PERSONNEL

ADVISORY COMMITTEE

James Cahill, Bonneville Power Administration
Chris Damaniakes, Pacific Gas & Electric
Brent Elton, Genics Inc
Moira Fry, Pacific Gas and Electric Co.
Randy Gross, ISK Biotech
Dennis Hayward, Western Wood Preservers' Institute
Manfred Jung, Dr. Wolman GMBH
Al Kenderes, New York State Electric & Gas Corp.
Sunni Miani, Portland General Electric Company
Nick Ong, Pacific Power
Alan Preston, CSI, Inc.
Tim Wandell, Portland General Electric Company
Rich Ziobro, Osmose Wood Preserving, Inc.

RESEARCH

Principle Investigator:

Jeffrey J. Morrell, Professor, Department of Forest Products (Wood Preservation), Oregon State University

Research Associates:

Theodore C. Scheffer, Forest Products, (Forest Products Pathology) (Retired)

Research Assistants:

Hua Chen, Department of Forest Products, Oregon State University
Camille Freitag, Department of Forest Products, Oregon State University
Ron Rhatigan, Department of Forest Products, Oregon State University

Graduate Students:

Sung Mo Kang, Ph.D., Department of Forest Products, Oregon State University
Mark Mankowski, Ph.D., Department of Forest Products, Oregon State University
Antonio Silva, Ph.D., Department of Forest Products, Oregon State University
Adam Taylor, Ph.D., Department of Forest Products, Oregon State University
Ying Xiao, Ph.D., Department of Forest Products, Oregon State University

Cooperators

* Bonneville Power Administration
* Central Hudson Gas and Electric
* CSI, Inc.
* Dr. Wolman, GMBH
* Genics Inc.
* Hickson, Inc.
* ISK Biotech
* New York State Electric and Gas
* Osmose Wood Preserving, Inc.
* Pacific Gas and Electric
* Pacific Corp.
* Portland General Electric Company
* Rochester Gas and Electric
* Western Wood Preservers Institute

TABLE OF CONTENTS

OBJECTIVE I
DEVELOP SAFER CHEMICALS FOR CONTROLLING INTERNAL DECAY OF WOOD POLES

Internal decay is an important problem in virtually all wood species used for utility poles. Internal decay often develops in thinner sapwood species following initial preservative treatment as drying checks open beyond the depth of the original treatment, but it also occurs in under-treated regions of thicker sapwood species such as southern pine. In all instances, moisture and fungal spores reach the untreated or under-treated wood, where they germinate and begin to decay the wood. Left untreated, internal decay will eventually weaken the pole, leaving it susceptible to sudden failure during wind, ice or other storm events or when impacted by vehicles. Controlling internal decay has been an especially important component of OSU research over the year, leading to the joint identification of fumigants for internal decay control (with Bonneville Power Administration),then later to the identification of first methylisothiocyanate and more recently basamid as potentially safer fumigants for internal decay control. More recently, we have focused on the water diffusible rod treatments as alternatives to the fumigants.

A. **Develop Improved Fumigants for Control of Internal Decay**

Fumigants remain the most widely used chemicals in North American for controlling internal decay in utility poles, but many users continue to seek safer chemicals for this purpose. As mentioned, previous research identified the suitability of methylisothiocyanate (MITC) for this purpose and this active ingredient was subsequently commercialized for wood treatment, first in glass and later in aluminum ampules. More recently we have studied basamid, a solid crystalline powder that decomposes to produce MITC. In this report, we describe our continuing tests with MITC and basamid as well as the results of a field trial of large timbers treated with metham sodium.

1. <u>MITC movement from MITC-FUME ampules stored under varying conditions</u>: Eight 250 mm diameter by 750 mm long Douglas-fir pole sections were end-coated with an elastomeric paint. One half of the sections were air-seasoned to a moisture content below 25% (at 25 mm from the wood surface), while the others were used while the wood was above the fiber saturation point

(>30 % moisture content). A single 205 mm long hole (19 mm in diameter) was drilled at a 45 degree angle near the center of each pole section and a single MITC-FUME vial containing 30 g of MITC was inserted with the open end downward. The holes were plugged with cork stoppers. Sets of three pole sections per moisture content were stored at 5C (cold room), outdoors at ambient temperatures, or at 32C and 90% relative humidity. At periodic intervals, the ampules were removed and weighed to assess chemical loss over time. This test was a small part of the larger assessment of MITC-FUME field efficacy. The results of the larger field trial were reported in 1999, ten years after treatment.

MITC loss from ampules exposed at 32C occurred within one year regardless of whether the poles were green or dry (Figure I-1). MITC release rates from ampules exposed under ambient conditions outdoors in Corvallis were far slower than those for the 32C exposure. Release rates were faster in poles that were dry at the time of treatment. The reasons for the differences in release rate between green and dry wood are unclear, although they may reflect the ability of the wood to sorb MITC. Dry wood is capable of sorbing larger quantities of MITC, although the differences are generally small. Interestingly, small amount of MITC remained for almost 9 years in the ambient exposure poles treated while green. Release rates from ampules in poles stored at 5 C have lagged far behind those for the other two exposures. Approximately 25% of the original MITC remains in the ampules 12 years after application. While the number of poles receiving MITC-FUME ampules in environments where the temperature does not exceed 5C are virtually non-existent, the results indicate that chemical will remain in ampules for longer periods in poles treated in cooler climates such as poles exposed at higher elevations or in northern climates. The amounts of MITC in the ampules remain relatively small and pose only minimal risk, however, it would be important to alert crews to the possibility that field activities such as drilling or sawing (i.e. for pole replacement) could intersect ampules that still contain some chemical.

2. Effect of copper sulfate on performance of Basamid in Douglas-fir transmission poles: Basamid was identified as a potentially safer internal treatment as early as 1977, but its slow rate of decomposition to MITC in wood largely limited its development. Further evaluation suggested that Basamid performance could be enhanced by adding small amounts of copper at the time of treatment. Bivalent metals such as copper markedly enhance basamid decomposition, suggesting that the rate of

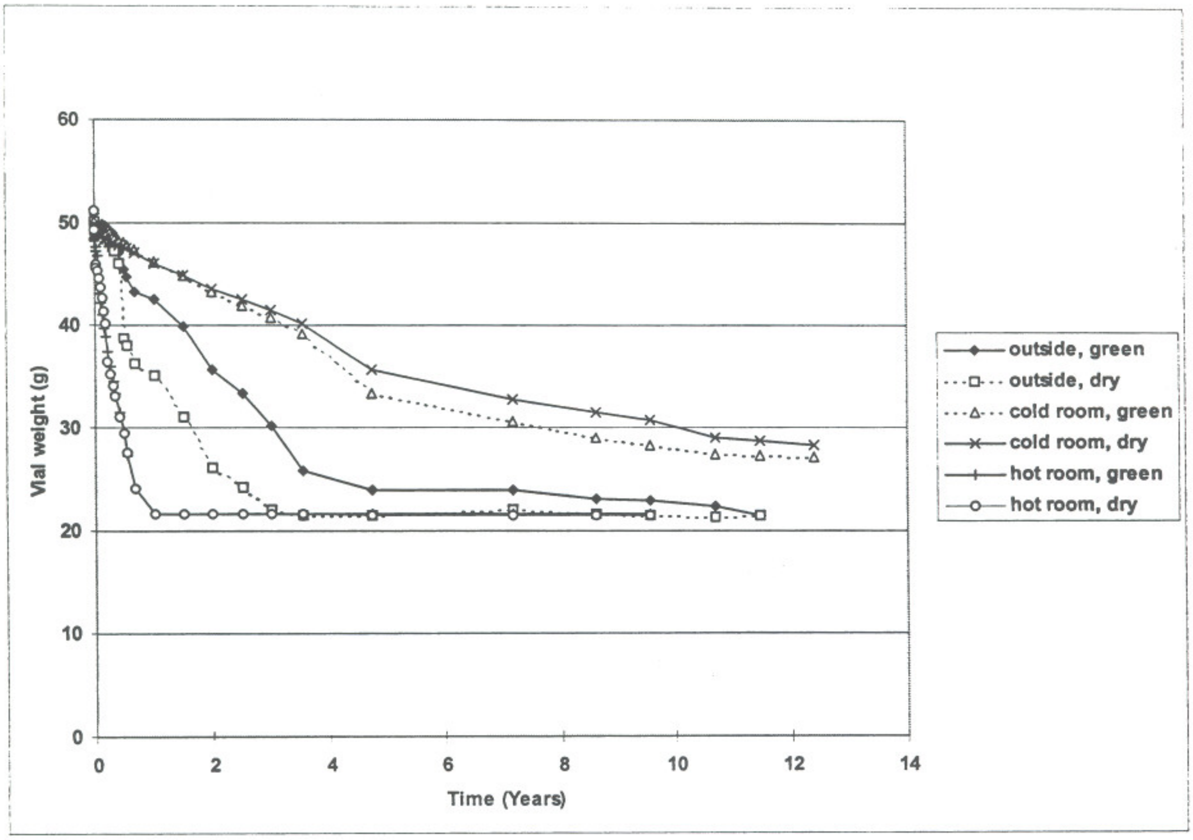


Figure I-1. Residual MITC in glass encapsulated ampules in Douglas-fir pole sections treated with glass encapsulated MITC and exposed in different environments.

MITC release could be tailored to produce varying levels of protection, depending on the condition of the pole.

In 1993, a field test was initiated in a Douglas-fir transmission line located near Corvallis, Oregon. Three steeply angled holes were drilled beginning at groundline and moving upward at 150 mm increments and around the pole 120 degrees. Drill shavings from each hole were collected in plastic bags. These shavings were later briefly flamed to minimize the potential for contaminating surface fungi, then placed on the surface of malt extract agar in petri dishes. The shavings were observed for evidence of fungal growth over one month and any fungi growing from the wood were examined for evidence of clamp connection and other characteristics typical of the Division Basidiomycota, a group of fungi containing many important wood decayers.

The poles were treated with 200 or 400 g of basamid with or without 1% copper sulfate. The dosages were premixed and were evenly distributed among the three holes. An additional set of poles was treated with 500 ml of metham sodium. The treatment holes

Table I-1. Fungal isolations from Douglas-fir transmission poles 0 to 7 years after treatment with metham sodium or basamid with without copper sulfate.																			
Chemical	Dosage	$CuSO^4$	Fungal Isolation Frequency (% $Decay^{non\text{-}decay}$)																
			0.3 m above GL						1.3 m above GL					3.3 m above GL					
			0 Yr	2 Yr	3 Yr	4 Yr	5 Yr	7 Yr	2 Yr	3 Yr	4 Yr	5 Yr	7 Yr	2 yr	3 Yr	4 Yr	5 Yr	7 Yr
metham sodium	500 ml	-	0^{47}	0^{10}	0^{5}	0^{10}	0 27	0^{40}	0 13	0^{3}	0 10	0^{30}	0 20	0^{10}	0^{7}	0^{10}	3^{40}	13 27
Basamid	400 g	-	0^{14}	0^{7}	0^{0}	0^{7}	0 27	0^{0}	0 23	0^{0}	0^{0}	0^{13}	0^{0}	0^{7}	0 25	0^{20}	0 27	0^{7}
		+	0^{27}	0^{7}	0^{20}	0^{7}	0 27	0^{0}	0 13	0^{7}	0^{0}	0^{27}	0^{0}	0^{13}	0^{7}	0^{7}	0 33	0^{7}
	200 g	-	7^{20}	0^{27}	0^{0}	0^{27}	0 33	0^{7}	0 33	0^{0}	0^{7}	0^{40}	0^{0}	0^{27}	0^{14}	7^{33}	0^{33}	7^{27}
		4	0^{0}	0^{0}	0^{0}	0^{0}	13 13	0^{20}	13^{0}	0^{20}	0^{0}	7^{40}	0^{20}	0^{2}	0^{0}	0^{7}	0^{27}	0^{7}

were plugged with tight fitting wooden dowels.

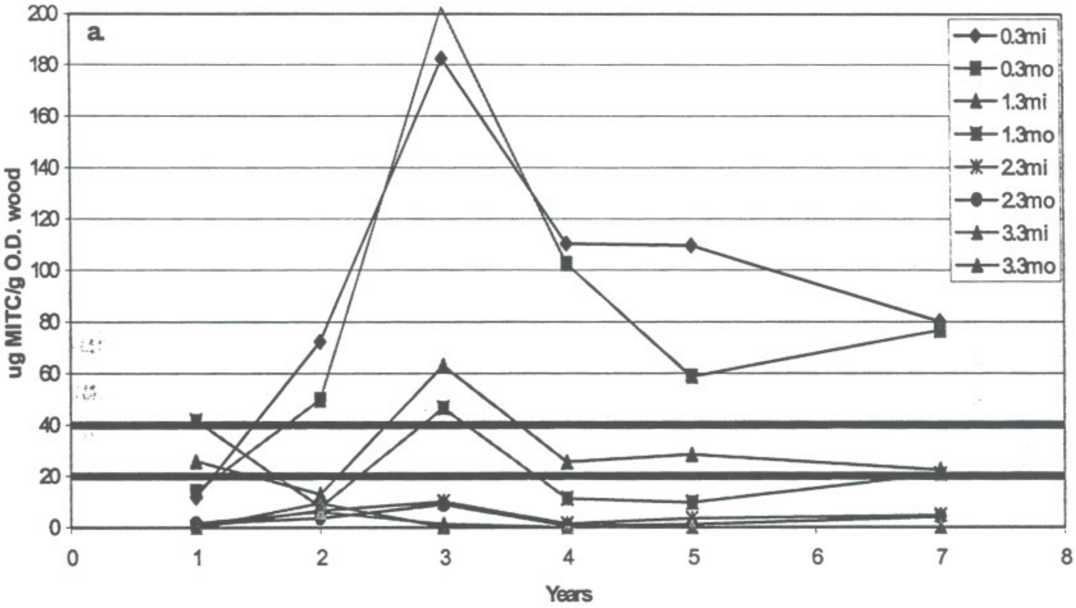
Chemical movement and efficacy were assessed 1, 2, 3, 4, 5, and 7 years after treatment by removing increment cores from three equidistant points around each pole 0.3, 1.3, 2.3 and 3.3 m above groundline. The outer, heavily treated shell was discarded, then the outer and inner 25 mm of each core was removed and placed into 5 ml of ethyl acetate. The cores were stored at room temperature for 48 hours, then the increment core was removed, oven dried and weighed. This weight was later used to determine residual chemical on a wood weight basis.

The ethyl acetate extracts were injected into a Shimadzu gas chromatograph equipped with a flame photometric detector and filters specific for sulfur (a component of MITC). Levels of MITC in extracts were quantified by comparison with analyses of prepared standards. The results were expressed on a ug of MITC/oven-dried g of wood.

The remainder of each increment core was cultured on malt extract agar for the presence of decay fungi as described above for the drill shavings.

Isolations of decay fungi in the poles have generally been low over the 7 years since treatment, reflecting the good initial treatment of these poles (Table I-1). While decay fungi have been isolated from at least one pole in every treatment group, the isolations have not been consistent in a single pole over several years, nor has there been a steady increase over time. These results suggest that the isolations represent scattered fungal colonization rather than a general failure of the treatment. As with decay fungi, isolations of non-decay fungi have also been sporadic in some cases oscillating between completely absent and moderately frequent (approximately 30 % of cores with non-decay fungi). The presence of non-decay fungi, while not an indicator of imminent treatment failure, has generally been a reasonable indicator of declining fumigant levels. The results suggest that chemical levels remain protective in all treatments after 7 years.

Last year, we used previous field data to develop relative thresholds for MITC. Our previous data suggested that fungal isolations increased sharply when levels declined below 20 ug/g of wood. While this is a relative threshold, it does provide some guidance for assessing the significance of chemical assay data. MITC levels in poles receiving 200 g of basamid were generally below the threshold range except 300 mm above groundline (Figure I-2). Chemical levels further up the poles in this treatment group were all below the 20 ug/g of wood threshold, suggesting that these poles are likely to be colonized in the near future. The addition of copper at the time of treatment produced a



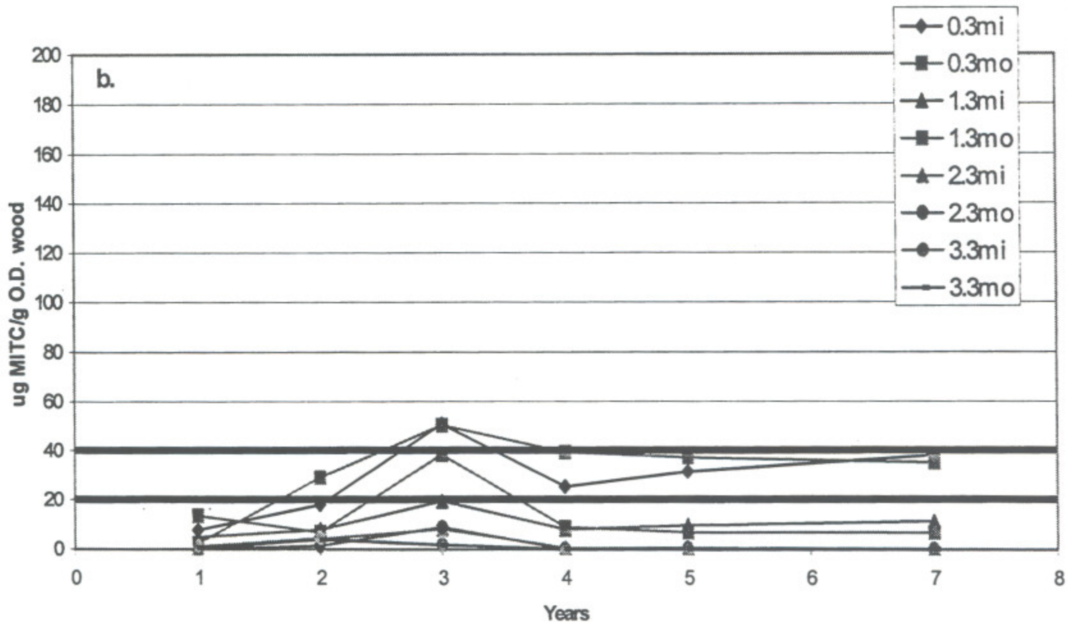


Figure I-2. MITC levels at selected distances above the groundline in Douglas-fir transmission poles 1 to 7 years after treatment with 200 g of basamid a) with or b) without copper sulfate dramatic increase in the levels of MITC produced for the first five years after treatment, particularly near the groundline, but this enhancement declined slightly between years 5 and 7. Chemical levels in the groundline zone of poles treated with basamid plus copper remain nearly double those found in the non-amended basamic treatments, while those 1.3 m above the groundline were just at the lower threshold range. Chemical levels further up that pole differed little between copper amended and non-amended poles.

MITC levels in poles receiving 400 g of basamid also experienced dramatic increases 3 to 4 years after treatment, then a gradual decline (Figure I-3). Chemicals levels 7 years after treatment were approximately double those found in the 200 g treatment suggesting that there might be some long term dosage effect. The addition of copper at the time of treatment produced sharp spikes in MITC levels 2 to 3 years after treatment. These levels have declined over time, to the point where there is little difference in MITC levels between the copper and non-copper amended treatments.

MITC levels in metham sodium treated poles tended to rise more rapidly than those in the basamid poles and reached levels slightly higher than those found with the 200 g basamid treatment (Figure I-4). MITC levels in these poles declined below the protective threshold within 4 years after treatment and this chemical is virtually absent form the poles 7 years after treatment. Clearly, metham sodium treatment, while initially effective, does not provide the long term residual MITC levels produced by any of the basamid treatments. The addition of copper at the time of treatment further accentuates these differences.

We will continue to monitor these poles to determine when MITC levels in the basamid treatments falls below our presumed thresholds, but this chemical has clearly shown its ability to provide long term protection to the wood.

