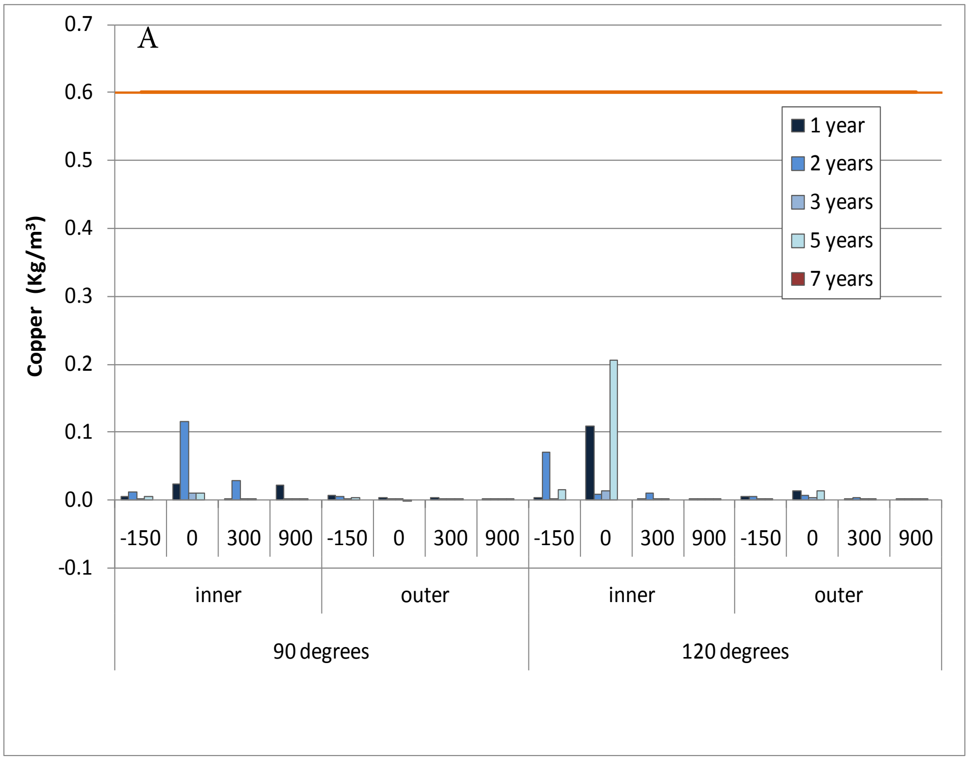


Figure I-11 Residual boron levels in Douglas-fir poles 1 to 7 years after application of A. 4 or B. 8 fused borate/copper rods in treatment holes spaced at 90 degree intervals around each pole.



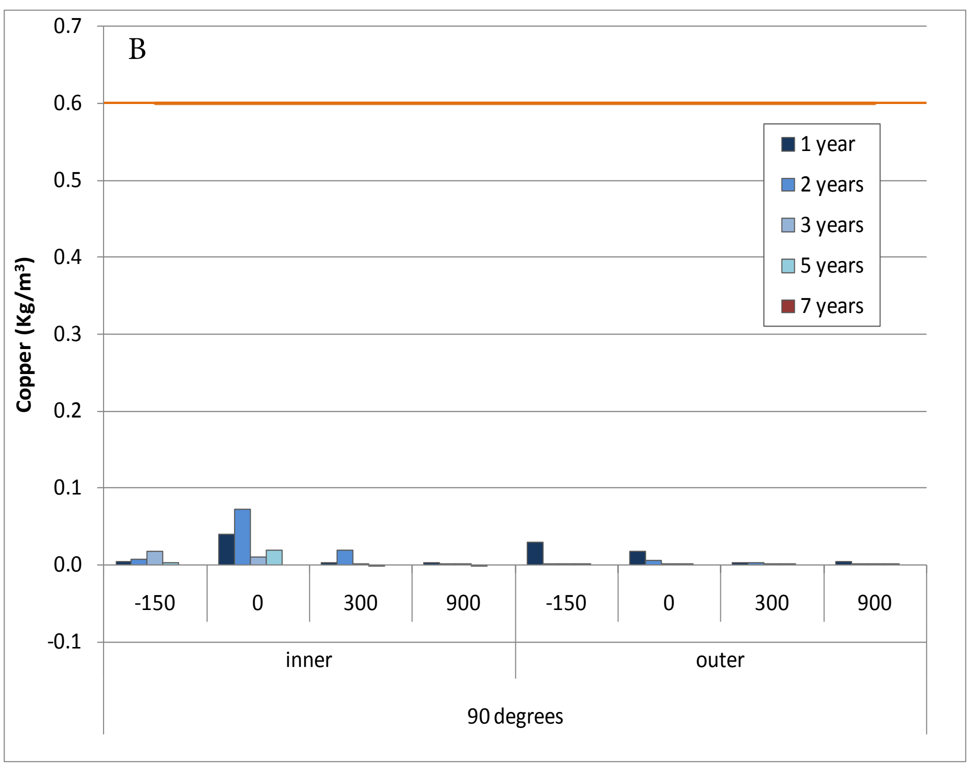


Figure I-12. Residual copper levels in Douglas-fir poles 1 to 7 years after application of A. 4 or B. 8 fused borate/copper rods in treatment holes spaced at 90 degree intervals around each pole.

Table I-4. Isolation frequencies of decay and non-decay fungi in increment cores removed from Douglas-fir pole sections 1 to 8 years after application of fused borate or fused borate/copper rods.

Treatment	Rod Spacing	Year Sampled	Isolation Frequency (%)[1]							
			-150 mm		0 mm		300 mm		900 mm	
4 copper/ boron rods	90°	1	0	7	0	10	0	20	0	7
		2	0	33	0	20	0	10	7	0
		3	0	27	0	10	0	0	7	13
		5	0	33	0	30	20	0	7	13
		7	0	44	0	14	20	20	0	11
4 copper/ boron rods	120°	1	0	40	0	0	0	0	0	13
		2	0	33	0	20	0	0	0	0
		3	0	47	0	30	0	0	7	7
		5	0	40	0	10	0	10	0	0
		7	0	9	0	14	0	13	29	0
4 boron rods	90°	1	0	7	0	10	0	0	0	0
		2	0	20	10	10	0	0	7	0
		3	0	40	10	50	0	0	13	7
		5	7	27	10	20	10	0	13	0
		7	10	40	0	33	0	0	0	0
4 boron rods	120°	1	0	0	0	0	0	0	0	20
		2	0	20	10	10	0	0	7	0
		3	0	40	10	50	0	0	13	7
		5	0	47	10	30	0	10	7	0
		7	0	0	0	50	0	0	0	0
8 copper/ boron rods	90°	1	0	0	0	0	0	0	0	7
		2	0	0	0	0	0	20	0	7
		3	0	27	0	10	0	0	0	0
		5	0	33	0	0	0	0	13	33
		7	0	0	0	0	0	0	0	0

1. Values represent the percent of 10 attempts yielding fungal cultures per treatment. Superscripts denote non-decay fungi.

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

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

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

Boron levels remained above threshold at groundline for the entire 15 year sampling period. This test is now completed.

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

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

While boron has been found to move with moisture through most pole species (Dickinson et al., 1988; Dietz and Schmidt, 1988; Dirol, 1988; Edlund et al., 1983; Ruddick and Kundzewicz, 1992), our initial field tests showed slower movement in the first year after application. One remedy to the initial slow movement that has been used in Europe has been the addition of glycol to the treatment holes. Glycol is believed to stimulate movement through dry wood that would normally not support diffusion (Bech-Anderson, 1987; Edlund et al., 1983).

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

Four 19 mm diameter holes were drilled at a 45 $^{\circ}$ downward sloping angle in each pole, beginning 75 mm above the groundline, then moving 90 degrees around and up to 230, 300, and 450 mm above the groundline. An equal amount of boron (227 g BAE) was added to each pole, but was delivered in different combinations of boron, water, or glycol (Table I-5). The borate rods were 100 mm long by 12.7 mm in diameter and weighed 24.4 g each. An equal weight of boron rod composed of one whole rod and a portion of another, were placed in each hole followed by the appropriate liquid supplement or were left dry. The holes were then plugged with tight fitting wooden dowels. Each treatment was replicated on five poles.

The pole sections were sampled 1, 2, 3, 5, 7, 10, 12 and 15 years after treatment by removing two increment cores 180 degrees apart from 300 mm below the groundline, and cores from three equidistant locations around the pole 150 and 300 mm above the groundline. The treated portion of the cores was discarded, then the remainder of each core was divided into zones

Table I-5. Combinations of boron rods and various boron additives used to treat Douglas-fir poles. All treatments delivered 227 g BAE per pole.						
Boron rod (g)	Supplement	Amount of supplement (g)	Total glycol (g)	Total water (g)	Supplement source	Supplement formulation
156	None	0	0	0		
137	BoraCare 1:1 in water	118	28	65	Nisus Corp. Rockford, TN	Disodium octaborate tetrahydrate plus poly and monoethylene glycol
137	Boracol 20	122	77	20	Viance LLC Charlotte, NC	Disodium octaborate tetrahydrate plus polyethylene glycol (20%)
104	Boracol 40	164	95	0	Viance LLC Charlotte, NC	Disodium octaborate tetrahydrate plus polyethylene glycol (40%)
156	Poly ethylene glycol	100	100	0	VanWaters and Rogers, Seattle, WA	
146	Timbor 10% in water	118	0	106	U.S. Borax Inc.	Disodium octaborate tetrahydrate

corresponding to 0-50 (O), 51-100 (M), and 101-150 (I) mm from the edge of the treated zone. The zones from the same depth and height from a given treatment were combined and ground to pass a 20 mesh screen. The resulting sawdust was then extracted and analyzed using the Azomethine-H method.

Boron continued to be detectable in virtually all pole sections 12 years after treatment. As in previous boron tests, chemical levels were lower in poles receiving only the borate rods after 1year (Table I-6). Boron tended to be higher in the inner and middle zones of each pole. This reflected the position of the original rod treatment toward the bottom of the treatment hole. Boron levels 7 years after treatment were much higher in poles receiving any of the various combinations of Boracare, Boracol, Timbor, or glycol, suggesting that some supplemental liquid enhanced boron movement, whether or not the additive contained boron or glycol.

Boron levels at the 15 year point were lowest in poles receiving only the boron rods although the differences were sometimes slight (Table I-7). The addition of any supplemental treatment enhanced boron levels, although there were some differences between the various additives. Boron levels tended to be lower in poles amended with Boracare or with Boracol 40 than with Timbor, glycol (no added boron) or Boracol 20 at 12 years, but this trtend had moderated at the 15 year point (Figures I-13 to I-18). The differences between Boracol 20 and Boracol 40 were perplexing since the primary difference between these systems is the level of boron present in the solution. Given the higher level of boron in the Boracol 40, one should expect higher levels

Table I-6. Boron levels in Douglas-fir poles 1 to 15 years after treatment with various combinations of fused boron rod and various water or glycol based additives[1].

Treatment	Height (mm)	Depth	Boron (Kg/m^3 BAE)			
			Year 1	Year 2	Year 3	Year 5
Rods alone	-300	I	**0.52** (0.45)	**1.40** (1.23)	**0.87** (0.82)	**0.53** (0.92)
		M	**0.81** (1.34)	**0.83** (0.91)	0.37 (0.30)	0.37 (0.69)
		O	0.30 (0.10)	0.43 (0.56)	0.24 (0.23)	**0.50** (0.59)
	0	I	**1.31** (1.91)	**2.16** (0.97)	**2.15** (1.97)	**2.88** (1.98)
		M	0.34 (0.24)	**1.05** (0.85)	**2.43** (2.66)	**1.86** (0.82)
		O	0.24 (0.13)	0.23 (0.29)	**1.67** (2.09)	0.42 (0.46)
	150	I	0.45 (0.29)	**1.65** (2.24)	**2.12** (1.62)	**1.87** (1.72)
		M	0.22 (0.07)	**1.39** (2.47)	**2.88** (3.32)	**1.47** (1.43)
		O	0.29 (0.18)	0.43 (0.86)	0.54 (0.86)	0.41 (0.49)
	300	I	0.23 (0.13)	0.30 (0.54)	0.49 (0.59)	**1.14** (2.03)
		M	0.20 (0.06)	0.17 (0.16)	0.33 (0.34)	**1.79** (3.13)
		O	0.16 (0.09)	0.10 (0.10)	0.11 (0.10)	**1.06** (1.77)
Rods plus Boracare	-300	I	**1.57** (1.80)	0.36 (0.25)	**0.51** (0.32)	0.20 (0.16)
		M	0.36 (0.20)	0.43 (0.37)	**0.56** (0.28)	0.07 (0.10)
		O	0.23 (0.05)	0.16 (0.03)	**0.58** (0.59)	0.04 (0.06)
	0	I	**2.80** (1.86)	**7.59** (6.38)	**2.40** (1.51)	**5.68** (6.61)
		M	0.32 (0.18)	**4.77** (4.78)	**1.34** (0.92)	**5.03** (4.71)
		O	0.22 (0.05)	0.40 (0.39)	**0.87** (0.93)	**0.83** (0.91)
	150	I	**4.35** (3.61)	**3.55** (1.22)	**4.13** (4.66)	**5.17** (3.72)
		M	**1.06** (1.10)	**1.32** (1.67)	**4.10** (4.50)	**1.86** (0.97)
		O	0.50 (0.34)	0.49 (0.90)	0.40 (0.30)	**1.08** (1.85)
	300	I	**1.79** (1.16)	**1.22** (1.09)	**0.81** (1.05)	**2.27** (3.19)
		M	**1.16** (1.91)	0.33 (0.29)	**0.89** (1.36)	**4.23** (8.09)
		O	0.33 (0.19)	0.15 (0.18)	**1.00** (1.77)	**1.62** (2.88)
Rods plus Boracol 20	-300	I	**0.87** (0.71)	**0.69** (0.75)	0.50 (0.53)	0.26 (0.19)
		M	0.49 (0.48)	0.29 (0.26)	0.26 (0.24)	0.22 (0.23)
		O	0.47 (0.49)	0.20 (0.21)	0.22 (0.15)	1.62 (3.36)
	0	I	**4.51** (5.32)	**2.41** (0.73)	**3.93** (2.95)	**3.33** (1.95)
		M	**1.44** (2.09)	**0.79** (0.53)	**2.38** (2.32)	**1.99** (1.25)
		O	0.32 (0.12)	**1.11** (2.11)	**2.96** (2.91)	**0.55** (0.63)
	150	I	**1.84** (0.95)	**3.64** (4.00)	**1.65** (1.79)	**3.69** (1.56)
		M	**0.73** (0.70)	**1.00** (0.65)	**3.39** (5.04)	**1.85** (1.16)
		O	0.36 (0.23)	**0.93** (1.45)	0.30 (0.27)	0.44 (0.41)
	300	I	**2.87** (4.37)	**0.70** (0.72)	**0.93** (1.12)	0.36 (0.70)
		M	**0.67** (0.62)	**1.09** (1.16)	**0.58** (0.82)	0.27 (0.56)
		O	0.24 (0.07)	**1.37** (2.44)	0.20 (0.24)	0.40 (0.72)

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

Table I-6. Boron levels in Douglas-fir poles 1 to 15 years after treatment with various combinations of fused boron rod and various water or glycol based additives[1].(continued)

Treatment	Height (mm)	Depth	Boron (Kg/m^3 BAE)			
			Year 7	Year 10	Year 12	Year 15
Rods alone	-300	I	0.46 (0.64)	0.35 (0.17)	0.23 (0.40)	0.49 (0.06)
		M	0.37 (0.56)	0.21 (0.35)	0.22 (0.39)	0.29 (0.11)
		O	0.10 (0.08)	0.28 (0.35)	0.11 (0.20)	0.07 (0.02)
	0	I	**1.10** (0.87)	**1.23** (0.38)	**0.81** (0.44)	**1.12** (0.90)
		M	**1.07** (0.92)	**0.69** (0.14)	**0.63** (0.65)	**0.64** (0.16)
		O	**0.69** (0.78)	0.32 (0.14)	0.25 (0.35)	0.20 (0.07)
	150	I	**2.54** (1.82)	**1.64** (0.72)	**0.57** (0.46)	**1.41** (1.39)
		M	**1.83** (1.66)	**2.74** (2.89)	**0.87** (0.59)	**1.61** (1.84)
		O	0.27 (0.28)	**0.54** (0.34)	**0.55** (0.50)	0.41 (0.26)
	300	I	**14.16** (29.02)	**0.73** (0.74)	0.01 (0.02)	**0.74** (0.37)
		M	**0.81** (0.90)	0.48 (0.52)	0.02 (0.03)	**0.74** (0.68)
		O	0.40 (0.46)	0.25 (0.15)	0.07 (0.11)	**0.94** (1.49)
Rods plus Boracare	-300	I	0.15 (0.14)	0.30 (0.24)	0.41 (0.62)	0.71 (0.55)
		M	0.12 (0.10)	0.28 (0.17)	0.18 (0.18)	0.34 (0.19)
		O	0.10 (0.04)	0.22 (0.14)	0.03 (0.05)	0.10 (0.01)
	0	I	**10.39** (9.85)	**2.00** (1.52)	**1.85** (1.45)	**1.55** (1.41)
		M	**0.78** (0.90)	**0.87** (0.67)	**1.00** (0.72)	**1.46** (1.27)
		O	**0.53** (0.67)	0.18 (0.11)	0.20 (0.18)	0.20 (0.10)
	150	I	**3.14** (2.65)	**1.84** (1.88)	**1.11** (1.42)	**2.67** (2.62)
		M	**1.69** (1.72)	**0.80** (1.01)	**1.04** (0.88)	**0.80** (0.62)
		O	0.21 (0.23)	0.28 (0.20)	0.35 (0.41)	0.23 (0.13)
	300	I	**1.83** (1.29)	**1.92** (1.64)	**1.31** (1.12)	**0.88** (1.17)
		M	**0.89** (0.68)	**1.09** (0.90)	**0.53** (0.72)	**0.93** (0.75)
		O	0.12 (0.06)	0.20 (0.14)	0.12 (0.18)	0.25 (0.26)
Rods plus Boracol 20	-300	I	**1.61** (1.06)	**0.73** (0.33)	**0.92** (0.72)	**0.50** (0.44)
		M	**0.99** (0.90)	**0.63** (0.21)	**0.79** (0.57)	0.36 (0.09)
		O	0.13 (0.19)	0.49 (0.22)	0.21 (0.26)	0.22 (0.11)
	0	I	**2.22** (2.74)	**1.87** (1.56)	**3.82** (4.14)	**1.48** (1.04)
		M	**0.89** (0.58)	**1.07** (1.08)	**0.89** (0.70)	**0.76** (0.48)
		O	0.11 (0.11)	**0.57** (0.35)	0.46 (0.36)	0.46 (0.55)
	150	I	**2.06** (1.47)	**2.39** (1.49)	**3.49** (1.98)	**1.69** (0.56)
		M	**3.86** (1.89)	**1.02** (0.97)	**1.25** (0.40)	**1.58** (0.91)
		O	0.27 (0.20)	0.15 (0.09)	0.46 (0.29)	**1.28** (1.34)
	300	I	**0.91** (1.22)	0.31 (0.24)	**0.89** (0.92)	**0.59** (0.65)
		M	**1.04** (1.66)	0.18 (0.15)	**0.59** (0.51)	0.31 (0.33)
		O	0.20 (0.36)	0.06 (0.03)	0.06 (0.05)	0.07 (0.05)

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

Table I-6. Boron levels in Douglas-fir poles 1 to 15 years after treatment with various combinations of fused boron rod and various water or glycol based additives[1].(continued)

Treatment	Height (mm)	Depth	Boron (Kg/m^3 BAE)			
			Year 1	Year 2	Year 3	Year 5
Rods plus Boracol 40	-300	I	**2.49** (2.38)	**0.92** (0.63)	**0.71** (0.62)	**0.62** (0.73)
		M	**0.55** (0.41)	**0.71** (1.09)	**1.53** (2.57)	0.37 (0.36)
		O	0.21 (0.08)	**0.74** (0.99)	**1.36** (2.66)	0.07 (0.07)
	0	I	**11.15** (6.98)	**10.41** (9.50)	**5.82** (3.21)	**10.82** (9.22)
		M	**3.38** (2.69)	**5.16** (3.23)	**9.54** (10.73)	**13.82** (10.66)
		O	0.45 (0.31)	**1.26** (1.47)	**2.65** (2.21)	**2.53** (1.85)
	150	I	0.37 (0.24)	0.33 (0.30)	0.35 (0.30)	**0.63** (0.86)
		M	0.22 (0.03)	0.44 (0.43)	0.41 (0.31)	0.33 (0.53)
		O	0.18 (0.11)	0.33 (0.28)	0.26 (0.08)	0.14 (0.27)
	300	I	0.18 (0.12)	0.10 (0.09)	0.08 (0.07)	0.03 (0.04)
		M	0.15 (0.10)	0.08 (0.05)	0.09 (0.08)	0.04 (0.05)
		O	0.15 (0.11)	0.07 (0.04)	0.08 (0.07)	0.02 (0.02)
Rods plus glycol	-300	I	0.32 (0.29)	0.33 (0.20)	0.16 (0.13)	0.14 (0.21)
		M	0.19 (0.06)	0.18 (0.11)	0.07 (0.13)	0.04 (0.09)
		O	0.16 (0.10)	0.10 (0.11)	0.10 (0.13)	0.03 (0.05)
	0	I	**5.30** (8.91)	**3.71** (2.92)	**3.88** (3.84)	**2.84** (1.97)
		M	**0.97** (1.20)	**0.61** (0.39)	**0.67** (0.46)	**2.81** (2.00)
		O	0.21 (0.16)	0.17 (0.17)	**0.68** (1.20)	**1.61** (1.90)
	150	I	**2.98** (3.50)	**5.02** (4.32)	**5.31** (1.72)	**2.77** (2.53)
		M	**1.34** (1.53)	**1.09** (1.36)	**2.34** (2.63)	**6.53** (10.12)
		O	0.29 (0.22)	0.10 (0.08)	**1.45** (2.03)	**4.29** (7.08)
	300	I	0.17 (0.11)	0.24 (0.16)	**1.50** (1.83)	**1.57** (2.79)
		M	0.19 (0.05)	0.18 (0.22)	**0.56** (0.69)	**3.44** (6.66)
		O	0.20 (0.04)	**0.61** (0.97)	**0.91** (1.72)	**2.33** (4.85)
Rods plus Timbor	-300	I	**0.83** (0.43)	0.67 (0.37)	0.30 (0.22)	0.32 (0.39)
		M	0.30 (0.07)	0.26 (0.11)	**0.54** (0.37)	0.13 (0.22)
		O	0.33 (0.18)	0.14 (0.06)	**0.51** (0.60)	0.03 (0.04)
	0	I	**2.75** (2.36)	**2.68** (2.36)	**5.67** (4.81)	**7.58** (11.41)
		M	0.32 (0.17)	**1.84** (1.99)	**1.46** (1.35)	**1.54** (0.78)
		O	0.34 (0.23)	0.20 (0.17)	**0.54** (0.55)	0.47 (0.49)
	150	I	**3.53** (3.44)	**2.89** (2.22)	**2.83** (2.85)	**2.22** (1.10)
		M	**6.60** (12.26)	**1.42** (1.89)	**1.74** (1.98)	**6.15** (7.51)
		O	**0.72** (0.79)	0.35 (0.30)	**0.94** (0.74)	**1.13** (0.83)
	300	I	**2.94** (5.56)	**1.74** (2.22)	**1.57** (1.91)	**3.38** (5.19)
		M	0.38 (0.23)	0.40 (0.35)	**1.84** (2.42)	**0.68** (0.66)
		O	0.45 (0.32)	0.15 (0.07)	**3.14** (2.42)	0.34 (0.48)

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

Table I-6. Boron levels in Douglas-fir poles 1 to 15 years after treatment with various combinations of fused boron rod and various water or glycol based additives[1].(continued)

Treatment	Height (mm)	Depth	Boron (Kg/m³ BAE) Year 7		Year 10		Year 12		Year 15	
Rods plus Boracol 40	-300	I	**1.32**	(1.17)	0.46	(0.30)	**0.51**	(0.49)	**0.69**	(0.26)
		M	0.41	(0.34)	**0.55**	(0.49)	0.20	(0.31)	**0.74**	(0.43)
		O	0.14	(0.28)	0.40	(0.22)	0.22	(0.39)	0.33	(0.40)
	0	I	**5.86**	(4.24)	**2.16**	(0.06)	**1.31**	(0.35)	**1.38**	(1.06)
		M	**7.49**	(3.73)	**1.23**	(0.46)	**1.17**	(0.23)	**1.33**	(0.54)
		O	**0.53**	(0.34)	0.42	(0.10)	0.34	(0.36)	0.27	(0.04)
	150	I	**1.39**	(1.58)	0.36	(0.49)	0.46	(0.37)	**0.60**	(0.32)
		M	0.47	(0.40)	0.44	(0.57)	0.40	(0.19)	**0.48**	(0.19)
		O	0.06	(0.04)	0.12	(0.14)	0.03	(0.03)	0.12	(0.07)
	300	I	0.37	(0.67)	0.04	(0.06)	0.03	(0.05)	0.22	(0.14)
		M	0.18	(0.17)	0.03	(0.01)	0.02	(0.03)	0.13	(0.06)
		O	0.04	(0.02)	0.27	(0.37)	0.00	0.00	0.05	(0.02)
Rods plus glycol	-300	I	0.30	(0.24)	**0.52**	(0.38)	**0.96**	(0.93)	1.04	(0.70)
		M	0.10	(0.07)	**0.79**	(0.48)	**0.80**	(0.98)	0.43	(0.19)
		O	0.19	(0.31)	0.44	(0.36)	0.35	(0.52)	0.11	(0.02)
	0	I	**4.86**	(3.37)	**2.83**	(2.02)	**3.07**	(3.21)	**4.09**	(4.30)
		M	**5.17**	(7.26)	**1.70**	(0.80)	**2.45**	(2.07)	**1.11**	(0.78)
		O	0.49	(0.46)	**0.54**	(0.38)	0.24	(0.32)	0.25	(0.13)
	150	I	**2.89**	(1.34)	**3.00**	(3.04)	**1.99**	(2.08)	**1.33**	(0.86)
		M	**3.08**	(2.69)	**1.74**	(1.46)	**2.78**	(3.78)	**1.59**	(1.74)
		O	0.27	(0.18)	0.33	(0.11)	**1.04**	(1.51)	**1.25**	(1.82)
	300	I	**0.63**	(1.10)	0.33	(0.08)	**0.65**	(0.76)	**0.50**	(0.24)
		M	**1.16**	(1.73)	0.19	(0.08)	0.11	(0.10)	0.19	(0.09)
		O	0.43	(0.48)	0.09	(0.02)	0.29	(0.47)	0.05	(0.02)
Rods plus Timbor	-300	I	**1.12**	(1.58)	0.35	(0.24)	0.69	(0.50)	1.23	(0.93)
		M	0.32	(0.33)	0.40	(0.36)	0.53	(0.52)	1.16	(0.83)
		O	0.04	(0.06)	0.26	(0.25)	0.24	(0.29)	0.40	(0.46)
	0	I	**2.59**	(2.46)	**1.58**	(0.37)	**2.35**	(0.45)	**1.44**	(0.42)
		M	**0.85**	(0.53)	**1.24**	(0.65)	**1.60**	(1.07)	**0.92**	(0.20)
		O	**0.55**	(1.10)	**0.56**	(0.52)	**0.69**	(0.87)	0.34	(0.06)
	150	I	**14.00**	(21.75)	**3.47**	(0.32)	**2.96**	(0.60)	**1.57**	(1.07)
		M	**2.51**	(2.13)	**2.86**	(0.60)	**2.04**	(0.44)	**1.31**	(0.70)
		O	**0.54**	(0.43)	**0.88**	(0.65)	**0.74**	(0.54)	0.44	(0.15)
	300	I	**1.33**	(1.30)	**2.03**	(1.55)	**1.61**	(1.22)	**0.71**	(0.37)
		M	**1.00**	(0.54)	**0.91**	(0.30)	**0.78**	(0.12)	0.45	(0.08)
		O	0.22	(0.25)	0.31	(0.19)	0.28	(0.35)	0.12	(0.03)

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

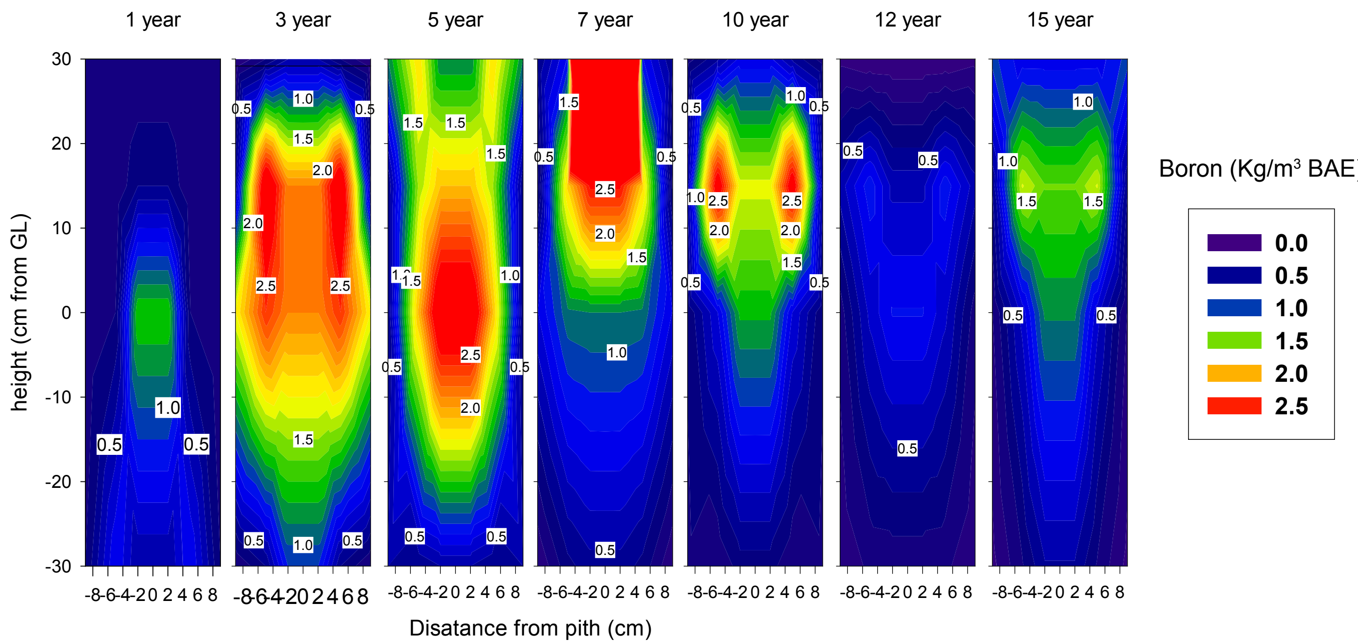


Figure I-13. Boron distribution (Kg/m³ BAE) in Douglas-fir poles 1 to 15 years after treatment with fused boron rods.

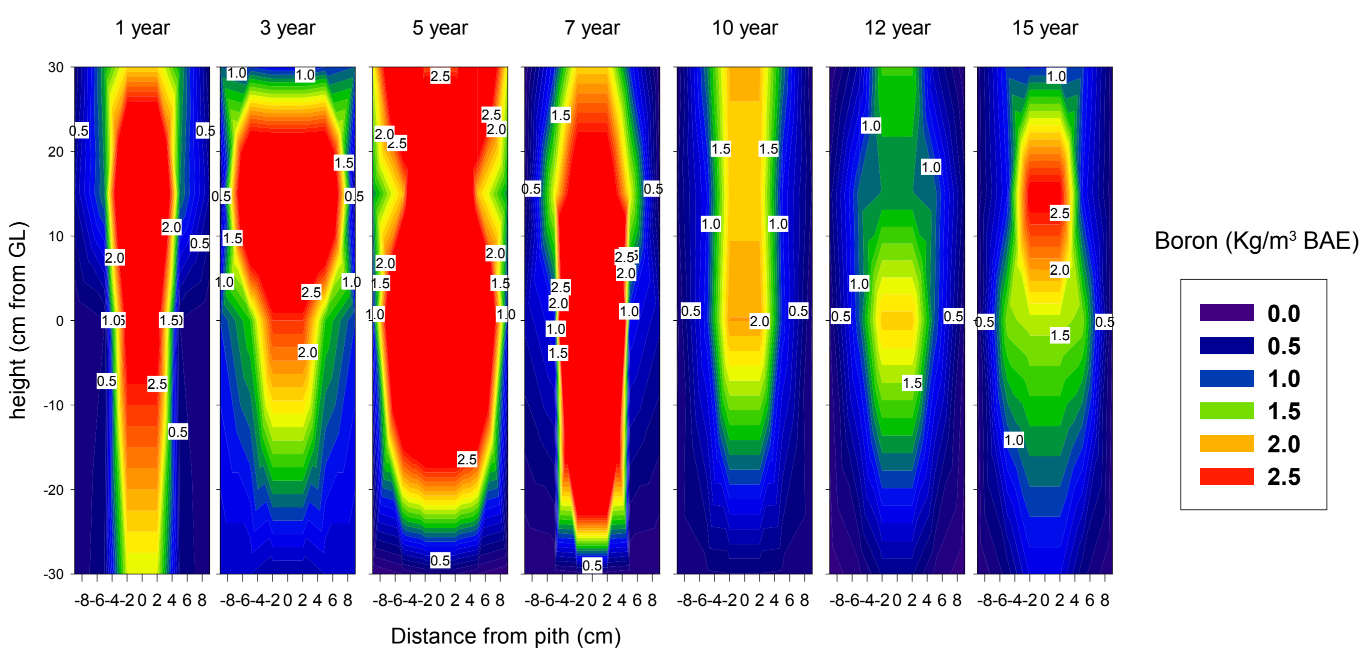


Figure I-14. Boron distribution (Kg/m³ BAE) in Douglas-fir poles 1 to 15 years after treatment with fused boron rods and Boracare.

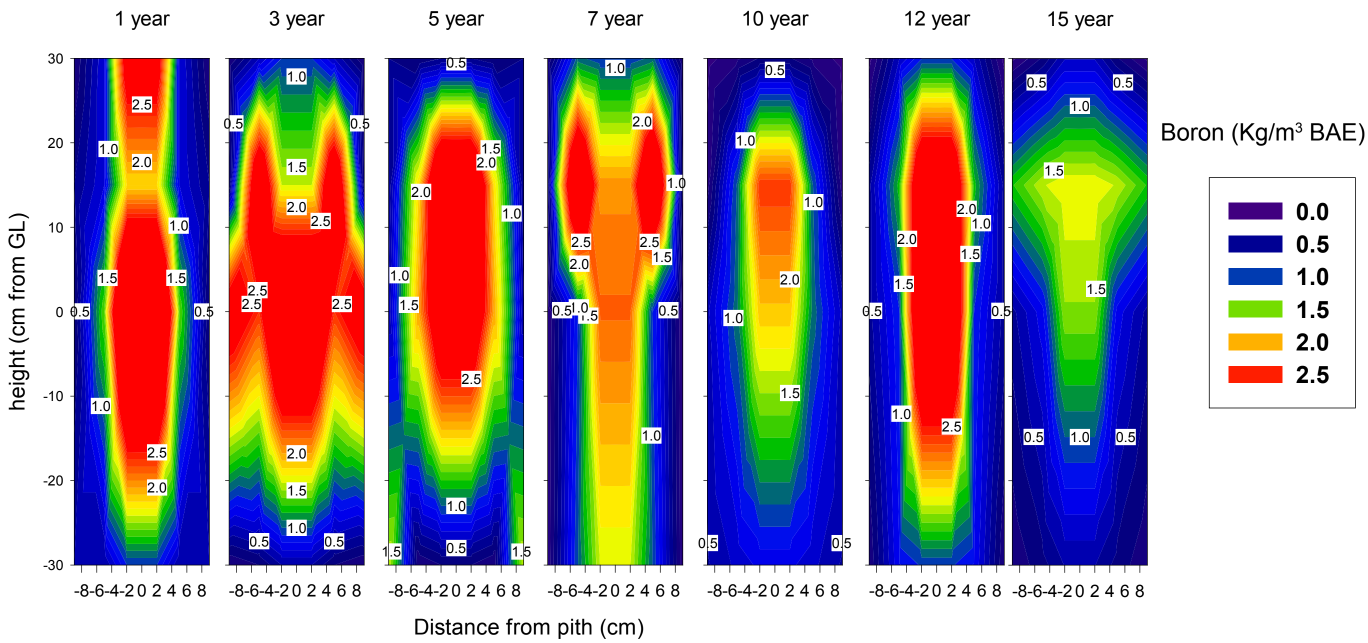


Figure I-15. Boron distribution (Kg/m^3 BAE) in Douglas-fir poles 1 to 15 years after treatment with fused boron rods and Boracol 20.

