Oregon State University Utility Pole Research Cooperative

Department of Wood Science & Engineering
Oregon Wood Innovation Center
35th Annual Report
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By:
J.J. Morrell, M. Konkler, J. Cappellazzi

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COOPERATORS

American Transmission Company

Arizona Public Service

Bonneville Power Administration

Brooks Manufacturing Inc.

Clark Public Utilities

Copper Care Wood Preservatives Inc.

BASF Wolman, GMBH

Fortis Alberta

Genics Inc.

Intec Services Inc. (Pole Care Inc.)

ISK Biocides

McFarland Cascade

Nisus

Osmose Utilities Services, Inc.

Pacific Gas and Electric

PacifiCorp

Poles Inc.

Portland General Electric Company

Puget Sound Energy Services

Rio Tinto Minerals

Salt River Project

Snohomish County Public Utility District

Stella-Jones Inc.

The Pentachlorophenol Working Group

Western Wood Preservers Institute

Wood Care Systems

Xcel Energy

PERSONNEL

ADVISORY COMMITTEE

Gerald Rhode	American Transmission Company
Mike Woodward	Arizona Public Service
Robert Ochs	Bonneville Power Administration
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Karen Perzanowski	Clark Public Utilities
William Abbott	Copper Care, Inc.
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Michael Hoffman	The Pentachlorophenol Working Group
Dallin Brooks/Butch Bernhardt	Western Wood Preservers Institute
James Renfroe	Wood Care Systems
Jeff Goodson	Xcel Energy

RESEARCH

Principle Investigators

Jeffery J. Morrell
Professor
Department of Wood Science and Engineering
Oregon State University

Scott Leavengood
Director
Oregon Wood Innovation Center

Faculty Research Assistants

Jed Cappellazzi
Matt Konkler

Visiting Scientists

Femi Owofadeju

Graduate Students

Paola Torres
Shahlinney Lipeh
Selim Uysal
Daniel Trebelhorn

Executive Summary

The Utility Pole Research Cooperative currently has 12 Utility members and 14 Associate members. Membership continues to fluctuate, primarily in the Associate member category. This is largely because of acquisitions and mergers.

Coop progress and results under each of six objectives will be summarized here.

Objective I examines the performance of internal remedial treatments. We continue to evaluate various dazomet treatments. MITC release rates from dazomet continue to provide excellent long term performance 15 years after application. Dazomet rods produced MITC levels that were similar to those found with powdered material when a copper accelerant was applied at the time of treatment.

An examination of the interactions between dazomet and copper naphthenate showed that copper naphthenate tended to concentrate at the upper portion of the treatment hole. There were also some differences in copper penetration between granular and powdered formulations, with more widespread movement into the powdered system. Preliminary tests on wood blocks showed a similar trend, suggesting most of the copper naphthenate moved either into wood adjacent to the treatment hole or remained in the upper region of the dazomet. This leaves much less copper available for accelerating dazomet decomposition. Further tests are underway to determine how this variable distribution affects MITC production.

The final assessment of boron levels in poles treated with boron rods, with or without water or glycol compounds, was made 20 years after treatment. The addition of glycol-based systems or Timbor produced permanent improvement in boron levels, suggesting simultaneous application of boron rods and a supplemental liquid system would improve rod performance.

The large scale internal remedial treatment test was sampled 78 months after treatment. Little or no MITC was detected in poles receiving metham sodium based treatments, while MITC-FUME and dazomet based systems continue to retain MITC levels well above the protective threshold. Boron rod treatments also continue to retain sufficient quantities of boron to provide protection against fungal attack. The results have largely mirrored previous field trials that were performed on individual products. This test provides more directly comparable results to help utilities decide which products are appropriate for their systems and the appropriate retreatment cycle for each system.

Follow-up investigations on the distribution of boron or MITC in the belowground zones of poles from the large scale remedial test indicate boron levels were relatively low 60 months after treatment and MITC levels were nearly non-detectable in metham sodium treated poles 78 months after application. MITC levels in the below ground zone of poles treated with MITC-FUME or dazomet were well above the threshold 78 months after treatment. These results were consistent with MITC levels found above the groundline in the same poles.

A follow-up test of boron movement through Douglas-fir with or without a preservative oil-treated shell revealed boron diffusion was more than ten-fold greater through non-treated wood compared with oil treated Douglas-fir. Further tests are underway to better understand how boron moves through wood in order to help explain why boron does not appear to remain in belowground portions of the poles.

Objective II examines methods for limiting internal decay above groundline. We have examined a variety of treatments for protecting field drilled bolt holes, but most have not been used. We have instead examined boron pre-treatments prior to conventional preservative treatment as a means for protecting the pole interior in service. Douglas-fir poles were pressure-treated with boron followed by copper naphthenate and then installed at our field test site. Boron levels were initially low and concentrated near the pole surface. We expected the boron to diffuse and become more evenly distributed within the pole over time, but boron has not moved further inward over the first two years of the test. These results differ from those observed in railway ties and further tests are planned.

Objective III examines a variety of activities designed to improve pole or crossarm performance. Tests of water shedding caps or coatings revealed that both markedly reduced wood moisture contents below the pole top, resulting in conditions that were less conducive to fungal growth. These results illustrate the benefits of capping poles after installation.

Evaluations of polyurea coated non-treated cross arms exposed in Hilo, Hawaii showed the coating had thinned considerably over the 6 year exposure period, while coated penta-treated arms experienced far less coating loss. The coated non-treated arms also experienced internal decay, suggesting the barrier was unable to prevent fungal ingress. Further tests are underway to better characterize the ultra-violet light damage experienced by these arms.

Tests of stakes treated with pentachlorophenol in diesel or a biodiesel based oil are continuing. While there are some differences in performance between the oils at low retention levels, the oils are performing similarly at the currently specified retention level. A follow-up stake trial examining diesel and biodiesel oils with copper naphthenate and pentachlorophenol has also been established and will be inspected for the first time this coming Fall (2015).

An evaluation of lodgepole pine and western redcedar poles for residual initial preservative retention and MITC levels was used to determine when retreatment might be advisable. CCA levels tended to remain elevated regardless of pole age, while penta levels declined with age, suggesting application of a supplemental preservative paste might be advisable for some poles. MITC levels had also declined to below the protective threshold 7 years after treatment, indicating retreatment would be advisable for these poles.

Trials have also been established to assess the ability of various fire retardant systems to protect penta treated Douglas-fir poles from wildfire. Poles treated with two different barriers or surface applied Fire-Guard or FireShield all performed well, while a short term topical treatment failed to provide protection under the conditions employed. Further tests are underway, but the results indicate that the test method produces representative results and is suitable for large scale testing.

Objective IV examines the efficacy of external preservative pastes as well as the ability of barriers to limit moisture ingress or preservative loss. Moisture assessments of poles receiving various barriers indicate that moisture contents in wrapped poles do not differ markedly over time from poles without barriers. When barriers were first explored, there were concerns that moisture levels might increase as the barriers retained moisture. This does not appear to the case.

A small scale test to evaluate external preservative pastes was assessed using 5 formulations. The results showed that there were some differences in boron and copper movement that could be explained by formulation differences. The results also indicated that the test method was suitable for examining paste systems, although further refinements might make it more suitable for systems that did not move substantially into the wood. The results also show the need for developing a better understanding of the efficacy of boron/copper mixtures.

Objective V examines the performance of copper naphthenate. Laboratory stake tests of copper naphthenate on western redcedar continue to show that this chemical provides excellent performance on this species. Field evaluations of copper naphthenate treated Douglas-fir poles are also underway as part of a larger effort to examine the effects of biodiesel as a co-solvent for this system. A total of 70 poles were examined this past year along with the 65 other poles examined in previous years will allow us to detect any changes in performance before problems become severe. The evaluation of these cores is still underway and will be reported in the next Annual Report.

There was no activity under **Objective VI** which examines preservative migration from utility poles.

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, they have gradually shifted to more controllable treatments. This shift has resulted in the availability of a variety of internal treatments for arresting fungal attack. Some of these treatments are fungitoxic based upon movement of gases through 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 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 Controlling Internal Decay of Wood Poles

While a variety of methods are employed to control internal decay 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 most effective, but both systems were prone to spills and carried risk of worker contact. Utility Pole Research Cooperative (UPRC) research identified two alternatives, methylisothiocyanate (MITC) and dazomet. Both chemicals are solid at room temperature, reducing spill risk and simplifying cleanup of spills that occur. MITC was commercialized as MITC-FUME, while dazomet has been labeled as Super-Fume, UltraFume and DuraFume (Table I-1). 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.

1. 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 intended for agricultural field application where it could be tilled into soil. Once in soil contact, dazomet rapidly reacts to release MITC, killing potential pathogens prior to planting. Drawbacks to the use of powdered formulations for treatment of internal pole decay include the risk of spillage during application, as well as potential exposure to inhalable chemical dusts. In our early trials, we produced dazomet pellets by wetting the powder and compressing the mixture, but these were not commercially available. The desire for improved handling characteristics, however, encouraged development of a rod form (BASF Wolman GmbH). These rods simplified application, but we wondered whether decreased wood/chemical contact associated with rods might reduce dazomet decomposition, thereby slowing fungal control.

Table I-1. Characteristics of fumigants used for internal remedial treatment of utility poles in North America

Trade Name	Active Ingredient	Conc. (%)	Manufacturer
TimberFume	trichloronitromethane	97	Osmose Utilities Services, Inc.
WoodFume	sodium n-methyldithiocarbamate	33	Osmose Utilities Services, Inc.
ISK Fume			ISK Biosciences
SMDC-Fume			Copper Care Wood Preservatives, Inc.
MITC-FUME	methylisothiocyanate	96	Osmose Utilities Services, Inc.
Super-Fume	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiodiazine-2-thione	98-99	Pole Care Inc.
UltraFume			Copper Care Wood Preservatives, Inc.
DuraFume			Osmose Utilities Services, Inc.

Pentachlorophenol (penta) 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 amendments 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, 10, 12 and 15 years after treatment by removing increment cores at three equidistant locations around each pole (0.3, 0.8 or 1.3 m above the groundline). The outer treated zone of each core was discarded, and the remaining inner and outer 25 mm of each core was placed into 5 ml of ethyl acetate. The core was extracted in ethyl acetate for 48 hours at room temperature, removed, oven dried and weighed. The ethyl acetate extract was analyzed for residual MITC by gas chromatography. The remainder of each core was placed on 1.5% malt extract agar and observed for fungal growth. Any fungal growth was examined for characteristics typical of basidiomycetes, a class of fungi containing many important wood decayers.

In evaluating treatment effectiveness, we have traditionally used a 20 ug of MITC/oven dried g of wood fungal protection threshold. This value is based upon examination of previous culturing and chemical analysis data from our many field trials. This is the 15th and final year of assessment. While we normally recommend retreatment on a 10 year cycle, we have included two additional assessments to illustrate cycle extension.

In general, MITC levels 1.3 m above groundline were rarely above threshold for the 10 year test, although MITC was detectable (Table I-2, Figures I-1 to I-6). For practical purposes, discussion will be confined to MITC levels 0.3 and 0.8 m above groundline.

MITC levels in pole sections treated with metham sodium were above threshold in the inner and outer zone 1 and 3 years after treatment 0.3 m above groundline. MITC levels were more variable 0.8 m above groundline (Figure I-1). MITC levels declined sharply at the 5 year sampling and continued to decline. No MITC was detected in any pole 15 years after treatment, indicating that any residual protective effect had been lost with this treatment. Metham sodium is viewed as a system that rapidly releases MITC, virtually eliminating decay fungi within one year of treatment. However, MITC levels typically decline sharply within 3 years of application. Our results closely follow that pattern. Fortunately, fungal attack does not immediately occur; it often takes 7 to 10 years to occur and this allows metham sodium to be used on a 10 year cycle (Morrell and Corden, 1986).

Dazomet must decompose to produce MITC and it typically does so at a relatively slow rate in the presence of water. Adding copper to the system (typically as copper naphthenate) markedly accelerates the decomposition process and this is a common recommendation when this system is applied to poles in drier climates. In this test, Dazomet was evaluated in rod or powdered form with or without an accelerant (water or copper naphthenate).

Treatment with dazomet without an accelerant should result in slower decomposition to MITC than with metham sodium. MITC levels in dazomet treated pole sections were slightly lower than metham sodium 0.3 m above groundline one-year after treatment, and levels were much lower 0.8 m above groundline (Figure I-2). However, MITC levels rose dramatically 5 years after treatment and have remained above the protective threshold in both the inner and outer zones 0.3 m above groundline since that time. MITC levels 0.8 m above groundline were above the threshold from 2 to 8 years after treatment while levels in the inner zone at this height were only above threshold in the third and fifth year of the test. These results illustrate the long-term ability of dazomet to decompose into MITC and for that MITC to remain in the wood at effective levels. The results also illustrate the relatively narrow protective zone produced by these fumigants.

MITC levels in poles receiving 160 g of dazomet in rod form (9 rods), but no other additive were above the threshold 0.3 m above the groundline 1 year after treatment and only slightly lower than those found with metham sodium (Figure I-3). Levels were slightly lower 2 years after treatment but then remained above the threshold for the next 13 years. MITC levels were also above the threshold 0.8 m above groundline in the inner zone between 2 and 12 years after treatment, but tended to be much lower in the outer zone at this height. MITC levels above this zone were much more variable. The results suggest that natural wood moisture in Western Oregon was sufficient to allow for decomposition to MITC even through the rods.

The addition of 100 g of water to pole treatment holes receiving 160 g (9 rods) of dazomet tended to follow trends similar to those found with the rod treatments without water (Figure I-4). While water can accelerate dazomet decomposition, the amount applied to the holes was relatively small compared to the wood mass surrounding the hole. As a result, while some water will sorb to the rod, most of the moisture will move into surrounding wood where it will dissipate. Thus, the limited effect of added moisture is consistent with the short time period in which this water interacts with the rods.

The addition of copper naphthenate to treatment holes receiving the 9 rod dosage slightly increased MITC levels in poles 0.3 m above groundline over the first 10 years after treatment and MITC remained at effective levels after 15 years (Figure I-5). MITC levels were slightly higher in the inner zone 0.8 m above groundline. Interestingly, use of a slightly lower dazomet dosage coupled with copper naphthenate produced results similar to those found with a higher number of rods (Figure I-6). This suggests that both dosages were above effective control levels and lower concentrations can be used.

The long period of testing with multiple treatments and sampling levels can make evaluation of overall treatment effectiveness difficult. For simplicity, we can examine MITC levels in the inner zone 0.3 m above groundline (Figure I-7). Near groundline is where decay is most prevalent and also where most remedial treatments are applied. If we examine these data, we can see that MITC levels in metham sodium treated poles rapidly declined after treatment, while levels in the dazomet rod treatment with water increased slightly between 3 and 5 years, remaining steady until 12 years after treatment. Interestingly, dazomet rods without water had slightly higher levels of MITC, although they followed trends that were similar to those found with rods plus water.

MITC levels in dazomet powder treatments were similar to those in the six and nine rod treatments that received a copper naphthenate accelerant. These results suggest placing dazomet in rod form had a slight effect on MITC levels in comparison with the powder, but addition of copper naphthenate mitigated possible treatment differences.

Table I-2. Residual MITC levels in pentachlorophenol treated Douglas-fir poles 1 to 15 years after treatment with metham sodium or dazomet in powdered or rod form in combination with water or copper naphthenate as accelerants.

Treatment	Dosage	Supplement	Year sampled	Residual MITC (ug/g wood)[a]					
				0.3 m above GL		0.8 m above GL		1.3 m above GL	
				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)
			12	**74** (38)	**28** (26)	14 (10)	7 (4)	4 (3)	2 (2)
			15	**80** (73)	**43** (38)	2 (4)	0 (2)	0 (0)	0 (0)
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)
			12	**63** (32)	**32** (29)	20 (11)	8 (3)	6 (3)	2 (1)
			15	**27** (17)	**20** (33)	1 (2)	(0) (1)	0 (0)	0 (0)
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)
			12	**60** (39)	**31** (20)	**21** (30)	11 (9)	7 (12)	3 (4)
			15	**48** (48)	**21** (22)	5 (10)	2 (4)	1 (1)	0 (1)
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)
			12	**72** (54)	**34** (18)	17 (16)	9 (9)	8 (11)	3 (5)
			15	**23** (18)	15 (23)	3 (4)	0 (1)	1 (2)	0 (0)
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)
			12	**69** (30)	**41** (37)	16 (10)	8 (4)	3 (3)	2 (2)
			15	**30** (19)	**40** (52)	2 (4)	1 (3)	0 (0)	0 (0)

Table I-2 cont. Residual MITC levels in pentachlorophenol treated Douglas-fir poles 1 to 15 years after treatment with metham sodium or dazomet in powdered or rod form in combination with water or copper naphthenate as accelerants.

Treatment	Dosage	Supplement	Year sampled	Residual MITC (ug/g wood)[a]					
				0.3 m above GL		0.8 m above GL		1.3 m above GL	
				inner	outer	inner	outer	inner	outer
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)
			12	0 (1)	0 (1)	0 (1)	0 (0)	0 (0)	0 (0)
			15	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

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

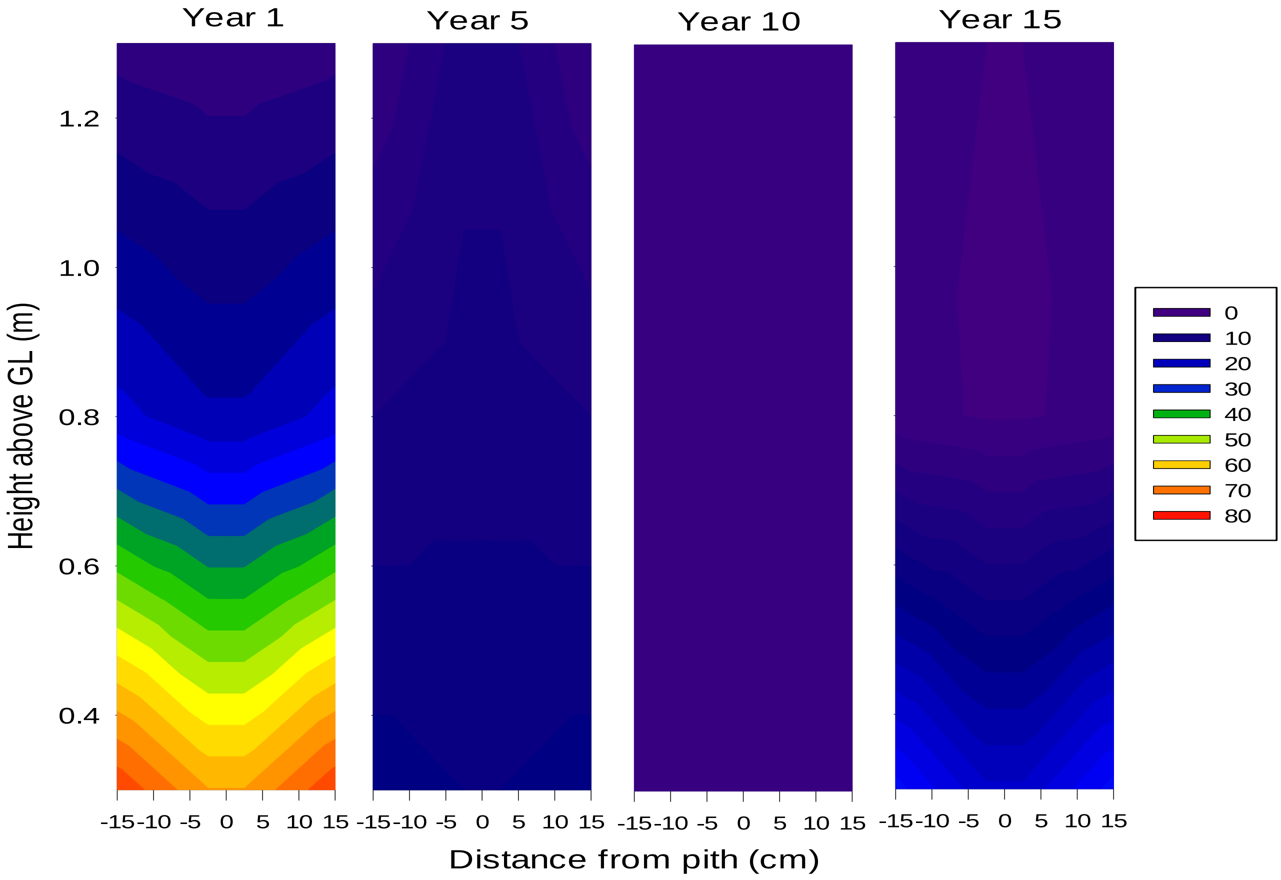


Figure I-1. Map showing residual MITC levels in pentachlorophenol treated Douglas-fir poles 1 to 15 years after treatment with metham sodium where dark blue represents MITC levels below the threshold for fungal attack and increasingly green to yellow or red color represent levels above that threshold. Charts are extrapolated from individual MITC analyses at assay locations described in Table I-2.

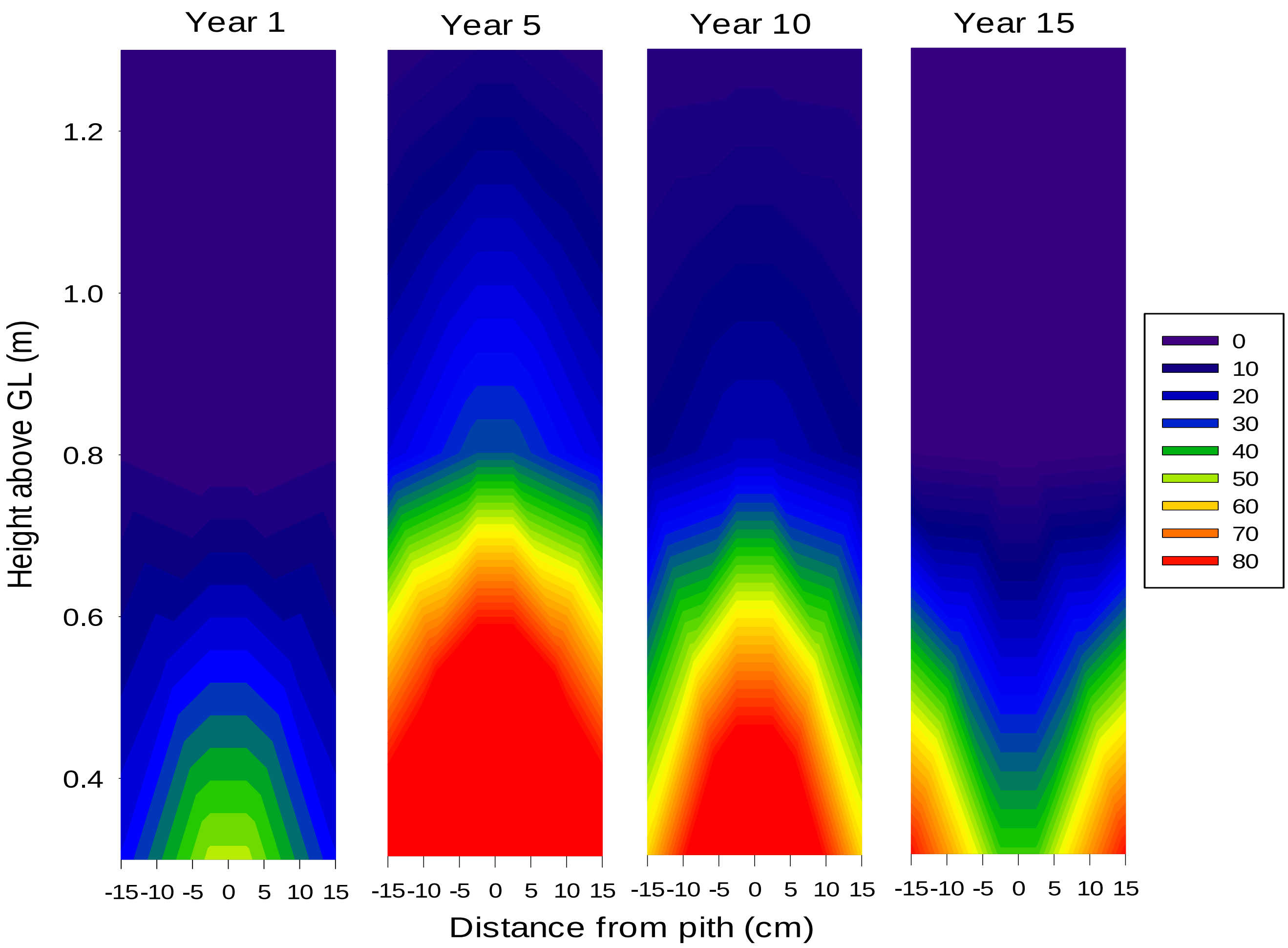


Figure I-2. Map showing residual MITC levels in pentachlorophenol treated Douglas-fir poles 1 to 15 years after treatment with powdered dazomet where dark blue represents MITC levels below the threshold for fungal attack and increasingly green to yellow or red color represent levels above that threshold. Charts are extrapolated from individual MITC analyses at assay locations described in Table I-2.

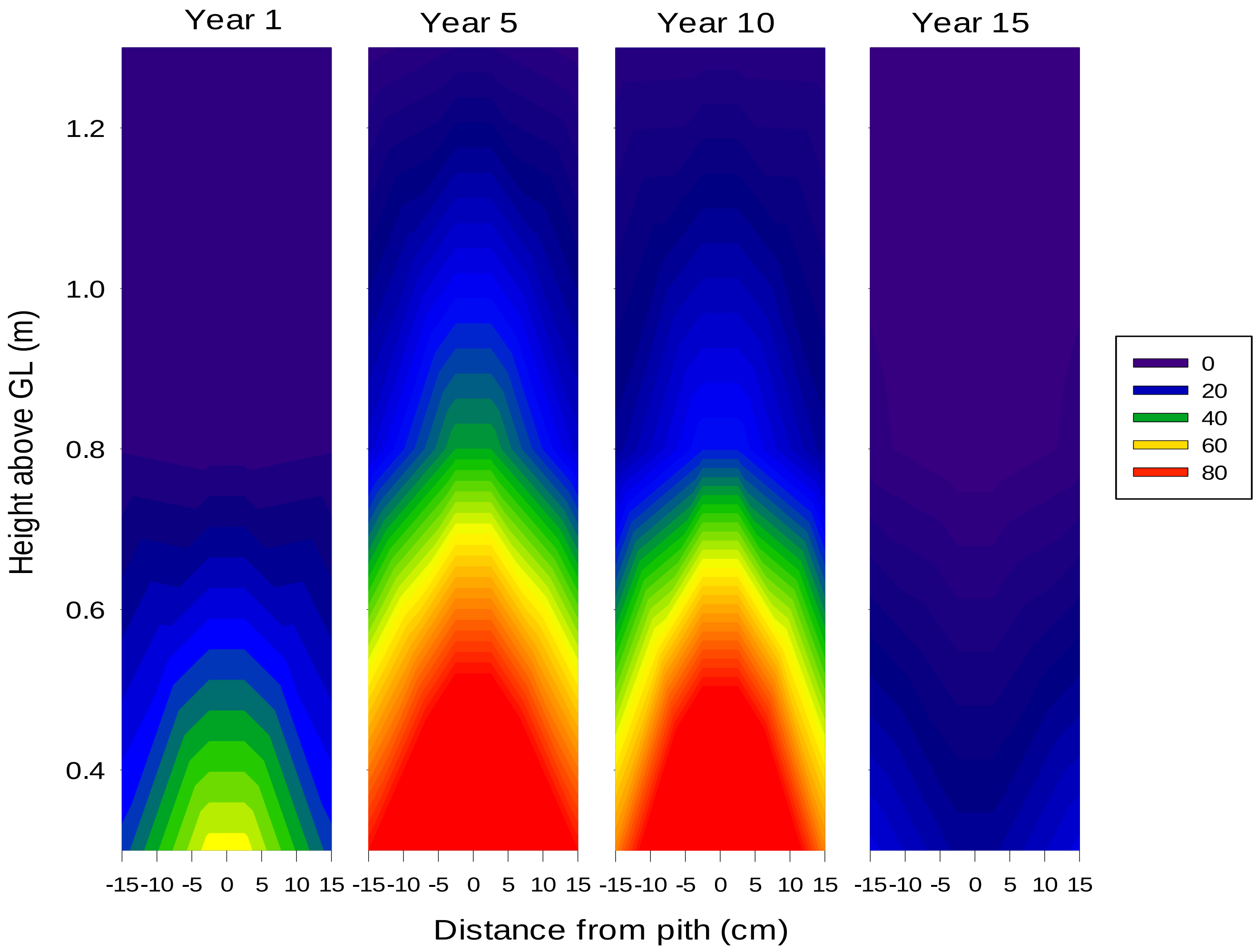


Figure I-3. Map showing residual MITC levels in pentachlorophenol treated Douglas-fir poles 1 to 15 years after treatment with 9 dazomet rods where dark blue represents MITC levels below the threshold for fungal attack and increasingly green to yellow or red color represent levels above that threshold. Charts are extrapolated from individual MITC analyses at assay locations described in Table I-2.

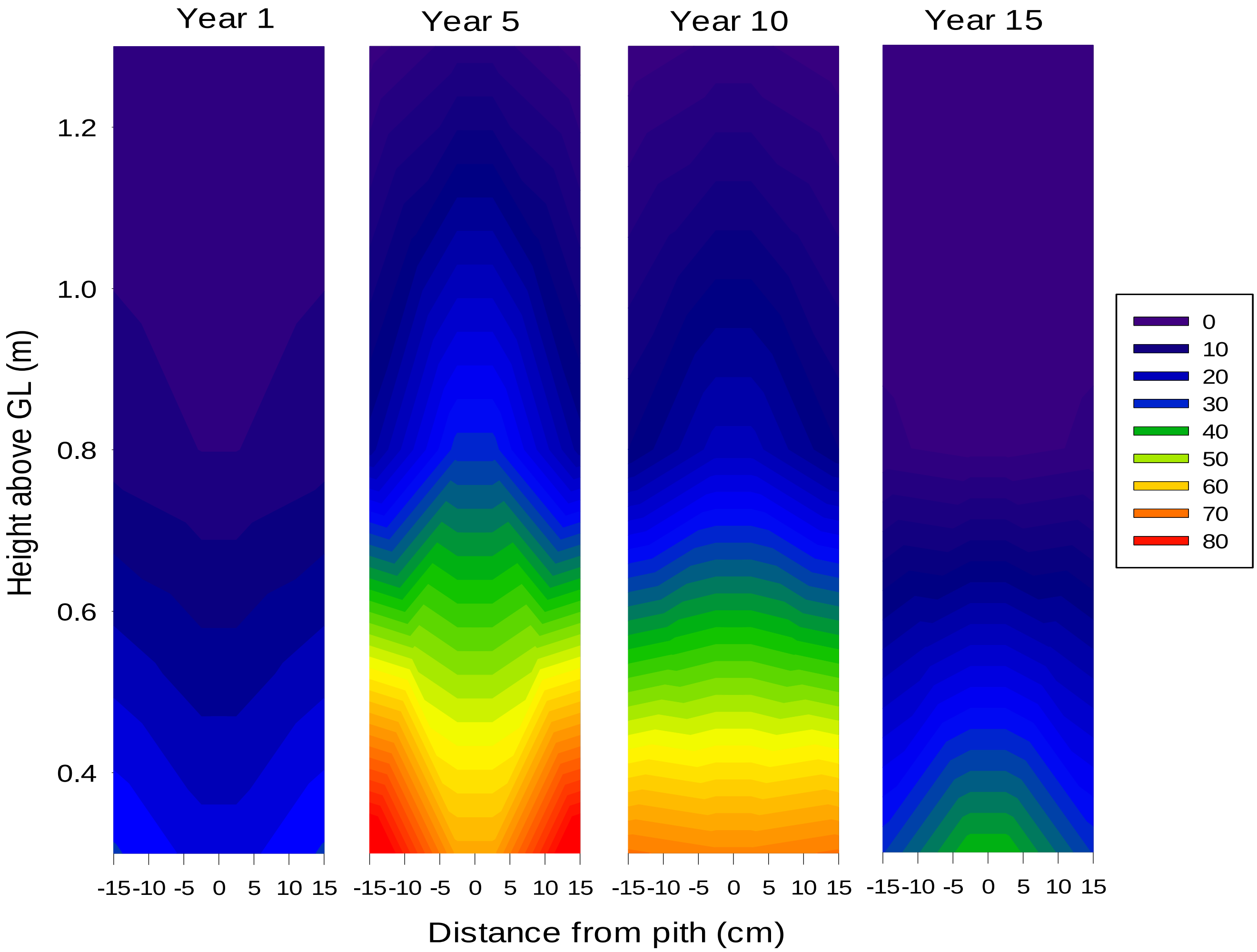


Figure I-4. Map showing residual MITC levels in pentachlorophenol treated Douglas-fir poles 1 to 15 years after treatment with 9 dazomet rods plus 100 g of water where dark blue represents MITC levels below the threshold for fungal attack and increasingly green to yellow or red color represent levels above that threshold. Charts are extrapolated from individual MITC analyses at assay locations described in Table I-2.

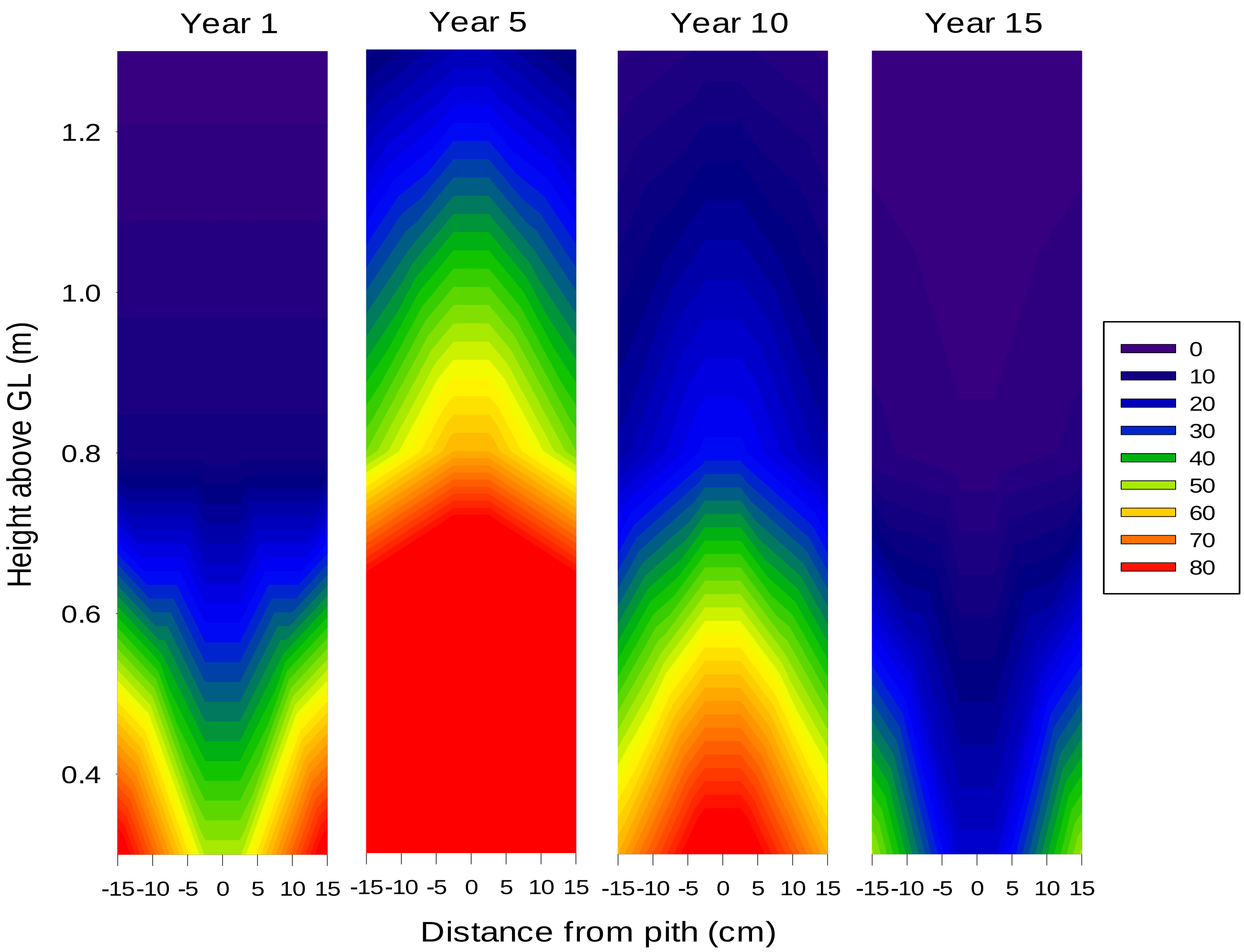


Figure I-5. Map showing residual MITC levels in pentachlorophenol treated Douglas-fir poles 1 to 15 years after treatment with 9 dazomet rods plus 100 g of copper naphthenate where dark blue represents MITC levels below the threshold for fungal attack and increasingly green to yellow or red color represent levels above that threshold. Charts are extrapolated from individual MITC analyses at assay locations described in Table I-2.

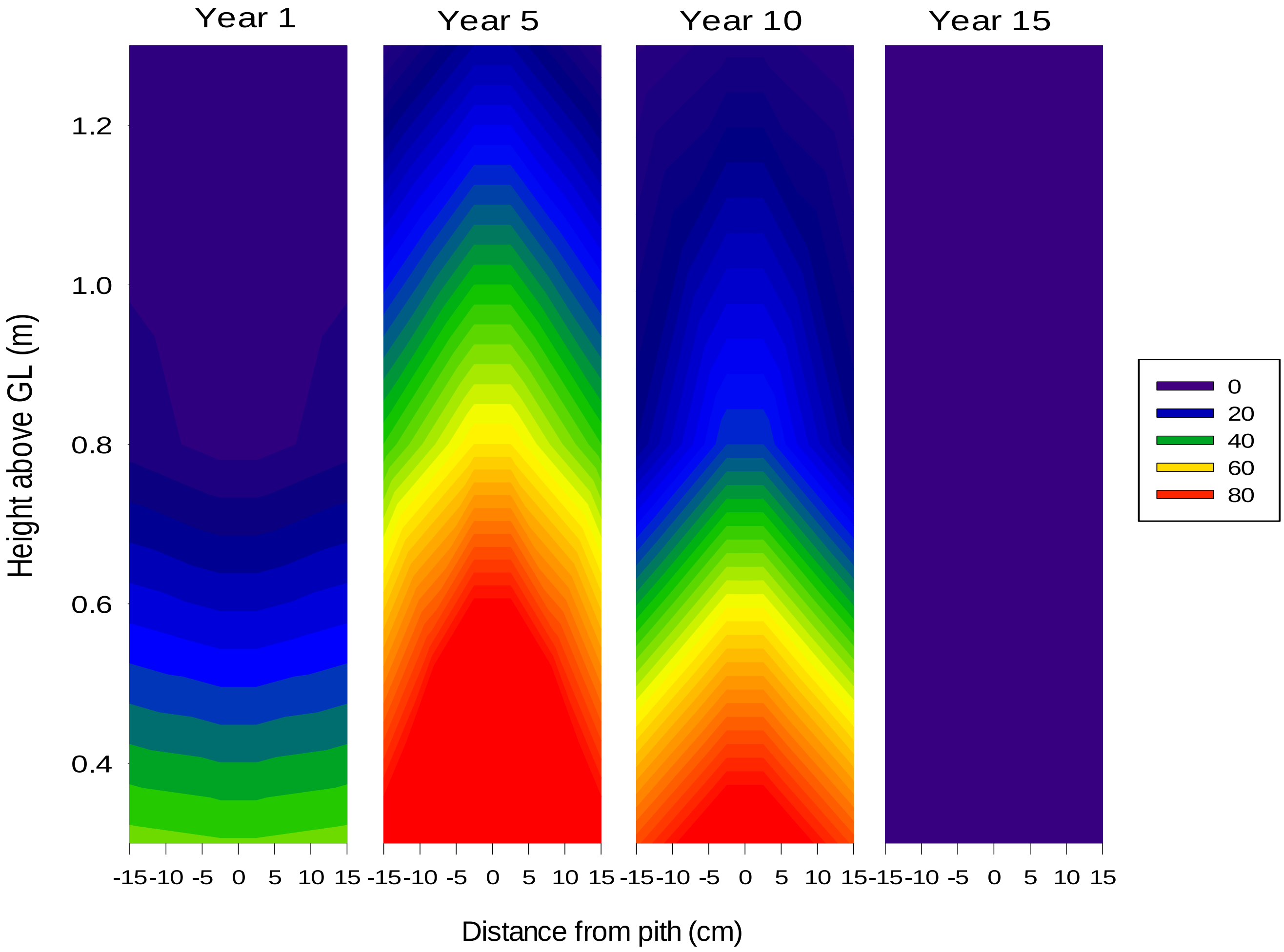


Figure I-6. Map showing residual MITC levels in pentachlorophenol treated Douglas-fir poles 1 to 15 years after treatment with 6 dazomet rods plus100 g of copper naphthenate where dark blue represents MITC levels below the threshold for fungal attack and increasingly green to yellow or red color represent levels above that threshold. Charts are extrapolated from individual MITC analyses at assay locations described in Table I-2.

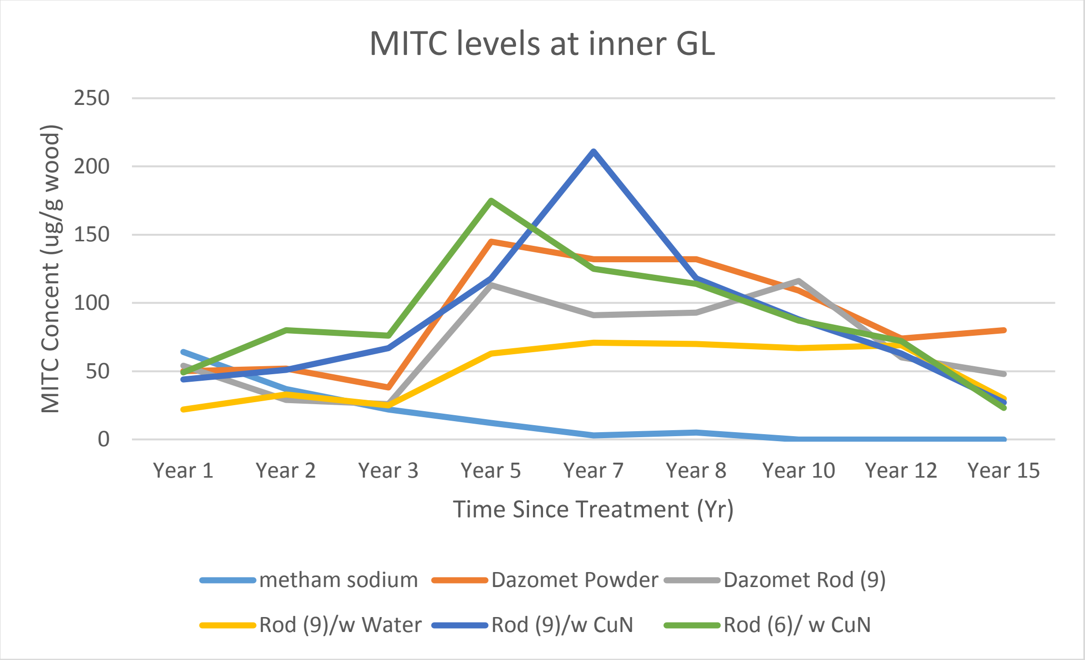


Figure I-7. MITC levels in the inner zone of increment cores removed from sites 0.3 m above groundline in pentachlorophenol treated Douglas-fir poles 1 to 15 years after treatment with metham sodium or dazomet in powdered or rod form with or without an accelerant. The threshold for fungal protection is 20 ug/g of oven dried wood.

Overall, results show dazomet treatment results in effective MITC levels for up to 15 years and illustrates the benefits of this system in climates where moisture is available for decomposition.

2. Behavior of Copper-Based Accelerants in Dazomet Treatment Holes

Dazomet is typically applied in conjunction with copper naphthenate to accelerate decomposition to MITC. The copper markedly improves decomposition, especially under drier conditions. In previous reports, we have discussed the ability of this copper naphthenate to become evenly distributed within the dazomet powder. Investigations of poles at a number of sites suggests copper naphthenate moves only a short distance downward and can sometimes form a hardened plug. It is unclear whether this plug inhibits further decomposition. It is difficult to assess the potential interactions between the dazomet and the copper naphthenate because of the opaque nature of wood. A number of investigators have examined mixing behavior in glass test tubes, but this approach does not completely represent the natural system because copper naphthenate cannot move outward into the surrounding wood. However, the tubes do allow examination of copper naphthenate flow around the different powdered formulations of dazomet.

One hundred mL glass test tubes were half filled with dazomet from two different sources with slightly different particle sizes (granular and powdered). Copper naphthenate (1% as supplied) was added to the tubes along with 20 g dazomet to produce various mass/mass ratios. The behavior of the mixture was studied and photographed over a 24 hour period.

In addition, non-treated Douglas-fir posts (87.5 by 87.5 mm) were obtained and cut into 200 mm long sections. The posts were mostly heartwood and were at a moisture content of approximately 20 % when prepared. A 25 mm diameter by 150 mm long hole was drilled at a slight angle at the center of one wide face of each section. These sections were ripped in half lengthwise through the angled hole. The sections were then reattached using silicon sealant between the cut faces and 62.5 mm long galvanized screws to hold the pieces in place. Ten g of dazomet was then added to each hole along with 3.5 mL of a copper based compound. The copper systems included copper naphthenate (1% as metal) or a micronized copper system (1% as metal). The treatment holes were then plugged with rubber stoppers and the blocks were incubated upright (angled hole down) at room temperature for 4, 8 or 12 weeks. At each time point, a 10 mm thick slice was cut from each end of three post sections per treatment, then a 5 mm thick slice was removed and cut into 16 equal sized sections. The middle 4 sections from a given slice was placed into 5 mL of ethyl acetate and extracted for 48 hours at room temperature. A small sub-sample of the extract was removed and analyzed for MITC content by gas chromatography. Wood sections were air-dried, then oven dried and weighed so that MITC content can be expressed on a ug of MITC per oven dried gram of wood. After cutting, the blocks were carefully reopened lengthwise and the distribution of copper around the dazomet were examined for depth of penetration as well as effect on dazomet texture (i.e. did it cause dazomet to harden into a plug). These tests are on-going and a more complete report will be provided in the next annual report.

Mixing dazomet and copper naphthenate in test tubes confirmed what had been seen in treatment holes. The copper naphthenate tended to soak into the upper portion of the dazomet, leaving the zone below devoid of any copper accelerant (Figure I-8). Considerable amounts of liquid copper naphthenate remained on top of the dazomet 24 hours after application. There also appeared to be differences in the depth of penetration of copper naphthenate between granular and more powered dazomet formulations (Figures I-9, 10). While copper naphthenate might be expected to penetrate more readily through a granular system, we observed slightly better penetration through the powdered formulation. It is unclear why this occurred, but it does suggest that the benefits of copper as an accelerant will differ with dazomet systems and this might require some reconsideration of application methods.