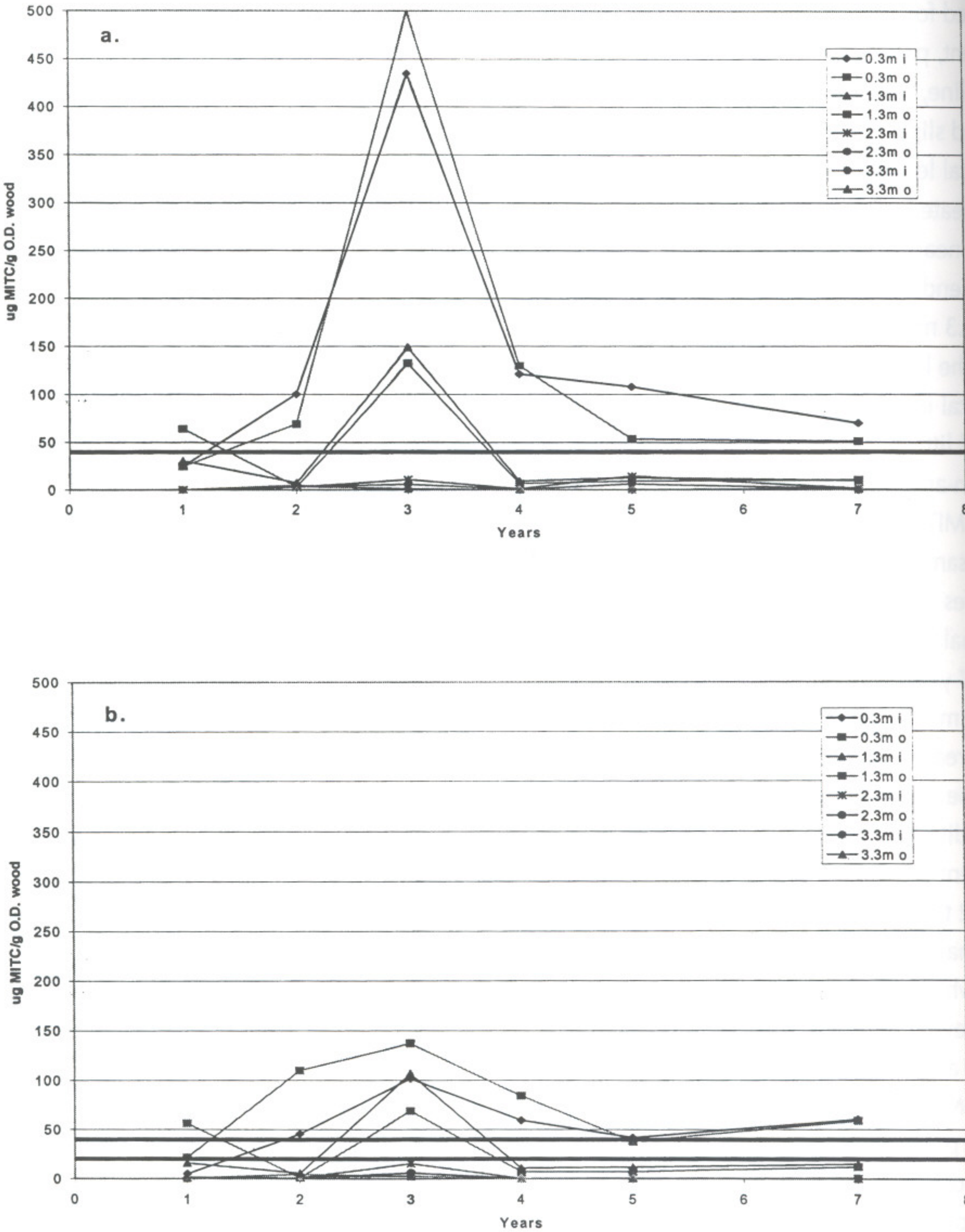


Figure I-3. MITC levels at selected distances above the groundline in Douglas-fir transmission poles 1 to 7 years after treatment with 400 g of basamid a) with or b) without copper sulfate

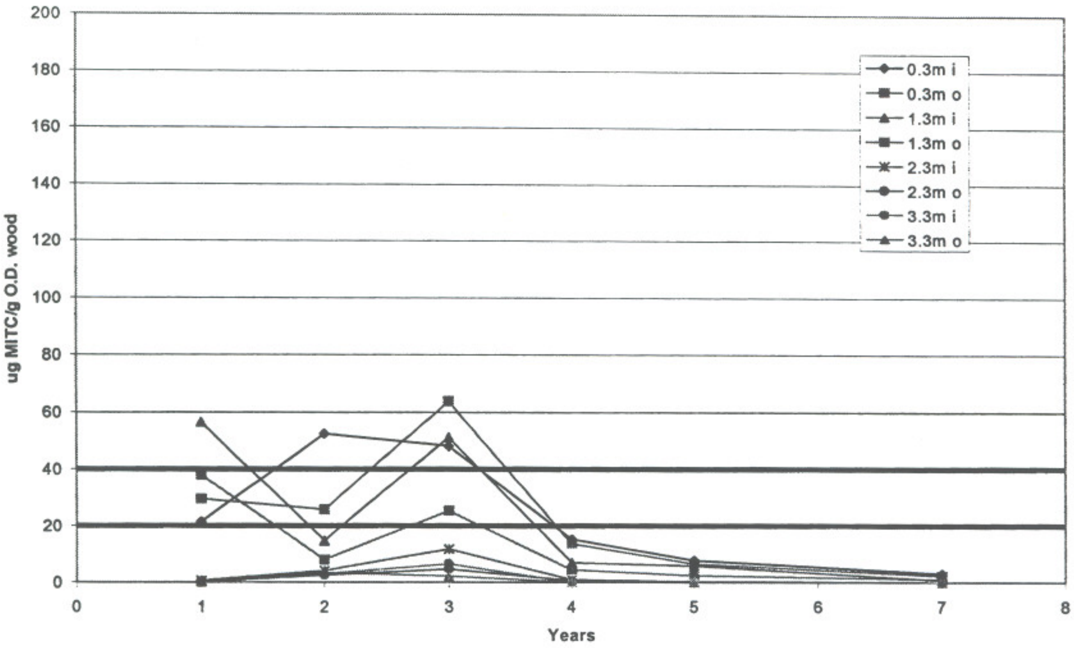


Figure I-4. MITC levels at selected distances above the groundline in Douglas-fir transmission poles 1 to 7 years after treatment with 500 ml of metham sodium.

3. Use of copper naphthenate to enhance performance of basamid in Douglas-fir poles: While copper sulfate clearly accelerates of basamid decomposition to MITC in wood, this chemical is not labeled for remedial treatment of wood poles. Rather than seek registration of copper sulfate for this application, it was suggested that other copper based biocides might be equally effective for this application. The most widely used topical treatment for protecting field damage to treated wood is copper naphthenate. This chemical has relatively low toxicity and its use is not restricted. As a result, incorporating copper naphthenate into treating holes at the time basamid application would be a logical approach to accelerating decomposition.

Douglas-fir poles sections (250-300 mm in diameter by 3 m long) were pressure treated with pentachlorophenol in P9 Type A oil. The poles were set into the ground to a depth of 0.6m, then three steeply sloping holes were drilled beginning at groundline and moving upward 150 mm and around the pole 120°. Two hundred grams of Basamid was equally distributed among the three treatment holes. One set of three poles received no additional treatment, three received 20g of copper sulfate, and three received 20g of 2% copper naphthenate. The treatment holes were then plugged with tight fitting wood dowels.

The poles were sampled 1, 2, and 3 years after treatment by removing increment cores from three equidistant points around each pole at sites 0.3, 1.3, and 2.3 m above groundline. The outer and inner 25 mm of each core was placed into 5 ml of ethyl acetate and extracted for 48 hours at room temperature. These extracts were then analyzed for residual MITC as described in Objective I-A-2. The remainder of each core was briefly flamed and then placed on the surface of 1.5 % malt extract agar and observed for evidence of fungal growth.

MITC levels have generally been above the minimum threshold for fungal colonization for all three years of sampling 0.3 m above groundline. MITC levels at the two higher sampling locations have been minimal, suggesting that MITC distribution was largely confined to the groundline treatment zone (Table I-2). MITC levels after one year tended to be higher in poles receiving copper sulfate, while levels were lowest in non-amended poles . MITC levels in copper naphthenate amended treatments tended to be intermediate between those for copper sulfate and non-amended poles for the first 2 years after treatment. MITC levels in the copper naphthenate treatments have continued to rise over the three year period and now exceed those present in either of the other treatments. These results indicate that copper naphthenate should be an acceptable alternative to copper sulfate for accelerating basamid decomposition in wood.

Fungal isolations were generally low from all poles except those initially treated with copper sulfate amended basamid (Table I-3). Decay fungi were isolated from 1.3 m above groundline after one or two years, suggesting that the treatment had been ineffective. Chemical analyses, however, revealed that the wood in this zone had only minimal amounts of MITC in either year. The decay fungus was not isolated in the third year, suggesting that the fumigant had finally eliminated the infestation. Isolation of non-decay fungi varied widely with position over time. Isolation levels of non-decay fungi were generally low at all three sampling heights three years after treatment. As noted previously, the role of non-decay fungi in fumigant performance is not clear, but these fungi do tend to recolonize wood more rapidly than decay fungi and their absence is an indicator of continued chemical protection.

Table I-2. Residual MITC in Douglas-fir poles 1 to 3 years after treatment with 200 g of basamid supplemented with copper naphthenate or copper sulfate.

Treatment	Distance Above GL	Inner/Outer	Residual MITC (ug/g of wood)[a]		
			Year 1	Year 2	Year 3
none	0.3	Inner	21 (14)	72 (47)	57 (27)
		Outer	18 (37)	36 (33)	32 (42)
	1.3	Inner	0 (0)	0 (0)	0 (0)
		Outer	0 (0)	0 (0)	0 (0)
	2.3	Inner	0 (0)	0 (0)	0 (0)
		Outer	3 (8)	0 (0)	0 (0)
Copper sulfate	0.3	Inner	103 (78)	101 (36)	78 (25)
		Outer	55 (86)	32 (17)	29 (17)
	1.3	Inner	4 (6)	7 (7)	7 (7)
		Outer	0 (0)	3 (7)	5 (8)
	2.3	Inner	0 (0)	0 (0)	0 (0)
		Outer	0 (0)	0 (0)	0 (0)
copper naphthenate	0.3	Inner	34 (19)	94 (45)	110 (29)
		Outer	43 (54)	94 (64)	59 (46)
	1.3	Inner	0 (0)	6 (7)	7 (7)
		Outer	0 (0)	5 (11)	4 (8)
	2.3	Inner	2 (5)	0 (0)	0 (0)
		Outer	6 (19)	0 (0)	0 (0)

[a]Values represent means of 9 analyses per position. Figures in parenthesis represent one standard deviation

Table I-3. Isolation frequency of decay fungi and non-decay fungi from Douglas-fir poles sections one and two years after treatment with Basamid alone or amended with copper naphthenate or copper sulfate.

Treatment	Distance Above GL (m)	Percentage of Cores With Fungi		
		Year 1	Year 2	Year 3
None	0.3	0^{11}	0^{0}	0^{0}
	1.3	0^{11}	0^{33}	11^{11}
	2.3	0^{11}	0^{33}	0^{33}
Copper Sulfate	0.3	0^{11}	0^{0}	0^{0}
	1.3	22^{33}	44^{56}	0^{33}
	2.3	0^{44}	0^{33}	0^{0}
Copper Naphthenate	0.3	33^{33}	0^{0}	0^{0}
	1.3	0^{22}	0^{0}	0^{0}
	2.3	0^{44}	0^{67}	0^{22}

4. Performance of basamid in rod or powdered formulations: While field tests have shown that basamid performs as well or better than metham sodium, one of the major advantages of this chemical is its form. This crystalline solid reduces the risk of direct worker exposure due to spillage and the material can be more easily removed should spills occur. While basamid is currently sold as a powder, previous Coop data has demonstrated the potential for forming this material into either pellets or rods. Basamid rods would be simpler to apply and would reduce the risk of dust inhalation during treatment.

Douglas-fir pole sections (250-300 mm in diameter by 3 m long) were set to a depth of 0.6 m in the ground at the Corvallis test site. Three steeply angled holes were drilled beginning at groundline and moving upward 150 mm and around 120°. The holes received either 160 g of powdered basamid, 107 g of basamid rod plus 100 g of copper naphthenate, 160 g of basamid rod, or 490 g of metham sodium. The powdered basamid, 107 g basamid and metham sodium treatments were replicated on 5 poles each The higher rod dosages were replicated on 15 poles. The treatment holes in five poles each of these fifteen received 100 g of copper naphthenate or water, or were left unamended.

The poles were samples one year after treatment by removing increment cores from equidistant points around each pole 0.3 m, 0.8 m and 1.3 m above groundline. The inner and outer 25 mm of each core were placed into 5 ml of ethyl acetate and the resulting extract was analyzed for MITC as described previously.

MITC was usually present 0.3 and 0.8 m above groundline, but was either absent or present only a low levels 1.3 m above groundline (Table I-4). MITC levels were highest in the metham sodium treatment 0.3 m above groundline. MITC levels in the remaining treatments were similar in the inner zone 0.3 m above groundline suggesting that the copper naphthenate had little effect on the rod treatments. More importantly, similar MITC levels in the powder and rod treatments at comparable dosages indicate the rod formulation did not affect the initial rate of MITC release. One concern with the rod was that the reduced wood/chemical contact would reduce the decomposition rate. This apparently did not occur and indicates that the treatments should perform comparably.

5. Performance of metham sodium in Douglas-fir timbers: Over the years, we have traditionally focused our fumigant research on round timbers, but many wood users also use fumigant to control decay of sawn timbers in bridges, cross arms, building timbers, and a host of other applications. There is, however, little data on the performance of fumigants in

Table I-4. Residual MITC in Douglas-fir pole sections at selected distances above the groundline one year after treatment with metham sodium, basamid powder, or basamid rods with or without supplemental copper.

Treatment	Dosage (g)	Supplement	Residual MITC (ug/g wood)[a]					
			0.3 m		0.8 m		1.3 m	
			inner	outer	inner	outer	inner	outer
Basamid powder	160	none	50 (35)	24 (24)	6 (17)	4 (8)	0 (0)	<1 (1)
Basamid rod	107	Cu naphthenate	45 (57)	46 (44)	2 (4)	6 (8)	0 (0)	0 (0)
Basamid rod	160	none	54 (95)	30 (30)	2 (4)	4 (7)	<1 (2)	1 (3)
Basamid rod	160	Cu naphthenate	49 (63)	85 (88)	9 (16)	9 (16)	1 (2)	1 (2)
Basamid rod	160	water	22 (22)	29 (35)	4 (6)	6 (10)	0 (0)	1 (2)
Metham sodium	490	none	64 (44)	75 (74)	17 (18)	22 (27)	1 (3)	2 (4)

[a]Values represent means of 15 analyses per treatment. Figures in parentheses represent one standard deviation

these applications. This section addresses evaluation of metham sodium performance in a bridge timbers.

Metham sodium was applied to creosoted douglas-fir timbers in a bridge located near Salem, Oregon. The chemical was applied through 19 mm diameter holes drilled at 1.2 m intervals along the length of each timber. The holes were plugged with tight fitting treated wood dowels. Residual chemical levels were assessed 1, 3, 6, 7, and 10 years after treatment by removing increment cores from near the top and bottom edge of each timber 0.6 m from the original treatment holes on each of 8 stringers. The outer, treated shell was discarded, then the inner and outer 25 mm of the remaining core were placed into 5 ml of ethyl acetate and extracted for 48 hours at room temperature. The resulting extract was analyzed for MITC by gas chromatography as described earlier. The remainder of each core was placed on malt extract agar and observed for growth of decay fungi which would serve as an indicator of failure of the remedial treatment.

While decay fungi were isolated from the timbers prior to treatment and for up to 3 years after chemical application, no decay fungi have been isolated from the timbers over the past 7 years (Table I-5). In addition, levels of non-decay fungi continue to remain low, suggesting that chemical levels in the wood remain protective against fungal invasion.

MITC levels in most timbers remained between the threshold range (20-40 ug/g of wood) for the first 7 years after treatment, suggesting that the treatment continued to provide protection against reinvasion by decay fungi (Table I-6). Sampling after 10 years revealed that MITC levels were at the threshold in 4 of the 8 timbers sampled. These results indicate that the protective effects of the treatment have declined to the point where fungal attack is possible; however, the cultural results indicate the fungi have not yet begun to invade the wood. Reinvasion of these timbers is likely to proceed more slowly than would be found at the groundline, given the lack of direct soil contact. As a result, it may be possible to extend the retreatment period for these timbers for several more years.

Table I-5 Fungal isolations from Douglas-fir timbers 0 to 10 years after treatment with metham sodium							
Structure Number	Percentage of Cores with Fungi[a]						
	Year 0	Year 1	Year 2	Year 3	Year 6	Year 7	Year 10
5	-	0^{42}	0^{90}	0^{22}	0^{0}	0^{0}	0^{0}
10	0^{17}	0^{42}	0^{58}	0^{50}	0^{0}	0^{8}	0^{0}
15	0^{17}	0^{0}	0^{100}	0^{67}	0^{0}	0^{0}	0^{8}
20	-	0^{0}	0^{100}	0^{83}	0^{8}	0^{8}	0^{8}
25	0^{29}	0^{0}	0^{100}	8^{58}	0^{0}	0^{17}	0^{8}
30	2^{43}	0^{8}	0^{100}	0^{0}	0^{8}	0^{0}	0^{0}
35	13^{87}	0^{0}	0^{17}	8^{33}	0^{27}	0^{0}	0^{0}
40	0^{17}	-	8^{42}	-	-	0^{0}	0^{0}
Mean	8^{35}	0^{13}	1^{70}	4^{60}	0^{7}	0^{4}	0^{3}

[a]Full scale numbers values represent decay fungi while superscripts represent percentages of non-decay fungi isolated.

Table I-6. Residual MITC in increment cores removed from Douglas-fir timbers 1 to 10 years after application of metham sodium												
Timber #	Residual MITC (ug/g of wood) [a]											
	Inner 25 mm						Outer 25 mm					
	Year 1	Year 2	Year 3	Year 6	Year 7	Year 10	Year 1	Year 2	Year 3	Year 6	Year 7	Year 10
5	32 (64)	44 (76)	21 (40)	40 (47)	15 (28)	17 (19)	12 (22)	70 (96)	44 (106)	79 (97)	66 (76)	19 (27)
10	58 (66)	126 (106)	57 (60)	53 (32)	32 (20)	14 (11)	47 (39)	60 (47)	97 (151)	50 (32)	29 (26)	10 (8)
15	22 (28)	83 (85)	32 (30)	51 (38)	43 (24)	25 (26)	31 (49)	86 (90)	94 (105)	61 (40)	36(25)	20 (20)
20	48 (64)	80 (100)	63 (54)	43 (27)	48 (44)	42 (55)	46 (54)	75 (139)	104 (131)	59 (31)	54 (44)	20 (22)
25	30 (32)	73 (103)	63 (58)	38 (34)	37 (27)	29 (19)	39 (57)	70 (72)	42 (31)	40 (28)	39 (25)	15 (12)
30	78 (58)	84 (90)	80 (66)	34 (20)	42 (23)	23 (12)	88 (85)	81 (79)	60 (42)	39 (24)	30 (20)	20 (15)
35	29 (40)	75 (90)	64 (90)	33 (20)	46 (28)	21 (23)	35 (67)	82 (166)	33 (46)	48 (42)	47 (46)	6 (6)
40	-	71 (111)	-	-	17 (14)	25 (15)	-	99 (95)	-	-	29 (40)	22 (21)
Mean	42	79	54	42	35	25	43	78	68	54	41	17
a. numbers in parentheses represent one standard deviation.												