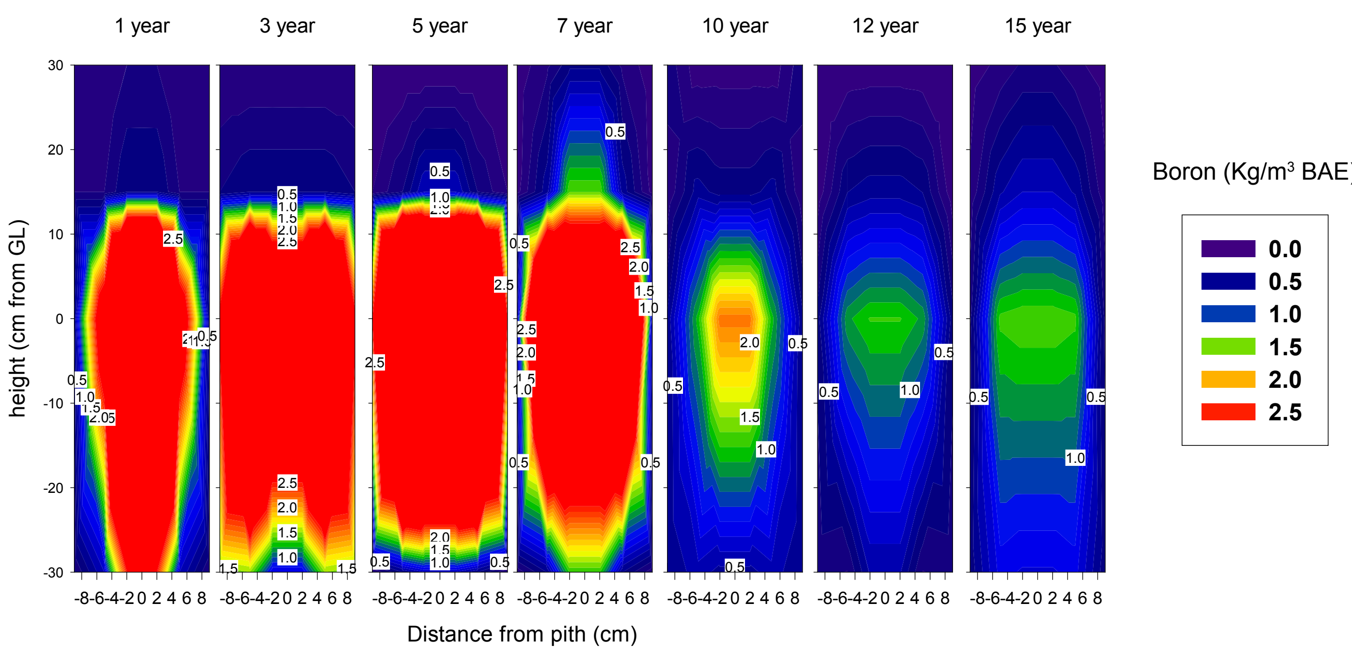


Figure I-16. Boron distribution (Kg/m^3 BAE) in Douglas-fir poles 1 to 15 years after treatment with fused boron rods and Boracol 40.

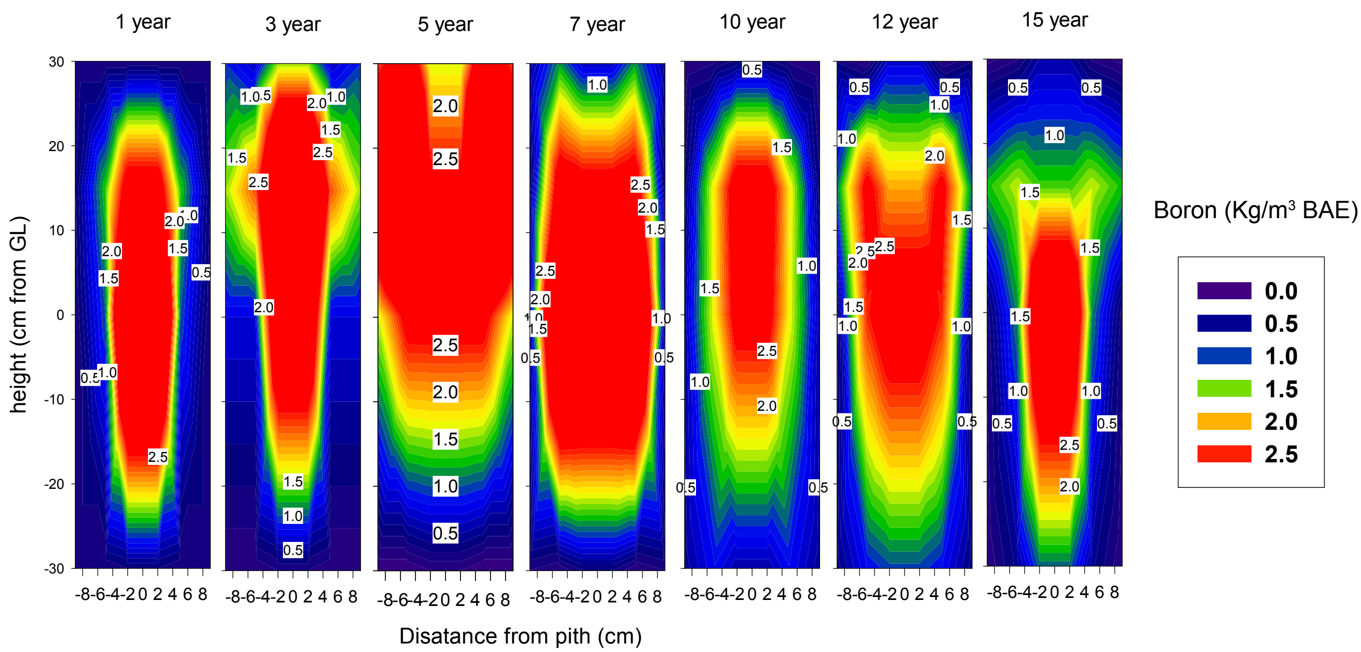


Figure I-17. Boron distribution (Kg/m^3 BAE) in Douglas-fir poles 1 to 15 years after treatment with fused boron rods and glycol.

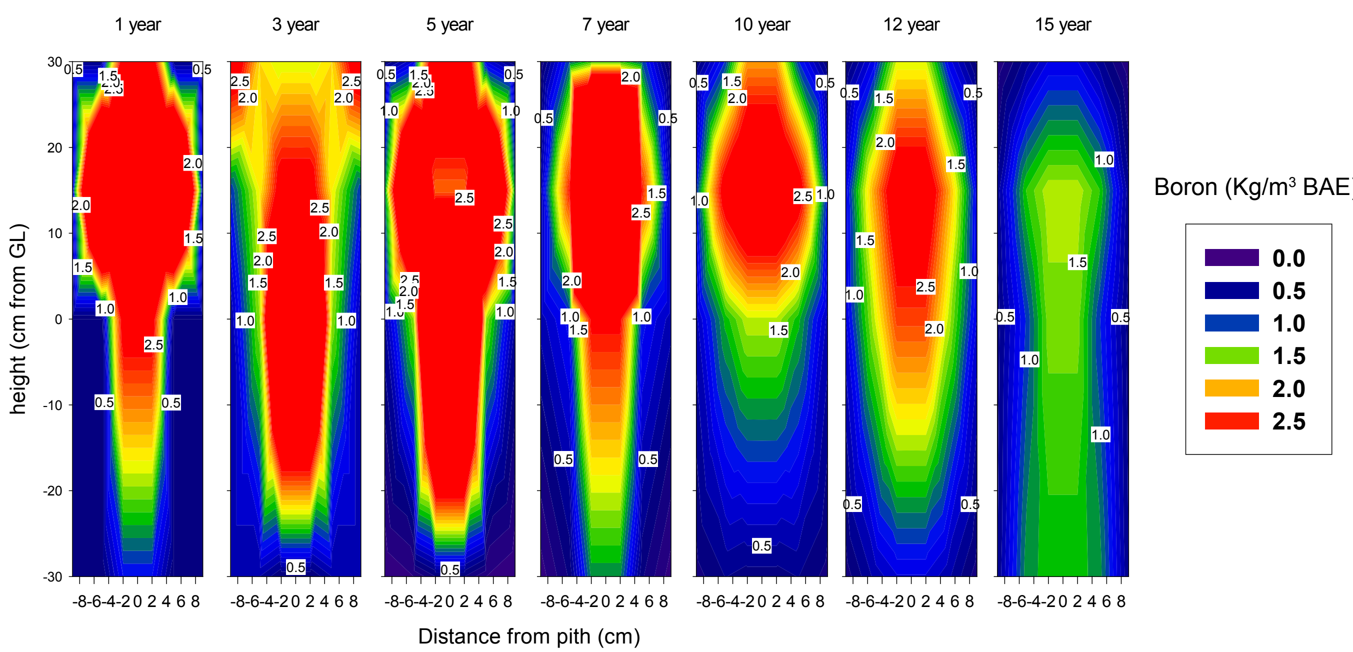


Figure I-18. Boron distribution (Kg/m^3 BAE) in Douglas-fir poles 1 to 15 years after treatment with fused boron rods and Timbor solution.

in the wood. It is unclear why this did not occur at the 12 year point, although one possibility would be that the Boracol 40 could not solubilize as much boron in the rods as the Boracol 20 and was therefore less effective as a mobilizing agent.

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

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

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

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

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

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

Chemical movement has assessed 1, 2, 3, 5, 7, 10, 12 and 15 years after treatment. The test was discontinued in 2008.

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

Date Established:	May 1995
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir, penta
Circumference @ GL (avg., max., min.)	97, 97, 81 cm

Fluoride has a long history of use as a water diffusible wood preservative and was long an important component in Fluor-Chrome-Arsenic-Phenol as well as in many external preservative pastes. Like boron, fluoride has the ability to move with moisture, but a number of studies have suggested that it tends to remain at low levels in wood even under elevated leaching conditions. Fluoride has also long been used in rod form for protecting the areas under tie plates on railway sleepers (ties) from decay. These rods may also have some application for internal decay control in poles.

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

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 can make it difficult to compare data from different trials.

We addressed this issue by establishing a single large scale test of all the EPA registered internal remedial treatments at our Corvallis test site (Table I-7).

Pentachlorophenol treated Douglas-fir pole stubs (280-300 mm in diameter by 2.1 m long) were set to a depth of 0.6 m. Three (for poles treated with diffusible rods) and four (for poles treated with fumigants) steeply sloping treatment holes (19 mm x 350 mm long) were drilled into the poles beginning at groundline and moving upward 150 mm and around the pole 120 degrees. The various remedial treatments were added to the holes at the recommended dosage for a pole of this diameter. The treatment holes were then plugged with removable plastic plugs. Copper nahpthenate (2%) was added to all dazomet treatments. The accelerant was poured onto the top of the dazomet in the treatment holes until the visible fumigant appeared to be saturated. No attempt was made to quantify the amount of copper naphthenate added to each treatment hole.

Chemical movement in the poles was assessed 18 and 30 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. 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

Product Name	Dosage/ pole	CuNaph (2% as Cu)	Common name	Active Ingredient
DuraFume	280 g	+	dazomet	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione
SUPER-FUME	280 g	+	dazomet	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione
UltraFume	280 g	+	dazomet	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione
Basamid	280 g	+	dazomet	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione
Basamid rods	264 g	+	dazomet	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione
MITC-FUME	120 g	-	methylisothiocya-nate	methylisothiocyanate
WoodFume	475 ml	-	metam sodium	Sodium N-methyldithiocarbamate
SMDC-Fume	475 ml	-	metam sodium	Sodium N-methyldithiocarbamate
Pol Fume	475 ml	-	metam sodium	Sodium N-methyldithiocarbamate
Chloropicrin	475 ml	-	chloropicrin	trichloronitromethane
Impel rods	238 g (345 g BAE)	-	boron rod	Anhydrous disodium octaborate
FLURODS	180 g	-	fluoride rod	sodium fluoride
PoleSaver rods	134 g	-	fluoride rod	disodium octaborate tetrahydrate, sodium fluoride

Table I-7. Remedial treatments evaluated in Douglas-fir poles at the Peavy Arboretum test site.

method appropriate for the treatment. The fumigants were analyzed by gas chromatography. Chloropicrin was detected using an electron capture detector while the MITC based systems were analyzed using a flame-photometric detector. The remainder of each core was plated on malt extract agar and observed for fungal growth. Boron based systems were analyzed using the Azomethine-H method; while fluoride based systems were analyzed using neutron activation analysis.

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 for protection against fungal attack is 20 ug/oven dried g of wood for fumigant based systems, both MITC and chloropicrin, 0.5 kg/m^3 of wood for internal decay control for boron and 0.10 kg/m^3 for fluoride (Freitag and Morrell 2005).

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-8; Figure I-19). 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 threshold 300, 450, and 600 mm above that level. MITC levels were 2 times the threshold in the inner zone 1 m above groundline, but just below threshold in the outer zone. The results indicate that the dazomet/copper naphthenate treatment

Table I-8. MITC or chloropicrin levels in Douglas-fir poles18 and 30 months after application of various internal remedial fumigant treatments as determined by gas chromatography of extracts of increment cores[1].

Treatment	Cu Naph	Mo	Height above groundline (mm)											
			-150				0				300			
			inner		outer		inner		outer		inner		outer	
Control	-	18	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
		30	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
Dazomet	+	18	**337**	(266)	**158**	(196)	**289**	(322)	**102**	(105)	**163**	(112)	**151**	(119)
		30	**253**	(257)	**78**	(73)	**366**	(278)	**78**	(60)	**201**	(139)	**109**	(77)
Dazomet rods	+	18	**283**	(260)	**181**	(347)	**254**	(166)	**51**	(73)	**159**	(66)	**95**	(115)
		30	**348**	(292)	**149**	(169)	**391**	(394)	**115**	(122)	**220**	(90)	**134**	(201)
DuraFume	+	18	**255**	(164)	**126**	(118)	**160**	(87)	**83**	(95)	**131**	(81)	**82**	(79)
		30	**297**	(232)	**106**	(88)	**333**	(359)	**79**	(55)	**212**	(201)	**72**	(44)
MITC FUME	-	18	**1868**	(1682)	**207**	(219)	**24710**	(88693)	**560**	(1335)	**2085**	(1906)	**372**	(430)
		30	**1773**	(1871)	**565**	(435)	**2328**	(1945)	**535**	(461)	**1318**	(1176)	**412**	(323)
Pol Fume	-	18	**132**	(74)	**63**	(56)	**661**	(1539)	**69**	(36)	**149**	(104)	**120**	(168)
		30	**53**	(30)	**47**	(49)	**52**	(36)	**40**	(37)	**50**	(23)	**47**	(24)
SMDS-FUME	-	18	**152**	(75)	**74**	(55)	**168**	(132)	**50**	(22)	**135**	(75)	**90**	(77)
		30	**76**	(50)	**48**	(27)	**75**	(41)	**40**	(19)	**64**	(28)	**45**	(24)
SuperFume Tubes	+	18	**173**	(152)	**50**	(77)	**121**	(85)	**46**	(46)	**91**	(72)	**54**	(47)
		30	**138**	(160)	**42**	(42)	**135**	(104)	**58**	(73)	**83**	(40)	**38**	(26)
UltraFume	+	18	**174**	(92)	**239**	(324)	**175**	(115)	**136**	(183)	**168**	(83)	**151**	(208)
		30	**229**	(188)	**318**	(821)	**300**	(198)	**136**	(162)	**195**	(85)	**170**	(204)
Wood Fume	-	18	**187**	(125)	**91**	(120)	**157**	(106)	**74**	(54)	**156**	(107)	**103**	(99)
		30	**68**	(52)	**38**	(32)	**75**	(61)	**45**	(45)	**57**	(40)	**37**	(24)
chloropicrin	-	18	**37096**	(134096)	**6052**	(11848)	**16347**	(24851)	**18001**	(25506)	**22498**	(27167)	**12951**	(16512)
		30	**12749**	(22396)	**4900**	(8571)	**1149**	(2837)	**1071**	(1895)	**6516**	(6511)	**1585**	(1853)

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

is performing well in test. MITC levels at 30 months were similar to those found at 18 months although there was some variation in levels at particular locations. Overall, however, the MITC distribution appeared to be similar at the two time points (Figure I-19).

MITC levels in the DuraFume plus copper naphthenate treated poles sections followed trends that were similar to the other two dazomet treatments although the MITC levels were somewhat lower 18 months after treatment (Figure I-19). MITC levels at this time 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. MITC levels 30 months after treatment had increased to levels similar to those found with the other two dazomet treatments suggesting that there was little difference in MITC levels among the three treatments.

MITC levels in poles treated 18 months earlier with UltraFume plus copper naphthenate were 8

Table I-8. (continued)MITC levels in Douglas-fir poles18 and 30 months after application of various internal remedial fumigant treatments as determined by gas chromatography of extracts of increment cores[1].

Treatment	Cu Naph	Mo	Height above groundline (mm)											
			450				600				900			
			inner		outer		inner		outer		inner		outer	
Control	-	18	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)	0	(0)
		30	0	(0)	0	(0)	0	(0)	0	(0)	1.2	(3.6)	0	(0)
Dazomet	+	18	**148**	(112)	**167**	(205)	**107**	(99)	**123**	(206)	**47**	(30)	19	(12)
		30	**165**	(102)	**93**	(55)	**142**	(110)	**106**	(95)	**75**	(38)	**48**	(46)
Dazomet rods	+	18	**147**	(55)	**118**	(168)	**97**	(53)	**53**	(69)	**49**	(36)	9	(21)
		30	**153**	(55)	**84**	(64)	**114**	(52)	**72**	(82)	**79**	(37)	**29**	(23)
DuraFume	+	18	**132**	(59)	**105**	(109)	**99**	(86)	**90**	(134)	**45**	(22)	**27**	(37)
		30	**120**	(73)	**57**	(37)	**92**	(51)	**49**	(23)	**58**	(34)	**32**	(18)
MITC FUME	-	18	**1574**	(2239)	**360**	(332)	**840**	(673)	**283**	(214)	**848**	(764)	**235**	(208)
		30	**882**	(932)	**292**	(236)	**904**	(1066)	**330**	(279)	**662**	(589)	**261**	(250)
Pol Fume	-	18	**136**	(76)	**123**	(111)	**118**	(61)	**78**	(58)	**65**	(29)	**35**	(26)
		30	**51**	(26)	**39**	(20)	**53**	(26)	**45**	(23)	**41**	(22)	**23**	(19)
SMDS-FUME	-	18	**144**	(112)	**71**	(52)	**114**	(89)	**61**	(47)	**72**	(51)	**24**	(23)
		30	**56**	(26)	**37**	(19)	**49**	(20)	**31**	(16)	**52**	(37)	**25**	(15)
SuperFume Tubes	+	18	**60**	(22)	**60**	(44)	**39**	(17)	**38**	(30)	**35**	(72)	16	(19)
		30	**54**	(21)	**31**	(15)	**37**	(19)	**24**	(22)	**25**	(10)	12	(11)
UltraFume	+	18	**112**	(51)	**113**	(134)	**98**	(72)	**77**	(65)	**59**	(69)	**26**	(20)
		30	**156**	(79)	**103**	(112)	**127**	(74)	**87**	(64)	**76**	(47)	**39**	(24)
Wood Fume	-	18	**127**	(79)	**85**	(112)	**129**	(62)	**100**	(112)	**95**	(48)	**46**	(60)
		30	**53**	(34)	**35**	(21)	**48**	(25)	**33**	(26)	**55**	(28)	**32**	(30)
chloropicrin	-	18	**9263**	(14788)	**6772**	(13209)	**3429**	(6239)	**606**	(853)	**795**	(780)	**86**	(181)
		30	**424**	(1009)	**2307**	(5072)	**3582**	(4241)	**1129**	(1819)	**3691**	(11390)	**278**	(339)

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

to 11 times threshold 150 mm below groundline and declined only slightly at groundline and 300 mm above that zone (Figure I-19). MITC levels were 3 to 5 times threshold 450 and 600 mm above groundline and 1-2 times threshold 900 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 30 months after treatment had risen considerably and were similar to those found with the other dazomet based treatments. It is unclear why this system had slightly lower MITC levels at the first sampling point although there are some slight differences in formulation density that might affect decomposition.

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 at the18 month sampling (Figure I-20). 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 900 mm above groundline but below on the outer. As with the granular dazomet, the system appears to be well distributed through the test poles at fungitoxic levels.

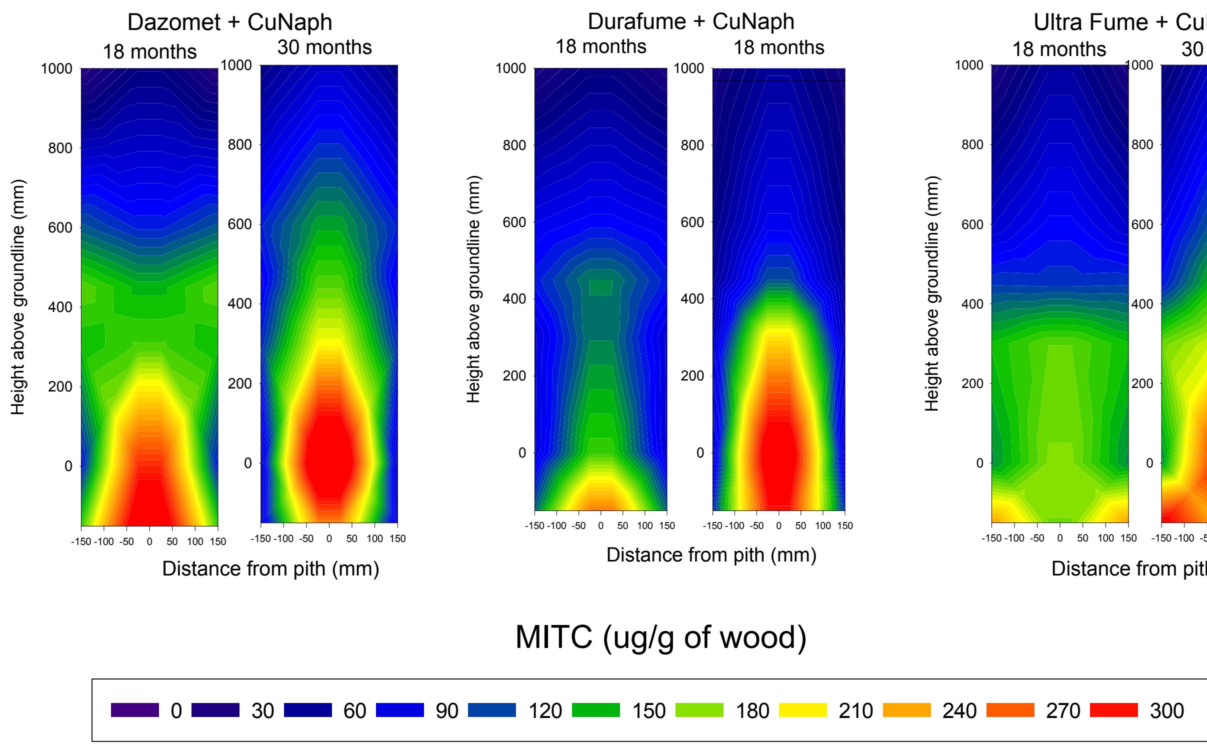


Figure I-19. Distribution of MITC in Douglas-fir poles sections 18 and 30 months after treatment with dazomet plus copper naphthenate, DuraFume plus copper naphthenate or UltraFume plus copper naphthenate.

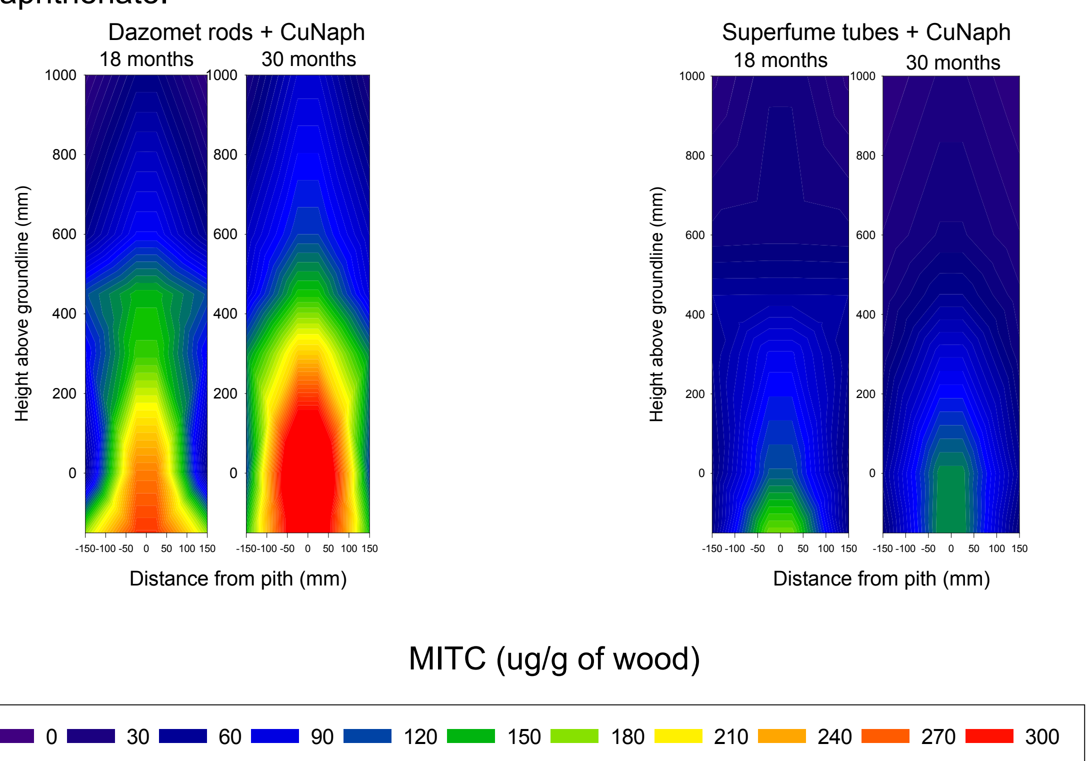


Figure I-20. Distribution of MITC in Douglas-fir poles sections 18 and 30 months after treatment with dazomet rods plus copper naphthenate or SUPER-FUME tubes plus copper naphthenate.

Chemical levels at 30 months appeared to be higher than those found at 18 months, suggesting that the rod formulation had no negative effect on release rate.

MITC levels in poles treated 18 months earlier 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 (Figure I-20). 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 at 30 months remained lower in comparison with those found with the other dazomet based systems. In our previous trials, we found relatively little effect of the tube on dazomet decomposition as measured by MITC levels; however, the tube did appear to have a negative effect on performance in this test. This suggests that the tube might improve handling safety during application; however, these potential benefits are out-weighed by the negative effects on MITC release rate.

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 18 months after treatment (Figure I-21). The elevated MITC levels in the inner zone continued through groundline to 900 mm 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 sublimes directly from a solid to a gas and can move rapidly into the wood. The results indicate that the MITC-FUME

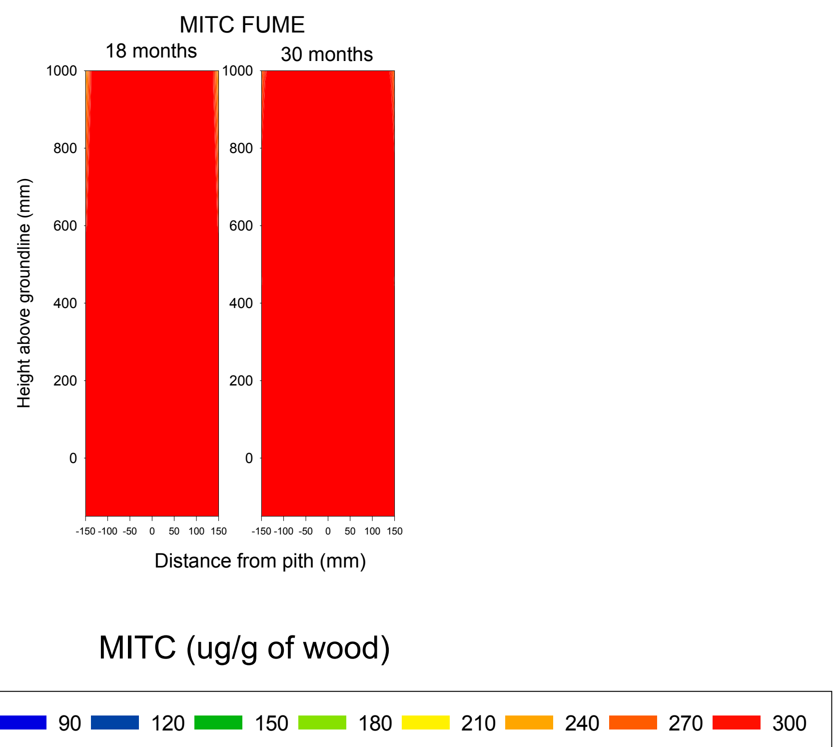


Figure I-21 Distribution of MITC in Douglas-fir poles sections 18 and 30 months after treatment with MITC-FUME.

has produced exceptional levels of protection at all sampling locations18 months after treatment. Although MITC levels 30 months after treatement had declined they were still 5 to 6 times those found with dazomet based treatements near the groundline zone and averaged 40 times the threshold. Clearly, MITC-FUME delivers a substantial pulse of chemical to the treated zone that should be capable of eliminating virtually all fungi present.

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 18 months earlier 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-22). Chemical levels were 5 to 7 times threshold 300 and 450 mm above groundline and 1 to 5 times threshold between 600 mm and 900 mm. Protective levels were found at all sampling locations. MITC levels in these same poles had declined substantially 30 months after treatment, although chemical levels remained above the threshold for fungal protection 900 mm above the groundline. The fairly steep decline in MITC levels is characteristic of metam sodium treatment.

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 and a sharp decline 30 months after treatment (Figure I-22). These results indicate that metam sodium-based treatments provide a relatively quick, large pulse of MITC followed by a fairly sharp decline in residual protection.   This behavior is consistent with the

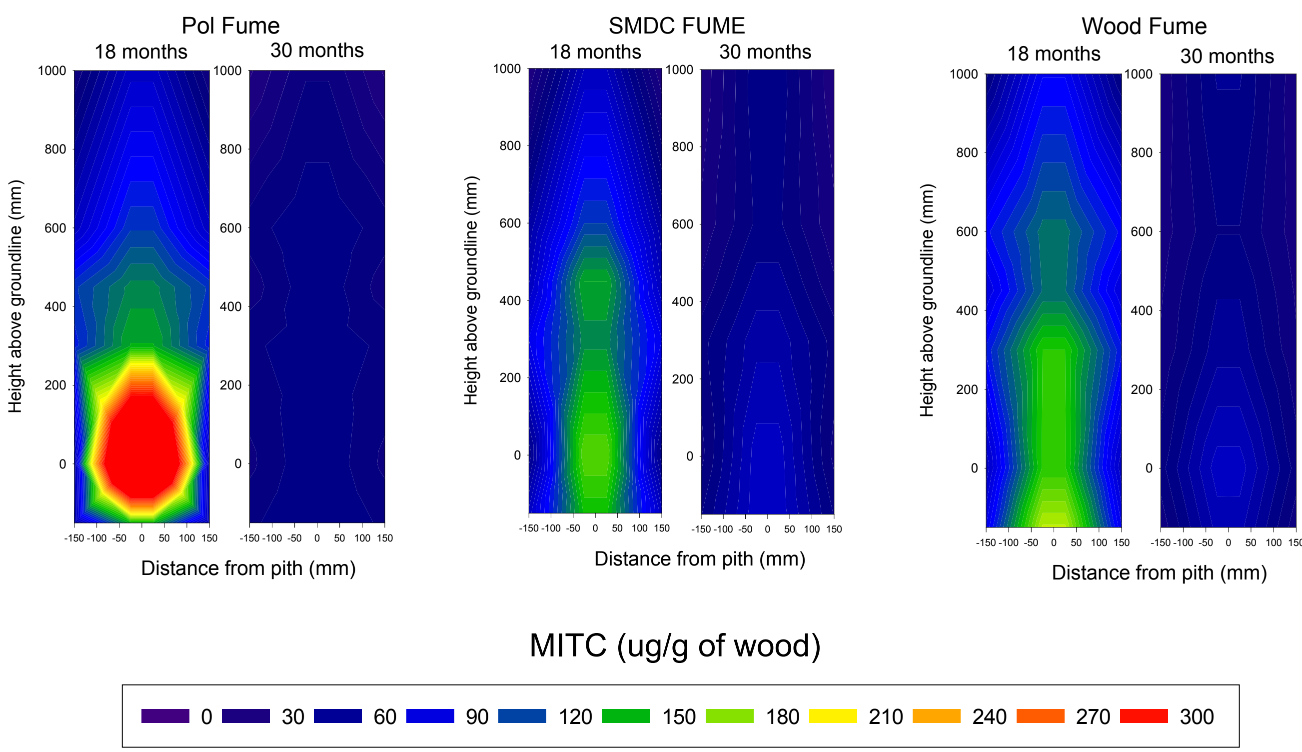


Figure I-22. Distribution of MITC in Douglas-fir poles sections 18 and 30 months after treatment with Pol-Fume, SMDC-Fume, or WoodFume.

tendency for decay fungi to begin to re-colonize metam sodium treated poles 5 to 7 years after treatment, although these fungi do not appear to cause substantial decay at this time. The relatively ephemeral nature of metam sodium should be considered whenever utilities are contemplating extending their inspection/remedial treatment program.

Chloropicrin levels in poles treated with this fumigant were several orders of magnitude greater than the threshold in the groundline region and still well above the threshold well above the zone 18 months after treatment (Table I-8, Figure I-23). The extremely high chemical levels associated with this treatment are consistent with previous tests and illustrate why this chemical is effective in poles for many years. Previous studies have found chloropicrin to be present at fungitoxic levels up to 20 years after treatment. Unfortunately, handling aspects and labeling requirements limit the use of this chemical to transmission poles in remote locations, but the results illustrate why chloropicrin remains desirable to use in these locations.

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 at both sampling times.

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-9). Boron levels were above threshold in the outer zones of the same poles 300 mm above groundline (Figure I-24). In general, boron is not widely distributed in these poles beyond the groundline at levels that would confer protection. These results are typical for water-based systems, which require longer time periods to become effective.

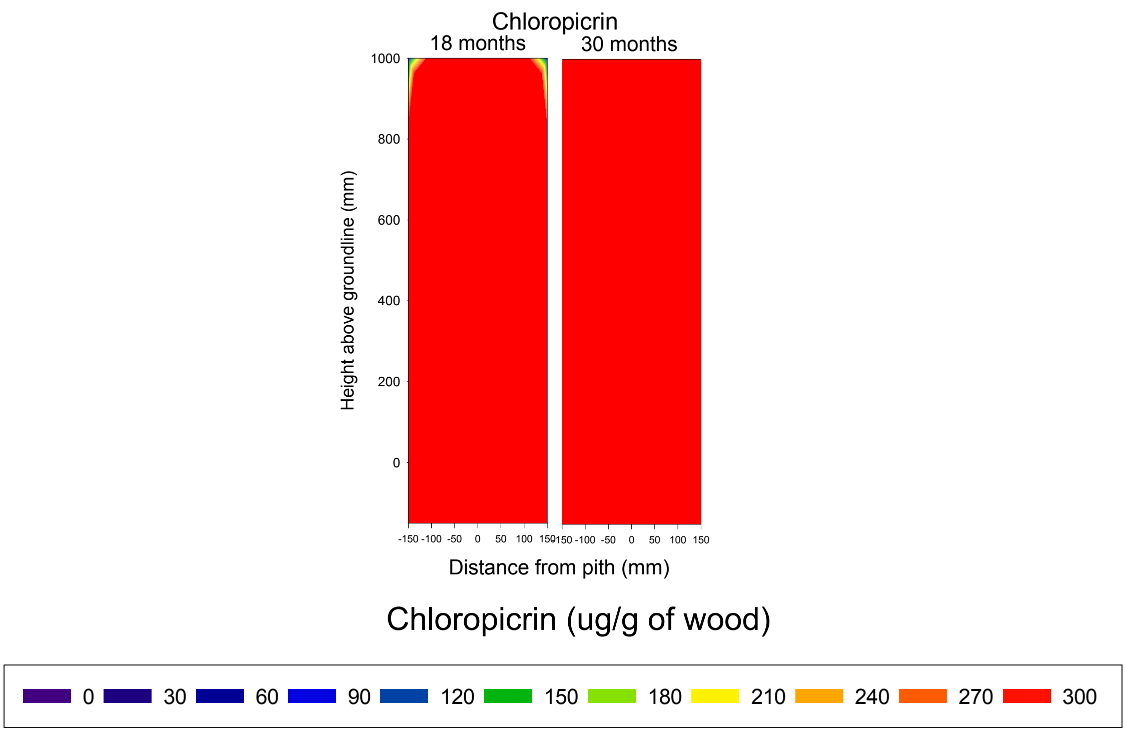


Figure I-23 Distribution of chloropicrin in Douglas-fir poles sections 18 and 30 months after treatment.

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 18 months after treatment (Table I-9; Figure I-24). Boron levels remained elevated in these same zones 30 months after treatment suggesting that the treatment was providing groundline protection. The test site is extremely wet and it was interesting to note that boron levels in the outer zone 150 mm below groundline remained below the threshold. This suggests that the higher moisture levels at this site may negate the effects of boron near the surface below ground. However, boron levels inside the wood do appear to be at effective levels.

Fluoride levels in poles 18 months after treatment with FLURODS were well above the threshold in the inner and outer sampling zones at groundline and 150 mm below groundline, indicating that the fluoride had rapidly moved from the rods into the surrounding wood (Table I-10). Fluoride was at background levels 300 mm above groundline indicating that little fluoride moved upward from the point of application. Fluoride levels declined markedly in the inner zone 150 mm below groundline 30 months after treatment, but remained the same in the outer zone. Fluoride levels increased markedly in the inner zone at groundline at the same sample time, but remained relatively unchanged in the outer zone. The results indicate that fluoride has moved well into the wood in the treatment zone of the poles.

Fluoride analyses are only available from the 30 month sampling for poles treated with PolSaver

Table I-9. Boron levels at various distances above and below the groundline in Douglas-fir poles 18 and 30 months after application of Impel or Pol Saver rods[1].

Treatment	Year	Height above groundline (mm)					
		-150		0		300	
		inner	outer	inner	outer	inner	outer
Control	1	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	2	0.07 (0.02)	0.07 (0.02)	0.07 (0.02)	0.06 (0.00)	0.08 (0.03)	0.08 (0.04)
Impel rods	1	**2.59** (1.44)	0.37 (0.35)	**7.68** (10.11)	0.16 (0.20)	0.02 (0.03)	**0.97** (2.17)
	2	**6.67** (8.01)	0.39 (0.40)	**1.30** (0.47)	**2.14** (3.60)	0.16 (0.13)	0.15 (0.14)
Pol Saver rods	1	**0.84** (0.11)	0.14 (0.24)	**7.50** (4.55)	**0.61** (0.74)	0.00 (0.00)	0.04 (0.08)
	2	**1.54** (1.98)	0.31 (0.18)	**4.44** (4.86)	**1.28** (0.57)	0.18 (0.01)	0.18 (0.11)

Treatment	Year	Height above groundline (mm)			
		450		600	
		inner	outer	inner	outer
Control	1	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	2	0.10 (0.03)	0.06 (0.01)	0.08 (0.00)	0.07 (0.02)
Impel rods	1	0.02 (0.03)	0.02 (0.03)	0.02 (0.04)	0.00 (0.01)
	2	0.07 (0.04)	0.10 (0.09)	0.07 (0.03)	0.05 (0.02)
Pol Saver rods	1	0.02 (0.04)	0.06 (0.06)	0.02 (0.03)	0.03 (0.04)
	2	0.12 (0.01)	0.09 (0.03)	0.09 (0.03)	0.07 (0.03)

1. Numbers in parentheses represent one standard deviation around the mean of three measurements for the control and Pol Saver treatments and five measurements for Impel rods.