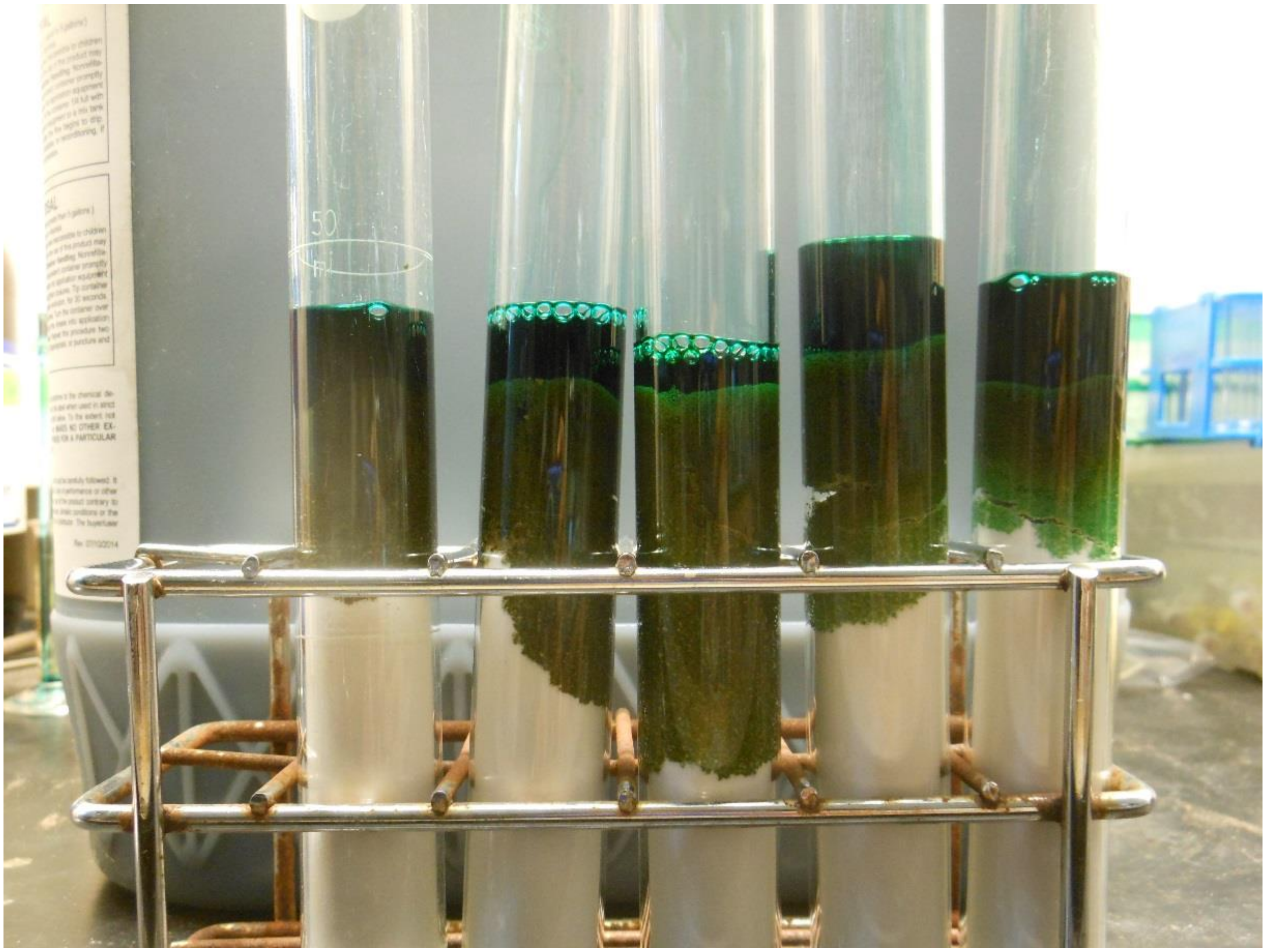


Figure I-8. Examples of dazomet in a test tube with added copper naphthenate showing copper naphthenate movement downward along the tube.

The test tube experiments were somewhat crude and did not directly assess the role of copper naphthenate since there was no opportunity for the liquid to move out of the treatment hole and into the surrounding wood. The small block tests offered a more realistic measure of copper movement since liquid could move away from the treatment hole.

Figure I-9. Examples of tests tubes containing equal amounts of 1% copper naphthenate and dazomet in either granular or powdered form and stored for 24 hours at room temperature.

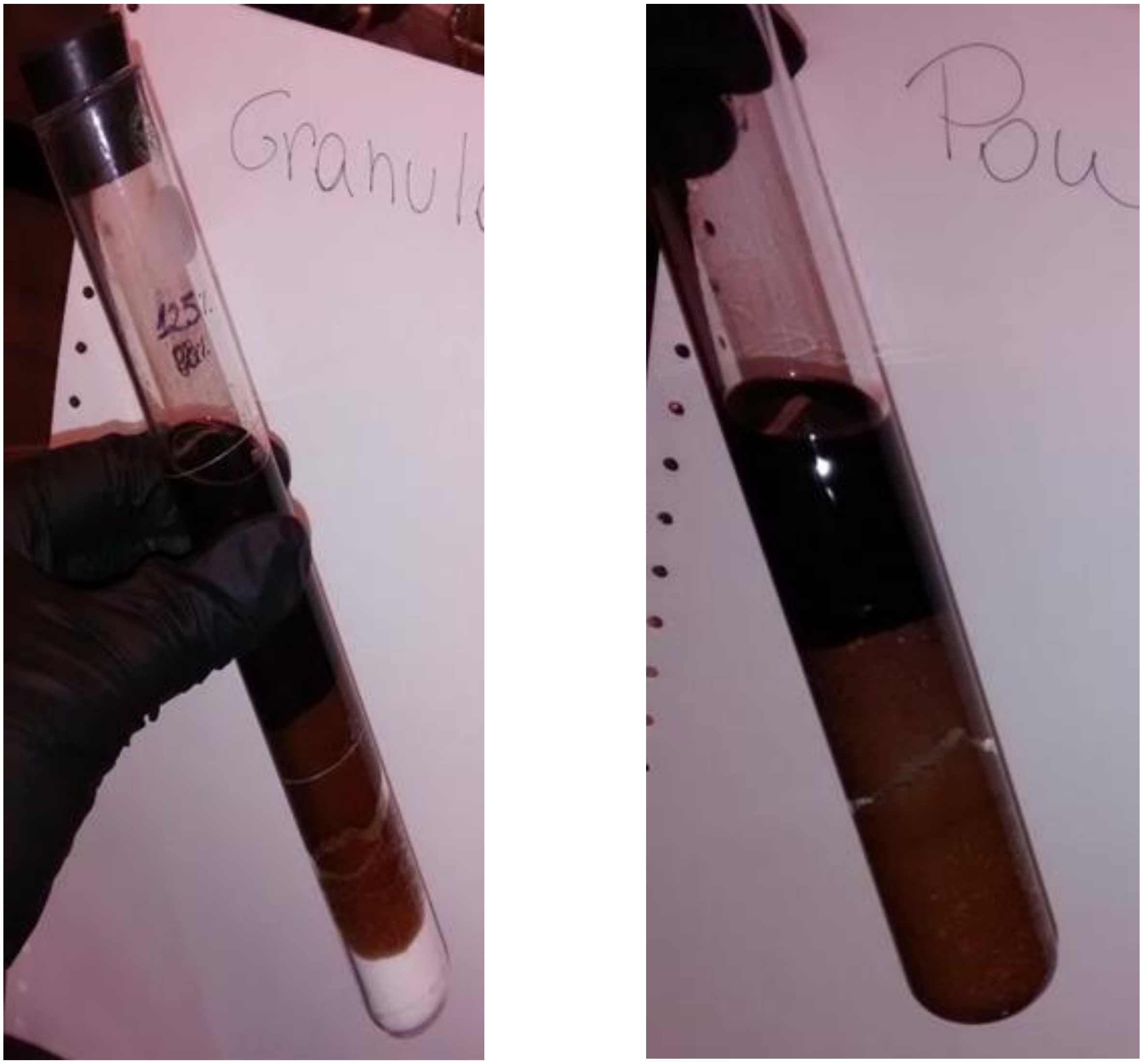


Figure I-10. Examples of tests tubes containing 1% copper naphthenate and dazomet in either granular or powdered form at a 125:100 m/m ratio of copper naphthenate:dazomet and stored for 24 hours at room temperature showing slightly better copper naphthenate penetration in the powdered formulation.

Although the small block tests have only just begun, dissection of one set immediately after treatment illustrated the differences in results between test tubes and wood blocks (Figure I-11). Copper naphthenate tended to penetrate the dazomet for about two thirds of the treatment-hole length, but also moved to a substantial extent longitudinally away from the treatment hole. As a result, the bottom third of the treatment hole received no copper accelerant. This observation is consistent with field tests. While some utilities have experiments with adding copper naphthenate in stages (some copper naphthenate first, then dazomet and finally additional copper naphthenate), this process is somewhat cumbersome.   In the original field trials, copper accelerant (as copper sulfate powder) was mixed with the dazomet powder prior to treatment, providing intimate contact between the two compounds through the treatment hole. However, since copper sulfate was not registered for this application, copper naphthenate was substituted. While numerous tests have shown that copper naphthenate is an acceptable accelerant, it clearly has different performance characteristics. These differences probably make relatively little difference in wetter climates where excess moisture is likely to produce acceptable dazomet decomposition to produce MITC, it becomes more problematic in drier climates.

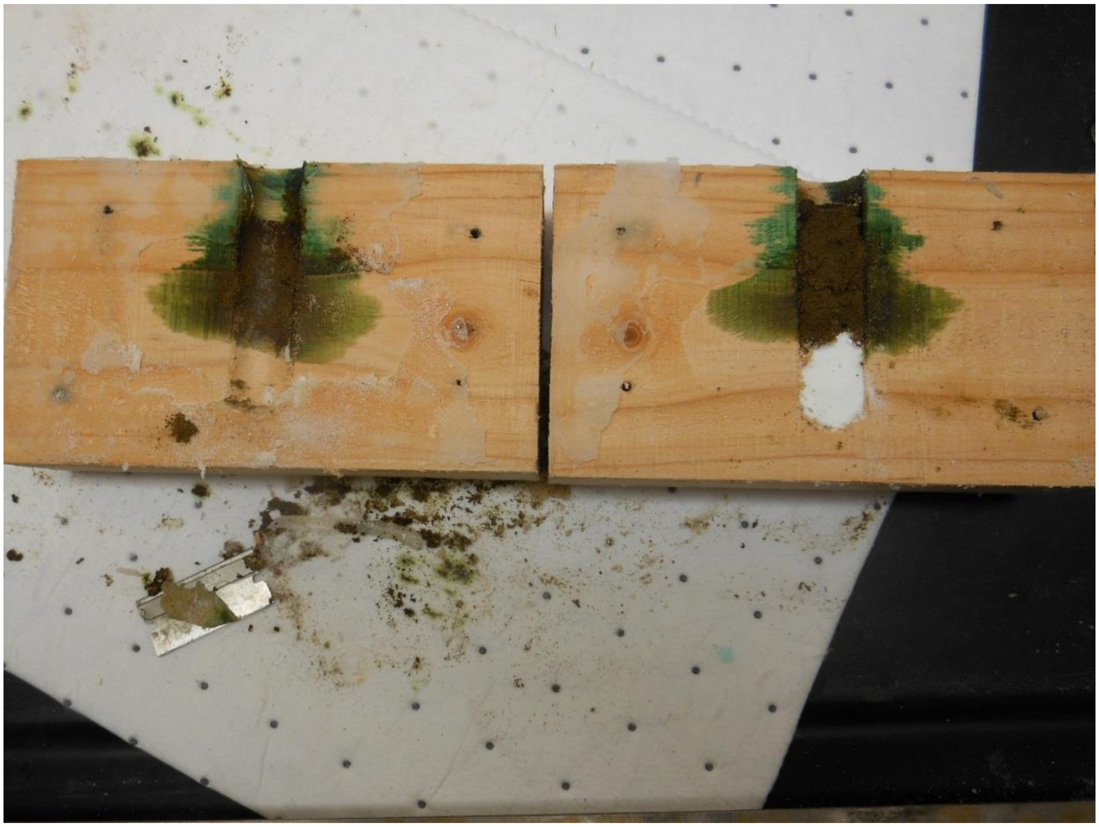


Figure I-11. Example of a 200 mm long block used to assess copper naphthenate distribution patterns in dazomet treatment holes showing copper naphthenate penetration limited to the upper zone of the treatment hole.

3. 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 rod 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 could also affect subsequent dazomet decomposition and the release of MITC. In order to investigate this possibility, the following trial was established.

Penta-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 150 mm and 120 degrees around the pole.

Seventy grams of dazomet was pre-weighed into plastic bottles. The content of one bottle was then added to each of the three holes in each of 10 poles. The holes in 10 additional poles each 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 damaging 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). Copper naphthenate is currently available over the counter at a 1% copper concentration. The holes were plugged with tight fitting plastic plugs. A second set of poles was treated one year later with an improved Super-Fume tube system using these same procedures. The newer tubes were constructed of perforated degradable plastic which should break down over time so removal will not be required before re-treating the poles.

MITC distribution was assessed 1, 2, 3, 5 and 7 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 outer 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 for MITC by gas chromatography. 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 decay fungi.

This test was not assessed this year and will be inspected in 2016.

B. PERFORMANCE OF WATER DIFFUSIBLE PRESERVATIVES AS INTERNAL TREATMENTS

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

Boron has a long history of use as an initial treatment of freshly sawn lumber to prevent infestations by various species of powder post beetles in both Europe and New Zealand. This chemical has also been used more recently for treatment of lumber in Hawaii to limit attack by the Formosan subterranean termite. Boron is attractive as a preservative because it has exceptionally low toxicity to non-target organisms, especially humans, and because it has the ability to diffuse through wet wood. In principle, a decaying utility pole should be wet, particularly near the groundline and this moisture can provide the vehicle for boron to move from the point of application to the points of decay. 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, 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 is available.

Fluoride has largely been phased out of use as a remedial treatment in North America because its limited use did not justify the costs for the testing required to maintain the EPA registration. Boron, however, remains widely used for both initial treatment of lumber and remedial treatment (primarily in external preservative pastes.

1. 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.)	84, 104, 65 cm

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

Penta-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° 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-3). The borate rods were 100 mm long by 12.7 mm in diameter and weighed 24.4 g each. An equal weight of boron 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.

Table I-3. 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 Rog- ers, Seattle, WA	
146	Timbor 10% in water	118	0	106	U.S. Borax Inc.	Disodium octaborate tetrahydrate

The pole sections were sampled 1, 2, 3, 5, 7, 10, 12, 15 and 20 years after treatment by removing two increment cores 180 degrees apart from 30 cm below the groundline, and cores from three equidistant locations around the pole 150 and 300 mm the groundline. The treated portion of the cores were discarded, then the remainder of each core was divided into zones corresponding to 0-50 (O), 51-100 (M), and 101-150 (I) mm from the edge of the treated zone. The zones from the same depth and height from a given treatment were combined and ground to pass a 20 mesh screen. The resulting sawdust was then extracted and analyzed using the azomethine-H method.

Boron levels in poles receiving only rods were above threshold at or below groundline one year after treatment, but below that level above groundline (Table I-4; Figure I-12). Levels at groundline remained above the threshold for the next 19 years after treatment and also increased to threshold levels 150 mm above groundline. Boron levels 300 mm above groundline were more variable, although they were generally still above threshold.

The addition of Boracare or Boracol 20 to the rods resulted in much higher overall boron levels at or above groundline one year after treatment, but had little to no effect on boron levels belowground (Figures I-13,14).   Boron levels remained above the threshold for the next 11 years and average boron levels (when outer, middle and inner zones were combined) were still over the threshold 20 years after treatment.

Addition of Boracol 40 to the boron rods produced much higher boron levels in wood at the groundline level years 1, 3, and 5 years after treatment (Figure I-15). The effect was interesting since both Boracol treatments delivered the same amount of boron and the Boracol 40 delivered less glycol. Glycol is presumed to enhance boron migration in dry wood.

The addition of glycol alone to the boron rods also resulted in an increase in boron levels over the course of the test, particularly at groundline and 150 mm above the level (Figure I-16). The enhanced boron effect was still evident 20 years after treatment. Similarly, boron levels in poles receiving rods with liquid Timbor were elevated compared to those just receiving rods (Figure I-17). It is unclear whether the enhanced boron levels in these treatments was due to the application of liquid or to the addition of solubilized boron. The results illustrate the benefits of added accelerants to the wood.

The overall trends in this test can be difficult to interpret because of the multiple sampling sites and inspection times. It is relatively simple to look at average boron content at groundline where treatment would be most critical, over time. Boron continued to be detectable in virtually all pole sections at groundline (Figure I-18). Boron levels at groundline were highest in poles receiving boron rods plus Boracol 40; however, these levels also declined to the lowest levels by the end of the test. These results suggest that accelerating release can result in an earlier decline below the threshold levels. The remaining treatments produced slight, periodic increases in boron levels, but the overall levels were similar for most treatments over the course of the test. Boron levels 10 to 20 years after treatment tended to be uniformly low (although levels were somewhat higher in the boron glycol treatment), but still over the threshold for protection against fungal attack.

The results with various combinations of boron rods and Boracare, Boracol, Timbor, or glycol suggest that some supplemental liquid enhanced boron movement, whether or not the additive contained boron or glycol.

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

Table I-4. Boron levels in Douglas-fir poles 1 to 20 years after treatment with various combinations of fused boron rod and various water or glycol based additives. Numbers in bold represent boron levels above the toxic threshold of 0.5 kg/m ^{3} BAE. Figures in parentheses represent one standard deviation.

Treatment	Height (mm)	Depth	Boron (Kg/m^3 BAE)^a								
			Year 1	Year 2	Year 3	Year 5	Year 7	Year 10	Year 12	Year 15	Year 20
Rods alone	-300	I	**0.52** (0.45)	**1.40** (1.23)	**0.87** (0.82)	**0.53** (0.92)	0.46 (0.64)	0.35 (0.17)	0.23 (0.40)	0.49 (0.06)	0.34 (0.14)
		M	**0.81** (1.34)	**0.83** (0.91)	0.37 (0.30)	0.37 (0.69)	0.37 (0.56)	0.21 (0.35)	0.22 (0.39)	0.29 (0.11)	**0.74** (0.19)
		O	0.30 (0.10)	0.43 (0.56)	0.24 (0.23)	0.50 (0.59)	0.10 (0.08)	0.28 (0.35)	0.11 (0.20)	0.07 (0.02)	**0.74** (0.37)
	0	I	**1.31** (1.91)	**2.16** (0.97)	**2.15** (1.97)	**2.88** (1.98)	**1.10** (0.87)	**1.23** (0.38)	**0.81** (0.44)	**1.12** (0.90)	0.45 (0.18)
		M	0.34 (0.24)	**1.05** (0.85)	**2.43** (2.66)	**1.86** (0.82)	**1.07** (0.92)	**0.69** (0.14)	**0.63** (0.65)	**0.64** (0.16)	**1.24** (0.92)
		O	0.24 (0.13)	0.23 (0.29)	**1.67** (2.09)	0.42 (0.46)	**0.69** (0.78)	0.32 (0.14)	0.25 (0.35)	0.20 (0.07)	**1.35** (1.27)
	150	I	0.45 (0.29)	**1.65** (2.24)	**2.12** (1.62)	**1.87** (1.72)	**2.54** (1.82)	**1.64** (0.72)	**0.57** (0.46)	**1.41** (1.39)	0.46 (0.23)
		M	0.22 (0.07)	**1.39** (2.47)	**2.88** (3.32)	**1.47** (1.43)	**1.83** (1.66)	**2.74** (2.89)	**0.87** (0.59)	**1.61** (1.84)	**1.19** (1.13)
		O	0.29 (0.18)	0.43 (0.86)	**0.54** (0.86)	0.41 (0.49)	0.27 (0.28)	**0.54** (0.34)	**0.55** (0.50)	0.41 (0.26)	**1.26** (0.94)
	300	I	0.23 (0.13)	0.30 (0.54)	0.49 (0.59)	**1.14** (2.03)	**14.16** (29.02)	**0.73** (0.74)	0.01 (0.02)	**0.74** (0.37)	0.33 (0.20)
		M	0.20 (0.06)	0.17 (0.16)	0.33 (0.34)	**1.79** (3.13)	**0.81** (0.90)	0.48 (0.52)	0.02 (0.03)	**0.74** (0.68)	**0.68** (0.61)
		O	0.16 (0.09)	0.10 (0.10)	0.11 (0.10)	**1.06** (1.77)	0.40 (0.46)	0.25 (0.15)	0.07 (0.11)	**0.94** (1.49)	**0.89** (0.53)
Rods plus Boracare	-300	I	**1.57** (1.80)	0.36 (0.25)	**0.51** (0.32)	0.20 (0.16)	0.15 (0.14)	0.30 (0.24)	0.41 (0.62)	**0.71** (0.55)	0.27 (0.30)
		M	0.36 (0.20)	0.43 (0.37)	**0.56** (0.28)	0.07 (0.10)	0.12 (0.10)	0.28 (0.17)	0.18 (0.18)	0.34 (0.19)	0.43 (0.39)
		O	0.23 (0.05)	0.16 (0.03)	**0.58** (0.59)	0.04 (0.06)	0.10 (0.04)	0.22 (0.14)	0.03 (0.05)	0.10 (0.01)	**1.28** (1.11)
	0	I	**2.80** (1.86)	**7.59** (6.38)	**2.40** (1.51)	**5.68** (6.61)	**10.39** (9.85)	**2.00** (1.52)	**1.85** (1.45)	**1.55** (1.41)	0.47 (0.52)
		M	0.32 (0.18)	**4.77** (4.78)	**1.34** (0.92)	**5.03** (4.71)	**0.78** (0.90)	**0.87** (0.67)	**1.00** (0.72)	**1.46** (1.27)	**1.50** (0.81)
		O	0.22 (0.05)	0.40 (0.39)	**0.87** (0.93)	**0.83** (0.91)	**0.53** (0.67)	0.18 (0.11)	0.20 (0.18)	0.20 (0.10)	**1.17** (1.47)
	150	I	**4.35** (3.61)	**3.55** (1.22)	**4.13** (4.66)	**5.17** (3.72)	**3.14** (2.65)	**1.84** (1.88)	**1.11** (1.42)	**2.67** (2.62)	**0.78** (0.49)
		M	**1.06** (1.10)	**1.32** (1.67)	**4.10** (4.50)	**1.86** (0.97)	**1.69** (1.72)	**0.80** (1.01)	**1.04** (0.88)	**0.80** (0.62)	1.01 (0.78)
		O	0.50 (0.34)	0.49 (0.90)	0.40 (0.30)	**1.08** (1.85)	0.21 (0.23)	0.28 (0.20)	0.35 (0.41)	0.23 (0.13)	**1.71** (1.49)
	300	I	**1.79** (1.16)	**1.22** (1.09)	**0.81** (1.05)	**2.27** (3.19)	**1.83** (1.29)	**1.92** (1.64)	**1.31** (1.12)	**0.88** (1.17)	0.42 (0.24)
		M	**1.16** (1.91)	0.33 (0.29)	**0.89** (1.36)	**4.23** (8.09)	**0.89** (0.68)	**1.09** (0.90)	**0.53** (0.72)	**0.93** (0.75)	**0.56** (0.30)
		O	0.33 (0.19)	0.15 (0.18)	**1.00** (1.77)	**1.62** (2.88)	0.12 (0.06)	0.20 (0.14)	0.12 (0.18)	0.25 (0.26)	**1.15** (0.82)
Rods plus Boracol 20	-300	I	**0.87** (0.71)	**0.69** (0.75)	0.50 (0.53)	0.26 (0.19)	**1.61** (1.06)	**0.73** (0.33)	**0.92** (0.72)	**0.50** (0.44)	0.13 (0.32)
		M	0.49 (0.48)	0.29 (0.26)	0.26 (0.24)	0.22 (0.23)	**0.99** (0.90)	**0.63** (0.21)	**0.79** (0.57)	0.36 (0.09)	0.34 (0.32)
		O	0.47 (0.49)	0.20 (0.21)	0.22 (0.15)	**1.62** (3.36)	0.13 (0.19)	0.49 (0.22)	0.21 (0.26)	0.22 (0.11)	0.25 (0.21)
	0	I	**4.51** (5.32)	**2.41** (0.73)	**3.93** (2.95)	**3.33** (1.95)	**2.22** (2.74)	**1.87** (1.56)	**3.82** (4.14)	**1.48** (1.04)	0.40 (0.19)
		M	**1.44** (2.09)	**0.79** (0.53)	**2.38** (2.32)	**1.99** (1.25)	**0.89** (0.58)	**1.07** (1.08)	**0.89** (0.70)	**0.76** (0.48)	**1.04** (0.51)
		O	0.32 (0.12)	**1.11** (2.11)	**2.96** (2.91)	**0.55** (0.63)	0.11 (0.11)	**0.57** (0.35)	0.46 (0.36)	0.46 (0.55)	**0.86** (0.38)
	150	I	**1.84** (0.95)	**3.64** (4.00)	**1.65** (1.79)	**3.69** (1.56)	**2.06** (1.47)	**2.39** (1.49)	**3.49** (1.98)	**1.69** (0.56)	**0.66** (0.64)
		M	**0.73** (0.70)	**1.00** (0.65)	**3.39** (5.04)	**1.85** (1.16)	**3.86** (1.89)	**1.02** (0.97)	**1.25** (0.40)	**1.58** (0.91)	**1.23** (0.76)
		O	0.36 (0.23)	**0.93** (1.45)	0.30 (0.27)	0.44 (0.41)	0.27 (0.20)	0.15 (0.09)	0.46 (0.29)	**1.28** (1.34)	**1.05** (0.88)
	300	I	**2.87** (4.37)	**0.70** (0.72)	**0.93** (1.12)	0.36 (0.70)	**0.91** (1.22)	0.31 (0.24)	**0.89** (0.92)	**0.59** (0.65)	**0.51** (0.28)
		M	**0.67** (0.62)	**1.09** (1.16)	**0.58** (0.82)	0.27 (0.56)	**1.04** (1.66)	0.18 (0.15)	**0.59** (0.51)	0.31 (0.33)	**0.79** (0.51)
		O	0.24 (0.07)	**1.37** (2.44)	0.20 (0.24)	0.40 (0.72)	0.20 (0.36)	0.06 (0.03)	0.06 (0.05)	0.07 (0.05)	**0.94** (0.83)

Table I-4 cont. Boron levels in Douglas-fir poles 1 to 20 years after treatment with various combinations of fused boron rod and various water or glycol based additives. Numbers in bold represent boron levels above the toxic threshold of 0.5 kg/m ^{3} BAE. Figures in parentheses represent one standard deviation.

Treatment	Height (mm)	Depth	Boron (Kg/m^3 BAE)[a]								
			Year 1	Year 2	Year 3	Year 5	Year 7	Year 10	Year 12	Year 15	Year 20
Rods plus Boracol 40	-300	I	**2.49** (2.38)	**0.92** (0.63)	**0.71** (0.62)	**0.62** (0.73)	**1.32** (1.17)	0.46 (0.30)	**0.51** (0.49)	**0.69** (0.26)	**0.89** (1.19)
		M	**0.55** (0.41)	**0.71** (1.09)	**1.53** (2.57)	0.37 (0.36)	0.41 (0.34)	**0.55** (0.49)	0.20 (0.31)	**0.74** (0.43)	0.12 (0.07)
		O	0.21 (0.08)	**0.74** (0.99)	**1.36** (2.66)	0.07 (0.07)	0.14 (0.28)	0.40 (0.22)	0.22 (0.39)	0.33 (0.40)	0.23 (0.29)
	0	I	**11.15** (6.98)	**10.41** (9.50)	**5.82** (3.21)	**10.82** (9.22)	**5.86** (4.24)	**2.16** (0.06)	**1.31** (0.35)	**1.38** (1.06)	0.17 (0.20)
		M	**3.38** (2.69)	**5.16** (3.23)	**9.54** (10.73)	**13.82** (10.66)	**7.49** (3.73)	**1.23** (0.46)	**1.17** (0.23)	**1.33** (0.54)	0.36 (0.24)
		O	0.45 (0.31)	**1.26** (1.47)	**2.65** (2.21)	**2.53** (1.85)	**0.53** (0.34)	0.42 (0.10)	0.34 (0.36)	0.27 (0.04)	0.47 (0.17)
	150	I	0.37 (0.24)	0.33 (0.30)	0.35 (0.30)	**0.63** (0.86)	**1.39** (1.58)	0.36 (0.49)	0.46 (0.37)	**0.60** (0.32)	0.20 (0.10)
		M	0.22 (0.03)	0.44 (0.43)	0.41 (0.31)	0.33 (0.53)	0.47 (0.40)	0.44 (0.57)	0.40 (0.19)	0.48 (0.19)	0.46 (0.29)
		O	0.18 (0.11)	0.33 (0.28)	0.26 (0.08)	0.14 (0.27)	0.06 (0.04)	0.12 (0.14)	0.03 (0.03)	0.12 (0.07)	0.49 (0.24)
	300	I	0.18 (0.12)	0.10 (0.09)	0.08 (0.07)	0.03 (0.04)	0.37 (0.67)	0.04 (0.06)	0.03 (0.05)	0.22 (0.14)	0.24 (0.24)
		M	0.15 (0.10)	0.08 (0.05)	0.09 (0.08)	0.04 (0.05)	0.18 (0.17)	0.03 (0.01)	0.02 (0.03)	0.13 (0.06)	0.44 (0.22)
		O	0.15 (0.11)	0.07 (0.04)	0.08 (0.07)	0.02 (0.02)	0.04 (0.02)	0.27 (0.37)	0.00 0.00	0.05 (0.02)	**0.67** (0.34)
Rods plus ethylene glycol	-300	I	0.32 (0.29)	0.33 (0.20)	0.16 (0.13)	0.14 (0.21)	0.30 (0.24)	**0.52** (0.38)	**0.96** (0.93)	**1.04** (0.70)	0.32 (0.28)
		M	0.19 (0.06)	0.18 (0.11)	0.07 (0.13)	0.04 (0.09)	0.10 (0.07)	**0.79** (0.48)	**0.80** (0.98)	0.43 (0.19)	0.30 (0.21)
		O	0.16 (0.10)	0.10 (0.11)	0.10 (0.13)	0.03 (0.05)	0.19 (0.31)	0.44 (0.36)	0.35 (0.52)	0.11 (0.02)	**0.66** (0.69)
	0	I	**5.30** (8.91)	**3.71** (2.92)	**3.88** (3.84)	**2.84** (1.97)	**4.86** (3.37)	**2.83** (2.02)	**3.07** (3.21)	**4.09** (4.30)	**1.11** (1.65)
		M	**0.97** (1.20)	**0.61** (0.39)	**0.67** (0.46)	**2.81** (2.00)	**5.17** (7.26)	**1.70** (0.80)	**2.45** (2.07)	**1.11** (0.78)	**0.97** (0.64)
		O	0.21 (0.16)	0.17 (0.17)	**0.68** (1.20)	**1.61** (1.90)	0.49 (0.46)	**0.54** (0.38)	0.24 (0.32)	0.25 (0.13)	**2.75** (3.95)
	150	I	**2.98** (3.50)	**5.02** (4.32)	**5.31** (1.72)	**2.77** (2.53)	**2.89** (1.34)	**3.00** (3.04)	**1.99** (2.08)	**1.33** (0.86)	**0.86** (1.23)
		M	**1.34** (1.53)	**1.09** (1.36)	**2.34** (2.63)	**6.53** (10.12)	**3.08** (2.69)	**1.74** (1.46)	**2.78** (3.78)	**1.59** (1.74)	**0.76** (0.50)
		O	0.29 (0.22)	0.10 (0.08)	**1.45** (2.03)	**4.29** (7.08)	0.27 (0.18)	0.33 (0.11)	**1.04** (1.51)	**1.25** (1.82)	**2.11** (2.40)
	300	I	0.17 (0.11)	0.24 (0.16)	**1.50** (1.83)	**1.57** (2.79)	**0.63** (1.10)	0.33 (0.08)	**0.65** (0.76)	**0.50** (0.24)	**0.59** (0.78)
		M	0.19 (0.05)	0.18 (0.22)	**0.56** (0.69)	**3.44** (6.66)	**1.16** (1.73)	0.19 (0.08)	0.11 (0.10)	0.19 (0.09)	**0.50** (0.30)
		O	0.20 (0.04)	**0.61** (0.97)	**0.91** (1.72)	**2.33** (4.85)	0.43 (0.48)	0.09 (0.02)	0.29 (0.47)	0.05 (0.02)	**0.84** (0.57)
Rods plus Timbor	-300	I	**0.83** (0.43)	**0.67** (0.37)	0.30 (0.22)	0.32 (0.39)	**1.12** (1.58)	0.35 (0.24)	**0.69** (0.50)	**1.23** (0.93)	0.42 (0.47)
		M	0.30 (0.07)	0.26 (0.11)	**0.54** (0.37)	0.13 (0.22)	0.32 (0.33)	0.40 (0.36)	**0.53** (0.52)	**1.16** (0.83)	**0.82** (0.79)
		O	0.33 (0.18)	0.14 (0.06)	**0.51** (0.60)	0.03 (0.04)	0.04 (0.06)	0.26 (0.25)	0.24 (0.29)	0.40 (0.46)	**0.72** (0.57)
	0	I	**2.75** (2.36)	**2.68** (2.36)	**5.67** (4.81)	**7.58** (11.41)	**2.59** (2.46)	**1.58** (0.37)	**2.35** (0.45)	**1.44** (0.42)	**0.70** (0.50)
		M	0.32 (0.17)	**1.84** (1.99)	**1.46** (1.35)	**1.54** (0.78)	**0.85** (0.53)	**1.24** (0.65)	**1.60** (1.07)	**0.92** (0.20)	**1.09** (1.16)
		O	0.34 (0.23)	0.20 (0.17)	**0.54** (0.55)	0.47 (0.49)	**0.55** (1.10)	**0.56** (0.52)	**0.69** (0.87)	0.34 (0.06)	**0.84** (0.50)
	150	I	**3.53** (3.44)	**2.89** (2.22)	**2.83** (2.85)	**2.22** (1.10)	**14.00** (21.75)	**3.47** (0.32)	**2.96** (0.60)	**1.57** (1.07)	**0.63** (0.27)
		M	**6.60** (12.26)	**1.42** (1.89)	**1.74** (1.98)	**6.15** (7.51)	**2.51** (2.13)	**2.86** (0.60)	**2.04** (0.44)	**1.31** (0.70)	**1.16** (0.70)
		O	**0.72** (0.79)	0.35 (0.30)	**0.94** (0.74)	**1.13** (0.83)	**0.54** (0.43)	**0.88** (0.65)	**0.74** (0.54)	0.44 (0.15)	**0.90** (0.43)
	300	I	**2.94** (5.56)	**1.74** (2.22)	**1.57** (1.91)	**3.38** (5.19)	**1.33** (1.30)	**2.03** (1.55)	**1.61** (1.22)	**0.71** (0.37)	**0.37** (0.27)
		M	0.38 (0.23)	0.40 (0.35)	**1.84** (2.42)	**0.68** (0.66)	**1.00** (0.54)	**0.91** (0.30)	**0.78** (0.12)	0.45 (0.08)	**0.70** (0.38)
		O	0.45 (0.32)	0.15 (0.07)	**3.14** (2.42)	0.34 (0.48)	0.22 (0.25)	0.31 (0.19)	0.28 (0.35)	0.12 (0.03)	**0.84** (0.36)

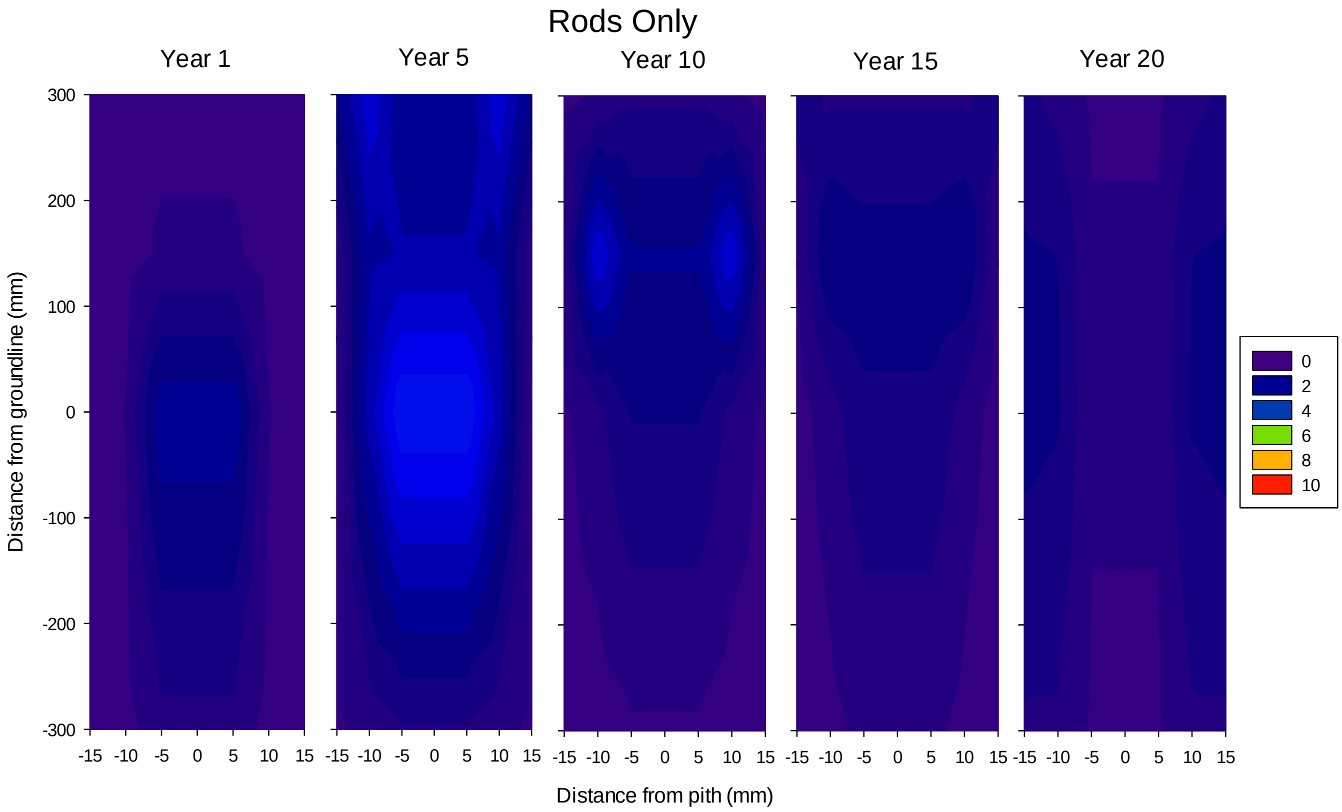


Figure I-12. Boron distribution in Douglas-fir poles 1 to 20 years after treatment with fused boron rods. Dark blue represents levels below the threshold for protection against fungal attack, while lighter blue, green and orange colors represent increasing boron concentrations in the wood. Charts are extrapolated from individual boron analyses at assay locations described in Table I-4.

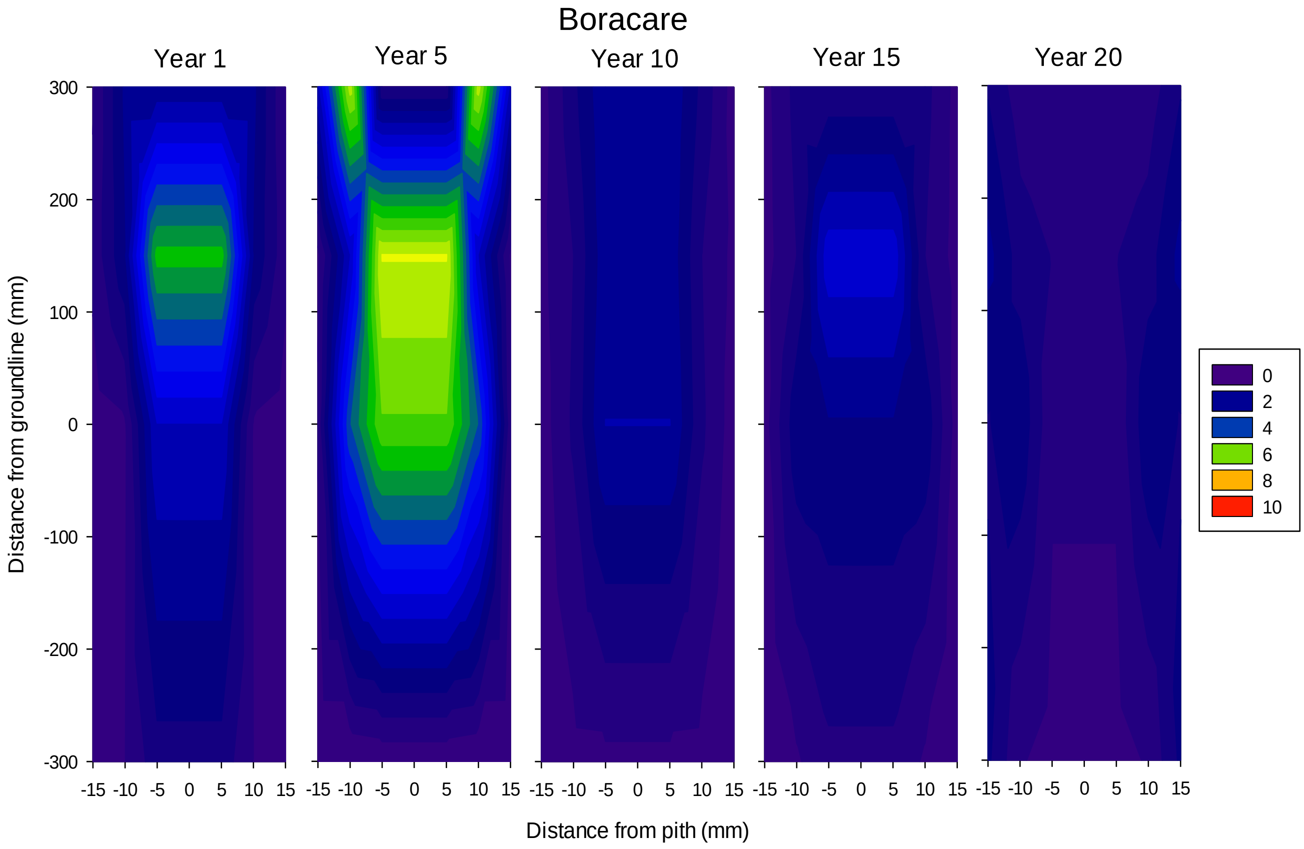


Figure I-13. Boron distribution in Douglas-fir poles 1 to 20 years after treatment with fused boron rods and Boracare. Dark blue represents levels below the threshold for protection against fungal attack, while lighter blue, green and orange colors represent increasing boron concentrations in the wood. Charts are extrapolated from individual boron analyses at assay locations described in Table I-4.

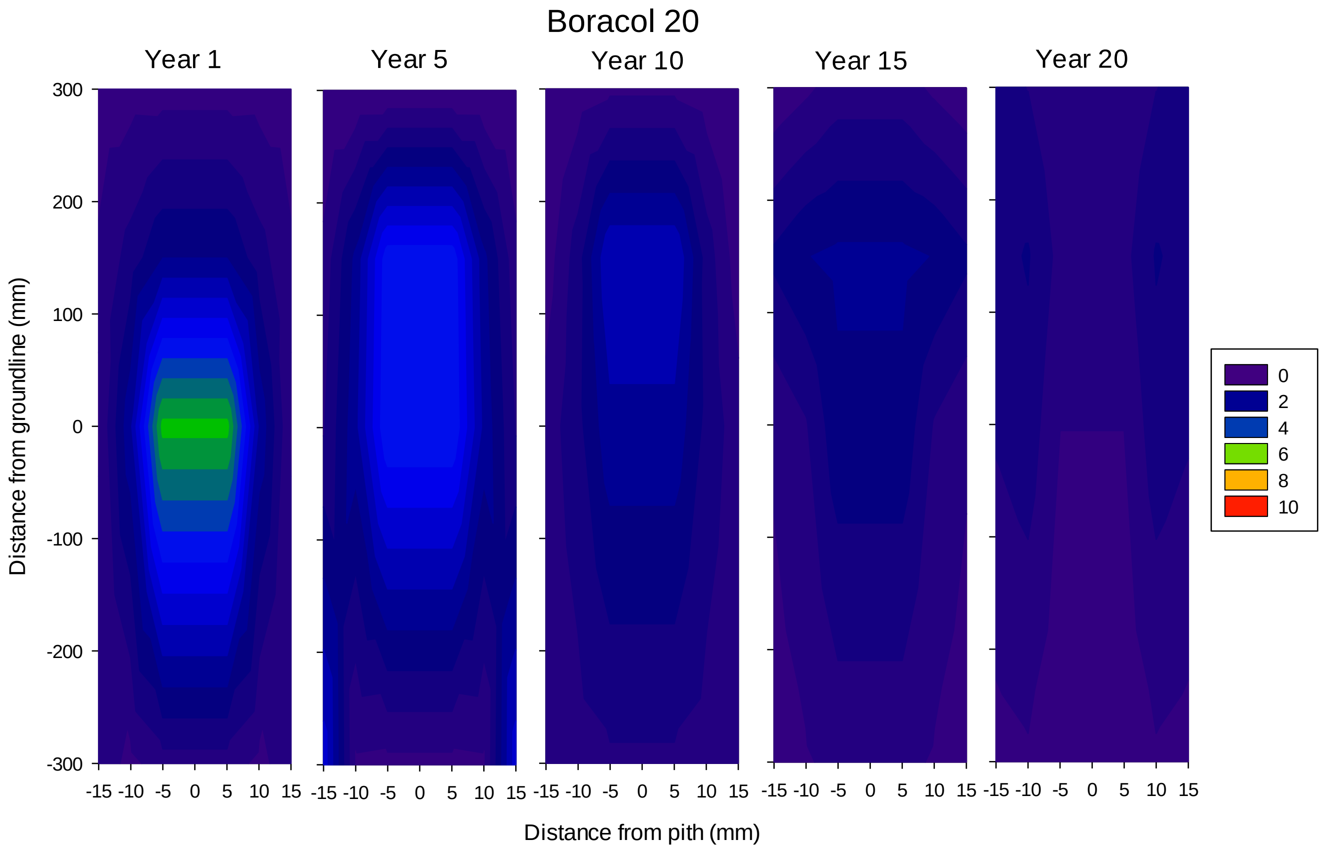


Figure I-14. Boron distribution in Douglas-fir poles 1 to 20 years after treatment with fused boron rods and Boracol 20. Dark blue represents levels below the threshold for protection against fungal attack, while lighter blue, green and orange colors represent increasing boron concentrations in the wood. Charts are extrapolated from individual boron analyses at assay locations described in Table I-4.