B. PERFORMANCE OF WATER DIFFUSIBLE PRESERVATIVES AS INTERNAL TREATMENTS

While fumigants have proven to be highly effective at arresting fungal attack inside large timbers and poles and have provided excellent long term protection against renewed fungal attack, many wood users have expressed concern about the toxicity of these chemicals. One alternative to fumigants for internal decay control is to substitute water diffusible chemicals such as boron or fluoride. Both boron and fluoride are capable of moving with free water in the wood, allowing them to diffuse from the point of application whenever the wood moisture content exceeds 30%. These chemicals are both good fungicides and boron has the added advantage of affecting insect attack. While both boron and fluoride have been available as fungicides since the 1930's, there is relatively little data on the performance of these chemicals as internal remedial treatments. In this section, we discuss the results form various field trials of boron and fluoride rods.

1. <u>Performance of fused boron rods in Douglas-fir poles sections</u>: Fused borate rods are produced by heating boron to approximately 800 C, in the process, expelling moisture. The molten boron is then poured into molds and allowed to cool. The resulting rods provide a highly concentrated boron treatment that can be applied to the same holes typically used for internal fumigant treatment. Boron rods have been used in Europe for many years to arrest decay in window frames, railway ties, and utility poles, but there is little data on their performance on U.S. species, particularly in larger wood members such as poles. In order to develop this data, we have established a number of field tests, both in Corvallis and at utility test sites.

Untreated Douglas-fir pole sections (200-250 mm in diameter by 1.05 m long) were dipped in 2 % chromated copper arsenate and allowed to dry. A 9 mm diameter hole was drilled through each pole 400 mm from the top and a galvanized bolt with a slot cut perpendicular to the threads was inserted into the hole. A second 9 mm diameter by 200 mm long hole was drilled into the pole 150 mm above the original hole to serve as a treatment hole. Each hole received 40 or 80 g of fused boron rod (1 or 2 rods), then the holes were plugged with tight fitting wood dowels. One half of the poles were sent to Hilo, Hawaii, while the remainder were exposed at our Corvallis site. All poles were placed on racks out of ground contact. The Hilo poles quickly experienced extensive checking that we believe largely negated the value of the test. The poles at the Corvallis site did not check and have continued in test for 10 years.

Boron movement from the rods was assessed 1,6, 7, and 10 years after treatment by removing increment cores from two sites 90 degrees around from and 75 mm below the bolt hole. The cores were segmented into zones corresponding to the inner and outer 50 mm. The segments were ground to pass a 20 mesh screen and analyzed for boron. Initially, these analyses were performed by ion coupled plasma spectroscopy, but later were performed using the Azomethine H method. In addition, one core was removed from 75 mm above the treatment hole. This core was ground as one sample and analyzed for boron. A second set of cores was removed from 75 mm below each bolt. These cores were placed on malt extract agar and observed for growth of decay fungi as described earlier in this section.

Boron levels in untreated control poles ranged from 0.005 to 0.19 kg/m^3 (Table I-7). Boron levels in poles receiving 40 g of boron rod were generally below the upper threshold for protection against fungal attack one year after treatment except for the inner zone at the lowest point sampled. Boron levels were generally higher in the inner zone, reflecting the tendency for moisture conditions to be more stable deeper in the wood, thereby facilitating more sustained boron diffusion. Boron levels tended to rise between 1 and 6 years after treatment and were often above the threshold. Once again, inner boron levels tended to be higher than outer levels. Boron levels in the lower dosage treatment tended to decline slightly between year 6 and 7, then more precipitously between years 7 and 10. None of the boron levels were above the threshold 10 years after treatment.

Boron levels in the higher dosage tended to be higher above the treatment hole but lower below that zone for most of the sample times. As with the lower dosage, chemical levels tended to be higher in the inner zone, although the differences were nearly absent 10 years after treatment. As with the lower dosage, boron levels at all sampling sites were below the threshold 10 years after treatment.

Fungal isolation from boron treated poles 7 and 10 years after treatment revealed that decay fungi had begun to colonize the untreated poles, while levels tended to be low in the 40 and 80 g treatments (Table I-8).

Table I-7. Boron levels at selected distances above and below the threaded rod in Douglas-fir pole sections 1 to 10 years after treatment with 40 or 80 g of fused boron rod. Treatment was applied 75 mm below rod.

Dosage (g)	Distance from bolt	Treatment zone	Residual boron levels (kg/m^3 BAE)			
			Year 1	Year 6	Year 7	Year 10
40	75 mm	whole	1.457 (1.694	1.176 (1.121)	0.471 (0.422)	0.387 (0.294)
	-75 mm	inner	0.343 (0.514)	4.445 (5.499)	1.832 (2.085)	0.520 (0.985)
		outer	0.291 (0.235)	1.321 (0.753)	1.432 (1.562)	0.524 (0.541)
	-225 mm	inner	3.159 (5.863)	1.711 (1.292)	1.248 (0.942)	0.119 (0.121)
		outer	0.291 (0.146)	1.363 (0.814)	0.780 (0.575)	1.235 (3.147)
80	75 mm	whole	3.987 (3.616)	3.487 (6.004)	1.667 (1.857)	0.382 (0.252)
	-75 mm	inner	0.331 (0.593)	2.878 (3.270)	5.700 (4.028)	0.485 (0.326)
		outer	0.137 (0.090)	1.071 (0.765)	1.484 (1.276)	0.693 (0.562)
	-225 mm	inner	0.240 (0.139)	1.338 (1.278)	1.990 (1.256)	0.531 (0.546)
		outer	0.217 (0.182)	0.599 (0.577)	0.682 (0.439)	1.143 (1.721)

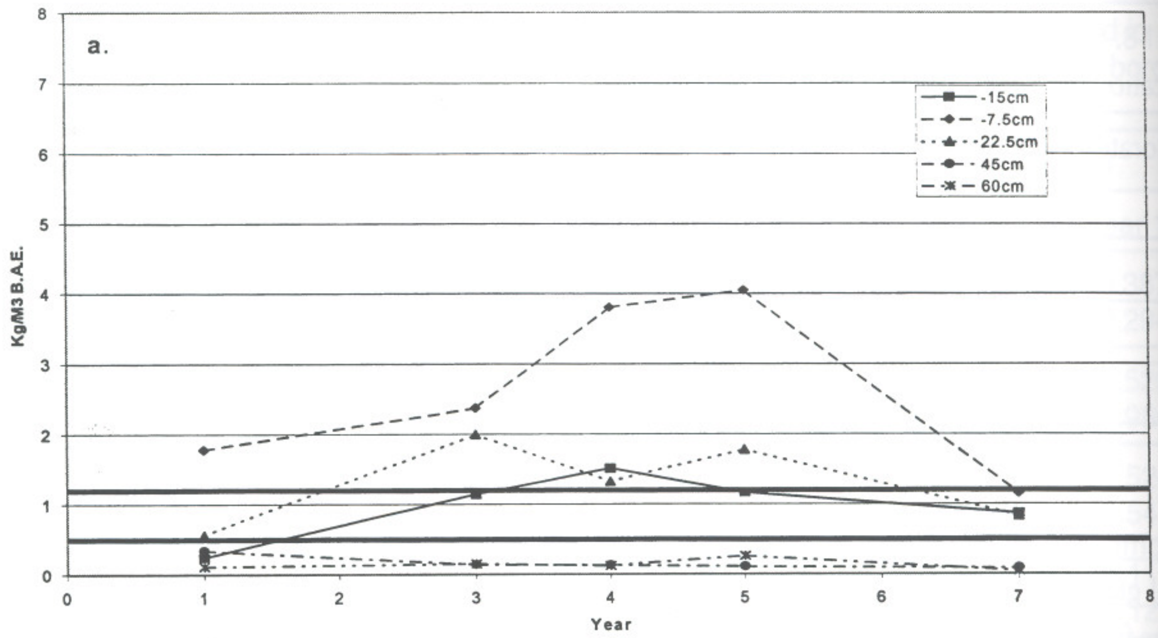
Table I-8. Fungal isolations from Douglas-fir pole sections 7 and 10 years after application of fused boron rods at two dosages.

Borate Rod Dosage (g)	Fungal Isolations (% decay$^{non\text{-}decay}$)	
	Year 7	Year 10
0	20 ^{100}	80 ^{100}
40	0 ^{90}	10 ^{100}
80	10 ^{100}	0 ^{100}

2. Performance of fused boron rods in internal groundline treatments of Douglas-fir poles: Twenty pentachlorophenol treated Douglas-fir pole sections (250-300 mm by 2 m long) were set to a depth of 0.6 m at the Peavy Arboretum test site. Three 19 mm wide by 200 mm long holes were drilled perpendicular to the grain beginning at groundline and moving around the pole 120° and upward 150 mm. Each hole received either 1 or 2 fused boron rods (180 or 360 g of rod, respectively, per pole). Each treatment was replicated on 10 poles.

The poles were sampled 1, 3, 4, 5, and 7 years after treatment by removing increment cores from sites located 150 mm below ground as well as 75, 225, 450, and 600 mm above the groundline. The outer treated shell was removed, then the remaining core was divided into inner and outer halves. Core segments for a given height and position (inner/outer) were combined for a given treatment and ground to pass a 20 mesh screen. The wood was hot water extracted, then the extract was analyzed for boron by either ion coupled plasma spectroscopy or the azomethine H method and expressed on a kg/m^3 of boric acid equivalent (BAE) basis (wt/wt).

Boron levels in poles receiving 180 g of rod tended to be low for the first 3 years after treatment, particularly above ground in the outer zone (Figure I-5). Boron levels rose sharply in the outer zones 5 years after treatment, then gradually declined 2 years later. This spike in chemical levels followed a very wet year and suggests chemical levels in the poles was closely tied to climatic conditions. Boron levels 7 years after treatment in the outer zone were still above the lower threshold, but the rate of



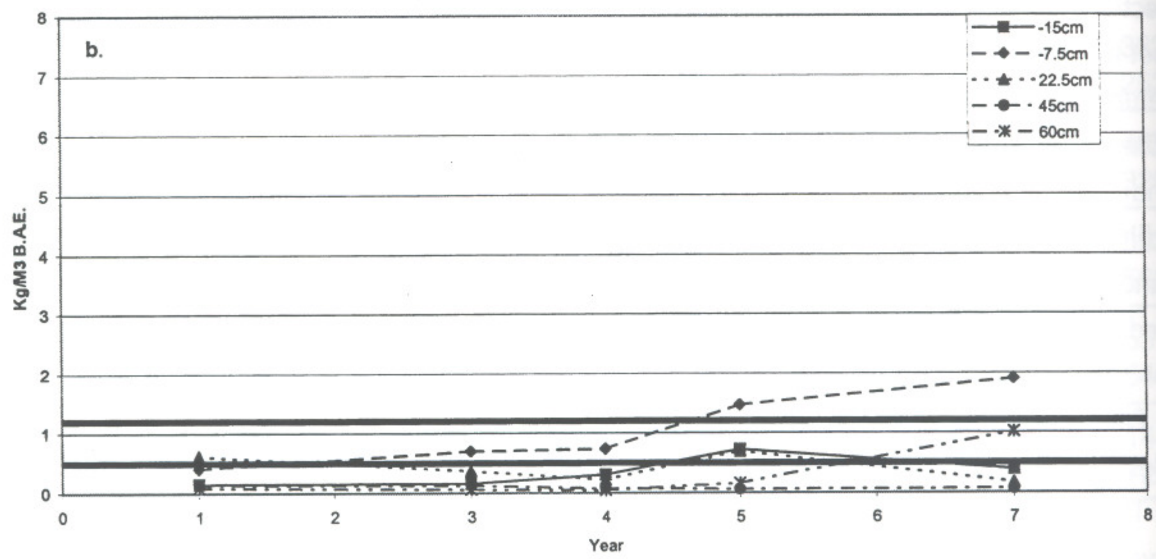


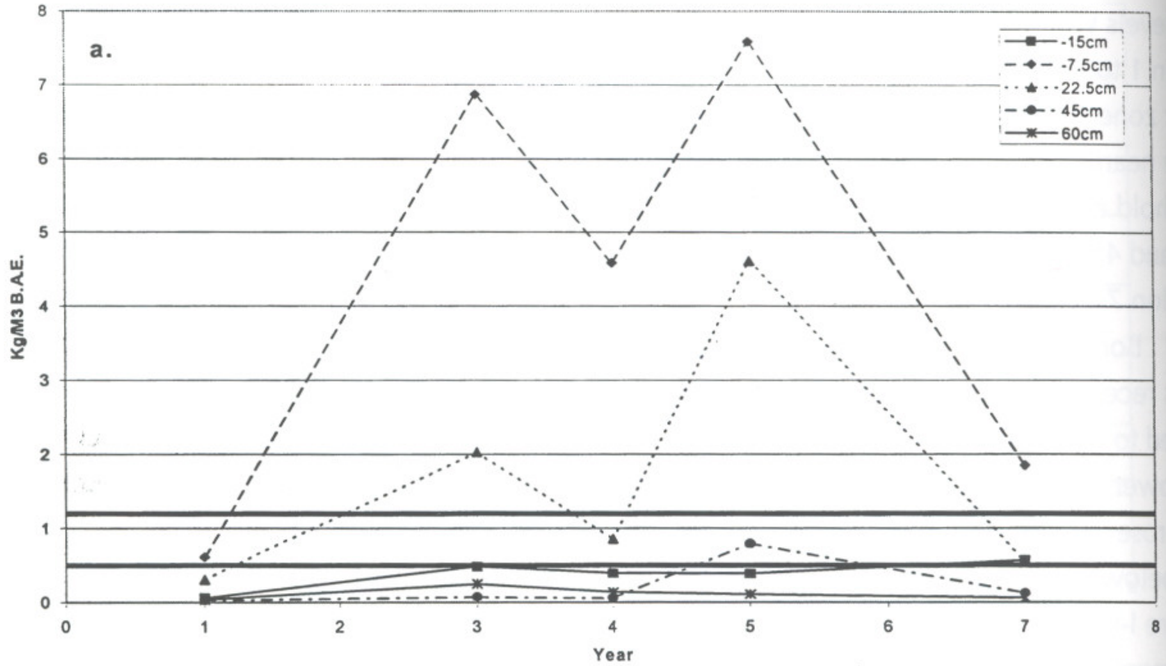
Figure I-5. Boron levels in the a) inner and b) outer regions of Douglas-fir pole sections 1 to 7 years after treatment with 180 g of fused boron rod.

decline between 5 and 7 years suggests that levels will be below the threshold within 1 to 2 years. Boron levels in the inner zone were generally higher than those nearer the surface and exceeded the threshold at all sample locations except 600 and 450 mm above the groundline location 7 years after treatment.

Boron levels in the inner zones of poles receiving 360 g of fused boron rod tended to be lower than those found in the lower dosage one year after treatment, then rose sharply between 2 and 5 years just below and above the treatment zone (Figure I-6). Boron levels higher above the treatment zone tended to remain below the lower threshold as did the lowest sampling point below groundline. Low levels further below ground may reflect the wet site in which these poles were exposed. Boron would be expected to migrate with moisture and the high water table during the wet winter months probably accelerated this process. Boron levels in the inner zones 7 years after treatment were at or above the threshold in 32 of four zones sampled, suggesting that retreatment may be necessary within 1 to 2 years. Boron levels near the surface remained low for most of the test period, but have gradually increased over the last 3 years and are now at or above the threshold in 3 of the sampling zones.

3. <u>Use of glycol additives to enhance movement of boron from fused boron rods</u>: Boron has been widely studied as a wood preservative because it effectively controls insect and fungus infestations in wood and has a low toxicity to non-target organisms. This chemical can be applied in a fused rod form that will diffuse through wood from the point of treatment if sufficient water is available (Dickinson et al., 1988; Dietz and Schmidt, 1988; Dirol, 1988; Edlund et al., 1983; Ruddick and Kundzewicz, 1992). Diffusion through Douglas-fir heartwood occurs slowly at moisture contents below the fiber saturation point, but does not usually produce levels necessary for wood protection (Morrell and Freitag, 1995; Morrell et. al. 1990). Diffusion occurs rapidly at moisture contents above 40% (Smith and Williams, 1969; Morrell et. al. 1990). Adding water at the time of boron rod application has been shown to have little effect on boron levels away from the treatment application point or on the isolation frequency of decay fungi (Morrell and Schneider, 1995). One approach for enhancing boron diffusion is to add glycol (Bech-Anderson, 1987; Edlund et al., 1983).

Several commercially available formulations of boron and glycol have been shown to enhance the diffusion of boron into drier wood (Edlund et al 1983). These products have been used in buildings, but their use in larger structures, such as utility poles, has not been investigated. The objective of this



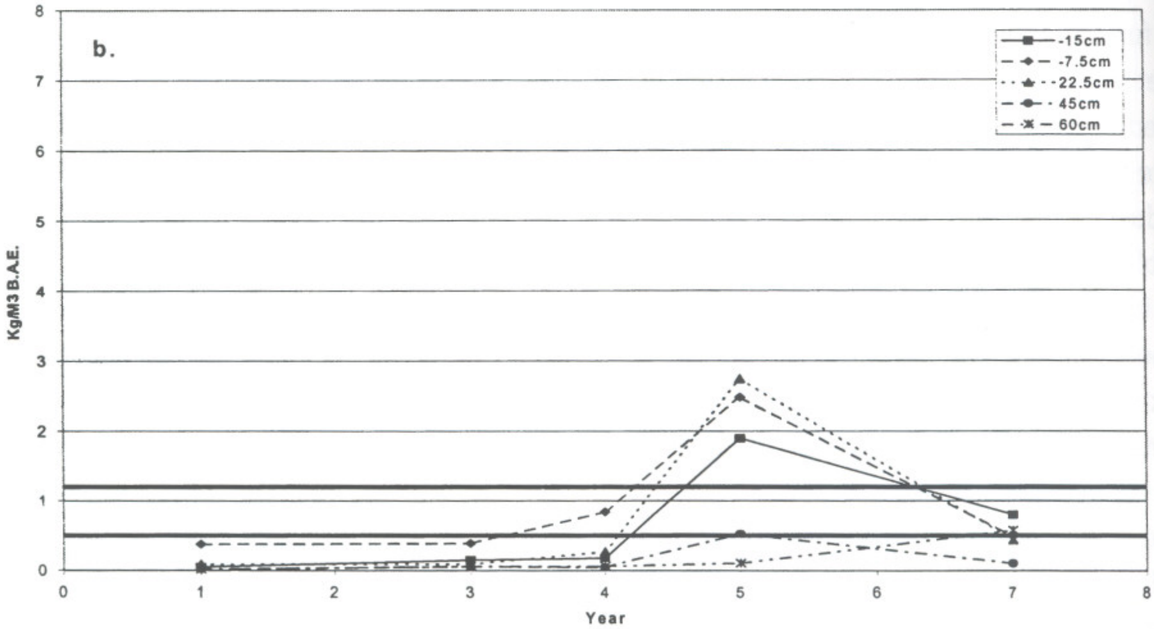


Figure I-6. Boron levels in the a) inner and b) outer regions of Douglas-fir pole sections 1 to 7 years after treatment with 360 g of fused boron rod.

study was to determine the effect of various boron/glycol formulations applied in conjunction with Impel rods® on the diffusion of boron through Douglas-fir utility poles.

Pentachlorophenol treated Douglas-fir pole sections (25 to 30 cm in diameter by 2.1 m long) were set to a depth of 0.6 m in the ground at the Oregon State University test site near Corvallis OR, USA. The pole test site in Corvallis receives average yearly rainfall of 1050 mm with 81% falling between October and March. The soil around the poles is an Olympic silty-clay loam and is saturated during much of the year.

Four 20 mm diameter holes were drilled at a 45° downward sloping angle in each pole, beginning at 75 mm above groundline, then moving 90° around and up to 230, 300 and 450 cm above groundline. An equal amount of boron (227g BAE) was added to each pole, but was delivered from a combination of sources in the different treatments (Table I-8.) The Impel rods® were 100 mm long by 12.7 mm in diameter and weighed 24.4 g each. An equal weight of boron rod composed of 1 whole rod and a portion of another was placed in each hole followed by the appropriate liquid supplement or left dry. The holes were then plugged with tight fitting, preservative-treated wooden dowels. Each treatment was replicated on 5 poles.