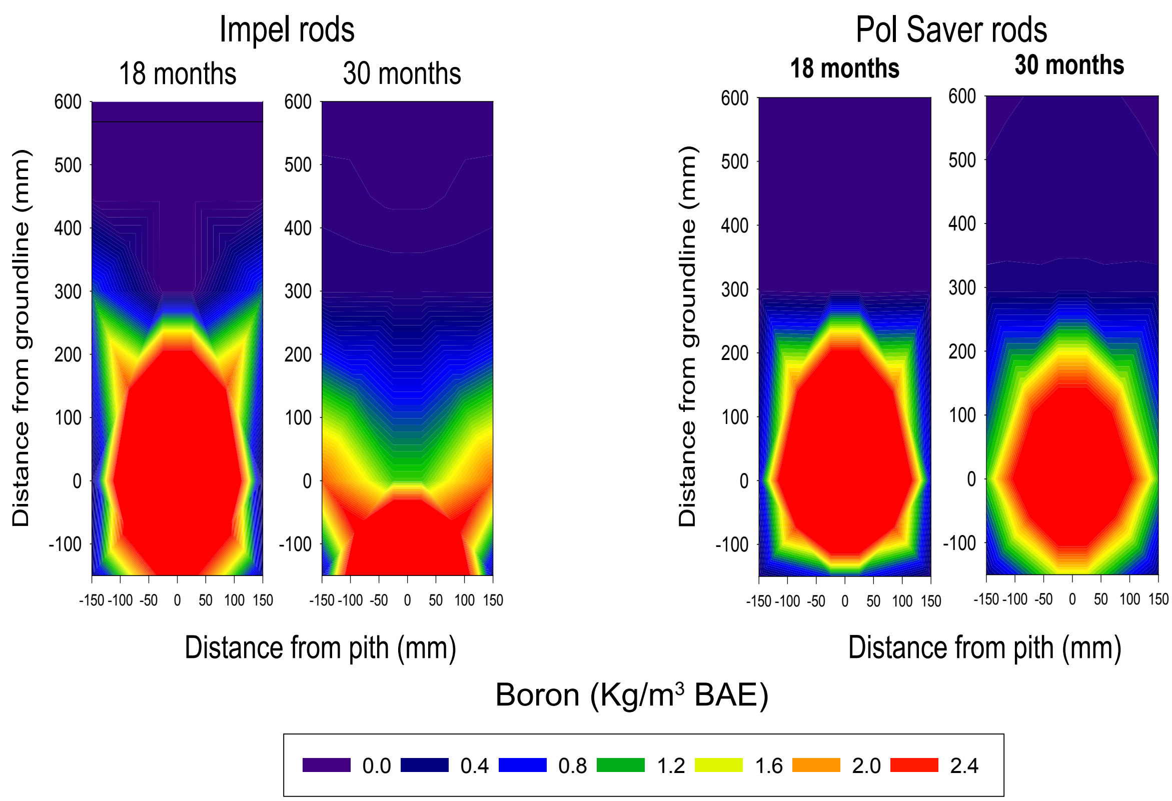


Figure I-24. Boron distribution in Douglas-fir poles 18 and 30 months after application of Impel or Pol Saver rods.

Table I-10. Residual fluoride levels in Douglas-fir pole sections 18 and 30 months after application of FLURODS or Pol Saver rods.

Treatment	Months	Fluoride Content (kg/m3)					
		-150 mm		Groundline		300 mm	
		inner	outer	inner	outer	inner	outer
FLURODS	18	1.01	0.12	0.36	0.39	0.05	0.02
	30	0.38	0.15	0.91	0.31	0.00	0.03
Pol Saver rods	18	-	-	-	-	-	-
	30	0.11	0.05	0.63	0.20	0.00	0.00

Rods. These results indicate that fluoride was present at protective levels in the inner zones 150 mm below groundline as well as in both the inner and outer zones at groundline (Table I-12). Fluoride levels 150 mm below groundline were much lower than those found with the FluRods, while those at groundline were only slight lower. As with the FluRod treatment, there was no evidence of fluoride movement 300 mm above groundline.

The results indicate that the fluoride based systems are moving into the poles at levels capable of providing fungal protection within the groundline and, with one system, slightly below that zone.

Fungal isolations remain low in all treatments, although some decay fungi have been isolated from non-remedially treated controls 18 and 30 months after treatment (Table I-11). Some decay fungi have also been isolated at scattered locations in treated poles, but the levels remain low and inconsistent.

D. Ability of Internal Remedial Preservative Systems to Migrate into Distribution Poles in an Arid Climate

The majority of internal remedial treatment trials established by the UPRC have been established in areas with mild, wet climates. Although these materials are used extensively in dry, cold climates we do not have data on their movement and effectiveness under these conditions.

We recently established a field trial of selected EPA registered internal remedial treatments on in-service distribution poles in the Rocky Mountain Power service district south of Salt Lake City, Utah to examine this issue.

Distribution poles that have been in service for at least 10 years and that had not previously received an internal remedial treatment were selected for the test. The poles were treated with oil-based preservatives. Poles were randomly allocated to a given treatment and each treatment was replicated on six poles.

The treatments were:

Dazomet with accelerant (2% elemental copper)
Dazomet w/o accelerant
MITC FUME
Metam sodium
Fused boron rods with accelerant (water)
Fused boron rods w/o accelerant
Non-treated control

Three steeply sloping treatment holes (19 mm x 350 mm long or 250 mm long for rods) were drilled into the poles beginning at groundline and moving upward 150 mm and around the pole 120 degrees. The various remedial treatments were added to the holes at the recommended dosage for a pole of this diameter, along with any recommended additive, and then the holes were plugged with plastic plugs. The non-treated control poles were not drilled.

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

Table I-11. Isolation frequencies of decay and non-decay fungi from pentachlorophenol treated Douglas-fir poles 18 and 30 months after treatment with selected internal remedial treatments.[1]

Treatment	Cu Naph	Year	Height above groundline (mm)					
			-150	0	300	450	600	900
Fumigant Control	-	1	33^{17}	17^{0}	0^{0}	0^{0}	0^{0}	0^{0}
		2	33^{50}	33^{50}	17^{17}	0^{17}	0^{17}	0^{0}
Dazomet	+	1	0^{7}	0^{0}	7^{13}	0^{7}	0^{7}	0^{7}
		2	0^{0}	0^{0}	0^{0}	0^{7}	0^{0}	0^{0}
Dazomet rods	+	1	0^{0}	0^{7}	0^{0}	0^{0}	0^{0}	0^{7}
		2	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}
DuraFume	+	1	0^{7}	0^{7}	0^{0}	0^{0}	0^{7}	0^{7}
		2	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}
MITC FUME	-	1	0^{0}	0^{13}	0^{0}	0^{0}	0^{0}	0^{0}
		2	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}
Pol Fume	-	1	0^{0}	0^{7}	0^{7}	0^{13}	0^{0}	0^{20}
		2	0^{0}	0^{13}	0^{0}	0^{0}	0^{0}	0^{7}
SMDS-FUME	-	1	0^{0}	0^{13}	0^{7}	0^{7}	0^{13}	0^{7}
		2	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}
SuperFume Tubes	+	1	0^{0}	0^{0}	0^{13}	0^{7}	0^{0}	0^{7}
		2	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}
UltraFume	+	1	0^{0}	0^{0}	0^{20}	0^{7}	0^{7}	0^{0}
		2	0^{0}	0^{0}	0^{0}	0^{7}	0^{0}	0^{7}
Wood Fume	-	1	0^{0}	0^{0}	0^{0}	0^{0}	0^{20}	0^{7}
		2	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}
Chloropicrin		1	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}
		2	0^{7}	7^{0}	0^{0}	0^{0}	0^{0}	7^{0}
Diffusible Control		1	0^{0}	14^{0}	0^{0}	0^{0}	0^{0}	0^{0}
		2	22^{56}	33^{11}	0^{22}	0^{0}	0^{22}	0^{0}
Impel rods		1	0^{7}	0^{8}	0^{18}	0^{8}	0^{7}	0^{0}
		2	7^{47}	0^{7}	0^{27}	7^{33}	0^{47}	0^{0}
Pol Saver rods		1	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}
		2	0^{67}	0^{0}	0^{33}	0^{44}	0^{44}	0^{0}
FLURODS		1	0^{0}	0^{0}	0^{20}	0^{40}	0^{13}	0^{0}
		2	0^{13}	0^{0}	0^{47}	0^{60}	0^{60}	0^{0}

1. Values represent the percent of 6 (fumigant control), 9 (diffusible control and Pol Saver) or 15 (all others) attempts yielding fungal cultures per treatment. Superscripts denote non-decay fungi.

E. Effects of Remedial Internal Treatments on Drywood Termites

Over the past 3 decades, fumigants have been extensively studied for their ability to control internal fungal decay in utility poles, but there has been little study on their efficacy against various wood inhabiting insects. Early field trials by the Bonneville Power Administration noted that subterranean termites were killed by application of chloropicrin or metam sodium, however, the chemicals were applied directly to the infested area and the observations were anecdotal, rather than the result of systematic attempts to use fumigants to control insects. In field trials in New York on CCA -treated Douglas-fir poles, gelatin encapsulated methylisothiocyanate and Vorlex treatments were found to have little effect on carpenter ants. The ants tended to move up and away from the treatment zone, but were otherwise unaffected by the treatment. Carpenter ants pose a special challenge for utilities because they inhabit but do not consume wood. As a result, carpenter ants are often less affected by preservative treatments. They are also fairly mobile in terms of colony location, making it less likely that a fixed treatment at groundline will eliminate a colony.

Unlike carpenter ants, termites are more confined in their nests but there may be differences in susceptibility within termite groups. For example, subterranean termites excavate tunnels through an area of soil and then move upward whenever they contact suitable woody biomass. Thus, most of the colony is probably not present in the utility pole, but is instead spread across the area. Fumigant treatment is likely to kill any workers in close proximity to the treatment, but most other workers and the queen are less likely to be affected. Other workers are also likely to seal off the treated area. As a result, the infestation may be controlled for a time, but workers will later re-explore the pole as the chemical levels decline. Thus, internal treatments may be only temporarily effective against these termites.

The group that is most likely to be affected by internal treatments is the drywood termite (Kalotermidae). These insects inhabit dry wood (<12 % moisture content) in the desert U.S. southwest, although they are reported to range from Oregon to California (McKern et al., 2007). Drywood termites are commonly found in dead branches in trees and utility poles provide a similar habitat. These insects are difficult to detect until the damage is severe and their presence high up the pole makes detection difficult.

As noted, there is little data on the ability of internal remedial treatments to affect drywood termites. This past year, we initiated controlled laboratory trials to assess the ability of methylisothiocyanate (MITC) to affect drywood termites. The procedures were a modification of those described by Indrayani et al. (2007)

Douglas-fir sapwood blocks (30 by 30 by 50 mm long) with 10 mm diameter and 40 mm deep holes drilled through one end grain were conditioned to stable moisture contents, then 18 *Incisitermes minor* pseudergates were added to each hole. The holes were then covered with a stainless steel mesh screen and the blocks were incubated over salt solutions designed to produce wood at 12 % moisture content (Figure I-25). Each block was placed in an individual jar. The blocks were incubated for 8 weeks to allow the termites to become conditioned and begin to feed on the wood. Three chambers were left as controls, then the remainder received measured amounts of MITC that, based upon previous studies, should produce MITC levels in the wood of 5, 10, 20 or 100 ug/oven-dried g of wood (Zahora and Morrell, 1989).

The blocks were then incubated at 32 C with minimal air-exchange designed to allow the workers to survive but to minimize MITC loss. These tests are still underway, however, once they are complete, the blocks will be opened, the workers removed and counted to determine how many died during exposure. The blocks will then be extracted in ethyl acetate and the extract analyzed for MITC. The blocks will then be reconditioned to the original moisture content to determine wood weight loss caused by termite exposure. The results should provide some guidance concerning the levels of necessary in wood to arrest drywood termite attack. These levels can then be compared with previous assessments of MITC levels in poles associated with metam sodium, dazomet and MITC-FUME treatments to determine if these levels can be achieved.

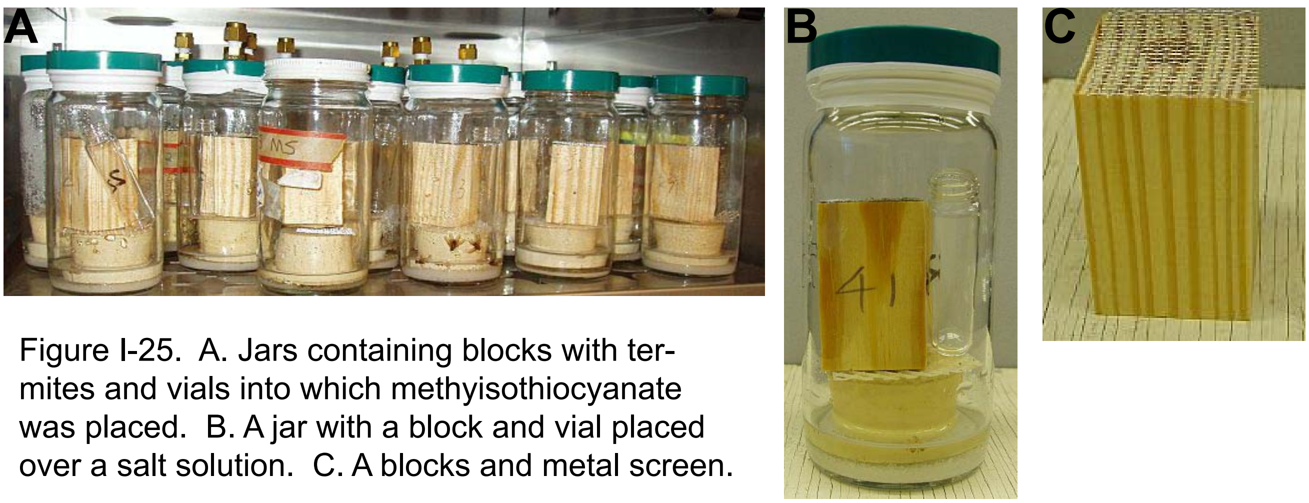


Figure I-25. A. Jars containing blocks with termites and vials into which methyisothiocyanate was placed. B. A jar with a block and vial placed over a salt solution. C. A blocks and metal screen.

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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 between the treated and non-treated zones can all expose non-treated wood to possible biological attack. The Standards of the American Wood Protection Association currently recommend that all field damage to treated wood be supplementally protected with solutions of copper naphthenate. While this treatment will never be as good as the initial pressure treatment, it provides a thin barrier that provides protection 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 and corrosion issues 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

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[1].

Treatment	Diffusion	Degree of Chemical Movement (mm)					
		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)

1. Numbers in parenthses 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[1].

Treatment	Diffusion	Degree of Chemical Movement (mm)					
		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)

1. Numbers in parenthses represent one standard deviation.

no motivation for following the specification.

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

The potential for these treatments was evaluated using both field and laboratory tests. In the initial laboratory tests, bolts were coated with either copper naphthenate (Cop-R-Nap) or copper naphthenate plus boron (CuRap 20) pastes and installed in Douglas-fir pole sections which were stored for one or two weeks at 32 C. The poles were then split through the bolt hole and the degree of chemical movement was assessed using specific chemical indicators (AWPA, 2006 a-c). Penetration was measured as average distance up or down from the bolt.

The results, to date, show that the coated bolts 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. The last of the pole stubs in this trial were sampled in 2009 and this test is now complete.

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OBJECTIVE III

EVALUATE PROPERTIES AND DEVELOP IMPROVED SPECIFICATIONS FOR WOOD POLES

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

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

Over the past 6 years, we have undertaken a series of full scale bending tests to assess the effects of various methods for improving treatment in the groundline zone on flexural properties. Three tests have been completed. In the first, 139 Class 4 forty foot long Douglas-fir poles were tested. Poles were left non-bored, or received 0.25, 0.5, 0.75 or 1.00 diameter holes in the groundline zone. These data showed that through-boring had no significant negative effects on flexural properties when the holes were 0.50 inches in diameter or less and the data were used to support the inclusion of through-boring in the ANSI 05.1 Standard. The committee reviewing the data asked for additional testing to assess the impact of loading perpendicular to the through-boring hole direction. A second test was performed in which poles with the same through-boring pattern used in the initial test along with poles that were radial drilled or deep incised were tested to failure. Non-bored control poles were not included in this test. This test showed that there was no significant difference in modulus of rupture at groundline (MOR-GL) between the three treatments; however, MOR-GL was much lower than that found in the original trial. The poles in the second study were obtained from a widely dispersed pole population, while those in the first test were obtained from a narrow geographic area in southern Oregon. In addition, the lack of non-bored controls in the second test made it difficult to compare results from the two trials. These concerns led us to include poles with no groundline boring along with poles that were radial drilled or through-bored in the third test in which through-bored poles were tested with the load applied perpendicular or parallel to the holes.

In all three tests, freshly peeled, green Class 4-40 foot long poles were obtained and randomly allocated to a given treatment. 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 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 used in test #2, 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 27-30 poles. The poles in the first two tests were supplied as 40 foot sections, and each pole was cut into a 20 foot long section for testing. The poles in the third test were supplied in 20 foot lengths. Pole circumference was measured at the butt, the theoretical groundline (10 % of pole length plus 2 feet), 20 feet and the tip.

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 or the inspection holes while maintaining a nearly constant moment in the high moment zone so that the bending moment at failure could be accurately calculated (Figures III-1, 2). The test setup was a modification of that described by Crews et al. (2004).

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

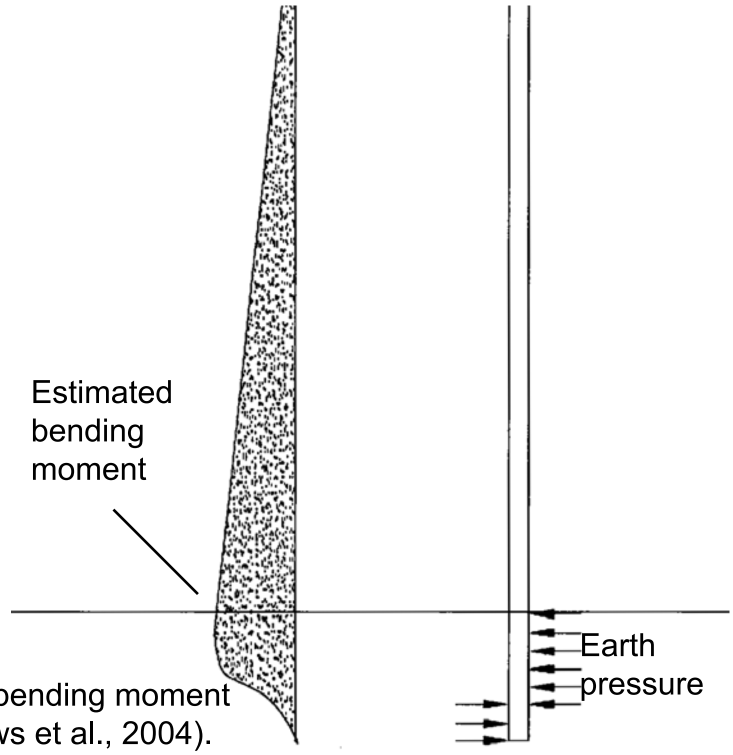


Figure III-2. Estimated true bending moment for an embedded pole (Crews et al., 2004).

The poles were tested as simply supported beams with two point loads applied near the assumed groundline. The end bearing points allow the pole to rotate as well as move longitudinally. Wood saddles were used at the bearing points, as well as the points of loading. 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 4 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).

A 200-kip capacity hydraulic actuator mounted on a steel portal frame attached to the laboratory strong floor was used to apply the load to the poles. The load was displacement-controlled and the rate of loading was .01 in. /sec. This rate was estimated from the D1036 (ASTM 2004). 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 complied 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. A single cross section was cut near the failure zone and weighed before being oven-dried and reweighed. The difference between initial and final weight was used to determine wood moisture content. The dry section was then used to determine the number of annual rings in the outer 2 inches as well as the total number of rings in the cross section.

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.

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.

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

P = the load applied at the point of measured deflection (kips)

Δ = the displacement measured at the failure point (in.)

d = the diameter measured at the failure point (in.)

In Test # 1, MOR gradually declined with increasing hole size, while the presence of holes appeared to reduce the variability in MOR at GL (Table III-1, Figure III-3). It was suggested that reduced variance was due to the holes acting as consistently located stress points in place of more randomly positioned knots. Statistical analysis of the data indicated that MOR did not differ significantly from the non-drilled control for 0.25 and 0.5 in diameter holes. These tests led to the decision to use 0.5 inch diameter holes in the proposed through-boring pattern submitted to ANSI.

In test # 2, poles were through-bored, radial drilled or deep incised in the groundline zone prior to testing (Table III-1). The lack of an effect through-boring 0.5 inch holes in Test # 1 led us to only test through-bored poles perpendicular to grain direction in order to answer the questions raised by the ASC committee. We included the other groundline preparation techniques because we were also interested in seeing these included in ANSI 05.1. We, regrettably, chose not to include controls.

t-Tests comparing radial drilling, deep incising, and through-boring showed that MOR at groundline was significantly lower in through-bored poles tested with the holes perpendicular to the loading direction than in poles that were either radial drilled or deep incised (Table III-2). Deep incised poles had a greater tendency to fail in shear; however, this did not appear to affect overall flexural properties of the poles.

The flexural properties of all poles in Test # 2 were lower than those from Test # 1. We later learned that the poles had been obtained from a much wider geographic area. In addition, the

Table III-1. Wood characteristics and flexural properties of Douglas-fir poles with various groundline boring treatments.

Test	Treatment	Reps	Circumference (inches)		Modulus of Rupture- GL (psi)			Ring Count	
			Butt	Tip	Mean[1]	Range	COV (%)	Outer 2 in.	Total
1	None	27	36.46	32.21	7353 (1332)	5328-10425	18	18.2	33.9
	0.25 in TB	28	36.70	31.90	7207 (913)	4887-9350	13	15.8	30.9
	0.50 in TB	28	35.87	31.71	6860 (774)	5445-8385	11	17.2	32.6
	0.75 in TB	28	36.14	31.96	6554 (766)	5026-8041	12	16.5	31.8
	1.00 in TB	28	36.78	31.82	6187 (746)	5328-7963	12	17.0	32.9
2	Radial drill	30	37.27	27.21	6177 (677)	5070-8248	11		
	TB- Perp	31	39.91	27.05	5736 (669)	4399-7063	12		
	Deep incised	31	37.31	27.07	6520 (894)	5055-9160	14		
3	Control	31	39.4	34.7	6575(1011)	4597-9026	15	18.3	32.5
	TB parallel	32	40.5	35.9	5132(879)	2578-6879	17	19.0	36.7
	TB-perp	32	40.6	35.1	5449 (879)	3750-6952	16	21.6	35.4
	Radial drill	30	41.1	35.4	5816(1422)	3550-7805	24	19.4	35.0

1. Numbers in parenthses represent one standard deviation from the mean.

poles were slightly larger. While the larger size should not adversely affect MOR at GL for poles of these dimensions, the sourcing might be an issue. The lack of control poles also made it difficult to determine if the lower flexural values were due to natural variations in wood properties or to a through-boring effect.

Test # 3 was initiated to resolve the questions raised by the ANSI committee and resolve the issues raised in Test # 2. Poles were through-bored either parallel or perpendicular to load direction, were radial drilled or were left as non-bored controls. t-tests showed that MOR at GL for poles receiving groundline boring treatments differed significantly from MOR-GL for the non-bored poles (Figures III-4, Table III-3). As with Test # 2, MOR values were much lower than those found in Test # 1, although the pole sample had a similar geographic origin. In addition, the ring counts in both the outer 2 inches and the entire cross section were similar (Table III-1) and all moisture contents were at or above the fiber saturation point. The results differ markedly from the MOR at GL values for the through bored poles tested with the holes parallel to load direction from Test # 1. Variability in wood properties is a given; however, the test populations were sufficient to allow for separation of treatment differences. The one major difference in wood characteristics between Tests 1 and 2 was the circumference at GL. Poles in the first test had average butt circumferences of 35.9 to 36.8, while those from Test # 3 had average circumferences ranging from 39.4 to 41.1 inches. The minimum circumference for a Class 4 forty foot long Douglas-fir pole is 36.5; inches similar to the measurements for the poles in the first population. The circumferences in Test # 3 were closer to a Class 3. It is unclear how this might affect groundline boring, since MOR is based upon actual groundline circumference and any differences due to size would have been considered in the calculations.

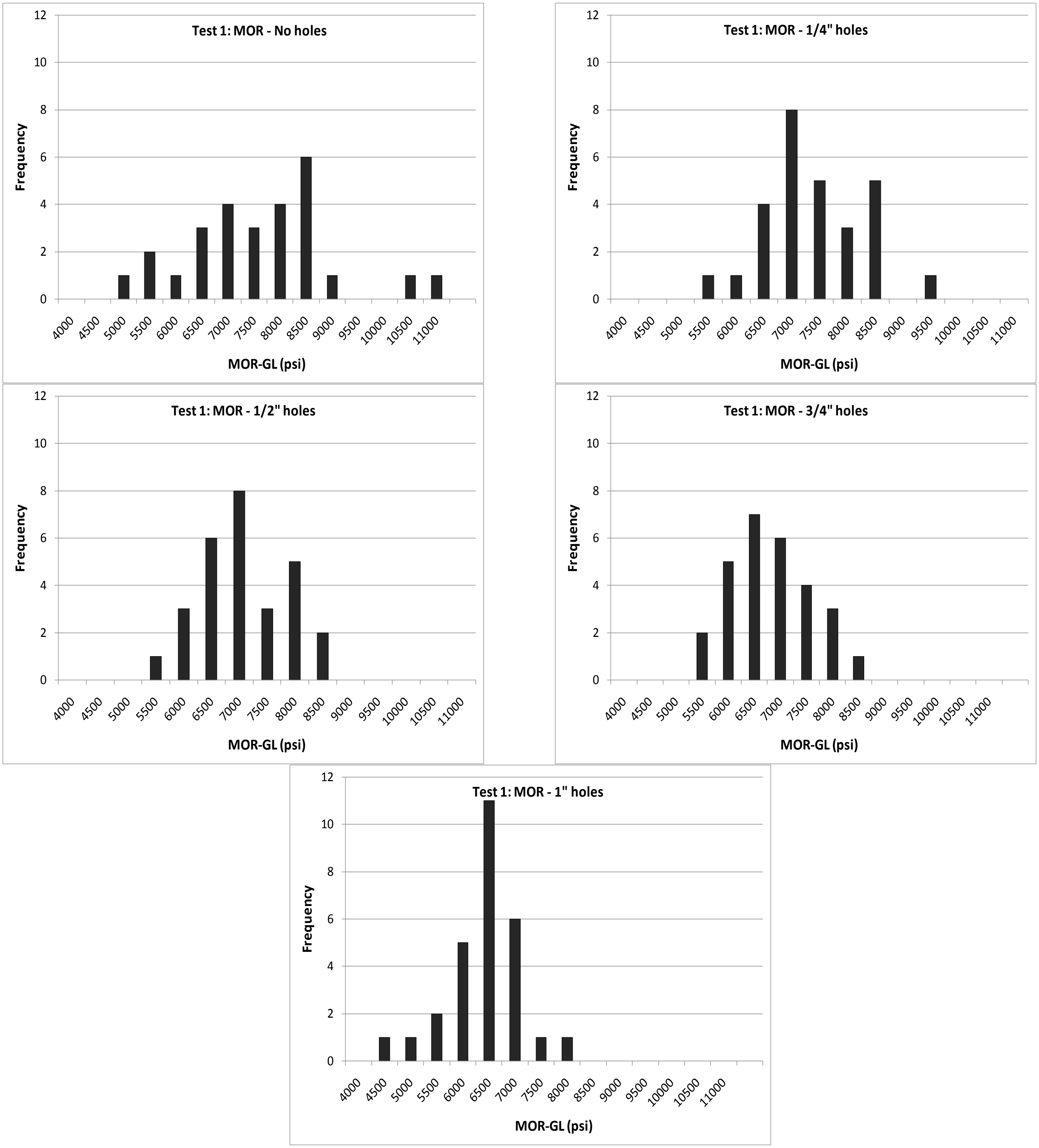


Figure III-3 MOR-GL distribution in Douglas-fir poles with or without 0.25, 0.50, 0.75 or 1.00 inch diameter through-boring holes in the groundline region.

Table III-2. t-tests comparing MOR-GL for Douglas-fir poles that were radial drilled, deep incised or through-bored prior to testing at alpha= 0.05.

	Radial	Through-bore	Radial	Incised	Through-bore	Incised
Mean	6177	5736	6177	6519	5736	6519
Variance	458864	447862	458864	799435	447862	799435
Observations	29	31	29	31	31	31
Hypothesized Mean Difference	0		0		0	
df	58		56		56	
t Stat	2.532		-1.678		-3.903	
P(T<=t) one-tail	0.007		0.0494		0.000	
t Critical one-tail	1.671		1.672		1.672	
P(T<=t) two-tail	0.0140		0.098		0.000	
t Critical two-tail	2.001		2.003		2.003	

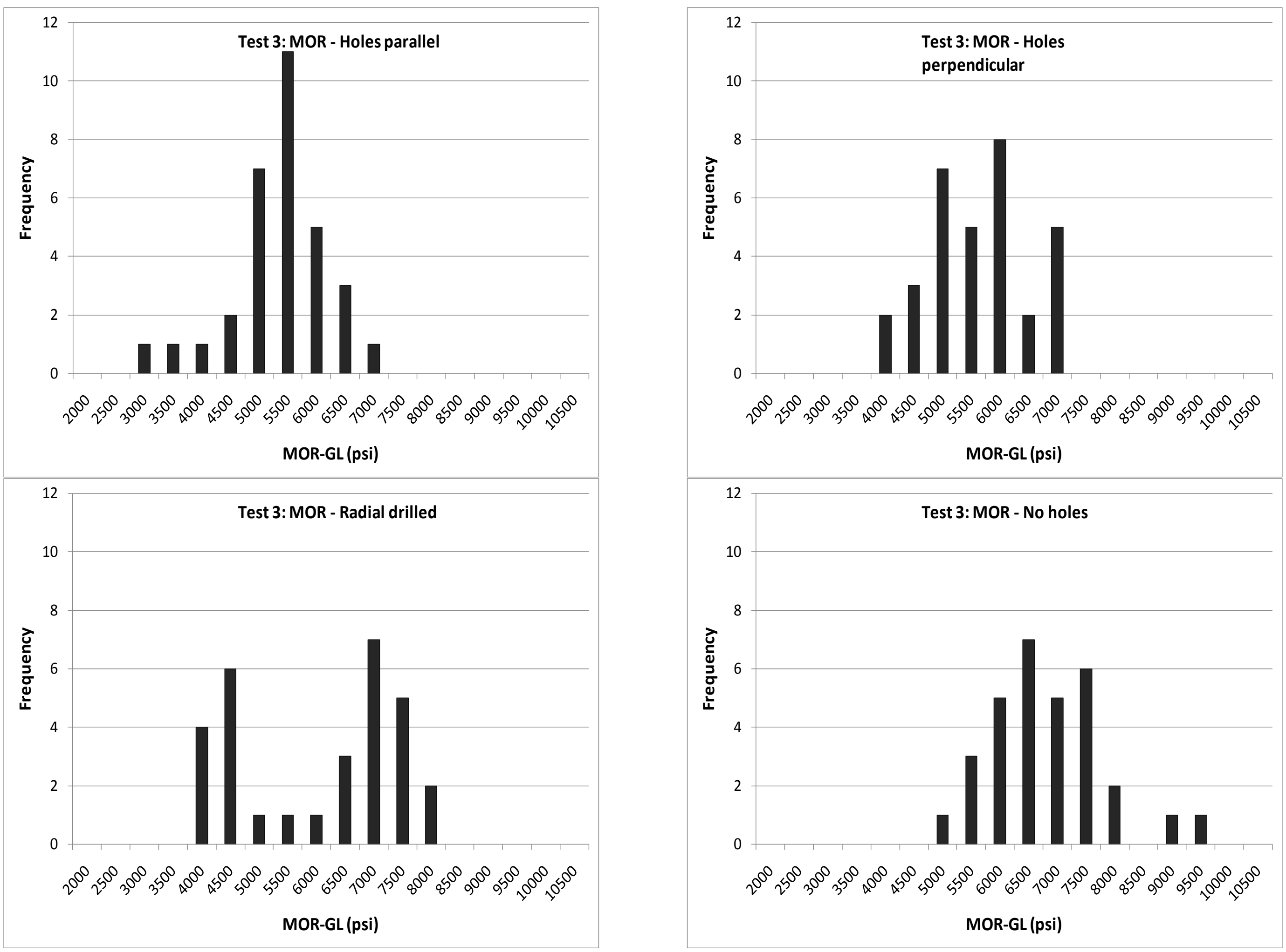


Figure III-4. MOR-GL distribution for Douglas-fir poles tested with the through-boring holes parallel or perpendicular to the loading direction, radial drilling or no holes in Test # 3.

Table III-3. t-tests comparing MOR- at GL for Douglas-fir poles with no through-boring, radial drilling or through-boring perpendicular or parallel to the load direction.

	None	TB perpen-dicular	None	Radial	None	TB parallel
Mean	6575	5449	6575	5815	6575	5132
Variance	1021850	772990	1021850	2021688	1021850	772641
Observations	31	32	31	30	31	30
Hypothesized Mean Difference	0		0		0	
df	59		52		29	
t Stat	4.711		2.398		-20.055	
P(T<=t) one-tail	7.7E-06		0.010		7.6E-19	
t Critical one-tail	1.671		1.674		1.699	
P(T<=t) two-tail	1.54E-05		0.020		1.5E-18	
t Critical two-tail	2.000		2.006		2.045	

At present, we have two conflicting data sets. Test # 1 shows no significant effect of holes up to 0.5 inches in diameter while the second shows a significant effect of through-boring regardless of whether the holes are oriented parallel or perpendicular to line direction.

We have provided preliminary data to the ASC committee and plan to provide all data in November. The data from Test # 3 would suggest that a strength reduction factor be applied to through-bored poles. However, it is important to look not only at initial strength but in-service performance. Through-boring produces a dramatic and well-documented reduction in the incidence of internal decay at groundline. Field inspections indicate that decay is virtually absent from through-bored zones. As a result, the normal reductions in section modulus that might occur in non-through-bored poles that experience internal decay are unlikely to occur in the through-bored zone. This means that, while a through-bored pole may be initially slightly weaker than a similar sized non-through-bored pole, the pole will be more reliable over its service life. We would contend that this negates the need to introduce a reduction in load and will pursue this approach within the ASC committee.

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. These poles averaged 3.6 inches in circumference at groundline which would make them a Class 6 forty foot long pole. The small size should a create worst case situation for assessing the impact of groundline 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 the first inspection of a pole, while the third was designed to simulate the 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, we have been informed that 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. **We do not recommend additional holes unless re-inspection suggests that the decay pocket has expanded.**

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-4). T-tests comparing the non-bored poles with poles receiving the three groundline inspection patterns showed that boring had no significant negative effect on MOR at groundline (Table III-5). 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. Drilling a second set of 7/8 inch diameter inspection holes also had no significant negative effect on flexural properties. **Despite the ability to drill additional holes, we would still recommend re-using inspection holes wherever possible.**

Table III-4. Effect of inspection holes on flexural properties of Douglas-fir pole sections.

Boring	Reps	GL Circumference (in)[1]	MOR-GL[1]	COV (%)
None	23	32.1 (2.1)	6006 (1,001)	16.7
Three 5/8"	23	31.1 (2.0)	5860 (1038)	17.7
Three 7/8"	22	31.6 (1.5)	5722 (1206)	21.0
Six 7/8"	23	31.5 (1.1)	5834 (701)	12.0

1.Values represent means while figures in parentheses represent one standard deviation.

Table III-5. t-tests comparing MOR-GL for poles that were not bored or received 3 or 6 inspection holes at groundline

	None	*Three 5/8"*	*None*	*Three 7/8 "*	*None*	*Six 7/8"*
Mean	6006	5859	6006	5721	6006	5834
Variance	1001866	1077558	1001866	1453834	1001866	491339
Observations	23	23	23	22	23	23
Hypothesized Mean Difference	0		0		0	
df	44		41		39	
t Stat	0.486		0.859		0.674	
P(T<=t) one-tail	0.314		0.197		0.252	
t Critical one-tail	1.680		1.682		1.684	
P(T<=t) two-tail	0.628		0.395		0.504	
t Critical two-tail	2.015		2.019		2.022	

The results indicate that inspection holes do not adversely affect pole flexural properties of Douglas-fir poles.

C. Performance of Fire Retardants on Douglas-fir poles

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

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

No fire tests were performed this year and we are looking for other products to include in future trials (Figure III-5).

Figure III-5. Example of a pole section with straw fuel in a wire cage prior to ignition.

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

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

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

Figure III-6. Example of an end-plate on a penta treated Douglas-fir cross arm.

Thirteen pentachlorophenol treated Douglas-fir cross arm sections (87.5 mm by 112.5 mm by 1.2 m) long were end-plated on both ends then cut in half to leave one plated end and one non-plated end on each arm (Figure III-6). 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 11 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 end-plated arms early in the test (Table III-6). 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 with 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.