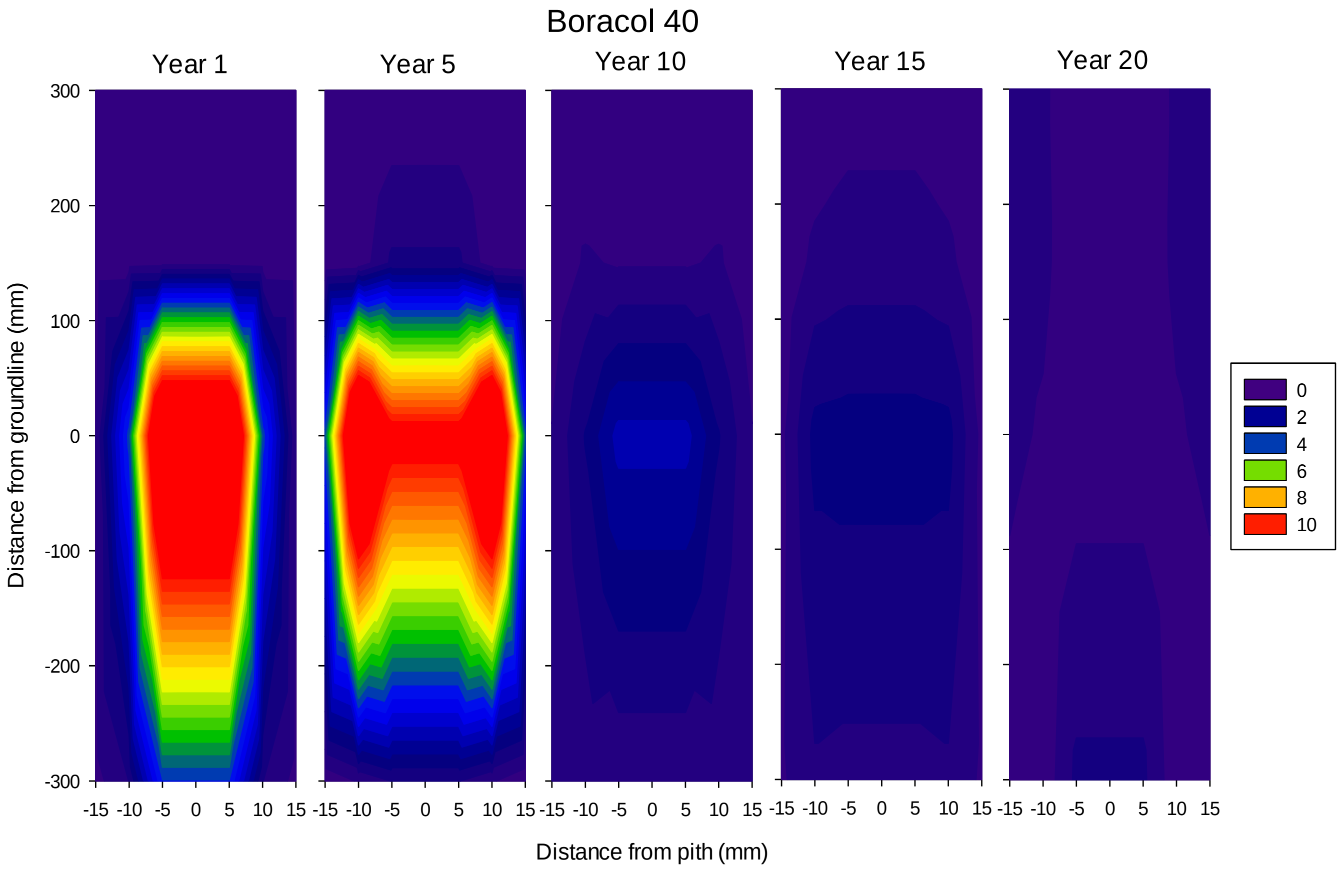


Figure I-15. Boron distribution in Douglas-fir poles 1 to 20 years after treatment with fused boron rods and Boracol 40. Dark blue represents levels below the threshold for protection against fungal attack, while lighter blue, green and orange colors represent increasing boron concentrations in the wood. Charts are extrapolated from individual boron analyses at assay locations described in Table I-4.

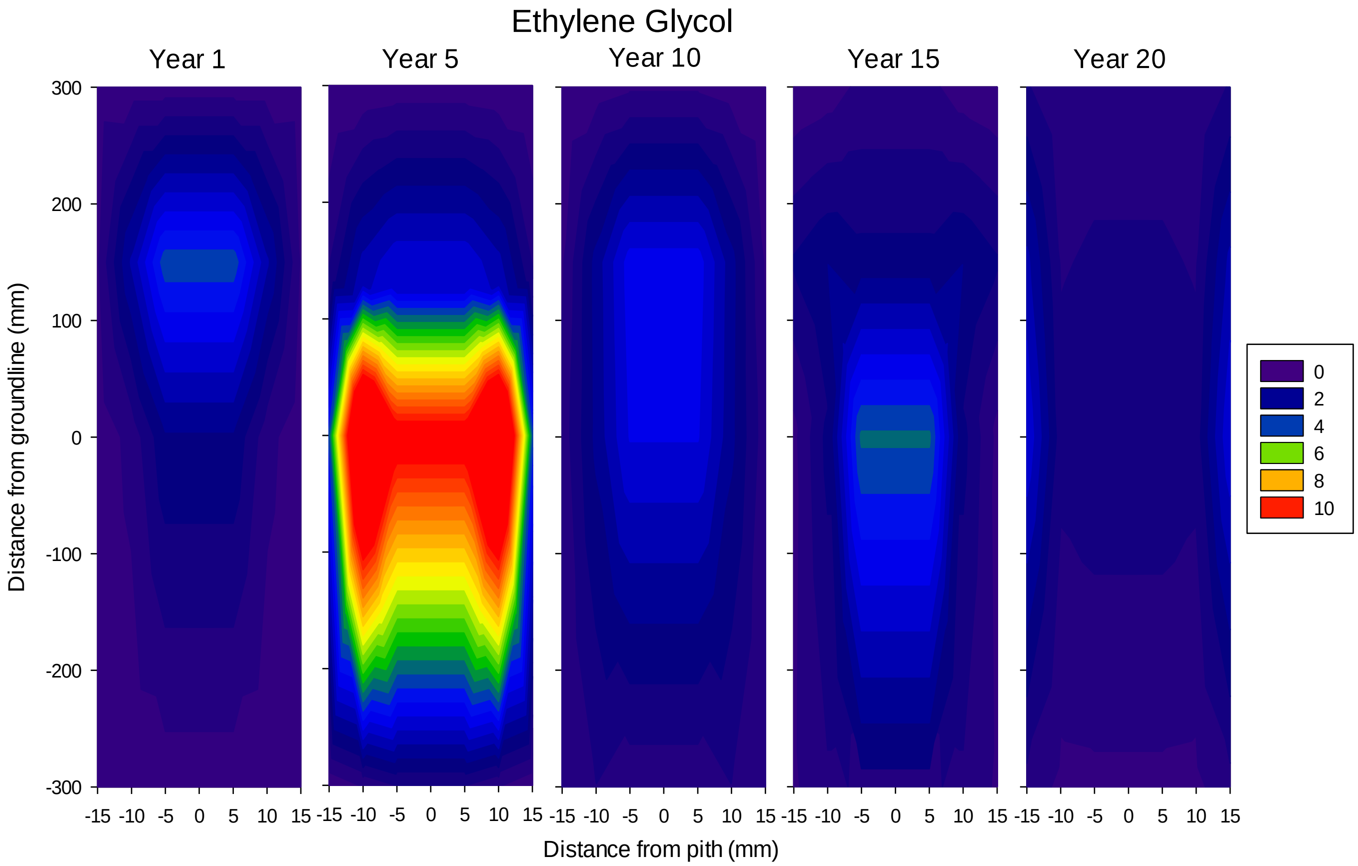


Figure I-16. Boron distribution in Douglas-fir poles 1 to 20 years after treatment with fused boron rods and glycol. Dark blue represents levels below the threshold for protection against fungal attack, while lighter blue, green and orange colors represent increasing boron concentrations in the wood. Charts are extrapolated from individual boron analyses at assay locations described in Table I-4.

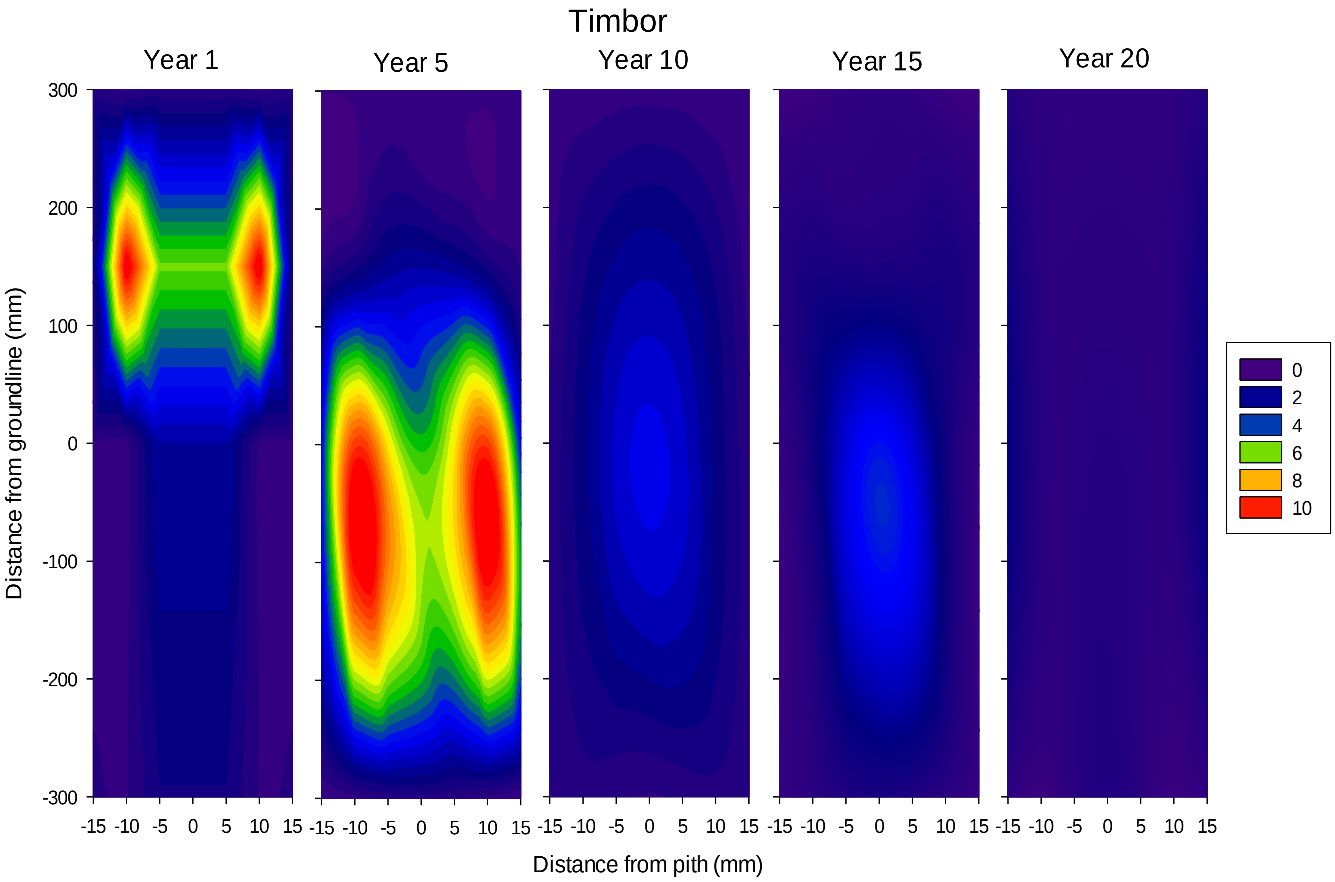


Figure I-17. Boron distribution in Douglas-fir poles 1 to 20 years after treatment with fused boron rods and Timbor solution. Dark blue represents levels below the threshold for protection against fungal attack, while lighter blue, green and orange colors represent increasing boron concentrations in the wood. Charts are extrapolated from individual boron analyses at assay locations described in Table I-4.

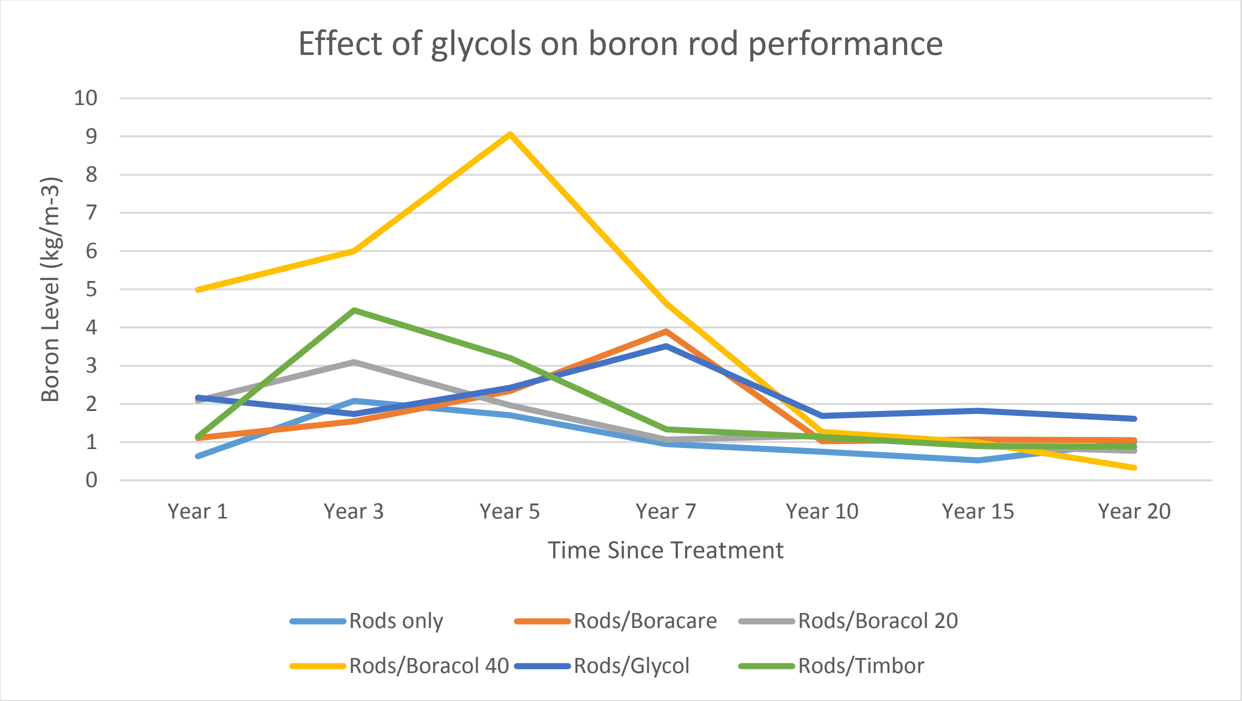


Figure I-18. Average boron levels at groundline in Douglas-fir poles 1 to 20 years after treatment with boron rods alone or in combination with various supplemental treatments.

2. Performance of Copper Amended Fused Boron Rods

Date Established:	November 2001
Location:	Peavy Arboretum, Corvallis, OR
Pole Species, Treatment, Size	Douglas-fir penta and 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 penta-treated Douglas-fir poles beginning at the groundline and 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, 7, 9 and 11 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 A65, the Azomethine-H assay (AWPA, 2012).   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).

This test was not sampled this year.

3. Diffusion of Boron Through Preservative Treated Wood

In previous reports, we have examined the movement of remedial treatments through poles. Last year, we reported on efforts to determine a mass balance for the amount of remedial treatment applied vs the amounts found within the wood. This first attempt was made with boron rods and it suggested that large amounts of boron were unaccounted for. We then examined boron levels in the belowground portion of poles receiving boron rods, but this still did not account for the levels of boron recovered. One further possibility is that the boron is diffusing through the wood into the preservative treated shell and out of the pole into the surrounding soil. Soil analyses do not show elevated boron levels around the poles, but the overall amount of boron moving into the soil is likely to be substantially diluted. While boron diffusion through wood has been well studied, there are no data on the ability of this compound to diffuse through a preservative oil treated shell. As a further step in this process of determining how these treatments move through and out of wood, we are examining the ability of boron to move through a preservative treated shell.

Douglas-fir lumber was used to create 25 mm diameter discs oriented so that the wide surface presented either a radial or tangential face. These discs were conditioned to a stable moisture content at 23°C and 65% relative humidity before being pressure treated to a target retention of 112 kg/m^3 with biodiesel oil.

Non-treated and oil treated discs were then inserted in a diffusion apparatus constructed using 100 mm diameter PVC piping with one chamber on either side of the disk. The disc was held in place using a threaded connector that effectively sealed each chamber so that any movement would have to occur through the wood. One chamber contained a 4% boric acid equivalent (bae) solution, while the other contained distilled water. Each chamber had a sampling port that allowed for solution to be removed for analysis of boron concentration (Figure I -19).

A sample was placed into the holder and the appropriate solutions were added to each side of the system. The assembly was placed on its side and maintained at room temperature (21 to 24°C). At intervals, 2 ml of solution sample was removed from each side of the system. These solutions were tested for boron concentration and a similar amount of either 4% bae solution or distilled water was added into the respective chambers so that the chambers remained full. The system was monitored until boron concentrations in the distilled water or receiving side stabilized.

Figure I-19. Photograph of five of the diffusion apparatus used to assess boron movement through non-treated or diesel oil treated Douglas-fir lumber. A wood sample is resting on the fourth chamber to provide a measure of scale.

The boron diffusion tests have only recently begun. Boron levels in non-treated samples increased slowly over the first 4 days of exposure and then rapidly increased. Concentrations in the receiving side reached 140 ppm in one non-treated sample exposed for 22 days, while concentrations in the receiving side of the other sample tested had reached almost 120 ppm after 10 days (Figure I-20). The initial lag in these samples was likely due to the time required for sample wetting. The samples were installed after conditioning to 12% moisture content. This allowed us to obtain a tight seal to avoid leakage, but also meant that the wood had become wet to the point where free water was present across the entire radial pathway before flow could occur. Once this occurred, boron diffused freely across the sample and concentrations increased.

Boron concentrations on the receiving end of samples containing radially oriented samples treated with biodiesel also showed little change in boron concentration for the first 4 days, but then boron levels slowly increased. Boron levels changed much more slowly with the biodiesel treated samples and were only 15% of those found with the non-treated samples at the same time point. These results indicate that the treatment presents a barrier that slows boron movement. In the field, this would translate into a system that would limit boron loss. Previous studies of railroad ties that were dipped in boron prior to air-seasoning and creosote over-treatment have shown that creosote helps retain boron in the tie interior for decades after treatment even when the ties are installed in track. Our test site is far wetter than the conditions to which a tie would be exposed in a track on well-drained ballast, but the diffusion tests suggest that boron losses are still slowed by this treated barrier, even when the samples are continuously exposed to liquid water. We will continue to expose samples in this apparatus over the next few months and will then use these data to determine how rapidly boron can be lost through the treated shell of a pole belowground. These data will, hopefully, help explain the results obtained from sampling the belowground region in boron rod-treated poles in the large scale internal remedial treatment test.

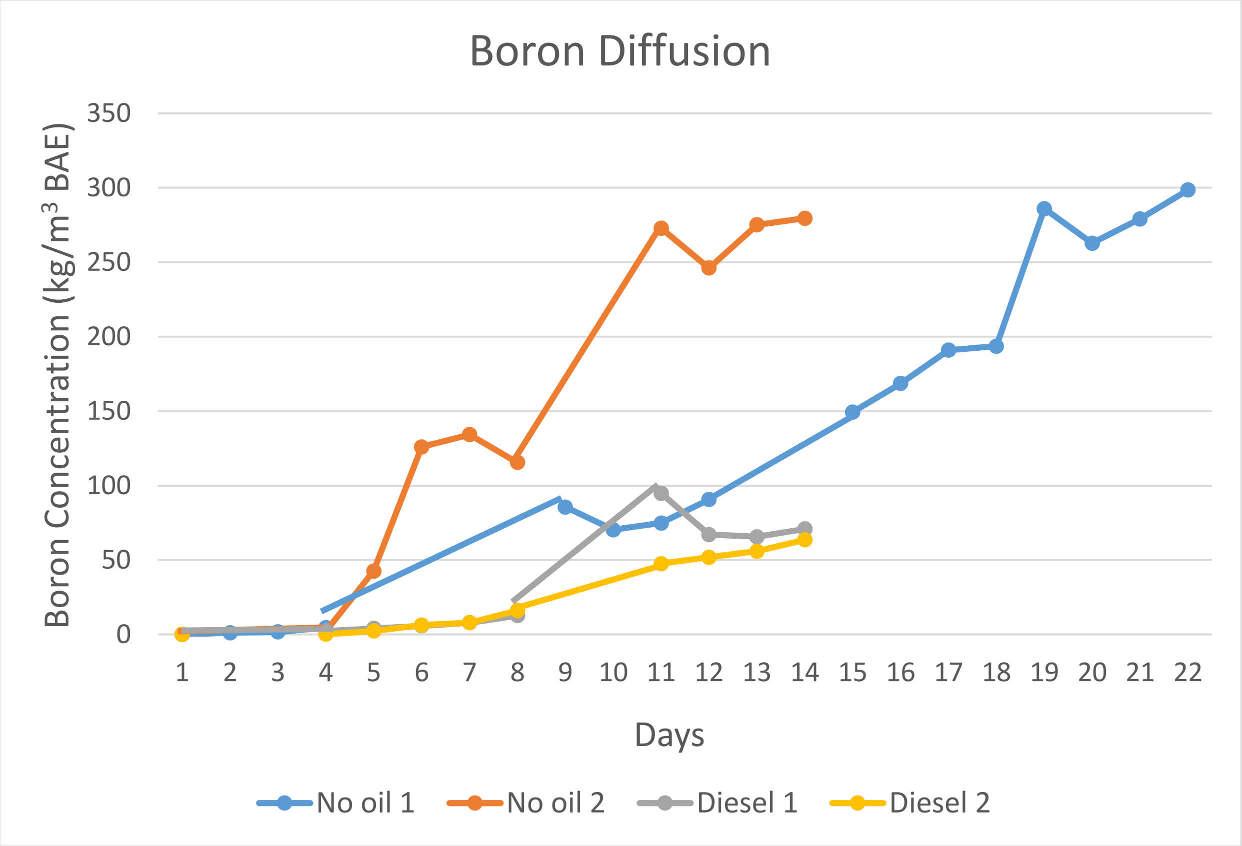


Figure I-20. Changes in boron concentration over time in the receiving side of the diffusion apparatus with non-treated or biodiesel-treated samples oriented with flow in the radial direction.

C. Tests Including Both Fumigants and Diffusibles

1. 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 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-5).

Table I-5. Internal remedial treatments evaluated on Douglas-fir poles at the Peavy Arboretum test site.

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

Penta-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 naphthenate (2% Cu) 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. The addition of copper naphthenate at concentrations higher than 1% is a violation of the product label and not allowed for commercial applications. No attempt was made to quantify the amount of copper naphthenate added to each treatment hole.

Chemical movement in the poles was assessed 18, 30, 42, 54 and 89 months after treatment by removing increment cores from three equidistant sites beginning 150 mm belowground, then 0, 300, 450 and 600 mm above groundline. An additional height of 900 mm above groundline was sampled for fumigant treated poles. The outer, preservative-treated shell was removed, and then the outer and inner 25 mm of each core was retained for chemical analysis using treatment appropriate methodology. The fumigants were analyzed by gas chromatography. Chloropicrin was detected using an electron capture detector while 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. Fluoride based systems were analyzed using neutron activation analysis.

Chemical levels in most poles were elevated 18 months after treatment and then gradually declined 89 months after treatment (Table I-6). Fumigant levels tended to be highest toward the center of the poles at a given height, reflecting the tendency for the sloping holes to direct chemical toward the center. Chemical levels were also highest at or below groundline and then typically declined with distance upward. This is also consistent with the application of the chemicals near groundline. Based upon previous field and laboratory studies, we have used a level of 20 ug of active/oven dried g of wood as a protective threshold for fumigants. This level is based upon extensive chemical analysis of cores removed from poles coupled with culturing of adjacent wood for the presence of decay fungi. Although the properties of the two primary active ingredients in all currently registered fumigants differ dramatically, the threshold for both chloropicrin and methylisothiocyanate (MITC) is the same.

Wood samples removed from the sodium n-methyldithiocarbamate based (NaMDC) treatments (Pol-Fume, SMDC-Fume, and WoodFume) contained MITC levels that were

Table I-6. Residual MITC levels in Douglas-fir poles 18 to 78 months after application of selected remedial treatments.[a]

Treatment	Cu Naph	months after treatment	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)
		42	11 (16)	5 (8)	8 (13)	4 (6)	5 (8)	4 (7)
		54	1 (1)	0 (1)	6 (13)	1 (2)	1 (1)	1 (1)
		78	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)
		42	**270** (297)	**165** (146)	**299** (281)	**196** (176)	**181** (212)	**121** (69)
		54	**102** (86)	**63** (45)	**472** (662)	**76** (74)	**123** (116)	**57** (36)
		78	**139** (126)	**55** (35)	**279** (237)	**62** (57)	**100** (65)	**35** (19)
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)
		42	**315** (198)	**171** (145)	**691** (1128)	**176** (129)	**253** (139)	**118** (74)
		54	**233** (256)	**107** (104)	**413** (564)	**107** (95)	**201** (311)	**66** (50)
		78	**113** (62)	**66** (64)	**238** (192)	**61** (77)	**120** (67)	**46** (39)
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)
		42	**256** (199)	**152** (171)	**243** (150)	**143** (117)	**329** (536)	**87** (43)
		54	**116** (122)	**60** (59)	**134** (131)	**55** (32)	**158** (209)	**54** (44)
		78	**185** (198)	**48** (36)	**146** (104)	**47** (33)	**98** (61)	**41** (39)
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)
		42	**1210** (1243)	**712** (1569)	**794** (617)	**334** (187)	**491** (311)	**246** (136)
		54	**612** (1472)	**155** (115)	**180** (123)	**150** (155)	**115** (83)	**78** (61)
		78	**66** (75)	**20** (18)	**37** (35)	20 (23)	18 (21)	9 (10)
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)
		42	**38** (28)	**21** (14)	**27** (17)	**24** (21)	**34** (24)	16 (7)
		54	14 (20)	8 (12)	18 (22)	11 (18)	8 (15)	3 (1)
		78	1 (2)	0 (0)	1 (2)	0 (0)	0 (1)	0 (0)
SMDC-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)
		42	**39** (28)	20 (9)	**36** (21)	**20** (10)	**25** (8)	14 (3)
		54	11 (8)	6 (6)	11 (13)	4 (3)	10 (18)	5 (4)
		78	0 (1)	0 (1)	0 (1)	0 (0)	0 (0)	0 (0)
Super-Fume 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)
		42	**132** (150)	**72** (60)	**157** (244)	**50** (38)	**68** (23)	**39** (26)
		54	**120** (211)	**63** (84)	**61** (44)	**36** (18)	**43** (20)	**42** (32)
		78	**87** (100)	**33** (33)	**57** (46)	**25** (40)	**53** (59)	18 (25)
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)
		42	**246** (267)	**206** (163)	**283** (236)	**194** (187)	**246** (152)	**166** (105)
		54	**158** (116)	**131** (126)	**179** (81)	**97** (59)	**119** (89)	**113** (150)
		78	**91** (62)	**59** (57)	**163** (131)	**50** (38)	**102** (102)	**47** (42)
WoodFume	-	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)
		42	**53** (24)	20 (22)	**33** (21)	17 (19)	**24** (21)	15 (16)
		54	16 (13)	6 (5)	15 (11)	5 (5)	9 (8)	8 (9)
		78	2 (7)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)
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)
		42	**6488** (6654)	**2904** (3671)	**4606** (3245)	**1257** (2437)	**3438** (2753)	**4059** (5007)
		54	**2317** (1768)	**267** (413)	**1808** (1503)	**331** (375)	**1023** (1088)	**226** (295)
		78						

[a] Numbers in parentheses represent one standard deviation around the mean of 15 replicates. Numbers in bold type are above the toxic threshold.

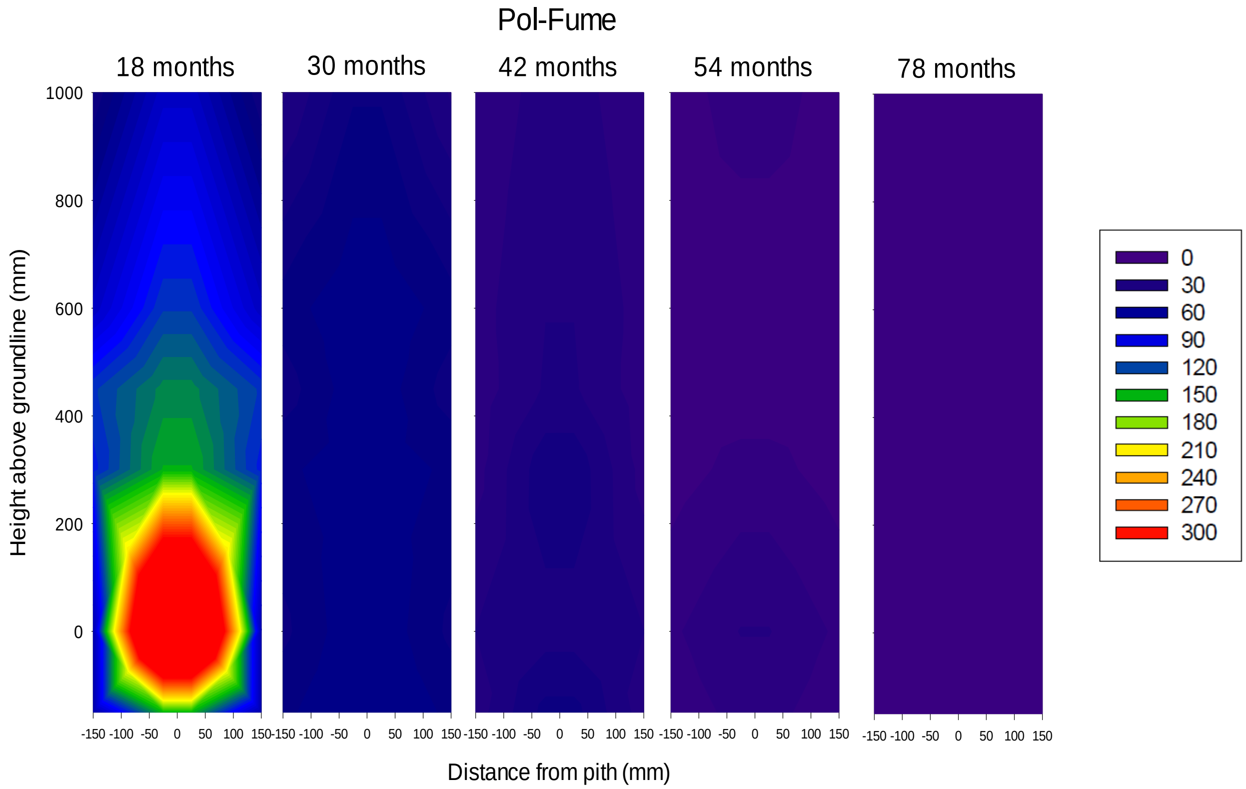
Table I-6 cont. Residual MITC levels in Douglas-fir poles 18 to 78 months after application of selected remedial treatments.[a]

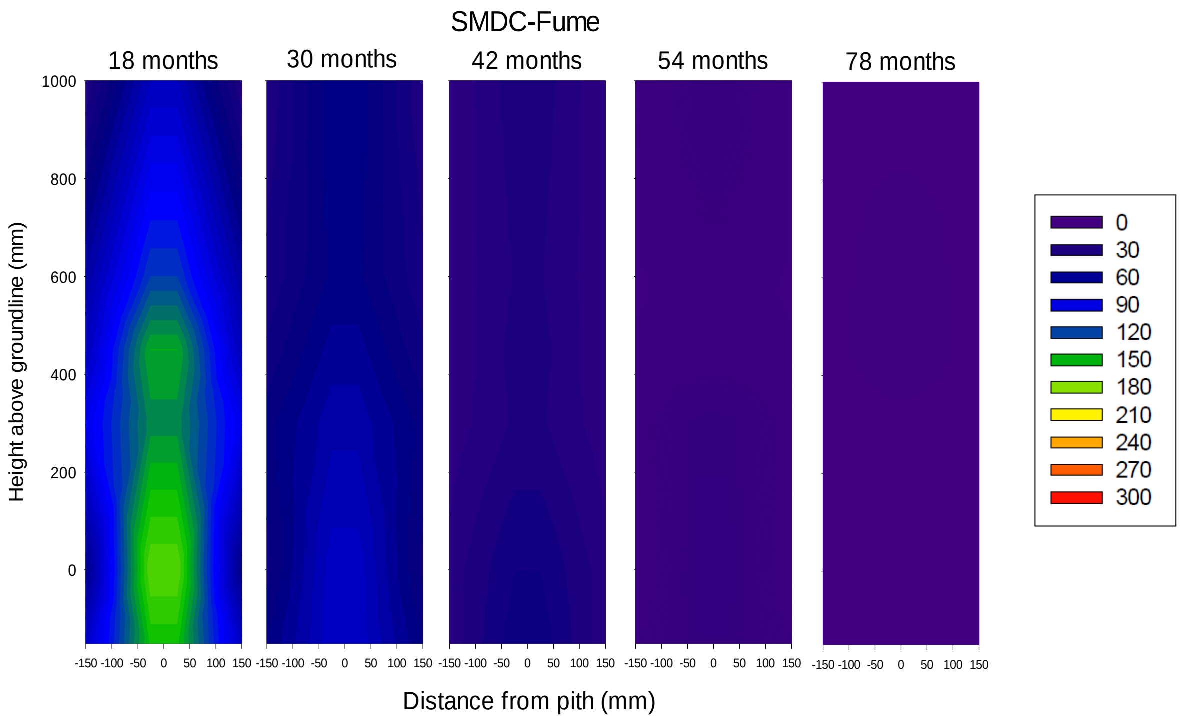
Treatment	Cu Naph	months after treatment	Height above groundline (mm)					
			450		600		1000	
			inner	outer	inner	outer	inner	outer
Control	-	18	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
		30	0 (0)	0 (0)	0 (0)	0 (0)	1 (4)	0 (0)
		42	8 (13)	5 (8)	5 (8)	5 (7)	7 (10)	5 (7)
		54	3 (5)	2 (4)	1 (1)	1 (1)	1 (1)	0 (1)
		78	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	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)
		42	**128** (66)	**125** (108)	**114** (58)	**106** (103)	**99** (63)	**96** (144)
		54	**90** (70)	**49** (26)	**87** (67)	**51** (39)	**65** (48)	**42** (56)
		78	**54** (28)	**27** (15)	**34** (21)	**25** (28)	**31** (23)	10 (8)
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)
		42	**170** (53)	**118** (98)	**138** (79)	**85** (71)	**77** (32)	**35** (21)
		54	**105** (96)	**59** (47)	**83** (58)	**80** (82)	**49** (39)	**89** (99)
		78	**77** (51)	**42** (58)	**51** (31)	**24** (24)	**34** (11)	7 (9)
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)
		42	**111** (52)	**88** (73)	**76** (38)	**56** (44)	**46** (26)	**36** (29)
		54	**60** (32)	**67** (64)	**68** (54)	**64** (88)	**60** (53)	**68** (97)
		78	**46** (33)	**26** (31)	**21** (20)	17 (18)	16 (12)	3 (5)
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)
		42	**389** (281)	**184** (107)	**350** (284)	**189** (106)	**369** (250)	**165** (117)
		54	**107** (70)	**77** (50)	**85** (41)	**68** (51)	**73** (50)	**98** (104)
		78	13 (13)	7 (7)	14 (13)	5 (7)	15 (14)	9 (11)
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)
		42	**25** (18)	15 (7)	**24** (17)	16 (8)	**20** (9)	14 (7)
		54	3 (2)	3 (2)	3 (1)	4 (2)	8 (13)	4 (2)
		78	0 (0)	0 (0)	1 (3)	0 (0)	0 (0)	0 (0)
SMDC-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)
		42	**26** (12)	13 (4)	**24** (10)	13 (5)	**27** (15)	13 (13)
		54	4 (2)	4 (2)	5 (3)	3 (2)	9 (19)	3 (3)
		78	1 (2)	0 (1)	1 (3)	0 (0)	0 (0)	0 (0)
Super-Fume 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)
		42	**53** (33)	**40** (32)	**44** (21)	**23** (10)	**24** (13)	11 (8)
		54	**30** (12)	**26** (21)	**37** (29)	**40** (67)	**27** (31)	**33** (54)
		78	**28** (26)	13 (18)	16 (19)	9 (14)	13 (19)	4 (7)
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)
		42	**150** (63)	**125** (81)	**143** (57)	**175** (187)	**78** (47)	**82** (80)
		54	**69** (36)	**211** (530)	**55** (24)	**52** (31)	**39** (19)	**30** (29)
		78	**44** (23)	**42** (37)	**37** (20)	**30** (40)	**20** (15)	10 (10)
WoodFume	-	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)
		42	20 (15)	14 (16)	**25** (24)	13 (13)	**26** (17)	12 (12)
		54	6 (5)	8 (13)	5 (5)	4 (3)	6 (4)	4 (4)
		78	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
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)
		42	**1546** (1472)	**1363** (1131)	**1720** (1489)	**678** (837)	**1639** (1990)	**310** (560)
		54	**867** (931)	**276** (376)	**984** (1040)	**381** (621)	**387** (509)	**604** (1219)
		78						

[a] Numbers in parentheses represent one standard deviation around the mean of 15 replicates. Numbers in bold type are above the toxic threshold.

3 to 5 times the 20 ug of MITC/oven dried g of wood threshold 18 months after treatment. These levels then declined steadily over the next 24 months but were still over this threshold at most sampling locations 42 months after treatment. MITC levels have continued to decline and are all uniformly below the threshold level 54 months after treatment (Figure I-21). MITC is virtually non-detectable in these same poles after 78 months. These findings are consistent with previous tests of this chemical. These formulations contain 33 % NaMDC in water. The NaMDC decomposes in the presence of organic matter (e.g. wood) to produce a range of sulfur containing compounds including carbon disulfide, carbonyl sulfide, and, most importantly, MITC.

The theoretical decomposition rate of NaMDC to MITC is 40% of the original 32.1%, but numerous tests suggest that the rate in wood is actually nearer to 20% of the original treatment. As a result, NaMDC based treatments should produce much lower levels of chemical in the wood and their retention should be relatively short. Some users of these treatments have raised concerns about the potential for this shorter protective period to allow decay fungi to re-colonize the poles and cause renewed damage before the next treatment cycle (which should be 10 years). However, there is evidence that decay fungi do not re-colonize the poles very quickly and, in some cases, they never reach the levels at which they were present prior to treatment. For this reason, there is a substantial time lag between loss of chemical protection and re-colonization that permits the use of this treatment.





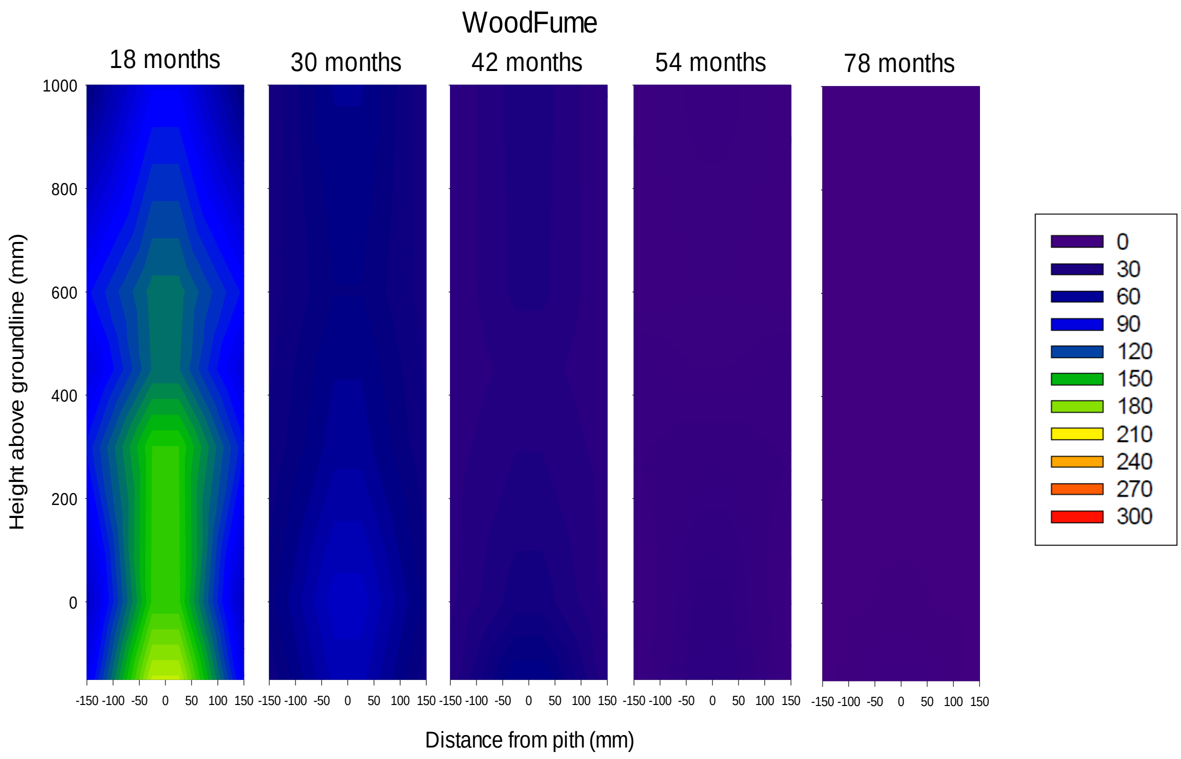


Figure I-21. Distribution of MITC in Douglas-fir pole sections 18 to 78 months after treatment with Pole Fume, SMDC Fume or Wood-Fume. Dark blue signifies little or no chemical while increasingly light blue to green or yellow signifies MITC levels above the threshold. Charts are extrapolated from individual MITC analyses at assay locations described in Table I-6.

MITC-FUME treated poles contained the highest levels of MITC of any treatment 18 months after treatment, with levels approaching 100 times the threshold 150 mm below groundline and 300 mm above that line. MITC levels have declined steadily since that time, but are still well above the threshold for protection against fungal attack (Figure I-22). For example, MITC levels in the inner zones of cores removed 150 mm below groundline average 612 ug/g of wood, over 30 times the threshold. MITC levels at other locations are somewhat lower, but are still three to nine times the threshold. MITC levels in poles 78 months after treatment had declined sharply from those at 54 months. While the levels were above the threshold at or below at groundline and 150 mm below that level, MITC levels above the ground were no longer protective. These results illustrate the excellent properties of this treatment and are consistent with the original field trials showing that protective levels remained in Douglas-fir poles 7 years after treatment. These results indicate that MITC-FUME would easily provide protection against renewed fungal attack for 10 years based upon the time required for fungi to begin reinvading fumigant treated poles.

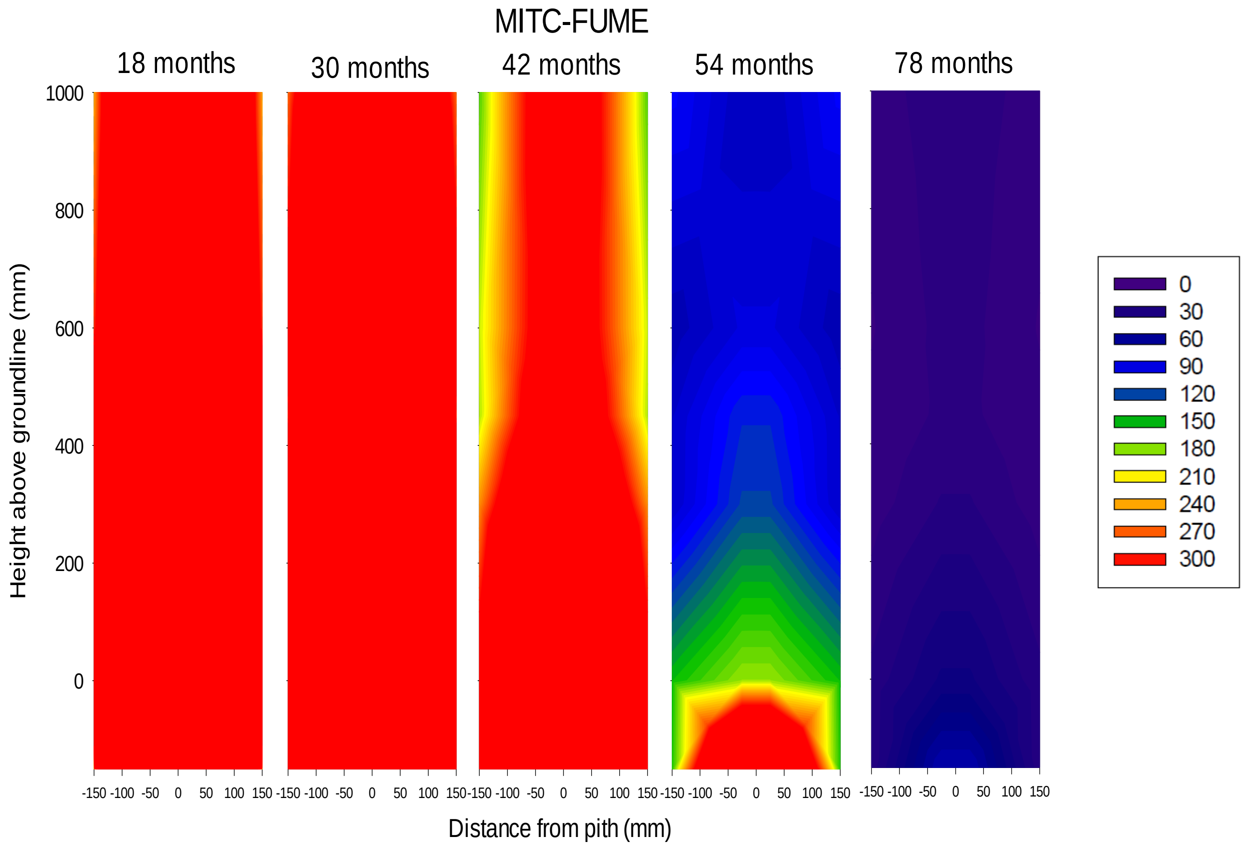
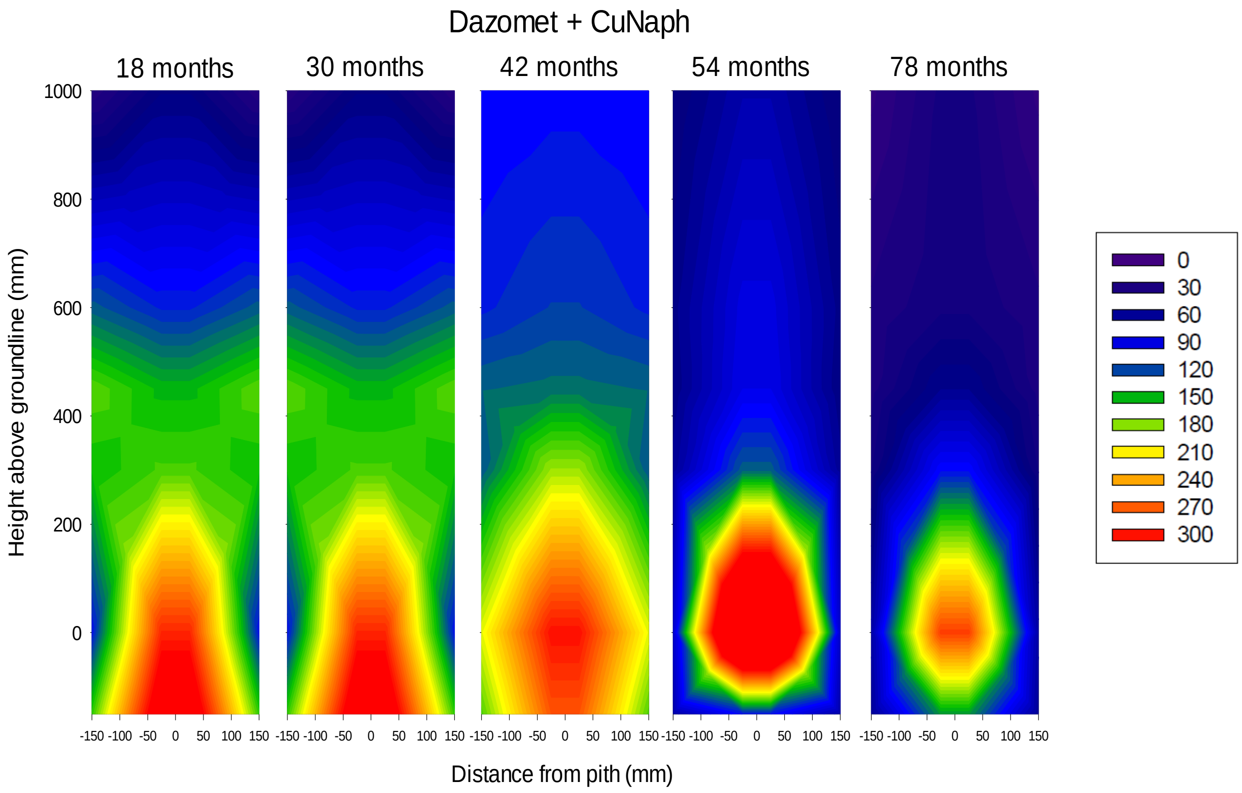


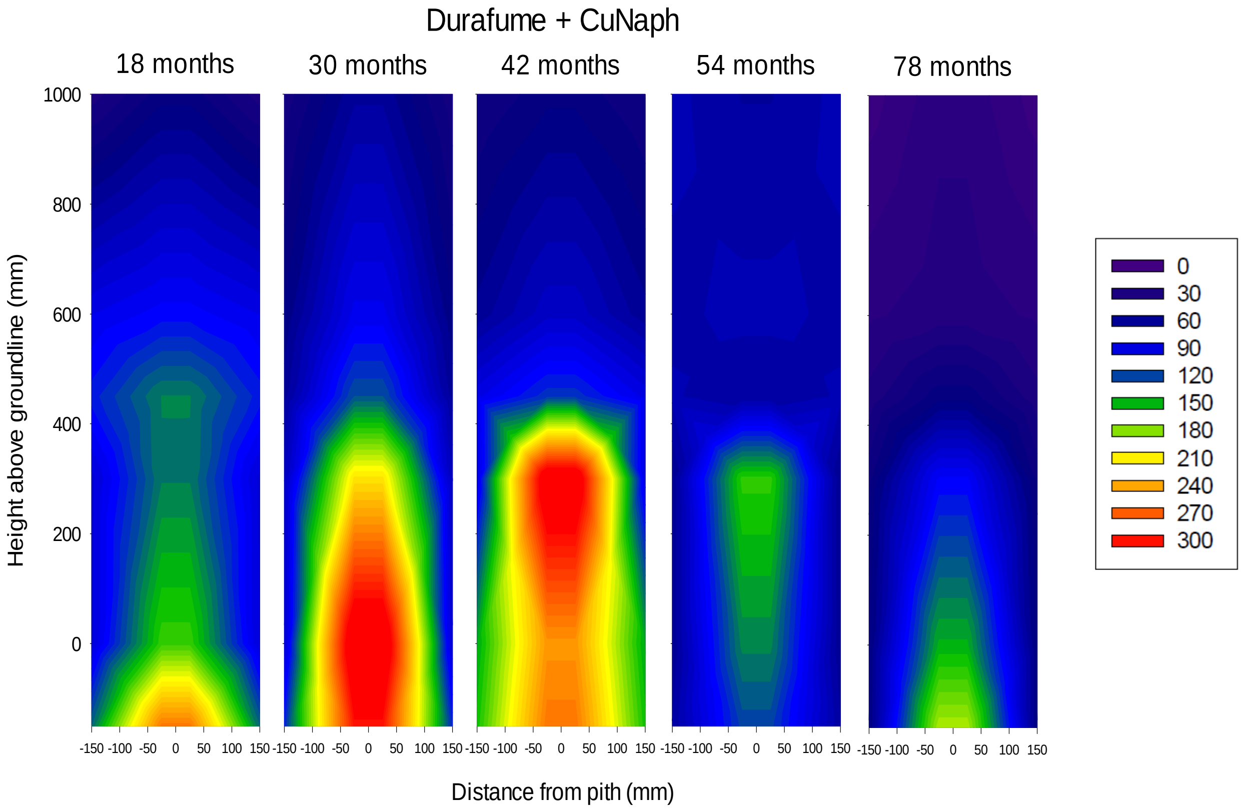
Figure I-22. Distribution of MITC in Douglas-fir pole sections 18 to 78 months after treatment with MITC-Fume. Dark blue signifies little or no chemical while increasingly light blue to green or yellow signifies MITC levels above the threshold. Charts are extrapolated from individual MITC analyses at assay locations described in Table I-6.