The pole sections were treated in March, 1995 and were sampled after 1, 2 and 3 years by removing 2 increment cores 180^0 apart from 300 mm below groundline, and 3 increment cores spaced 120^0 apart at groundline, 150 and 300 mm above groundline. The pentachlorophenol treated portion of each core was discarded and the remainder of each core was divided into outer (0-50 mm), middle (51-100mm) and inner (101-150 mm) sections. The 3 core sections from the same depth and height taken at groundline and above were combined and ground to pass a 20 mesh screen. The boron content of the sawdust was determined by ion coupled plasma spectroscopy for the first year samples and by the azomethine method (American Wood Preservers Association Standard A2) for the remaining samples (AWPA 1999).

Wood moisture content was assessed gravimetrically 1 year after treatment on all poles. Moisture content cores were taken at the same heights and zones as those removed for boron analysis This single moisture measurement does not reveal seasonal variations, but provided an internal moisture profile at one point during the test.

The toxic threshold required for boron to kill fungi in wood in contact with soil has been estimated to be between 0.4 and 0.5% BAE (Williams and Amburgy 1987), however levels as

Table I-8. Combinations of boron treatments applied internally to Douglas-fir pole sections in 1995. All treatments deliver 227 g boric acid equivalent per pole.						
Impel Rod® (g)	Supplement	Supplement (g)	Total Glycol (g)	Total water (g)	Supplement Source	Supplement Formulation
156	None	0	0	0		
137	Bora-Care® 1:1 in water	118	28	65	Nisus Corp. Rockford, TN	Disodium octaborate tetrahydrate plus poly and monoethylene glycol
137	Boracol 20®	122	77	20	CSI Inc. Charlotte, NC	Disodium octaborate tetrahydrate plus polyethylene glycol (20%)
104	Boracol 40®	164	95	0	CSI Inc. Charlotte, NC	Disodium octaborate tetrahydrate plus polyethylene glycol (40%)
156	Ethylene glycol	100	100	0	VanWaters and Rogers, Seattle, WA	
146	Timbor® 10% in water	118	0	106	U.S. Borax Inc.	Disodium octaborate tetrahydrate

low as 0.10 %BAE may be sufficient to prevent colony formation from spores and hyphal fragments (Morrell et. al. 1998).

Boron levels 300 mm below groundline: One year after treatment, the wood moisture content 300 mm below groundline was above the fiber saturation point (~30%) in all core sections. The boron content of the wood was below the upper toxic threshold value of 0.5% BAE in all but the rod only and rods plus Boracol 40® treatments. The Boracol 40® treatment produced a level of 0.56% BAE in the inner core sections one year after treatment, then declined to just above the lower threshold level over the next 4 years. Boron levels were generally higher in the inner segments, probably because most of the treatment was at the bottom of the sloping holes, near the center of the pole. The bottom of the lowest treatment hole was approximately 230 mm above the lowest sample zone. Boron levels below ground remained fairly steady over 5 years with most treatments. Boron levels in poles treated with Boracol 40® declined in the inner segments, but increased in the middle and outer segments.

Boron levels at groundline: Wood moisture contents at groundline one year after treatment were slightly above the fiber saturation point in the inner sections, but slightly below in the middle and outer sections. Boron levels were above the toxic threshold in the inner sections in all treatments except for the rods alone at one year in all 4 sample years. Boron levels in the middle segments did not reach the threshold with most treatments until 2 to 3 years after treatment, then most increased to levels well above the threshold (Figure I-8). Boron levels in the middle zones of the Boracol 40® treated cores again exceeded 0.5% BAE in all 5 years while levels in the outer sections rose above the threshold in the third year. All 3 segments from the Boracol 20® treated poles also exceeded the threshold in the fifth year as well. Boron levels in the Boracol 40® treated poles followed the same trend over time as found with the below ground sample (Figure I-7). Levels in the middle and outer sections increased each year. The Impel rod® treatment without any supplement resulted in levels of boron approaching the threshold after 3 years and well above that level 5 years after treatment. The groundline sampling zone was approximately 50 mm above and 100 mm below the first and second treatment holes. The assay results indicate that boron has become well distributed in the groundline zone between the treatment holes.

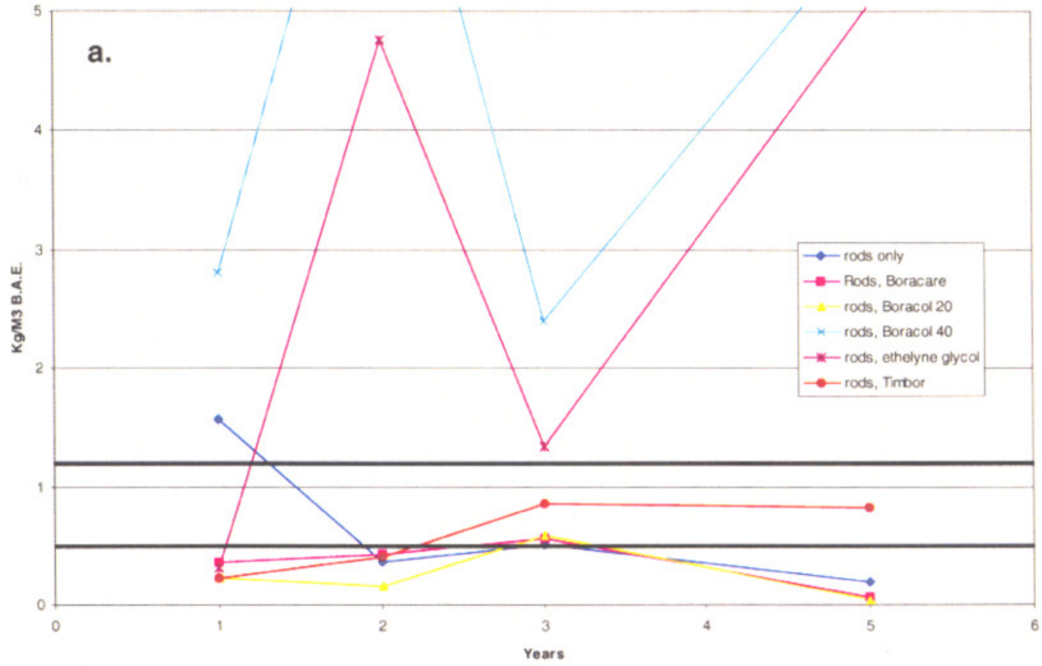
Table 1-9. Boron levels in increment cores removed from various distances above and below groundline from Douglas-fir pole sections treated with fused boron rods with or without diffusion enhancers.

treatment	height (mm from groundline)	depth	year 1	year 2	year 3	year 5
			Average boron content (Kg/m3 BAE)/standard deviation			
rods only	-300	I	**0.518** 0.448	**1.400** 1.229	**0.865** 0.825	**0.527** 0.925
		M	**0.807** 1.339	**0.827** 0.905	0.373 0.301	0.372 0.686
		O	0.299 0.097	0.431 0.561	0.243 0.228	0.499 0.594
	0	I	**1.306** 1.910	**2.161** 0.970	**2.147** 1.965	**2.884** 1.976
		M	0.345 0.240	**1.054** 0.853	**2.427** 2.660	**1.864** 0.818
		O	0.236 0.128	0.229 0.289	**1.669** 2.093	0.423 0.461
	150	I	0.450 0.289	**1.655** 2.236	**2.118** 1.624	**1.872** 1.724
		M	0.223 0.067	**1.386** 2.472	**2.878** 3.325	**1.473** 1.429
		O	0.293 0.182	0.429 0.859	**0.543** 0.861	0.409 0.489
	300	I	0.230 0.132	0.301 0.540	0.489 0.586	**1.144** 2.030
		M	0.202 0.063	0.165 0.159	0.327 0.339	**1.787** 3.127
		O	0.158 0.094	0.097 0.098	0.109 0.096	**1.063** 1.766
Rods plus Boracare	-300	I	**1.567** 1.801	0.360 0.251	**0.510** 0.319	0.195 0.163
		M	0.361 0.197	0.431 0.370	**0.560** 0.278	0.070 0.096
		O	0.226 0.046	0.157 0.030	**0.584** 0.587	0.041 0.064
	0	I	**2.803** 1.864	**7.592** 6.378	**2.397** 1.510	**5.677** 6.605

		M	0.316 0.179	**4.766** 4.784	**1.344** 0.920	**5.031** 4.708
		O	0.223 0.052	0.402 0.394	**0.865** 0.926	**0.830** 0.915
	150	I	**4.352** 3.611	**3.549** 1.219	**4.125** 4.665	**5.165** 3.721
		M	**1.062** 1.096	**1.323** 1.667	**4.097** 4.495	**1.862** 0.966
		O	0.497 0.341	0.490 0.904	0.405 0.304	**1.075** 1.854
	300	I	**1.789** 1.157	**1.221** 1.095	**0.811** 1.045	**2.270** 3.191
		M	**1.161** 1.905	0.328 0.292	**0.886** 1.358	**4.226** 8.090
		O	0.328 0.192	0.148 0.185	**0.998** 1.775	**1.621** 2.882
Rods plus Boracol 20	-300	I	**0.871** 0.710	**0.690** 0.746	0.496 0.530	0.264 0.186
		M	0.490 0.480	0.287 0.258	0.256 0.241	0.222 0.231
		O	0.466 0.491	0.198 0.211	0.219 0.146	**1.619** 3.360
	0	I	**4.513** 5.324	**2.406** 0.730	**3.933** 2.952	**3.331** 1.952
		M	**1.444** 2.085	**0.790** 0.527	**2.379** 2.323	**1.986** 1.251
		O	0.318 0.119	**1.109** 2.109	**2.962** 2.906	**0.546** 0.633
	150	I	**1.845** 0.949	**3.640** 3.998	**1.647** 1.793	**3.692** 1.562
		M	**0.735** 0.695	**1.004** 0.648	**3.388** 5.037	**1.849** 1.158
		O	0.363 0.230	**0.925** 1.453	0.301 0.274	0.441 0.414
	300	I	**2.869** 4.368	**0.702** 0.721	**0.932** 1.120	0.362 0.696
		M	**0.669** 0.620	**1.085** 1.161	**0.580** 0.817	0.268 0.565
		O	0.241 0.065	**1.369** 2.443	0.203 0.240	0.399 0.722

Rods plus Boracol 40	-300	I	**2.493** 2.375	**0.923** 0.633	**0.715** 0.622	**0.617** 0.734
		M	**0.552** 0.411	**0.710** 1.093	**1.526** 2.573	0.369 0.358
		O	0.209 0.076	**0.740** 0.994	**1.359** 2.656	0.067 0.069
	0	I	**11.152** 6.976	**10.407** 9.501	**5.817** 3.208	**10.822** 9.222
		M	**3.382** 2.692	**5.156** 3.233	**9.540** 10.730	**13.818** 10.665
		O	0.448 0.305	**1.263** 1.475	**2.651** 2.214	**2.532** 1.847
	150	I	0.366 0.245	0.326 0.302	0.350 0.301	**0.635** 0.864
		M	0.219 0.030	0.438 0.428	0.408 0.314	0.332 0.528
		O	0.180 0.108	0.334 0.279	0.257 0.082	0.139 0.272
	300	I	0.178 0.118	0.100 0.085	0.085 0.073	0.029 0.043
		M	0.147 0.099	0.082 0.055	0.094 0.079	0.036 0.050
		O	0.153 0.109	0.073 0.035	0.081 0.070	0.017 0.023
Rods plus Ethelyne Glycol	-300	I	0.318 0.290	0.326 0.204	0.162 0.135	0.143 0.209
		M	0.186 0.065	0.184 0.108	0.069 0.132	0.041 0.092
		O	0.159 0.103	0.104 0.113	0.103 0.125	0.032 9,948
	0	I	**5.297** 8.913	**3.712** 2.920	**3.881** 3.836	**2.837** 1.972
		M	**0.975** 1.196	**0.612** 0.393	**0.667** 0.459	**2.812** 2.001
		O	0.211 0.158	0.171 0.173	**0.679** 1.198	**1.6121** .900
	150	I	**2.983** 3.501	**5.024** 4.325	**5.308** 1.722	**2.766** 2.529
		M	**1.343** 1.528	**1.085** 1.363	**2.344** 2.632	**6.532** 10.115

		O	0.289 0.218	0.104 0.084	**1.453** 2.034	**4.289** 7.081
	300	I	0.172 0.112	0.237 0.164	**1.498** 1.831	**1.572** 2.789
		M	0.189 0.047	0.177 0.224	**0.556** 0.690	**3.437** 6.665
		O	0.197 0.040	**0.613** 0.973	**0.911** 1.717	**2.335** 4.853
Rods plus Timbor	-300	I	**0.830** 0.428	**0.665** 0.373	0.303 0.220	0.323 0.388
		M	0.305 0.070	0.264 0.109	**0.542** 0.367	0.126 0.218
		O	0.335 0.181	0.136 0.064	**0.509** 0.603	0.027 0.040
	0	I	**2.752** 2.361	**2.677** 2.364	**5.670** 4.813	**7.576** 11.414
		M	0.324 0.173	**1.841** 1.989	**1.463** 1.345	**1.538** 0.781
		O	0.342 0.230	0.203 0.170	**0.537** 0.551	0.472 0.493
	150	I	**3.534** 3.439	**2.888** 2.220	**2.835** 2.853	**2.217** 1.096
		M	**6.597** 12.260	**1.421** 1.893	**1.744** 1.984	**6.151** 7.508
		O	**0.719** 0.790	0.353 0.299	**0.935** 0.744	**1.133** 0.833
	300	I	**2.940** 5.556	**1.736** 2.218	**1.571** 1.913	**3.378** 5.192
		M	0.377 0.234	0.402 0.352	**1.836** 2.423	**0.678** 0.663
		O	0.446 0.322	0.152 0.069	3.143 2.419	0.336 0.482



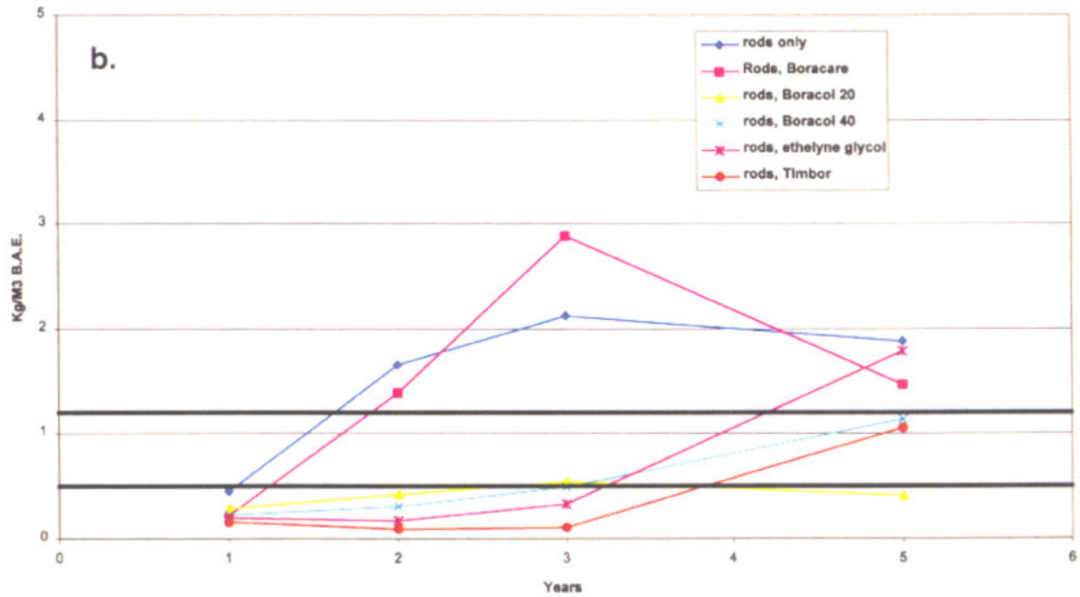


Figure 1-7. Boron levels in the outer (a), middle (b), and inner (c) zones of increment cores removed 300 mm below groundline from Douglas-fir poles sections 1 to 5 years after treatment with fused boron rods with or without various diffusion enhancers.

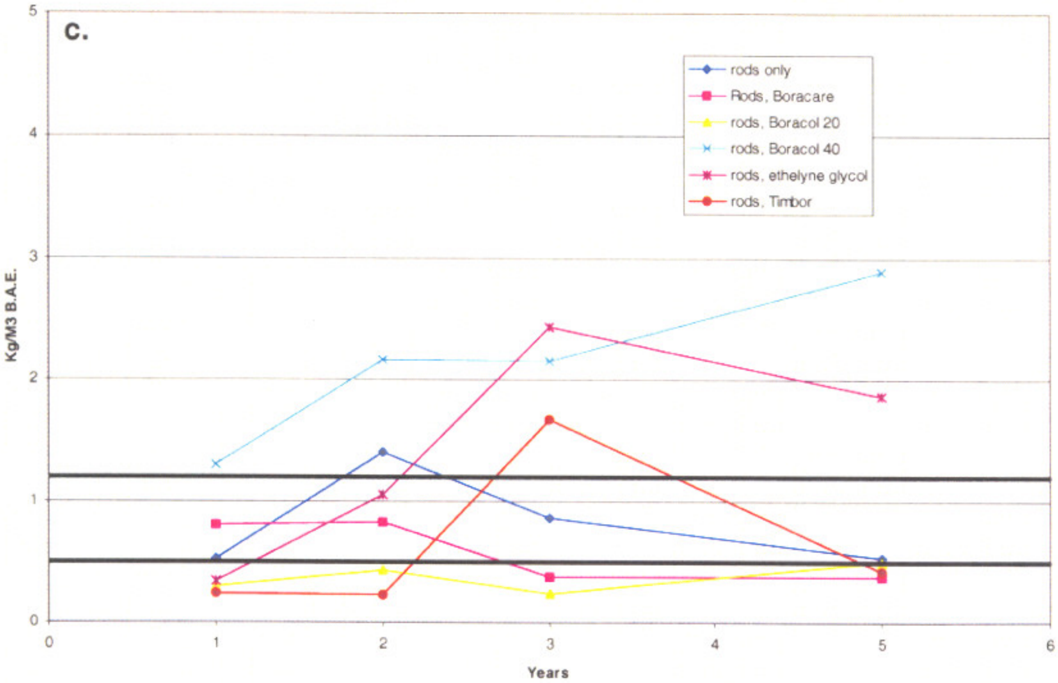
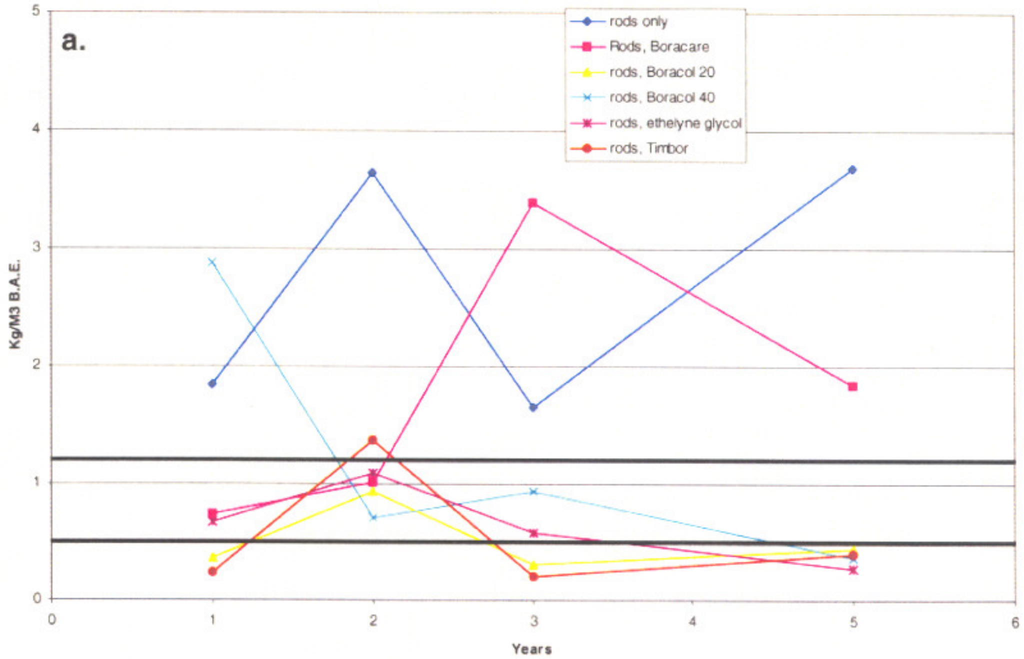


Figure 1-7. Boron levels in the outer (a), middle (b), and inner (c) zones of increment cores removed 300 mm below groundline from Douglas-fir poles sections 1 to 5 years after treatment with fused boron rods with or without various diffusion enhancers.