Table III-6. Number and width of checks in crossarms with or without end-plates after 1 to 12 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
11	0.84	0.40	3.40	2.32	2.11	1.19	6.98	2.98
12	3.16	1.40	3.60	2.36	1.15	0.81	2.41	1.65

E. Effect of External Crossarm Coatings on Termite and UV Resistance

Cross arms present a much lower risk of decay than wood exposed in soil contact, but even these materials do eventually experience decay. In previous tests, we have examined arms that had been in service for 20 to 50 years. In general, arm appearance is a poor indicator of condition. Weathering can make an arm look badly decayed, but the wood underneath may be quite sound. Our results indicated that arms in wishbone configurations were in good condition, probably because they had been exposed on an angle, allowing water to run off the upper surfaces.

Subsequent evaluations of arms exposed horizontally showed that these arms tended to experience much more decay because the upper surfaces developed deep checks that penetrated beyond the original depth of preservative treatment. It would be virtually impossible to completely stop check development on the upper wood surfaces, but one alternative approach is to coat the cross arm to limit moisture entry. This approach is identical to that used for external groundline protection although the primary goal is to reduce ultraviolet light degradation and fungal attack instead of reducing preservative migration.

In order to develop information on the performance of these coatings, the following tests were established.

Douglas-fir cross arm sections were either left without treatment or treated to the current American Wood Protection Association Standards with pentachlorophenol for Use Category UC4A. The arms were cut into 600 mm long sections and allocated to be either left without coating or coated with a pigmented urethane barrier. The sections were shipped to Hilo, Hawaii where they were installed above ground on racks in an area that receives approximately 4 m of rainfall per year and experiences elevated conditions for both decay and UV exposure. The samples have been exposed for 1 year. While there is some evidence of lightening of the wood and coated surfaces, there is no evidence of decay on any of the pieces (Figure III-7).

In an additional trial, 50 by 100 mm by 100 mm long samples of incised Douglas-fir were either treated to the UC 4A retention with penta or left untreated. These blocks were then left non-coated or coated with the same urethane coating described above. Each treatment was replicated on 10 samples. The blocks were then shipped to Hawaii for exposure to Formosan termites following the proposed American Wood Protection Association Standard.

In the termite tests, hollow concrete blocks were laid directly on the soil in a 1 m square in an area with known attack by *Coptotermes formosanus*. This species is considered to a very aggressive wood destroyer and is found in the southern US as well as Hawaii and the tip of Southern California. A series of 19 mm by 19 mm southern pine sapwood stakes were driven into the ground in the block openings to provide avenues for termite workers to explore upward. A sheet of 6 mm thick southern pine plywood was then placed on top of the concrete blocks. The test pieces were arranged on the array so that every piece was surrounded by southern pine sapwood sticks. This allowed foraging termite workers to explore throughout the array and to be able to choose to attack specific wood samples while avoiding those that might be repellant. The entire assembly was covered to prevent overhead wetting. This arrangement posed little or no risk of chemical leaching.

The degree of termite damage was visually assessed 6 months after exposure using the following scale

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

0 sample destroyed

Non-coated, non-treated wood was destroyed by Formosan termite attack 6 months after installation as was the non-treated feeder stock placed around the array (Table III-7). These results indicate that conditions were suitable for aggressive termite attack. Interestingly, coated, but non-treated blocks were also completely destroyed at the 6 month point. The coatings; however were largely intact, except for entry holes along the end-grain. The ability of the termites to locate non-treated wood beneath the coating also illustrates the aggressive nature of these insects. The test configuration is designed to limit the potential for moisture entry that might result in leaching of extractives from the wood that could be attractive to foraging workers. The results suggest that the attack was initiated by volatiles moving through the coatings and into the covered chamber. These also indicate that barriers alone are insufficient to limit attack by this insect.

Penta treated wood in the arrays was free of termite attack regardless of whether it was coated or not, although the surfaces were heavily mudded by the workers (Figure III-8). This lack of damage reflects the exceptional performance of penta as a wood preservative. Additional non-treated wood has been placed around the surviving samples to encourage further termite attack and the test will continue for at least another 18 months.

Table III-7. Effect of a urethane coating on degree of damage experienced by penta-treated and non-treated Douglas-fir lumber.

Preservative Treatment	Average Termite Rating[1]	
	Non-Coated	Coated
Non-treated	0	0
Penta-treated	10	10

[1]Values represent means of 10 replicates per treatment.

F. Assessing 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. Several years ago, we initiated a cooperative inspection program with Portland General Electric, inspecting poles in a number of lines across their service territory. The results indicated that above-ground decay was an issue in older poles, particularly in areas of the Coast Range of Western Oregon, where wind driven rain tends to be most prevalent. These findings led PGE to institute system-wide climbing inspections of their older transmission lines. While these inspections have identified a number of poles in need of replacement, one problem with the inspection

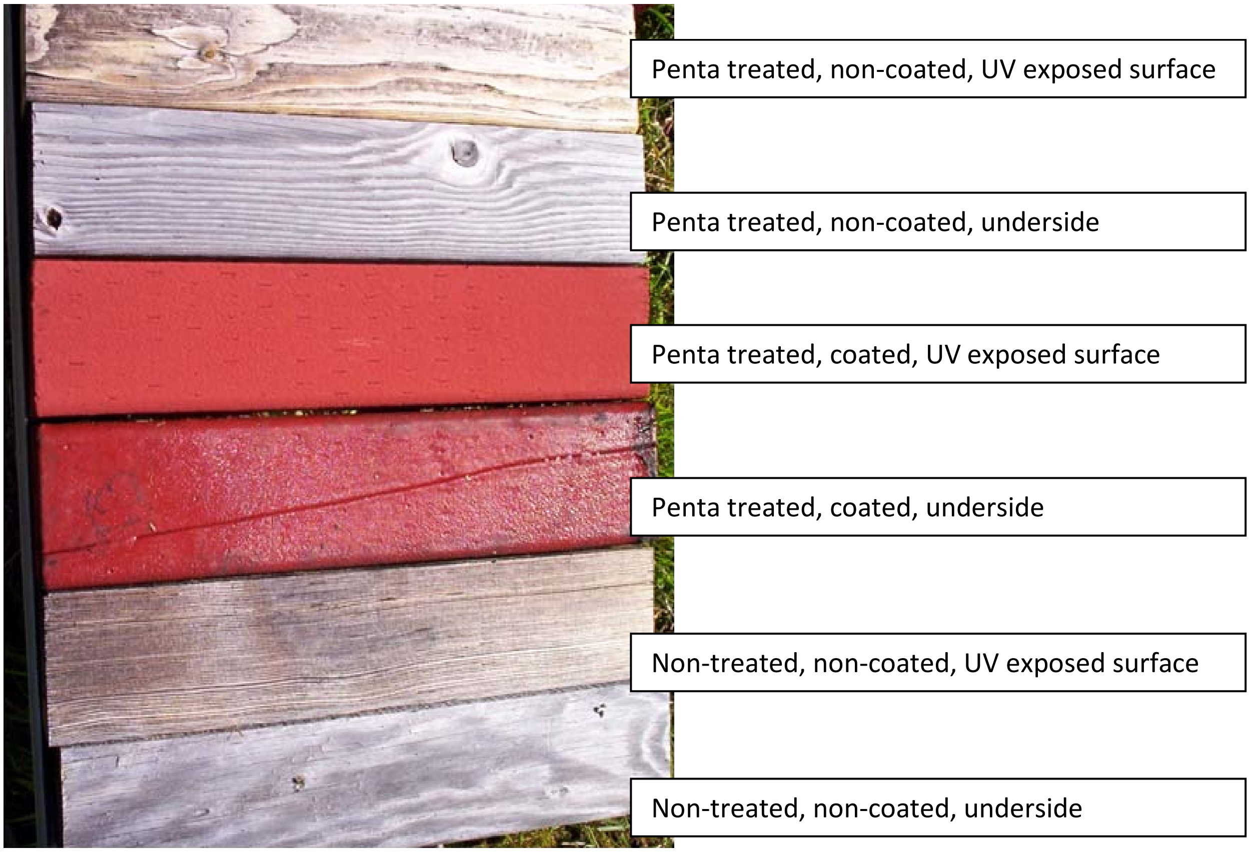


Figure III-7. Examples of coated and non-coated Douglas-fir cross arm sections after 1 year of exposure near Hilo, Hawaii.

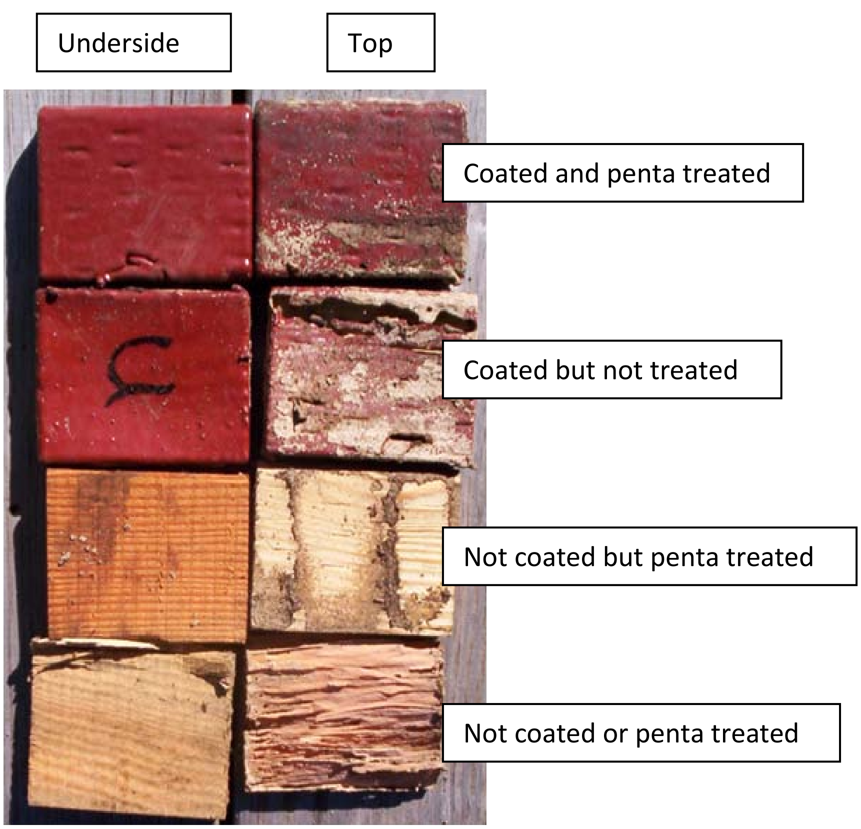


Figure III-8. Examples of undersides (top) and upper surfaces of coated and non-coated Douglas-fir lumber with and without penta treatment.

process is the subjectivity of the process. Line personnel climb the pole, sounding with a hammer as they move upward. Any suspect areas are then more closely assessed by drilling. The process is fairly subjective, although there is an ability to calculate residual section modulus using residual shell depths as measured in the inspection holes. Ideally, however, the use of some form of non-destructive testing could be used to delineate any internal damage so that more precise engineering calculations could be made. These types of devices would also create a record of internal condition that could be used in subsequent inspections to track the progress of any internal defects.

Unfortunately, there are few inspection devices capable of developing the kind of internal pole condition information needed to accurately assess remaining pole strength. Recently, however, we identified a device from New Zealand that has some potential for this application.

The current-generation PoleScan is a modification of an earlier device. Previously, a sensor was screwed into the pole at a set location and then a second device applied a sound pulse at set locations around the pole. The time it took for the wave to travel back and forth across the pole or, time-of-flight, was then used to determine if there was any defect across that wave path. Multiple readings across the pole in a given plane allowed the inspector to create a map showing the presence of potential internal defects and these suspect areas were then further explored using more traditional invasive methods.

While the original device was unsuitable for above-ground inspections, PoleScan has modified the device so that a series of sensors on a cord are attached to the pole, then the signal is sent and the device collects all the data at once, without the need for screwing in a sensor. This improved device could allow for fairly rapid inspection above ground by line personnel.

In order to test this possibility, Portland General Electric identified transmission poles in their

Figure III-9. Line personnel inspecting the above ground zone of a transmission pole.

Figure III-10. Line personnel sounding a Douglas-fir transmission pole above the groundline.

system that had previously been found to have internal defects. Line crews along with a group of observers then inspected the poles (Figure III-9 &10).

The process consisted of the following:

1. The inspector ascended the pole, sounding periodically, to identify any defect areas. The inspector then brought the device up the pole and attached it below the area of concern.
2. The device was used to collect data from areas below, within and above the affected zone.
3. Traditional inspection holes were then drilled around the pole to determine residual shell thickness.

Pole Scan personnel then took the data back to New Zealand for processing. This post-processing was necessary because the current device is not really designed for this application and is in the midst of being re-designed based upon these trials as well as another trial in the Eastern United States.

It is difficult to directly compare the sound and bore results with those obtained by the PoleScan because of the resulting output. The sound and bore produces estimated residual shell mea-

Table III-8. Poles in the PGE system used to compare physical testing with the PoleScan device.

Pole #	Year Treated	Class	Height	Condition
878	1973	2	70	Decay pockets at 21 to 25 feet. Minimum shell 2-2.5 inches
4225	1976	2	75	Large pocket 6 ft to underbuild, woodpeckers
1143	1961	2	60	Small void at 10 ft, void increased at 15 & 20 ft. Shell:1.75 to 2.0 inch at 20 ft
1074	1974	2	55	Small pocket at 15 feet- shell 2.25 inches on one side
Depot	-	-	-	Pole section in disposal pile- numerous decay pockets

surements; however, the number of sampling sites at a given location is limited (Table III-8) while the PoleScan collects data from seven locations around the pole at a given height (Figure III-11). Both data sets can be used to construct an internal condition map; however, the PoleScan has the potential to produce a more detailed image.

In general, the PoleScan was able to detect voids in the poles; however, the maps did not always directly compare with those produced by sounding and boring. In practice, this device would be used to identify areas that merited further assessment using traditional sounding and boring methods. This is important since the device can detect voids that may result from decay as well as those associated with other activities such as deep checks or field drilling. As a result, follow-up physical inspection will be important.

Figure III-11. PoleScan device attached to a Douglas-fir pole section showing the multiple sampling points as well as a large internal decay pocket.

There were also a number of observations and suggestions from the line crew. First, the device must be easily attached to the pole. While the potential for remote signal collection to a handheld device on the ground was attractive, the current device is not designed for above-ground applications. The system needs to be modified to allow for signal collection further away from the ground. In addition, the attachment system is cumbersome and might have resulted in poor signal collection at some points.

This device has considerable potential for above-ground inspection if it can be modified so that it can be attached around the pole and then rolled upward with the line personnel stopping at set intervals to collect signals. These signals need to be capable of being rapidly processed on the ground so that the line personnel can decide whether further assessment is necessary. At present, the device can do that with manipulation by the groundline operator, but this would need to be sped up. In addition, the output would need to recorded so that it could be examined later to assess the impact of any defects detected on residual pole capacity. For the present, we have included the PoleScan outputs from our inspection (Figure III-12) which can be used in conjunction with the Table of Pole Condition as determined by physical inspection.

These results are preliminary. Once PoleScan develops an improved device, we plan to identify a population of poles with and without defects that can be scanned, physically inspected, and then sawn to delineate the ability of each tool to detect internal defects.

G. Effect of Capping on Pole Moisture Content

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

Ten poles that had been removed from service were cut into 2.5 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 Pole Topper. Initial

IAMSL - Wood Pole Report

Portland General Electric

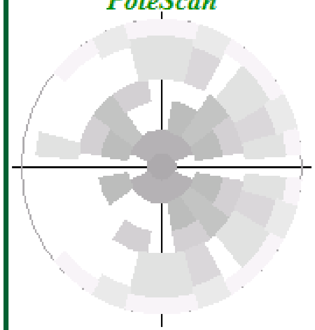
PGE PoleScan test for Jeff Morrell

Network	BEAVERTON	*Species*	Douglas-fir, coastal - DF
Line Ref	BEAVERTON	*Calculated Class*	3
Owner Ref	PGE	*Length (ft)*	55.00
Site Ref	2147	*Treatment Type*	Penta-oil
Address	Berween Banks and Highway 47	*Circ @ 6' (inch)*	41.00
Editor Id	IAMSL	*Circ @ GL (inch)*	43.00
Function	Inspection	*Probe (inch)*	0.00
Inspector	JK	*Age*	36
Edit Date	14-Jul-10		

Comments

Pole scannned at 15ft

PoleScan

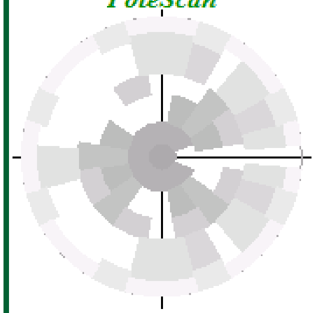


	XLine	*ALine*		
% Original Strength	62	62	*MOR (psi)*	4308
Breaking Strength (lbf)	2755	2763		

Comments

Scanned at 16 ft

PoleScan



	XLine	*ALine*		
% Original Strength	59	55	*MOR (psi)*	3810
Breaking Strength (lbf)	2609	2436		

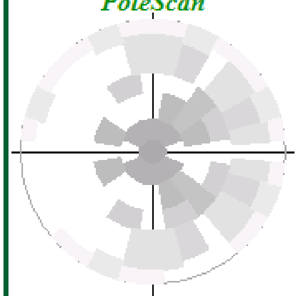
Figure III-12. PoleScan output from above ground inspection of poles within the PGE system showing internal pole condition.

Network	BEAVERTON	Species	Douglas-fir, coastal - DF
Line Ref	BEAVERTON	Calculated Class	2
Owner Ref	PGE	Length (ft)	60.00
Site Ref	1143	Treatment Type	Penta-oil
Address	BEAVERTON Highway	Circ @ 6' (inch)	43.00
Editor Id	IAMSL	Circ @ GL (inch)	44.50
Function	Inspection	Probe (inch)	0.00
Inspector	JK	Age	49
Edit Date	15-Jul-10		

Comments

Scanned at 10 ft

PoleScan

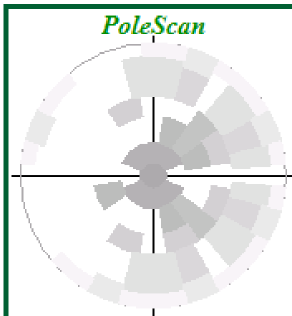


	XLine	ALine		
% Original Strength	66	63	MOR (psi)	4358
Breaking Strength (lbf)	4607	4443		

Comments

Scanned at 15ft

PoleScan

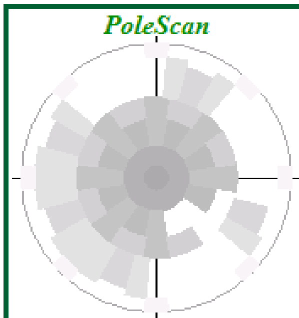


	XLine	ALine		
% Original Strength	65	62	MOR (psi)	4260
Breaking Strength (lbf)	3145	3019		

Comments

Scanned at 20ft

PoleScan



	XLine	ALine		
% Original Strength	61	45	MOR (psi)	3076
Breaking Strength (lbf)	2963	2180		

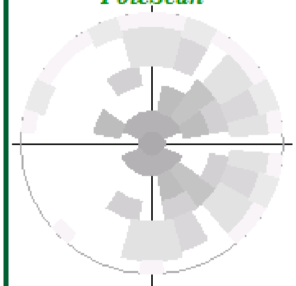
Figure III-12 continued. PoleScan output from above ground inspection of poles within the PGE system showing internal pole condition.

Network	BEAVERTON	Species	Douglas-fir, coastal - DF
Line Ref	BEAVERTON	Calculated Class	1
Owner Ref	PGE	Length (ft)	60.00
Site Ref	873	Treatment Type	Penta-oil
Address	BEAVERTON	Circ @ 6' (inch)	48.00
Editor Id	IAMSL	Circ @ GL (inch)	50.00
Function	Inspection	Probe (inch)	0.00
Inspector	JK	Age	37
Edit Date	14-Jul-10		

Comments

Scanned at 23.5 ft

PoleScan

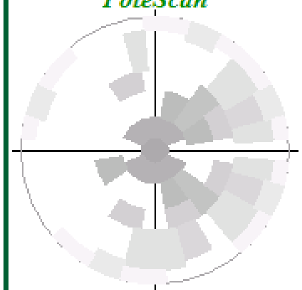


	XLine	ALine		
% Original Strength	68	63	MOR (psi)	4230
Breaking Strength (lbf)	4556	4252		

Comments

Scanned at 25 ft

PoleScan

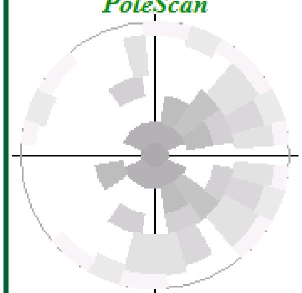


	XLine	ALine		
% Original Strength	71	65	MOR (psi)	4321
Breaking Strength (lbf)	4735	4344		

Comments

Scanned at 26 ft

PoleScan



	XLine	ALine		
% Original Strength	71	65	MOR (psi)	4321
Breaking Strength (lbf)	4735	4344		

Figure III-12 continued. PoleScan output from above ground inspection of poles within the PGE system showing internal pole condition.

IAMSL - Wood Pole Report

Portland General Electric

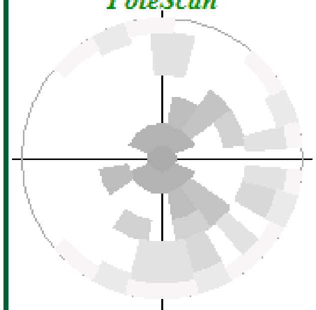
PGE PoleScan test for Jeff Morrell

Network	BEAVERTON	*Species*	Douglas-fir, coastal - DF
Line Ref	BEAVERTON	*Calculated Class*	5
Owner Ref	PGE	*Length (ft)*	40.00
Site Ref	4225	*Treatment Type*	CCA
Address	BEAVERTON	*Circ @ 6' (inch)*	30.50
Editor Id	IAMSL	*Circ @ GL (inch)*	32.00
Function	Inspection	*Probe (inch)*	0.00
Inspector	JK	*Age*	11
Edit Date	14-Jul-10		

Comments

Scanned at 20ft

PoleScan



	XLine	*ALine*		
% Original Strength	70	81	*MOR (psi)*	5235
Breaking Strength (lbf)	1379	1601		

Figure III-12 continued. PoleScan output from above ground inspection of poles within the PGE system showing internal pole condition.

IAMSL - Wood Pole Report

Portland General Electric

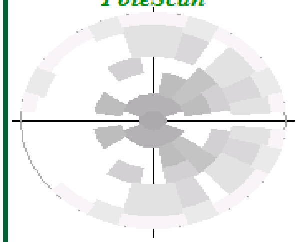
PGE PoleScan test for Jeff Morrell

Network	BEAVERTON	Species	Douglas-fir, coastal - DF
Line Ref	BEAVERTON	Calculated Class	2
Owner Ref	PGE	Length (ft)	55.00
Site Ref	PGE DEPOT1	Treatment Type	Penta-oil
Address	PGE depot	Circ @ 6' (inch)	44.50
Editor Id	IAMSL	Circ @ GL (inch)	46.00
Function	Inspection	Probe (inch)	0.00
Inspector	JK	Age	36
Edit Date	14-Jul-10		

Comments

Pole at PGE yard

PoleScan

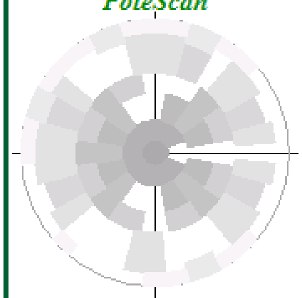


	XLine	ALine		
% Original Strength	62	62	MOR (psi)	4225
Breaking Strength (lbf)	3326	3307		

Comments

Pole at PGE depot

PoleScan



	XLine	ALine		
% Original Strength	62	43	MOR (psi)	2902
Breaking Strength (lbf)	3324	2272		

Figure III-12 continued. PoleScan output from above ground inspection of poles within the PGE system showing internal pole condition.

moisture contents were determined by removing increment cores 150 mm below the top of each pole (Figure III-13). The outer treated zone was discarded, then the inner and outer 25 mm of the remainder of the core were weighed, oven-dried and re-weighed to determine wood moisture content.

Figure III-13. Example of a capped pole (Osmose Pole Topper)used to assess the effects of capping on wood moisture content.

The effect of the caps on moisture content was assessed 4 months after treatment at the end of our rainy season. Increment cores were removed from just beneath the pole cap or at an equivalent location on the non-capped poles. The cores were processed as described above.

Moisture contents at the start of the test were 17 and 19 % for the outer 25 mm of non-capped and capped poles, respectively, while they were 20 and 28 % for the inner zones (Table III-9). 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 pole 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 the non-capped poles were wetter.

Table III-9. Wood moisture contents 0 to 32 months after installation of water shedding caps to Douglas-fir pole sections.

Treatment	Wood Moisture Content (%)									
	0 Months		4 Months		12 Months		28 months		32 months	
	inner	outer	inner	outer	inner	outer	inner	Outer	inner	outer
Caps	20.1	17.2	25.2	19.1	14.2	16.4	15.5	15.9	13.6	13.5
No cap	28.4	19.7	19.0	18.3	37.5	25.6	60.7	28.5	29.3	18.0

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.

Moisture contents in capped poles have continued to remain at low levels after 28 and 32 months. The levels are within the expected equilibrium moisture content for wood exposed outdoors and far below those required for active fungal decay. Moisture contents in poles without caps continue to cycle with season. Moisture contents in the inner zones of non-capped poles were 60 % 28 months after installation, and just at the point where fungal decay would begin in the outer zone. While these poles dried somewhat in the summer, the elevated moisture levels will eventually allow decay fungi to become established, ultimately leading to top decay.

Clearly, capping has a marked effect on moisture content. Over time, we would expect the lower moisture content in capped poles 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.

H. Effect of Initial Preservative Treatment on Electrical Conductivity in Douglas-fir Pole Sections

Wood poles provide an excellent material for supporting overhead electrical distribution and transmission lines. One important aspect of wood is its excellent insulation properties compared to other materials, notably steel. Preservative treatment is required for most pole species and many utilities are concerned about the potential effects of treatment on conductivity.

The primary treatments used in the U.S. for wood pole treatment are pentachlorophenol (penta) in heavy oil and chromate copper arsenate (CCA). While CCA has the potential to increase conductivity, the effects are generally slight. Penta, by virtue of its oil system, has little effect on conductivity. Recently, a number of utilities have added copper naphthenate to their specifications and the presence of copper, a metal well known for its electrical conductivity, has raised questions about the potential impacts of this treatment on conductivity. While the amount of copper in a copper naphthenate treated pole is small in proportion to the amount of treatment chemical and solvent, it is important to verify that the presence of even this small amount of metal does not adversely affect conductivity.

The conductivity of non-treated, copper naphthenate-treated and pentachlorophenol-treated wood was assessed in Douglas-fir pole sections.

There is no standard method for measuring conductivity or electrical resistance for treated wood poles. As a result, we developed our own method, based upon readily available instrumentation and personnel safety.

Ten non-treated Douglas-fir pole sections (4.8 m long) cut from Class 4 thirteen meter long poles that had been seasoning for approximately 4 months, were cut into three 1.2 m long sections. The 1.2 m sections were allocated to be left without treatment or treated to the AWPA Use Category 4b retention with pentachlorophenol or copper naphthenate in P9Type A oil (9.6 kg/m^3 and 1.2 kg/m^3), respectively. Each section was end-coated to retard longitudinal preservative penetration prior to treatment, thereby simulating a section from a longer pole. The pole sections were pressure treated in commercial facilities located in Eugene or Sheridan, Oregon.
The pole sections were stored outdoors after treatment where they were subjected to approximately 1 m of rainfall and ambient temperatures that ranged from 0 to 13 C. Moisture contents at the time of testing were well above the fiber saturation point, creating excellent conditions for electrical conductivity.

Two Delmhorst Teflon coated 37.5 mm long moisture meter pins were driven to a depth of 31 mm into the wood approximately 225 mm inward from each end (Figure III-14),resulting in pins located 750 mm apart. One pin at each location was used to measure resistance when the pole sections were subjected to high voltages. Two steel nails (Stanley Bostitch 3.375 mm in diameter by 87.5 mm long) were driven to a depth of 31 mm in line with the two moisture meter pins so that a nail was approximately 225 mm from its respective moisture meter pin. This resulted in the nails being 300 mm apart.

A Fluka DVM Model 77 with an impedance greater than 10 megohms was attached to the two nails, and a AEMC Model 1000 Megohmmeter was attached to the moisture meter pins. Resistance and voltage drop were measured using the AEMC and Fluka systems, respectively as 100, 250, 500 or 1000 volts were passed through the pole section. Each specimen was tested at four equidistant points around the pole.

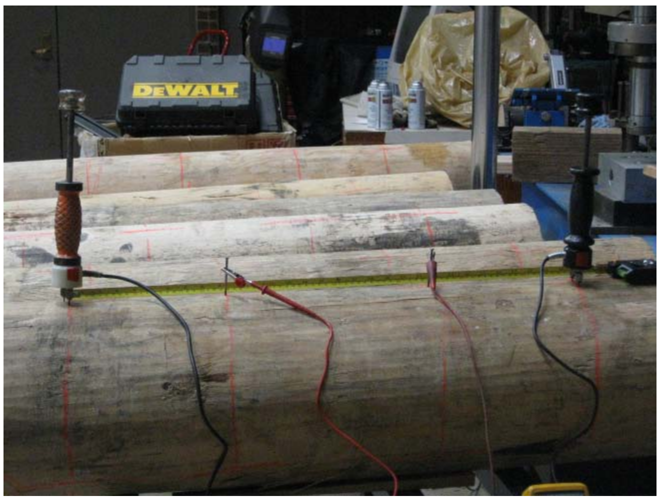


Figure III-14. Locations of moisture meter pins and nails used to measure conductivity and resistance, respectively, in Douglas-fir pole sections treated with pentachlorophenol or copper naphthenate.

The moisture meter pins at each location were then used to measure moisture content. Independent moisture meter measurements were made using a Delmhorst Model RDM-25 moisture meter equipped with 37.5 mm long pins.

The tests were run two times; the first shortly after the poles had been treated and the second 3 months later to determine if weathering and additional exposure to wetting and drying had affected the readings.

Moisture measurements of the non-treated pole sections ranged from 33 to 45 % shortly after arrival, while penta treated sections ranged from 18 to 25 % and copper naphthenate treated sections ranged from 15 to 21 % (Figure III-15). Lower moisture contents for the oil treated sections reflect the water repellency afforded by the treatment. These readings should be viewed as relative, not exact owing to the potential for the oil and the preservative to affect meter behavior.

Non-treated pole sections had the widest variations in voltage drop and these drops were highly dependent on the voltage applied across the pole (Figure III-16). Voltage drops varied from less than 4 kV/m at 100 V to almost 13 kV/m when 1000 V was applied to the non-treated samples. Voltage drops for the penta treated sections also varied with the voltage applied and ranged from 5 kV/m to almost 10 kV/m. Variations between individual pole samples tended to be lower in penta treated samples.

Voltage drops in copper naphthenate treated pole sections tended to be the same regardless of the current applied, In addition, the drops were much lower, ranging from less than 0.5 Kv/m to less than 4 kV/m. The reasons for the lower voltage drops with the copper naphthenate are unclear, but they are consistent with small scale studies on copper-naphthenate treated southern

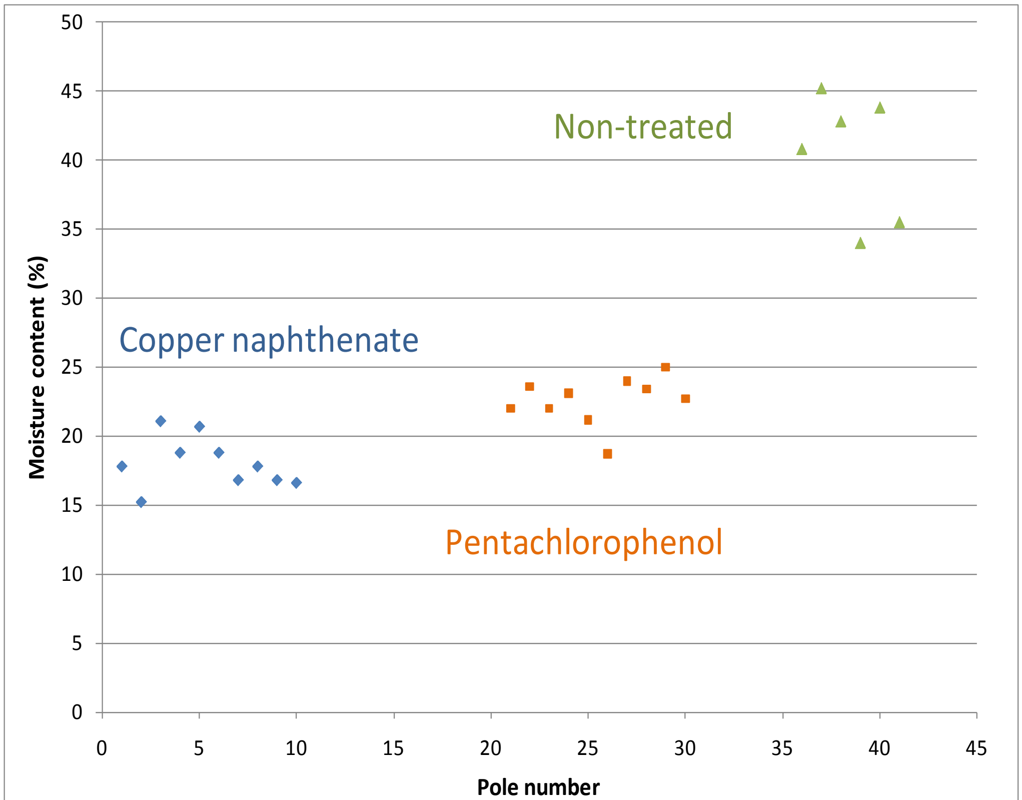


Figure III-15. Moisture contents of Douglas-fir pole sections shortly after treatment with copper naphthenate or pentachlorophenol or left without treatment.

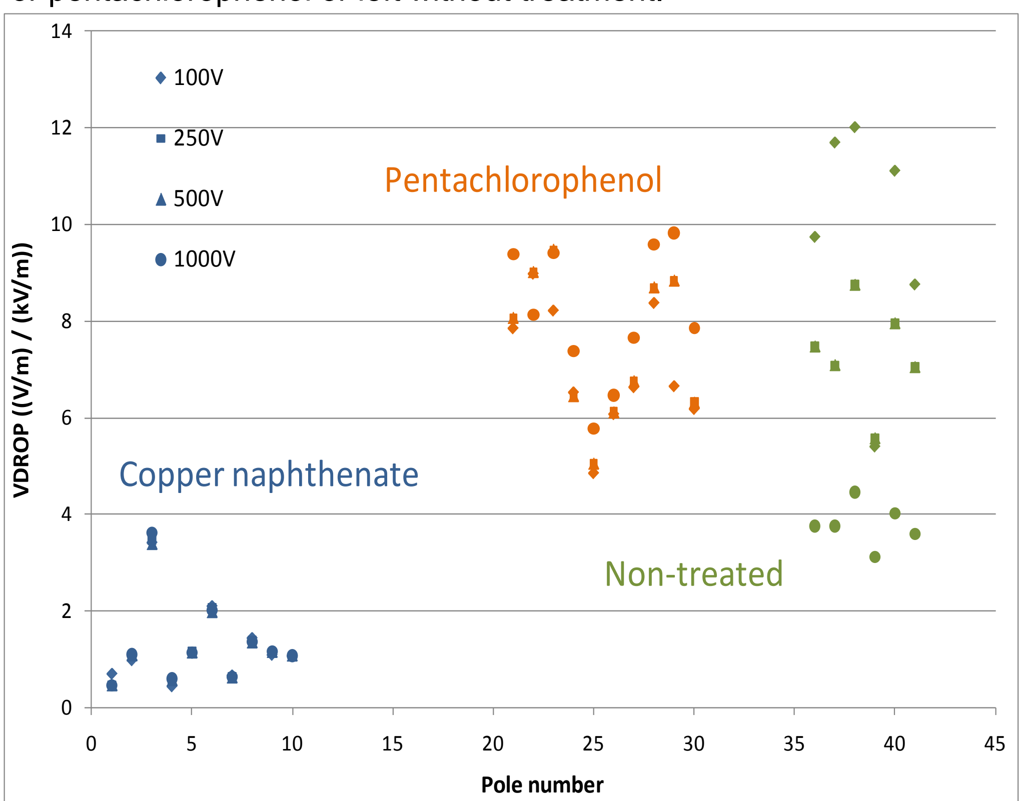


Figure III-16. Voltage drops across Douglas-fir pole sections tested untreated or shortly after treatment with copper naphthenate or pentachlorophenol.

pine.

Resistance measurements followed similar trends with non-treated and penta treated pole sections having similar resistance readings (Figure III-17). All values fell within 0 to 2.5 X 10^6 ohm/m. Resistance readings for copper naphthenate treated pole sections were much higher and more variable, ranging from 6 to 37 X 10^6 ohm/m.

Moisture contents of penta and copper naphthenate treated pole sections became similar over the 3 month outdoor exposure, while the non-treated poles remained wet (Figure III-18). Voltage drops also became more similar between the two chemically treated pole groups, although the penta group still tended to have more poles that experienced greater voltage drops (Figure III-19). Resistance readings were similar to those found in the first test, with copper naphthenate exhibiting much great resistance (Figure III-20).

Conductivity in wet non-treated and penta-treated Douglas-fir pole sections were similar while conductivity was much lower in copper naphthenate treated sections. The results indicate that poles treated with copper naphthenate in diesel oil do not pose a conductivity risk.