Dazomet is an increasingly common remedial treatment for poles. Like NaMDC, dazomet decomposes to produce a range of sulfur containing compounds. The most important of these decomposition products is MITC. Unlike NaMDC, dazomet is a powder, which sharply reduces the risk of worker contact or spilling. Originally, dazomet decomposition in wood was viewed as too slow for this chemical to be of use as a remedial pole treatment, but extensive research indicated that the process could be accelerated by adding copper compounds to the powder at the time of application to accelerate decomposition to MITC. At present, dazomet is commonly applied with a small dosage of oil-borne copper naphthenate.

Dazomet was applied to the test poles as a powder, in rod form or in tubes. All holes received copper naphthenate at the time of treatment to accelerate decomposition. MITC levels 150 mm below groundline in poles receiving dazomet powder (dazomet, DuraFume, or UltraFume) 18 months earlier ranged from 8-11 times the threshold in UltraFume treated poles to 7 to 16 times threshold in the dazomet treated poles. In general, MITC levels were well over the threshold in all dazomet treatments although the levels 900 mm above groundline were sometimes below that level. MITC levels were all above the threshold 30 and 42 months after treatment, reflecting the ability of this treatment to continue to decompose to produce MITC over time. MITC levels 54 months after treatment were still above the threshold at all sampling locations, but the overall levels had declined by 30 to 50% over the 12 month interval (Figure I-23). MITC levels after 54 months were still 3 to 11 times above the minimum threshold, and, as in previous trials, we have observed periodic surges in MITC levels in dazomet-treated poles. We have attributed these increases to periods of elevated rainfall that increased the wood moisture content, thereby enhancing decomposition of residual dazomet in the treatment holes. It is impossible to predict whether this will occur during our testing, but MITC levels do remain more than sufficient to provide protection against fungal attack in all dazomet treatments. MITC levels 78 months after application of the three dazomet systems were still above the threshold from below groundline all the way up to 600 mm above the groundline. Overall levels were still continuing to decline but MITC concentrations remained 3 to 6 times the threshold at many locations. These results are also consistent with previous field trials and indicate this system will provide at least the 10 year protective period used by most utilities in their inspection and treatment cycles.

MITC levels in poles receiving either dazomet in rod form or in tubes (Super-Fume tubes) tended to be lower than levels found in poles receiving powdered treatments, but were still above the threshold at all sampling points below groundline and up to the 900 mm above groundline. Chemical levels near the surface at 900 mm were more variable than in the powdered treatments (Figure I-24). The rods and tubes both may restrict


Dazomet + CuNaph
18 months
30 months
42 months
54 months
78 months
Height above groundline (mm)
1000
800
600
400
200
0
-150 -100 -50 0 50 100 150
Distance from pith (mm)
0
30
60
90
120
150
180
210
240
270
300


Durafume + CuNaph
18 months
30 months
42 months
54 months
78 months
Height above groundline (mm)
1000
800
600
400
200
0
-150 -100 -50 0 50 100 150
Distance from pith (mm)
0
30
60
90
120
150
180
210
240
270
300

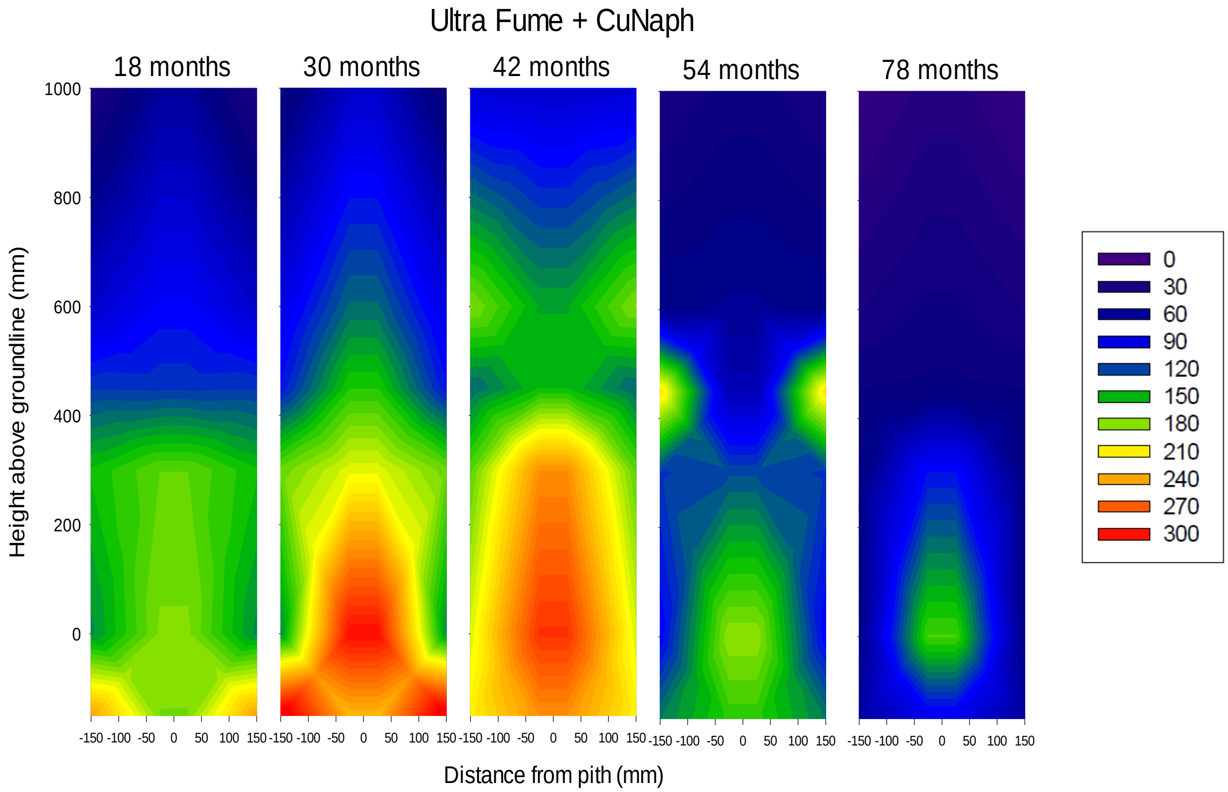


Figure I-23. Distribution of MITC in Douglas-fir pole sections 18 to 78 months after treatment with dazomet, DuraFume or UltraFume plus copper naphthenate. Dark blue signifies little or no chemical while increasingly light blue to green or yellow signifies MITC levels above the threshold. Charts are extrapolated from individual MITC analyses at assay locations described in Table I-6.

contact between the wood and the chemical, creating the potential for reduced decomposition. There were negligible differences in MITC levels between poles receiving powdered or rod dazomet. The tubes appeared to have a greater effect on MITC levels, with consistently lower MITC levels than the other dazomet based systems; however, levels remained 1.5 to 6 times the threshold at 54 months at all sampling locations. These results indicate that, while the tubes slow MITC release, this does not result in chemical levels below the threshold at 54 months. The results at 78 months indicated that MITC levels continued to decline in poles treated with either the rod or the tube system. MITC levels were still above the threshold up to 300 mm above the groundline, then declined below the threshold higher up the pole. As in previous inspections, MITC levels tended to be slightly lower in poles receiving tubes than rods. The dazomet rods appeared to produce MITC levels that were similar to those found with the powder. The results indicate that the dazomet rod or tube systems would provide protection in the typical 10 year inspection cycle.

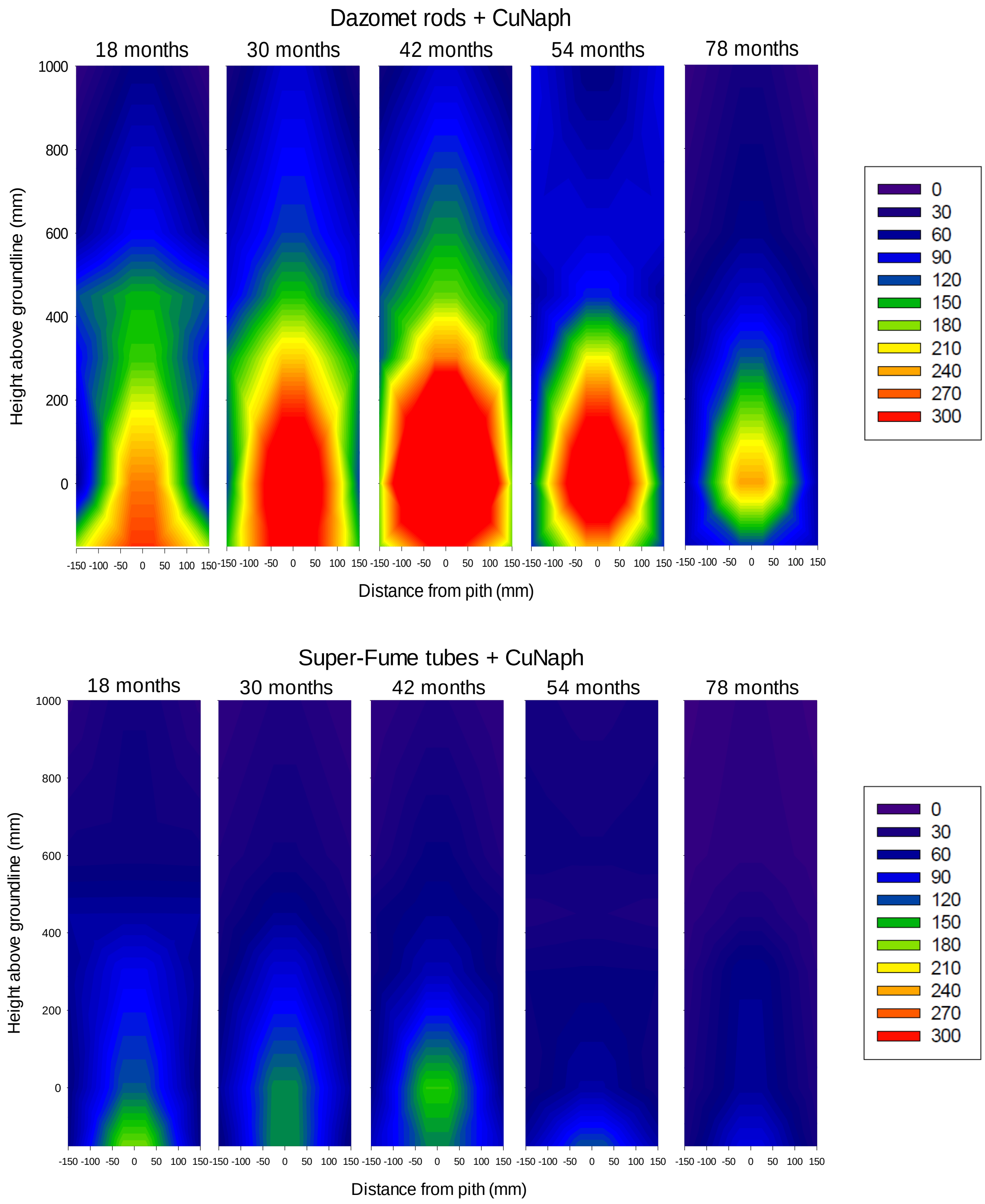


Figure I-24. Distribution of MITC in Douglas-fir pole sections 18 to 78 months after treatment with dazomet rods or Super-Fume tubes plus copper naphthenate. Dark blue signifies little or no chemical while increasingly light blue to green or yellow signifies MITC levels above the threshold. Charts are extrapolated from individual MITC analyses at assay locations described in Table I-6.

The results of all treatments have supported previous tests done on individual systems as they were developed. In general, the results show that metham sodium provides the shortest protective period, while MITC-FUME and the dazomet treatments provide longer term protection that is consistent with the typical pole retreatment cycle. This test will next be inspected at 120 months, which would be the typical time for retreatment.

Chloropicrin levels in the poles were more than 2000 times the 20 ug/oven dried g of wood threshold in the inner zone of poles belowground 18 months after treatment. Levels declined slightly 30 months after treatment, but remained extremely high. Chloropicrin levels appeared to increase in the wood at the 42 month evaluation, but a re-examination of the data revealed that the levels reported in the 2012 annual report were approximately double the actual value. The revised values continue to show a steady decline at the 42 month point, but chloropicrin levels remained 17 to 350 times the threshold. Chloropicrin retentions 54 months after treatment continue to decline, but were still 13 to 100 times the threshold (Figure I-25). Unlike MITC, chloropicrin has strong chemical interactions with wood which results in much longer residual times. We have found detectable chloropicrin in poles 20 years after treatment and the results in the current study are consistent with a long residual protective period for this fumigant. The chloropicrin analysis for the 78 month sample are still underway and will be reported in the next Annual Report.

The threshold for boron for protection against internal decay has been calculated at 0.5 kg/m^3 (Freitag and Morrell 2005). This value is based upon carefully controlled trials of wafers treated to specific levels with boron.

The boron levels in poles receiving either Impel rods or Pole Saver rods tended to be below the threshold 300 or more mm above the groundline, regardless of sampling time or core position (inner/outer) (Table 1-7). While boron is water diffusible, it has a limited ability to diffuse upward. Boron levels 150 mm below groundline and at groundline were above the threshold in the inner zone for both Impel Rod and Post Saver rod-treated poles 18 months after treatment, but below the threshold in the outer zone. The difference again reflects the tendency of the sloping treatment holes to direct chemical downward toward the center of the pole. Boron levels were above the threshold for both inner and outer zones 30 months after treatment with either rod system, but still below threshold in the outer zone 150 mm below groundline. Boron levels were all well above threshold both below and at groundline 42 and 54 months after treatment (Figure I-26). Boron levels in pole sections treated with either of the rod systems were still well above the threshold in the inner zones at or below groundline 78 months after treatment, but

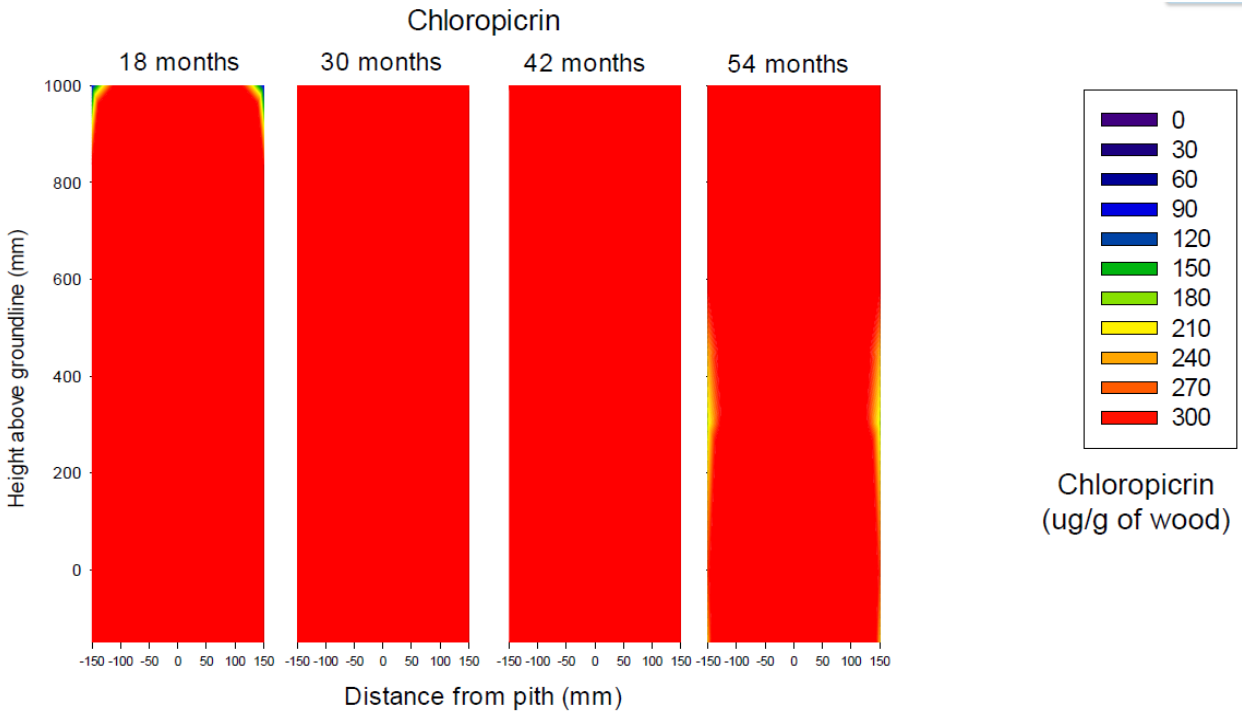
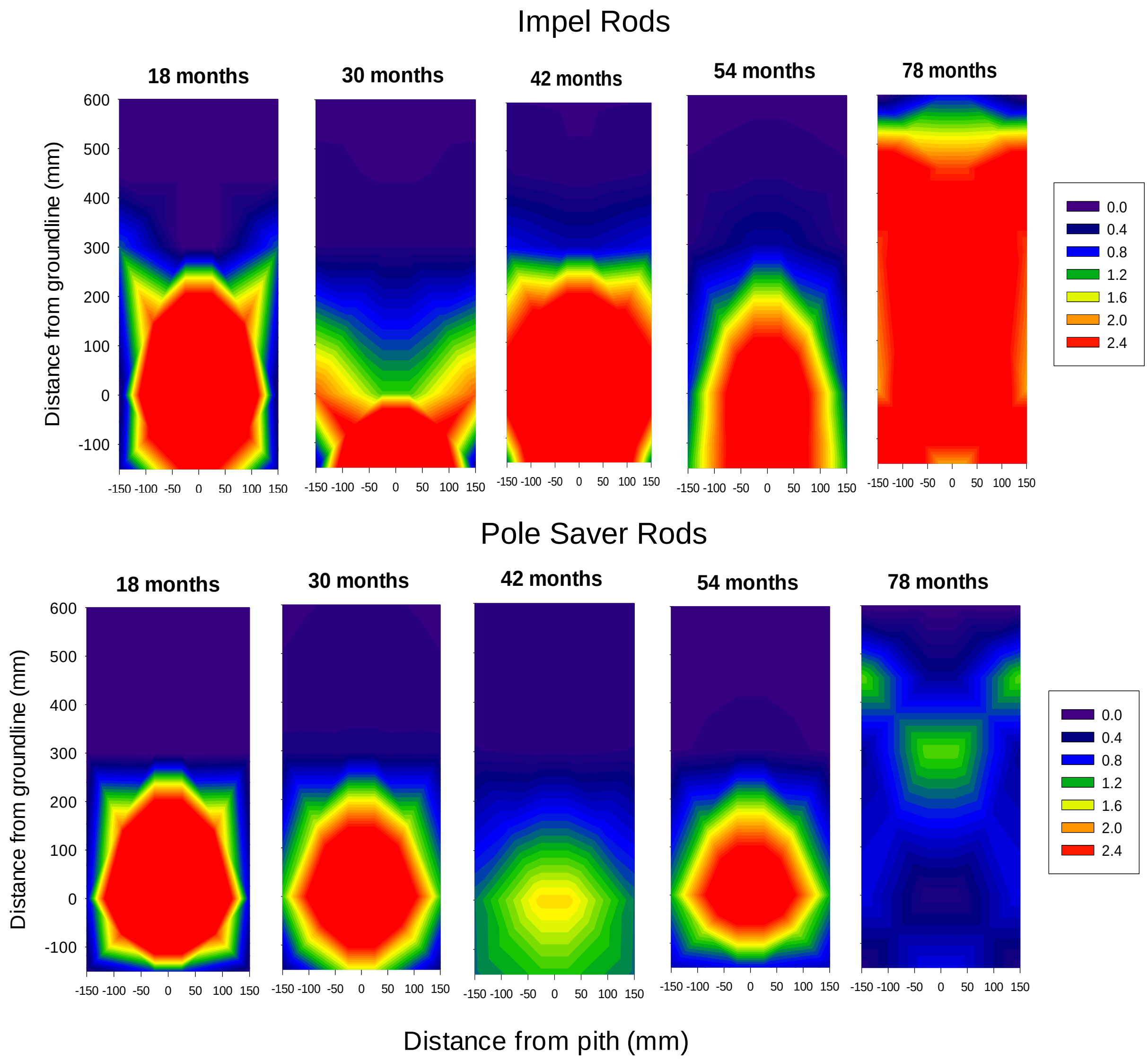


Figure I-25. Distribution of chloropicrin in Douglas-fir pole sections 18 to 54 months after treatment with TimberFume. Data from 78 months will be added in the final version of the 2015 report. Red indicates chloropicrin levels multiple times over the threshold. Charts are extrapolated from individual chloropicrin analyses at assay locations described in Table I-6.

had declined below that level in the outer zones of poles receiving the PolSaver rods. Boron was at the threshold level 300 mm above groundline at only one point in the inner zone of poles receiving Impel Rods. These results are consistent with previous tests showing that uniform boron movement requires several years. If these trends continue, we would expect to find elevated boron levels in the poles for 5 to 7 more years. Boron levels in Impel Rods and Post Saver rods appear to be similar near groundline while boron levels are higher in Impel Rod-treated poles in the inner zone belowground. An alternative approach to examining boron distribution would be to look at the inner zones at groundline or belowground over the test period (Figure I-27). The inner zone is likely to present a more stable environment for moisture that would facilitate boron movement over time. As we view these data, it is important to note that all levels in the inner zone are above the threshold 78 months after treatment, but we can begin to see distribution patterns. Boron levels belowground in the inner zones of poles treated with PolSaver rods remained low for the entire exposure period, while they were at very high levels early in the exposure period then declined over time at groundline. Soil moisture levels at this test site are high in winter which should facilitate boron loss from poles over time, especially belowground. Boron levels in poles treated with Impel rods rose between 18 and 30 months 150 mm below groundline, then steadily declined over time. However, boron levels were more than two times higher than those found in PolSaver poles. Boron levels at groundline in Impel rod treated poles tended to vary more widely over the test, but were more than twice those found in Pol Saver poles at the same locations. Impel rods represent a highly densified boron delivery system, while the PolSaver rods are less dense and therefore have less material to deliver. Our results closely follow those differences, although it is important to note that boron levels in poles treated with both systems are well over the protective level 78 months after treatment. The overall trends indicate boron-based systems are producing protective levels within the groundline zone, but diffusion above this zone is very limited.


Impel Rods

Pole Saver Rods

Figure I-26. Distribution of boron in Douglas-fir pole sections 18 to 78 months after treatment with Impel or PolSaver Rods. Dark blue signifies little or no chemical while increasingly light blue to green or yellow signifies boron levels above the threshold. Charts are extrapolated from individual boron analyses at assay locations described in Table I-7.

Table I-7. Boron levels at various distances above and below the groundline in Douglas-fir poles 18 to 78 months after application of Impel or Pole Saver rods.

Treatment	Time (Mo)	Residual Boron Content (kg/m^3 B$_2$O$_3$)[a]									
		150 mm below GL		Groundline		+300 mm		+450 mm		+600 mm	
		inner	outer	inner	outer	inner	outer	inner	outer	inner	outer
None	18	0	0	0	0	0	0	0	0	0	0
	30	0.07	0.07	.07	0.06	0.08	0.08	0.10	0.06	0.08	0.07
	42	0.18	0.19	0.21	0.18	0.21	0.20	0.19	0.21	0.21	0.08
	54	0	0.04	0.03	0.01	0	0	0	0.01	0	0.03
	78	0	0	0	0	0	0	0	0	0	0
Impel Rods	18	**2.59**	0.37	**7.68**	0.16	0.02	**0.97**	0.02	0.02	0.02	0
	30	**6.67**	0.39	**1.30**	**2.14**	0.16	0.15	0.07	0.10	0.07	0.05
	42	**5.49**	**0.98**	**6.30**	**3.09**	**0.53**	**0.72**	0.09	0.17	0.07	0.08
	54	**3.34**	**1.12**	**3.57**	**0.84**	0.47	0.13	0.12	0.09	0.06	0.04
	78	**1.91**	**3.95**	**3.16**	**2.25**	**0.76**	0	0.06	0	0	0
Pol Saver	18	**0.84**	0.14	**7.50**	**0.61**	0	0.04	0.02	0.06	0.02	0.03
	30	**1.54**	0.31	**4.44**	**1.28**	0.18	0.18	0.12	0.09	0.09	0.07
	42	**1.24**	**1.02**	**1.73**	**1.03**	0.13	0.16	0.11	0.11	0.13	0.11
	54	**0.74**	**0.53**	**3.56**	**1.17**	0.15	0.05	0.06	0	0.05	0
	78	**0.72**	0.18	**1.34**	0.44	0.01	0	0.08	0	0	0.07

[a] Values represent means of 3 samples per height from each of 5 poles per treatment. Figures in bold are above the threshold for protection against internal fungal attack. Inner represents the innermost 25 mm of the core, while outer represents the 25 mm inside the preservative treated zone.

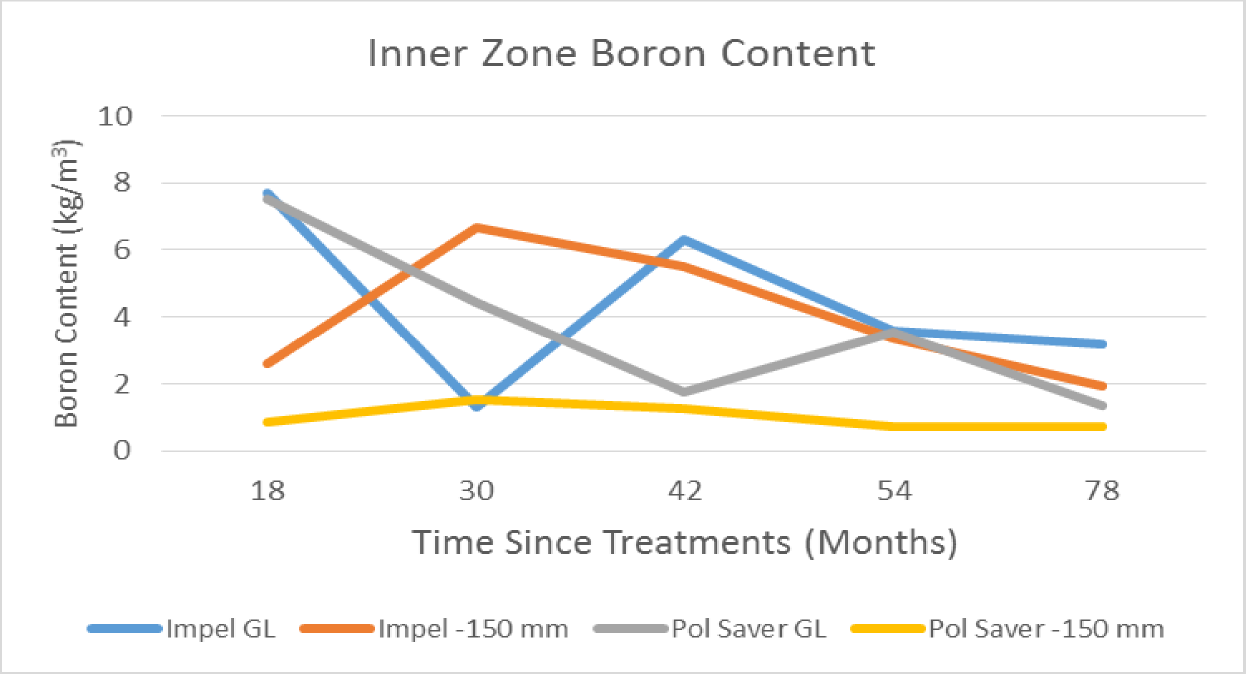


Figure I-27. Boron content in the inner assay zone at or below groundline in Douglas-fir poles 18 to 78 months after treatment with Impel or PolSaver rods.

In the past, we often have not included fungal colonization rates in our discussion; however, we have completed these analyses on the 78 month sample (Table I-8). Also included are the previous fungal colonization data. The incidence of decay fungi were fairly high in the non-remedially treated control poles especially at or below groundline. Isolation levels were also somewhat higher in poles treated with the metham sodium systems (Pole Fume, SMDS Fume or Wood -Fume), reflecting the relatively short term protection afforded by this fumigant. Isolations were highest in poles treated with Pole Fume in the zone 300 mm to 1 m above groundline. This zone would be consistent with the area where the fumigant was likely to dissipate most quickly after treatment. Decay fungi were also isolated sporadically from poles treated with Super-Fume tubes or Dura-Fume, but the levels were low and showed no evidence of a pattern of colonization.

Decay fungi were also isolated from cores removed from Impel rod, Post-Saver rod or FluRod treated poles; however, the levels were extremely low with FluRod and Post Saver rods. Decay fungi were present at higher levels beginning 300 mm above groundline in Impel rod poles. Water diffusible systems tend to remain relatively close to the point of application and should not move upward for appreciable distances. Isolation of decay fungi above the application point is consistent with these tendencies and illustrates the needs to reconsider application patterns for water diffusible treatments.

Table I-8. Degree of fungal colonization (%) in Douglas-fir poles 18 to 78 months after internal remedial treatment with water diffusible rods or fumigants. [a]

Treatment	Cu Naph	Months After Treatment	Height above groundline (mm)						Pole
			-150	0	300	450	600	1000	
Fumigant Control	-	18	33 ^{17}	17 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	8 ^{3}
		30	33 ^{50}	33 ^{50}	17 ^{17}	0 ^{17}	0 ^{17}	0 ^{0}	14 ^{25}
		42	50 ^{50}	50 ^{50}	50 ^{50}	33 ^{50}	33 ^{17}	0 ^{50}	36 ^{44}
		54	22 ^{11}	33 ^{0}	11 ^{0}	33 ^{0}	33 ^{0}	22 ^{0}	26 ^{2}
		78	33 ^{56}	56 ^{56}	56 ^{33}	56 ^{11}	44 ^{22}	22 ^{44}	44 ^{37}
Dazomet	+	18	0 ^{7}	0 ^{0}	7 ^{13}	0 ^{7}	0 ^{7}	0 ^{7}	1 ^{7}
		30	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{0}	0 ^{1}
		42	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
		54	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
		78	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{7}	0 ^{2}
Dazomet rods	+	18	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{7}	0 ^{2}
		30	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
		42	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{1}
		54	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{1}
		78	0 ^{7}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{1}
DuraFume	+	18	0 ^{7}	0 ^{7}	0 ^{0}	0 ^{0}	0 ^{7}	0 ^{7}	0 ^{4}
		30	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
		42	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{0}	0 ^{2}
		54	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
		78	0 ^{0}	0 ^{7}	0 ^{7}	7 ^{7}	0 ^{0}	0 ^{0}	1 ^{3}
MITC-FUME	-	18	0 ^{0}	0 ^{13}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{2}
		30	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
		42	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{1}
		54	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
		78	0 ^{7}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{1}
Pol Fume	-	18	0 ^{0}	0 ^{7}	0 ^{7}	0 ^{13}	0 ^{0}	0 ^{20}	0 ^{8}
		30	0 ^{0}	0 ^{13}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{7}	0 ^{3}
		42	7 ^{7}	0 ^{0}	7 ^{7}	0 ^{7}	7 ^{7}	0 ^{0}	3 ^{4}
		54	0 ^{7}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{1}
		78	0 ^{60}	0 ^{87}	27 ^{27}	40 ^{27}	27 ^{7}	0 ^{40}	16 ^{41}
SMDS-Fume	-	18	0 ^{0}	0 ^{13}	0 ^{7}	0 ^{7}	0 ^{13}	0 ^{7}	0 ^{8}
		30	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
		42	0 ^{0}	0 ^{0}	0 ^{7}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{1}
		54	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}	0 ^{0}
		78	0 ^{67}	7 ^{73}	0 ^{13}	0 ^{27}	0 ^{40}	0 ^{20}	1 ^{40}

Table I-8 cont. Degree of fungal colonization (%) in Douglas-fir poles 18 to 78 months after internal remedial treatment with water diffusible rods or fumigants. [a]

Treatment	Cu Naph	Months After Treatment	Height above groundline (mm)						Pole
			-150	0	300	450	600	1000	
Super-Fume Tubes	+	18	0^{0}	0^{0}	0^{13}	0^{7}	0^{0}	0^{7}	0^{4}
		30	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}
		42	0^{7}	0^{0}	0^{7}	0^{7}	0^{7}	0^{0}	0^{4}
		54	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}
		78	7^{0}	0^{0}	0^{20}	0^{13}	0^{0}	0^{0}	1^{6}
UltraFume	+	18	0^{0}	0^{0}	0^{20}	0^{7}	0^{7}	0^{0}	0^{6}
		30	0^{0}	0^{0}	0^{0}	0^{7}	0^{0}	0^{7}	0^{2}
		42	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}
		54	0^{0}	0^{0}	0^{0}	0^{7}	0^{0}	0^{0}	0^{1}
		78	0^{13}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{2}
WoodFume	-	18	0^{0}	0^{0}	0^{0}	0^{0}	0^{20}	0^{7}	0^{4}
		30	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}
		42	0^{0}	0^{0}	0^{0}	0^{20}	0^{7}	0^{0}	0^{4}
		54	0^{0}	0^{7}	0^{0}	0^{0}	0^{0}	0^{0}	0^{1}
		78	0^{47}	0^{33}	7^{27}	13^{13}	0^{27}	7^{7}	4^{26}
Chloropicrin		18	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}
		30	0^{7}	7^{0}	0^{0}	0^{0}	0^{0}	7^{0}	2^{1}
		42	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}
		54	0^{27}	0^{7}	0^{7}	0^{0}	0^{0}	0^{0}	0^{7}
		78	0^{13}	0^{13}	0^{0}	0^{0}	0^{7}	0^{13}	0^{8}
Diffusible Control		18	0^{0}	14^{0}	0^{0}	0^{0}	0^{0}	n/a	3^{0}
		30	22^{56}	33^{11}	0^{22}	0^{0}	0^{22}		11^{22}
		42	33^{67}	33^{67}	33^{33}	22^{44}	0^{44}		24^{51}
		54	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}		0^{0}
		78	0^{67}	0^{56}	11^{22}	0^{56}	11^{56}		4^{51}
Impel rods		18	0^{7}	0^{8}	0^{18}	0^{8}	0^{7}	n/a	0^{10}
		30	7^{47}	0^{7}	0^{27}	7^{33}	0^{47}		3^{32}
		42	0^{67}	0^{27}	7^{60}	13^{60}	7^{60}		5^{55}
		54	0^{0}	0^{0}	7^{0}	0^{0}	0^{0}		1^{0}
		78	0^{60}	0^{27}	20^{67}	40^{40}	7^{53}		13^{49}
Pol Saver rods		18	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}	n/a	0^{0}
		30	0^{67}	0^{0}	0^{33}	0^{44}	0^{44}		0^{38}
		42	0^{78}	0^{56}	0^{78}	0^{78}	0^{78}		0^{73}
		54	0^{0}	0^{0}	0^{0}	0^{0}	0^{0}		0^{0}
		78	0^{44}	0^{56}	0^{22}	0^{44}	11^{33}		2^{40}
FLUROD		18	0^{0}	0^{0}	0^{20}	0^{40}	0^{13}	n/a	0^{15}
		30	0^{13}	0^{0}	0^{47}	0^{60}	0^{60}		0^{36}
		42	0^{20}	0^{20}	0^{33}	0^{20}	0^{53}		0^{29}
		54	0^{0}	0^{0}	0^{0}	0^{7}	0^{0}		0^{1}
		78	0^{47}	0^{20}	0^{27}	0^{13}	7^{20}		1^{25}

[a] Values represent percentage of cores containing decay fungi. Superscript values represent percent of cores containing non-decay fungi.

2. Residual Chemical Levels Below-Ground in Poles Receiving Internal Remedial Treatments

In virtually all of our internal remedial treatment trials, we have examined residual chemical content or degree of fungal control from slightly below groundline upward. As a result, we have excellent data on levels of boron, MITC or chloropicrin that develop in these regions over time; this has allowed us to develop threshold requirements for each chemical, as well as to determine when chemical reapplication is advisable.

These data are useful where the greatest decay risk is at, or above, groundline; they become less useful when decay risk is highest below that zone. They are also less useful when attempting to determine a mass balance for the amount of chemical applied versus the amount found in wood.

In 2014, we attempted to use our boron distribution data in poles receiving Impel rods to establish a chemical balance between dosage applied and resulting levels in pole sections. There were substantial differences in the amount of boron originally applied and the amounts found in the poles over time. These results led us to investigate the levels of boron present below the groundline where we normally do not inspect.

Two pole sections treated with Impel rods as part of the large scale internal treatment test were selected for study. The poles were removed from the ground and increment cores were removed from sites at groundline, 150 mm and 300 mm below groundline. These cores were analyzed for residual boron. Results indicated boron levels were still adequate near groundline but were far below the protective level further belowground. This led to considerations about residual chemical levels belowground in poles receiving other remedial treatments (Table I-9, Figure I-28). To address this issue, two poles treated with dazomet or MITC-FUME and one pole treated with metham sodium were removed and increment cores were taken from 3 equidistant points around the pole at groundline, 150 mm below groundline or 300 mm below that point. The treated zone was discarded and the inner and outer 25 mm of each core was placed in ethyl acetate to extract any residual MITC. The resulting extracts were analyzed for MITC by gas chromatography and results were expressed on a ug of fumigant /g of oven dried wood.

MITC levels belowground in poles treated 78 months earlier with metham sodium, dazomet or MITC-FUME varied widely (Table I-10). MITC was not detectable belowground in poles treated with metham sodium (Figure I-29). These results are consistent with our findings above the ground and illustrate the relatively short term nature of this treatment.

Table I-9. Boron levels at or below the groundline in Douglas-fir poles 60 months after application of fused boron rods.

Pole	Boron Content (kg/m³ BAE)[a]								
	Groundline			-300mm			-750 mm		
	outer	middle	inner	outer	middle	inner	outer	middle	inner
408	0.42	**2.28**	**3.16**	0.13	0.26	0.45	0.05	0.10	0.13
428	0.20	0.28	0.33	0.14	0.20	0.33	0.08	0.10	0.16

[a] Values in bold are above the 0.5 kg/m³ threshold for protection against internal fungal attack.

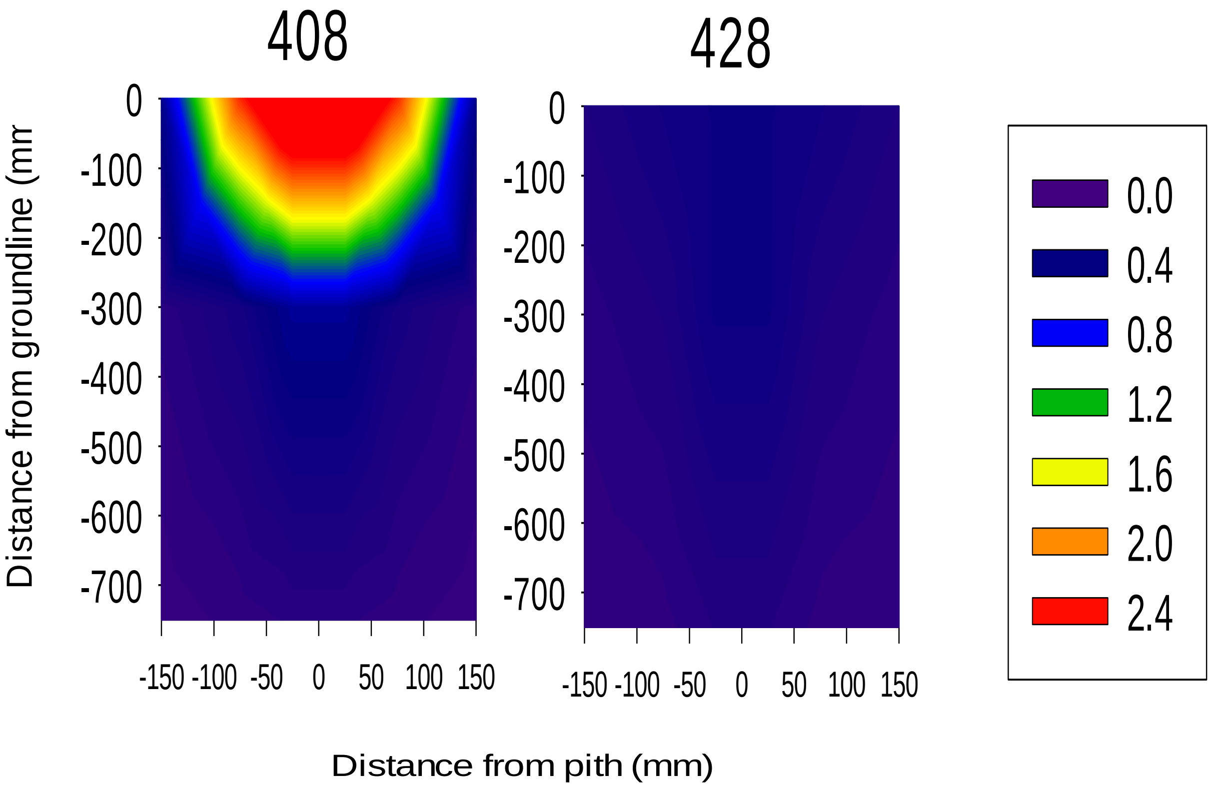


Figure I-28. Map illustrating boron levels at or below groundline in two Douglas-fir poles 60 months after application of fused boron rods, where changes in colors from blue to yellow to red represent increasing boron concentrations in the wood. Dark blue signifies little or no chemical while increasingly light blue to green or yellow signifies boron levels above the threshold. Charts are extrapolated from individual boron analyses at assay locations described in Table I-9.

Table I-10. MITC levels at or below the groundline in Douglas-fir poles 78 months after application of metham sodium, dazomet, or MITC FUME.

Treatment	MITC Content (ug/g of oven dried wood)[a]					
	Groundline		-300		-750 mm	
	outer	inner	outer	inner	outer	inner
Metham Sodium	0	0	0	0	0	0
Dazomet	**62.0**	**279.2**	**55.1**	**139.0**	9.5	**92.3**
MITC-FUME	19.2	**37.1**	**20.5**	**65.7**	**151.4**	**544.3**

[a] Values in bold are above the 20 ug/g of oven dried wood threshold for protection against internal fungal attack.

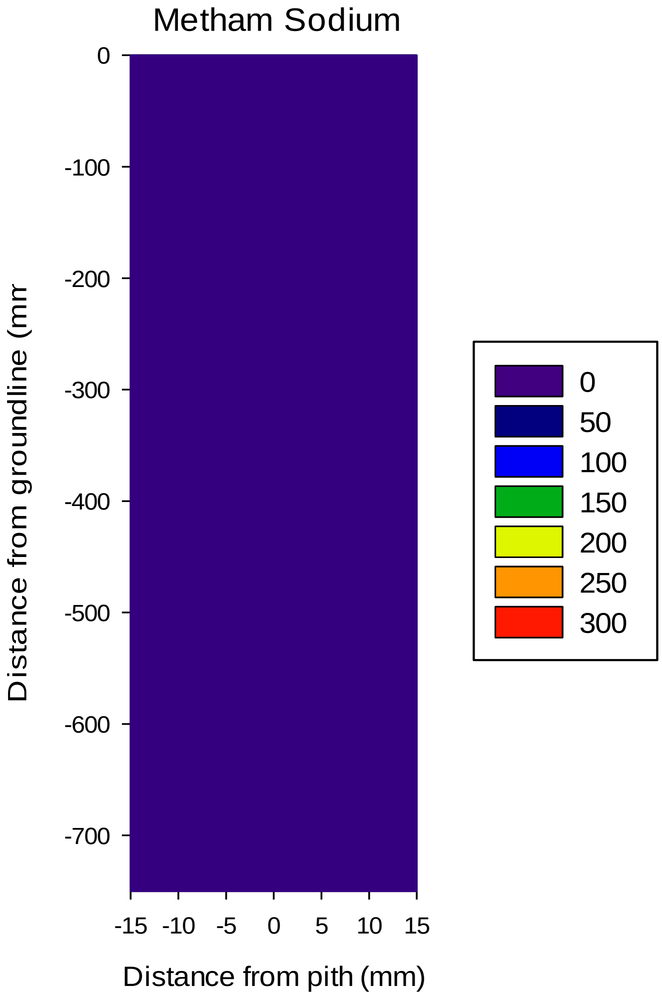


Figure I-29. Map illustrating MITC levels at or below groundline in a Douglas-fir pole 78 months after application of metham sodium where changes in colors from blue to yellow to red represent increasing MITC concentrations in the wood. Dark blue signifies little or no chemical while increasingly light blue to green or yellow signifies MITC levels above the threshold. Charts are extrapolated from individual MITC analyses at assay locations described in Table I-10.