Boron levels 150 mm above groundline. Wood moisture content 150 mm above groundline averaged 27%, with a significant moisture gradient from the outer to the inner segments Boron levels in this zone were lower than at groundline, particularly 5 years after treatment, despite the close proximity to the treatment holes. Inner core segments from this zone were taken approximately 50 mm above the bottom of the second and 50 mm below the bottom of the third treatment holes. Boron levels above 0.5% BAE were consistently found in the inner core segments of the Bora-Care®, ethylene glycol and Timbor® treatments (Figure 1-9).

Levels in the Boracol 20® treatment were variable, but rose with time in the middle core segments. The ethylene glycol treatment also resulted in higher boron levels over time, exceeding the threshold in the outer and middle segments by the third year. The Boracol 40® treatment resulted in uniformly low boron levels 150 mm above groundline. The boron rod without supplemental treatment resulted in boron levels approaching 0.5% BAE by the third year. All boron levels rose sharply between 3 and 5 years. Rain in the two previous years were either average or well above average for the test site, suggesting that the additional moisture had enhanced diffusion from the treatment zone.



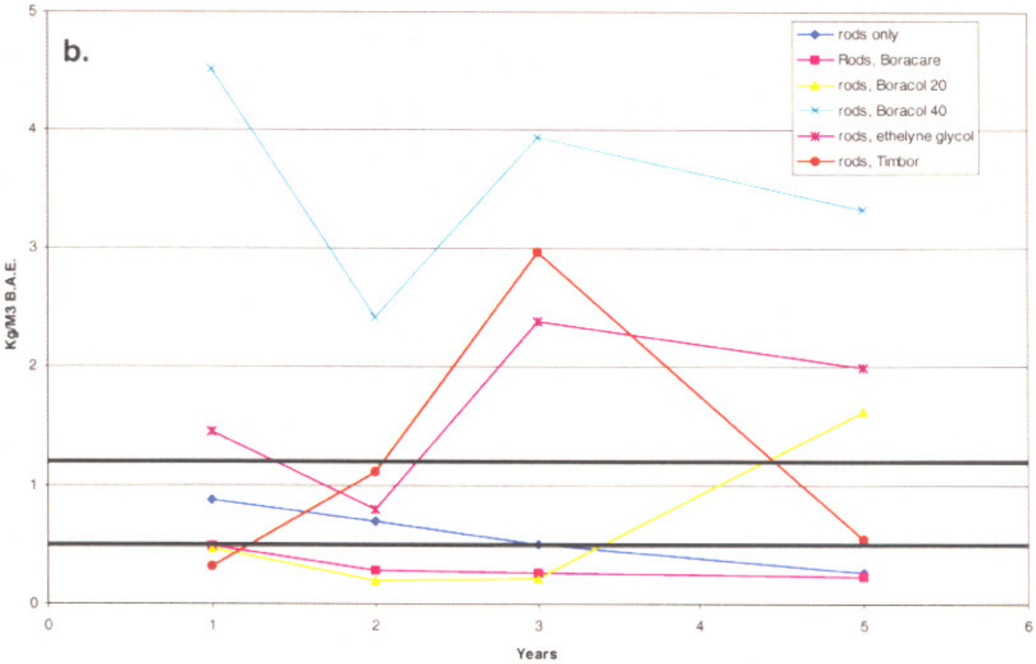


Figure 1-8. Boron levels in the outer (a), middle (b), and inner (c) zones of increment cores removed at groundline from Douglas-fir poles sections 1 to 5 years after treatment with fused boron rods with or without various diffusion enhancers.

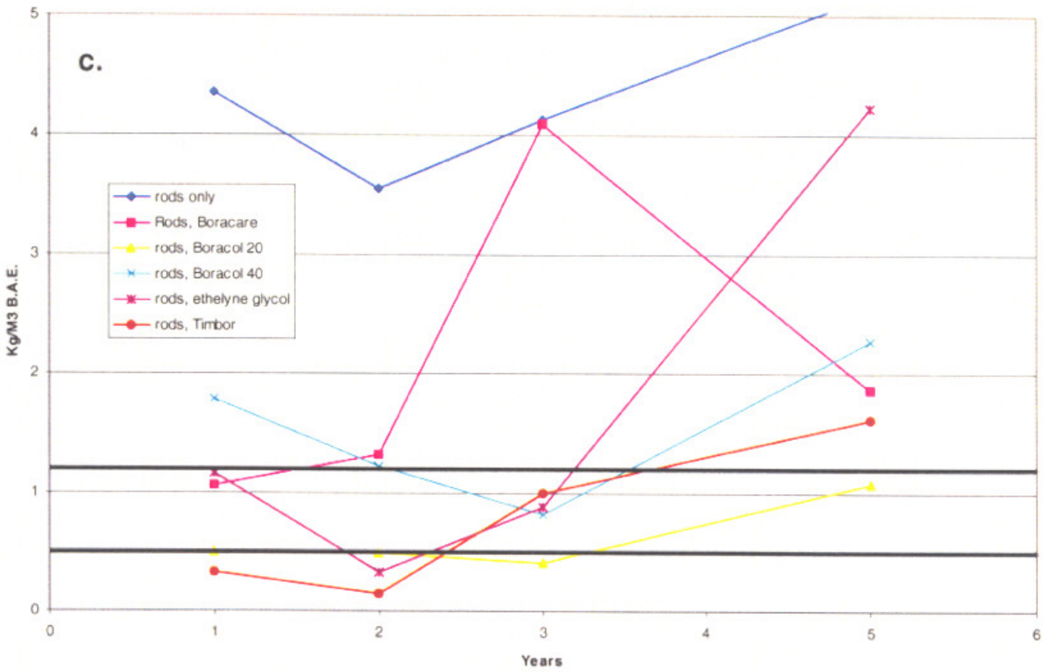


Figure 1-8 cont. Boron levels in the outer (a), middle (b), and inner (c) zones of increment cores removed at groundline from Douglas-fir poles sections 1 to 5 years after treatment with fused boron rods with or without various diffusion enhancers.

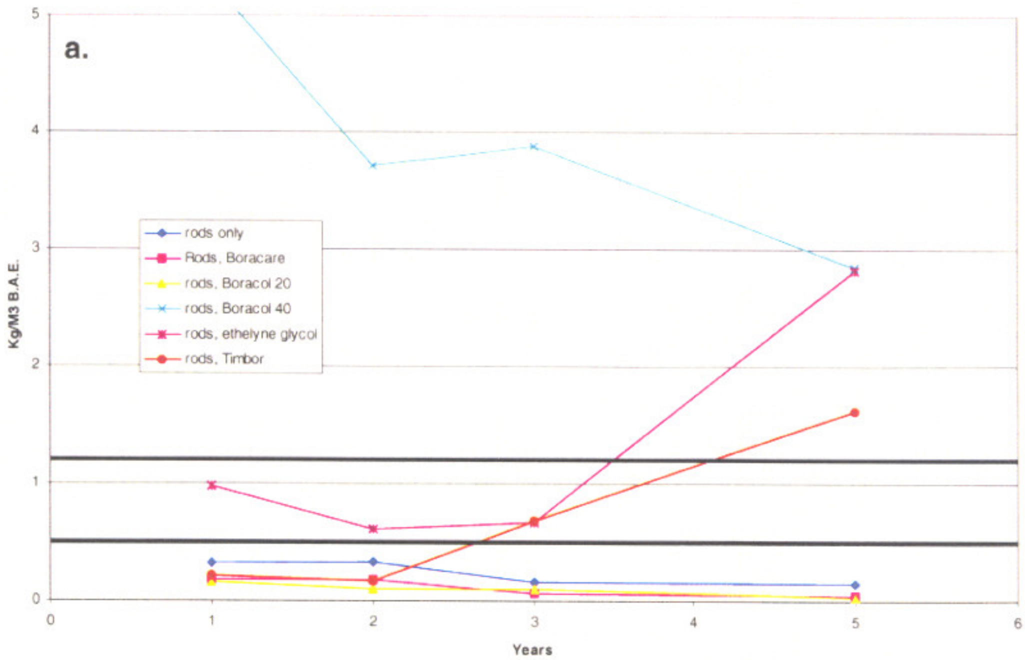


Figure 1-9. Boron levels in the outer (a), middle (b), and inner (c) zones of increment cores removed 150 mm above groundline from Douglas-fir poles sections 1 to 5 years after treatment with fused boron rods with or without various diffusion enhancers

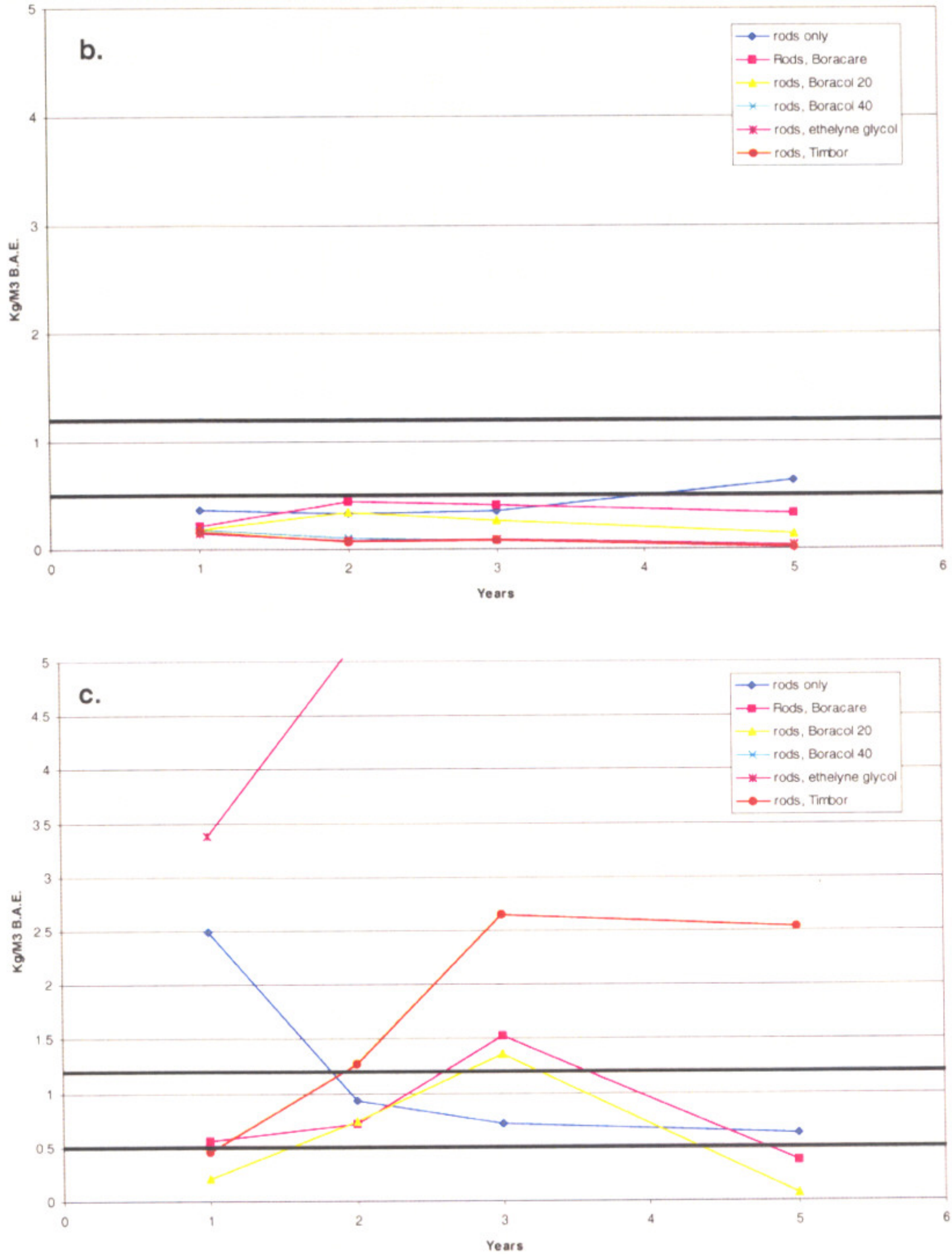
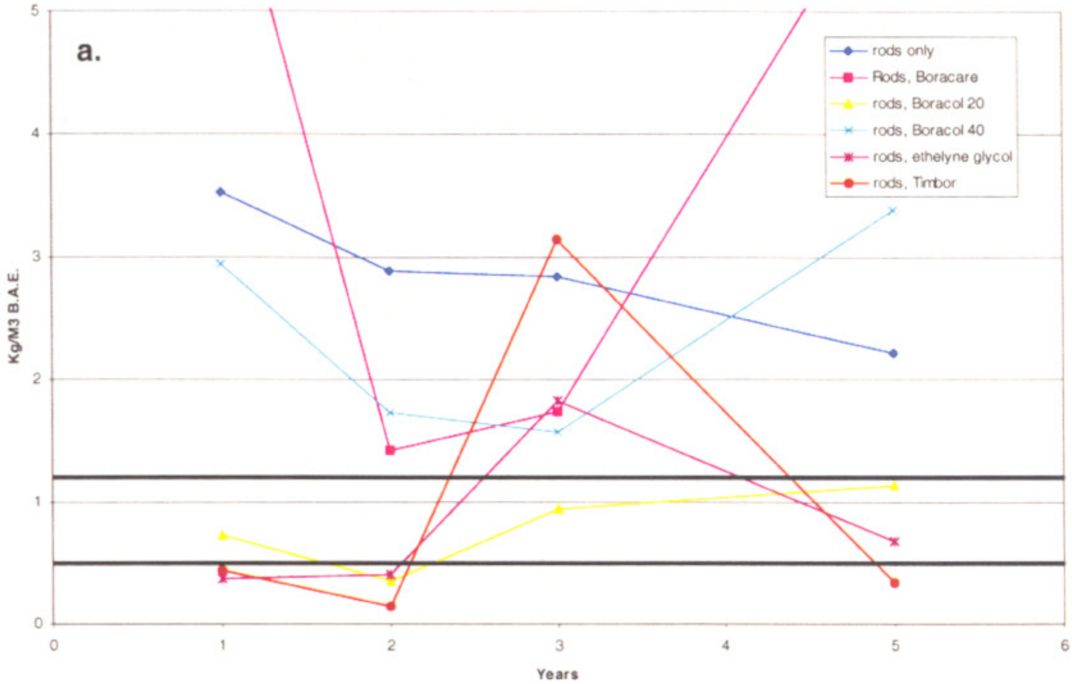


Figure 1-9. Boron levels in the outer (a), middle (b), and inner (c) zones of increment cores removed 150 mm above groundline from Douglas-fir poles sections 1 to 5 years after treatment with fused boron rods with or without various diffusion enhancers.

Boron levels 300 mm above groundline. Wood moisture content 300 mm above groundline averaged 27% with no significant gradient from the outer to inner core segments . The 300 mm sampling zone was close to the bottom of the highest treatment hole. Boron levels in this zone were below threshold with most treatments over the first 3 years after treatment, then rose sharply over the additional 2 years to the point where many boron levels were at or above the threshold (Figure I-10). The Timbor® treatment resulted in the highest boron levels, near or above threshold in all 3 core segments by the third year. Boron levels in this treatment remained high in the inner zone, but declined in both the middle and outer segments. Both Boracol® treatments resulted in fairly steady , but low boron levels that were mostly below the toxic threshold. Boron levels in Boracare® treated poles were initially low, but increased to levels above the threshold 5 years after treatment. Boron levels from the ethylene glycol treatment increased each year and may have provided some protection by the third year. Levels were clearly above the threshold with this treatment 5 years after chemical application.

The uniform moisture contents above the groundline do not seem to account for the large differences in boron retention 150 mm and 300 mm above groundline, but our single sample could not account for seasonal variations. The test site tends to experience very dry summers, which would likely lead to low internal wood moisture contents for a major portion of the year. The relatively low levels of boron below ground may be due to diffusion from the pole into the surrounding soil. Boron from fused borate rods has been shown to be highly mobile at moisture contents above 40% (Morrell et. al. 1990). Boracol 40® was able to move more quickly through drier wood than the other formulations, resulting in early depletion from the higher sampling zones. The moisture content of these poles seems conducive to diffusion of boron from most treatments at groundline and 150 mm above groundline.

All of the supplements tested enhanced boron movement through Douglas-fir heartwood. Boron diffused from the fused rods alone at levels high enough to protect wood at groundline and 150 mm above after 3 years, but levels diffusing from treatments with supplements were usually much greater. The Boracol 40® treatment appeared to increase the mobility of the boron to the point where it moved down the pole from the higher treatments even after one year. Boron movement at groundline tended to occur from the center of the pole outward. Further sampling will reveal



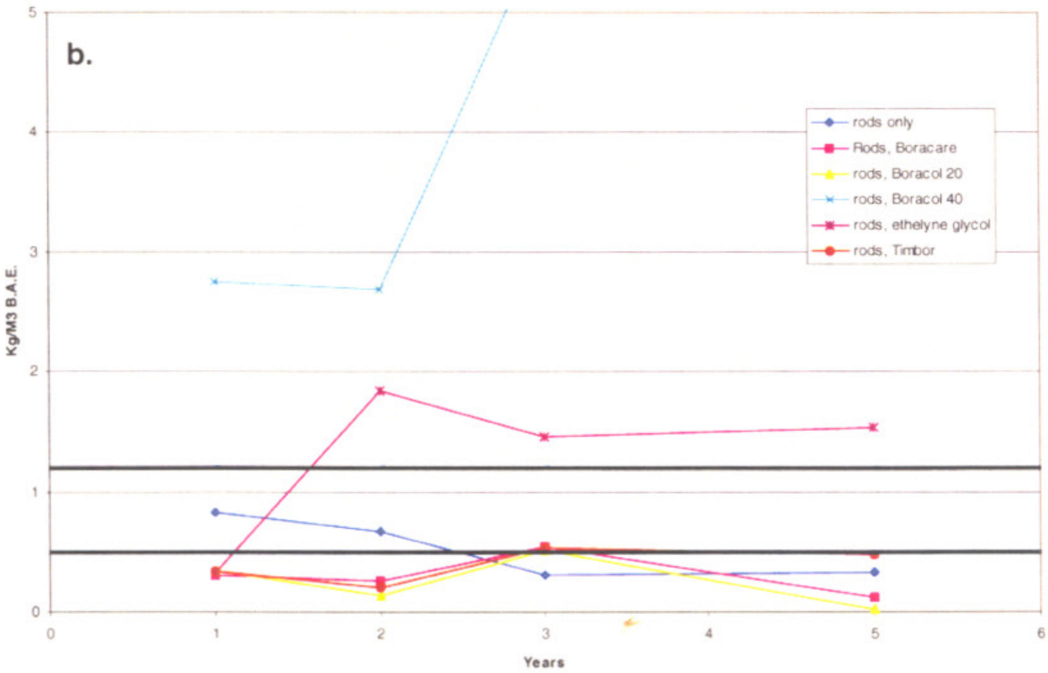


Figure 1-10. Boron levels in the outer (a), middle (b), and inner (c) zones of increment cores removed 300 mm above groundline from Douglas-fir poles sections 1 to 5 years after treatment with fused boron rods with or without various diffusion enhancers.