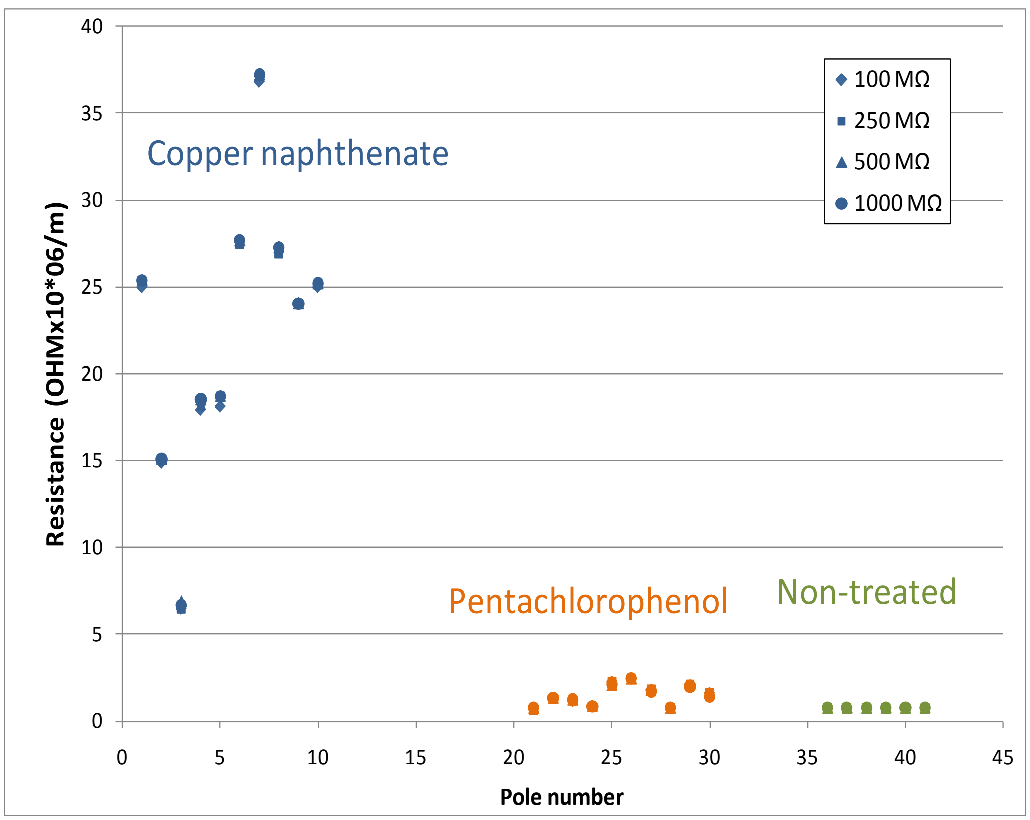


Figure III-17. Electrical resistance across Douglas-fir pole sections tested untreated or shortly after treatment with copper naphthenate or pentachlorophenol.

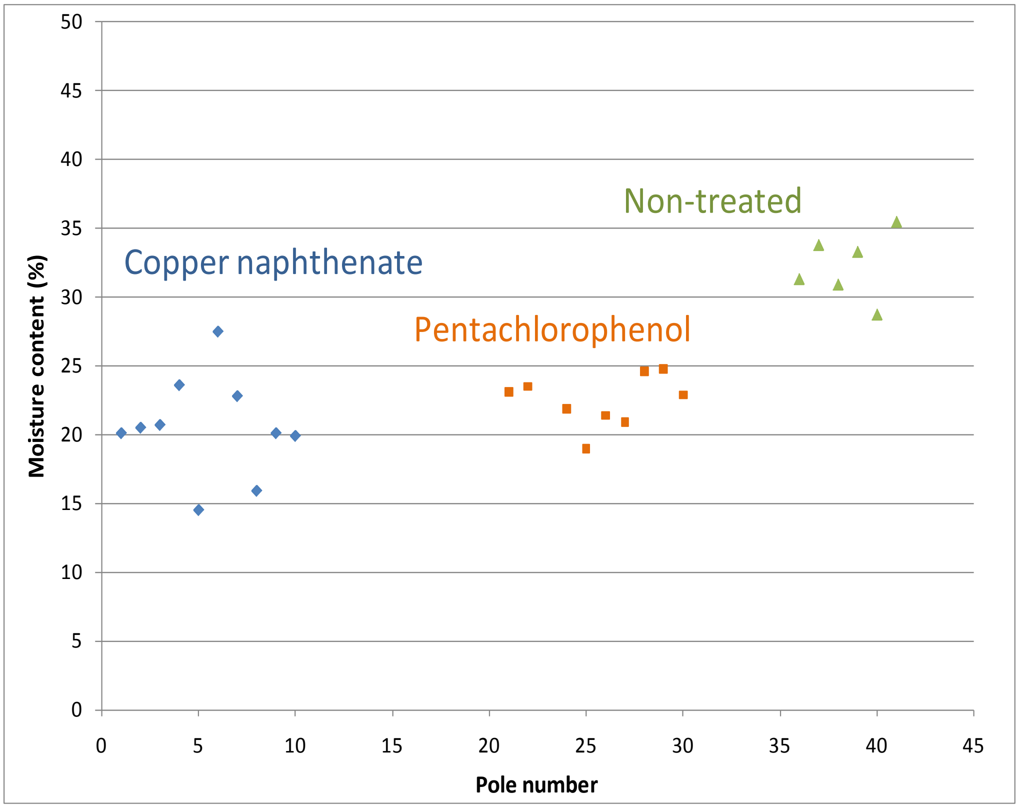


Figure III-18. Moisture contents vs voltages drops of Douglas-fir poles shortly treated with copper naphthenate or pentachlorophenol or left untreated and stored outdoors for 3 months.

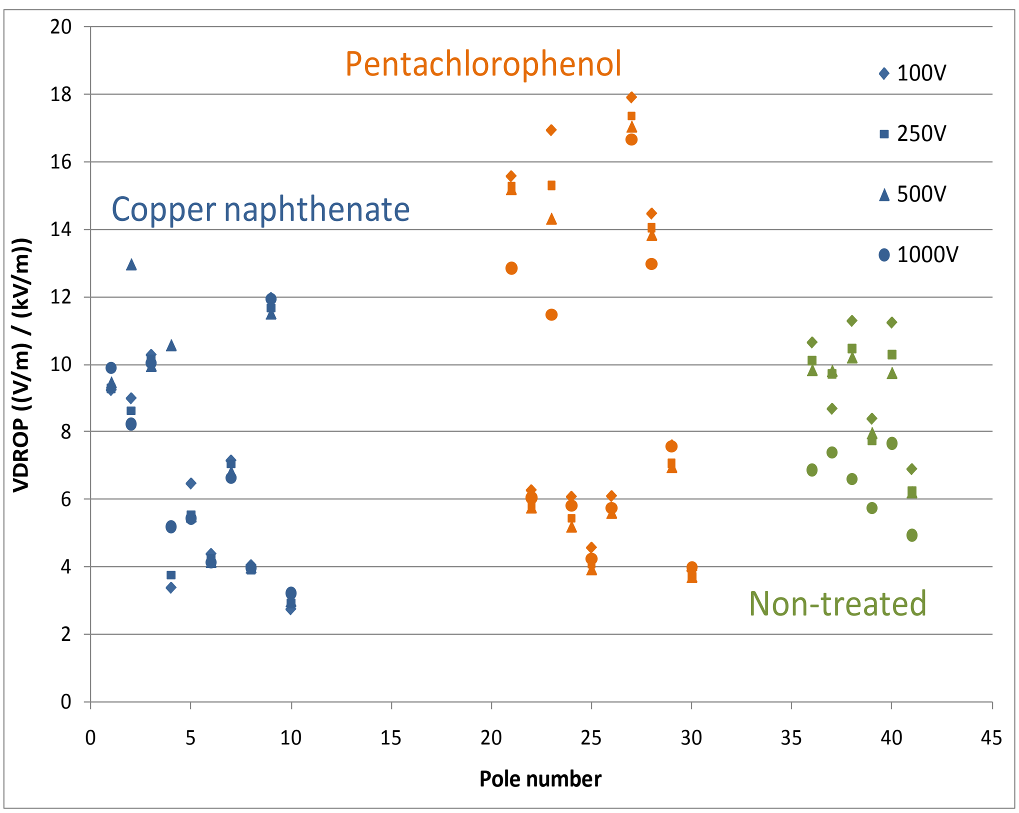


Figure III-19. Voltage drops across Douglas-fir pole sections that were untreated or treated with copper naphthenate or pentachlorophenol and stored outdoors for 3 months.

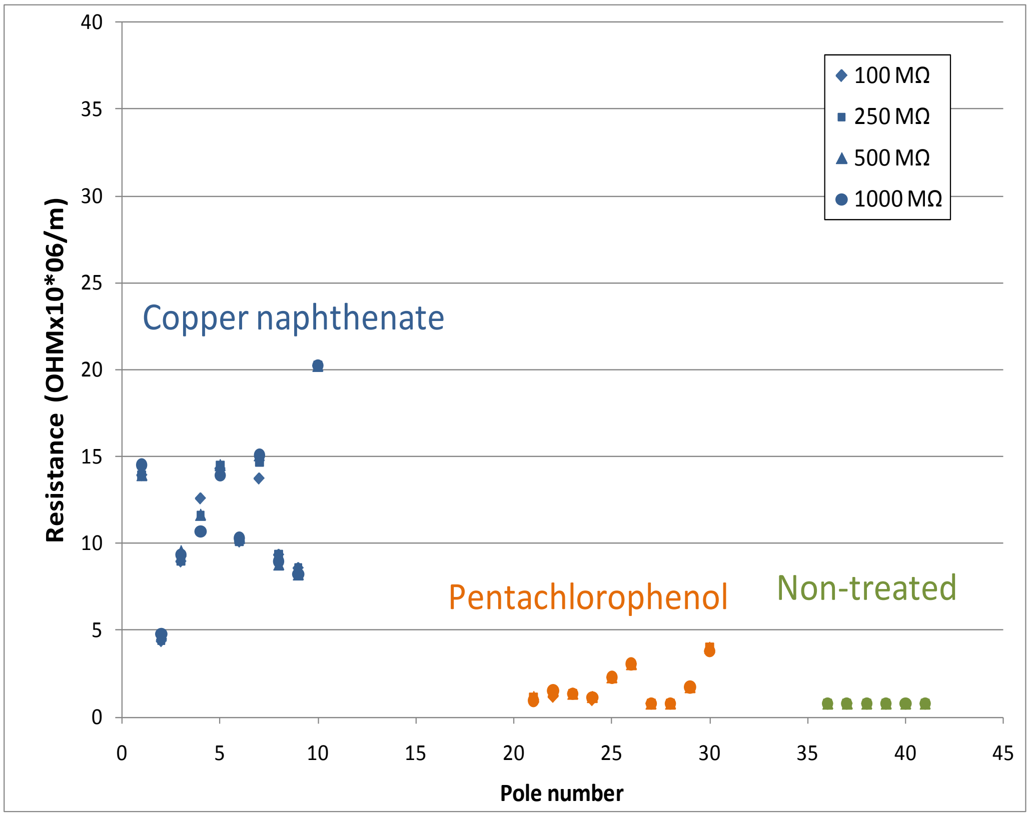


Figure III-20. Electrical resistance across Douglas-fir pole sections untreated or treated with copper naphthenate or pentachlorophenol and stored outdoors for 3 months.

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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 re-invasion by fungi in the surrounding soil.

For many years, the pastes used for this purpose incorporated a diverse mixture of chemicals including pentachlorophenol, potassium dichromate, creosote, fluoride and an array of insecticides. The re-examination of pesticide registrations by the U.S. Environmental Protection Agency in the 1980s resulted in several of these components being listed as restricted use pesticides. This action, in turn, encouraged utilities and chemical suppliers to examine alternative preservatives for this application. While these chemicals had prior applications as wood preservatives, there was little data on their efficacy as preservative pastes and this lack of data led to the establishment of this Objective. The primary goals of this Objective are to assess the laboratory and field performance of external preservative systems for protecting the below ground portions of wood poles.

A. 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

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 ten and received one of the following treatments:

- Osmose Cop-R-Plastic
- Osmose Pole Wrap RTU
- BASF Wrap with Cu/F/B
- BASF Wrap with Cu/B

Genics Cobra Wrap
Genics Cobra Slim (an experimental wrap)
Triangle Laboratories Biological Treatment

The treatments were applied to the poles 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 non-treated 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.

This test is completed. The final results from this test were presented in the 2009 Annual Report.

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

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 Beacon 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 had been in service for at least 10 years were selected for the test. The poles were treated with oil-based treatments (CCA would interfere with analysis of copper containing systems) and, ideally, 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 below ground. 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 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 and we have no data supporting the premise of synergy.

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/m3) but still below the level we have traditionally used for performance of fluoride based materials in soil contact (2.24 kg/m3). Fluoride levels further inward ranged from 0.46 to 0.62 kg/m3. 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 in poles prior to treatment.

Proposed Treatment	Distance from Surface (mm)	Fluoride Level (kg/m^3)[1]
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)

1. Numbers in parenthses represent one standard deviation around the mean of 10 measurements.

Poles in the test were allocated to a given treatment and each treatment was replicated on a minimum of ten poles. An additional ten 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 0.87 kg of Cop-R-Plastic paste per pole, compared with 0.78 and 0.79 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 89.6 and 85.1% 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 the outer barriers recommended by the manufacturer 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	1.20	0.74	0.0148
CuRap 20	1.26	0.78	0.0156
Cop-R-Plastic	1.41	0.87	0.0174

Chemical movement from the pastes into the wood was assessed in five poles per treatment 1, 2, 3 and 5 years after treatment by removing increment cores from approximately 150 mm below the groundline. A small patch of the exterior bandage and any adhering paste 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 was combined and then ground to pass a 20 mesh screen. Copper was assayed by x-ray fluorescence spectroscopy (XRF). Initially, we used a dilution method for copper analysis. A re-analysis of these results suggested that dilution considerably under-estimated copper levels. As a result, all of the retained samples were analyzed by extraction and ion coupled plasma spectroscopy to determine copper content. Unfortunately we cannot locate the samples for years 1 or 2. As a result, we have elected to present the test data on two graphs showing years 1 and 2 or 3 and 5. Comparisons between XRF and ICP data for the diluted year 3 samples indicate that the XRF values are low. If the volume of sawdust is sufficient for analysis, the XRF and ICP analyses are very similar. The samples from year 5 for all poles of the same treatment were combined to provide more material for analysis and copper was measured by XRF.

Copper and boron were both detected in year 5 samples removed from supposedly non-treated control poles (Figures IV-1 and IV-3). The copper and boron levels are much higher than in previous samples from the controls. At this point, it is not possible to segregate the copper samples, since all cores were combined to provide sufficient wood for analysis. The boron samples were analyzed separately and boron was present in two of the five control poles. The samples numbers may have been mixed up during handling in the lab, but we think it more likely that treated poles were mistakenly sampled as controls. If the mistake were merely in labeling there would be two sets of samples assigned to treated poles with no detectable boron. This was not the case. The chemical levels in wood from the treated poles were still above those found in the controls, allowing us to make some inferences about potential treatment differences, but we will have to sort this problem out when we sample the poles next year.

Copper levels in the outer 6 mm have been consistently at or over the threshold for fungal protection both 3 and 5 years after treatment (Figure IV-1). Copper levels fell off sharply in the 6 to 12 mm and 12 to 25 mm zones, although levels were still above the threshold in most treatments in the 6 to 12 mm zone. It was also interesting to note that copper levels were still increasing in the outer zone between years 3 and 5. These results suggest that the treatments will provide continuing protection to the wood.

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.

Fluoride levels in poles receiving Cop-R-Plastic or PoleWrap tended to become well distributed within 1 year after chemical application (Figure IV-2) and remained well above threshold for the next 2 years. Fluoride levels declined markedly 5 years after treatment, although the levels were still above those found in control poles. The sharply lower fluoride levels at 5 years are interesting because our initial analysis prior to installation suggested that the prior fluoride treatment was present at near threshold levels in the inner zones. The poles had reportedly been treated 10 years prior to installation of our test. The current data suggest that fluoride levels in these same zones in poles receiving additional supplemental treatment have declined below those levels. It

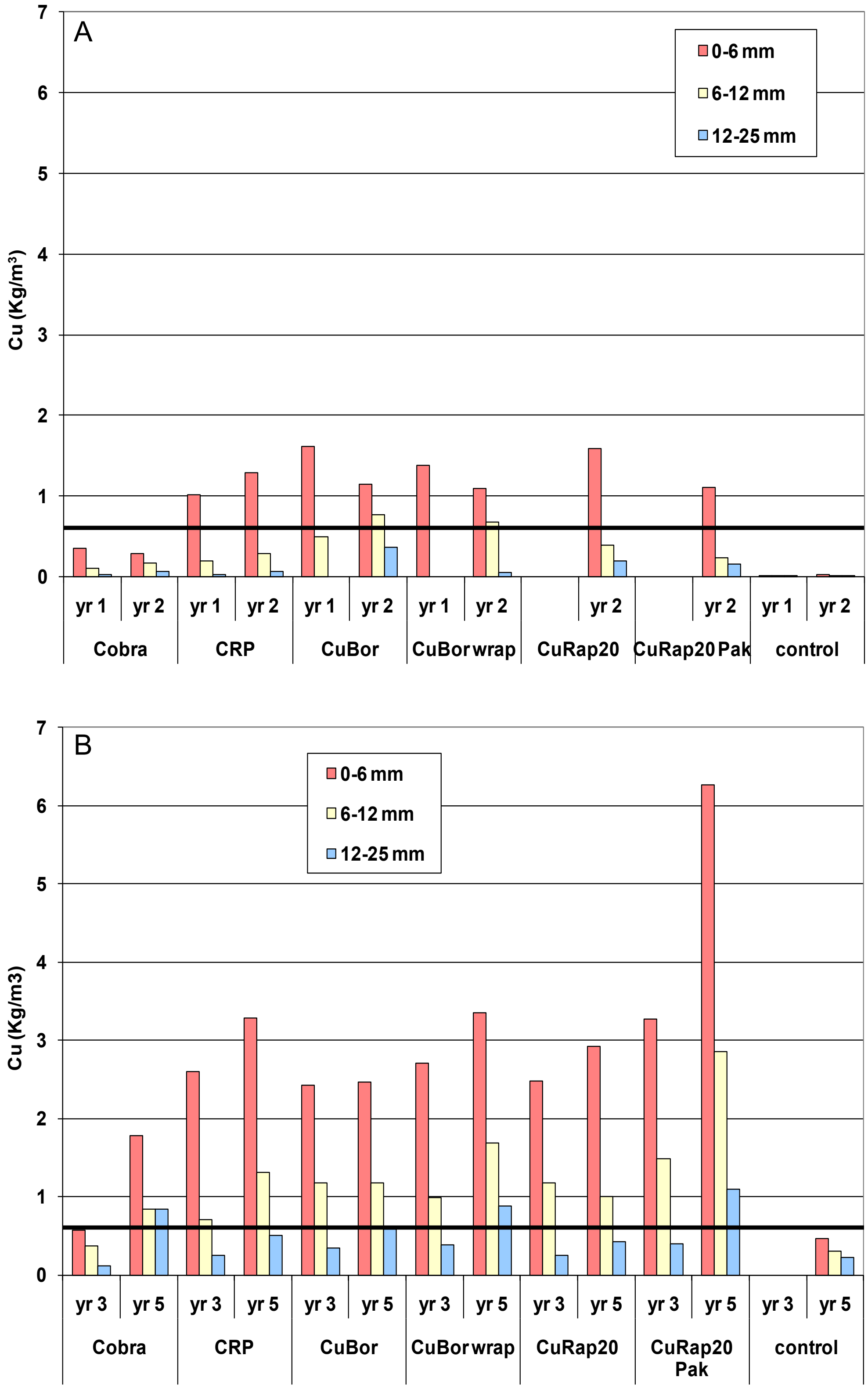

Figure IV-1. Copper levels in southern pine poles A. 1 and 2 and B. 3 and 5 years after application of various external supplemental preservatives.

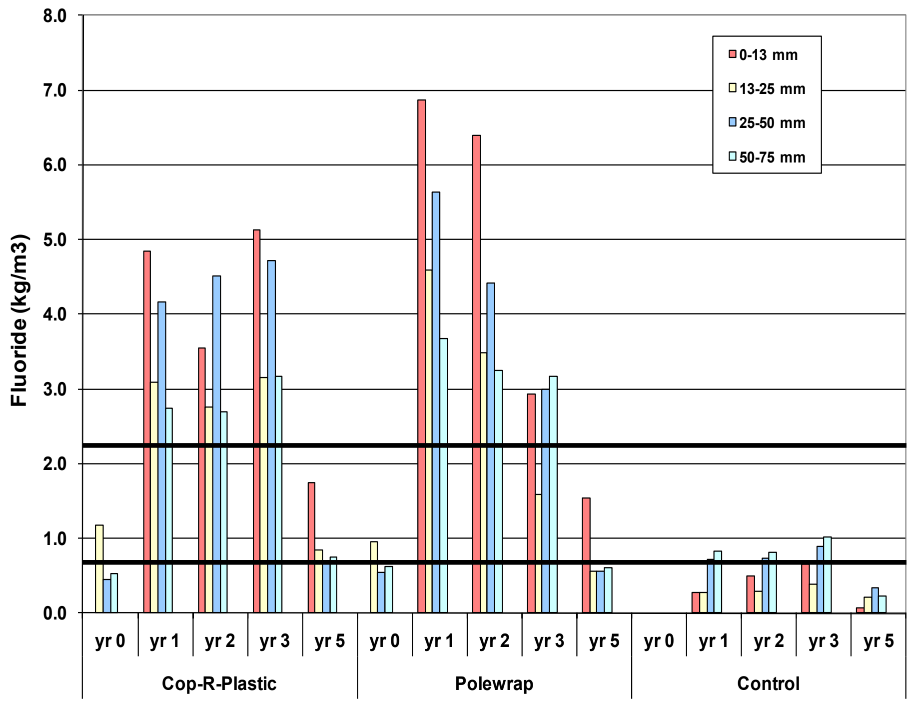

Figure IV-2. Fluoride levels in southern pine poles 1 to 5 years after application of various external supplemental preservatives.

is possible that one or both of the missing two control samples were mistakenly assigned to the fluoride treatments. The fluoride samples were tested for boron and none was detected. Fluoride analysis of the diffusible control samples is underway.

Boron levels in poles treated with paste or wrap formulations of CuBor or CuRap 20 generally increased rapidly after treatment (Figure IV-3). Boron became more evenly distributed across the pole within 2 years after treatment. Boron levels tended to decline within 5 years after treatment and only the CuRap 20 bandage treatment retained boron levels above the threshold for protection against external fungal attack. Boron levels in the remaining treatments remained above the internal threshold level, but these treatments are primarily designed for external, not internal treatment.

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 non-treated wood. While these tests have produced data showing that the systems can move into the wood, one of the short-comings of this data is the difficulty in determining just how much chemical is required to confer protection.

This is a particularly difficult topic to study because of the groundline environment. In most cases, the wood still has some level of initial preservative treatment present and the goal is to supplement that chemical loading. At the same time, the soil environment harbors fairly aggressive microorganisms and the wood may already be colonized by fungi. Finally, most of the previous data on fungal thresholds has been developed for traditional wood decay fungi, while surface decay below ground is dominated by soft rot fungi. Soft rot fungi tend to be more chemically

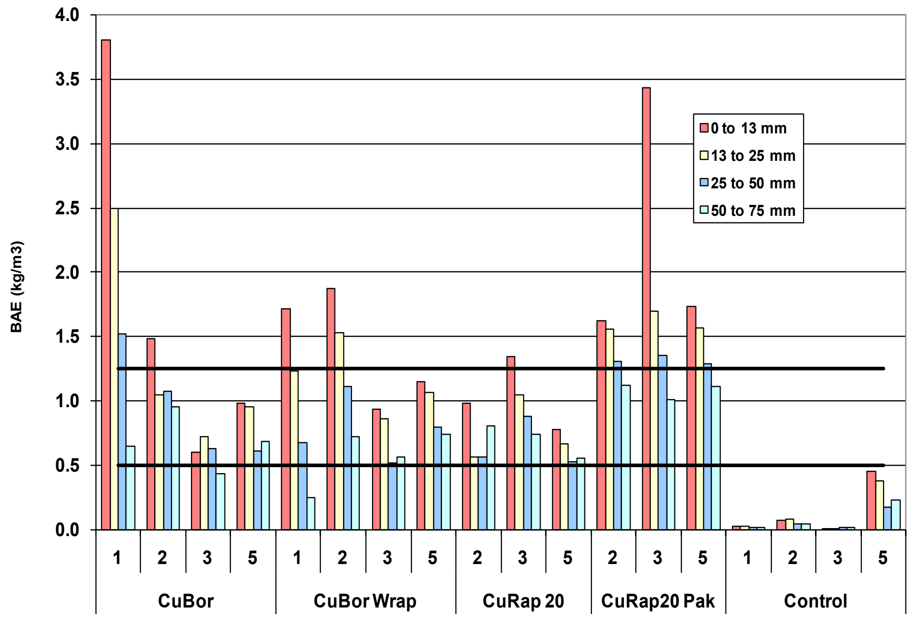

Figure IV-3. Boron levels in southern pine poles 1 to 5 years after application of various external supplemental preservatives.

tolerant and their location within the wood cell wall makes them potentially less susceptible to chemical action. Finally, a number of these systems contain both water diffusible and oil soluble components which move at different rates into the wood.

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

We are currently evaluating a new method for assessing external preservatives on a small scale basis and will report on this work in 2011.

F. Performance of External GroundlineTreatments in Drier Climates

External groundline preservatives are applied throughout the United States and we have established field trials in Oregon, California, Georgia and New York to assess the effectiveness of these systems under a range of environmental conditions. One area where we have neglected to collect field performance data is in drier climates. Conditions in these areas differ markedly from those in wetter climates. While soil moisture content near the surface may be low, subsurface moisture contents can be very conducive to decay. Soil conditions may also differ with a tendency toward more alkaline conditions in some areas. These characteristics may alter the performance of supplemental groundline treatments.

In order to assess this possibility, western pine, southern pine, western redcedar and Douglas-fir poles in both the Salt River Project and Arizona Public Service systems were selected for study.

The pole population consisted of poles treated with pentachlorophenol in AWPA Solvent Types A, B, and D. Solvent types B and D are both volatile systems that evaporate from the wood after treatment, leaving a clean and dry surface, while Solvent Type A remains in the pole. There has been a long history of performance issues related to the use of Solvent Types B and D. The absence of residual solvent tends to render penta less effective against soft rot fungi and these poles tend to experience substantial surface degradation in relatively short times after installation. While neither Solvent Types B or D is still used, many utilities have hundreds of thousands of poles in service that were initially treated with these systems.

Each of the seven treatments (Table IV-3) was applied to an equal number of poles of each species/solvent combination when possible. The exception was Bioguard Tri-Bor paste, which was applied only to Douglas-fir poles treated with pentachlorophenol in solvent type A. The area around the pole was excavated to a depth of 450 to 600 mm, and then any decayed surface wood was removed. The pole circumference was measured to ensure that the pole retained sufficient section area to be retained in the system. Small pieces of surface wood were then removed from the poles and placed in plastic bags for later culturing. These samples will be placed on malt extract agar in petri dishes and any fungi growing from the wood will be examined microscopically. The goal will be characterize the surface flora present at the time of treatment.

The systems were all supplied in paste form. The circumference of each pole to be treated was measured at groundline and the amount of paste to be applied to each pole was calculated using the actual product unit weight and recommended paste thickness. The bucket containing the paste was weighed and then the paste was applied using the calculated paste dosage to the

Table IV-3. Groundline treatments applied to poles in Arizona

Trade Name	Active Ingredients	Density (kg/l)	Supplier
CuRap 20	Sodium tetraborate decahydrate, copper naphthenate	1.21	ISK Biosciences
MP400-EXT	Sodium tetraborate decahydrate, micronized oxine copper, tebuconazole, bifenthrin	1.27	Osmose Utilities Services, Inc.
Bioguard Paste	Boric acid, sodium fluoride	1.32	Preschem, Ltd
Cop-R-Plastic II	Sodium fluoride, copper naphthenate	1.49	Osmose Utilities Services, Inc.
CuBor	Copper hydroxide, sodium tetraborate decahydrate	1.21	Osmose Utilities Services, Inc.
Osmose Experimental Paste	unknown	1.29	Osmose Utilities Services, Inc.
BioGuard Tri-Bor Paste (experimental)	Boric acid, Borax 5 mol, Boroguard ZB	1.32	Preschem, Ltd

pole from 75 mm above groundline to a depth of 450 mm below groundline. The bucket was reweighed and the difference between initial and final weight was used to ensure that the calculated paste coverage per unit area was achieved.

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

The degree of chemical migration will be assessed 1, 2, 3 and 5 years after treatment by excavating on one side of each pole, removing a small section of external barrier (100 by 100 mm) 150 mm below the groundline and scraping away any excess paste. We will remove two 12 mm deep sections of shavings using a 38 mm diameter Forstner bit. A portion of the shavings will be placed on malt extract agar in Petri plates to determine if soft rot fungi are present and the remainder of the sample will be ground to pass a 20 mesh screen. One half will be analyzed for copper while the other will be analyzed for any organic preservative present in the system. An additional six increment cores will be removed from the exposed zone. The cores will be segmented into zones corresponding to 0-6, 6-13, 13-25, 25-50 and 50-75 from the surface. The wood from a given zone on an individual pole will be combined and ground to pass a 20 mesh screen. It may be necessary to combine the wood from the outer 0 to 6 mm zone from all poles of a treatment to accumulate a sufficient quantity of material for analysis. The resulting wood samples will be analyzed for residual chemical using the most appropriate method. Boron will be analyzed by the Azomethine-H method while copper will be analyzed by x-ray fluorescence spectroscopy unless we find that the active ingredient levels are below the threshold for detection. In that case, copper will be analyzed by ICP. At the start, we will analyze both cores and the shavings for copper until we can establish whether the two samples produce similar values. Bifenthrin will be analyzed by extraction and gas chromatography, while tebuconazole will be analyzed by extraction and high performance liquid chromatography.

The results will be summarized and compared with the reported threshold for each component.

G. Effects of Pasture Wrap on Preservative Migration From Externally Treated Poles

One of the questions that arose in our field trial in Georgia was the role of pasture wrap on external preservative treatments. Pasture wrap is applied to the top of external preservative bandages to limit the potential for animals coming into contact with the preservative paste; however, the wrap may also alter the ability of rainfall runoff to move down the pole and through the paste. Some poles in the Georgia trial had received pasture wrap while others had not and there was some concern that this might affect performance. In order to test this potential, pentachlorophenol treated Douglas-fir posts (150 mm in diameter by 2.4 m long) were attached to an external framework so that rainfall could strike the pole surfaces and run down the surfaces where it could be collected. Two posts were left untreated to serve as controls, and six posts were treated with a preservative paste containing copper naphthenate and boron. The posts were then wrapped with a plasticized paper barrier. Three of the treated posts then received pasture wrap applied around the top of the barrier. Polyvinylchloride (PVC) tubes (150 mm diameter) were fitted around each post from the butt to a point 450 mm above the butt. Plastic funnels were attached to the base of these PVC tubes and the tubes were filled with coarse sand. The funnels were

Figure IV-4 Assembly used to capture water running down post sections treated with a boron/ copper naphthenate preservative paste.

connected to 12 L containers that captured all water running down the poles and through the sand (Figure IV-4). Water was collected at each rainfall event and weighed to determine total rainfall. A subsample of this water was then analyzed for copper and boron.

Boron levels increased gradually over the first 35 days of the test except for the non-treated control where no boron was detected (Figure IV-5). While there were differences in boron levels in water collections among the six treated posts, the differences were inconsistent. For example, boron levels were higher in one post receiving pasture wrap and lower in the others. These results suggest that the pasture wrap has no measurable effect on boron losses. Copper levels also increased steadily over time, but once again, there was no consistent effect of the pasture wrap on performance.

It was also of interest to note the amounts of preservative that moved from the posts with rainfall. These results suggest that altering the application pattern to better seal the base of the wrap might help retain chemical and improve efficacy.

H. Effect of External Barriers on Pole Performance

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

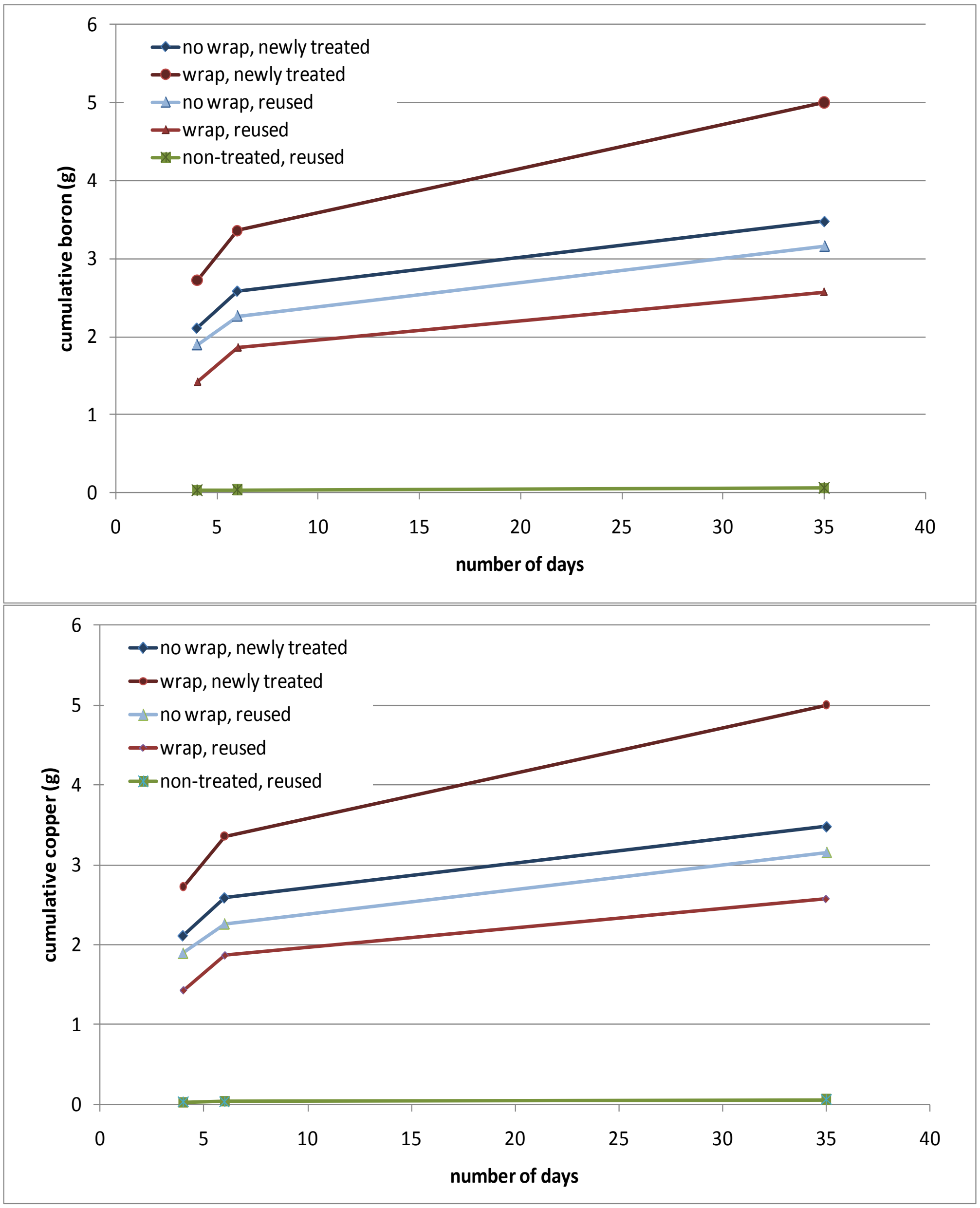

Figure IV-5. Boron and copper levels in rainfall runoff from posts treated with a boron/copper naphthenate paste with or without pasture wrap.

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 (Figures IV-6 to IV-9). As might be expected, poles

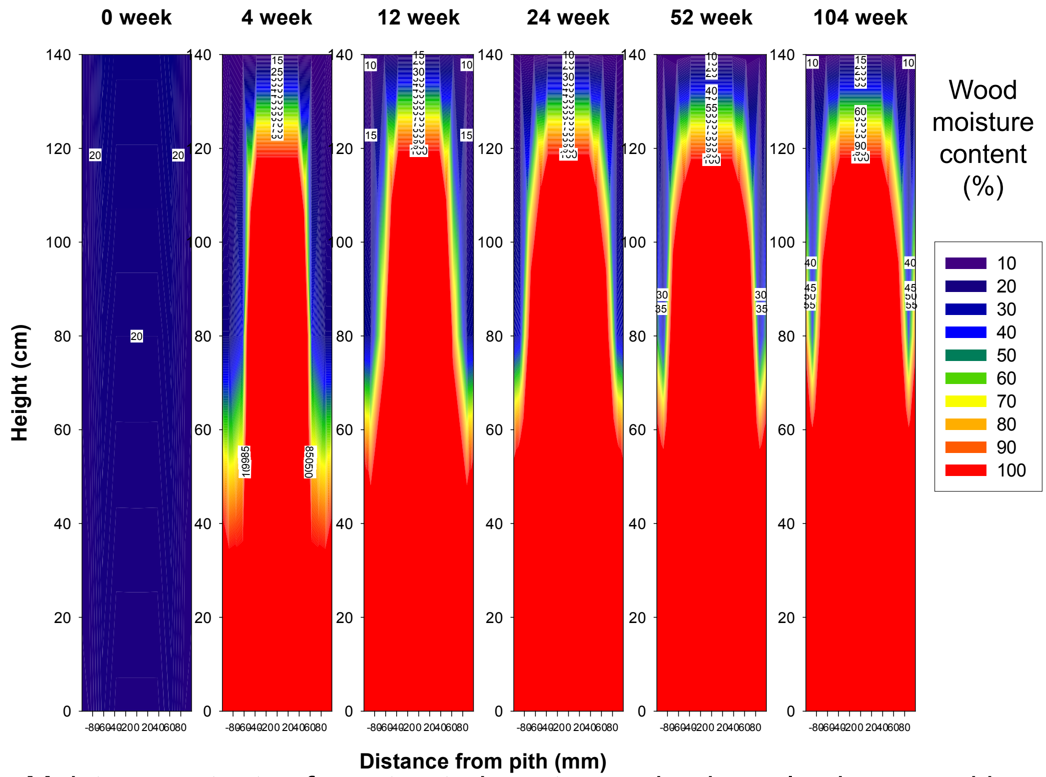

Figure IV-6. Moisture contents of non-treated western redcedar poles immersed in water for 0 to 104 weeks.