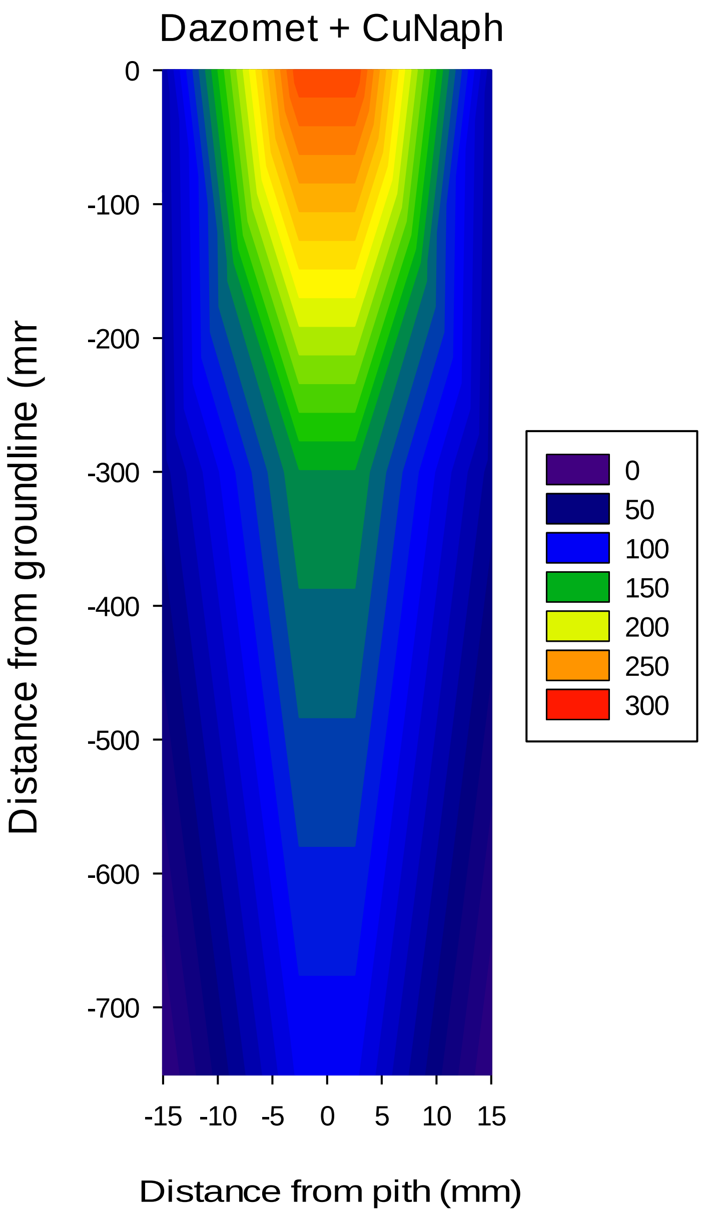


Figure I-30. Map illustrating MITC levels at or below groundline in a Douglas-fir pole 78 months after application of dazomet where changes in colors from blue to yellow to red represent increasing MITC concentrations in the wood. Dark blue signifies little or no chemical while increasingly light blue to green or yellow signifies MITC levels above the threshold. Charts are extrapolated from individual MITC analyses at assay locations described in Table I-10.

MITC levels below-ground in poles treated with either MITC-FUME or dazomet plus copper naphthenate were generally above threshold levels (Figures I-30, 31). Levels 300 mm belowground were 7 to 27 times the threshold for MITC-FUME treated poles and slightly below to almost 5 times the threshold at the same location for dazomet treated poles (Table I-10). MITC levels were consistently lower in the outer zone which is consistent with previous aboveground data, but the differences were much sharper.

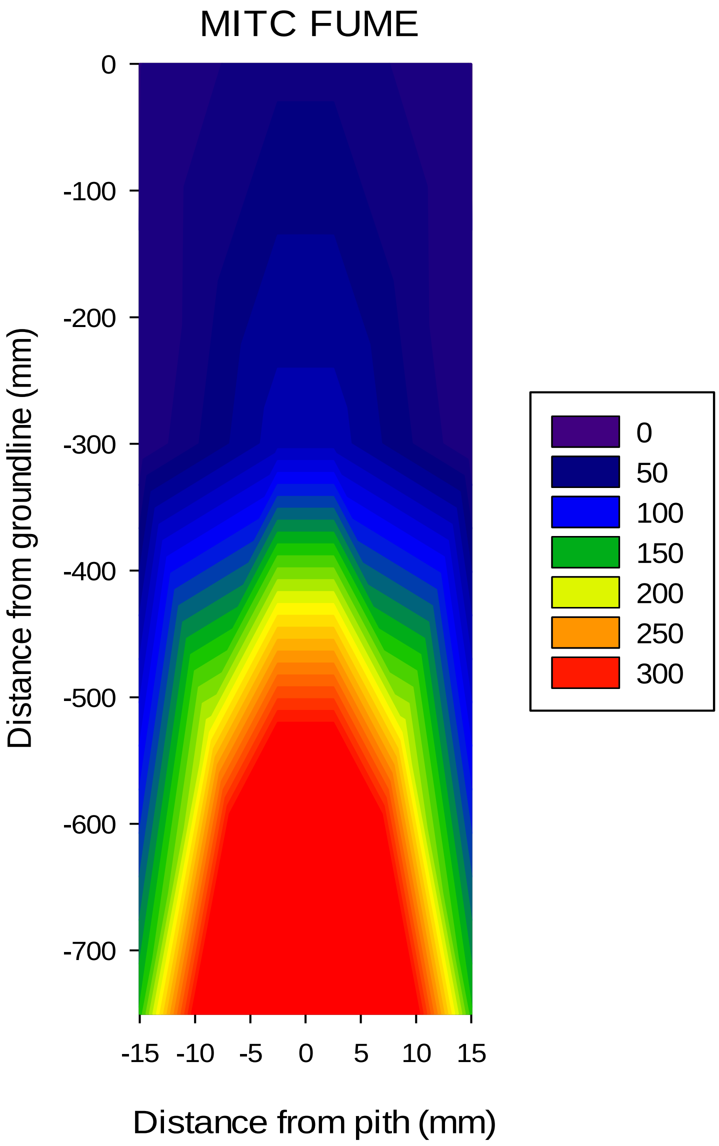


Figure I-31. Map illustrating MITC levels at or below groundline in two Douglas-fir poles 78 months after application of MITC-FUME where changes in colors from blue to yellow to red represent increasing MITC concentrations in the wood. Dark blue signifies little or no chemical while increasingly light blue to green or yellow signifies MITC levels above the threshold. Charts are extrapolated from individual MITC analyses at assay locations described in Table I-10.

This likely reflects the more active surface environment belowground that results in chemical movement into the treated shell and eventually out of the poles more rapidly as it approaches the surface. The results indicate fumigant levels remain well above threshold in belowground portions of MITC-FUME and dazomet plus copper treated test poles 78 months after treatment. The results are also consistent with the findings above groundline for each system.

3. Performance of Internal Remedial Treatments in Arid Climates: Rocky Mountain Power Test

Date Established:	August 2010
Location:	Utah
Pole Species, Treatment, Size	Pine, cedar, Douglas-fir, penta, creo, cellon
Circumference @ GL (avg., max., min.)	87, 107, 71 cm

Internal remedial treatments are widely used to arrest internal fungal decay in poles. These treatments have proven to be highly effective, rapidly eliminating fungi and protecting against reinvasion for periods ranging from 7 to 10 or more years. While these treatments are highly effective, nearly all of the testing has been performed in wet temperate climates and there is little data on the efficacy of these treatments under drier conditions common to most of the western United States. While decay risk is also lower in these locations, absence of wood moisture at the time of treatment can result in inadequate release of fungicidal compounds. Moisture can be a critical requirement for decomposition of dazomet to produce MITC and it is essential for diffusion of boron from fused boron rods.

Douglas-fir, western redcedar and lodgepole pine poles located 220 kilometers south of Salt Lake City, Utah were selected for study. The poles were selected on the basis of accessibility and absence of prior internal treatment. The site is a high desert and receives little rainfall (Salt Lake gets an average of 400 mm of rain and 1.4 m of snow/year). The research area receives 150-200 mm of precipitation, primarily as snow, per year.

Each pole was sounded, then inspection/treatment holes were drilled beginning at groundline adjacent to the largest check and moving around the pole 120 degrees and upward 150 mm. The poles were treated, following label recommendations, with dazomet alone, dazomet with 1% copper naphthenate (10% w/w), MITC-FUME, metham sodium, fused borate rods (one 3 inch rod per hole) with water (10% w/w), fused borate rods without water or were left untreated. The treatment holes were plugged with tight fitting plastic plugs.

The treatments applied were:

Dazomet with accelerant (2 % elemental copper)
Dazomet with no accelerant
MITC-FUME
Metham sodium
Fused boron rods with water
Fused Boron rods without water
Non-treated control

The poles were sampled 14 and 26 months after treatment by removing increment cores from three equidistant locations around a pole at heights of 150 mm below groundline, at groundline, as well as 300, 450, 600 and 900 mm above groundline. The treated shell was discarded and the outer and inner 25 mm of the remainder of each core was removed. The core segments from poles treated with dazomet, metham sodium or MITC-FUME were placed into a glass vial and sealed with a Teflon lined cap. The remainder of the core was placed into a plastic drinking straw which was labeled with the pole #/sampling height and location and then stapled shut. For poles treated with fused boron rods, the entire core was placed in a drinking straw. The vials and straws were returned to Oregon State University for processing.

In the lab, cores from vials were transferred individually to tubes containing 5 ml of ethyl acetate and extracted for a minimum of 48 hours at room temperature before the extract was analyzed for MITC content by gas chromatography. The cores were then oven-dried and weighed. MITC content was expressed on a µg MITC/oven dried gram of wood basis. The outer and inner 25 mm segments of cores from boron treated poles were combined from the three cores from the same height on a pole, ground to pass a 20 mesh screen and extracted in hot water. The resulting extract was then analyzed by the Azomethine H method. Results were expressed on a kg/m^3 boric acid equivalent (BAE).

The remaining center sections of all the cores were briefly flamed to reduce the risk of surface contamination and placed on 1% malt extract agar in plastic petri dishes. The cores were observed for evidence of fungal growth on the agar and any growth was examined for characteristics typical of wood decay fungi.

This test will be sampled in October and the results reported in the 2016 annual Report.

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OBJECTIVE II

IDENTIFY CHEMICALS FOR PROTECTING EXPOSED WOOD SURFACES IN POLES

Preservative treatment of utility poles prior to installation provides an excellent barrier against fungal, insect, and marine borer attack; however, this barrier remains effective only while intact. Deep checks that form after treatment, field drilling holes for attachments including guy wires and communications equipment, cutting poles to height after setting and heavy handling of poles resulting in fractures or shelling between the treated and non-treated zones can all expose non-treated wood to possible biological attack. Most utility standards recommend that all field damage to treated wood be supplementally protected with copper naphthenate solutions. While this treatment will never be as good as the initial pressure treatment, it provides a thin barrier that can be effective aboveground. Despite their merits, these recommendations are often ignored by field crews who dislike the liquid nature of the treatment and know it is highly unlikely that anyone will later check to confirm proper treatment application. In 1980, the Coop initiated a series of trials to assess the efficacy of various treatments for protecting field drilled bolt holes, non-treated western redcedar sapwood and non-treated Douglas-fir timbers above groundline. Many of these trials have been completed and have led to further tests assessing decay levels present in above-ground zones of poles in this region and efforts to develop accelerated test methods for assessing chemical efficacy. Despite the length of time this objective has been underway, above-ground decay and its prevention remain problematic for many utilities as they encounter increased restrictions on chemical use. 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 damage done as these systems are attached can result in substantial long-term savings and is the primary focus of this objective.

A. Effect of Boron Pretreatment on Performance of Preservative Treated Douglas-fir Poles

Douglas-fir heartwood has a well-deserved reputation for being difficult to impregnate with preservatives. Through-boring, radial drilling and deep incising can all improve treatment, but their application is generally limited to groundline. While this represents the area with the greatest risk of internal decay, fungi can attack non-treated heartwood above this zone. Decay above-ground poses great future risk. Entities are attaching equipment to poles are almost all field-drilling holes for these attachments. Non-treated, field-drilled holes represent access paths into non-treated heartwood. While progression of fungal attack and decay is slower above the ground, these field drilled holes eventually become sites for decay. Under Objective II we have examined simple methods for treating holes with boron compounds and evaluated the potential for using preservative-coated bolts. None of these practices have been adopted or have led to changes in practices.

Another approach to reduce decay risk in non-treated heartwood might be to initially treat poles with water diffusible chemicals such as boron or fluoride prior to seasoning and treatment. Diffusible chemicals could move into heartwood as a pole dries and then be over-treated with conventional oil-borne preservatives such as copper naphthenate, penta or creosote to help retain the boron.

We explored this possibility in the 1980s to reduce the risk of fungal colonization during air-seasoning, first with ammonium bifluoride (fluoride) and later with disodium octaborate tetrahydrate (DOT). Results with fluoride were initially promising. Poles were flooded with a 20% solution of ammonium bifluoride and exposed at four sites in the Pacific Northwest and California. Fungal colonization was assessed over a three year period by removing increment cores for culturing. Initially, the percentage of cores containing basidiomycetes was low at all sites, but steadily increased at the wetter sites (Table II-1). Results indicated fluoride could initially limit fungal colonization, but eventually a more weather resistant treatment would be required.

Table II-1. Basidiomycete isolations from Douglas-fir pole sections with or without an ammonium bifluoride treatment after 1 to 3 years of exposure in various locations in the Pacific Northwest (from Morrell et al., 1989).

Seasoning Location	Cores Containing Basidiomycetes (%)					
	Non-Treated			Fluoride Treated		
	1 Yr	2 Yr	3 Yr	1 Yr	2 Yr	3 Yr
Arlington,WA	39	74	71	14	38	69
Scappoose,OR	27	56	76	14	36	45
Eugene,OR	36	52	72	12	19	35
Oroville,CA	29	39	37	8	11	12

In a follow up study near Corvallis, OR, Douglas-fir pole sections were either dipped for 3 minutes in a 20% BAE solution of DOT or sprayed at 6 month intervals with a 10% solution of DOT and exposed for 1 to 3 years. Dip treated pole sections contained much lower basidiomycete levels 1 year after treatment than non-treated controls, while isolation levels were similar after 2 years of exposure (Table II-2). Spray treatments followed similar patterns, even when sprays were applied at 6 month intervals. Results indicated that boron and fluoride could inhibit fungal attack, but their protection was limited and needed to be followed by over-treatment with a traditional non-diffusible wood preservatives.

The potential for boron as a pre-treatment has also been explored on railroad ties in the southern United States. Extensive studies at Mississippi State University have clearly demonstrated that dip or pressure treatment with boron followed by air seasoning and creosote treatment markedly improved performance of ties; this approach is now widely used by mainline railroads. Boron may also have value as a pre-treatment for utility poles. In order to assess this potential, we have undertaken the following test.

Table II-2. Basidiomycete isolations from Douglas-fir pole sections with or without a disodium octaborate tetrahydrate treatment after 1 to 3 years of exposure in various locations in the Pacific Northwest (from Morrell et al., 1991).

Treatment	Cores Containing Basidiomycetes (%)		
	Year 1	Year 2	Year 3
Control	23	59	87
Dip	9	47	30
Sprayed (0/6 mo)	19	43	61

Freshly peeled Douglas-fir pole sections (2.4 m long by 250-300 mm in diameter) were pressure treated with a 7% solution (BAE) of DOT, then six increment cores were removed from two sides near the middle of each pole. Cores were divided into 25 mm segments from surface to pith and combined by depth for each pole. Combined cores were ground to pass a 20 mesh screen before extraction in hot water and boron analysis according to AWPA Standard A2, Method 16. No AWPA borate retention is specified for pre-treatment of utility poles. The current AWPA Standard for borate pre-treatment of ties specifies 2.7 kg/m^3 of boron (as B_2O_3, equal to 4.9 kg/m^3 BAE); however, our data suggests that the threshold of boron for protecting Douglas-fir from internal decay is far lower (0.8 kg/m^3). Clearly, a proper treatment level will need to be determined. For the purposes of this discussion the tie level will be used, although it is probably much higher than necessary.

Five poles not subjected to further treatment were set aside to air-dry. Five of the remaining ten poles were kiln dried to 25% MC 50 mm from the surface, and pressure treated with copper naphthenate to the AWPA U1 UC4B target retention of 0.095 pcf (as Cu). The remaining five poles were pressure treated with copper naphthenate to the same retention, but the poles were seasoned in the cylinder using the Boulton process. Following treatment, all poles were returned to OSU, sampled and analyzed for boron content as described above. Eight additional cores were taken from each copper naphthenate-treated pole so the outer 6 to 25 mm could be assayed for copper by x-ray fluorescence spectroscopy.

Boron retentions (as kg/m^3 BAE) were highest in the outer 25 mm of each pole, ranging from 4.56 to 15.17 kg/m^3 immediately after treatment but before drying (Table II-3). With the exception of one pole, retentions were extremely low in the next 25 mm inward and remained low toward the pole center. These results are typical of any short term pressure treatment of Douglas-fir poles.

If all boron in pole sections immediately after treatment were considered, poles would contain an average of 2.36 kg/m^3 BAE, or about half the required level. These values are skewed by one pole that had extremely high boron levels in four of the six assay zones. The remaining four poles had much lower boron levels. Most boron was largely confined to the outer 25 mm.

Table II-3. Boron levels in Douglas-fir poles immediately after pressure treatment with disodium octaborate tetrahydrate and prior to drying/treatment.

Pole #	Boron Retention (kg/m^3)					
	0-25 mm	25-50 mm	50-75 mm	75-100 mm	100-125 mm	125-150 mm
758	**15.17**	**8.85**	0.36	0.30	5.85	7.95
759	**10.30**	0.21	0.16	0.08	0.73	0.11
760	**7.22**	0.09	0.12	0.06	0.11	0.02
761	**10.29**	0.10	0.03	0.03	0.08	0.03
762	**7.47**	0.11	0.11	0.07	0.09	0.05
763	**10.24**	0.23	0.06	0.08	0.05	0.08
764	**4.56**	0.12	0.05	0.04	0.08	0.06
765	**7.23**	0.11	0.08	0.08	0.08	0.31
766	**10.57**	0.14	0.07	0.05	0.02	0.03
767	**11.66**	0.19	0.08	0.00	0.16	0.11
770	**8.42**	0.15	0.02	0.02	0.00	0.05
786	**5.90**	0.05	0.00	0.03	0.00	0.05
787	**7.16**	0.16	0.00	0.07	0.00	0.35
788	**14.21**	0.24	0.16	0.08	0.07	0.00
789	**9.71**	0.11	0.04	0.10	0.00	0.03
Average	9.34	0.72	0.09	0.07	0.49	0.61
Standard deviation	2.93	2.25	0.09	0.07	1.49	2.03

After kiln drying, boron levels were elevated in the outer 25 mm of pole sections, but declined sharply inward (Table II-4). Boron levels, if averaged across the entire pole cross section would average 1.02 kg/m^3 BAE, far below the specified level. Boron levels in the outer 25 mm were lower after drying in nine of the ten pole sections and, in some cases, the differences were substantial (Table III-5). Some of these reductions may be attributed to differences in sampling locations at different time points as well as to movement of boron into the next 25 mm from the surface, but the levels of loss also suggest that some of the boron was lost from the wood during drying. The results suggest that drying schedules will have to be adjusted to reduce boron loss.

Boron should become more uniformly distributed over time as it diffuses inward from the surface after treatment. Boron levels in poles 2 months after treatment averaged 2.14 kg/m^3 BAE, and levels were slightly higher in the 25 to 50 mm zone (Figure II-1).

However, boron levels in four of the five poles in this treatment group remained very low 50 mm or further inward. The overall shape of the preservative gradient changed only slightly (Figure II-1). This suggests that the majority of boron remained in the outer pole zones.

Treated poles were set to a 0.6 m depth at Peavy Arboretum, Corvallis OR. Five Boulton seasoned and copper naphthenate treated poles and five kiln dried and copper naphthenate poles were installed. Boron content was assessed one and two years after treatment by removing increment core pairs from three equidistant points around each pole at groundline and 1.2 m. Coring holes were plugged with tight-fitting wooden dowels. Increment cores were divided into 25 mm segments from the outside towards the center. Core segments from a given height and zone were combined and ground to pass a 20 mesh screen. Ground wood was analyzed for boron as described above.

Table II-4. Boron levels in Douglas-fir poles immediately after pressure treatment with disodium octaborate tetrahydrate and drying/treatment.

	Boron Retention (kg/m^3)					
Pole #	0-50 mm	25-50 mm	50-75 mm	75-100 mm	100-125 mm	125-150 mm
759	**3.21**	0.42	0.01	0.02	0.12	1.80
760	**4.22**	**0.60**	0.06	0.00	0.01	0.05
762	**6.60**	0.14	0.03	0.00	0.00	0.06
763	**4.04**	0.12	0.01	0.01	0.02	0.03
764	**3.37**	0.26	0.02	0.03	0.08	0.07
766	**3.50**	0.07	0.01	0.01	0.00	0.01
767	**3.74**	0.15	0.08	0.03	0.01	0.02
770	**4.30**	**1.06**	0.12	0.06	0.31	0.13
788	**14.82**	**0.63**	0.03	0.01	0.00	0.00
789	**6.17**	0.45	0.04	0.00	0.02	0.02
Average	5.40	0.39	0.04	0.02	0.06	0.22
Standard deviation	3.50	0.31	0.03	0.02	0.10	0.56

Table II-5. Differences in boron retentions in the outer 25 mm of poles immediately after treatment and after kiln drying.

Pole #	Boron Retention (kg/m^3) in the outer 25 mm		
	Pre-Drying	Post-Drying	Difference
759	10.30	3.21	7.09
760	7.22	4.22	3.00
762	7.47	6.60	0.87
763	10.24	4.04	6.20
764	4.56	3.37	1.19
766	10.57	3.50	7.07
767	11.66	3.74	7.92
770	8.42	4.30	4.12
788	14.21	14.82	-0.61
789	9.71	6.17	3.54

Boron levels in the outer 25 mm of poles one year after treatment had declined in the poles (Figure II-2, Table II-6). The field site receives about 1200 mm of rainfall per year and tends to be extremely wet during the winter. Previous tests have shown that the interior pole MC at groundline tends to be above 30% most of the year, but only reaches that level above groundline near the end of winter. Elevated moisture contents are expected to help boron diffuse and distribute evenly. Declines suggest that boron is moving out of poles and into surrounding soil. Boron levels in the outer 25 mm of wood 1.2 m above groundline were higher than those at groundline. This suggests that boron was moving at the same rate out of soil contact. Boron levels were similar or slightly lower in the inner 25 to 150 mm at both heights, suggesting there had been relatively little inward movement after installation. It is important to remember that the initial boron application levels could be increased by using a stronger treatment solution. Pole sections were treated with a process typically used on lumber for the Hawaiian market and solution concentrations might have been somewhat lower than needed. Lack of substantial boron redistribution suggests that other methods may be needed to ensure boron movement beyond the surface to protect the non-treated interior once the pole is placed in service.

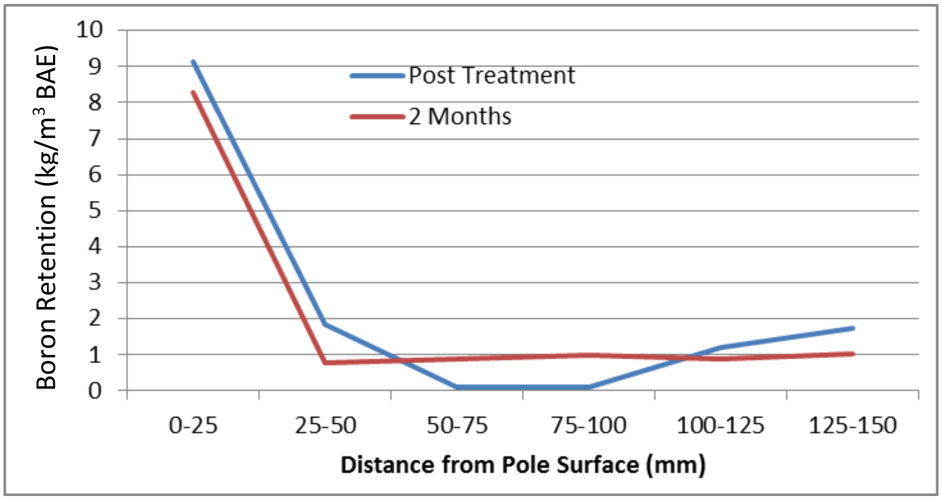

Figure II-1. Boron retentions in 25 mm increments inward from the surface in Douglas-fir poles immediately after pressure treatment with disodium octaborate tetrahydrate and again 2 months later.

Boron levels in poles 2 years after installation had declined in the outer 25 mm of the poles at both groundline and 1.2 m above that level (Table II-6). Boron levels in the outer zone tended to be much higher 1.2 m above the groundline, suggesting that some boron was leaching from the poles in soil contact (Figure II-2). Levels further inward remained similar to those found after one year. These results suggest boron lost from the outer 25 mm zone is not moving to a substantial extend inward to help increase boron levels in those zones.

These results are quite different from those found with railroad ties, where boron remains at elevated levels for many years after initial treatment followed by a creosote over-treatment. However, there are several important differences in this test. First, ties are typically installed over well-drained ballast which should reduce the potential for excessive wetting that leads to boron loss. In addition, overall boron levels in these poles were much lower than those typically placed into an air-seasoning tie. This occurred because the poles were pressure treated with a treatment solution that was intended for lumber treatment. Thus, the initial loadings were somewhat lower than desired given the larger volume of wood that needs to be protected. The lower loadings, however, should not have affected overall diffusion as evidenced by absence of gradually increasing boron levels further away from the outer 25 mm zone. The results suggest higher loadings alone may not be sufficient to produce the desired internal boron loadings. Wood species may have also affected results. The tie work was performed on hardwoods. Boron movement through Douglas-fir has tended to be much slower than in other species, although it also appeared to remain in the wood for longer periods of time.

We will continue to monitor boron levels in these poles over the next 3 years to determine if chemical redistribution occurs to produce levels that minimize the risk of internal fungal attack. We also intend to set up a second trial using a more controlled boron treatment to better evaluate the potential for using this process to protect poles in service.

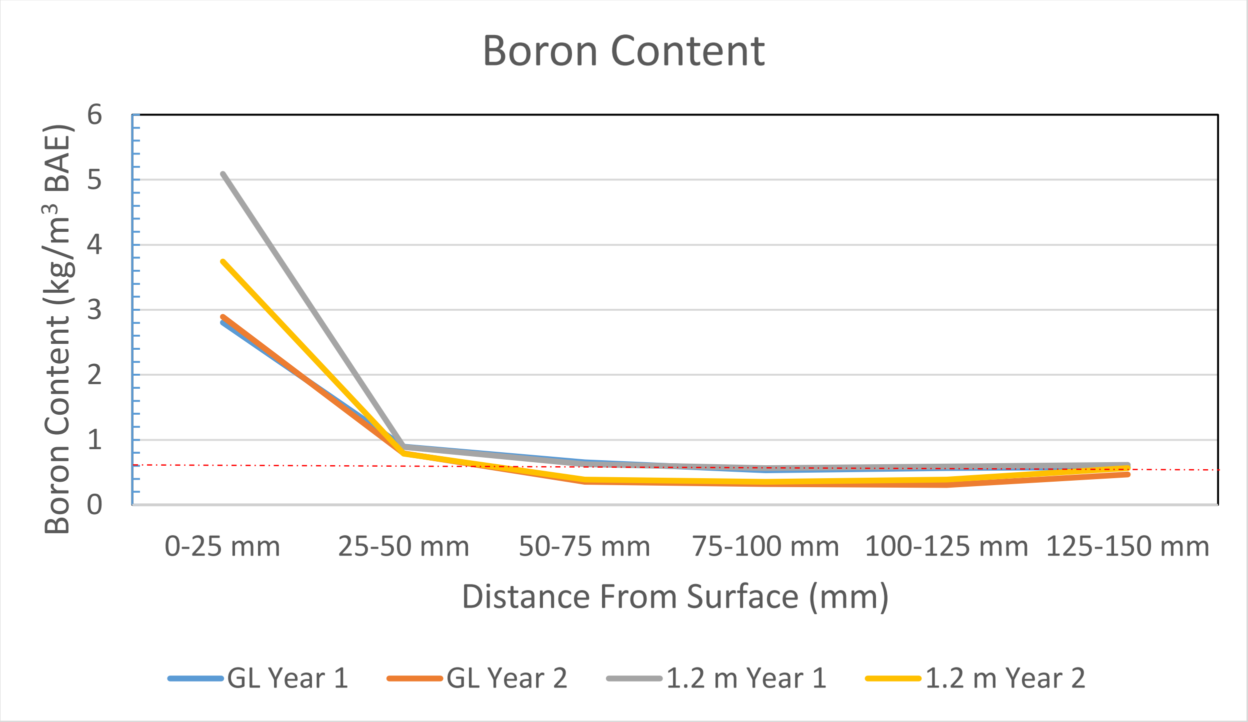

Figure II-2. Boron content at 25 mm increments from the surface of Douglas-fir poles one or two years after pre-treatment with disodium octaborate tetrahydrate followed by either kiln drying or Boulton seasoning and copper naphthenate treatment. Red line indicates 0.6 kg/m3 BAE.

Table II-6. Boron content in increment cores removed from the groundline or 1.2 m above the groundline of Douglas-fir poles 1 or 2 years after pre-treatment with disodium octaborate tetrahydrate followed by kiln drying or Boulton seasoning and pressure treatment with copper naphthenate.

Pole #	Kiln/ Boulton	Boron Retention (kg/m³ BAE)[a]											
		0-25 mm		25-50 mm		50-75 mm		75-100 mm		100-125 mm		125-150 mm	
		gl	1.2 m	gl	1.2 m	gl	1.2 m	gl	1.2 m	gl	1.2 m	gl	1.2 m
759	Boulton Year 1	**2.37**	**4.57**	**1.12**	**1.12**	**0.67**	**0.72**	**0.58**	**0.72**	0.54	**0.72**	0.58	**0.72**
760		**2.51**	**3.09**	**1.66**	**1.39**	**1.12**	**0.99**	**0.67**	**0.72**	**0.63**	0.58	0.63	0.49
762		**3.00**	**4.52**	**0.81**	**0.76**	0.49	0.54	0.45	0.49	0.49	0.58	0.54	**0.72**
763		**3.63**	**4.97**	0.58	**0.67**	0.54	0.49	0.54	0.45	0.58	0.54	0.54	0.49
764		**2.60**	**3.23**	**1.61**	**1.16**	**1.12**	0.63	0.00	**0.63**	**1.08**	0.54	1.16	0.54
Mean (SD)		**2.82** (0.51)	**4.08** (0.86)	**1.16** (0.48)	**1.02** (0.27)	**0.79** **(0.28)**	**0.67** **(0.17)**	0.56 (0.26)	**0.60** **(0.13)**	**0.66** **(0.24)**	0.59 (0.07)	**0.69** **(0.27**)	0.59 (0.12)
759	Boulton Year 2	**3.22**	**4.48**	**1.34**	**1.12**	0.49	0.36	0.40	0.40	0.31	0.40	0.22	0.36
760		**2.87**	**2.91**	**1.75**	**1.57**	**0.81**	**0.94**	**0.67**	**0.72**	**0.67**	0.45	0.31	**0.72**
762		**3.27**	**3.72**	**0.45**	**0.85**	0.45	0.13	0.45	0.54	0.09	0.49	0.09	**0.72**
763		**0.36**	**3.18**	**0.13**	**0.58**	0.05	0.27	0.27	0	0.27	0.58	0.05	**-**
764		**2.78**	**2.51**	**1.30**	**1.08**	**0.76**	0.54	**0.72**	0.19	0.36	0.19	**0.81**	0.49
Mean (SD)		**2.50** **(1.22)**	**3.36** **(0.77)**	**0.99** **(0.68)**	**1.04** **(0.37)**	0.51 (0.30)	0.45 (0.31)	0.50 (0.19)	0.37 (0.28)	0.34 (0.21)	0.42 (0.15)	0.42 (0.28)	0.57 (0.18)
766	Kiln Year 1	**2.20**	**3.58**	0.54	0.58	0.54	0.54	0.45	0.49	0.49	0.54	0.49	0.54
767		**2.28**	**4.12**	**0.63**	**0.63**	0.54	0.49	0.49	0.54	0.45	0.49	0.40	0.45
770		**3.00**	**3.63**	**0.63**	**0.85**	0.54	**0.81**	**0.63**	**0.67**	0.49	**0.90**	0.49	**1.25**
788		**3.81**	**9.27**	**0.72**	**0.85**	0.54	0.45	0.49	0.45	0.40	0.54	0.49	0.40
789		**2.64**	**9.90**	**0.63**	**0.90**	0.45	**0.63**	0.45	0.49	0.54	0.49	0.49	0.54
Mean (SD)		**2.79** (0.65)	**6.10** (3.20)	**0.63** **(0.06)**	**0.76** (0.15)	0.52 (0.04)	0.58 (0.14)	0.50 (0.07)	0.53 (0.09)	0.47 (0.05)	0.59 (0.17)	0.47 (0.04)	0.64 (0.35)
766	Kiln Year 2	**1.84**	**2.87**	0.13	0.40	0.31	0.36	0.09	0.31	0.05	0.36	0.54	0.13
767		**2.96**	**3.72**	0.58	0.22	0.31	0.09	0.05	0.09	0.31	0.22	0.27	0.22
770		**5.51**	**3.67**	**1.52**	**1.03**	0.13	0.72	0.27	0.40	0.22	0.36	0.32	**1.30**
788		**3.62**	**5.96**	0.36	0.36	0.05	0.27	0.05	0.67	0.05	0.54	0.09	-
789		**2.46**	**4.44**	0.36	0.63	0.22	0.22	0.22	0.22	0.31	0.31	**1.12**	0.58
Mean (SD)		**3.28** **(1.41)**	**4.13** **(1.16)**	0.59 (0.54)	0.53 (0.32)	0.20 (0.11)	0.33 (0.24)	0.14 (0.10)	0.34 (0.22)	0.27 (0.15)	0.36 (0.12)	0.51 (0.43)	0.56 (0.53)

[a] Values in bold type signify boron retentions above the threshold for protection against internal fungal attack. SD= Standard deviation

Literature Cited

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OBJECTIVE III

EVALUATE PROPERTIES AND DEVELOP IMPROVED SPECIFICATIONS FOR WOOD POLES

A well-treated pole will provide long, 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. Performance of Polyurea-Coated Douglas-fir Crossarm Sections Exposed in Hilo Hawaii: 72 month report

Preservative treated Douglas-fir performs extremely well when exposed above the ground out of soil contact such as when used as a crossarm to support overhead electrical lines in a distribution system. However, checks that open beyond the depth of the original preservative treatment can permit the entry of moisture as well as fungi and insects that can result in deterioration and premature failure. Douglas-fir contains a high percentage of difficult to treat heartwood and it is generally not feasible to completely penetrate this material with preservative. One alternative is to coat the exterior of the arm to retard moisture entry and presumably limit entry by fungi and insects. Polyurea coatings have been employed for protecting a variety of surfaces and appear to have potential as wood coatings in non-soil contact. We have been evaluating the use of these coatings for protecting Douglas-fir cross arms.

Douglas-fir arm sections were either left non-treated or pressure treated to the AWPA Use Category requirement with pentachlorophenol (penta) in P9 Type A oil. One half of the arms from each treatment group were then coated with polyurea. The arms were then shipped to Hilo, Hawaii, where they were exposed on test racks 450 mm above the ground. The site receives approximately 5 m of rainfall per year and the temperature remains a relatively constant 24-28 C. The site has an extreme biological hazard (280 on the Scheffer Climate Index Scale which normally runs from 0 (low) to 100 (high) decay risk within the continental U.S.) and a severe UV exposure. Non-treated pine sapwood exposed aboveground normally fails within 2 years at this site, compared to 4 to 5 years in western Oregon. The arms were installed in June 2009.

Assessment has been primarily visual and consisted of examining coating condition on the upper (exposed) and lower surfaces (Figure III-1). Additional coated samples were exposed in June of 2011.

The non-treated, non-coated Douglas-fir samples have begun to experience decay on the sides and undersides where moisture can collect and there is evidence of fungal fruiting bodies (Figures III-2,3). These samples have an average rating of 7.0 on a scale of 10 (perfectly sound, no evidence of biological attack) to 0 (complete failure). Non-coated penta-treated samples have some weathering on the upper surfaces, but remain sound and free of decay. All of the penta-treated, non-coated samples rate 10.

Figure III-1. Polyurea coated and non-coated samples shortly after exposure in Hilo Hawaii.

Polyurea coated samples are challenging to evaluate without damaging the coating. Last year, one sample from each treatment was removed and dissected to determine the degree of damage inside the coating. Penta-treated samples were sound and free of decay, although there were some differences in the thickness of the coating on the upper, UV-exposed surface and the bottom that had not been exposed to sunlight (Figure II-2, 3). Penta had also migrated through the surfaces of the polyurea coated samples to a limited extent, but the samples otherwise appear to be free of attack.

The non-treated but coated samples also appeared to be free of fungal attack, but there were a few differences in appearance. The upper coated surfaces on these samples were more heavily degraded. Cutting revealed that the sample had decay pockets immediately beneath the coating. These results suggested that the coating was not a complete barrier against fungal attack.

Figure III-2. Example of lower, non-UV exposed surface of a coated, penta-treated section showing evidence of oil migration towards the coating surface after 6 years of exposure in Hilo, Hawaii.

Figure III-3. Example of a non-treated, non-coated wood sample after 6 years of exposure in Hilo, Hawaii showing evidence of fungal decay and fruiting bodies.

The coatings on the two samples were carefully separated from the wood and the thickness was measured on the upper and lower surfaces. The coatings were then tested in tension to determine peak load. The results were limited because only one sample from each treatment was examined, but they suggested that the coatings on non-treated wood experienced losses in thickness on the UV exposed surface. Coating thickness also declined slightly on the coated, penta-treated samples, but the difference was slight. The reduced effect on the penta-treated samples was attributed to migration of oil from the original penta treatment through coating and to the surface. This material appeared to have provided some UV protection.

Table III-1. Condition of polyurea coatings removed from the upper (UV exposed) and lower (non-UV exposed) surfaces of non-treated and penta-treated Douglas-fir sections exposed for 48 months in Hilo, Hawaii.[a]

Treatment	Top/Bottom	Thickness (mm)	Density (g/cm^3)	Peak Load (N)
None	Top	0.89	0.88	257
	Bottom	1.85	0.99	455
Penta	Top	1.68	0.94	533
	Bottom	1.85	1.05	709

[a] Values represent means of 2 samples per material exposure.

This past year, an additional two samples were removed from each treatment group for further examination. While removing more samples might provide a better indication of condition, we are concerned about leaving too few samples for the long term evaluation. This would be especially true for the penta-treated materials which have experienced relatively little change in condition (Figure III-4).

No non-coated samples were removed since the non-treated samples are showing evidence of advanced decay and the penta-treated samples show no signs of any decay. Thus, dissecting these samples would provide little useful information.

The samples collected after 6 years were cut lengthwise in approximately four equal sections so that the upper and lower surfaces (UV and non-UV exposed) were exposed. The sections were examined for evidence of decay. Penta-treated samples were sound and exhibited no evidence of visible decay or discoloration. The non-treated samples had small pockets of decay on both the upper and lower surfaces immediately adjacent to the coating. This was interesting because we might expect to see fungal attack on the upper surface where the coating had thinned to the point where fungal hyphae could penetrate into the wood, but the coating on the lower surface was thick enough to provide a barrier against fungal attack (Figure III-4). One possibility is that the fungi grew around the timbers along the wood/coating interface so that attack was occurring all around the timber. We plan further assessments to determine the possible point

Figure III-4. Photos of the upper surfaces of coated, non-treated control samples after 6 years of exposure in Hilo, Hawaii showing erosion of the coating and complete loss of coating on the corner.

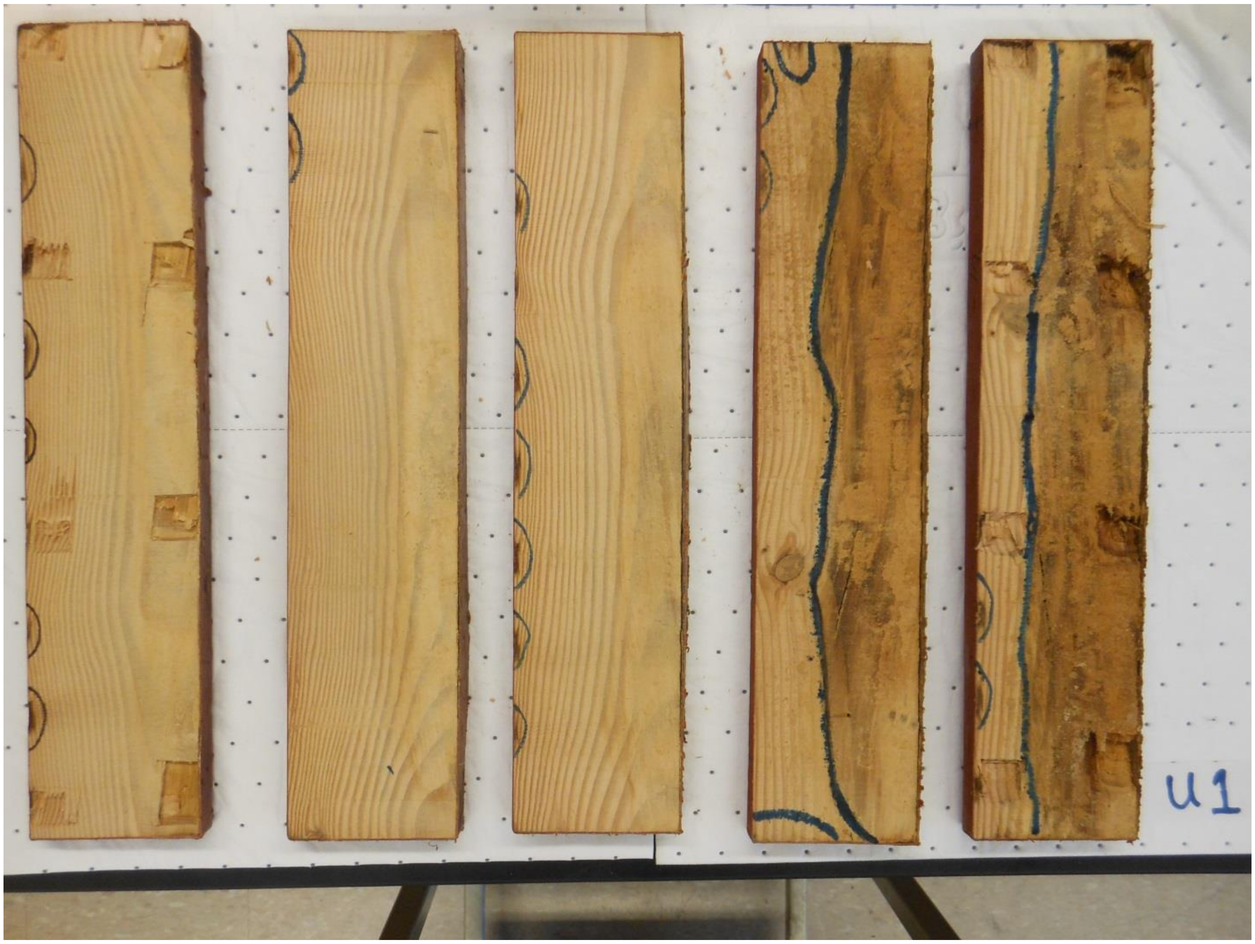

Figure III-5. Example of the interior of a coated, untreated Douglas-fir section after 6 years of aboveground exposure in Hilo, Hawaii.

where fungal attack was initiated. In addition, we will carefully separate the coating from the wood and the thickness of the each piece will be measured using digital calipers. We also plan to cut the coating into 10 mm wide by 150 mm long strips that will be tested to failure in tension. Finally, small samples were cut from the decayed zones and placed onto benlate amended malt extract agar (Figure III-5). The plates will examined for evidence of growth of basidiomycetes. Fungal culturing of wood beneath the coating was only recently initiated and the results will be presented in the next annual report.

B. Performance of Southern Pine Stakes Treated with Pentachlorophenol in Diesel or HTS Solvent

There has been considerable controversy over the use of biodiesel as a co-solvent for treatment of wood with penta. Extensive laboratory trials indicated that the presence of biodiesel did not negatively affect the performance of penta in southern pine sapwood blocks, but the artificial nature of laboratory tests can sometimes produce anomalous or misleading results. The best way to evaluate preservative performance is to test under field conditions at a number of sites with varying environmental conditions. This process can take many years to produce meaningful results under some conditions, but one way to accelerate the process is to use smaller test media with increased surface to volume ratios that magnify the decay effects. Fahlstrom stakes are an excellent example of this approach, wherein traditional 19 mm by 19 mm stakes are replaced with 4 x 38 x 254 mm long stakes. The smaller stakes magnify any surface decay effects, producing results much earlier in an exposure process.

In this report, we describe field test results of Fahlstrom stakes treated with penta using diesel or a biodiesel (HTS) amended solvent and exposed at two sites for 18 to 54 months.

Southern pine sapwood stakes were prepared and treated by Forest Products Research Laboratory Inc. personnel according to the procedures described in AWPA Standard E7 and supplied to OSU for exposure. Stakes were treated with diesel or HTS solvent alone to serve as solvent controls. Additional sets of 20 stakes were treated to target retentions of 0.1, 0.2, 0.3 or 0.6 pounds per cubic foot of penta (1.6, 3.2, 4.8, and 9.6 kg/m^3). An additional 30 stakes were treated to 0.6 pcf with penta in either diesel or HTS. The latter stakes were intended for periodic removal to assess preservative depletion. The treated stakes were allocated to two groups, one for exposure in Oregon and the other for exposure in Hawaii.

The Oregon exposure site was sprayed with glyphosate just prior to setting stakes. A synthetic landscape fabric was then placed on the site and a metal dibble was used to create holes for the stakes. While the fabric creates a slightly different exposure than allowing vegetation to accumulate around the stakes, we felt that it would avoid the need to mow or remove grass, thereby reducing the risk of stake damage. The treated stakes were then buried in soil to half their length approximately 300 mm apart. The Oregon site has a maritime climate and receives approximately 1.15 m of rainfall per year, primarily between October and June. The Hawaii site is sub-tropical, has a well-drained volcanic clay soil and receives nearly 5 m of rainfall per year.