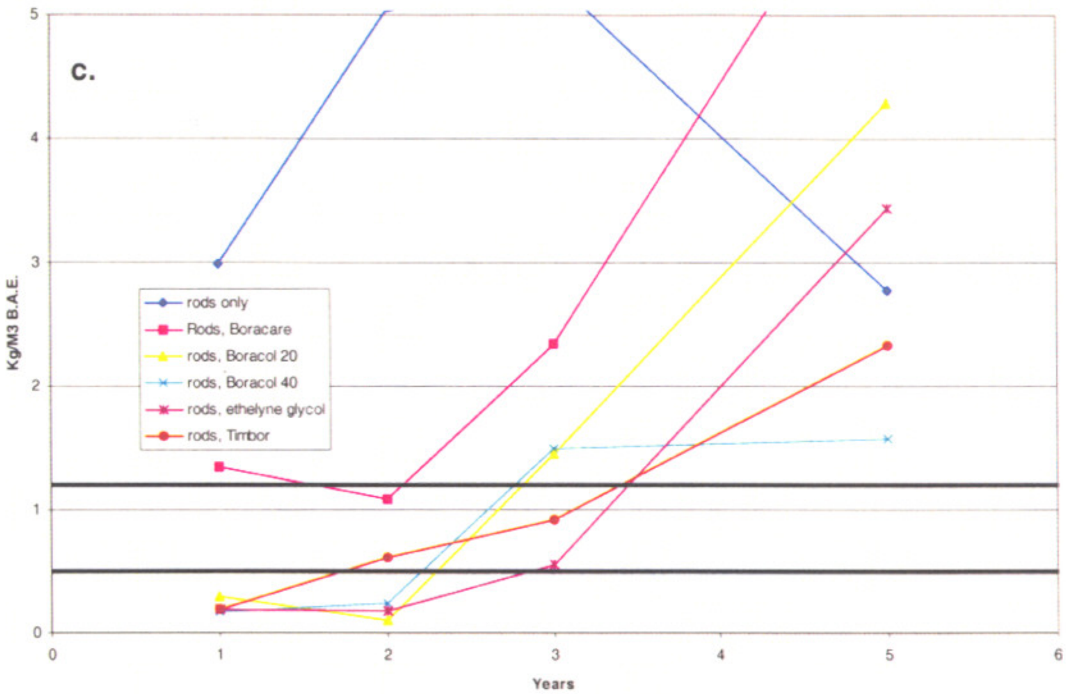


Figure 1-10 cont. Boron levels in the outer (a), middle (b), and inner (c) zones of increment cores removed 300 mm above groundline from Douglas-fir poles sections 1 to 5 years after treatment with fused boron rods with or without various diffusion enhancers.

whether boron is being lost from the pole to the surrounding soil. The Bora-Care®, Boracol 20®, ethylene glycol and Timbor® treatment all tended to produce more uniform levels of boron throughout the sampling zone. The Timbor® treatment does not contain any glycol, yet it improved boron diffusion and resulted in the most even distribution of boron throughout the sampling zone. The limited wood moisture content data available confirms that boron diffusion was highly dependent on moisture.

4. <u>Performance of sodium fluoride rods in Douglas-fir poles:</u> While most of our work has concentrated on boron as a water diffusible remedial treatment, fluoride based systems are also available. Fluoride has a long history of use for protection the external surfaces of poles below ground and has also been used for internal treatment around spikes in railroad ties. The formulation use for the latter purpose is also registered for application to wood poles and might prove useful for internal treatments either above the groundline or in locations where utilities object to the use of fumigants.

Pentachlorophenol treated Douglas-fir poles sections (250-300 mm in diameter by 2.4 m long) were set to a depth of 0.6. Three 19 mm diameter by 200 mm long holes were drilled into the poles beginning at groundline and moving around 120° and upward 150 mm. Each hole received either one or two sodium fluoride rods, then the holes were plugged with tight fitting wood dowels. Each treatment was assessed on 7 or 8 poles for the first 3 years and 5 poles at year 5. Fluoride movement was assessed by removing increment cores from 3 sites around each pole 150 mm below groundline as well as 225 mm above groundline and 150 mm above the highest treatment hole (450 mm above groundline). The outer treated shell was discarded, then the remainder was divided into inner and outer halves. These halves from a given treatment and position were combined and ground to pass a 20 mesh screen. The samples were then analyzed by Osmose Wood Preserving Inc. (Buffalo, NY), on a blind sample basis, for fluoride according to procedures specified in AWPA Standard A2 Method 7 (AWPA, 2000).

A precise threshold value for fluoride or other diffusible chemicals used to protect wood against deacy is somewhat difficult to determine. The difficulty in determining which value to use reflects the problem of assessing a chemical which moves with moisture and therefore is capable of migrating from the wood during conventional decay tests. As a result, initial chemical loadings may not accurately reflect the amount of fluoride actually required to protect wood. In addition, fluoride levels required to prevent fungal attack of large amounts of actively growing fungal mycelium in direct soil contact would probably be considerably higher than that required to kill individual spores or hyphal fragments. In most instances, internal decay control above ground more closely reflects that latter instance. As a result, it is probably prudent to consider two thresholds; one for direct soil contact where the fluoride can move with soil moisture and is challenged by a diverse array of organisms and an internal threshold, where fluoride moves more slowly and has fewer biological challenges.

Laboratory trials of fungi exposed to agar amended with sodium fluoride suggested that the threshold for some fungi was 0.11 % fluoride (Richards, 1924). Soil block trials by Baechler and Roth (1956) suggested that the threshold for many fungi ranged from 0.26 to 0.31 % fluoride, although thresholds for some fungi including *T. versicolor*, were much higher, ranging from 1.33 to 2.27 %. Fahlstrom (1964) confirmed these thresholds, then examined the effect of the presence of creosote on the threshold. Thresholds for southern pine blocks with 32 kg/m^3 of creosote plus fluoride ranged from 0.11 to 0.14 % fluoride. The evaluation of the impact of a subthreshold creosote retention on the fluoride threshold value is a reasonable approach for external remedial preservatives applied to in-service utility poles.

However, this approach has less application to internal treatments, where heartwood impermeability largely limits the potential for creosote or any other oil-based preservative to be present. Our laboratory tests of sodium fluoride in Douglas-fir sapwood suggested that the threshold for protection against *G. trabeum* and *P. placenta* were lower than the elevated levels suggested by Baechler et al. (1956), falling between 0.02 and 0.05 %. No significant weight losses were found with these two fungi in Douglas-fir heartwood when fluoride was present, suggesting that the combination of fluoride and heartwood extractives provided enhanced wood protection. These tests were performed using procedures designed to limit the potential for leaching during treatment and used limited amounts of fungal inoculum to simulate natural colonization. These procedures should result in a decay environment that more closely approximates the interior of a Douglas-fir pole. On the basis of our results, a threshold of 0.10 to 0.15 % as originally proposed by Fahlstrom (1964) is probably a reasonable, but conservative guide for control of internal decay given the presence of both the fluoride and heartwood extractives.

Fluoride levels in Douglas-fir poles 1 to 5 years after treatment varied widely with distance above groundline and dosage (Figure I-11). Fluoride levels were initially low in most locations except in the outer zone 150 mm below the groundline in the higher dosage. Most fluoride levels gradually increased between 1 and 3 years, although the increases were not always consistent. Fluoride levels in several locations were well above the minimum 0.10 % threshold 5 years after chemical treatment even 450 mm above the original treatment zone. The reasons for the sudden increase in fluoride concentration are unclear, although they may reflect the higher rainfall totals in the 4^{th} and 5^{th} years of the test. Chemical levels tended to be higher in the inner zones, except for the 150 mm below groundline sample from poles receiving the higher fluoride dosage.

The results clearly show that fluoride continues to move from the original application point and is well above the internal threshold at many locations 5 years after treatment.

5. <u>Performance of fluoride/boron rods in Douglas-fir pole sections</u>:
Pentachlorophenol treated Douglas-fir poles sections (250-300 mm in diameter by 2.4 m long) were set to a depth of 0.6 m. Three 19 mm diameter by 300 mm long holes were drilled into the poles beginning at groundline and moving around 90 or 120 degrees and upward 150 mm. Each hole received either one or two rods each containing 23.5 g of a mixture consisting of 24.3 % sodium

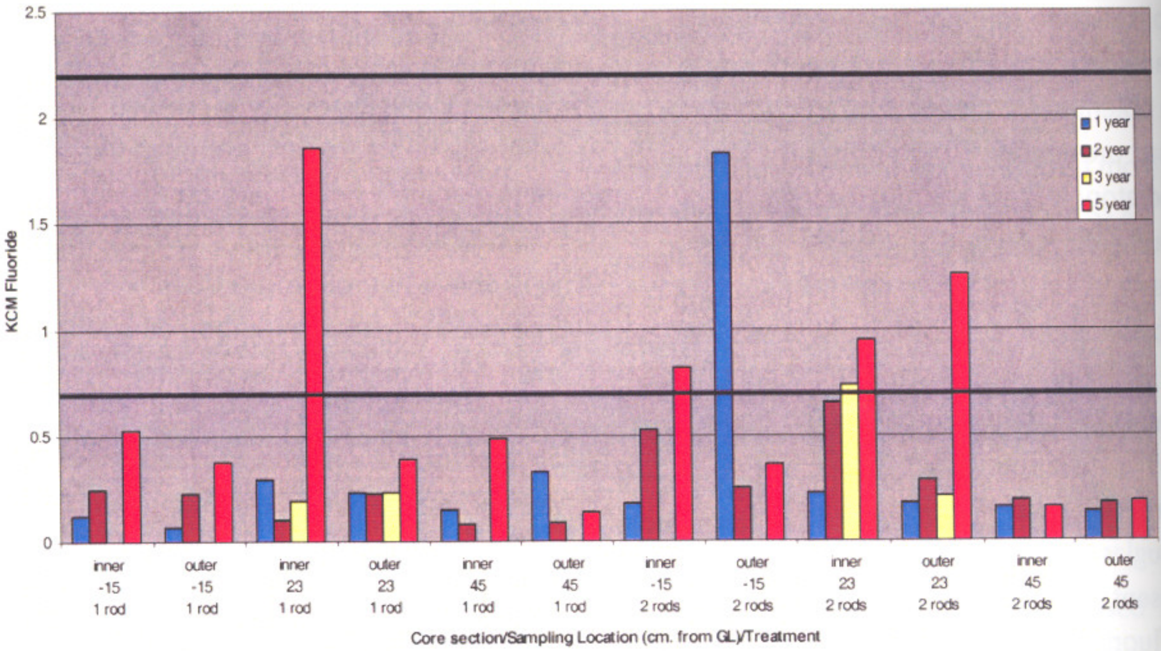
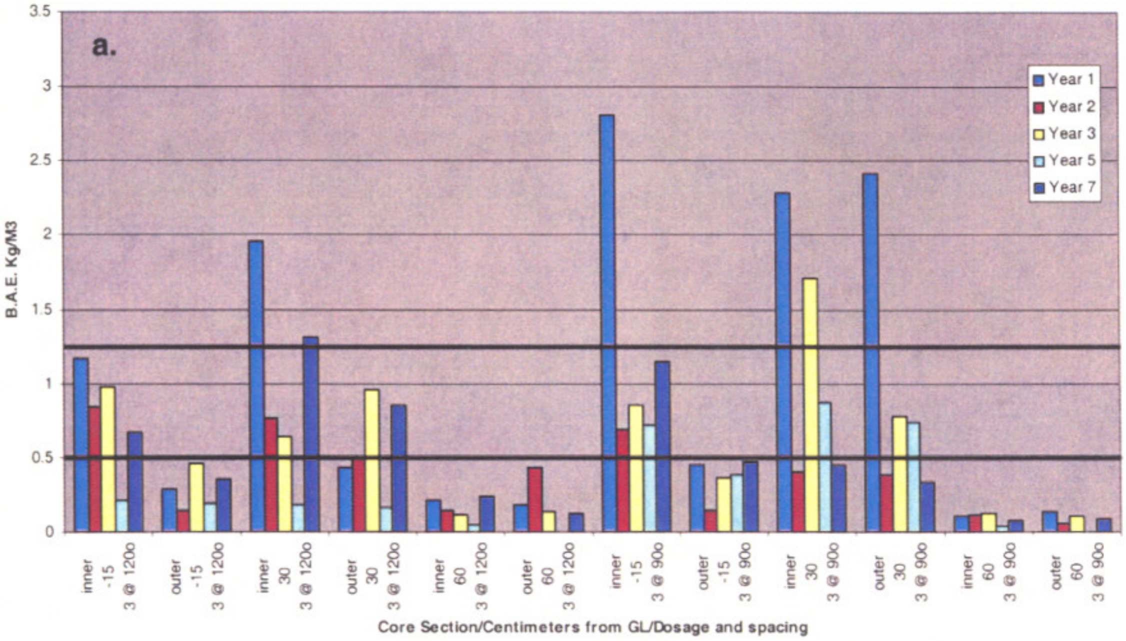


Figure 1-11. Fluoride concentrations at selected distances above or below groundline in Douglas-fir pole section 1 to 5 years after treatment with 3 or 6 fluoride rods per pole.

fluoride and 58.2 % sodium octaborate tetahydrate (Preschem Ltd. Australia), then the holes were plugged with tight fitting wood dowels. Each treatment was assessed on 5 poles. Fluoride movement was assessed 1, 2, 3, 5, and 7 years after treatment by removing increment cores from 3 sites around each pole 300 mm below groundline as well as 300 and 800 mm above groundline. The outer treated shell was discarded, then the outer and inner 25 mm of the remaining core were retained. Core segments from a given zone for the same sampling height were combined for the five poles in each treatment. These segments were then ground to pass a 20 mesh screen and the resulting sawdust was divided into 2 equal portions. One portion was hot-water extracted and analyzed for boron using the azomethine H method. The remainder was extracted in hydrochloric acid and eventually fluoride was determined using a specific ion electrode.

Boron levels 150 mm below and 300 mm above groundline in the inner assay zone tended to be above 0.5 kg/m^3 within one year after treatment with three fluoride/boron rods (Figure 1-12), but were much lower 600 mm above groundline. Boron levels tended to be at or above the threshold in most inner zones at the two lower sampling sites over the 7 year test



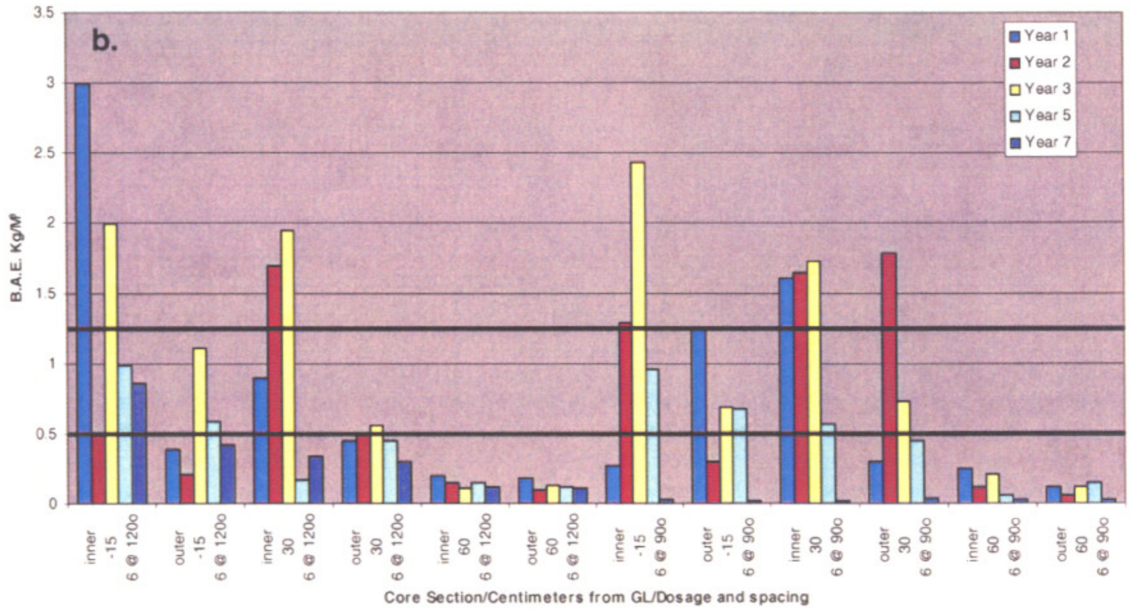


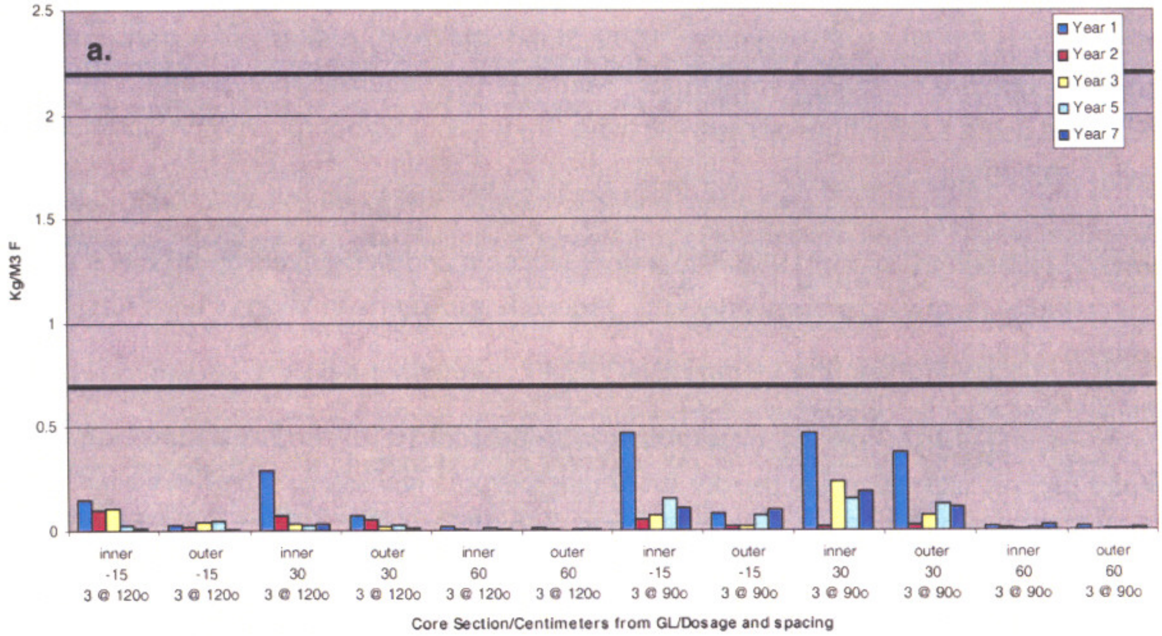
Figure 1-12. Residual levels of boron in Douglas-fir poles 1 to 7 years after treatment with 2) three or b) six fluoride/boron rods distributed in holes spaced 90 or 120 degrees around the pole.

period. Boron levels 600 mm above groundline remained below the threshold for the entire test period. Altering the application pattern also appeared to affect boron distribution. Treatment holes spaced 90° degree apart around the pole were consistently associated with higher boron levels 150 mm below and 300 mm above groundline. The reasons for this enhanced boron distribution are unclear in light of the use of the same rod dosage for both treatment patterns.

Boron levels in poles receiving the 6 rod treatment tended to be much higher than those for poles receiving 3 rods. Once again, little boron was detected 600 mm above groundine, until nearly 7 years after treatment. Boron levels again tended to be higher in the inner zone, reflecting the delivery of the rods towards the pole center. While there appeared to be differences in boron levels between the two treatment patterns, the differences were small in comparison with those seen in poles receiving the lower dosage. Nearly all boron levels rose sharply 7 years after treatment, following two wet years. This sharp rise in boron levels highlights the importance of local climate conditions on performance of these diffusible systems.

Fluoride levels in poles receiving the fluoride/boron rods tended to nearly uniformly fall below the 0.1 % fluoride threshold for internal protection against fungal attack (Figure I-13). The exceptions were the 90° spacing low dosage samples 150 mm below and 300 mm above groundline and the 120° spacing 150 mm below groundline at the higher dosage. Fluoride levels remained uniformly low in all other treatments, sampling locations and times. The limited levels of fluoride reflect, in part, the small percentage of this component present in the rods (10.9 % as fluoride compared with 58 % sodium octaborate), but even these differences do not completely account for the low levels of fluoride found in the poles. These results suggest that either the fluoride is less capable of moving from the rods or that once it migrates, it is rapidly lost from the system.