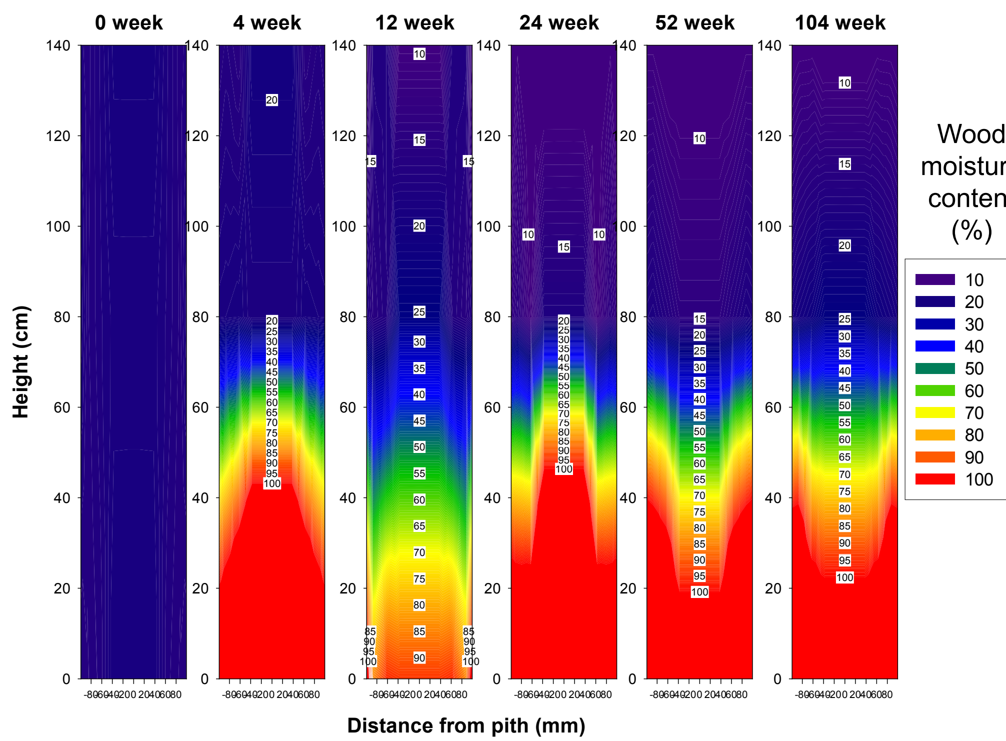

Figure IV-7. Moisture contents of non-treated western redcedar poles immersed in moist soil for 0 to 104 weeks.

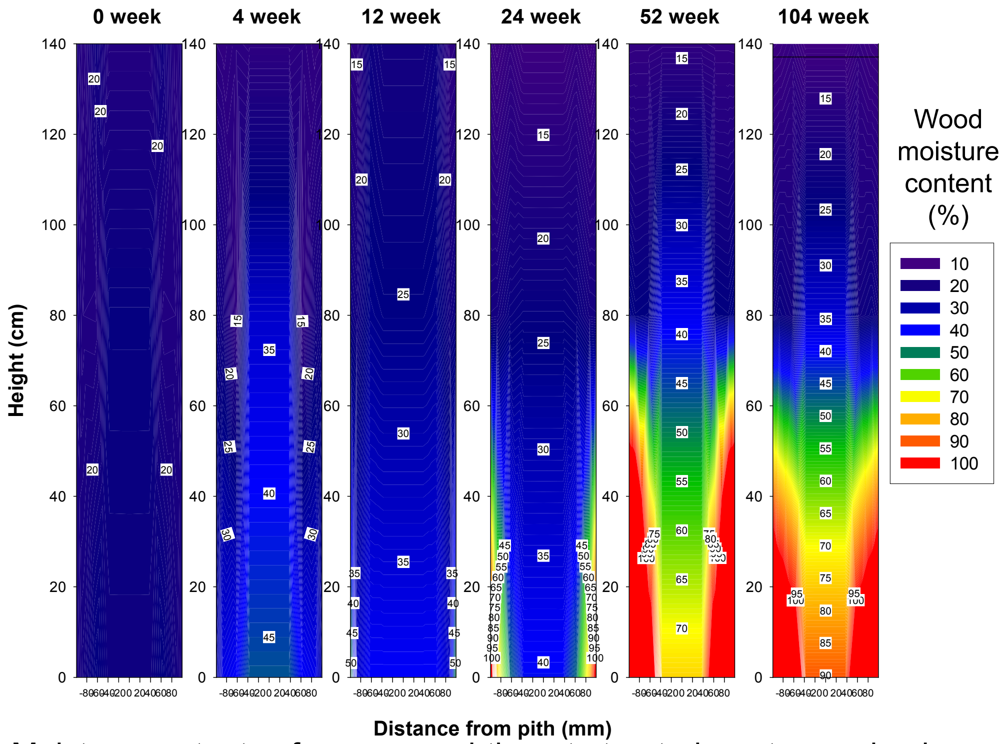

Figure IV-8. Moisture contents of copper naphthenate treated western redcedar poles wrapped with a UPC liner from the butt to the groundline and immersed in water for 0 to 104 weeks.

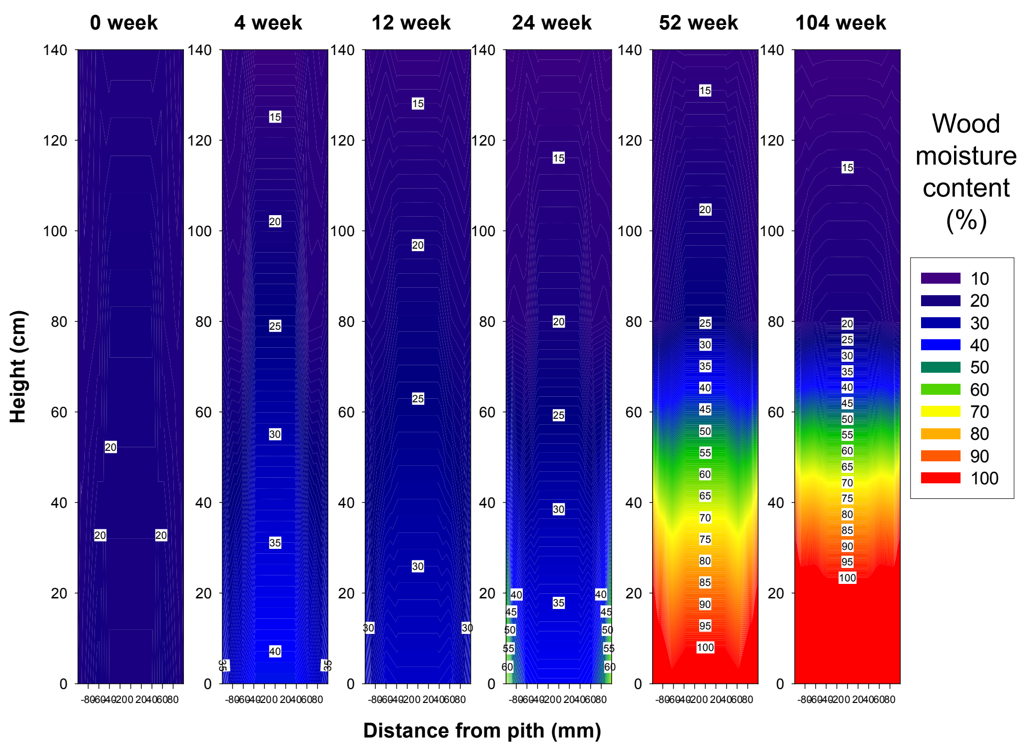

Figure IV-9. Moisture contents of copper naphthenate treated western redcedar poles wrapped with a UPC liner from the butt to the groundline and immersed in moist soil for 0 to 104 weeks.

immersed in water wetted more quickly than those in wet soil; however, all poles were generally wet enough for decay to occur within 2 years of installation. These poles have subsequently been moved to our field test site and set so that the tops of the barriers extend 150 mm above the soil level. These pole sections were then sampled for wood moisture content at groundline, 150 mm above the groundline and 300 mm above groundline immediately after installation and 2 years after installation as described above.

In 2007, an additional set of penta-treated Douglas-fir pole stubs were encased in the newest generation of Biotrans liner and set into the ground at our Peavy Arboretum research site (Figure IV-10). 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 1 m above groundline; five received a Biotrans liner that extended 300 mm above groundline and eleven poles were left unlined.

Six, 12 and 18 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 poten-

Figure IV-10. Examples of external barriers assessed on Douglas-fir poles

Table IV-4. Wood moisture contents at selected distances from the surface of poles with and without a field barrier.

Treatment	Exposure Period (Mo)	Wood Moisture Content (%)[1]			
		0-13 mm	13-25 mm	25-50 mm	50-75 mm
Biotrans Liner 150 mm above groundline	0	39.5 (10.0)	35.1 (7.4)	34.0 (11.8)	33.5 (10.5)
	6 (wet)	57.8 (19.0)	48.1 (10.5)	37.6 (2.6)	37.7 (5.5)
	12 (dry)	48.7 (13.9)	35.6 (10.3)	35.7 (14.6)	34.6 (16.1)
	18 (wet)	48.8 (11.9)	40.6 (11.2)	34.7 (5.3)	31.6 (4.7)
Biotrans Liner 300 mm above groundline	0	38.5 (7.7)	32.2 (3.9)	32.2 (8.1)	40.3 (24.3)
	6 (wet)	67.1 (18.3)	49.5 (5.7)	38.8 (3.0)	35.5 (3.2)
	12 (dry)	45.1 (20.7)	34.6 (9.8)	33.3 (7.0)	33.1(6.7)
	18 (wet)	60.0 (14.6)	40.1 (6.3)	37.4 (5.0)	36.5 (5.6)
Non-lined	0	34.4 (3.5)	28.9 (2.7)	27.2 (3.2)	29.1 (3.30
	6 (wet)	54.3 (14.9)	47.1 (7.4)	42.1 (7.9)	43.7 (10.8)
	12 (dry)	20.2 (4.9)	28.7 (15.7)	28.8 (8.3)	29.5 (4.3)
	18 (wet)	47.3 (15.0)	34.7 (6.1)	31.5 (3.6)	31.7 (5.4)

1. Numbers in parentheses represent one standard deviation from the mean of 15 measurements for wrapped poles or 33 measurements for non-wrapped poles.

tial for moisture to move into the wood through the sample holes.

Sampling of these poles 6 months after installation revealed that moisture contents 150mm above the groundline were similar although the moisture levels in poles without a liner were slightly lower. Moisture contents 6 months after installation were elevated in the outer zone (0-13 mm from the surface) and declined with distance inward (Table IV-4). There appeared to be little difference in above ground moisture content between poles with and without barriers. The 6 month sampling coincided with the middle of our rainy season when wood moisture content would be expected to be elevated. Sampling 12 months after setting revealed moisture contents that were uniformly low in the poles without a barrier, while those with barriers remained at or above 45 % moisture content in the outer 13 mm. These results suggest that the barrier limited drying. While this does not necessarily mean that barriers will affect the rate of decay, it does mean that conditions suitable for decay extend further upward from the groundline than they do in poles without barriers and inspectors would need to alter their inspection procedures to ensure that they detect decay in these structures.

Moisture contents 18 months after setting once again rose to levels above the fiber saturation point in the non-barrier treated poles, but changed little in the barrier protected poles. These results indicate that poles without barriers experience much greater seasonal fluctuations in moisture content although all of the moisture contents measured were near or above the point where fungal attack can begin. One interesting finding was that the moisture contents in barrier treated poles have not tended to increase over time. In our original assessment, one possible development was for moisture to continue to move down checks and into the below ground portions of the poles. This would result in an ever increasing moisture content that might produce very high moisture contents that could limit oxygen and thereby inhibit decay. This has not, to date, occurred.

PostSaver, a commercial barrier system (PostSaver, Inc.) has been evaluated on Spruce-Pine-Fir posts treated with chromate copper arsenate or borates installed at a site located 20 km north of Corvallis, Oregon. The CCA treated posts were treated to the above ground retention (4.0 kg/m^3), and borate treated posts are only recommended for non-soil contact where the wood is not subjected to wetting (AWPA, 2010). As a result, neither of these treatments should perform well in direct soil contact. The posts were set so that the top of the barrier was approximately 100-150 mm above the soil level. Post condition was assessed by periodically subjected each post to a flexural test as described in Morrell et al., 1996. Wood moisture content was assessed 12, 16 and 29 months after installation. The 12 month sample point corresponded to the middle of the wet season when the wood should be at its wettest, while the 16 and 29 month times corresponded to the end of the wet season when the material should have begun to dry. Increment cores were removed at groundline as well as at 150 mm above and and 150 mm below the groundline. The outer and inner 25 mm of each core segment were individually placed into tared glass vials which were tightly capped. The vials were weighed to determine the wet wood weight, then opened and oven-dried for 24 to 48 hours at 103 C. The vials were reweighed and the difference between pre- and post- oven dry weight was used to determine wood moisture content.

Moisture contents of PostSaver coatrd posts were between 25 and 46 % in the middle of the wet season (Table IV-5). Moisture levels were highest below groundline, but the differences were not great. Moisture levels at 16 months ranged from 17 to 38 % with the highest moisture contents at groundline. As expected, moisture levels were lowest 150 mm above ground. Moisture levels 29 months after setting ranged from 23 to 46 % MC, with the lowest moisture levels again occurring above ground. Moisture levels were highest below groundline although the differences between groundline and below groundline were slight. The results suggest that moisture has begun to accumulate below ground in these posts.

Flexural inspection indicated that virtually all posts remained in test 4 years after installation. The exceptions were three borate treated posts which failed in the middle of the barrier wrapped zone, suggesting that the higher moisture levels had depleted the boron in this zone. Further

Table IV-5. Moisture contents of wood 150 mm below groundline, at groundline and 150 mm above the groundline of PostSaver coated spruce-pine-fir posts 12, 16, and 29 months after setting.

Sampling Location	Zone	Wood Moisture Content (%)		
		12 Months	16 Months	29 Months
<150 mm GL	Inner	37	29	46
	Outer	43	29	40
Groundline	Inner	36	38	40
	Outer	36	30	36
>150 mm GL	Inner	25	19	27
	Outer	34	17	23

analysis of the residual boron in these posts is planned.

One of the concerns with barrier systems is that water running down the poles along checks will move into the barrier zone where it will be absorbed by the wood. Over time, this may allow the wood moisture content to reach fairly high levels. This would create low oxygen conditions that would sharply limit the risk of decay. At some point above the barrier, however, moisture conditions will diminish to the point where conditions are ideal for fungal growth. While this would not preclude the use of barriers, it is important to determine where this point is mostly likely to occur so that future inspections concentrate on this zone.

The results indicate that barriers do not markedly affect moisture levels in posts, possibly because the smaller size of the posts allows them to dry during the dry season. Moisture contents in pole sections with barriers remained elevated, suggesting that the combination of a water trapping barrier and the larger size of the poles increased moisture retention. While this increased water retention does not mean that barriers will negatively affect pole performance, it does suggest that utilities may need to alter their pole inspection practices to ensure that they explore above ground zones of these poles.

I. Establish a Field Trial of Current Liner Systems

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

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

Douglas-fir pole sections (250-300 mm in diameter by 3.1 m long) were treated to 9.6 kg/m^3 with pentachlorophenol and southern pine pole sections of the same dimensions were treated with CCA to a retention of 9.6 kg/m^3 or penta to a retention of 7.2 kg/m^3. The pole sections were sampled using an increment borer prior to use to determine initial preservative penetration and a sufficient number of cores were removed to determine retention per pole section. The pole sections were set to a depth of 0.9 m with or without field liners. Poles with liners were set so that the liner was 150 mm above the groundline. One set of poles will be used for monitoring potential migration of preservative components into the surrounding soil, and the other set will be used for measuring wood moisture content above and below the barrier.

Soil samples were collected prior to pole installation from 20 random locations at the test site using a trowel. A small pit was dug at each sampling location and soil was removed from depths of 0 to 25 mm, 25 to 50 mm, 50 to 75 mm and 75 to 150 mm below the ground level. The soil was air dried, screened through a #6 brass sieve and then divided into two samples. The first will be

Table IV-6. Treatments evaluated for assessing field liners on Douglas-fir and southern pine poles.

Species	Treatment	Barrier	Number of Poles	
			Migration	Moisture
Douglas-fir	Penta	+	4	4
	Penta	-	4	4
Douglas-fir	None	-	4	-
Southern pine	Penta	+	4	4
	Penta	-	4	4
Southern pine	CCA	+	4	4
	CCA	-	4	4

analyzed for copper, chrome and arsenic by ICP. The remaining sample will be analyzed by solvent extraction and, after cleaning up, analysis by GC-MS for penta. These results will be used to establish baseline levels of preservative in the soil for comparison to soil samples removed in subsequent years.

At annual intervals after installation, cores will be removed from the soil beginning immediately adjacent to the poles, as well as 150 and 300 mm away. A minimum of three poles with, and three poles without field liners will be sampled per treatment/species combination. The soil cores will be divided into zones as described above and then analyzed for the appropriate preservative. We would expect to move the sampling further outward if we detect increased chemical levels at the initial sampling sites.

Wood moisture content was assessed at the time of installation. and will again be assessed at the beginning and end of the rainy season over a 3 year period. At each time point, increment cores will be removed from three locations around each of four poles per treatment/species combination beginning 150 mm below groundline, then moving upward to groundline, and 300 and 900 mm above groundline. Each increment core will be divided into zones corresponding to 0 to 25 mm, 25 to 75 mm and 75 mm to the pith. Each core section will be placed into a tared glass vial which will be sealed and returned to the lab where the cores will be weighed, oven dried and reweighed to determine wood moisture content. The sampling holes will be plugged with tub-caulking to retard moisture entry and the liner will be repaired. The results will be used to develop moisture content profiles over time for the wrapped and non-wrapped poles.

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OBJECTIVE V

PERFORMANCE OF COPPER NAPHTHENATE TREATED WESTERN WOOD SPECIES

Copper naphthenate has been available as a wood preservative since the 1940's, but the real commercial use of this system has only occurred in the last 2 decades, as utilities sought less restrictively labeled chemicals. Copper naphthenate is currently listed as a non-restricted use pesticide, meaning that applicators do not require special licensing to apply this chemical. This has little bearing on the use of preservative treated wood, since there are no restrictions on who can use any of the preservative treated wood products currently on the market (although there are recommended practices for the use of each product); however, some users have sought to soften their environmental image by shifting to alternative preservatives such as copper naphthenate.

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

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

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

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

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

In 2006, we replaced the decay chambers, which had degraded to the point where they did not tightly seal. This often resulted in drier conditions that were less conducive to decay. The new chambers created much more suitable decay conditions and this was evidenced by subsequent drops in ratings for all treatments.

Freshly sawn stakes continue to outperform weathered stakes at all retention levels. (Figures V-1, 2). All of the freshly sawn stakes treated with copper naphthenate to retentions of 4.0 kg/

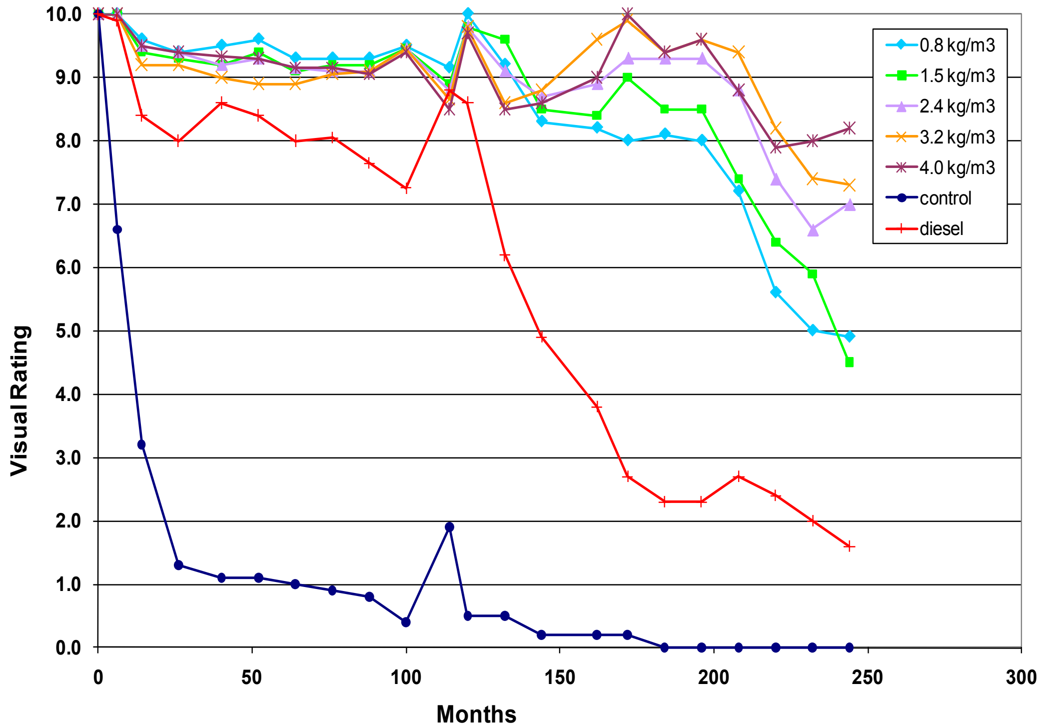

Figure V-1. Condition of freshly sawn western redcedar sapwood stakes treated with selected retentions of copper naphthenate in diesel oil and exposed in a soil bed for 244 months.

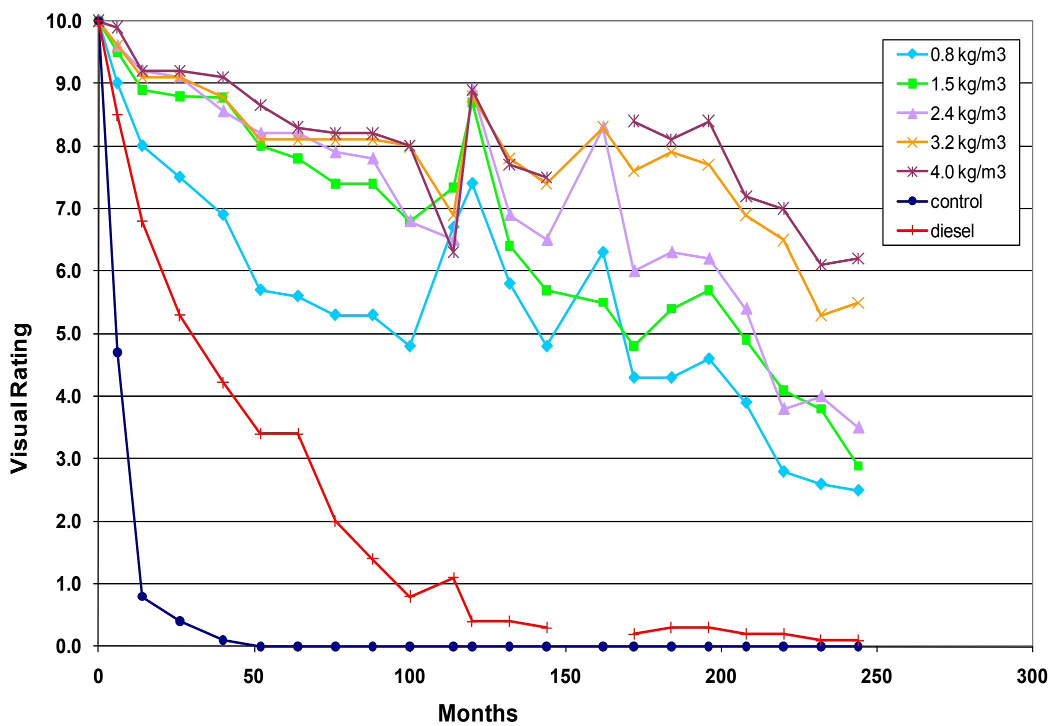

Figure V-2. Condition of weathered western redcedar sapwood stakes treated with selected retentions of copper naphthenate in diesel oil and exposed in a soil bed for 244 months.

m^3 continue to provide excellent protection after 244 months, while the conditions of the stakes treated to the two lower retentions continued to decline this past year. Stakes treated to the two lowest retentions have declined below a 5.0 rating suggesting that decay has begun to affect the wood. Ratings for the intermediate retention were just above 6.0, indicating that the treatment had begun to lose some of its efficacy.

Weathered stakes tended to exhibit much greater degrees of damage at a given treatment level. Weathered stakes treated to the three lowest retentions had ratings below 4.0 and the lowest retention had ratings below 3.0 (Figure V-2). The stakes treated to these three retentions continued to experience declining ratings while those treated to the two higher retentions did not change. Clearly, prior surface degradation from both microbial activity and UV light tended to sharply reduce the performance of the weathered material.

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

C. Effect of Biodiesel Co-Solvents on Performance of Copper Naphthenate

Copper naphthenate has generally been used with diesel as the solvent. The combination of the diesel components and the co-solvent used to solubilize copper naphthenate produce a combined solvent that meets the requirements specified in American Wood Protection Association Standard P9 Type A. While diesel generally works well as a solvent, its major drawback is odor and many treating plants have sought solutions to reducing the odor issues associated with this solvent. One approach that has recently gained favor is to add varying amounts of biodiesel as a co-solvent.

The use of biodiesel as a co-solvent for solubilizing pentachlorophenol has raised considerable controversy because of concerns that the solvent would reduce penta efficacy or lead to early failures. Tests performed so far show no evidence of early penta failures when using biodiesel as a co-solvent; however, there are no similar test data on biodiesel as a copper naphthenate co-solvent.

Morgan et al, (2010) reported on soil block tests of a biodiesel amended P9 Type A solvent. Although the focus was on the performance of this solvent with pentachlorophenol, copper naphthenate was also studied. The copper naphthenate data showed that the treatments including biodiesel as a co-solvent were less effective against a copper tolerant fungus (Table V-1). Thresholds for protection against *Postia placenta* were four times higher for the biodiesel amended solvent than for # 2 diesel alone in non-weathered blocks. In fact, no threshold for fungal protection could be calculated for weathered blocks treated to the same retentions.

Although the solvent in question is not used for copper naphthenate treatment, we were concerned about the potential negative effects of biodiesel on other solvents used with this chemical. Copper naphthenate has typically been dissolved in #2 diesel and our field evaluations have shown that this treatment combination has performed well on Douglas-fir poles. There is no public data on the performance of copper naphthenate with diesel amended with biodiesel. In order to address this issue, the following test was performed.

Table V-1. Estimated toxic thresholds for copper naphthenate in two P9 Type A solvents against two brown rot fungi and a white rot fungus as determined using the AWPA Standard E10 soil block method (Morgan et al, 2010).

Carrier	Estimated Toxic Threshold (Kg/m^3 as Cu)					
	G. trabeum		*P. placenta*		*T. versicolor*	
	non-weathered	weathered	non-weathered	weathered	non-weathered	weathered
Diesel	0.40	0.40	0.43	0.43	0.37	0.42
FP9-HTS	0.40	0.40	1.73	ND	0.42	0.40

ND= Not Determined because highest retentions still had too much weight loss.

Before we describe the tests, a little information on how biodiesel fits into the current American Wood Protection Standards is included.

At present, the AWPA Standards allows the use of biodiesel as well as other co-solvents in P9 Type A oils as long as the mixture meets the distillation, viscosity, flash point and solvency parameters in the specification. The Standard requires that the solvent be derived from petroleum distillates, however, there is no such requirement on co-solvents nor is there a limit on the amount of co-solvent that can be used. There is admittedly debate over this interpretation and one opponent of biodiesel use has asked the AWPA for a ruling on whether the current Standard allows for its use. In an April 20, 2009 letter, the AWPA stated that "In general the panel noted that while there is not a numeric limit explicitly listed in the Standard, common sense dictates that some type of limitation is implied. In any case, the panel could not agree on how to render such a determination. Further, the Standard may or may not preclude the use of biodiesel as a co-solvent, since it is not known whether or not all biodiesels meet the specifications which apply to co-solvents in the Standard.

There is ample evidence that solvent characteristics can have a dramatic influence on biocide performance. The best example of this effect occurs when pentachlorophenol is solubilized in liquefied petroleum gas (lpg) and used to treat Douglas-fir untility poles. While penta is highly effective in heavy oil, poles treated with penta in lpg experienced substantial soft rot attack and continue to pose major maintenance challenges for utilities unfortunate enough to have purchased poles treated using this process. This treatment has not been used for almost 2 decades, but the problems associated with this treatment have led utilities to take a strong interest in ensuring that the solvents used to treat their poles are capable of providing maximum performance.

ASTM defines biodiesels as "mono-alkyl esters of long chain fatty acids that are derived from vegetable oils or animal fats." Biodiesels can be derived from rendering of animal wastes or oil seeds such as soybean or palm oil. The National Biodiesel Board reports that over 170 facilities manufacture biodiesel with a potential annual production capacity of over 2 billion gallons. This material is primarily used as a blend in conventional diesel but it can also be used to solubilize penta. The mixture can then be diluted with other carriers (including conventional diesel) for treatment much in the same way as penta concentrate. The amount of biodiesel required ranges from 25 to 35 % of the final mixture. While pure biodiesels can also be used, they are far more costly than other solvents.

In this report, we describe laboratory tests of three biodiesel sources as co-solvents in #2 diesel for the treatment of southern pine sapwood blocks with copper naphthenate.

Southern pine blocks (19 mm^3) were oven-dried (50 C) and weighed (nearest 0.01 g). The blocks were then sorted by density as per the Standard and allocated to groups of 36 for treatment. A preliminary test was conducted to determine uptake of each solvent diluted in toluene. The goal was to deliver approximately 120 kg of oil per m^3 of wood. The solvents were then diluted in toluene to produce the target level with each solvent.

Biodiesel was obtained from recycled vegetable oil, canola, or soy based sources. The biooils were then tested as 10, 20, and 30 % wt/wt mixtures with #2 diesel. Solutions of a given solvent mixture were prepared to produce target retentions of 0.4, 0.8, 1.2, 1.8 and 2.4 kg/m^3 of copper naphthenate (as Cu metal). The current AWPA Standard for poles treated with copper naphthenate are 0.96, 1.28 and 2.08 kg/m^3 for southern pine and 1.20, 1.50, and 2.40 kg/m^3 for Douglas-fir in Use Categories UC4 a, b, or c, respectively

The blocks were then placed into containers with their respective solution and these containers were placed into a treatment vessel. The treatment vessel was closed and a vacuum was drawn over the solution (-760 mm Hg or -0.102 Mpa) for 30 minutes. The vacuum was released, then the pressure was raised to 100 psi (0.689 Mpa) and held for 30 minutes. Pressure was then released, and the blocks were removed, blotted dry and weighed to determine net solution absorption.

The blocks were allowed to stand for 7 days under non-drying conditions before being air-dried. The blocks were then oven-dried (50 C) and weighed. One half of the blocks from each treatment were then subjected to a 14 day weathering exposure, while the remaining blocks were not subjected to weathering.

The blocks were soaked with water prior to being placed in plastic bags and sterilized by exposure to 2.5 mrad of ionizing radiation from a cobalt 60 source.

Decay chambers were prepared by half-filling 454 ml french squares with moist forest loam and placing a western hemlock feeder strip on the soil surface. The bottles were loosely capped and autoclaved for 45 minutes at 121 C.

After cooling, the bottles were inoculated with 2 to 3 mm diameter malt agar disks cut from the actively growing edges of cultures of the test fungus. The fungi evaluated in these procedures were *Postia placenta* (Fr.) Larsen et Lombard (Isolate Madison 698) or *Gloeophyllum trabeum* (Pers.ex. Fr.) Murr. (Isolate Madison 617). Both species cause brown rot. *G. trabeum* is known to be tolerant of organic compounds such as penta, while *P. placenta* is tolerant of copper-based preservatives. The agar plugs were placed on the edges of the wood feeder strips, then the jars were loosely capped (to allow air exchange), and incubated until the feeder strip was thoroughly covered with fungal mycelium. The sterile test blocks were then placed, cross section down, on the surfaces of the feeder strips, the bottles were loosely capped and incubated at 28 C for 12 weeks.

At the end of the incubation period, the blocks were removed, scraped clean of adhering mycelium and weighed to determine wet weight. The blocks were then oven-dried (50 C) and weighed. The difference between initial and final oven-dry weight was used as a measure of the effect of fungal exposure. The weight losses were then plotted against chemical loading. The intersection of the best fit line for fungal associated weight losses and the line for weight losses associated with the method (i.e. losses caused by handling, weighting, and drying) was the estimated threshold for protection against fungal attack.

Copper retentions in blocks before and after leaching tended to vary around the target levels but there was no consistent difference that would suggest selective absorption by any particular biodiesel amended solvent (Table V-2). Solvent retentions in the blocks varied from 110 to 141 kg/m^3 and appeared to be slightly lighter in blocks treated in canola amended diesel (Table V-3). The main concern in treatment was to limit the overall oil retentions to those typically found in freshly-treated poles since excess oil could enhance biological performance. This did not appear to be the case, although many of the oil retentions were above the target 120 kg/m^3.

Weight losses of blocks exposed to *G. trabeum* tended to fall rapidly with increasing copper naphthenate retentions regardless of the amount and source of biodiesel used to amend the # 2 diesel (Table V-4,Figures V-3, 5, 7, 9). The lack of copper tolerance is consistent with previous findings with this fungus. Leaching had a slight effect on weight loss, but the thresholds found in these tests were within the range of those found with the previous oil study (Tables V-1 and V-6). The results indicate that biodiesel does not negatively affect the performance of copper naphthenate treated blocks exposed to *G. trabeum*.

The presence of biodiesel as a co-solvent in blocks exposed to *P. placenta* had a very dramatic effect on decay resistance of the blocks (Table V-5). Wood weight losses tended to increase with increasing biodiesel concentration for all three biodiesel sources. The effect was greater on weathered blocks; however, it was present on both non-weathered and weathered materials treated to the same retentions. Weight losses in our tests tended to be greater than those found in the earlier test, resulting in slightly higher threshold values for even the non-amended #2 diesel.

Table V-2. Copper retentions in southern pine sapwood blocks treated with copper naphthenate in various combinations of # 2 diesel and canola, soy or recycled biodiesel as determined by x-ray fluorescence spectroscopy.

Bio oil	% bio oil	Target retentions (Kg/m3 Cu)											
		0.0	0.4	0.8	1.2	1.8	2.4	0.0	0.4	0.8	1.2	1.8	2.4
		Not weathered						Weathered					
none (#2 diesel)	0	-0.08	0.37	1.14	1.49	2.09	3.02	-0.08	0.44	0.69	1.31	2.11	2.39
soy	10	-0.08	0.51	0.84	1.42	1.95	2.48	-0.07	0.36	0.99	1.34	1.85	2.09
	20	-0.07	0.42	0.81	1.18	1.41	2.50	-0.08	0.38	0.84	1.22	1.44	1.64
	30	-0.08	0.40	0.76	1.25	1.86	2.75	-0.01	0.47	0.85	1.39	1.78	2.27
used	10	-0.04	0.47	0.75	1.31	2.17	2.47	-0.09	0.32	0.77	0.97	1.57	2.57
	20	-0.07	0.39	0.83	1.33	1.98	2.31	-0.08	0.31	0.72	1.15	1.74	1.83
	30	-0.10	0.40	0.97	1.21	2.06	1.76	-0.09	0.39	0.89	1.10	1.44	2.11
canola	10	-0.09	0.35	0.83	1.02	1.32	1.81	-0.09	0.33	0.69	1.15	1.69	1.25
	20	-0.10	0.28		0.88	1.54	2.13	-0.09	0.43	0.74	1.00	1.71	1.98
	30	-0.10	0.26	0.64	0.95	1.23	2.17	-0.12	0.22	0.79	1.09	1.33	2.41
Toluene	0	-0.07	-	-	-	-	-	-0.08	-	-	-	-	-
Water	0	-0.04	-	-	-	-	-	-0.04	-	-	-	-	-

Table V-3. Average solvent retentions in southern pine blocks treated with copper naphthenate in various combinations of # 2 diesel and canola, soy or recycled biodiesel.

Bio oil	% bio oil	Target retentions (Kg/m^3 oil)					
		0.0	0.4	0.8	1.2	1.8	2.4
none (#2 diesel)	0	133	129	129	129	139	141
soy	10	128	137	137	137	137	134
	20	135	125	126	124	122	118
	30	125	125	125	127	127	127
used	10	126	123	124	126	126	127
	20	129	129	129	130	128	131
	30	132	131	129	110	111	109
canola	10	115	119	111	117	111	116
	20	115	113	110	108	116	116
	30	122	113	115	116	118	118

Table V-4. Weight losses of southern pine blocks treated with copper naphthenate in various combinations of # 2 diesel and canola, soy or recycled biodiesel prior to exposure to *G. trabeum* for 12 weeks in an AWPA E10 soil block test.

Non-weathered													
Bio oil	% bio oil	Target retentions (Kg/m^3 Cu)[1]											
		0.0		0.4		0.8		1.2		1.8		2.4	
none (#2 diesel)	0	31.1	(1.9)	8.1	(0.4)	7.2	(1.2)	7.5	(1.1)	6.9	(1.0)	7.4	(1.5)
soy	10	35.0	(3.4)	7.4	(0.7)	6.4	(0.9)	6.2	(0.5)	5.2	(0.7)	5.5	(0.5)
	20	32.9	(2.7)	8.8	(0.9)	5.9	(0.5)	4.8	(0.4)	5.3	(0.5)	5.3	(0.5)
	30	33.5	(0.5)	8.3	(1.7)	6.1	(1.3)	5.9	(0.8)	5.0	(0.5)	5.0	(0.9)
used	10	33.3	(1.6)	8.9	(1.2)	6.2	(0.5)	5.3	(0.8)	5.3	(0.9)	5.2	(0.9)
	20	35.0	(2.6)	8.0	(0.6)	5.9	(0.4)	5.0	(0.7)	4.5	(0.4)	4.5	(0.7)
	30	30.3	(3.7)	8.1	(1.7)	6.5	(0.8)	5.8	(1.3)	5.3	(0.8)	4.9	(1.0)
canola	10	24.6	(3.2)	6.0	(1.1)	4.4	(0.2)	4.0	(0.8)	3.9	(0.8)	3.8	(0.6)
	20	29.0	(5.6)	5.4	(1.1)	4.7	(0.8)	4.3	(1.2)	3.4	(0.4)	3.0	(0.5)
	30	23.7	(3.4)	4.2	(1.0)	2.7	(0.3)	2.8	(0.4)	2.7	(0.5)	2.5	(0.2)
Toluene	0	60.4	(3.6)										
Water	0	53.6	(7.1)										

1. Figures in paraenthses represent one standard deviation.

Table V-4 continued. Weight losses of southern pine blocks treated with copper naphthenate in various combinations of # 2 diesel and canola, soy or recycled biodiesel prior to exposure to *G. trabeum* for 12 weeks in an AWPA E10 soil block test.