Stake condition was evaluated at the Oregon site after 12, 42, and 54 months of exposure while stakes at the Hawaii site were assessed after 6, 12, 24, 31 and 43 months of exposure. Each stake was removed from the soil, wiped clean and probed with small screwdriver for evidence of softening. Stake condition was rated on a scale from 10 to 0 as described in AWPA Standard E7 where:

Grade No.	Description of Condition
10	Sound. Suspicion of decay permitted
9	Trace decay to 3% of cross section
8	Decay from 3 to 10% of cross section
7	Decay from 10 to 30% of cross section
6	Decay from 30 to 50% of cross section
4	Decay from 50 to 75% of cross section
0	Failure

In some cases, the fragile condition of the stakes made removal from the soil difficult. The Hawaii site had no termite activity, while the Oregon site had minor termite activity. No evidence of termite activity was observed on any stakes. Depletion stakes were also removed from the Hawaii site after 31 months for residual preservative analysis. The stakes were removed and the bottom 50 mm, top 60 mm and the 50 mm zone around the groundline were removed, ground to pass a 20 mesh screen and analyzed for penta by X-ray fluorescence spectroscopy. These values were compared with matched retained pieces that had not been exposed in the field. All of the HIlo stakes were removed after 43 months of exposure and that part of the test is complete.

Activity at the Oregon site was very limited, with only minor damage to any of the stakes after 12 months of exposure. The location chosen was near the bottom of the test site and was extremely wet for most of the year. This resulted in an oxygen-limiting environment that reduced the risk of decay. The stakes were moved to a better drained site and have been exposed for a total of 54 months.

The majority of the control stakes at the Corvallis site have failed, although 6 of 20 total control stakes still have average ratings of 7 or better, suggesting that they have only minimal decay (Table III-2). We are unsure about the cause for the exceptional performance of these stakes; however, the remaining stakes have all failed.

Stakes treated with 0.1 pcf penta in diesel had nearly all failed after 54 months while those treated with the same amount of penta in HTS had a slightly higher rating. Samples treated with 0.2 pcf penta in diesel were in good condition while those treated with penta in HTS solvent had much lower ratings. The trend was similar at 0.35 pcf; however, average ratings for stakes treated with 0.6 pcf of penta were slightly higher in HTS oil than in diesel. These results illustrate the variations found in field trials, but they also showed that there was little overall consistent difference between the two solvents with regard to penta performance. These results are also consistent with the results found at Hilo under more aggressive decay conditions.

Table III-2. Average condition Fahlstrom stakes treated to varying retentions with pentachlorophenol in either petroleum based diesel of a biodiesel blend (HTS) and exposed in Corvallis, Oregon for 12 to 54 months.

Target Retention (PCF)	Carrier	Reps	Average Stake Condition[a]		
			12 months	42 months	54 months
-	Diesel	10	9.4 (1.0)	1.8 (3.8)	1.9 (3.5)
0.1	Diesel	10	9.4 (1.0)	1.4 (3.0)	0.6 (1.7)
0.2	Diesel	10	10 (0)	6.5 (3.8)	6.3 (3.7)
0.35	Diesel	10	10 (0)	5.5 (4.1)	5.3 (4.1)
0.60	Diesel	25	10 (0)	8.6 (1.3)	8.2 (2.0)
-	HTS	10	9.9)0.3)	1.8 (3.8)	2.2 (4.0)
0.1	HTS	10	8.2 (3.1)	3.7 (4.2)	2.1 (3.9)
0.2	HTS	10	9.8 (0.4)	5.1 (4.5)	2.2 (3.6)
0.35	HTS	10	9.6 (1.4)	3.3 (4.3)	3.2 (4.1)
0.60	HTS	25	10 (0)	9.1 (0.4)	9.2 (1.1)

[a] Where 10 represents a sound stake and 0 represents complete failure. Values represent means while figures in parentheses represent one standard deviation.

C. Effect of Solvents on Performance of Copper Naphthenate and Pentachlorophenol

While the Fahlstrom stake tests described in Objective III-B showed that there was little difference in performance for penta in either diesel or biodiesel, additional questions arose over the course of that study. Primary among these was the effect of biodiesel on the performance of copper naphthenate. Our laboratory studies had shown that biodiesel had a detrimental effect on the performance of this preservative against copper tolerant brown rot fungi. In addition, there were lingering questions about the potential effects of both solvents on performance of penta and copper naphthenate. In order to address these questions, a follow-up test was established. In this case, more traditional 19 by 19 by 900 mm long Douglas-fir sapwood stakes were treated with various combinations of penta or copper naphthenate and differing ratios of solvents. The solvent mixtures employed were diesel alone or amended with 30, 50, 70 or 100 % biodiesel. In addition, each biocide was examined in an aromatic oil, a paraffinic oil and FPRL oil (the solvent originally examined in Objective III-B). The copper naphthenate target retentions were 0.66, 0.99, 1.33, and 1.66 kg/m^3 as Cu. The penta retentions were 2.4, 4.8, 6.4 and 9.6 kg/m^3. Finally, penta solutions were also made from a concentrate commonly used in the Southeastern U.S. using diesel as the diluent. These stakes were only installed at the Peavy Arboretum test site last Fall and will be inspected for the first time this coming month, following substantial rain to allow stake excavation.

D. 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 (> 50 to 60 years old) Douglas-fir distribution poles 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 Douglas-fir 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 without caps while the remainder received Osmose pole caps.

Initial moisture contents for each pole were determined during installation from increment cores taken 150 mm below the top of the pole. The outer treated zone was discarded, and then the inner and outer 25 mm of the remainder of the core were weighed, oven-dried and re-weighed to determine wood MC.

The effect of the caps on MC was assessed 4 to 90 months after installation by removing increment cores 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 20 and 28% for the inner zones and 17 and 19% for the outer 25 mm of non-capped and capped poles, respectively (Table III-3). The elevated levels in the inner zones of the capped poles was due to the high MC on one very wet pole. Moisture contents at the 4 month point in non-capped poles were slightly higher than those at the time of installation while those in capped poles had declined in both the inner and outer zones, even though sampling took place during our winter rainy season. While the moisture increases in the non-capped poles were not major, they did show the effect of capping on moisture entry.

Continued monitoring has shown that moisture levels in non-capped poles tended to increase sharply in the winter, then decline over the drier summer months. Moisture contents in the inner zones of cores removed from non-capped poles in June near the end of our rainy season have ranged from 25% to as high as 99% after 40 months in service. Moisture levels nearer the surface are much lower, reflecting the greater potential for the surface of the pole to dry as the rain stops and temperatures increase. Moisture contents in poles without caps also remained elevated in the interior after 96 months. These poles have begun to experience decay in this zone which will tend to wet more quickly and hold more moisture during wet winters. The results indicate that moisture conditions in the pole interiors are suitable for microbial attack for a large proportion of the year.

Moisture levels in capped poles have remained consistently below 17 % since the 12 month point. These moisture regimes are far lower than those required for fungal attack, indicating that capping should virtually eliminate the risk of top decay (Table III-3).

Moisture is critical for fungal growth and development. Maintaining wood MC below 20% represents a simple method for protecting the non-treated wood in the pole interior from decay. Capping is an inexpensive method for accomplishing this task. We will continue assessing these pole sections over the coming seasons to monitor cap condition.

Table III-3. Moisture contents in Douglas-fir poles with or without water shedding caps as determined over 90 months.

Exposure Time (Mo)	Sampling Month	Moisture Content (%)			
		No Cap		Capped	
		Inner	Outer	Inner	Outer
0	February	20.1	16.8	28.4	19.7
4	June	25.2	18.9	19.0	18.3
12	February	37.5	26.1	14.2	16.4
28	June	60.7	27.4	15.5	15.9
32	October	29,3	17.4	13.6	13.5
40	June	99.3	35.5	13.6	16.1
44	October	53.1	21.5	14.7	14.1
52	June	85.1	22.0	-	-
56	October	41.7	23.3	9.8	9.4
64	June	48.4	13.0	8.8	8.3
90	August	83.6	28.2	13.3	11.0

E. Evaluation of Polyurea Coating as a Method for Controlling Moisture Levels in Douglas-fir Pole Tops

Polyurea barriers have proven to be durable on crossarm sections in sub-tropical exposures at Hilo, Hawaii. We wondered if these materials would also be effective for protecting the tops of newly installed utility poles.

To investigate this possibility, six penta treated Douglas-fir pole sections (3 m long) were coated with polyurea from the tip to approximately 0.9 m below that zone (Figure III-6). The poles were set to a depth of 0.6 m at a test site on the OSU campus. Increment cores were removed from the non-coated section of the pole and divided into inner and outer 25 mm sections as described above. Each core section was weighed immediately after removal from the pole, then oven-dried and re-weighed. The difference was used to determine MC. The sampling hole was covered with a patch of seal-fast tape (Mule-Hide Products, Beloit, WI). Moisture contents at the time of installation ranged from 16.0 to 31.8%. The averages for the inner and outer zones were 23.8% and 19.0%, respectively. The poles, installed in the spring of 2011, were sampled after 4, 12, 16 and 24 months of exposure to assess the effect of the coating on internal moisture. Increment cores were removed in the same manner as previously described and MC was determined for each pole. Non-coated, non-capped poles from the previously-installed moisture shedding pole cap study served as controls. The condition of the surface coating was also visually monitored for evidence of adhesion with the wood as well as the development of surface degradation.

Pole moisture contents declined sharply over the first 4 months of exposure and averaged 5.9 and 7.5% for the inner and outer zones, respectively. Moisture levels continued to decline over the next 8 months through the rainiest part of the year (Table III-4). Moisture contents have risen over the past 12 months, but are all still below 18% MC. The threshold for fungal attack is typically considered to be the fiber saturation point or approximately 30% MC. Architects and engineers generally use 20% as the maximum MC for wood in buildings. This provides a margin of safety since wood moisture contents in the absence of liquid water will rarely rise above 19%, even under the most humid conditions. Our results with the coated tops indicate that the barriers are resulting in moisture contents well below this safety level.

These results indicate that barriers are effectively limiting moisture entry. The barriers show little evidence of weathering and appear to be in excellent condition. The coating integrity is consistent with results from the polyurea coated crossarms in Hawaii, which have been exposed for a longer period under much more severe UV conditions. We will continue to monitor these poles over time; however, the results suggest coatings provide a reliable method for limiting moisture entry through pole tops.

Figure III-6. Example of a poluyurea capped pole top.

Table III-4. Moisture content beneath the tops of Douglas-fir poles with and without a water-shedding polyurea coating.

Exposure Tie (mo)	Sampling Month	Moisture Content (%)[a]			
		No Cap		Polyurea Coated	
		Inner	Outer	Inner	Outer
0	June	99.3	35.5	23.8	19.0
4	October	5.1	21.5	21.6	13.2
12	June	85.1	22.0	4.6	8.3
16	October	41.7	23.3	17.9	16.2
24	June	48.4	13.0	17.8	14.0
38	August	83.6	28.2	17.3	18.3

[a] Values for non-capped control were from the Osmose test and are presented for relative comparison.

F. Further Assessments of Western Redcedar and Lodgepole Pine Poles in Alberta, Canada

In 2009, we undertook an evaluation of poles in Alberta, Canada to determine both the residual retentions of original preservative treatment in the poles as well as the levels of any remedial treatments that had been applied. A total of 44 poles were inspected: 2 creosote treated, 6 CCA treated and the remainder were treated with penta. The majority of the poles with penta had been installed between 1958 and 2004. Some of the poles had been treated with metham sodium while 27 poles had received an external groundline paste. The poles were a mixture of lodgepole pine and western redcedar.

Retention results suggested the poles were generally properly treated, while MITC levels (the primary fungitoxic breakdown product ofmetham sodium) remaining in metham sodium treated poles varied widely. The suggestion was that these poles would need to be re-treated within 2 to 3 years. Residual boron content in poles that received a supplemental surface treatment were somewhat lower than expected, but the sample size was fairly small. Copper was found near the surface, which is typical of poles treated with these external preservative paste systems.

This past year, we sampled an additional 66 poles (Table 1). The population included 20 CCA treated lodgepole pine, 14 CCA treated western redcedar, 17 penta-treated lodgepole pine and 17 penta-treated western redcedar poles.

Increment cores were removed at six equidistant locations around the pole at groundline and 300 mm above that zone to provide enough wood for analysis. The outer assay zones for each core were removed and these segments were combined for each pole before being ground to pass a 20 mesh screen and analyzed for residual CCA or penta by x-ray fluorescence spectroscopy. The remainder of each core was further divided by taking the outer and inner 25 mm segments and placing each into 5 ml of ethyl acetate. The cores were extracted in ethyl acetate for 48 hours before the ethyl acetate was poured off for analysis of MITC by gas chromatography. The core was then oven dried and weighed so that MITC content could be expressed on a ug/oven dried g of wood basis. Sampling for this project is ongoing to examine enough poles to create a statistically relevant sample size. Increment cores removed from poles in future sampling will be placed on malt extract agar and observed over 28 days for evidence of fungal growth. This growth will be examined for characteristics typical of the basidiomycetes, a class of fungi containing many important wood decayers. These data will provide a measure of the ability of the various treatments to exclude decay fungi

The current retention for CCA treatment of lodgepole pine is 9.6 kg/m^3. Retention in all of the CCA treated lodgepole pine poles were over that level and averaged 15.2 kg/m^3 for poles installed after 1990 and 14.2 kg/m^3 in poles installed between 1986 and 1988. These results indicate that the CCA retentions remain far in excess of those needed for wood protection and no supplemental treatment would be required for these poles.

The required initial CCA retention for western redcedar poles is also 9.6 kg/m^3; however, this level is far in excess of that required for wood protection. All of the poles sampled had retentions in excess of 12 kg/m^3, indicating that these poles also required no supplemental protection.

The initial penta retention required for lodgepole pine is 12.8 kg/m^3. Average penta retentions in lodgepole pine poles installed between 1971 and 1979 averaged 7.85 kg/m^3, while those installed in 1981-1986 averaged 7.47 kg/m^3 (Table 2). While both were below the minimal level required for initial treatment, they are still well above the ground contact threshold required for other applications of penta. Averages can be deceptive, since they over-look poles where retentions are below the protective threshold. Four of the 15 penta-treated lodgepole pine poles had retentions below 6.4 kg/m^3, suggesting that these poles were beginning to lose sufficient amounts of penta to make it prudent to consider application of supplemental surface treatments.

The initial penta retention required for western redcedar is 16.0 kg/m^3, while retentions in poles installed between 1961 and 1965, and those installed between 1973-1978 averaged 4.63 and 4.86 kg/m^3, respectively. These poles were clearly in the range where retreatment would be prudent. All of the poles contained less than the minimum initial retention and 10 of 17 had retentions below 6.4 kg/m^3, further reinforcing the need for retreatment. Retentions in poles installed between 1986 and 1988 averaged 10.36 kg/m^3 suggesting the poles did not need retreatment; however, one of these poles had an extremely low retention (3.76 kg/m^3). These results indicate that poles in this age group might merit further investigation to determine if retreatment would be prudent.

Table III-5. Characteristics of penta and CCA treated lodgepole pine or western redcedar poles sampled in Alberta, Canada.

Species	Year Installed	Age (Yrs)	Initial Treatment	Year Fumigated	Residual Retention (kg/m^3)	
					Penta	CCA
LP	1987	28	CCA	2010		14.80
LP	1994	21	CCA	2010		19.27
LP	1994	21	CCA	2010		19.70
LP	1994	21	CCA	2010		16.99
LP	1994	21	CCA	2010		15.23
LP	1996	19	CCA	2011		18.40
LP	1994	21	CCA	2011		16.56
LP	1994	21	CCA	2011		13.94
LP	1994	21	CCA	2011		10.47
LP	1994	21	CCA	2011		16.74
LP	1986	29	CCA	2008		12.77
LP	1986	29	CCA	2008		11.22
LP	1986	29	CCA	2008		16.51
LP	1986	29	CCA	2008		15.95
LP	1986	29	CCA	2008		12.32
LP	1988	27	CCA	2009		15.50
LP	1994	21	CCA	2009		15.70
LP	1990	25	CCA	2009		10.00
LP	1990	25	CCA	2009		11.00
LP	1990	25	CCA	2009		13.23
LP	1981	34	Penta	2011	6.40	
LP	1982	33	Penta	2011	6.72	
LP	1982	33	Penta	2011	9.17	
LP	1979	36	Penta	2011	9.42	
LP	1979	36	Penta	2011	8.33	
LP	1986	29	Penta	2008	**5.96**	
LP	1986	29	Penta	2008	7.41	
LP	1986	29	Penta	2008	6.83	
LP	1986	29	Penta	2008	**4.52**	
LP	1986	29	Penta	2008	**5.05**	
LP	1986	29	Penta	2009	6.85	
LP	1983	32	Penta	2009	12.74	
LP	1979	36	Penta	2009	8.78	
LP	1971	44	Penta	2009	**4.77**	
LP	1975	40	Penta	2009	10.21	
WRC	1989	26	CCA	2008		14.33
WRC	1989	26	CCA	2008		17.70
WRC	1989	26	CCA	2008		14.74
WRC	1989	26	CCA	2008		12.63
WRC	1989	26	CCA	2008		18.69

Table III-5 cont. Characteristics of penta and CCA treated lodgepole pine or western redcedar poles sampled in Alberta, Canada.

Initial Treatment	Year Fumigated	Age (Yrs)	CCA	2010		18.33
WRC	1994	21	CCA	2010		14.07
WRC	1994	21	CCA	2010		13.07
WRC	1996	19	CCA	2011		16.89
WRC	1989	26	CCA	2011		17.48
WRC	1988	27	CCA	2009		18.16
WRC	1990	25	CCA	2009		18.78
WRC	1975	40	CCA	2009		20.90
WRC	1975	40	CCA	2009		12.99
WRC	1975	40	CCA	2009		21.68
WRC	1973	42	Penta	2010	**1.90**	
WRC	1965	50	Penta	2011	**3.39**	
WRC	1965	50	Penta	2011	**5.18**	
WRC	1965	50	Penta	2011	**5.14**	
WRC	1965	50	Penta	2011	6.48	
WRC	1965	50	Penta	2011	**4.26**	
WRC	1986	29	Penta	2008	13.84	
WRC	1986	29	Penta	2008	9.20	
WRC	1986	29	Penta	2008	13.77	
WRC	1986	29	Penta	2008	10.77	
WRC	1986	29	Penta	2008	10.84	
WRC	1961	54	Penta	2009	**3.92**	
WRC	1961	54	Penta	2009	**3.85**	
WRC	1988	27	Penta	2009	**3.76**	
WRC	1961	54	Penta	2009	**4.81**	
WRC	1977	38	Penta	2009	**5.31**	
WRC	1978	37	Penta	2010	7.38	

[a] Where LP signifies lodgepole pine and WRC signifies western redcedar

[b] The current initial retentions for chromated copper arsenate (CCA) are 9.6 kg/m^3 for lodgepole pine and western redcedar. The current pentachlorophenol retention is 9.6 kg/m^3 for lodgepole pine and 16.0 kg/m^3 for western redcedar. For the purpose of this assessment, retentions below 6.4 kg/m^3 (the ground contact retention for these systems in other applications) were considered suggestive of the need for some attention to wood surface protection. Retentions below that threshold are bolded.

As expected, MITC levels varied widely among poles and at different locations within a pole (Table 3). These data must be viewed with caution since we lack data on initial treatment quality, nor do we know how well the initial chemical moved through the wood. MITC is the primary fungitoxic decomposition product of metham sodium, the only fumigant allowed in Canada for pole treatment; however, the decomposition process is rather inefficient. It is estimated that only 12% of the total weight of metham sodium applied to a pole is converted to MITC (Morrell and Corden, 1986). Previous studies have shown that this MITC is rapidly released and kills established decay fungi within 1 year of application. The protective period produced by metham sodium; however, is far lower than the periods provided by other internal treatments because the initial MITC release appears to rapidly exit the wood. Typically, MITC remains at effective levels in metham sodium treated Douglas-fir poles for only 3 to 4 years. The protective period will be even lower in poles of more permeable wood species which will tend to lose chemical more rapidly. By comparison, MITC levels in poles treated with two other fumigants used for this application, MITC-FUME or dazomet, remain at effective levels for 8 to 14 years after treatment. Ideally, Fortis Alberta would switch their program to use either of these treatments, however, neither of these chemicals is currently registered for application to wood in Canada.

Table III-6. Preservative retentions in lodgepole pine and western redcedar poles treated with CCA or penta as shown by decade of installation.

Species	Treatment	Year Installed	N	Retention (kg/m^3)	
				Average	Range
LPP	CCA	1986-1988	7	14.2 (2.0)	11.2-16.5
		1990-1996	13	15.2 (3.3)	10.5-19.7
	Penta	1971-1979	6	7.9 (2.2)	4.8-10.2
		1981-1986	10	7.5 (2.3)	4.5-12.7
WRC	CCA	1975	3	18.5 (4.8)	13.0-21.7
		1988-1989	8	16.5 (2.3)	12.6-18.7
		1990-1996	4	15.7 (2.6)	13.1-18.8
	Penta	1961-1965	8	4.6 (1.0)	3.4-6.5
		1973-1978	3	4.9 (2.8)	1.9-7.4
		1986-1988	6	10.4 (3.7)	3.8-13.8

The MITC threshold for fungal protection is approximately 20 ug/g of wood. Analysis of increment cores removed from 4 to 7 years after treatment indicated that MITC was detectable in most poles near the groundline as well as 300 mm above that zone. The levels; however, were generally below the threshold at most sampling sites. Interestingly, MITC levels were sometimes higher 300 mm above the groundline than at groundline. The short residence time of MITC in the poles following metham sodium treatment in this test is consistent with those found in other tests with this chemical. There also appeared to be little difference in MITC levels between lodgepole pine and western redcedar, suggesting that differences in wood chemistry and permeability did not alter MITC behavior over time.

Examining MITC levels in poles at groundline 4 to 7 years after metham sodium treatment showed levels trended downward except for the lodgepole pine inner assay zones, which appeared to increase (Figure 1). These data must be considered carefully because they are taken from poles that were not all treated at the same time and were likely treated by different people. The variations may also reflect pole conditions, site or remedial treatment quality. In general; however, the MITC levels at 7 years clearly indicate that treatment should be reapplied to provide continued protection against fungal invasion.

There is a tendency to think that the decline in MITC content below the threshold translates to near immediate recolonization by decay fungi. However, the recolonization process is slow and it often takes several years before fungi can again begin to degrade wood. Thus, the protective period is somewhat longer than the 3-4 year period that would be predicted by chemical level. The variations in chemical levels after 7 years, however, do indicate that reapplication of metham sodium might be prudent at this point.

Table III-7. Residual MITC in poles lodgepole pine (LPP) or western redcedar (WRC) poles 4 to 7 years after application of metham sodium (NaMDC).

Wood Species	Initial Treatment	Years since NaMDC	Residual MITC Content (ug/g of wood)[a]			
			Groundline		300 mm above GL	
			Inner	Outer	Inner	Outer
Lodgepole pine	CCA	4	4.5 (7.6)	**34.1 (27.2)**	12.0 (19.0)	**24.6 (19.8)**
		5	10.2 (12.0)	7.9 (15.9)	17.4 (25.5)	13.6 (16.7)
		6	**27.2 (27.1)**	15.7 (23.6)	**38.8 (43.5)**	6.9 (15.8)
		7	15.1 (11.7)	4.2 (8.6)	**36.4 (22.7)**	14.7 (20.1)
	Penta	4	14.5 (19.3)	**40.3 (28.6)**	**22.6 (25.6)**	**50.4 (40.2)**
		5	0	0	0.1 (0.6)	0
		6	19.0 (29.7)	11.4 (25.6)	19.8 (21.0)	5.8 (9.6)
		7	**38.4 (56.3)**	2.6 (6.0)	**28.2 (36.6)**	9.5 (13.4)
Western redcedar	CCA	4	10.4 (21.3)	**20.8 (22.5)**	1.6 (1.9)	**35.5 (39.5)**
		5	3.4 (7.8)	7.2 (21.6)	17.5 (17.6)	9.8 (16.2)
		6	1.9 (5.1)	0.1 (0.3)	4.1 (11.8)	0
		7	1.2 (4.5)	1.0 (2.6)	1.4 (3.4)	0.3 (1.1)
	Penta	4	12.6 (24.6)	**20.3 (20.9)**	**35.3 (29.4)**	**34.2 (31.6)**
		5	**21.0 (29.7)**	11.2 (15.3)	**32.0 (31.1)**	1.9 (2.9)
		6	3.1 (6.1)	5.8 (13.6)	**26.9 (29.6)**	3.2 (4.8)
		7	12.6 (10.6)	2.7 (4.6)	14.3 (15.2)	7.3 (9.3)

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

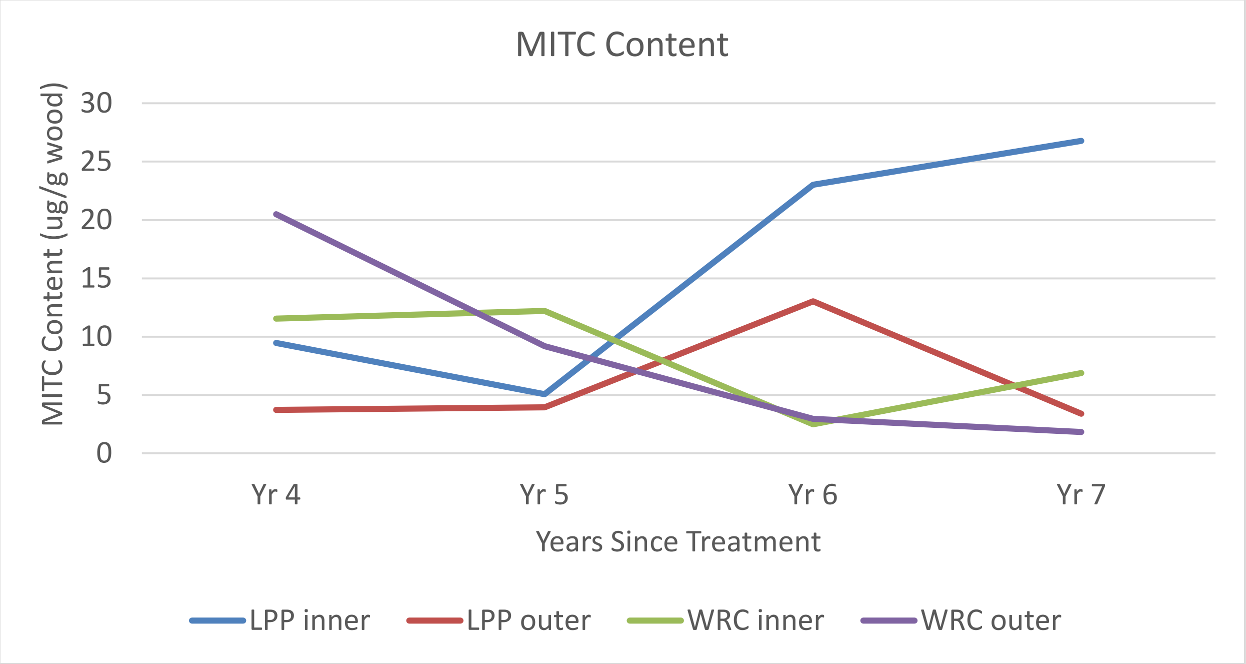

Figure III-7. MITC content in the inner and outer 25 mm of increment cores removed from the groundline of lodgepole pine (LPP) or western redcedar (WRC) poles 4 to 7 years after treatment with metham sodium. The threshold for fungal protection for MITC is 20 ug/g of oven dried wood.

G. Developing Data on the Ability of Various Systems to Protect Poles from Wildfire

Changing climatic conditions in North America are predicted to result in hotter, drier summers with increased risk of wildfire. At the same time, decades of fire suppression, failure to otherwise manage large sections of publically owned forests, and regional bark beetle outbreaks have created unprecedented fuel loadings in many forests. These conditions create the risk of major conflagrations, especially across the western parts of the United States and Canada. These risks have raised major concerns among the electric utilities whose distribution and transmission lines run through these at-risk areas. These lines are largely supported by either wood or steel poles.

At first glance, replacement of wood with steel seems like a logical approach; however, it is important to look more closely at the problem (Smith, 2014). The ability of wood to burn is well known; however, less well considered is the tendency of steel to melt and deform when exposed to elevated temperature. In essence, both materials are susceptible to failure during wildfires. Calls to place all lines underground would be technically difficult and prohibitively expensive. Going underground would also create other long term maintenance issues that could reduce system reliability and slow outage repairs. As a result, identifying methods for limiting the risk of fire damage to poles would be a more practical approach to maintaining system reliability in the face of increasing fire danger. One of the most important aspects of this process is better right of way vegetation management. This is essential regardless so the material used to support overhead lines. It will also be important to develop new treatments that protect poles against fire for the life of the pole as well as treatments that can be applied to in-service poles to increase their fire resistance.

Developing initial fire retardant treatments for long term exterior exposure is challenging. While there are several exterior fire retardants on the market for wood in houses, wood poles present special challenges. First, they are either treated with petroleum based solvents that are inherently flammable or they are treated with metal based preservatives containing chromium or copper that will slowly combust once ignited (Preston et al., 1993). Furthermore, poles in very dry areas may develop wide, deep checks that can act as chimneys to accelerate burning. In addition, treatments must last the 60-80 years in which a pole remains in service. Finally, unless a separate process is employed to limit treatment to the surface, a substantial amount of the intended fire retardant will be delivered to the interior where it will serve little purpose except as a possible long term reservoir for replenishing chemical on the surface. An alternative approach would be to develop fire retardant wraps or barriers that could be applied immediately after treatment. This approach is being applied in Western Australia with some success (Powell, personal communication). Developing effective fire retardant systems for new poles should be a research direction for chemical companies and the electric utility industry, but it is a long range goal. Given the long time required to replace all poles already in service (using an estimated 60-80 year pole service life), it will be equally important to address protecting millions of poles already in service.

In Service Pole Protection: Protecting poles against fire is not a new concern. Utilities have attempted to use various methods for limiting pole fire risk. Many utilities have considered placing thin steel sheets around the poles at groundline. These barriers can provide fire resistance; however, they tend to trap moisture and create conditions for development of extensive surface decay between the steel sheet and the wood. They can also make it more difficult to climb a pole (depending on how far up the pole they are placed). In addition, it is unclear whether these sheets would be completely protective against the charring that can occur with copper based preservative systems such as chromated copper arsenate, ammoniacal copper zinc arsenate or alkaline copper quaternary systems. The metals in these systems can ignite following relatively short, but intensive fires and will continue to smolder until the pole fails. The metal sheet would protect the wood from direct flame, but would also readily transmit heat to the wood and could ignite the metal, thereby negating any protective value.

Another alternative for fire protection is to apply a protective coating to the pole surface. Fire retardant coatings have long been available for this application; however, interest in these materials has increased as utilities become aware of their potential exposure to fire risk. These materials need to be relatively inexpensive and easy to apply in the field. Given the high cost of driving to a given structure, they must also be capable of providing protection for 5 to 10 years. There are a second group of protectants that are sprayed on the wood surface shortly before a pole is subjected to a fire. These systems were originally designed for temporary protection of houses and other high value assets and are applied just ahead of an advancing fire. Temporary coatings could also be applied to poles, but systems would be applied every time fire threatened a structure.

The wide array of possible fire protection products with varying claims of efficacy have created interest in developing improved methods for evaluating these systems. The simplest method for evaluating fire protection has been to place a measured amount of dry straw in a basket surrounding a pole, light the straw and allow the test to proceed until the pole ceases to burn (Figure III-8) (Love and Morrell, 2009; Morrell and Rhatigan, 2000; Preston et al., 1993). The depth and area of char provide measures of fire resistance. This method is simple to use, but it has a number of drawbacks. The results can vary widely depending on the conditions at the time of test. Relatively minor changes in relative humidity, temperature or wood MC can markedly alter the results. Although the straw can be uniformly dried prior to the test, even the straw placement can affect the intensity of the burn. As a result, test results can vary widely with time of year and this makes it difficult to compare results from different tests.

Test uniformity can be improved by using a gas burner as the heat source (Figure III-9) (Love and Morrell, 2009). The flame intensity can be standardized to produce a specific flame size and temperature, thereby reducing some of the variability. However, the test is still prone to some variability as a result of wind, relative humidity, and wood MC.

Figure III-8. Example of straw in a wire mesh basket surrounding a pole with a candidate fire retardant wrap.

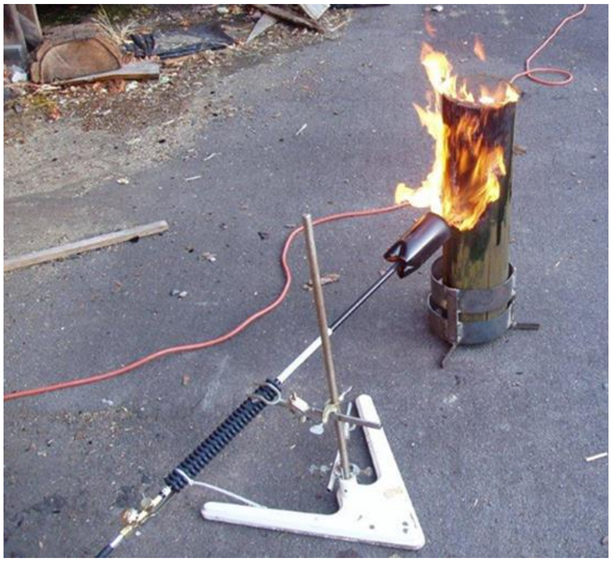

Figure III-9. Example of a fire test system using a weed burner as the heating source.

More recently, work has been underway in Australia to assess the fire resistance of wood poles of various species (Gardner and White, 2009). As a part of this work, a standard was developed that used more reproducible methods for developing fire conditions. The apparatus uses heaters that create an intense flame with a chimney effect to encourage burning. While this system is highly effective, it is also a fairly sophisticated device that would be expensive to construct and would be less than ideal for assessing poles in the field. This approach would limit fire testing to a few highly specialized facilities across North America and would sharply reduce the ability to economically evaluate a wide array of fire retardant systems.

There is a critical need for the development of a simple, mobile system for assessing the effectiveness of both initial and supplemental fire retardants on poles. The system would:

1. Employ standard materials
2. Test small pole sections
3. Produce reproducible heating
4. Have a relatively low cost

The device that is being tested uses a stainless steel shield to contain the heat as close to the pole as desired (Figure III-10). Two infrared heating elements are placed along the stainless steel walls. A thermocouple is placed into the pole from the backside (non-heated side) of the pole to within 6 mm of the pole surface on the heat-exposed face. This thermocouple is connected to a data-logger to record temperature during exposure. In addition, an infrared scanner is used to monitor temperature of the air between the heating elements and the wood. The system allows the pole surface to be heated incrementally with the ability to determine maximum temperatures as well as surface temperatures over the exposure period. In preliminary testing, poles were allowed to burn for 20 minutes after ignition (they could also be run to failure of a system). The degree of protection afforded by a given treatment can be assessed by determining depth of char and the area burned. In addition, thermal data can provide clues as to how a given system performed, although characteristics such as time to ignition may not be useful since some treatments may actually begin to react much earlier in order to form a protective char layer.

The device was first evaluated on a limited number of poles without supplemental fire protection (Figure III-11). Penta-treated Douglas-fir pole stubs (~150 mm diameter by 1 m long) were conditioned to approximately 6% MC before being tested. The device was placed 150 mm away from the pole and the test was initiated. Infrared readings were taken every 10 seconds until ignition, then the flames were allowed to continue for 20 minutes before being extinguished. The system allows the test conditions to be varied in terms of heat intensity, proximity to the heating source, and time of heat exposure.

The poles rapidly ignited and continued to burn until they were extinguished. The test apparatus was simple and very inexpensive to construct. The total cost for the assembly was less than $200 and provided a system that was easy to move, reproducible, and simple to operate. Further tests are underway using fire retardant treated materials.

Figure III-10 Example of a potential small scale fire test apparatus showing the heating shield on a tripod and close up of the heating elements.

The system was used to evaluate poles receiving two external wraps (Brooks and CopperCare) along with three surface applied systems (FireSheath, FireGuard, and SunSeeker). The tests were run as previously described. Following the tests, the area charred by the fire was estimated, then the depth of char was measured by scraping away the charred wood until sound, non-charred wood was visible (Figure III-12). The depth of the wood removed was then measured to the nearest mm. One other approach would be to use loss in circumference; however, this figure is less useful because the current test apparatus only applies heat to one face of the pole and the poles are not allowed to burn to completion. Thus, any loss in cross section is limited by the surface area exposed. These tests are continuing and only one pole treated with each system has been evaluated.

Time to ignition was 10 minutes for the non-protected control and only slightly longer for the SunSeeker (12 minutes) (Table III-8). The remaining systems did not ignite although they did experience surface charring on either the barrier or the applied film (Table III-8). Thus, time to ignition may not be as useful for assessing efficacy. The maximum temperatures measured near the wood surface were 365°C for both the non-protected control and the SunSeeker system. The CuCare barrier reached a temperature of 271°C, while the remaining treatments reached temperatures between 182 and 197°C. The systems also affected the heating pattern observed (Figure III-13).

Figure III-11. Example of the fire test apparatus being applied to a pentachlorophenol treated Douglas-fir pole showing initial heating, the beginning of combustion with smoke and finally, the pole on fire.

Poles treated with the barrier systems (Brooks and CuCare) both tended to experience charring of the barrier, however, there was little damage beneath the burned barrier (Figures III-14 to III-17). This would necessitate replacement of the barrier, but the pole would remain sound and free of damage. The Fire Guard and Fire Sheath systems both also experienced charring of the film, but relatively little damage beneath the surface. As with barriers, these systems would need to be reapplied to provide continued protection. The SunSeeker system provided the lowest degree of protection. It is unclear whether the addition of a thicker coating of SunSeeker would have helped this system perform better, however, the system provided little protection at the rate applied.

The final measures of treatment efficacy were the maximum char depth and char area (Table III-8). Fire Guard along with the Brooks and CuCare barrier systems all experienced less than 1 mm of charring, while the FireSheath experienced 2 mm of charring. The SunSeeker system experienced 5 mm of charring compared with 8 mm of char for the control. Char area was more variable, with the FireGuard and Fire Shield treated poles experiencing 20 and 90 cm^2 of char area, compared with the entire surface for the control and SunSeeker treated poles. The Brooks and CuCare wraps experienced 480 and 200 cm^2 of char area; however, as the photos illustrated, the char was confined to the barrier itself, which acted as a sacrificial shield for the wood beneath. Char area may be a less useful method for assessing fire resistance because the damage can be extensive but superficial. In addition, some systems may char quickly as a means for limiting further fire ingress, artificially inflating the area.

These results should be viewed as preliminary in nature; however, they demonstrate that the fire system can be used to rapidly evaluate a variety of materials on poles. Further tests are planned the coming months and will be reported in the next annual report.

Figure III-12. Example of char scrapped from the pole surface to reveal non-burned wood beneath.

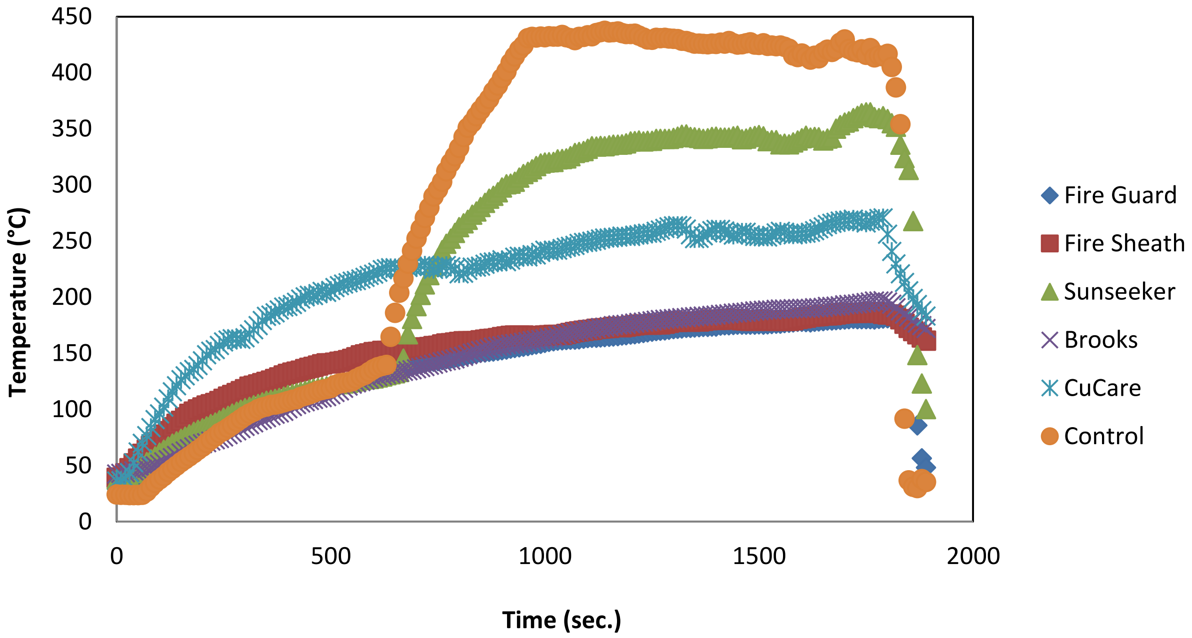

Figure III-13. Heating rates on the surface of poles treated with various fire-retardant systems.

Figure III-14. Brooks fire retardant wrap after test showing charred area of the barrier that protected the pole from fire.

Figure III-15. CopperCare barrier system showing damage to the barrier but only slight charring beneath after the barrier was removed.

Figure III-16. Example of SunSeeker fire retardant treated pole on fire and pole condition after the fire.

Figure III-17. Example of a FireGuard treated pole section showing slight charring where the barrier was sacrificed.

Table III-8. Characteristics of pole sections treated with various surface fire retardants and exposed to a fire test.

Treatment	Char Area (cm^2)	Char Depth (mm)	Ignition	Ignition Temp (°C)	Time to Ignition (Min)	Maximum Temperature (°C)
None	Total	8	Yes	145	10	438
FireGuard	20	>1	No	-	-	182
Fire Sheath	90	2	No	-	-	187
SunSeeker	Total	5	Yes	157	12	365
Brooks Barrier	480	>1	No	-	-	197
CuCare Barrier	200	>0.5	No	-	-	271

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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 losses 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 from the surrounding soil.

For many years, the pastes used for this purpose incorporated a diverse mixture of chemicals including pentachlorophenol, potassium dichromate, creosote, fluoride and an array of insecticides. The 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 Objective IV. The primary goal of Objective IV is to assess the laboratory and field performance of external preservative systems for protecting the below-ground portions of wood poles, but we also address the ability of physical barriers to restrict moisture uptake and/or chemical loss.

A. Previous External Groundline Treatment Tests

Over the past 20 years, we have established a number of field trials of external groundline preservative pastes on pole stubs at our Peavy Arboretum field test site or on poles within active utility lines. Most of these trials have been completed. A summary of these trials can be found in Table IV-1 along with references to the last annual report for which results are presented.

B. Effect of External Barriers on Pole Performance

Preservative treatment is a remarkably effective barrier against biological attack, but these same chemicals can be susceptible to migration into the surrounding soil. A number of studies documenting the levels of chemical migration have shown that the migration occurs for only a short distance around a treated

Table IV-1. Summary of completed tests evaluating external groundline preservatives.

Location	Year Initiated	Wood Species	Initial Treatment	Treatments Tested	Manufacturer	Final Report
Corvallis	1989	Douglas-fir	None	CuNap Wrap	Tenino (Viance)	1996
				CuRap 20 II	ISK Biosciences	
				Pol Nu	ISK Biosciences	
				Cop-R-Wrap	ISK Biosciences	
				CRP 82631	Osmose Utilities Services	
Corvallis	1990	Douglas-fir	None	CuRap 20	ISK Biosciences	1993
				PAtox II	Osmose Utilities Services	
				CuNap Wrap	Viance	
Merced, CA	1991	Douglas-fir W redcedar Western pine	Penta	CuNap Wrap	Viance	2002
				CuRap20	ISK Biosciences	
				Patox II	Osmose Utilities Services	
Binghamton, NY	1995	W. redcedar S. pine	Penta creosote	CuRap 20	ISK Biosciences	2003
				CuNap Wrap	Viance	
				Cop-R-Wrap	ISK Biosciences	
Corvallis	1998	Douglas-fir	None	Propiconazole	Janssen Pharmaceutica	2003
				D. Wolman Cu/F/B	BASF	
				CuRap 20	ISK Biosciences	
Beacon, NY	2001	S. pine	Penta	Cop-R-Plastic	Osmose Utilities Services	2009
				Pole Wrap	Osmose Utilities Services	
				Dr. Wolman Wrap C/F/B	BASF	
				Dr. Wolman Wrap Cu/B	BASF	
				CobraWrap	Genics, Inc	
				Cobra Slim	Genics, Inc	
Douglas, GA	2004	S. pine	Creosote	CuBor	Copper Care Wood	2010
				CuRap 20	ISK Biosciences	
				Cobra Wrap	Genics, Inc	
				Cop-R-Plastic	Osmose Utilities Services	
				Pole Wrap	Osmose Utilities Services	

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. As might be expected, poles 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 such that the tops of the barriers extend 150 mm above the soil level. These pole sections were then sampled for wood moisture content (MC) 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-1). The poles were each sampled prior to installation to determine chemical penetration and retention and baseline MC. Five poles received a Biotrans liner that extended 150 mm above groundline; five received a Biotrans liner that extended 300 mm above groundline and eleven poles were left without liners.

The poles were sampled 6, 12, 18, 42, 45 and 77 months after installation by removing three increment cores from a single location 150 mm below groundline. 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 MC. The sampling holes were plugged and any damage to the external coating was repaired to limit the potential for moisture to move into the wood through the sample holes.

Figure IV-1. Example of a Biotrans liner at the Peavy Arboretum test site.

Initial MC of the poles was approximately 30%, which is near the fiber saturation point for Douglas-fir (Table IV-2). These conditions are barely suitable for fungal attack. Moisture contents 6 months after installation had increased for all three treatments especially in the outer 25 mm of the pole. These samples were removed at the end of our wet season. The test site receives approximately 1.1 m of rainfall per year, but most of this rain falls between November and May. The soil at the field site becomes extremely wet and the water table approaches the surface in some areas. This should create conditions for extreme wetting of non-protected poles. However, the Biotrans liners should limit that potential. The results suggest that water running down the poles was entering the wood to increase the wood MC.

Moisture contents in samples taken from non-wrapped poles at the end of the dry season were less than 30% and levels were lowest near the surface. Moisture levels in poles with the liners tended to approach 45% near the wood surface. Moisture contents 18 months after installation followed patterns similar to those found at 6 months. Poles without barriers had moisture contents over 45 % at the surface, while poles with liners had even higher moisture contents (60 % for the liner that extended 300 mm above groundline), suggesting that the liners tended to retain moisture.

Moisture patterns at 42 and 45 months followed similar trends with higher moisture levels at the end of the rainy season in poles with no barriers and relatively little difference in MC in poles with the barrier that extended 300 mm above ground. Moisture levels in poles with barriers extending 150 mm above groundline tended to be similar to those found with poles with no barriers.

Moisture contents at 77 months followed trends similar to previous assessments, although moisture contents in poles with no barrier tended to be lower at groundline than poles with barriers (Figure IV-2). Moisture contents in pole centers tended to be more stable for the first 42 months of the test; interior moisture contents were higher at 45 months and slightly lower at 77 months.