The presence of adequate levels of boron suggests that these treatments are performing well within the groundline zone of the poles 7 years after treatment, but do not appear to protect wood further above the treatment zone.



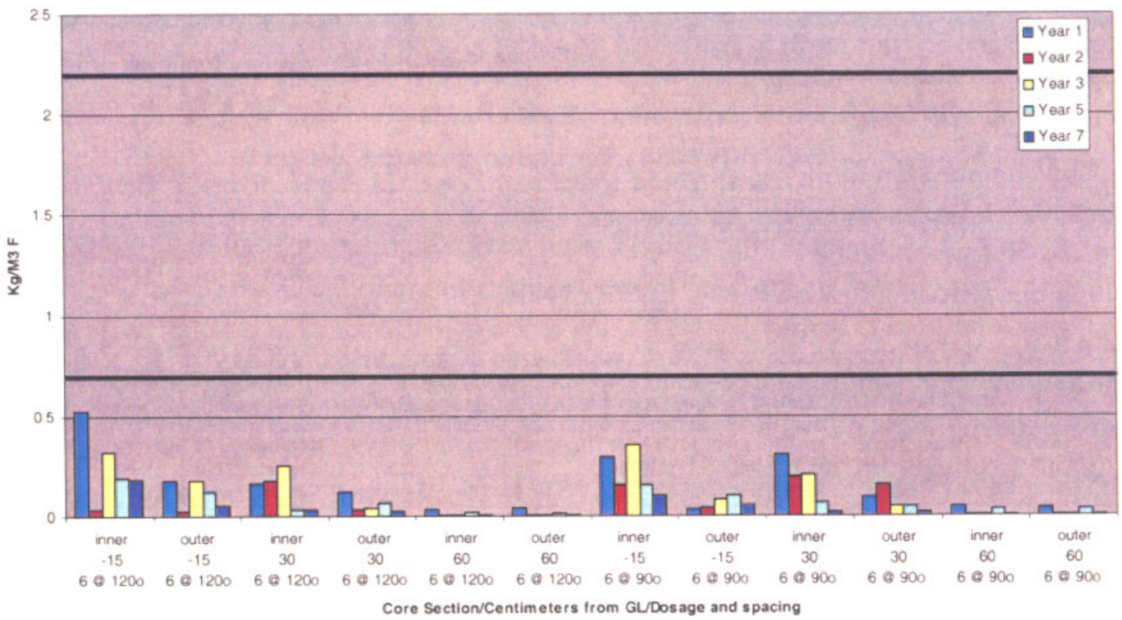


Figure 1-13. Residual levels of fluoride in Douglas-fir poles 1 to 7 years after treatment with three or b) six fluoride/boron rods distributed in holes spaced 90 or 120 degrees around the pole.

Literature Cited

American Wood Preservers' Association. 1999. Standard A2-98. Analysis of waterborne preservatives and fire retardant formulations. Methods 16. Determination of boron in treated wood using azomethine of carminic acid. In: Book of Standards, AWPA, Granbury, TX. Pages 207-209.

Baechler, R.H. and H.G. Roth. 1956. Laboratory leaching and decay tests on pine and oak blocks treated with several preservative salts. Proceedings American Wood Preservers' Association 52:2433.

Bech-Anderson, J. 1987. Practical experiments with Boracol 10 Rh used as a fungicide in the repair process after attack by the dry rot fungus (*Serpula lacrimans*). International Research Group on Wood Preservation document No IRG/WP/3458. Stockholm, Sweden. 9 pages.

Chudnoff, M., W.E. Eslyn, and R. Wawriw. 1978. Effectiveness of groumndline treatments of creosoted pine poles under tropical exposure. Forest Products Journal 28(4):26-32.

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

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

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

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

Fahlstrom, G.B. 1964. Threshold values for wood preservatives. Forest Products Journal

14:529-530.

Leutritz, J. and G.Q. Lumsden. 1962. The groundline treatment of standing southern pine poles. Proceedings American Wood Preservers' Association 58:79-86.

Morrell, J.J. and C.M. Freitag. 1995. Effect of wood moisture content on diffusion of boron-based biocides through Douglas-fir and western hemlock lumber. Forest Products Journal 45(3):51-55.

Morrell, J.J., Freitag, C.M. and S. Unger. 1998. Development of threshold values for boron compounds in above ground exposures: preliminary trials. International Research Group on Wood Preservation Document No. IRG/WP/98-30179. Stockholm, Sweden. 7 pages.

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

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

Panek, E., J.O. Blew Jr, and R.H. Baechler. 1961. Study of groundline treatments applied to five pole species. U.S.D.A. Forest Products Laboratory Report 2227. Madison, WI. 22 pages.

Richards, C.A. 1924. The comparative resistance of 17 species of wood-destroying fungi to sodium fluoride. Proceedings American Wood Preservers' Association 20:1-7.

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

Smith, D.N. and R. Cockroft. 1967. The remedial treatment of telephone and electric transmission poles. Part 1. Treatment for external decay. Wood 32(9)35-37.

Smith, D.N. and A.I. Williams. 1969. Wood preservation by the boron diffusion process-

The effect of moisture content on diffusion time. J. Institute of Wood Science 4(6):3-10.

Theden, G. 1967. The effectiveness of wood preservatives against soft rot determined by the soil burial method. Holz als Roh-und Werkstoff 19(9):352-357 (German).

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

OBJECTIVE II
IDENTIFY CHEMICALS FOR PROTECTING EXPOSED WOOD SURFACES IN POLES

Preservative treatment prior to installation provides an excellent barrier against fungal, insect and marine borer attack, but this barrier only remains effective as long as it is intact. Deep checks that form after treatment, drilling holes after treatment for attachments such as guy wires, cutting poles to height after setting, and heavy handling of poles that results in fractures or shelling between the treated and untreated zones can all expose untreated wood to possible biological attack. The Standards of the American Wood Preservers' Association currently recommend that all field damage to treated wood be treated with solutions of copper naphthenate. While this treatment will never be as good as the initial treatment, it provides a slight barrier that can be effective above the ground. Despite their merits, these recommendations are often ignored by field crews who dislike the oily nature of this treatment and know that it is highly unlikely that anyone will later check to confirm that the treatment has been properly applied.

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

A. EVALUATE TREATMENTS FOR PROTECTING FIELD DRILLED BOLT HOLES

Douglas-fir pole sections (200 to 250 mm in diameter by 4.5 m long) were

Boultonized in pentachlorophenol in P9 Type A oil then removed from the cylinder. The goal was to create dry, but shallowly treated poles. A series of eight 25 mm diameter holes were then drilled perpendicular to the grain beginning 600 mm above groundline and extending upwards at 450 mm intervals to within 450 mm of the top. The holes were off set 90 degrees from those above and below. The holes were then randomly assigned to be treated with 10 % pentachlorophenol in diesel oil, powdered ammonium bifluoride, powdered sodium octaborate tetrahydrate (Timbor), or 40 % boron in ethylene glycol (Boracol). Each chemical was replicated on eight holes in each of 4 poles. An addition set of 8 poles received no chemical treatments. The holes were then plugged with galvanized metal hardware and either metal or plastic gain plates. An additional set of four poles received no chemical treatment, but chemically impregnated washers containing 37.1 % sodium fluoride, 12.5 % potassium dichromate, 8.5 sodium pentachlorophenate, 1 % sodium tetrachlorophenate, and 11% creosote were used to attach bolts to these poles. For the first 4 years, fungal colonization was assessed on four control poles by removing increment cores from sites directly below the gain plates on one side of the pole and from directly above the washer on the opposite side. The cores were placed in plastic drinking straws which were labeled with core location and stapled shut. The cores were then stored at 5 C, generally for 3 to 7 days. The cores were later removed from the straws, flamed briefly to kill contaminating surface microflora and placed on 1 % malt extract agar in plastic petri dishes. The plates were observed over a 30 day period and any fungi growing from the wood was examined microscopically for the presence of clamp connections and characteristics typical of fungi in the Division Basidiomycota. This group contains many important wood decay fungi. Fungi were then classified as either decay or non-decay fungi. The initial pole sampling was designed to allow fungi to develop in all the poles without disturbing the treated poles. Fungal isolation levels in the 4 control poles after 4 years remained low and we became concerned that the other poles might already be experiencing fungal attack. As a result, we began sampling all of the poles in the test using the same procedures 5 years after installation.

The slow development of fungal attack was initially puzzling, given the known prevalence of above ground decay in this region; however, nearly 30 % of increment cores removed from zones around the untreated bolt holes in control poles were eventually colonized (Figure II-1). The presence of decay fungi in 30%

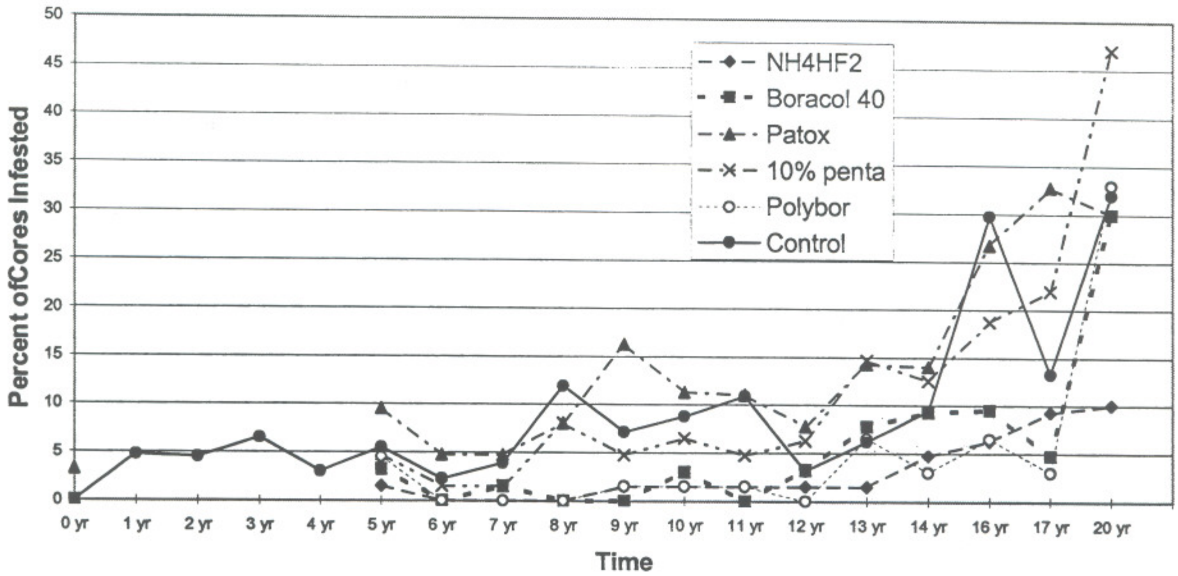


Figure II-1. Effect of application of supplemental treatments to feild drilled bolt holes in Douglas-fir poles on the isolation frequency of decay fungi 1 to 20 years after treatment.

of the field drilled bolts holes in underbuilt telecommunication lines should be a major concern to any utility and clearly illustrates the insidious nature of the failure to apply supplemental treatments in these regions.

The selected topical treatments produced varying effects on the presence of decay fungi in the poles. As noted earlier, the chemically impregnated washers failed to perform as expected, probably because they were poorly positioned to allow chemical to difuse from the washers into the exposed, untreated wood inside the hole. Bolt holes treated with 10 % pentachlorophenol also experience levels of fungal colonization that were similar to those for the control, a surprising finding given the long time recommendation to treat field damaged wood with this chemical. We suspect that the penta was unable to migrate for substantial distances from the initial point of chemical treatment. As a result, it was incapable of protecting the wood as small splits or checks opened over time.

In general, water diffusible preservatives provided excellent protection against fungal attack, although performance differences emerged over time. Fungal isolation levels were low from poles treated with the three diffusible compounds for 12 years after installation. We believe these lower levels of fungal colonization reflect the ability of the boron and fluoride to migrate further into the wood. As a result, these compounds were ideally positioned to protect against fungal attack as small checks or splits opened around the bolt holes. Over time, however, we suspect that continued diffusion would result in depleted boron and fluoride levels around the bolt holes. Eventually, fungal spores and hyphal fragments would penetrate into the unprotected wood and fungal attack would be initiated. This process appears to have begun for both boron compounds around 13 years into the test and has progressed to the point where isolation levels in these treatments are similar to those for the untreated controls (Table II-1). However, the sharp increases have only occurred in the last 3 years, suggesting that substantial fungal attack has only recently been initiated. While the protective effects of the boron have declined after 20 years, the benefits of delaying fungal attack for 2 decades should not be overlooked. Delaying colonization should sharply reduce the risk of above ground decay, reducing long term maintenance costs as poles age. While all of the other compounds appear to have lost their effectiveness, fluoride continued to provide a reasonable level of protection to the wood. Bolt holes treated with ammonium bifluoride had fungal colonization levels that were one third of those from the untreated controls. While fluoride compounds are less commonly used for protecting wood against fungal attack, they clearly out-performed all other chemicals in this application.

One remaining question from this test is how much of the original treatment chemical remains around the bolt holes. This winter we plan to sample selected poles to assess residual chemical distribution.

B. DEVELOP METHODS FOR ENSURING COMPLIANCE WITH REQUIREMENTS FOR PROTECTING FIELD-DAMAGE TO TREATED WOOD

Over the past 2 decades, we have developed a wealth of knowledge concerning the fungi invading poles above ground and the efficacy of various alternative treatments, it is readily apparent that most of these treatments are not being employed, either by contractors working on poles, or even many of the utility employees. As a result, utilities face the risk of an increasing level of decay in the telecommunication region of their poles that only promises to become worse as groundline maintenance extends the service life of poles. This will save utilities many millions of dollars, but it also means that slower decay development above the ground may now become an issue.

Developing effective methods for preventing decay in field damaged wood that will actually be used by line personnel poses a major challenge. Line

Table II-1. Effect of application of supplemental treatments to field drilled bolt holes in Douglas-fir poles on the isolation frequency of decay and non-decay fungi 1 to 20 years after treatment.

Treatment	Increment Cores containing Decay Fungi$^{\text{(Non-Decay Fungi)}}$ (%)[a]													
	Yr 0	Yr 5	Yr 6	Yr 7	Yr 8	Yr 9	Yr 10	Yr 11	Yr 12	Yr 13	Yr 14	Yr 16	Yr 17	Yr 20
Control	0^{63}	6^{55}	2^{32}	4^{33}	12^{53}	7^{66}	9^{35}	11^{86}	3^{56}	6^{81}	9^{68}	30^{77}	14^{67}	32^{100}
NH_4HF_2	0^{41}	2^{17}	0^{5}	0^{16}	0^{19}	2^{44}	2^{9}	2^{47}	2^{39}	2^{39}	5^{39}	6^{35}	9^{53}	10^{78}
Boracol 40	0^{57}	3^{44}	0^{19}	2^{46}	0^{33}	0^{64}	3^{16}	0^{71}	3^{42}	8^{60}	9^{80}	10^{57}	9^{53}	30^{99}
Patox	0^{60}	10^{41}	5^{13}	5^{22}	8^{31}	16^{67}	11^{39}	11^{55}	8^{46}	14^{49}	14^{55}	27^{71}	33^{72}	30^{96}
10 % penta	0^{44}	5^{56}	2^{25}	2^{19}	8^{31}	5^{53}	7^{25}	5^{80}	6^{61}	15^{67}	13^{64}	19^{70}	17^{59}	47^{91}
Timbor	0^{38}	5^{27}	0^{11}	0^{25}	0^{28}	2^{38}	2^{14}	2^{75}	0^{40}	7^{60}	3^{69}	7^{46}	3^{97}	33^{100}

[a] Values represent cultural results from 64 samples for the control and 32 samples for all other treatments.

personnel dislike oily materials, but they also object to water-based systems that might be conductive. While some line crews will use rod type treatments, these systems are not suitable for protecting field drilled holes unless an additional hole is drilled above or below the initial hole to hold the rod treatment. Given the cost of crews, we suspect that this additional drilling would be unacceptable to many contractors. As a result, most of the traditional methods for protecting field damage appear to be unsuitable for this application.

One possible alternative to traditional treatment of the wood is to incorporate the treatment around the fastener that is inserted into the hole. Dry or paste-like chemical systems could be applied to rods and then this material could be thinly encapsulated with a water resistant barrier. The barrier would be strong enough to resist damage during storage, transportation, and handling, but would fracture as it was driven into the bore hole. Water that later entered the hole would then release the chemical allowing it to diffuse into the wood around the treatment hole. An ideal system would contact both oil- and water-soluble components. The oil component would create a barrier on the exposed wood surface, while the water-soluble component would penetrate into the wood and protect wood that might be exposed through later drying and checking. This approach would take advantage of the attributes of both types of preservatives in a system where line personnel did not need to remember to apply treatment.

The potential for producing treated field bolts was assessed using threaded, galvanized rods which were first weighed, then the threads were packed with commercially produced pastes containing copper naphthenate with or without sodium tetraborate decahydrate. The rods were then weighed and oven dried for 48 hours at 60 C dry. The rods were then inserted in Douglas-fir pole sections and stored at 90 % relative humidity and 32 C for 2 weeks. The pole sections were then split and the distance which the copper and boron moved were assessed by spraying the exposed surface with the appropriate indicator and measuring the visibly colored wood. Each treatment was assessed on 2 pole sections. Copper movement from the copper naphthenate alone treatment was largely confined to the zone in contact with the rod, while copper moved 7 to 10 mmm from the copper/boron coated rods. The differences in penetration reflect the differences between an oil and water soluble copper naphthenate. The copper/boron paste contained the water soluble copper naphthenate which was apparently capable of much greater movement in the wood. Boron movement in the copper/boron system ranged from 5 to 6 mm from the rods, suggesting that this component had not yet begun to move a substantial levels.

Further trials have been installed to evaluate the effects of various surface sealers that could be used to limit the potential for flaking of chemical from rods during storage and handling. The initial trials, however, suggest that reasonable levels of chemical can be applied to the rods and that these chemicals are capable of good movement away from the rods once they are inserted in the wood.

OBJECTIVE III

EVALUATE PROPERTIES AND DEVELOP IMPROVED SPECIFICATIONS FOR WOOD POLES

A. SEASONAL VARIATIONS IN WOOD MOISTURE CONTENT IN DOUGLAS-FIR AND WESTERN REDCEDAR POLES

Moisture content in poles in service has important implications for performance. First, moisture content can affect strength properties below the fiber saturation point (~30%). Wet poles have lower strength values and the need to use wet strength design values requires substantially stouter poles to carry the equivalent load. Moisture is also important for the development of fungal decay. Most fungi grow poorly in wood at or below 30% moisture content.

While moisture has important implications on performance, relatively little is known about in service moisture contents of commercially important species. In this report, we summarize seasonal moisture measurements in Douglas-fir and western red cedar poles in the Willamette Valley of Western Oregon.

Douglas-fir and western red cedar transmission poles were assessed for moisture content using a resistence type moisture meter equipped with 75mm long pins. The moisture contents of each pole was measured 125, 25, 50 and 75 mm from the wood surface at four equidistant points around the pole at groundline, 0.3m and 1.2m above groundline. The Douglas-fir poles were all either kerfed or through-bored prior to treatment. The western redcedar poles were either butt-treated or full-length treated. Moisture contents were measured in June 2000, September 2000, December 2000, and March 2001. Rainfall in the valley is seasonally concentrated between November and march. Total rainfall averages 1125mm per year. Rainfall totals during the measurement period were well below historical levels (Figure III-1). Internal moisture contents should lag behind but reflect seasonal precipitation.

Moisture contents in kerfed poles ranged from 20 to 40% at groundline in creosote treated poles and 15 to 30% for pentachlorophenol treated poles (Figure III-2). The reasons for the variations between treatments are unclear, since both oil-type treatments tend to have water repellency.