Bio oil	% bio oil	Target retentions (Kg/m³ Cu)					
		0.0	0.4	0.8	1.2	1.8	2.4
Weathered							
none	0	49.7 (1.8)	5.2 (1.0)	2.7 (1.3)	2.5 (0.7)	1.7 (0.3)	2.0 (0.2)
soy	10	43.0 (5.6)	5.2 (1.6)	3.3 (0.6)	2.5 (0.3)	2.3 (0.4)	2.3 (0.4)
	20	37.7 (3.0)	5.8 (1.3)	3.2 (0.9)	2.7 (0.6)	2.5 (0.3)	2.1 (0.5)
	30	33.5 (6.5)	5.5 (1.4)	2.3 (0.3)	3.5 (1.7)	2.3 (0.2)	2.7 (0.5)
used	10	40.1 (3.3)	7.5 (2.2)	5.3 (1.6)	4.5 (1.0)	1.7 (0.4)	1.9 (1.4)
	20	41.8 (6.2)	5.7 (2.4)	4.6 (1.3)	4.0 (0.9)	2.6 (0.3)	2.1 (0.2)
	30	33.8 (6.4)	4.8 (1.8)	2.7 (0.6)	2.4 (0.5)	2.5 (0.4)	2.2 (0.3)
canola	10	37.0 (4.6)	2.1 (1.5)	1.6 (0.5)	1.2 (0.3)	1.3 (0.2)	1.3 (0.1)
	20	38.6 (7.7)	3.1 (1.2)	2.6 (0.8)	1.7 (0.5)	1.3 (0.3)	1.2 (0.2)
	30	32.3 (8.1)	3.6 (1.0)	1.7 (0.5)	1.6 (0.2)	1.0 (0.2)	1.1 (0.2)
Toluene	0	49.5 (3.9)					
Water	0	49.0 (5.1)					

Table V-5. Weight losses of southern pine blocks treated with copper naphthenate in various combinations of # 2 diesel and canola, soy or recycled biodiesel prior to exposure to *P. placenta* for 12 weeks in an AWPA E10 soil block test.

Bio oil	% bio oil	Target retentions (Kg/m³ Cu)					
		0.0	0.4	0.8	1.2	1.8	2.4
Non-weathered							
none	0	38.8 (3.1)	14.8 (3.1)	9.1 (2.0)	7.6 (0.7)	9.0 (1.9)	7.5 (0.9)
soy	10	41.8 (1.5)	20.1 (3.9)	11.2 (1.8)	7.4 (0.9)	8.4 (1.6)	6.1 (0.7)
	20	39.2 (1.8)	21.5 (5.3)	18.2 (6.3)	11.3 (3.6)	6.5 (0.8)	7.1 (0.8)
	30	40.0 (2.9)	27.7 (5.3)	25.4 (4.5)	22.3 (7.8)	14.2 (3.1)	10.8 (2.5)
used	10	44.3 (2.1)	22.5 (5.2)	15.4 (6.0)	14.4 (6.9)	7.9 (1.9)	6.1 (1.2)
	20	43.2 (4.5)	25.1 (6.1)	17.1 (7.7)	19.9 (7.7)	12.3 (5.9)	7.5 (1.2)
	30	36.0 (4.5)	29.5 (4.0)	30.9 (6.4)	24.6 (4.0)	20.6 (4.3)	10.2 (3.4)
canola	10	41.7 (2.5)	31.5 (3.1)	18.8 (6.5)	16.4 (7.9)	9.3 (4.3)	5.2 (1.4)
	20	44.2 (4.6)	30.4 (9.3)	25.2 (3.8)	21.9 (4.0)	14.7 (4.3)	13.3 (5.6)
	30	33.6 (2.3)	41.4 (2.3)	29.8 (7.2)	25.0 (6.9)	19.8 (6.4)	16.1 (4.8)
Toluene	0	47.1 (3.1)					
Water	0	51.1 (1.5)					
Weathered							
none (#2 diesel)	0	47.6 (3.4)	27.5 (13.2)	30.0 (6.1)	22.1 (5.2)	6.4 (3.7)	6.4 (2.1)
soy	10	43.2 (3.0)	31.3 (6.3)	20.0 (6.0)	24.9 (8.1)	11.2 (5.3)	7.6 (7.5)
	20	46.8 (3.0)	31.4 (4.7)	30.5 (11.0)	21.5 (12.2)	17.2 (6.4)	11.4 (7.9)
	30	41.8 (4.2)	24.6 (8.0)	30.2 (8.5)	26.7 (5.0)	23.6 (6.5)	21.0 (6.1)
used	10	47.4 (7.1)	33.0 (7.8)	24.3 (7.2)	20.9 (6.8)	16.3 (5.5)	10.0 (9.7)
	20	44.9 (4.1)	33.7 (8.9)	34.9 (7.0)	34.5 (4.4)	33.1 (5.1)	16.9 (6.6)
	30	43.3 (3.1)	37.8 (5.5)	29.8 (3.4)	32.8 (5.0)	25.3 (5.5)	26.3 (7.1)
canola	10	42.4 (2.6)	45.0 (6.0)	38.4 (8.3)	27.2 (9.8)	30.6 (1.9)	14.1 (6.4)
	20	42.9 (3.1)	42.3 (2.3)	41.6 (2.8)	37.8 (5.1)	35.4 (5.8)	27.2 (10.0)
	30	42.9 (3.5)	40.8 (3.0)	38.5 (8.7)	41.1 (6.0)	36.4 (4.5)	33.3 (5.2)
Toluene	0	49.6 (3.9)					
Water	0	50.7 (3.0)					

Table V-6. Estimated toxic thresholds for copper naphthenate in # 2 diesel with varying levels of biodiesel obtained from canola, soy or used oils against two brown rot fungi as determined using the AWPA Standard E10 soil block method.

bio oil	bio oil %	*G. trabeum*		*P. placenta*	
		not weathered	weathered	not weathered	weathered
none	0	0.40	0.41	0.71	1.82
soy	10	0.40	0.41	1.01	1.64
	20	0.41	0.41	1.55	ND
	30	0.41	0.41	ND[1]	ND
used	10	0.41	0.38	1.49	ND
	20	0.41	0.42	ND	ND
	30	0.41	0.44	ND	ND
canola	10	0.39	0.42	1.48	ND
	20	0.39	0.41	ND	ND
	30	0.41	0.41	ND	ND

1. ND= Not Determined because the highest retentions still had too much weight loss.

The thresholds for blocks treated with copper naphthenate in #2 diesel alone and exposed to *P. placenta* were 0.71 and 1.82 kg/m^3 (Table V-6, Figure V-4). These threshold values for the non-weathered blocks were slightly higher than those found in the previous study, but still below currently specified levels of copper naphthenate. The threshold for weathered blocks treated using only # 2 diesel were much higher than those found in the earlier tests. These small blocks lose a considerable amount of material in the leaching phase, but the procedures were identical for the two tests and it is still unclear why the threshold was so much higher in this test.

Threshold levels rose to 1.01 kg/m^3 and then 1.64 kg/m^3 as the concentration of soy based biodiesel content increased to 10 and then 20 % in non-weathered blocks. No threshold could be calculated when 30 % biodiesel was added to the #2 diesel for non-weathered blocks. Weathering of the blocks markedly increased weight losses caused by *P. placenta* and thus, the thresholds. Thresholds were 1.82 kg/m^3 for blocks treated with #2 diesel and1.64 kg/m^3 for blocks treated with 10 % soy biodiesel amended oil. No threshold could be calculated for weathered blocks treated with copper naphthenate in 20 or 30 % soy amended solvent. The slightly lower threshold for the 10 % soy amended treatment compared with the # 2 diesel control was also interesting, given the increased threshold observed when 10 % soy amended soil blocks were exposed without weathering.

Supplementing # 2 diesel with biodiesel derived from used cooking oils or canola oil produced effects that were very similar to those found with soy based biodiesel (Figures V-5-8). Threshold values increased with increasing biodiesel content and also with weathering. The results clearly illustrate that copper naphthenate is much more sensitive to solvent variations than previously considered.

When copper naphthenate was first reintroduced as a wood preservative in the early 1980s, wood treaters attempted to use conventional P9 Type A oils and found that these were unsuitable for this chemical system. Diesel was found to be an ideal solvent and field inspections of poles treated using this chemical in the Pacific Northwest showed that the system performed well. Copper naphthenate, however, can be susceptible to copper tolerant fungi, including *P. placenta*

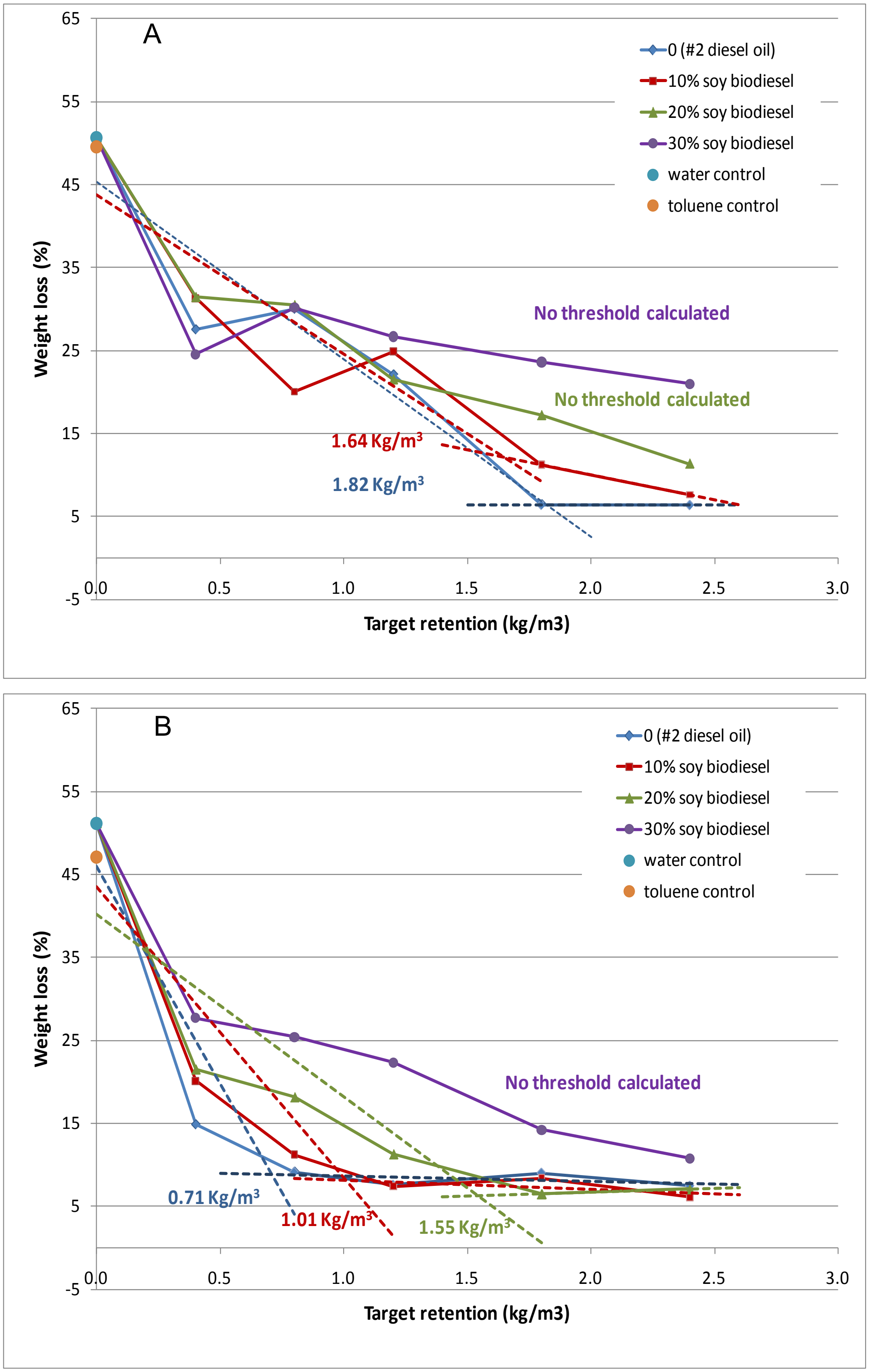

Figure V-3. Effect of soy-based biodiesel concentration in # 2 diesel on weight losses of A. weathered and B. non-weathered copper naphthenate treated blocks exposed to *P. placenta* in an AWPA E10 soil block test.

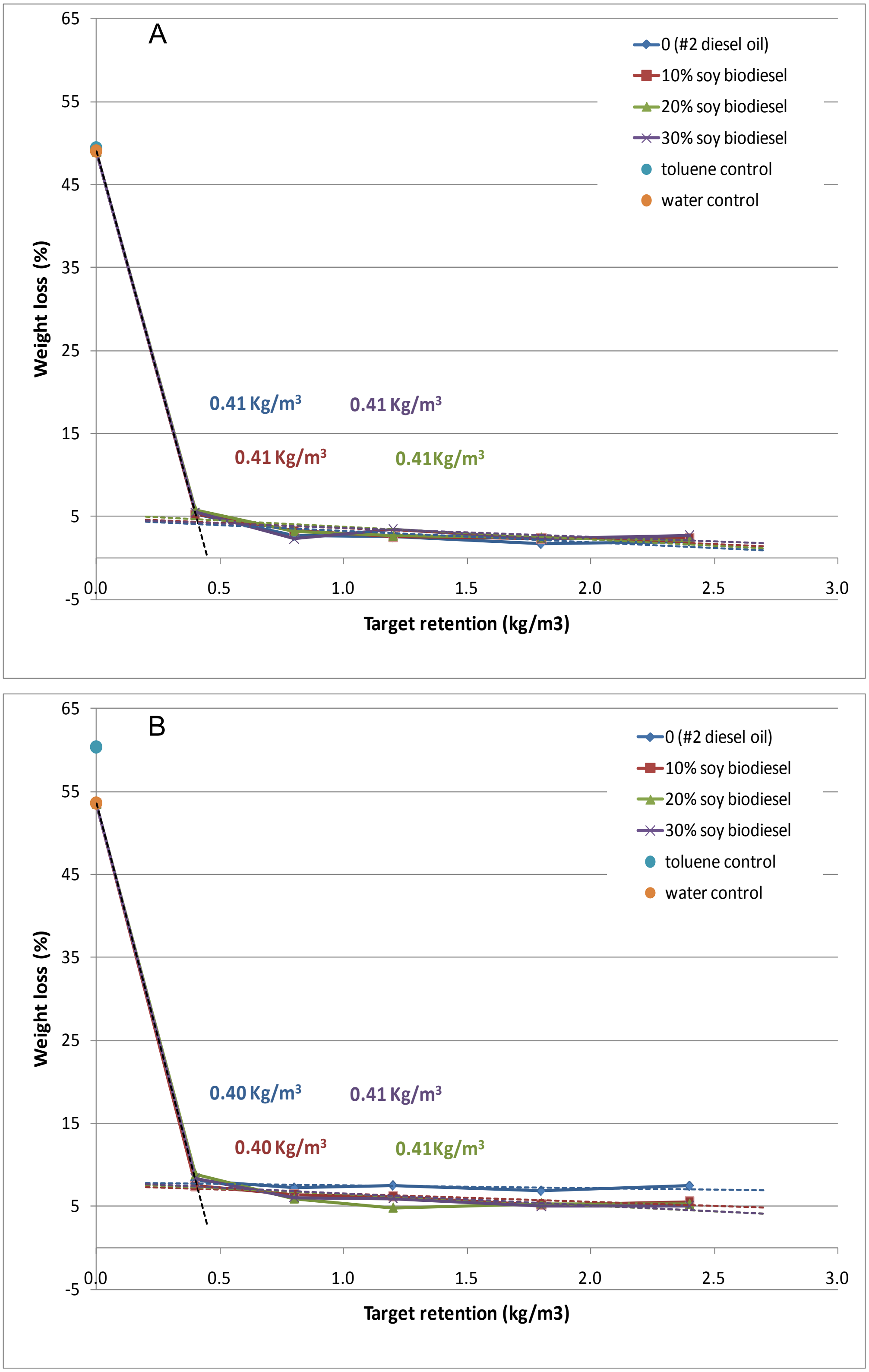

Figure V-4. Effect of soy-based biodiesel concentration in # 2 diesel on weight losses of A. weathered and B. non-weathered copper naphthenate treated blocks exposed to *G. trabeum* in an AWPA E10 soil block test.

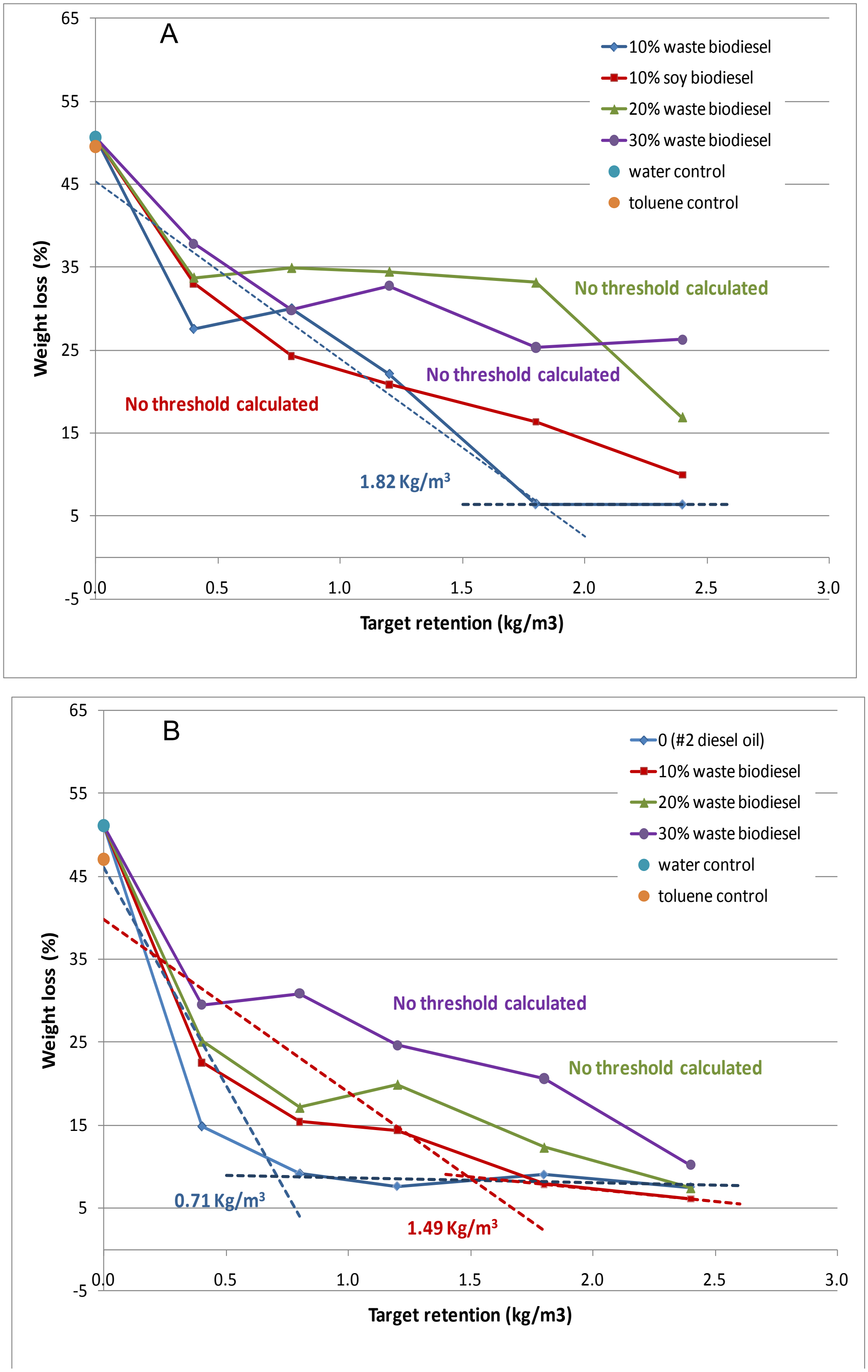

Figure V-5. Effect of waste oil-based biodiesel concentration in # 2 diesel on weight losses of A. weathered and B. non-weathered copper naphthenate treated blocks exposed to *P. placenta* in an AWPA E10 soil block test.

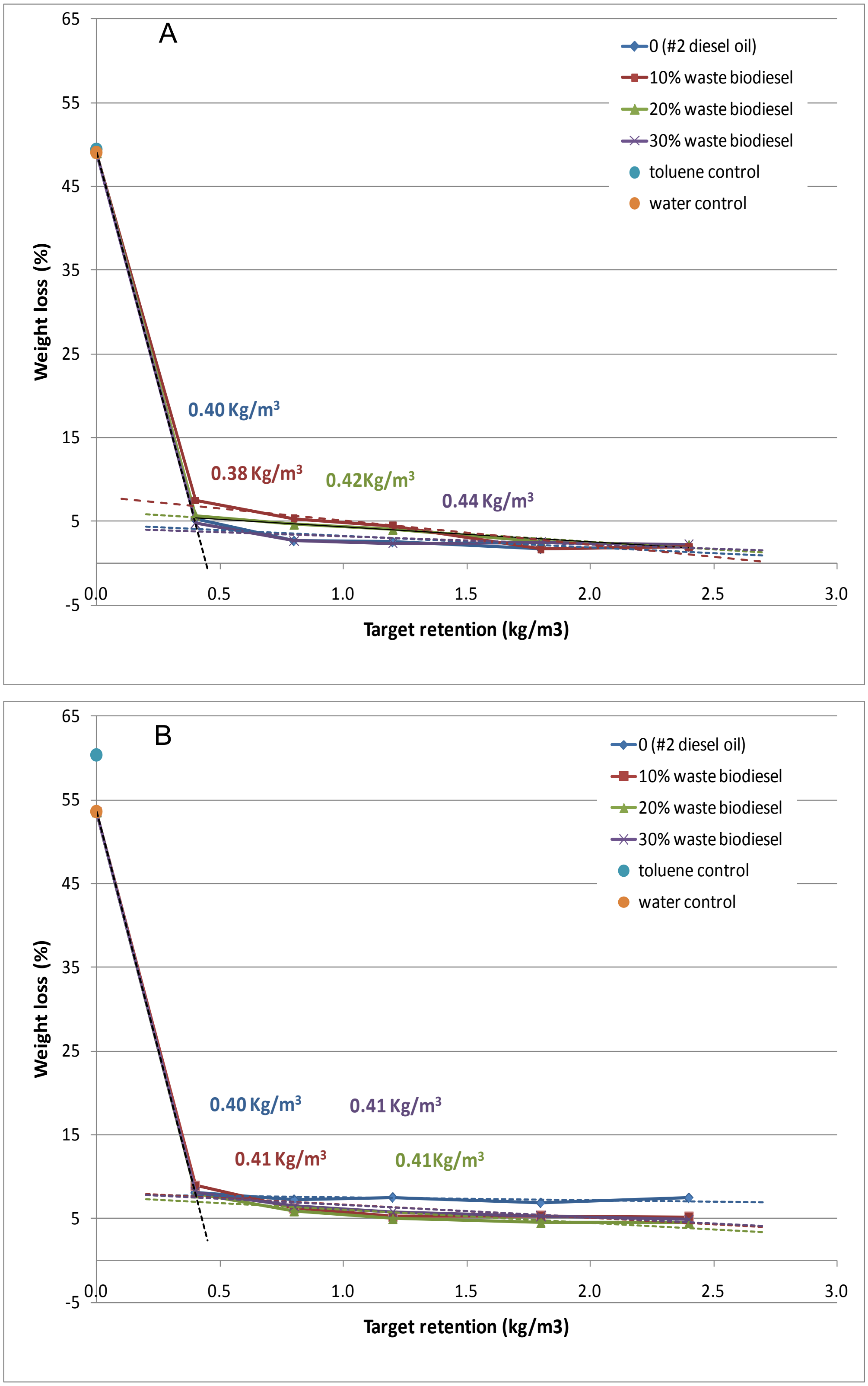

Figure V-6. Effect of waste oil-based biodiesel concentration in # 2 diesel on weight losses of A.weathered and B. non-weathered copper naphthenate treated blocks exposed to *G. trabeum* in an AWPA E10 soil block test.

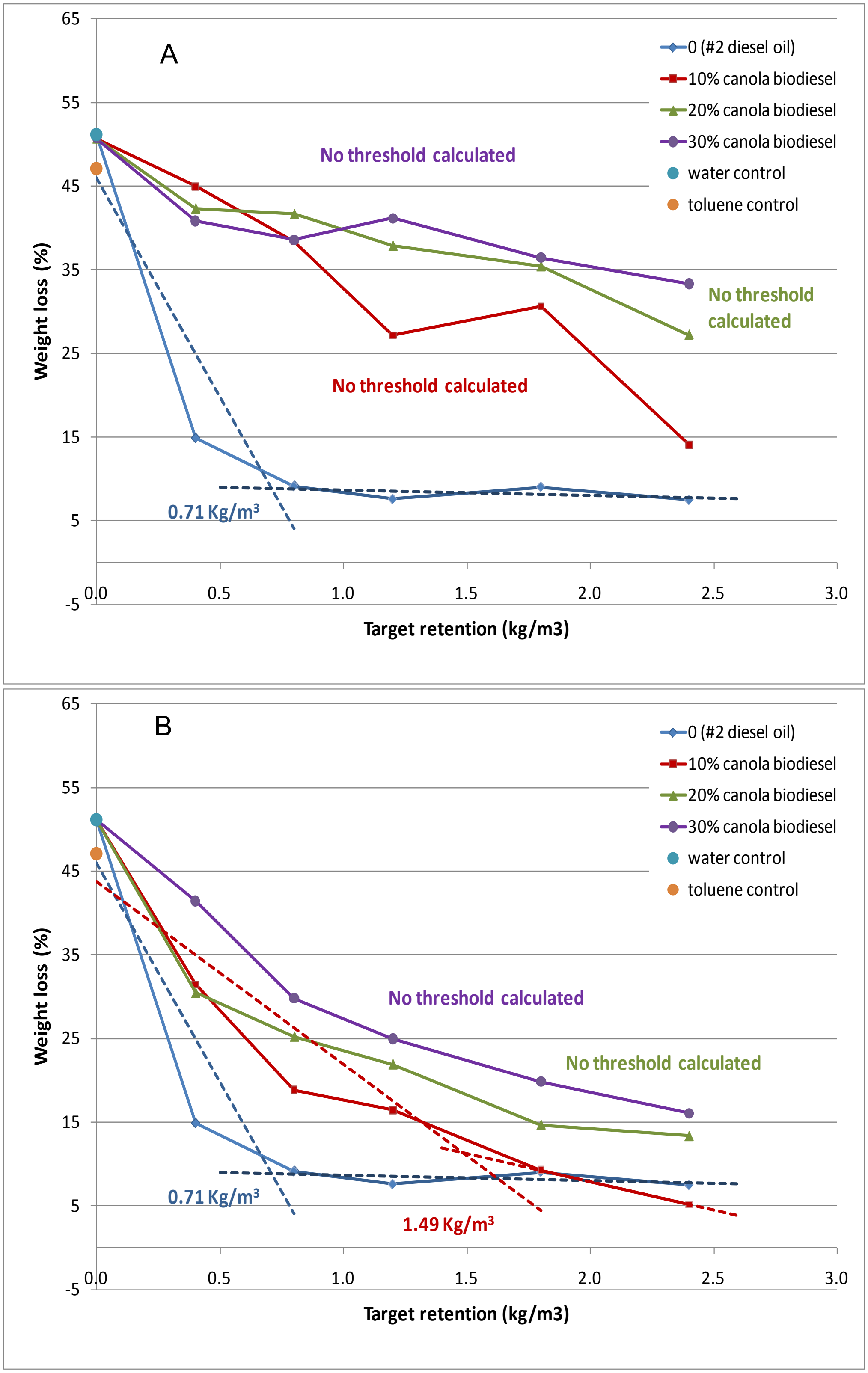

Figure V-7. Effect of canola oil-based biodiesel concentration in # 2 diesel on weight losses of A. weathered and B. non-weathered copper naphthenate treated blocks exposed to *P. placenta* in an AWPA E10 soil block test.

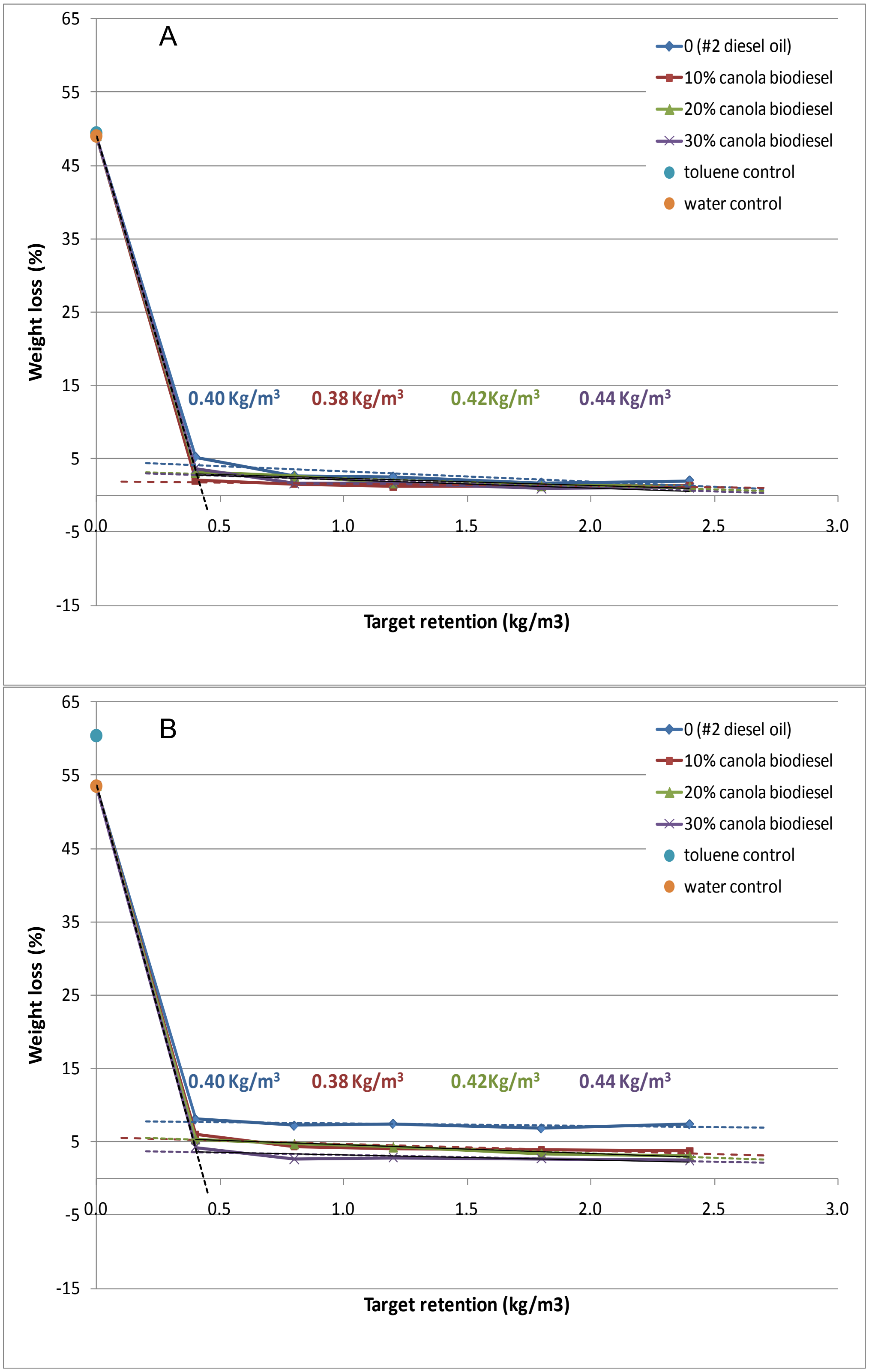

Figure V-8. Effect of canola oil-based biodiesel concentration in # 2 diesel on weight losses of A. weathered and B. non-weathered copper naphthenate treated blocks exposed to *G. trabeum* in an AWPA E10 soil block test.

and that was an important consideration when this preservative system was standardized. The resulting discussion during the standardization process led to the inclusion of higher retention levels because of concerns about periodic copper tolerance in soils across the U.S. Our data suggest that, while there is a slightly higher threshold for protection against this fungus in # 2 diesel, the addition of biodiesel sharply increases that risk. Based upon these trials, we would strongly urge caution in copper naphthenate specifications that allow biodiesel to be included as a co-solvent with #2 diesel.

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American Wood Protection Association (AWPA). 2006. Standard E10. Standard method of testing wood preservatives by laboratory soil-block cultures. In: AWPA Book of Standards. Birmingham, Alabama.

American Wood Protection Association. 2006. Standard P9. Standard for solvents and formulations for organic preservative systems. In: AWPA Book of Standards. Birmingham, Alabama.

OBJECTIVE VI

ASSESS THE POTENTIAL ENVIRONMENTAL IMPACTS OF WOOD POLES

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

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

In an ideal system, utilities would receive poles only 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 pole 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.

In the past, 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 that were presented in the 2009 Annual Report. 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

Figure VI-1. Photo showing the two six-pole configurations. A. configuration 1, B. configuration 2, and C. the four pole configuration in our small scale preservative migration chamber.

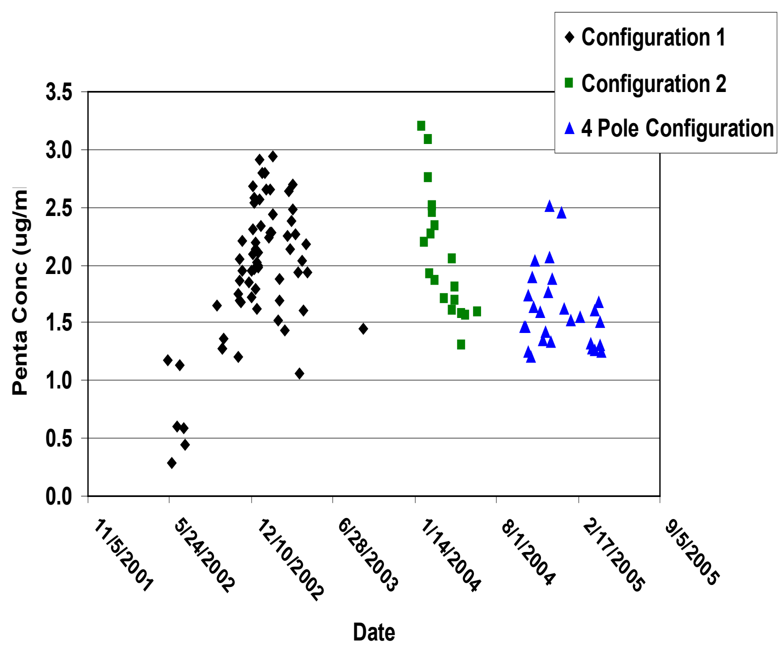


Figure VI-2. Penta concentrations as a function of sampling date in leachate collected from penta treated Douglas-fir poles following rainfall events over a 4.5 year exposure period showing data for three stacking configurations of poles.

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. 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.

The penta tests have been completed and the final data have been provided in the 2009 annual report.

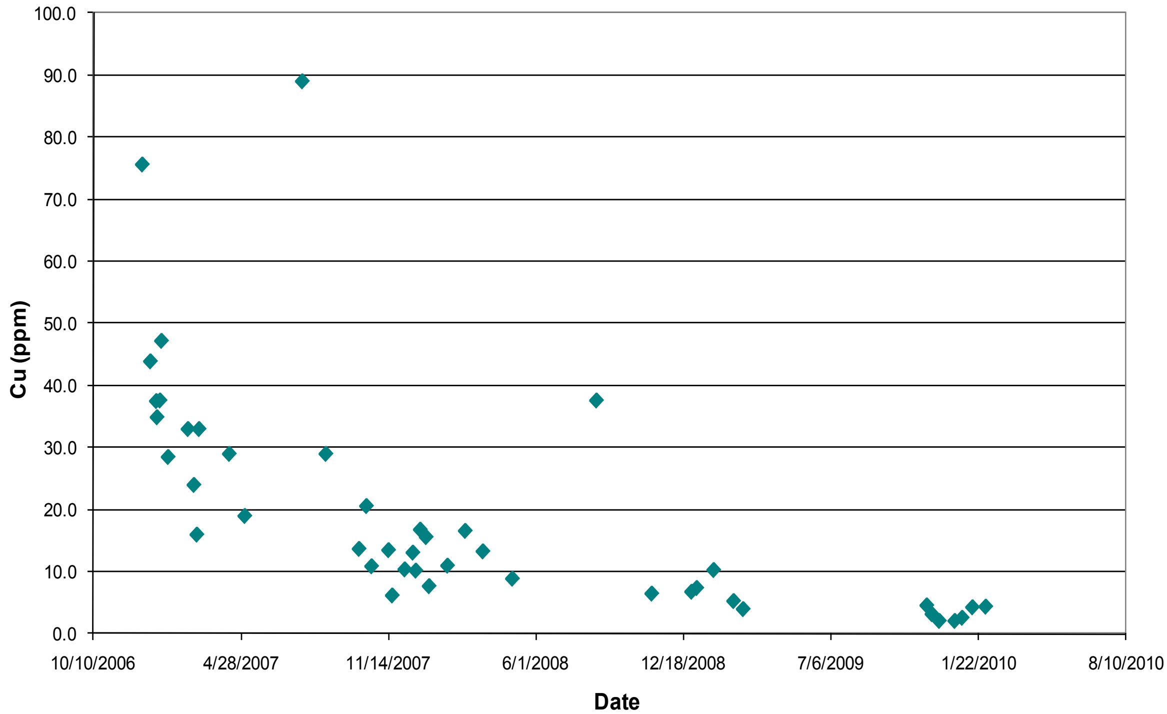
B. Migration of Metal Elements from Douglas-fir Poles Treated with Ammoniacal Copper Zinc Arsenate According to Best Management Practices

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 not sealed. The idea was to simulate a longer pole section where some end-grain loss was possible, but the amount of exposed end-grain did not dominate the overall surface area exposed. Six poles were then stacked on stainless steel supports in a stainless steel tank designed so that all rainfall striking the poles would be captured. 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 on the Oregon State University campus where they were subjected to natural heating and rainfall.