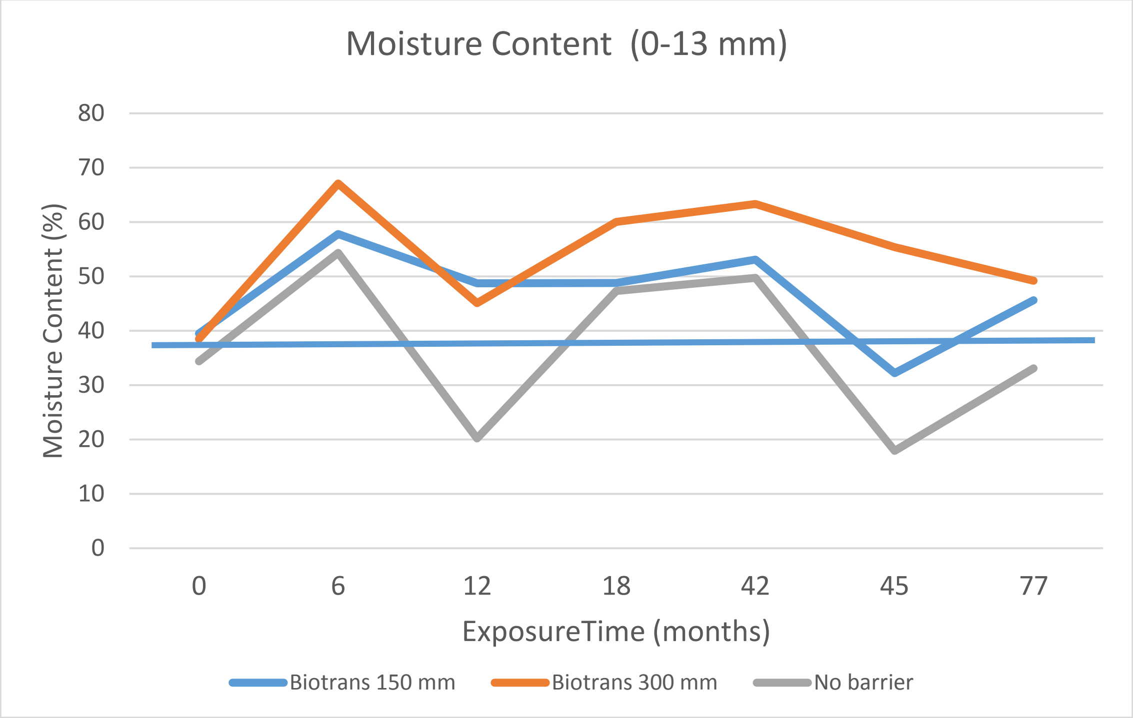
While there was an initial tendency for the barrier to hold moisture within the pole, there was also evidence that moisture contents cycled with season in poles with barriers and were not building up to extremely high levels. The potential for extremely high moisture contents was a concern when these barriers were first proposed for poles. Elevated moisture contents would not necessarily be a risk since moisture contents above 100 to 120% would limit the presence of oxygen in cell lumens and this would reduce fungal attack potential. However, barriers might shift the location of any decay and this might necessitate changes in inspection practices to ensure decay detection before substantial damage occurred. The moisture levels present in poles with barriers have tended to be slightly higher than those without, but the differences have been small.

The differences in moisture contents between barriers set to 150 mm above groundline versus those set 300 mm above that zone were also surprising. Both barriers should restrict the potential for moisture to move into the zone below the groundline, thereby limiting moisture ingress to water running down the poles and entering the below ground area through checks. It is unclear why placing the barrier slightly higher up the pole would reduce that potential. But it does suggest that there is some advantage to placing the barriers above the groundline.

Table IV- 2. Moisture contents at groundline at selected depths from the surface of poles with and without a barrier wrap.

Barrier	Exposure (Months)	Average Moisture Content (%)[a]			
		0-13 mm	13-25 mm	25-50 mm	50-100 mm
Biotrans (150 mm)	0	**39.5**	**35.1**	**34.0**	**33.5**
	6 (wet)	**57.8**	**48.1**	**37.6**	**37.7**
	12 (dry)	**48.7**	**35.6**	**35.7**	**34.6**
	18 (wet)	**48.8**	**40.6**	**34.7**	**31.6**
	42 (wet)	**53.1**	**42.7**	**47.6**	**46.2**
	45 (dry)	**32.2**	28.7	**32.3**	**34.4**
	77 (wet)	**45.6**	**41.3**	**66.3**	**53.4**
Biotrans (300mm)	0	**38.5**	**32.2**	**32.2**	**40.3**
	6 (wet)	**67.1**	**49.5**	**38.8**	**35.5**
	12 (dry)	**45.1**	**34.6**	**33.3**	**33.1**
	18 (wet)	**60.0**	**40.1**	**37.4**	**36.5**
	42 (wet)	**63.3**	**47.4**	**45.8**	**53.5**
	45 (dry)	**55.4**	**36.7**	**37.0**	**37.2**
	77 (wet)	**49.2**	**36.8**	**35.9**	**41.1**
None	0	**34.4**	28.9	27.2	29.1
	6 (wet)	**54.3**	**47.1**	**42.1**	**43.7**
	12 (dry)	20.2	28.7	28.8	29.5
	18 (wet)	**47.3**	**34.7**	**31.5**	**31.7**
	42 (wet)	**49.7**	**45.4**	**62.6**	**61.1**
	45 (dry)	17.9	24.7	**39.9**	**63.5**
	77 (wet)	**33.1**	29.3	**38.0**	**32.6**

[a] Values represent means of 6 measurements per location. Figures in bold are above 30 % moisture content (the approximate fiber saturation point for wood).



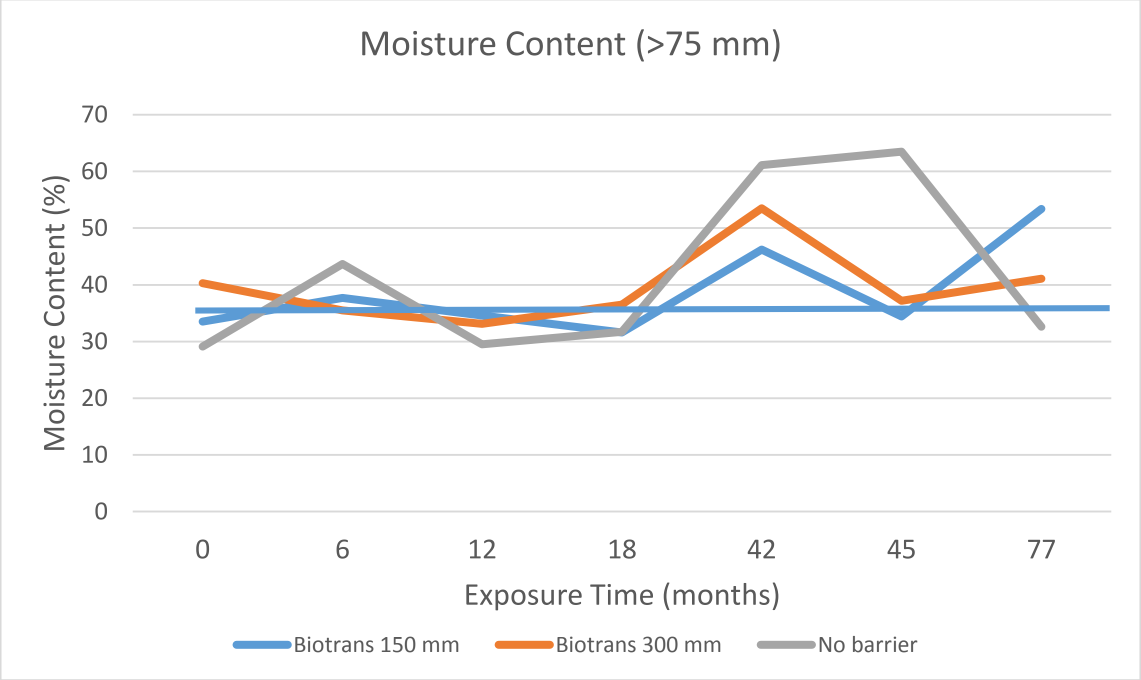


Figure IV-2. Moisture contents in the outer (0-13 mm) and inner (>75 mm) zones of pentachlorophenol treated Douglas-fir poles with or without a Biotrans liner set so the liner top was 150 or 300 mm above the groundline. The line at 30% represents the approximate fiber saturation point.

C. 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 Fall of 2010, we installed a field test of poles with and without liners to address the following objectives:

- Assess the ability of external barriers to retard preservative migration from poles in soil contact.
- 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 a target retention of 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. Additional non-treated poles were included in the test as controls. The pole sections were sampled using an increment borer prior to setting 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 half of the poles will be used for monitoring potential migration of preservative components into the surrounding soil, and the other half will be used for measuring wood MC above and below the barrier.

Wood MC was assessed at the time of installation, then 14, 22, 33 and 60 months afterward. At each time point, increment cores were removed from one side of each pole beginning 150 mm below groundline, then moving upward to groundline, and 300 and 900 mm above groundline. Each increment core was divided into zones corresponding to 0 to 25 mm, 25 to 50 mm, 50 to 75 mm and 75 mm to the pith. Each core section was placed into a tared glass vial which was sealed and returned to the lab where the cores were weighed, oven dried and reweighed to determine wood MC. The sampling holes were plugged with wood plugs and the liner repaired. These results will be used to develop MC profiles over time for lined and non-lined poles.

Moisture contents of the penta treated Douglas-fir poles were below 30% at all four sampling locations and ranged from 9.7% in the outer zone of the lined poles to 26.7% in the inner zones of the non-lined poles at the time of installation (Table IV-3). Non-treated southern pine poles without liners followed similar trends. Moisture contents of penta-treated southern pine poles tended to be higher than the Douglas-fir poles, ranging from 22.3% in the outer zone to 54.3% in the inner zone. The differences in initial MC between penta-treated pine and Douglas-fir may reflect differences in post-treatment drying processes. The pine poles were kiln-dried while the Douglas-fir poles were dried using a combination of air seasoning and Boultonizing (boiling in oil under vacuum). The kiln process used for southern pine is fairly aggressive and can be manipulated to dry the outer shell. Air-seasoning and Boultonizing tend to produce a more uniformly seasoned pole. This is less important in pine, which will tend to have a deeper zone of treatment that is more forgiving of checks that might develop after treatment. It is essential for Douglas-fir, because deep checks that develop after treatment will invariably expose non-treated wood to fungal attack and eventual internal decay.

Table IV-3. Moisture contents at the time of installation at selected distances from the surface in Douglas-fir and southern pine poles with various treatments with or without a field liner.

Species	Treatment	Liner	Moisture Content (%)			
			0-25 mm	25-50 mm	50-75 mm	>75 mm
Douglas-fir	Penta	+	10	19	25	26
		-	11	19	25	27
Southern Pine	CCA	+	37	59	84	81
		-	29	44	42	60
	None	-	13	20	26	26
	Penta	+	22	38	41	42
		-	24	38	40	54

Moisture contents of CCA treated southern pine were well above those found in the penta treated poles, reflecting the introduction of large amounts of water in the treating process. Moisture contents in the inner zone were over 80% at the time of installation.

Although there were sometimes large differences in MC between species and treatments, there were no differences between lined and non-lined poles with the same treatment.

Moisture contents of the poles 14 months after installation again varied with initial treatment and wood species (Table IV-4; Figures IV-3-5). This sampling occurred at the end of our long, dry season and the results reflect that prolonged drying. Moisture contents for both non-treated and penta-treated Douglas-fir poles were below 35% and most were below 20%. Moisture contents were slightly higher near the groundline, but conditions were generally not suitable for fungal growth. There also appeared to be no difference in moisture contents for penta-treated Douglas-fir poles with and without a liner.

Non-treated southern pine poles tended to have higher moisture contents at groundline than Douglas-fir. Pine is more permeable and susceptible to fungal attack and the higher moisture contents could reflect both the greater tendency of this species to absorb water and the potential for fungal colonization to further enhance permeability. Moisture contents of penta-treated southern poles were higher than those for Douglas-fir at or below groundline and ranged from 28 to 45%. Moisture contents 300 and 900 mm above groundline were lower than those at groundline but still higher than those for Douglas-fir. There appeared to be no consistent differences in moisture contents between poles with and without barriers. Moisture contents for CCA treated southern pine were higher than those found with penta treated poles of the same species, reflecting the tendency of this treatment to increase hygroscopicity of the wood, but there were no noticeable differences in moisture contents between poles with and without barriers.

Sampling of poles 22 months after installation at the end of the wet season indicated that the trends with regard to wood treatment and species were the same as those found after 14 months (Table IV-5; Figures IV-3-5). Moisture contents were much higher than those found at 14 months with levels in the inner zones of non-treated southern pine poles exceeding 100% below groundline. This test site has poor drainage and tends to collect water during the wet season. This creates ideal conditions for moisture uptake. In addition, regular rainfall creates ample opportunity for water to run down the pole in checks to the pole base where it can be more slowly absorbed by the wood. Over time, we might expect moisture contents in poles with the field liners to increase because of the limited opportunities for drying. However, there appear to be few consistent differences in moisture contents between poles with and without field liners.

Moisture contents in poles 33 months after installation tended to be lower than those found at 14 or 22 months (Table IV-6, Figures IV-3-5). Wood moisture contents tended to be over the fiber saturation point at or below groundline, but levels dropped off sharply above that zone. There appeared to be little difference in MC with or without a barrier for the same treatment and species combination.

Once again, moisture levels tended to be higher in southern pine poles, regardless of treatment, possibly reflecting the more permeable nature of this wood species. There appeared to be little difference in MC with preservative treatment on pine.

Moisture contents 60 months after installation tended to be much higher than those found in previous inspections (Table IV-7; Figure IV-3-5). This was interesting because rainfall in this year was slightly below average, suggesting that wood moisture levels might be lower than normal. Moisture levels at several locations were over 100% in CCA and penta-treated southern pine poles. They were also over this level in many of the non-treated pine poles, but this reflects the presence of advanced decay that has left the wood spongy and more likely to absorb water. Moisture levels tended to be above 30% MC well above the groundline, particularly in pine poles. As in previous assessments, moisture levels tended to be lower in Douglas-fir poles, although the differences were sometimes slight. Furthermore, there were few consistent differences in moisture levels in poles receiving the same initial preservative treatment with or without a barrier wrap. These results suggest that the barriers are not appreciably altering the wood/moisture relationships in the groundline zone.

D. Evaluation of Selected External Preservative Pastes in a Small Block Laboratory Test

Over the past decade, we have examined a number of alternative preservative pastes using combinations of field trials and small block tests. The small block tests are tedious to set up, but provide some measure of the ability of paste components to diffuse into wood at levels that would confer protection against fungal attack under carefully controlled conditions. As a part of our efforts to better understand how systems perform using this small block procedure, the following test was performed. It is important to remember that these data are not intended to show one system to be better or worse than another. Rather, this method and the resulting data are presented to show how different systems behave and how the small block test can be used to characterize a system so that it can be further developed before proceeding to larger scale tests.

Freshly cut Douglas-fir boards (nominal 50 by 100 mm by varying lengths) that were free from knots or excessive resins and showed no evidence of prior colonization by mold, stain or decay fungi were selected for use and air dried. The lumber was cut into 150 mm lengths and a 25 mm diameter by 5 mm deep treatment well was cut into the approximate center of one tangential wide face of

Table IV-4. Moisture contents 14 months after installation at selected distances from the surface at various locations along the pole length in Douglas-fir and southern pine poles with various treatments with or without a field liner.

Species/ Treatment	Lined	Wood Moisture Content (%)															
		-150 mm				Groundline				+300 mm				+900 mm			
		0-25	25-50	50-75	>75	0-25	25-50	50-75	>75	0-25	25-50	50-75	>75	0-25	25-50	50-75	>75
DF (None)	-	**33**	**31**	28	**34**	24	20	26	**32**	17	17	22	24	16	20	22	25
DF-Penta	+	23	26	**31**	29	17	22	24	26	12	17	21	22	12	18	21	21
	-	24	29	**33**	**33**	16	24	26	28	14	19	21	21	13	17	21	22
Pine-CCA	+	**37**	**44**	**59**	**72**	29	**39**	**45**	**54**	20	24	**32**	**46**	19	23	27	**31**
	-	**33**	**46**	**46**	**52**	**31**	**50**	**48**	**49**	23	**32**	**31**	**34**	19	24	**35**	29
Pine (None)	-	**35**	**70**	**65**	**41**	**45**	**34**	**47**	**33**	20	19	23	24	17	16	28	18
Pine-Penta	+	**45**	**40**	**40**	**41**	**31**	**37**	**40**	**39**	22	29	**35**	**35**	22	26	**34**	**37**
	-	**43**	**49**	**44**	**44**	28	**34**	**37**	**40**	21	25	**31**	**32**	22	26	30	**31**

Table IV-5. Moisture contents 22 months after installation at selected distances from the surface at various locations along the pole length in Douglas-fir and southern pine poles with various treatments with or without a field liner.

Species/ Treatment	Lined	Wood Moisture Content (%)															
		-150 mm				Groundline				+300 mm				+900 mm			
		0-25	25-50	50-75	>75	0-25	25-50	50-75	>75	0-25	25-50	50-75	>75	0-25	25-50	50-75	>75
DF (None)	-	**33**	26	27	30	27	26	27	28	14	16	19	21	14	17	19	20
DF-Penta	+	30	**35**	**38**	**34**	**23**	**34**	**40**	**34**	15	26	28	27	18	26	28	26
	-	**35**	**46**	**50**	**42**	**26**	**43**	**42**	**33**	18	28	30	29	18	26	**37**	31
Pine-CCA	+	**53**	**59**	**72**	**77**	**37**	**49**	**57**	**68**	29	**32**	**33**	**35**	22	26	27	40
	-	**52**	**64**	**76**	**64**	**50**	**61**	**81**	**61**	30	**41**	**48**	**40**	23	**32**	**35**	30
Pine (None)	-	**59**	**72**	**104**	**86**	**68**	**68**	**60**	**44**	17	17	20	21	13	16	18	20
Pine-Penta	+	**59**	**52**	**49**	**46**	**44**	**50**	**54**	**50**	24	**41**	**45**	**43**	24	**36**	**37**	**37**

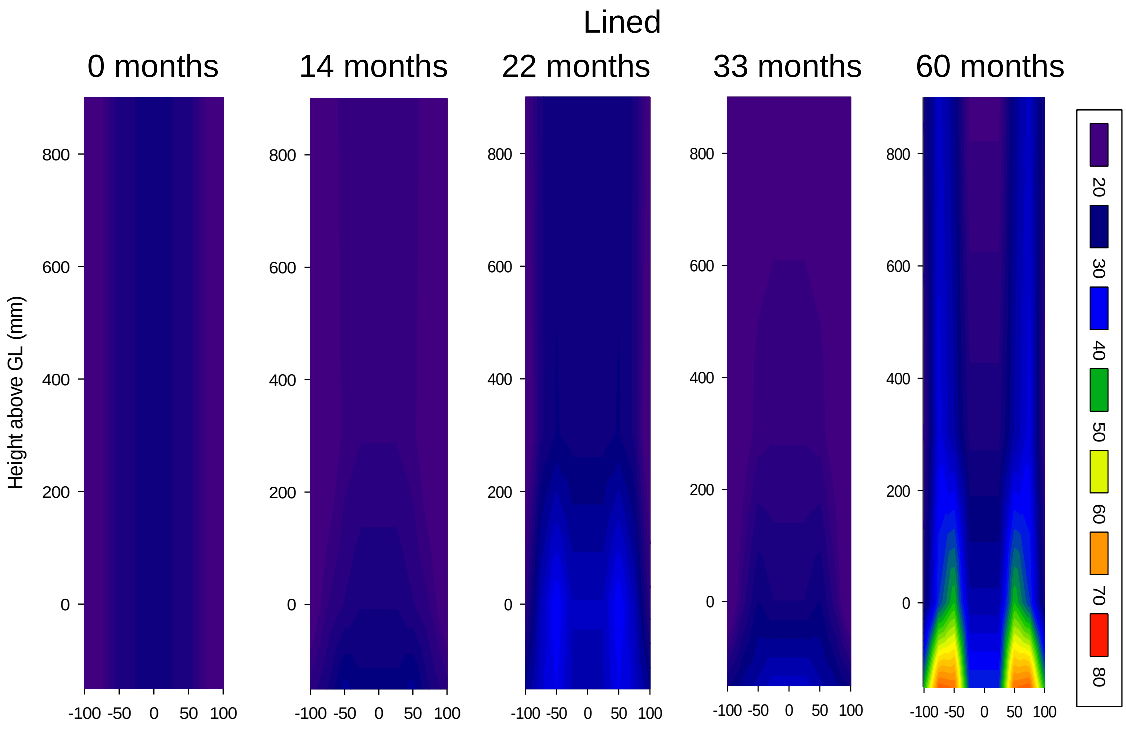
	-	**58**	**47**	**43**	**46**	**56**	**48**	**36**	**38**	20	29	**34**	**39**	21	**31**	**33**	**35**

Table IV-6. Moisture contents 33 months after installation at selected distances from the surface at various locations along the pole length in Douglas-fir and southern pine poles with various treatments with or without a field liner.

Species/ Treatment	Lined	Wood Moisture Content (%)															
		-150 mm				Groundline				+300 mm				+900 mm			
		0-25	25-50	50-75	>75	0-25	25-50	50-75	>75	0-25	25-50	50-75	>75	0-25	25-50	50-75	>75
DF (None)	-	**36**	**33**	29	30	24	25	26	26	14	17	19	20	12	16	18	17
DF-Penta	+	27	**31**	**32**	**35**	14	23	28	26	11	18	21	22	12	17	18	18
	-	25	30	**35**	**36**	18	25	29	**31**	11	19	21	23	11	18	20	20
Pine-CCA	+	**47**	**59**	**62**	**72**	24	**38**	**54**	**75**	13	19	24	27	12	16	17	16
	-	**36**	**50**	**63**	**64**	26	**36**	**42**	**48**	15	22	29	29	13	17	18	17
Pine (None)	-	**75**	**74**	**86**	**76**	**42**	**51**	**50**	**48**	15	20	27	24	14	18	22	21
Pine-Penta	+	**61**	**56**	**50**	**50**	29	**53**	**61**	**71**	18	**32**	**40**	**40**	22	29	**32**	**31**
	-	**64**	**55**	**49**	**50**	30	**41**	**39**	**40**	19	28	**32**	**36**	18	27	**31**	**35**

Table IV-7. Moisture contents 60 months after installation at selected distances from the surface at various locations along the pole length in Douglas-fir and southern pine poles with various treatments with or without a field liner.

Species/ Treatment	Lined	Wood Moisture Content (%)															
		-150 mm				Groundline				+300 mm				+900 mm			
		0-25	25-50	50-75	>75	0-25	25-50	50-75	>75	0-25	25-50	50-75	>75	0-25	25-50	50-75	>75
DF (None)	-	**52**	**76**	**63**	**40**	22	**48**	**43**	**34**	16	26	30	30	27	28	**45**	23
DF-Penta	+	**49**	**73**	**72**	**42**	26	**42**	**50**	**33**	22	**37**	**32**	25	26	**35**	30	19
	-	29	**53**	**76**	**84**	22	**39**	**57**	**37**	21	**38**	**50**	23	23	19	**42**	22
Pine-CCA	+	**86**	**122**	**124**	**116**	**34**	**47**	**67**	**76**	27	**40**	**42**	**32**	**36**	**37**	**34**	21
	-	**54**	**66**	**65**	**61**	**31**	**52**	**50**	**44**	**31**	**38**	**35**	**26**	**31**	**39**	**45**	19
Pine (None)	-	**99**	**85**	**133**	**131**	**50**	**54**	**72**	**63**	**32**	24	**54**	29	**33**	**32**	**35**	23
Pine-Penta	+	**105**	**97**	**105**	**73**	23	**48**	**71**	**78**	**24**	**42**	**44**	**48**	24	**42**	**43**	30
	-	**65**	**103**	**82**	**60**	**43**	**50**	**67**	**43**	**34**	**52**	**59**	**33**	**33**	**50**	**56**	**40**



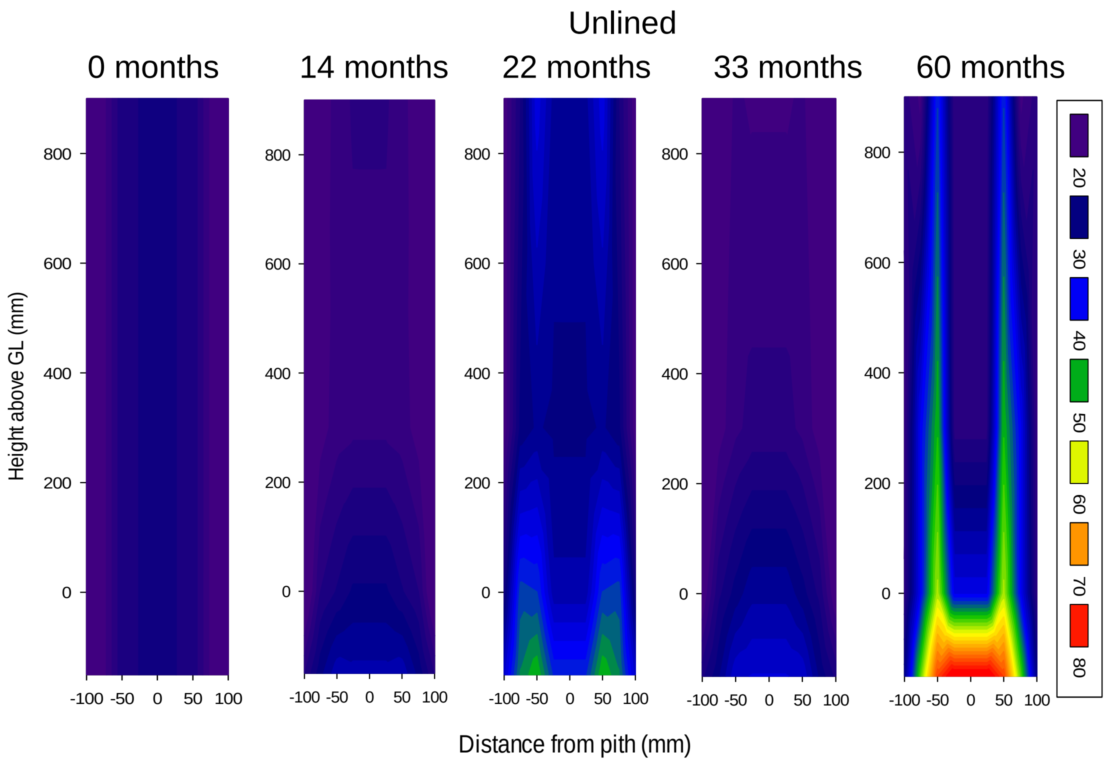


Figure IV- 3. Moisture contents in penta-treated Douglas-fir poles with or without a field liner after 0, 14, 22, 33, or 60 months in the ground at the Peavy Arboretum test site. These charts are extrapolated from data in Tables IV-4 to IV-7.

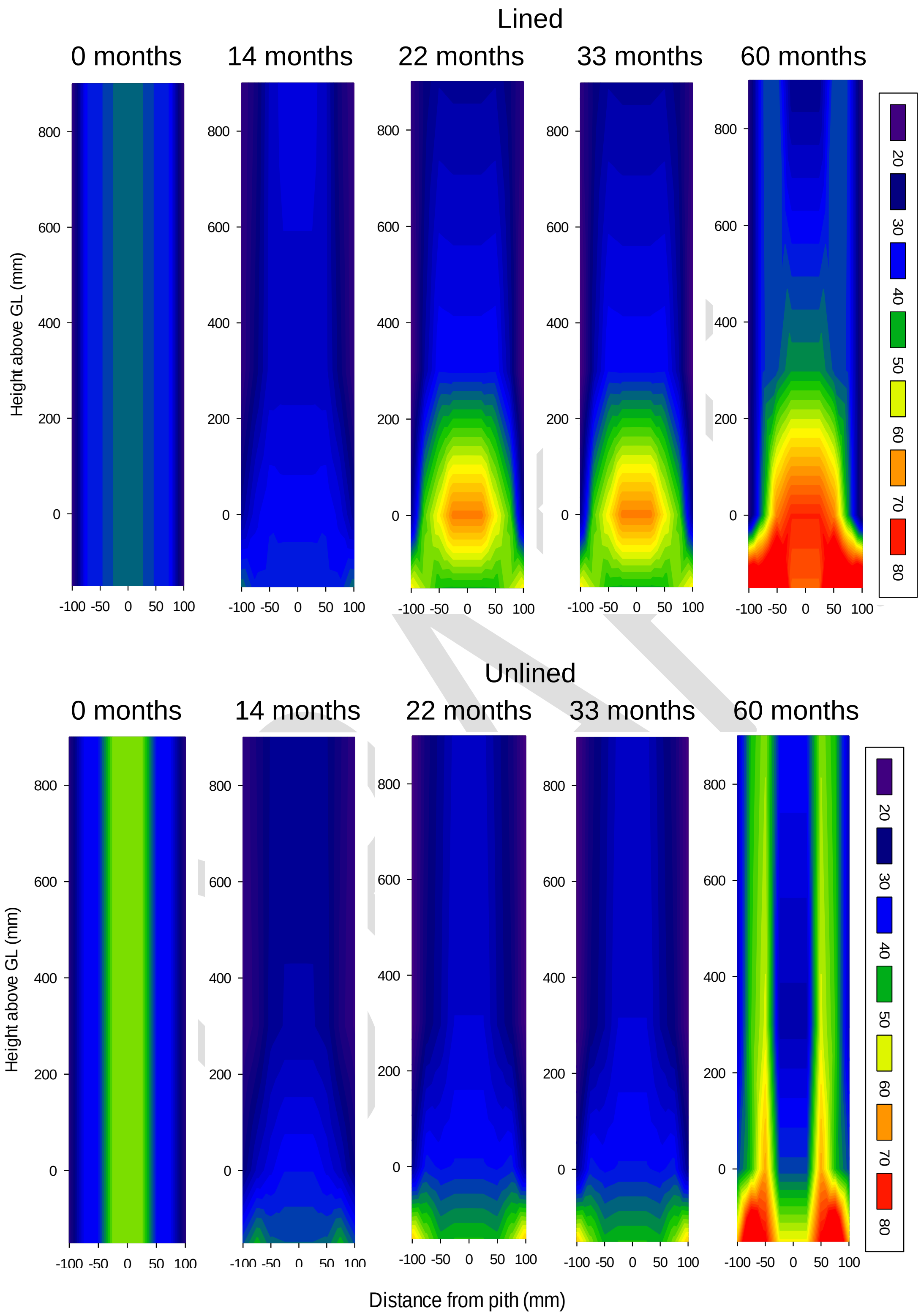


Figure IV- 4. Moisture contents in penta-treated southern pine poles with or without a field liner after 0, 14, 22, 33, or 60 months in the ground at the Peavy Arboretum test site. These charts are extrapolated from data in Tables IV-4 to IV-7.

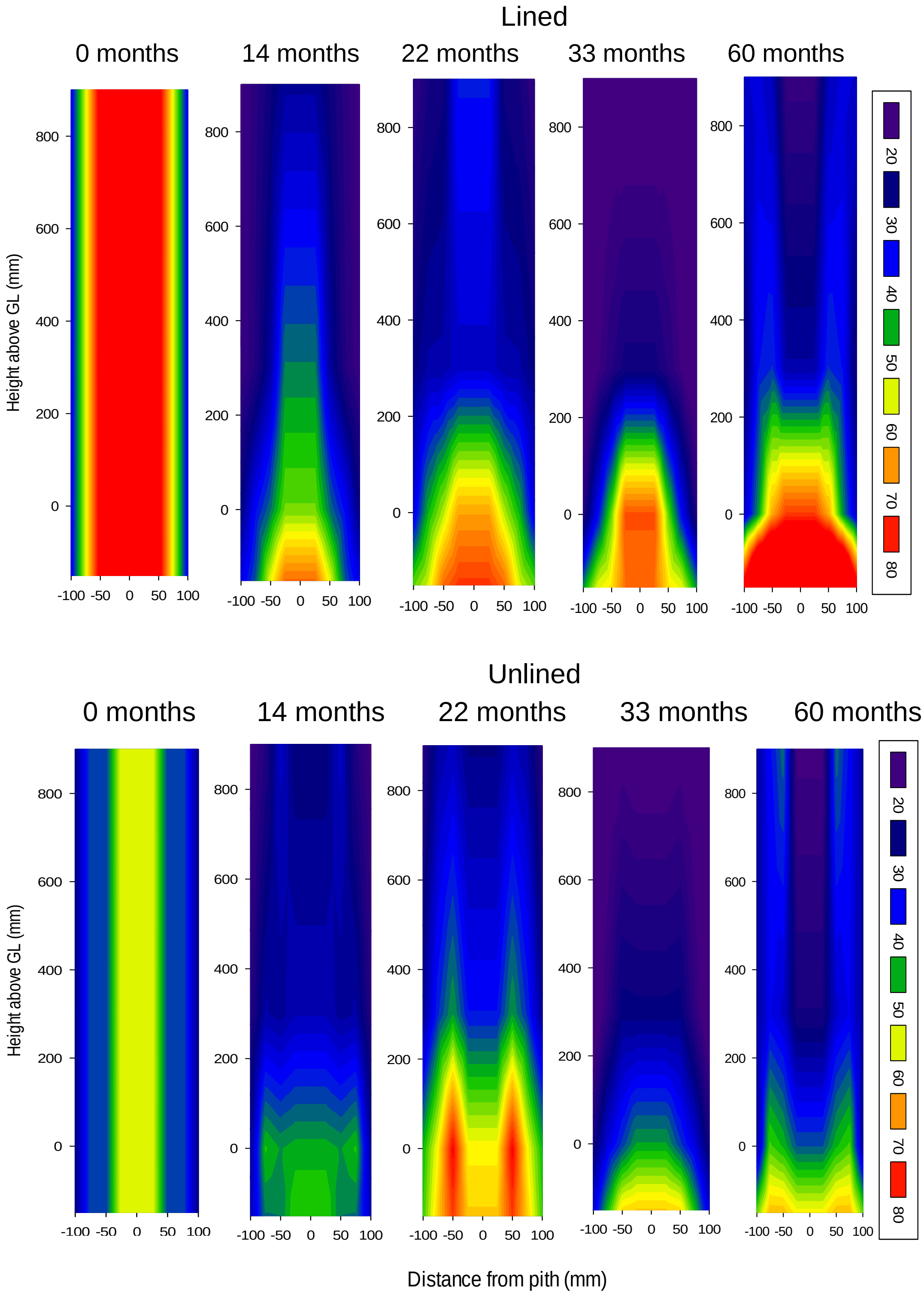


Figure IV- 5. Moisture contents in CCA-treated southern pine poles with or without a field liner after 0, 14, 22, 33, or 60 months in the ground at the Peavy Arboretum test site. These charts are extrapolated from data in Tables IV-4 to IV-7.

each block. This well provided a location in which the preservative paste could be applied. The samples were then oven-dried (60°C) and weighed.

Samples were wetted by submerging in water in pans and subjecting the pans to a 20 minute vacuum followed by a 30 minute pressure period to saturate the blocks. Blocks were weighed and randomly assigned to condition to either 30 or 60% MC. Samples were aerated and periodically weighed until each sample reached its target MC.

Once the block reached its target MC, a piece of duct tape was placed over the 5 mm deep treatment well and the block was dipped in molten paraffin to retard further moisture loss. The conditioned blocks were then placed in plastic bags and stored at 5°C for at least 2 to 3 weeks to allow moisture to become evenly distributed in the block.

The tape was removed from the treatment well and the block placed on a balance. The desired amount of preservative paste (Table IV-8) was added into the well, being sure to cover the entire bottom of the well with paste. Pastes were applied at 3 and 6 mm thicknesses. Once the desired amount of chemical was applied, the tape was replaced. A minimum of 3 replicates were prepared for each preservative formulation for each wood species and sampling time.

Treated blocks were placed in plastic bags with the end-grain upward to simulate a pole surface and incubated at 5°C to limit microbial growth that might confound results.

Table IV-8. Characteristics of external preservative paste systems used to evaluate a small scale block test.

Trade Name	Content	% Active
Paste A	Copper Naphthenate Sodium Pentaborate Decahydrate	18.16 40.00
Paste B	Copper Hydroxide Sodium Tetraborate Decahydrate	3.10 43.5
Paste C	Copper Hydroxide Boric Acid Disodium Octaborate Tetrahydrate	0.99 0.89 9.10
Paste D	Copper Naphthenate Disodium Octaborate Tetrahydrate	18.16 30.00
Paste E	Copper-8 Quinolinolate Sodium Tetraborate Decahydrate	0.30 43.70

Three blocks per treatment were destructively sampled after 6, 12, or 24 weeks of incubation to follow chemical movement from the surface inward. The tape was removed from blocks and as much chemical paste as possible was scraped from the well. The area beneath the well surface was sampled by cutting a 12 mm diameter plug perpendicular to the well face to 50 mm. The plug was cut into segments corresponding to 0 to 6, 6 to 13, 13 to 25, 25 to 38 and 38 to 50 mm from the paste-treated surface. Wood from a given zone was combined for the 3 blocks per treatment. The wood was ground to pass a 20 mesh screen and analyzed for the chemical constituents using the appropriate analytical method; copper was analyzed by x-ray fluorescence spectroscopy while boron was analyzed by hot water extraction followed by Azomethine H analysis.

Paste A has a long history of use as an external preservative paste and has served as our benchmark system for a number of years. Boron levels in Paste A samples were elevated in the outer 5 mm in 30 and 60% MC blocks 6 weeks after receiving 3 or 6 mm of paste (Figure IV-6). Boron levels were slightly higher in blocks receiving 6 mm of paste, but the differences were small. Boron levels also did not appear to be affected by MC. Boron levels further inward from the surface declined sharply.

Boron levels 12 weeks after treatment were lower in the outer 5 mm of blocks conditioned to 60% MC than at the 6 week point and similar in blocks conditioned to 30% MC. Boron levels further inward from the surface were elevated in blocks conditioned to both moisture levels. Boron levels were above the threshold for fungal protection 0 to 5 and 5 to 10 mm below the surface.

Boron levels 24 weeks after treatment were similar to those found after 12 weeks in the outer 5 mm, but increased in both the 5 to 10 mm and 10 to 20 mm assay zones. This suggests continued boron diffusion away from the surface. Boron levels were higher in blocks conditioned to 60% MC and treated with 6 mm of paste than in those receiving 3 mm of paste. The results indicate that the boron in this paste is moving well through the blocks and that blocks at the higher MC tended to facilitate more boron movement.

Boron levels in Paste C blocks incubated for 6 weeks after treatment tended to be higher in blocks receiving 6 mm of paste compared with the 3 mm thickness (Figure IV-7). There appeared to be little difference in boron levels in the outer 5 mm between blocks conditioned to 30% MC vs those conditioned to 60%. Boron levels were above threshold 5 to 10 mm from the surface in blocks at 60% MC, but only above threshold in 30% MC blocks when 6 mm of paste was applied. Results further inward indicate boron movement was better in the wetter blocks.

Boron levels in the outer 5 mm of Paste C treated blocks declined slightly with an additional 6 weeks of incubation, while boron levels increased in zones further inward. Boron levels in the outer 5 mm continued to decrease in blocks incubated for 24 weeks, particularly the wetter blocks. Boron levels in 60% MC blocks receiving the 6 mm thick dosage were similar 5, 10 and 20 mm from the surface, indicating that boron became more evenly distributed with time in the blocks with more moisture. The effect was less noticeable on blocks conditioned to 30% MC.

Boron levels in Paste D treated blocks were similar to Pastes A and C, although levels were slightly higher than those found with the other two systems (Figure IV-8). Boron did not move as readily into the inner zones with this treatment, although there was some indication of increased boron concentrations 5 to 10 mm from the surface.

Boron levels in Paste B blocks tended to be much lower than those found with the other systems although the concentrations were still above the threshold for internal protection (Figure IV-9). Boron levels remained fairly stable in the outer 5 mm zone over the 24 week incubation period, but they did increase steadily in the 5 to 10 and 10 to 20 mm assay zones indicating continued boron movement inward from the surface. Lower boron levels in this system could be viewed as a positive if they translated to a longer release period into the wood and a corresponding increase in the protective period. Conversely, results would be negative if boron that did not initially move into the wood was lost to the surrounding environment. This could only be verified with field testing.

Boron levels in blocks treated with Paste E followed trends that were similar to those found with the Paste B treated blocks 6 weeks after treatment (Figure IV-10). However, boron levels in the outer 5 mm of the blocks were similar after an additional 6 weeks of incubation but declined slightly after 24 weeks. There was one large anomalous spike in boron level 24 weeks after treatment of 30% MC blocks with 3 mm of paste, but this might have been due to contamination.

While there were differences in boron levels in all the treatments, boron was capable of moving into the outer 20 mm of the test blocks over 24 weeks of incubation. The test results also show the effects of MC on paste movement, which would also be important in field exposure.

Copper levels in Paste A treated blocks were elevated in the outer 5 mm but barely detectable further inward (Figure IV-11). Copper levels were similar in the outer 5 mm 6 or 12 weeks after treatment, but more variable at 24 weeks. There appeared to be no difference in copper levels with MC, while levels were higher in blocks receiving 6 mm of paste compared to the 3 mm thick treatment 24 weeks after treatment. The tendency of copper to be limited to the outer 5 mm is consistent with previous tests and illustrates the limited copper movement; this is not a problem because the role of copper is to create a surface barrier that limits renewed fungal attack from the surrounding soil.

Copper levels in Paste D blocks were much lower than Paste A and copper again was largely confined to the outer 5 mm (Figure IV-12). There also appeared to be little difference in levels with either MC or paste thickness. There was also little change in copper level with incubation time, suggesting copper moved into the area immediately beneath the application point but did not move into the blocks.

Copper levels were also low in the outer 5 mm of blocks treated with Paste C; however, copper did tend to move more deeply into the wood than in either Pastes A or D treated blocks (Figure IV-13). It is not clear whether this degree of copper movement is useful since the system also has boron, which tended to move well into the inner block zones; however, the results illustrate the usefulness of the small block test for characterizing the chemical behavior of various systems under controlled moisture conditions. Copper levels in Paste B treated blocks were higher than in the blocks treated with CopperBor, but lower than those found with blocks treated with Paste A (Figure IV-14). Once again, copper moved more deeply into the wood than Paste A treated blocks and there was little effect of either paste thickness or wood MC on copper level.

Copper levels in blocks treated with Paste E were much lower than those found with the other treatments; however, it is important to remember that the copper in this system is copper-8-quinolinolate, which is far more biologically active than other copper compounds (Figure IV-15). The copper in this system is not solubilized, although it will slowly solubilize to move into wood over time. As a result, we would expect the copper to initially form a layer on the outer surface. This would result in far lower levels of copper when a 5 mm zone from the surface is assayed. The need to obtain fairly sizable amounts of wood for analysis is one short-coming of this method when it is used on systems that are more strictly surface barriers such as the micronized copper. Another short-coming of this test is that it does not assess efficacy, just absolute levels of copper. One method for improving this method might be to assay a shallower zone, but this would require taking far more surface area to collect enough wood for analysis. There is also a continuing need to develop better threshold data on the various copper/boron combinations used in this application.

We will continue to develop this test method as means for assessing new external preservative systems with the ultimate goal of developing an accurate, reproducible system for rapidly evaluating new pastes. Once we have achieved this goal, we will pursue standardization under the American Wood Protection Association Standards.

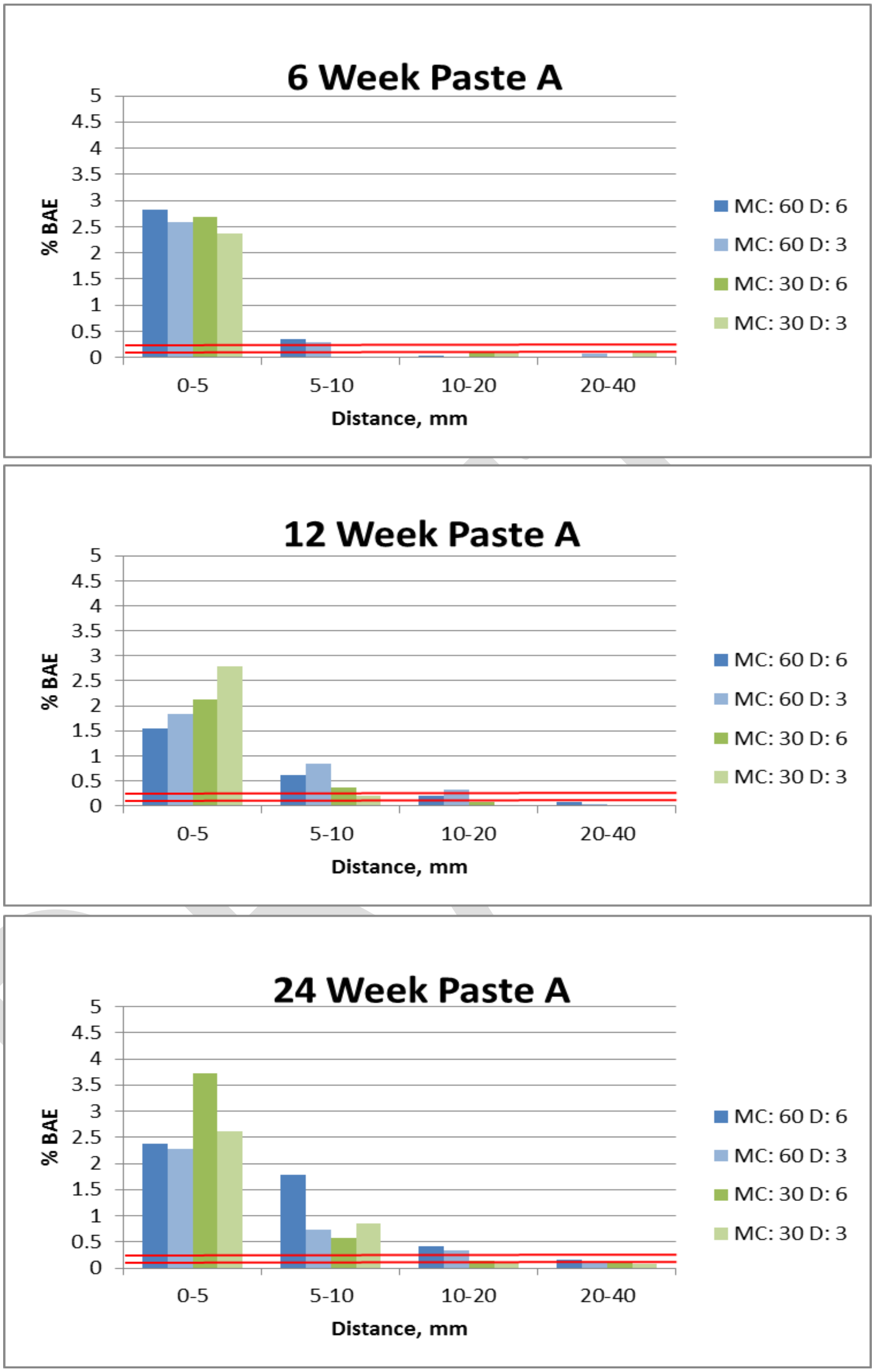


Figure IV-6. % BAE levels at selected depths in Douglas-fir sapwood blocks conditioned to 30 or 60% moisture content and sampled 6, 12 or 24 weeks after application of 3 or 6 mm thick layers of Paste A. Threshold lines for the outer zone (0-5 mm, 0.275% BAE) and inner zones (5-40 mm, 0.1% BAE) are represented in red.