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

Water samples were then analyzed for copper, zinc or arsenic by ion-coupled plasma spectroscopy. The data were arrayed by date of collection, total rainfall, and days between rainfall events (Figure VI-3 to VI-6).

Exposure began 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 first winter (Figure VI-3). After a 2 ½ month dry spell in the summer, zinc and copper levels were again high with the first rain and then declined over the winter. The first rain following the next seasonal dry spell resulted in a similar, but smaller spike in metal concentrations. Zinc levels remained somewhat elevated



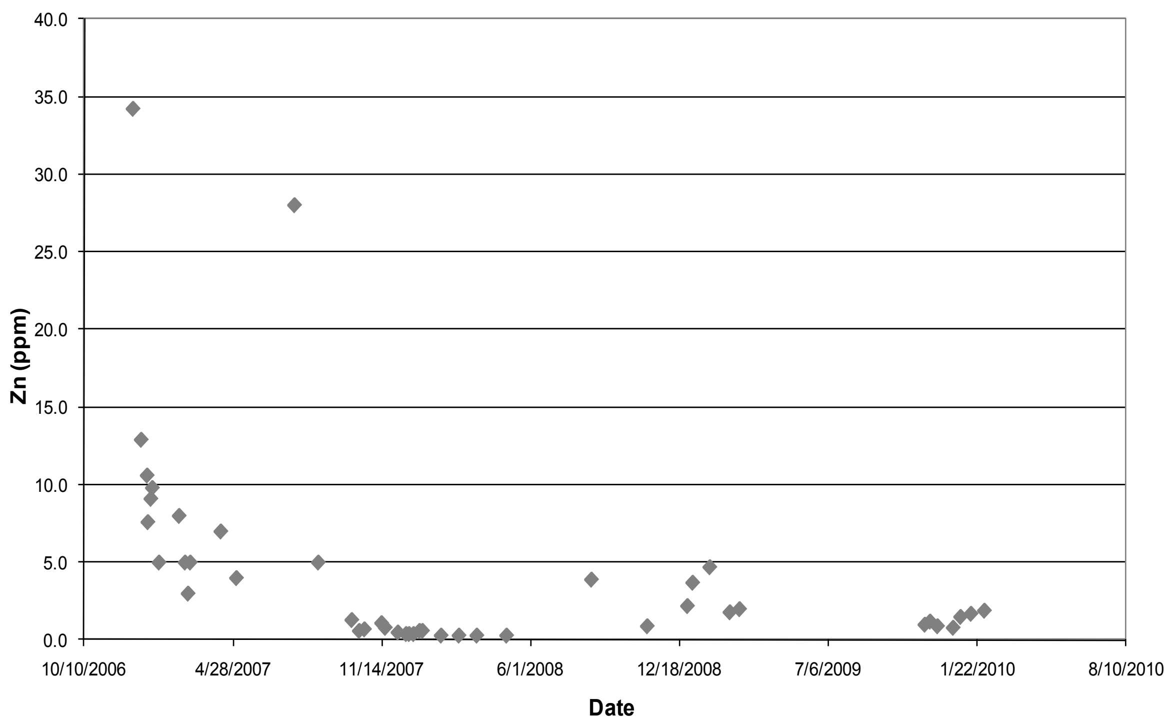
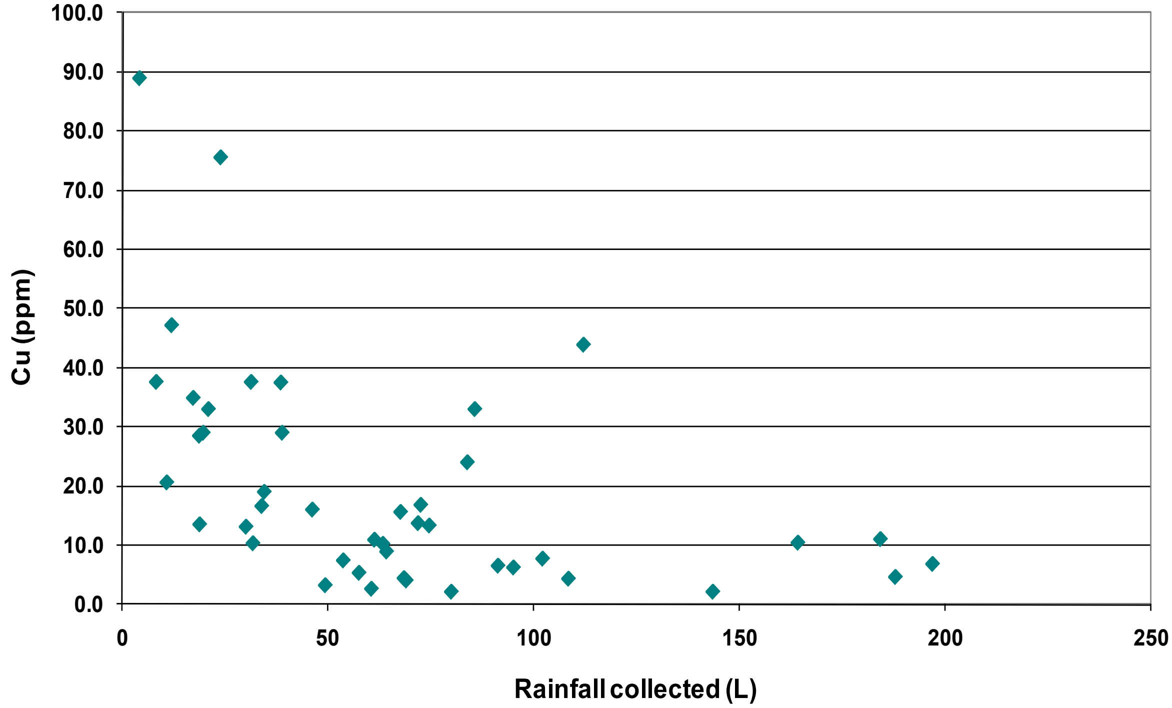


Figure VI-3. Zinc and copper levels in rainwater runoff from poles treated with ammoniacal copper zinc arsenate as a function of date of rainfall.



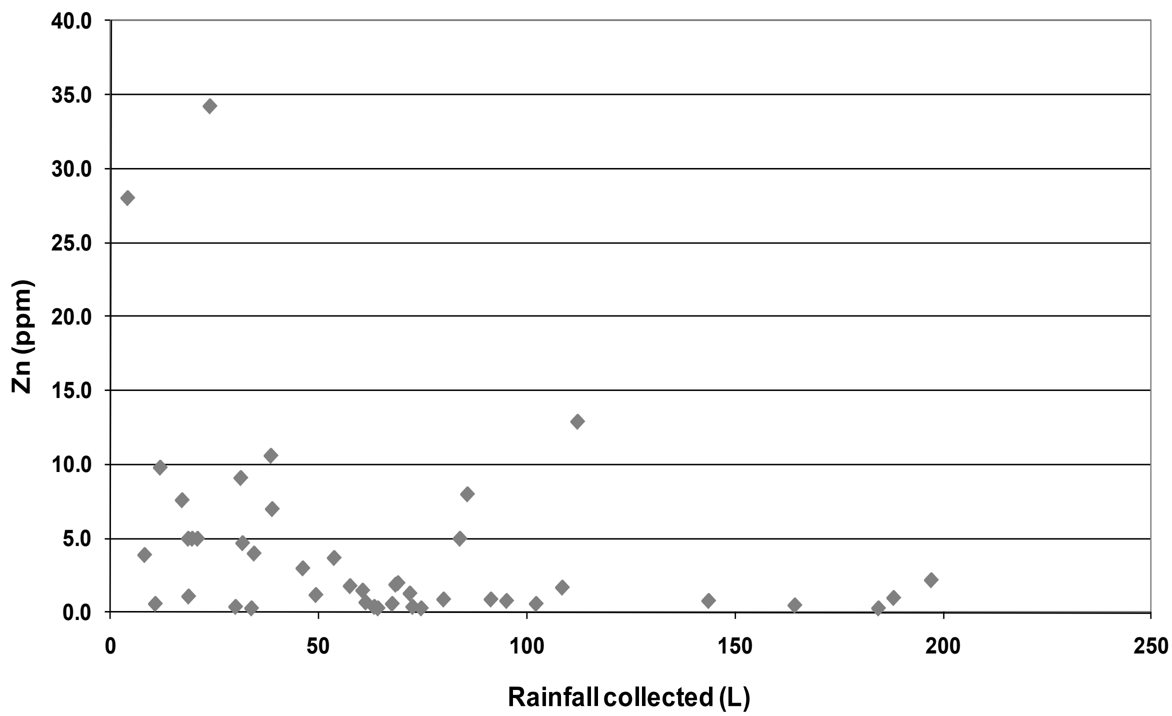


Figure VI-4. Zinc and copper levels in rainwater runoff from poles treated with ammoniacal copper zinc arsenate as a function of total rainfall collected.

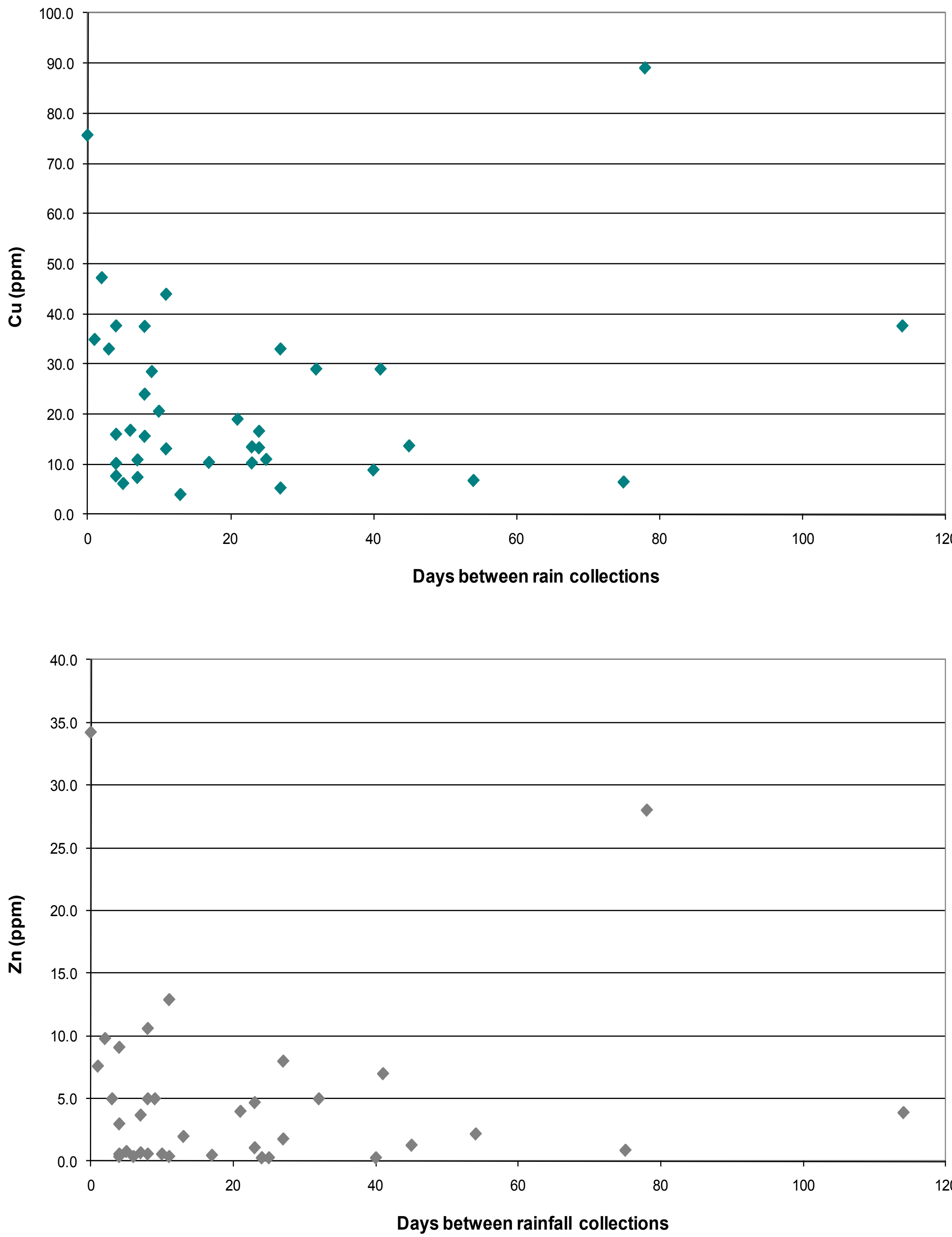
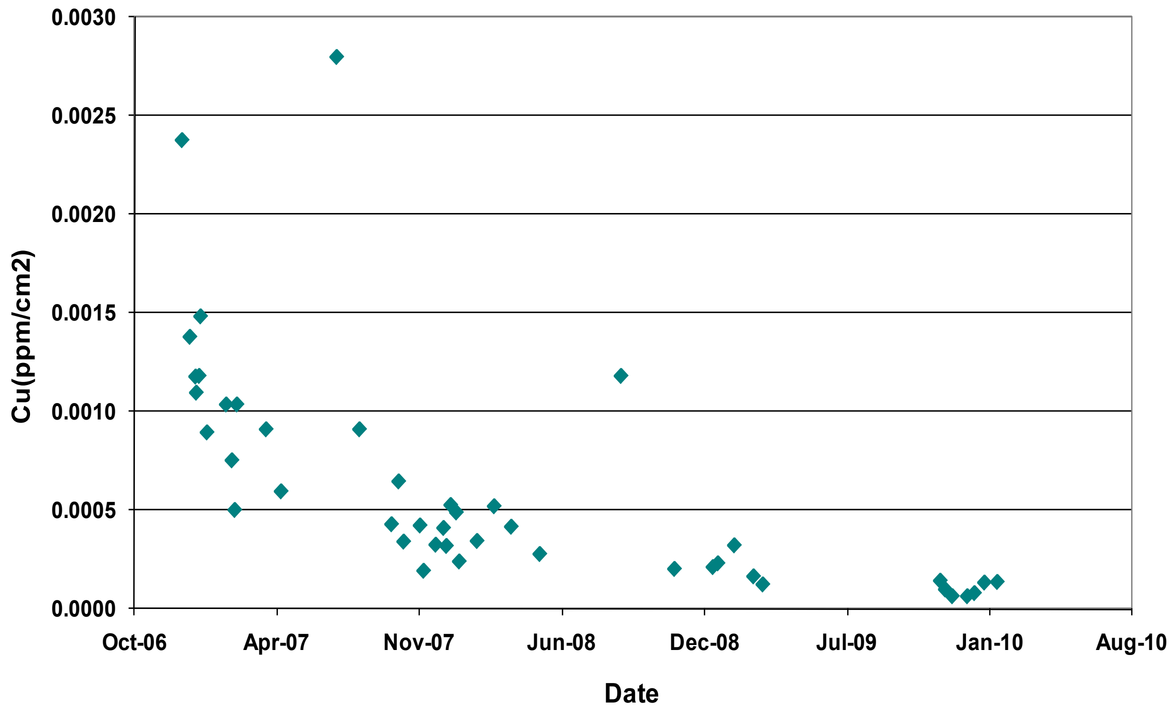


Figure VI-5. Zinc and copper levels in rainwater runoff from poles treated with ammoniacal copper zinc arsenate as a function of days between rainfall collections.



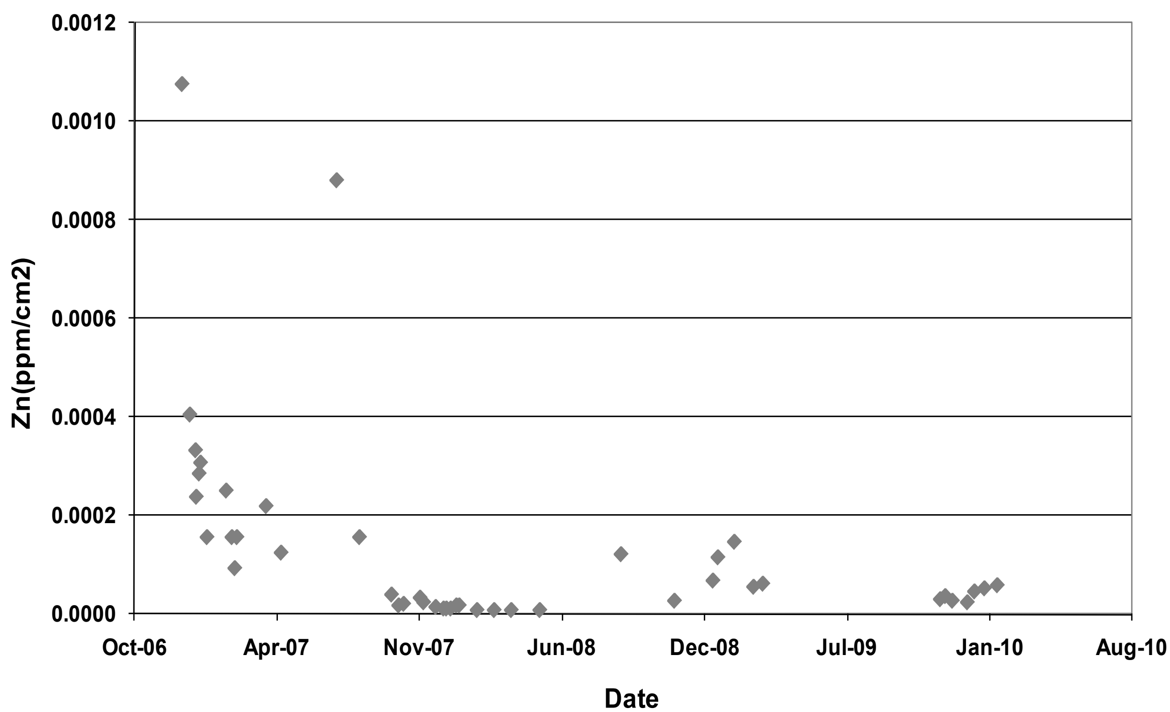


Figure VI-6. Zinc and copper levels in rainwater runoff from poles treated with ammoniacal copper zinc arsenate as a function of date of rainfall and pole surface area.

throughout the following winter, but copper levels fell to below 10 ppm. Metal levels declined further between Fall 2009 and Spring 2010, and there was no spike in metal levels in water from the first rainfall. These results suggest that any migration of metal to the surface during drying at the end of the rainy season was limited to the period shortly after installation.

There is a slight correlation between total volume of rainfall and metal concentrations (Figure VI-4), but it seems more likely that the high values in low total volumes were caused by the time of year the samples were taken. Summer rainfall tends to be brief, and a large percentage is absorbed by the wood. This may result in much higher metal concentrations from summer rain. A second factor might be degree of drying. While some drying occurs between rainfalls during the winter, the wood dries to a much greater extent during the summer. As a result, any moisture moving to the surface that carries metals is likely to deposit these elements at or near the surface where they will be available during the next rain event.

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

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

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

The data were used to predict the amount of zinc or copper released from a sample of stored poles. This process was similar to that used for the previous penta work. A population of 15 poles was arrayed in a triangular stack, a square stack or arrayed in one row (Figure VI-7). These configurations presented surface areas of 14.4, 18.0 or 54 square meters, respectively. The total amount of rainfall that would strike the poles was then calculated for annual rainfall totals ranging from 0.375 m to 1.50 m and it was assumed that all rain falling on the polls would then move through the stack to strike the ground (Table VI-1). The average rainfall totals were then used

Table VI-1. Total amount of rainfall that would fall each year 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

with the concentrations of zinc and copper found in rainfall runoff from our poles to calculate the total metal that would leave the poles in the three configurations (Tables VI-2 to VI-3). This metal release was then distributed over the surface area covered by the poles to a depth of 75 or 150 mm of soil of one of two densities (1620 and 2160 kg/m^3) based upon average soil densities for the U.S (Table VI-4).

Our prior tests indicated that concentrations of penta in water striking poles remained relatively constant regardless of pole configuration and that the surface area exposed to rainfall had the

Table VI-2. Total amount of zinc that would migrate over a 4 year period from 15 Class 4 forty foot long ACZA treated poles arrayed in three different configurations.												
Total Annual Rainfall (m)	Total Zinc Released from Poles in Various Configurations (mg)											
	Stack (14.4 m^2)				Triangle (18 m^2)				Arrayed (54 m^2)			
	1yr	2 yr	3 yr	4 yr	1yr	2 yr	3 yr	4 yr	1yr	2 yr	3 yr	4 yr
0.375	378	432	540	594	473	541	676	811	1418	1611	2016	2219
0.750	756	864	1080	1188	945	1081	1352	1622	2835	3221	4132	4437
1.125	1134	1296	1620	1782	1418	1622	2028	2433	4253	4832	6048	6656
1.500	1512	1728	2160	2376	1890	2162	2704	3244	5670	6442	8064	8876
[a]Values are based upon zinc concentrations in the runoff of 30, 17, 7 and 3 mg/l for years 1, 2, 3, and 4, respectively												

Table VI-3. Total amount of copper that would migrate over a 4 year period from 15 Class 4 forty foot long ACZA treated poles arrayed in three different configurations.												
Total Annual Rainfall (m)	Total Copper Released from Poles in Various Configurations (mg)[a]											
	Stack (14.4 m^2)				Triangle (18 m^2)				Arrayed (54 m^2)			
	1yr	2 yr	3 yr	4 yr	1yr	2 yr	3 yr	4 yr	1yr	2 yr	3 yr	4 yr
0.375	1620	2538	2916	3078	2025	3173	3646	3849	6075	9518	10936	11544
0.750	3240	5076	5832	6156	4050	6345	7291	7697	12150	19035	21871	23087
1.125	4860	7614	8748	9234	6075	9518	10937	11546	18225	28553	32807	34631
1.500	6480	10152	11664	12312	8100	12690	14582	15394	24300	38070	43742	46174
[a]Values are based upon copper concentrations in the runoff of 30, 17, 7 and 3 mg/l for years 1, 2, 3, and 4, respectively												

Table VI-4. Effect of storage of 15 ACZA treated poles on increased copper or zinc concentrations in the underlying soil.

Total Annual Rainfall (m)	Copper Concentration (ppm)		Zinc Concentration (ppm)	
	75 deep zone	150 mm deep zone	75 mm deep zone	150 mm deep zone
0.375	1.32-1.76	0.66-0.87	0.25-0.34	0.13-0.17
0.750	2.64-3.52	1.32-1.76	0.50-0.68	0.25-0.34
1.125	3.96-5.28	1.98-2.63	0.75-1.02	0.38-0.51
1.500	5.28-7.04	2.64-3.52	1.00-1.36	0.50-0.68

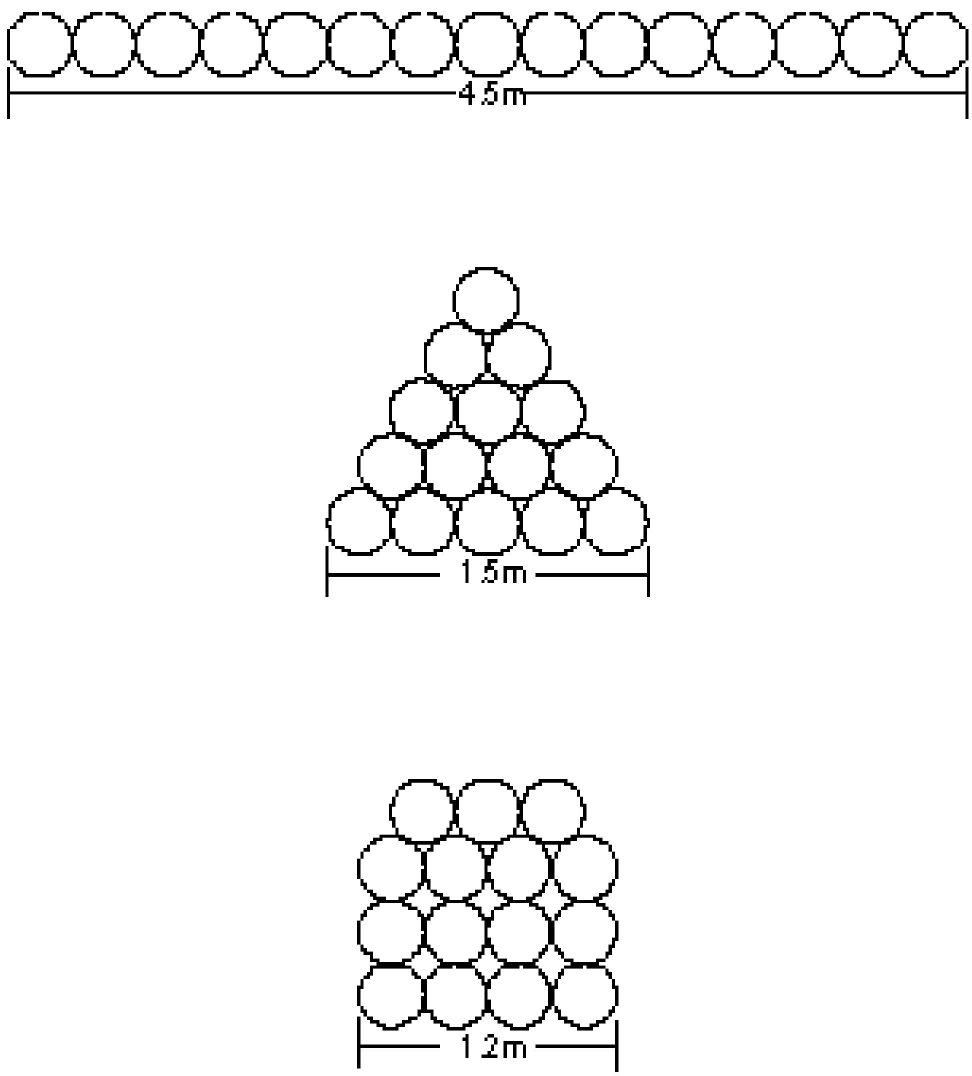


Figure VI-7. Configurations of 15 Class 4 forty foot long poles used to model predicted copper and zinc concentrations in soil beneath ACZA treated poles as a result of rainwater runoff. Poles were configured as 15 individual poles, poles in a triangular stack and poles in four courses with stickers in between each course.

greatest effect on total runoff. As a result, poles inside a stack have relatively little effect on overall chemical concentration in the runoff, even though water running from the upper surfaces does pass along these poles. As a result, the previous tests indicated that exposed upper surface area is the primary factor affecting total preservative releases. While we have confirmed this for penta treated poles, we have not assessed any other configurations that might expose different surface areas. As a result, these estimates should be viewed as preliminary, pending verification trials.

Using the penta data as a model, it is expected that total releases of copper or zinc both will increase steadily over the 4 year period and these releases will increase with increased rainfall (Tables VI-2 to VI-3, Figures VI-8 to VI-9). However, poles in more closely packed configurations will tend to release much lower levels of metals. For example total predicted zinc release after 4 years from poles in a stack was 594 mg while the level rises to 2219 mg in poles arrayed individually in an area with 0.375 m of annual rainfall. Similar effects are predicted with copper. Clearly, stacking poles has an advantage in terms of reducing the overall release levels of metals from poles.

The other concern among utilities with regard to pole storage is the area affected by metal releases. To assess this aspect, we took a very conservative approach and assumed that all metal leaving the poles will be confined to an area 75 or 150 mm beneath the soil. This approach assumes that metals do not migrate and dilute in the surrounding soil. As a result, metal levels would be expected to be much higher in these soils than would be found under natural conditions where there would be a possibility of further dilution.

Although total metal levels from poles in different configurations will vary, the absolute amount beneath the poles should be the same because the concentration is controlled by the exposed surface area. Increases in zinc levels in soils beneath poles stored for 4 years in climates receiving 0.375 m (16 inches) of rainfall per year would range from 0.25 to 0.34 ppm, depending on the soil density, if the metals were confined to a 75 mm zone (Table VI-4). The increased zinc concentrations would fall to 0.13 to 0.17 ppm if the soil depth were expanded to 150 mm. Increases in copper levels under the same annual rainfall, soil density and soil depth regimes would be 1.32 to 1.76 ppm and 0.66 to 0.87 ppm for the 75 and 150 mm deep zones, respectively. Copper and zinc levels in soils in climates receiving higher levels of rainfall experience corresponding increases. For example, copper levels in soils beneath poles stored for 4 years in climates receiving1.125 m (48 inches) of rainfall per year would increase to 3.96 to 5.28 ppm in a 75 mm deep horizon compared to 1.98 to 2.63 ppm in a 150 mm deep horizon. Zinc levels under this same regime would increase to 0.75 to 1.02 ppm in a 75 mm deep horizon and 0.38 to 0.51 ppm in a 150 mm deep horizon.

While copper and zinc levels will increase beneath the poles over prolonged storage, it is important to compare these values with natural background levels of copper. Natural levels of copper appear to be around 25 ppm, depending on the soil type and density, but can range upward to 85 ppm or more. Copper toxicity also depends on the form of copper, with elemental copper being less available than more soluble forms of copper.

The model indicates that close stacking of poles will result in the lowest overall total metal losses, although it has no impact on the concentrations of metals that will develop beneath the poles.

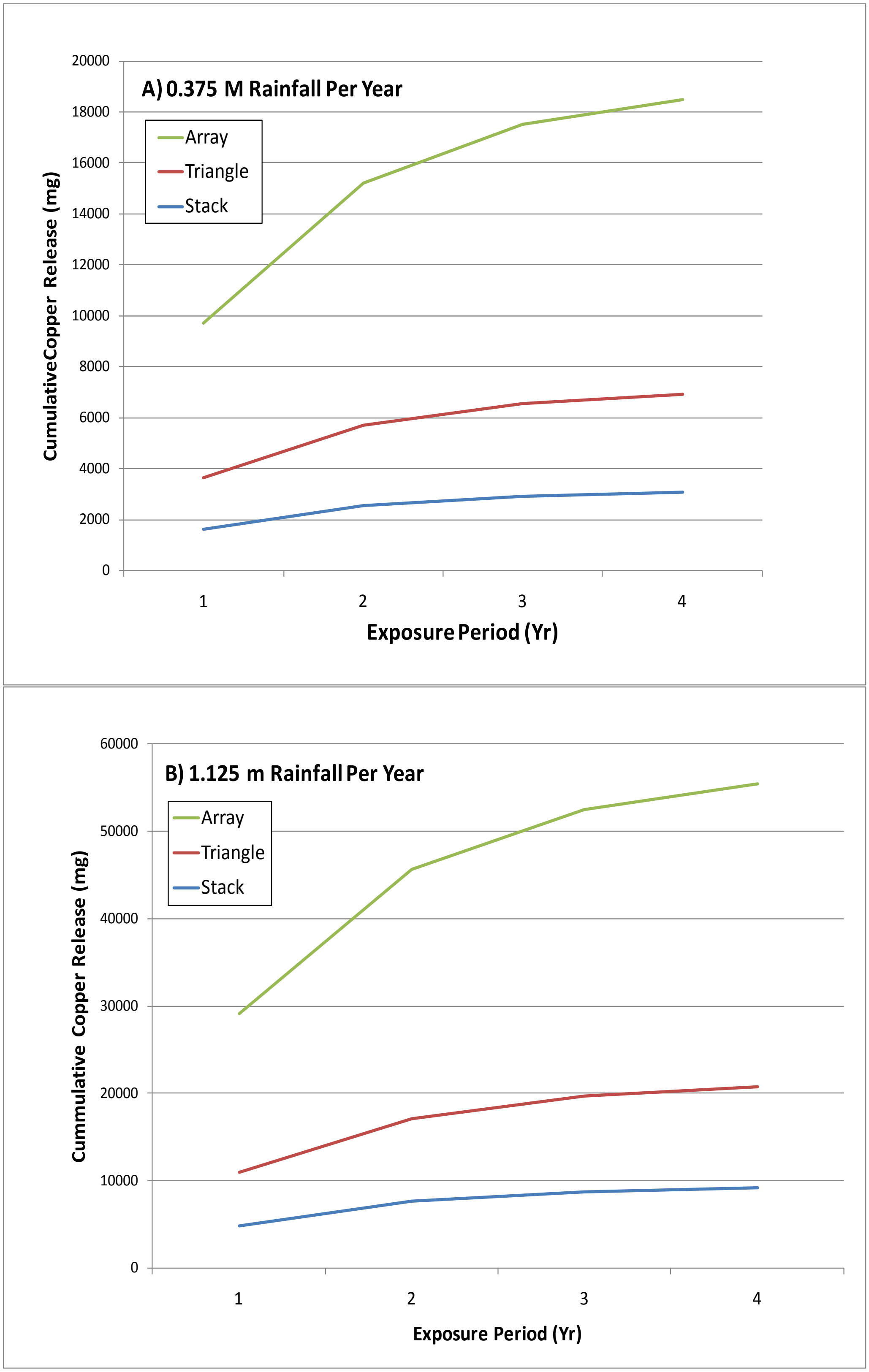


Figure VI-8. Predicted copper releases from 15 ACZA treated Douglas-fir poles stored for 4 years in one of three configurations and subjected to A.) low or B.) high rainfall.

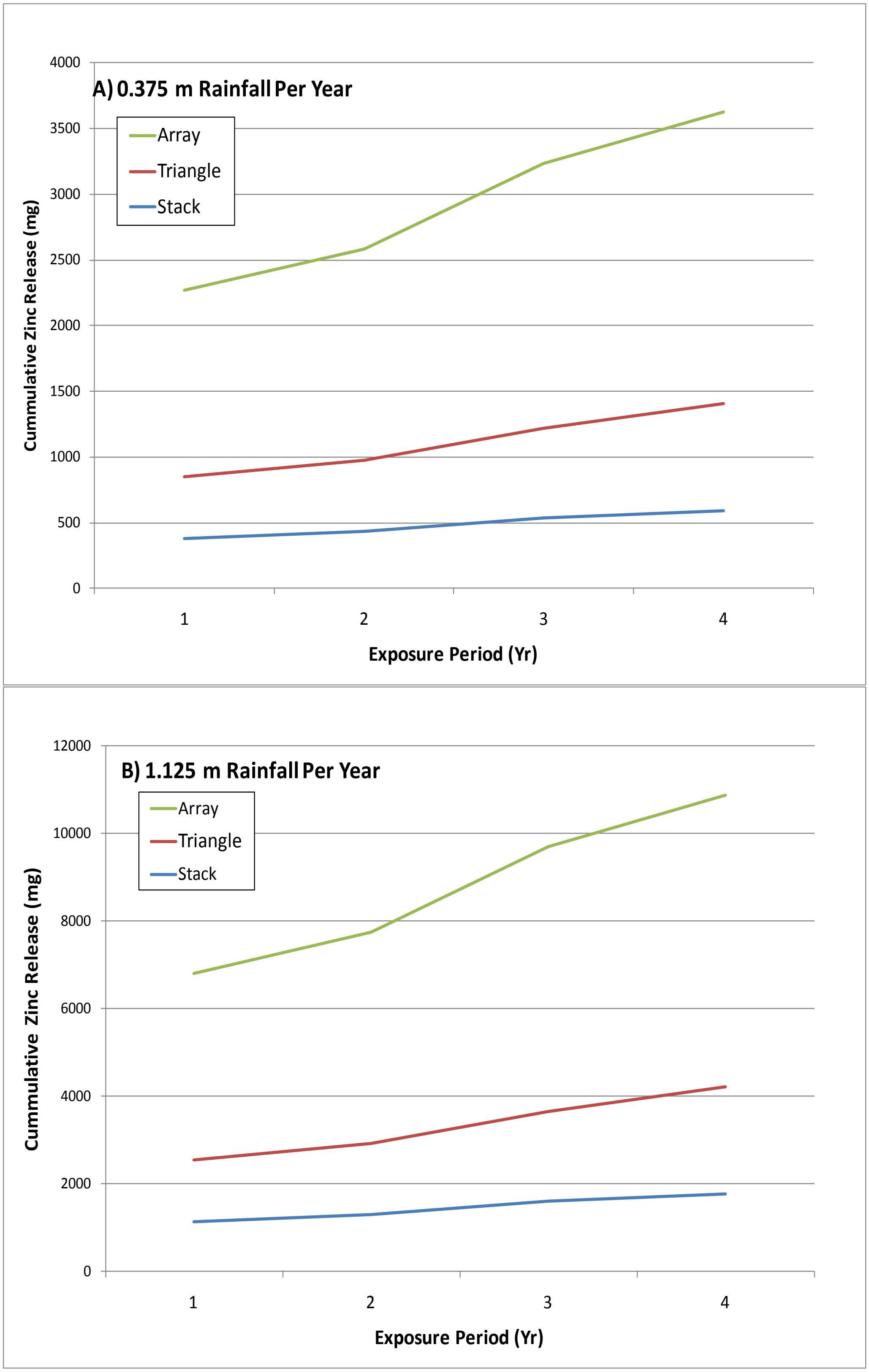


Figure VI- 9. Predicted zinc releases from 15 ACZA treated Douglas-fir poles stored for 4 years in one of three configurations and subjected to A.) low or B.) high rainfall.

Increases in zinc and copper associated with pole storage over time; however, will generally be low and not of concern in most situations particularly if continued migration resulted in further dilution to background levels.

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