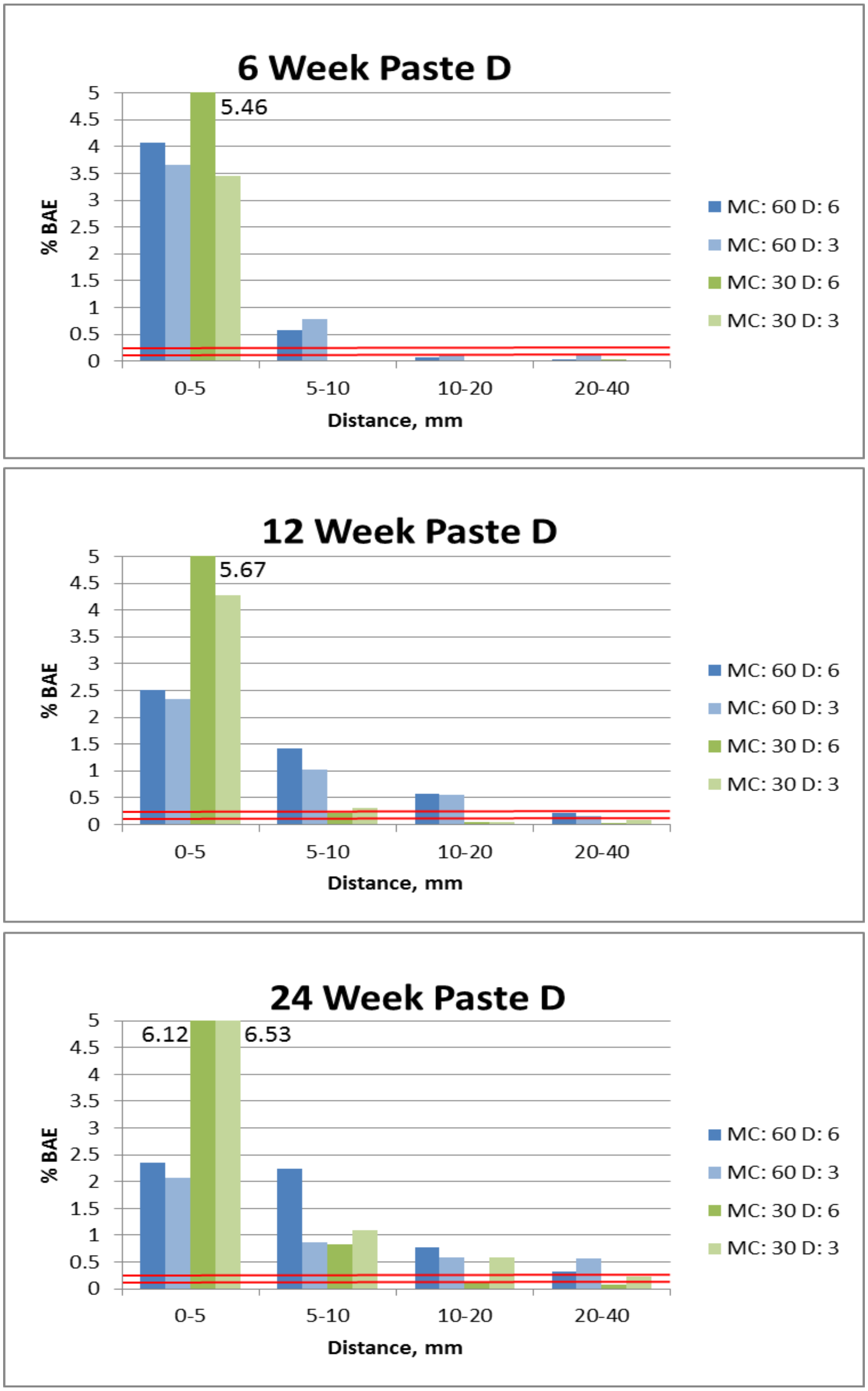


Figure IV-7. Boron oxide levels at selected depths in Douglas-fir sapwood blocks conditioned to 30 or 60% moisture content and sampled 6, 12, or 24 weeks after application of 3 or 6 mm thick layers of Paste D. Threshold lines for the outer zone (0-5 mm, 0.275% BAE) and inner zones (5-40 mm, 0.1% BAE) are represented in red.

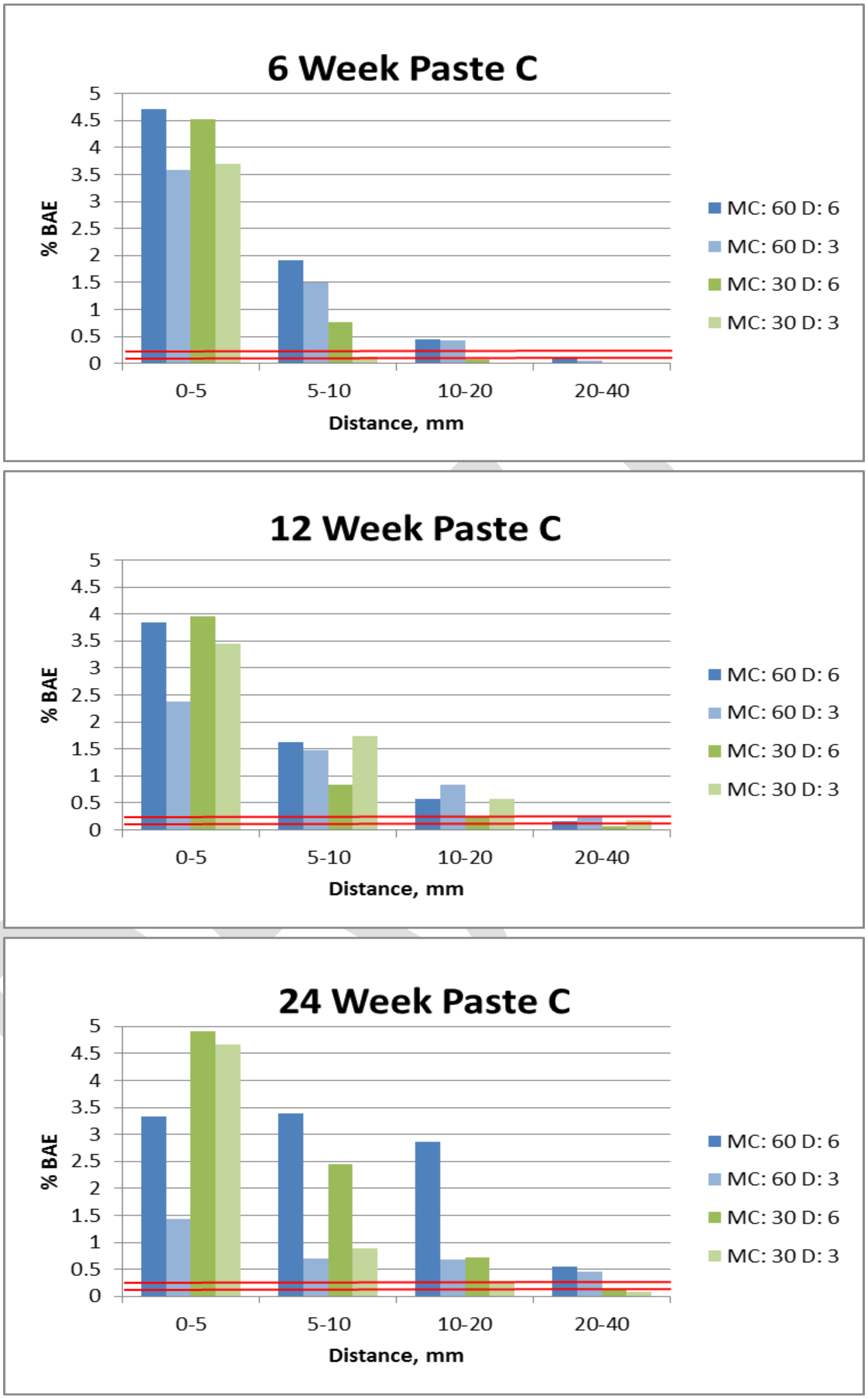


Figure IV-8. Boron oxide levels at selected depths in Douglas-fir sapwood blocks conditioned to 30 or 60% moisture content and sampled 6, 12 or 24 weeks after application of 3 or 6 mm thick layers of Paste C. Threshold lines for the outer zone (0-5 mm, 0.275% BAE) and inner zones (5-40 mm, 0.1% BAE) are represented in red.

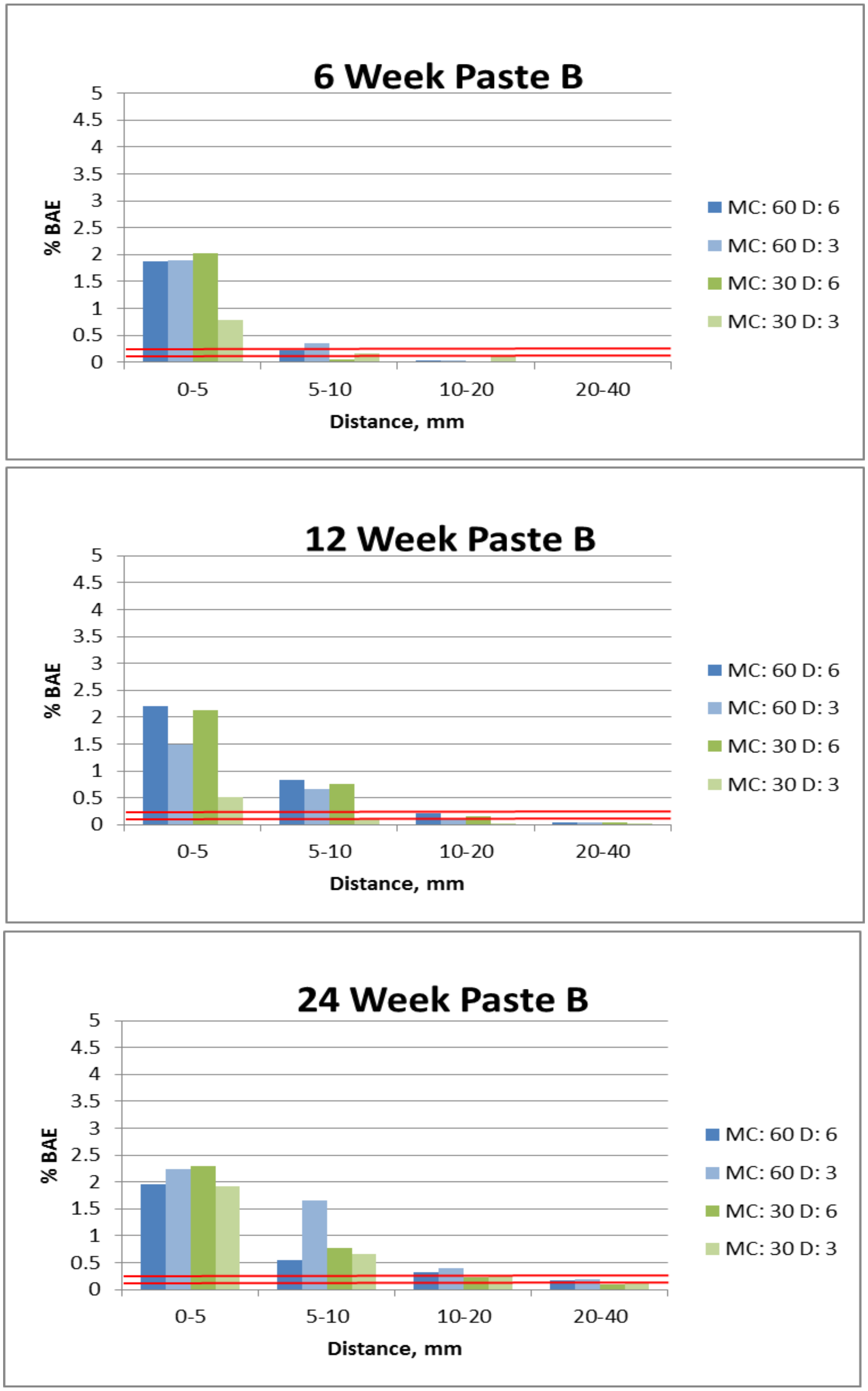


Figure IV-9. Boron oxide levels at selected depths in Douglas-fir sapwood blocks conditioned to 30 or 60% moisture content and sampled 6, 12 or 24 weeks after application of 3 or 6 mm thick layers of Paste B. Threshold lines for the outer zone (0-5 mm, 0.275% BAE) and inner zones (5-40 mm, 0.1% BAE) are represented in red.

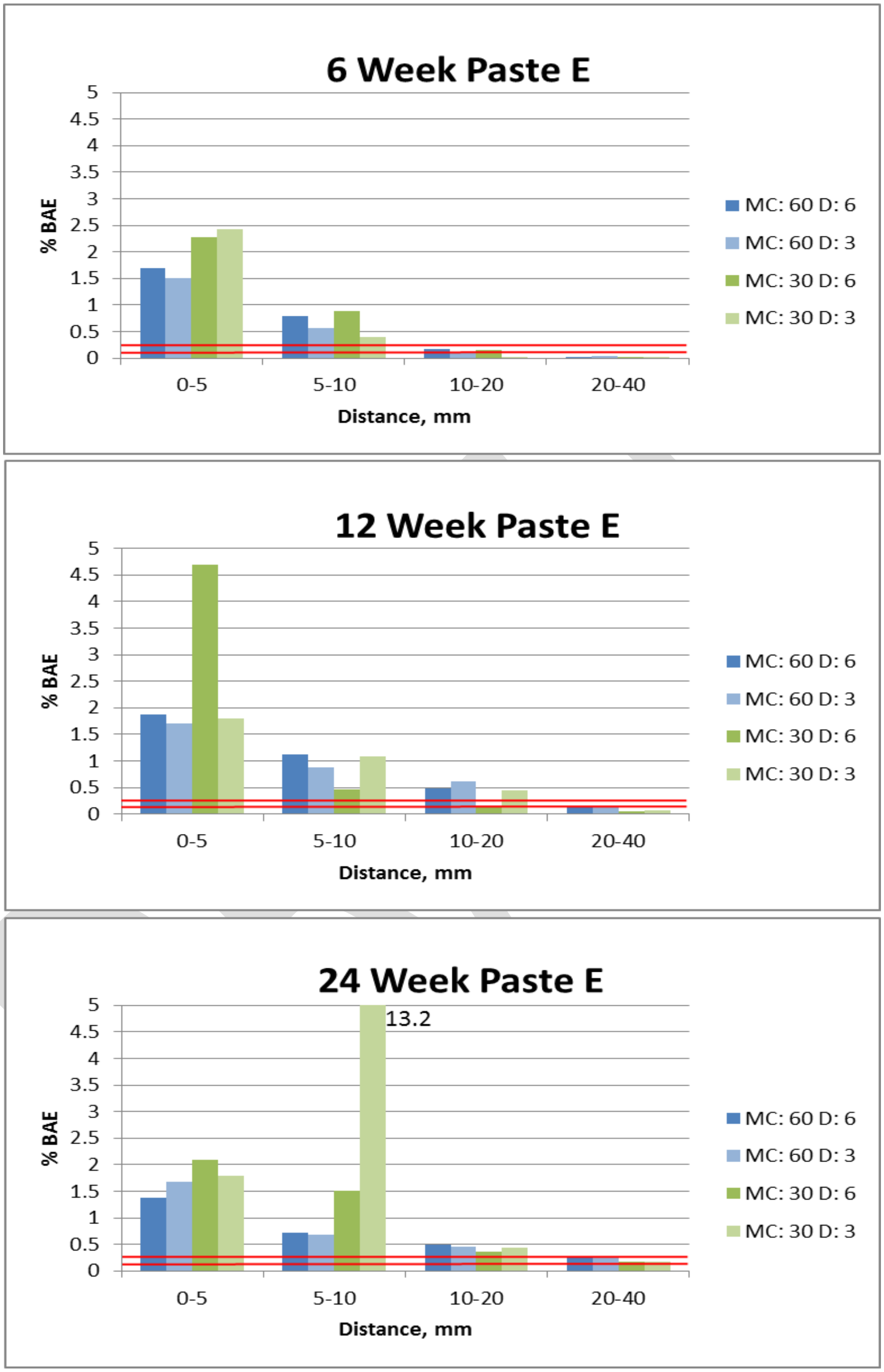


Figure IV-10. Boron oxide levels at selected depths in Douglas-fir sap wood blocks conditioned to 30 or 60% moisture content and sampled 6, 12, or 24 weeks after application of 3 or 6 mm thick layers of Paste E. Threshold lines for the outer zone (0-5 mm, 0.275% BAE) and inner zones (5-40 mm, 0.1% BAE) are represented in red.

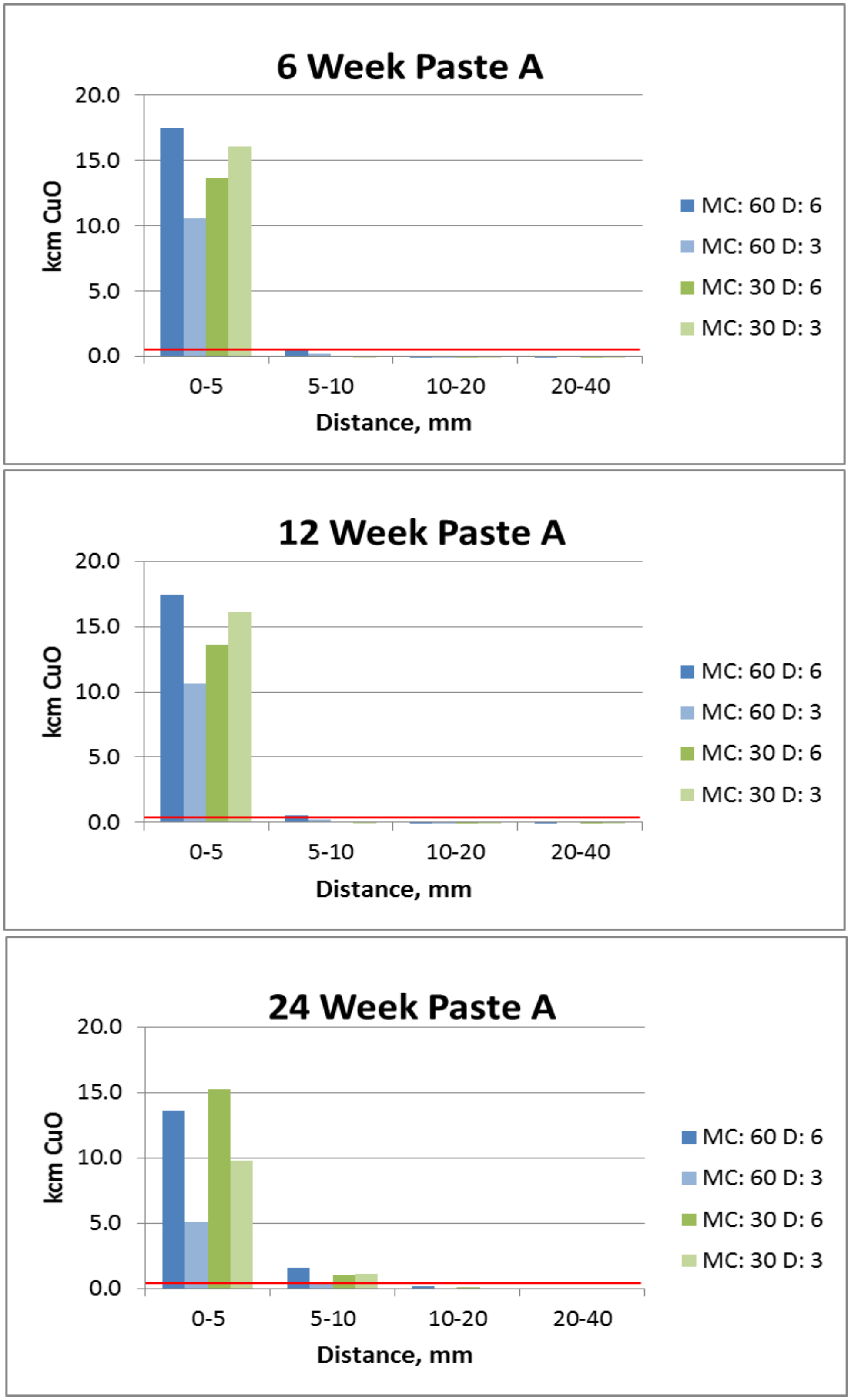


Figure IV-11. Copper oxide levels at selected depths in Douglas-fir sapwood blocks conditioned to 30 or 60% moisture content and sampled 6, 12 or 24 weeks after application of 3 or 6 mm thick layers of Paste A. The fungal threshold value of 0.46kg/m^3 is indicated by a red line.

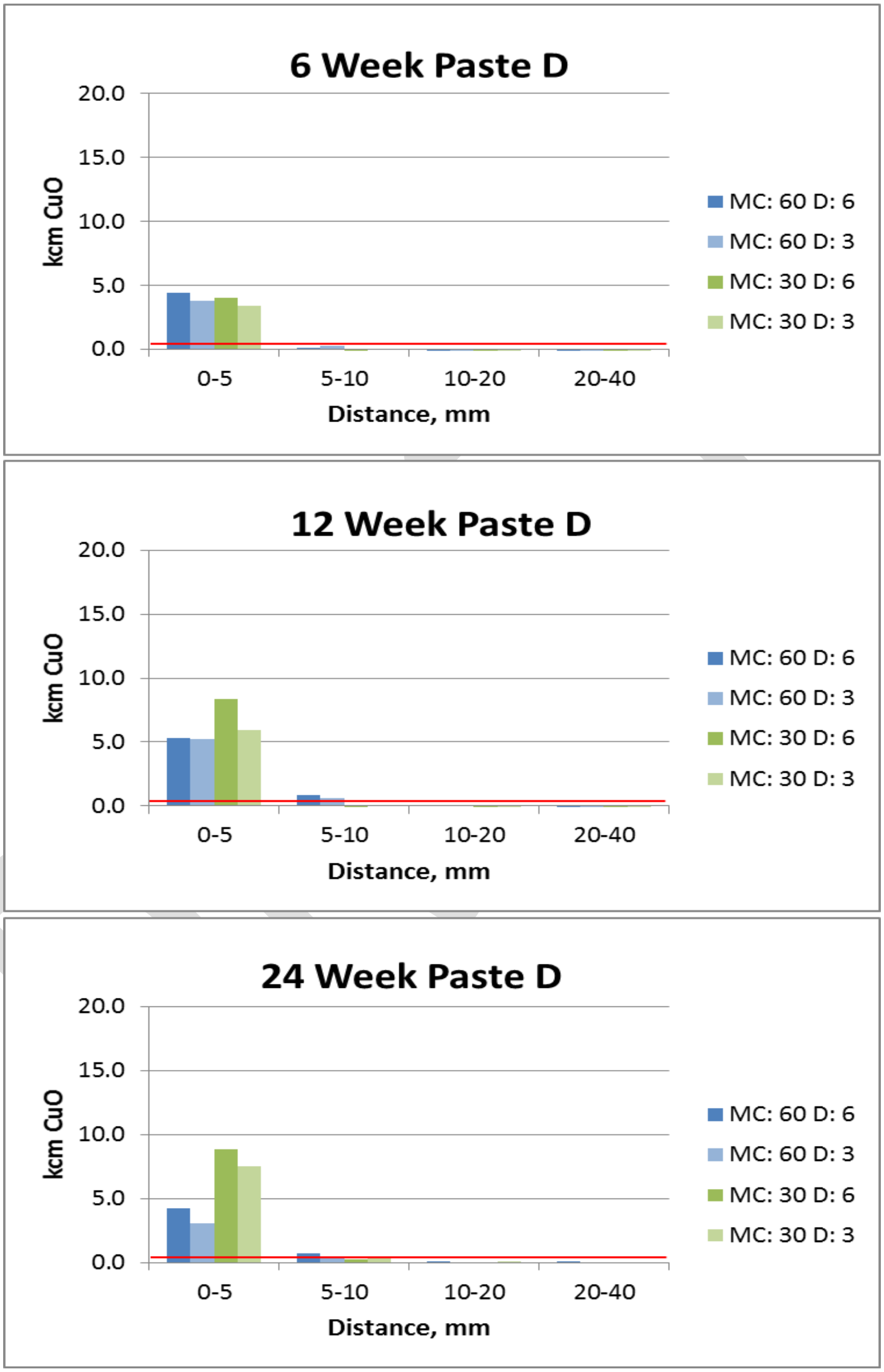


Figure IV-12. Copper oxide levels at selected depths in Douglas-fir sapwood blocks conditioned to 30 or 60% moisture content and sampled 6, 12, or 24 weeks after application of 3 or 6 mm thick layers of Paste D. The fungal threshold value of 0.46kg/m^3 is indicated by a red line.

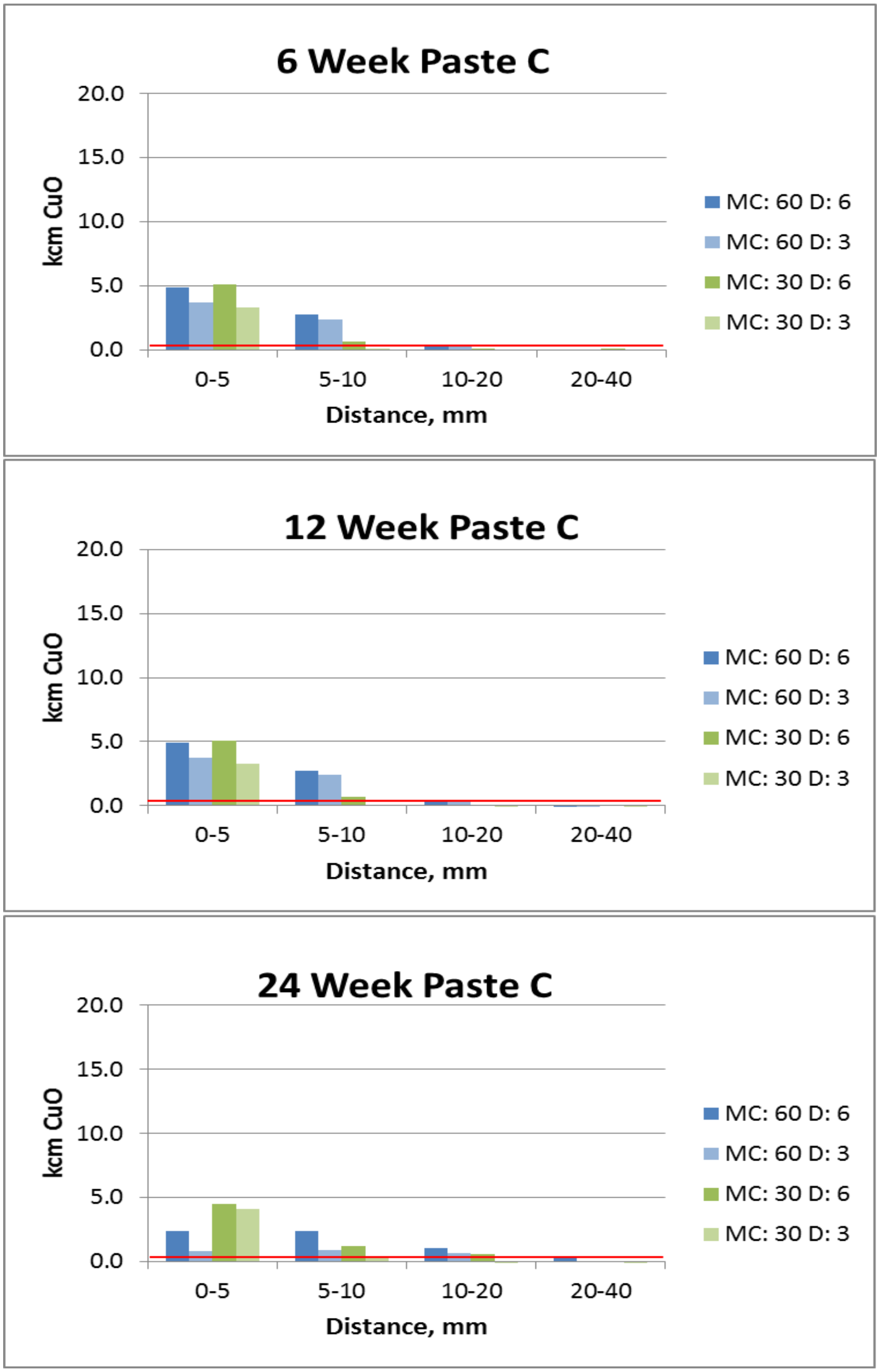


Figure IV-13. Copper oxide levels at selected depths in Douglas-fir sapwood blocks conditioned to 30 or 60% moisture content and sampled 6, 12 or 24 weeks after application of 3 or 6 mm thick layers of Paste C. The fungal threshold value of 0.46kg/m^3 is indicated by a red line.

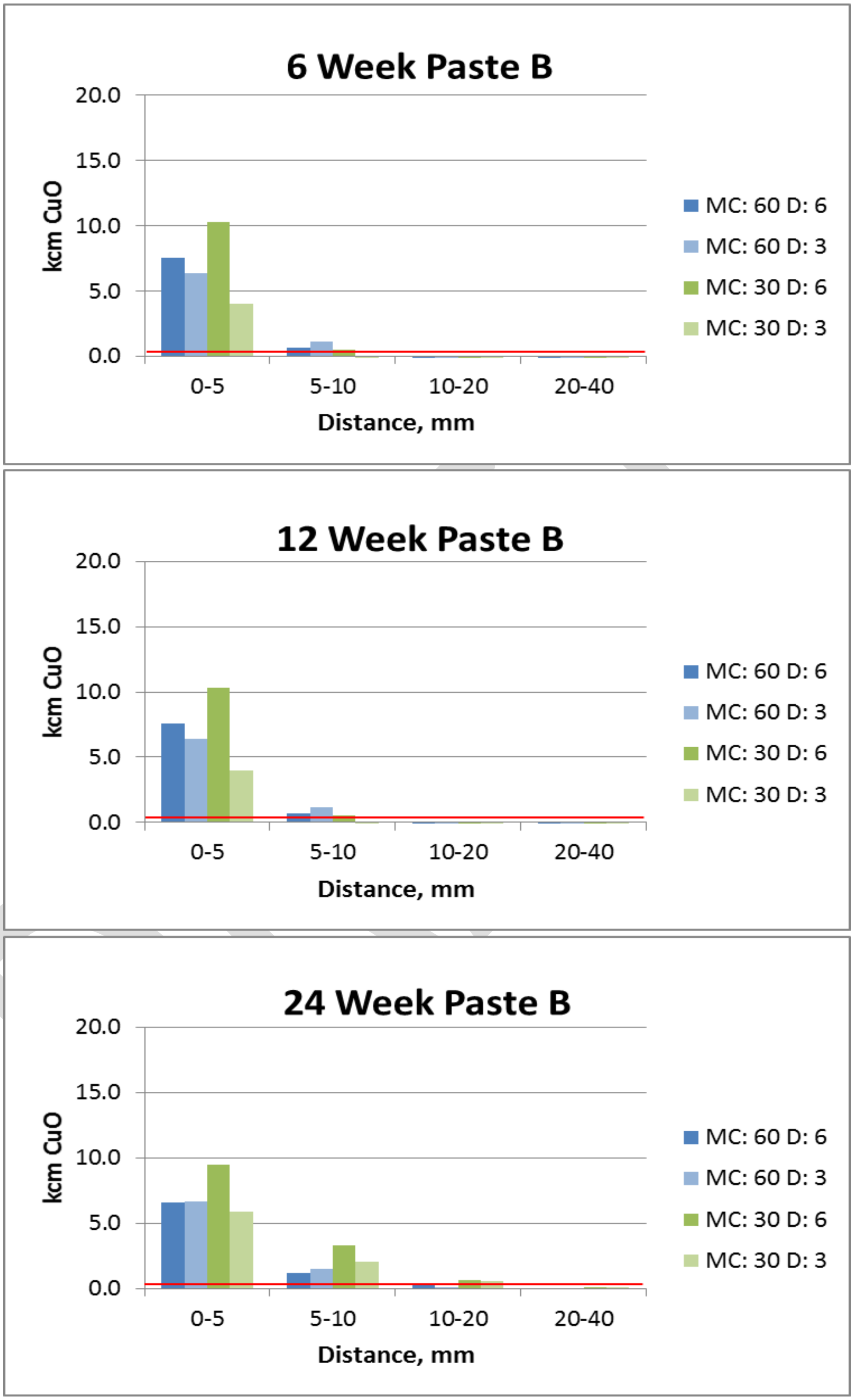


Figure IV-14. Copper oxide levels at selected depths in Douglas-fir sapwood blocks conditioned to 30 or 60% moisture content and sampled 6, 12 or 24 weeks after application of 3 or 6 mm thick layers of Paste B. The fungal threshold value of 0.46kg/m^3 is indicated by a red line.

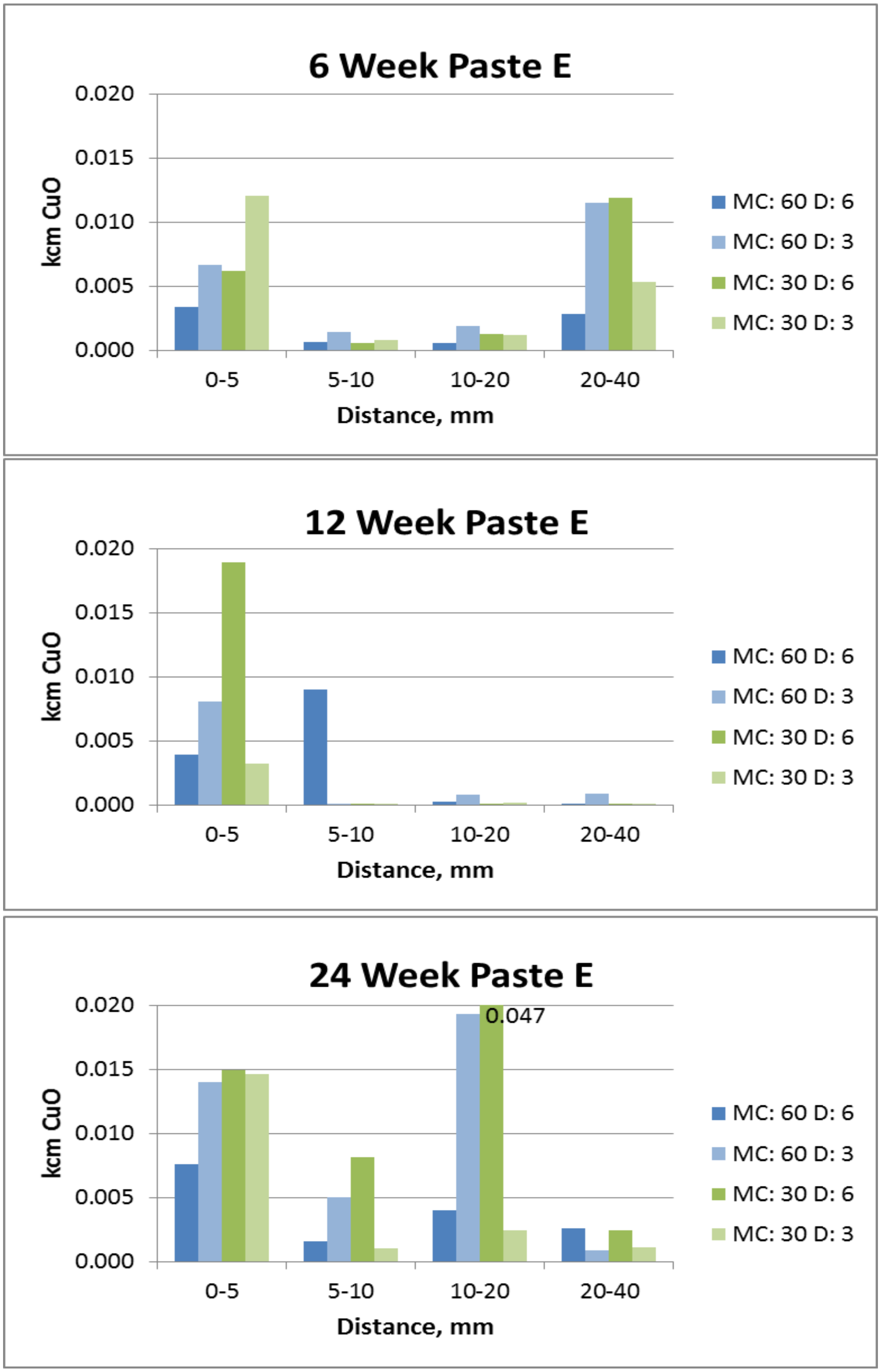


Figure IV-15. Copper oxide levels at selected depths in Douglas-fir sap wood blocks conditioned to 30 or 60% moisture content and sampled 6, 12, or 24 weeks after application of 3 or 6 mm thick layers of Paste E. This paste contains oxine copper which is much more active against fungi than other copper compounds.

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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 1940s, but commercial use for treating utility poles has only occurred in the last 20 years as utilities sought less restrictively labeled chemicals. Copper naphthenate is currently listed as a non-restricted use pesticide, meaning 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 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. Many utilities include copper naphthenate in the specification as an alternative treatment.

Copper naphthenate has a long history of successful use on southern pine. We performed a number of tests to ensure the suitability of this system for use on western wood species, notably Douglas-fir and western redcedar. Initial tests examined the copper naphthenate performance on western redcedar, but concerns about the effects of solvent substitutions on biocide performance encouraged us to set up field evaluations of copper naphthenate poles in service. Our first work examined the condition of Douglas-fir poles treated with copper naphthenate and diesel as the primary solvent and we found no evidence of early decay in poles exposed in Oregon or California. More recently, data suggesting that the addition of biodiesel as a co-solvent to reduce diesel odors had a negative effect on performance led us to evaluate poles in the Puget Sound area. We will continue to evaluate copper naphthenate performance to ensure that utilities are aware of the effects of process changes on performance.

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, the following test was established.

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

Stakes were conditioned to 13% moisture content, 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.

Stakes were then exposed in a fungus cellar maintained at 30 C and approximately 90% relative humidity. Soil moisture cycled between wet and slightly dry to avoid favoring soft rot attack (which tends to dominate in soils that are maintained at high moisture levels). Stake condition was visually assessed on an annual basis using a scale from 10 (completely sound) to 0 (completely destroyed).

In 2007, 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 more suitable decay conditions as evidenced by subsequent drops in ratings for all treatments after the change.

Freshly sawn stakes continue to out-perform weathered stakes at all retention levels (Figures V-1, 2). All freshly sawn stakes treated with copper naphthenate to retentions of 4.0 kg/m^3 continue to provide excellent protection after 302 months, while the conditions of stakes treated to the two lower retentions continued to decline over the past 2 years. Stakes treated to the two lowest retentions have declined to a rating near 5.0, suggesting that fungal decay significantly degraded the wood. Ratings for the intermediate retention were just above 6.0, indicating treatment efficacy loss.

Weathered stakes exhibited greater degrees of damage at a given treatment level and their condition continued to decline. The three lowest retentions had ratings below 3.0 indicating they are no longer serviceable (Figure V-2). The condition of stakes treated to these three retentions continue to decline. The conditions of stakes treated to the two higher retentions also declined slightly in the past year. Ratings for the highest retention are approaching 5.0, while those for the next highest retention have declined to below 4. Clearly, prior surface degradation from both microbial activity and UV light sharply reduced performance of the weathered material.

Weathered wood was included in this test because the cooperating utility planned to remove poles from service for re-treatment and reuse. While this process remains possible, it is clear the performance characteristics of weathered retreated material will differ substantially from those of freshly sawn material. The effects of these differences on overall performance may be minimal. Even if the outer, weathered wood were to degrade over time, this zone is relatively shallow on western redcedar and would not markedly affect overall pole properties.

Copper naphthenate should continue to protect weathered western redcedar sapwood above-ground; allowing utility personnel to safely climb these poles. Any slight decrease in aboveground protection would probably take decades to emerge. As a result, retreatment of western redcedar still appears feasible for avoiding pole disposal and maximizing value of the original investment.

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

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

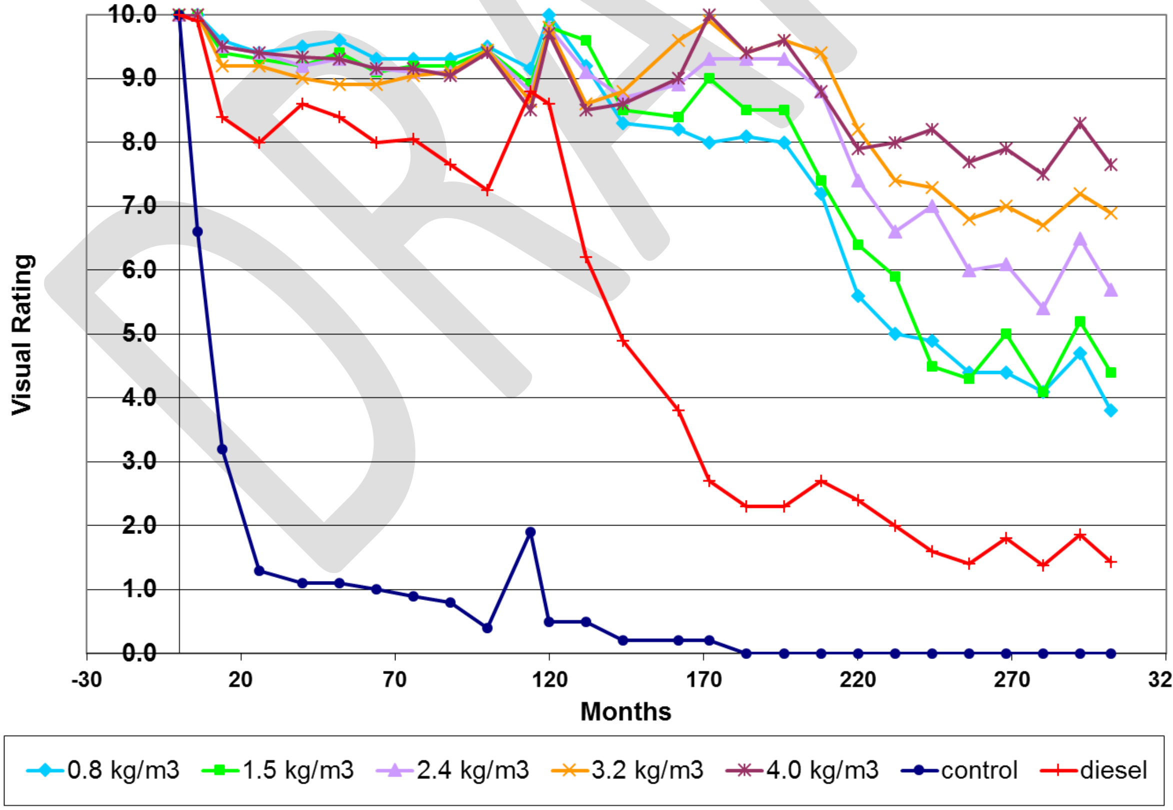

Figure V-1. Condition of freshly sawn western redcedar sapwood stakes treated with selected retentions of copper naphthenate in diesel oil and exposed in a soil bed for 302 months.

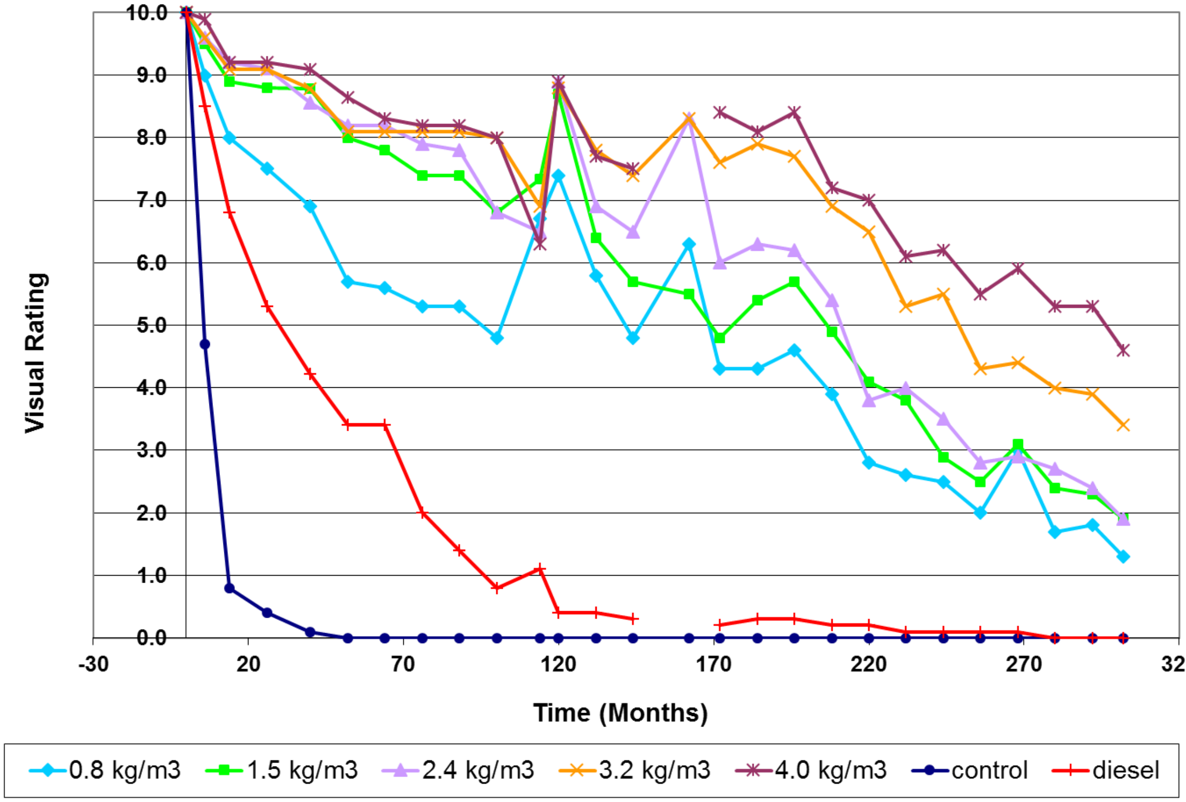

Figure V-2. Condition of weathered western redcedar sapwood stakes treated with selected retentions of copper naphthenate in diesel oil and exposed in a soil bed for 302 months.

B. Evaluate the Condition of Douglas-fir poles Treated with Copper Naphthenate in Diesel or Bio diesel Blends

As noted, copper naphthenate has provided excellent performance when dissolved in diesel as a solvent; however, there have been concerns about the performance of this system when dispersed in solvents containing biodiesel. As a part of our evaluation of copper naphthenate performance, we have inspected 65 copper naphthenate treated Douglas-fir poles in the Puget Sound area. These poles had been treated with various combinations of biodiesel and conventional diesel solvents. The intent of these inspections was to assess preservative retention and determine if surface decay was developing more rapidly on these poles. These poles would then be monitored over the next decade to detect any early issues associated with the use of biodiesel. This past year we added an additional population of poles into this data base. The poles were inspected just below groundline by probing the wood surface for the presence of softened wood, then removing increment cores from 3 locations around each pole at groundline and then approximately 1 m above that location. The outer 6 mm of each core was removed for assessing the presence of soft rot, then the zone from 6 to 25 mm from the surface was removed and the zones from cores from a given location on each pole will be combined before being ground to pass a 20 mesh screen. The resulting sawdust will be analyzed for copper by x-ray fluorescence spectroscopy. The remainder of each core will be plated on malt extra and observed for the growth of decay fungi as previously described. The outer segments will be digested into individual wood fibers and these fibers will be examined for evidence of fungal attack as either cell wall thinning or diamond shaped cavities. Cavities and cell wall thinning are evidence of fungal soft rot attack which is the primary cause of surface decay on utility poles. We have seen some evidence of soft rot attack in the previous investigations. The core analyses are still underway and will be reported in the next annual report.