Moisture contents above 30% MC should support development of fungal attack, although previous sampling of

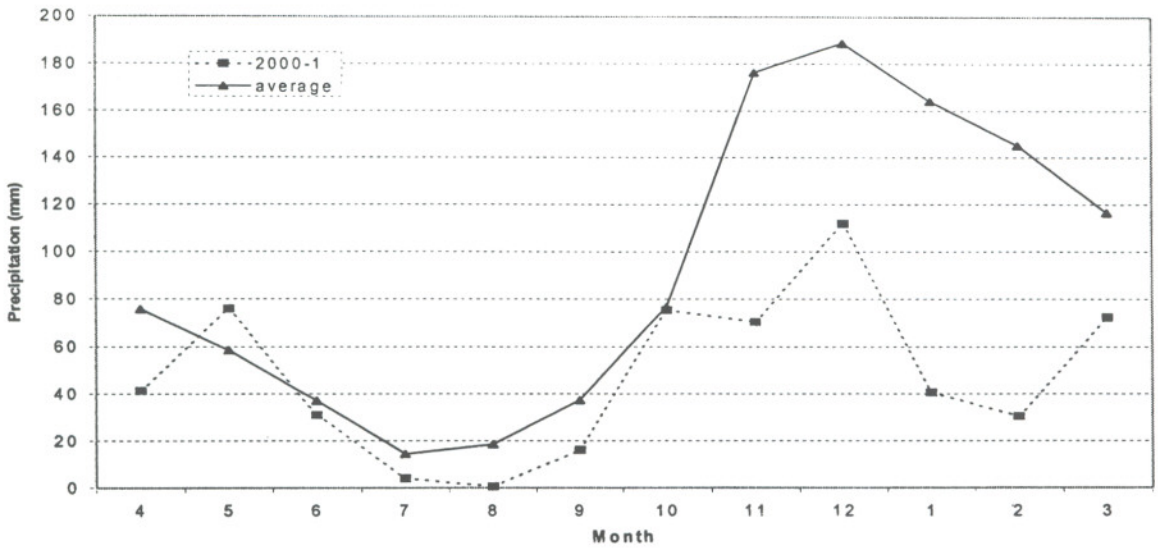


Figure III-1. Monthly rainfall totals for the mid-Willamette Valley for March 2000 to March 2001 and for the historical average.

these poles indicates that relatively few were attacked by fungi. The moisture levels in these poles suggest that kerfing did not appreciably alter the moisture absorbing characteristics at groundline. Moisture contents above ground also increased with distance from the surface but decreased with height above groundline.

Moisture contents of through-bored poles were consistently lower than those found with kerfed poles (Figure III-3). The presence of oil throughout the cross section of through bored poles should provide excellent water repellency and this effect is largely reflected in the measurements. Moisture contents at groundline in creosoted and copper naphthenate treated poles were all below 30%, indicating that conditions were not suitable for fungal growth. Moisture contents at groundline for penta treated poles just exceeded 30% seventy-five mm from the surface suggesting that the oil used for this treatment was slightly less water repellent, but still largely limited moisture ingress. MC's above the groundline declined to well below 30%, suggesting that conditions were largely unsuitable for fungal growth in these poles.

Moisture contents in western red cedar poles varied widely between butt-end and full-length treated poles. MC's in full length-treated poles followed trends that were similar to those found with Douglas-fir poles with highest MC's at groundline 75mm from the surface (Figure (III-4). Moisture also varied slightly seasonally. MC's above

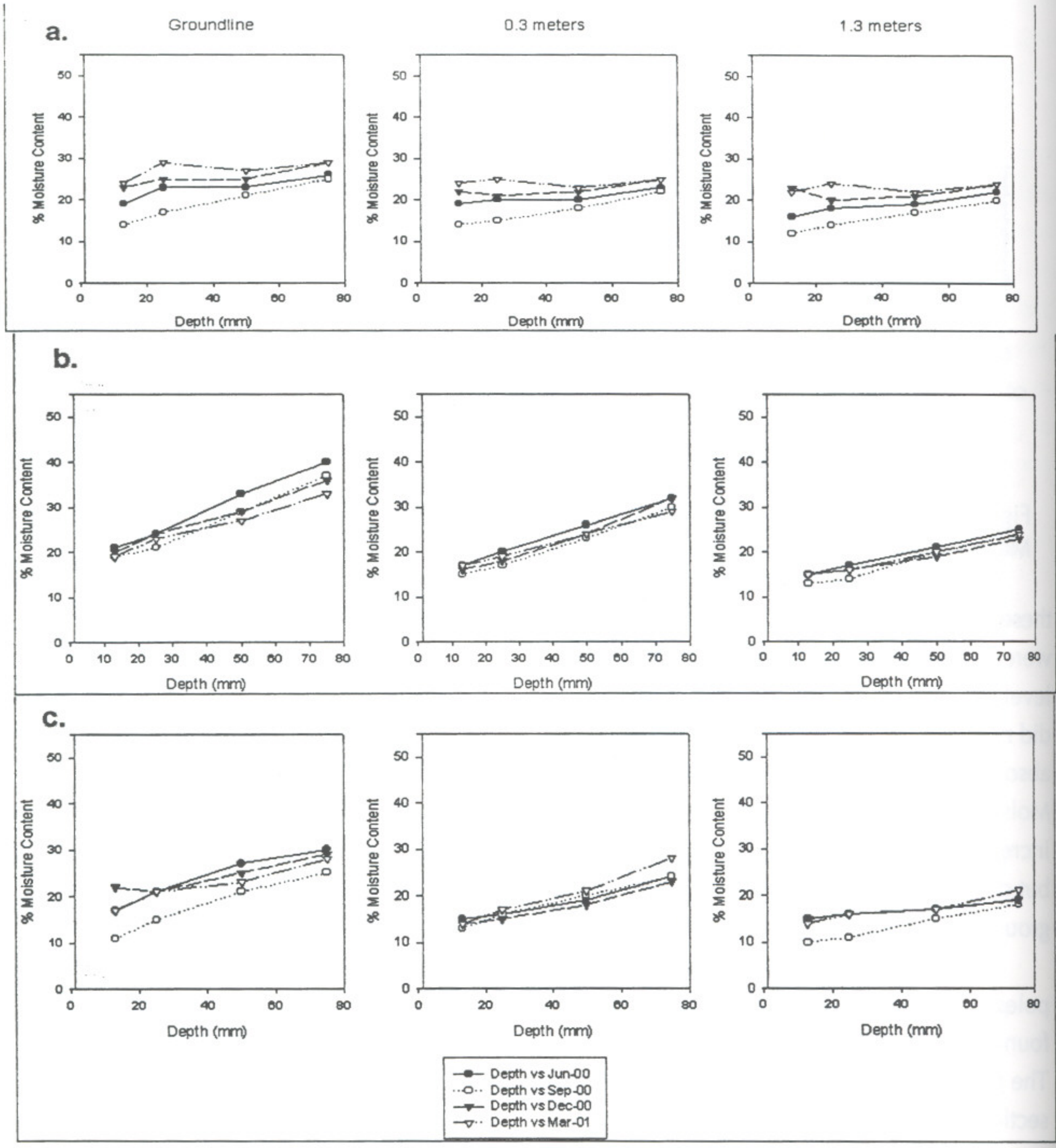


Figure III-2. Wood Moisture content at selected depths for kerfed Douglas-fir poles treated with a) pentachlorophenol, b) creosote or c) deeply incised and creosoted.

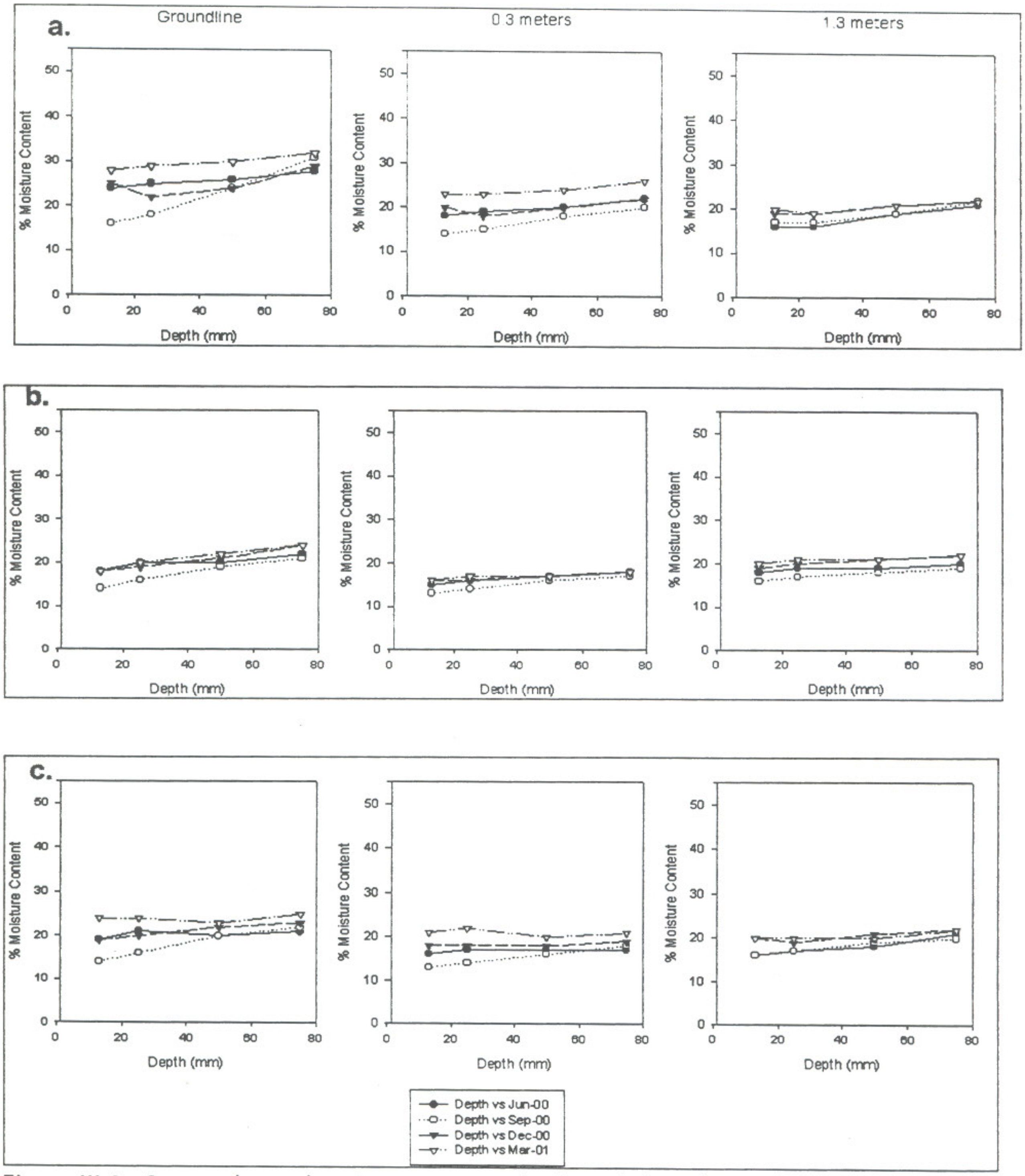


Figure III-3. Seasonal wood moisture contents in through-bored Douglas-fir poles treated with a) pentachlorophenol, b) creosote or c) copper naphthenate.

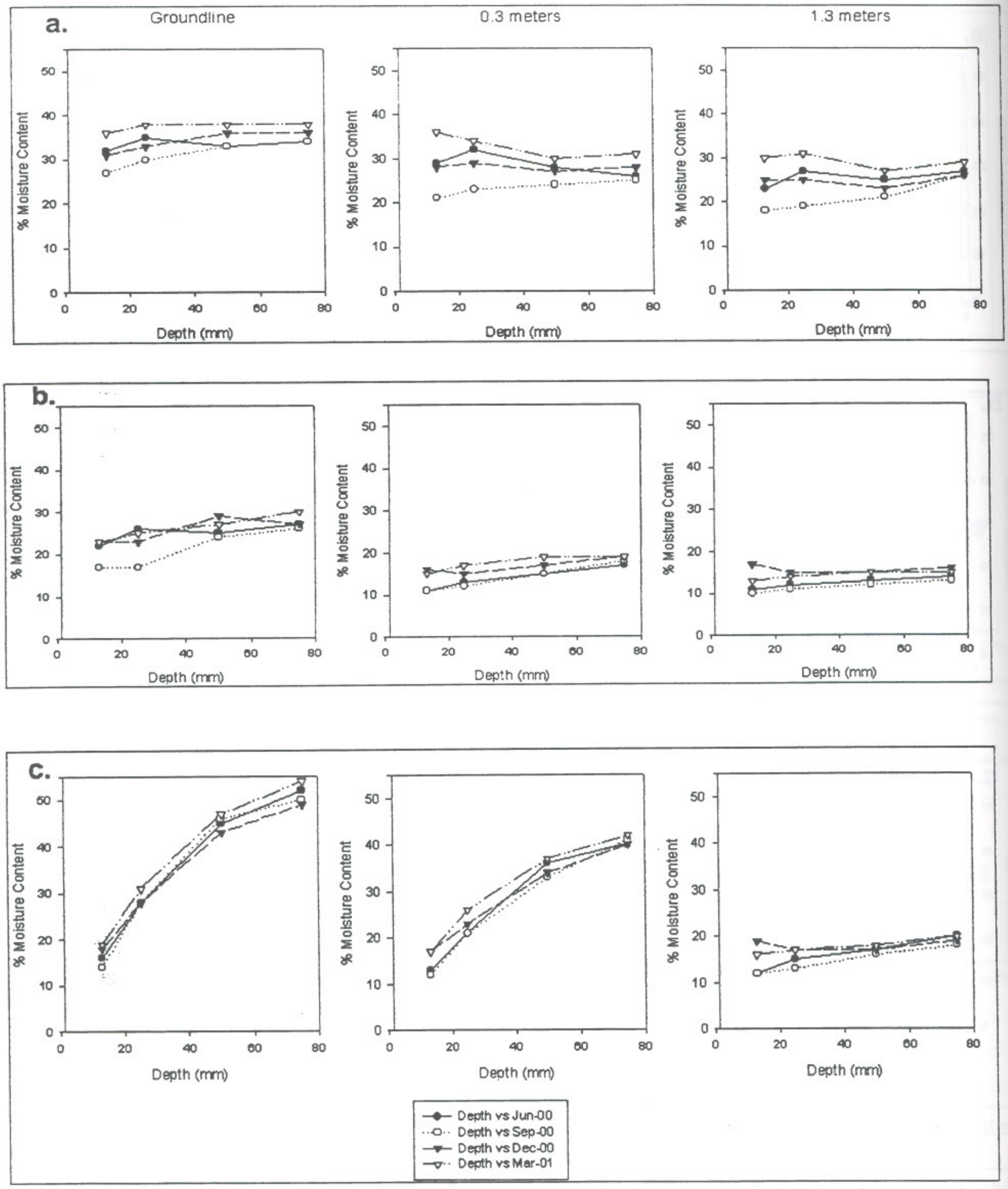


Figure 111-4. Seasonal wood moisture contents in a) through-bored and densly incised pentachlorophenol treated poles, b) western red cedar poles that were full length treated with pentachlorophenol or c) western red cedar poles that were butt-treated with creosote.

groundline were all well below 20%, indicating that conditions in these poles were largely unsuitable for fungal attack.

Moisture contents in old, butt treated western red cedar differed markedly from all other poles sampled (Figure III-4c). MC's at the center near groundline exceeded 50% and declined little with season. Moisture levels were also elevated 0.3 m above groundline, suggesting that conditions suitable for fungal attack were present in a fairly large section of the pole. Moisture contents 1.3 m above ground declined below 20%.

The implications of having very high moisture contents in poles containing naturally durable heartwood are difficult to discern. Available moisture likely enhances the activity of extractives, creating an extremely hostile environment for fungal growth. At the same time, elevated moisture levels could permit leaching of extractives into the surrounding soil, eventually depleting protection. Elevated moisture levels near the surface between groundline and 0.3 m may also accelerate decay of the untreated sapwood shell on these poles. While not a major contributor to pole strength, the loss of this zone may lead line personnel to make earlier changeouts on an appearance basis.

The moisture measurements indicate that moisture levels near groundline approach 30% most of the year, suggesting that wet-use design values are appropriate. The results also indicate that through-boring can markedly reduce internal moisture levels, an added benefit of the improved treatment associated with this process. Finally, and most importantly, the results clearly illustrate the benefits of full length treatment of western red cedar poles.

B. POTENTIAL FOR RESAWING UTILITY POLES REMOVED FROM SERVICE

Wood utility poles are an excellent material for supporting overhead lines for both power transmission and telecommunications. For many years, utility poles were manufactured from naturally durable wood species such as western redcedar or American chestnut. Inadequate supplies of these species encouraged the use of less durable species that were supplementally protected with preservatives to extend their service lives. The success of these techniques is clearly shown by the nearly 160 million poles in service in the U.S. Wood poles remain the choice for most utilities.

One aspect of wood pole use that has drawn increasing attention is the nature of the preservatives used to extend their service lives. While a number of reviews have concluded that the use of preservative treated wood poles poses little risk to human health or the environment, changing public perceptions about chemicals have encouraged the development of alternative chemicals and strategies for their use. One aspect of wood pole usage that has been particularly vexing is what to do with the pole once its has lost its usefulness for supporting overhead wires.

The U.S. Environmental Protection Agency generally recommends that treated wood be reused in an application similar to that in which it was originally employed (Malecki, 1992). It would be dangerous to reuse a wood pole removed from service due to decay or other weakness in another structural application, but used utility poles make excellent fence posts and parking bumpers. Utilities generally deal with used poles by either giving them to adjacent landowners or making them available to local groups for use as parking bumpers. In urban areas, or where public concerns about treated wood are extreme, poles may be taken to either a municipal solid waste facility or a secure hazardous waste facility. The cost for this form of disposal in Oregon ranges from as little as $10 to up to $500 depending on whether the pole ends up in a municipal solid waste facility or a secure hazardous waste facility. While disposal represents a potentially unnecessary cost, many utilities are concerned about the potential liabilities associated with giving away their used wood poles (Morrell, 1999).

Land-filling poles clearly eliminates a risk, but it also consumes limited landfill capacity and prevents the use of a potentially valuable wood resource. The specifications for wood poles are such that trees used for this purpose are among the most valuable removed in a harvesting operation. While portions of poles removed from service may be decayed and therefore unusable, a large proportion of a pole contains sound wood that could potentially be remanufactured into other products.

The concept of remanufacturing lumber or other products from utility poles is not new, but there is relatively little information on the potential for developing such a facility in the Pacific Northwest. This document assesses the feasibility of developing a remanufacturing facility to recycle wood poles into lumber products.

OBJECTIVE: The overall objective of this project was to develop information on markets, supply, environmental considerations, and operational obstacles to the development of a pole remanufacturing facility in the mid-Willamette Valley of Western Oregon.

Identify the potential supply of poles within 50, 100, 150 and 200 miles of the mid-Willamette Valley including species mix, initial treatments, and

size/class distributions. While there are three major utilities whose service territories cover the immediate zone around the mid-Willamette Valley (PacifiCorp, Portland General Electric and Bonneville Power Administration), there are a number of smaller public utilities and coops that serve many rural areas. All of these utilities may be potential sources of used poles; however, there is little relevant information on the numbers of poles in service, as well as the mixture of species, the sizes/classes, and ages of these poles. Finally, there is little data on the rates at which poles are removed from service among area utilities or the willingness of these utilities to participate in a recycling program.

We used mail and follow-up phone surveys to sample utilities within the above geographic areas regarding the characteristics of their pole plants. The survey contacted eight major Investor Owned Utilities as well as 9 Public Utility Districts and Rural Electric Cooperatives and the regional federal utility (BPA). Each utility was asked, to the best of their ability, to characterize their pole plant and then describe their current maintenance practices as well as their rate of pole replacement. Utilities were also asked to characterize the seasonality of pole replacements in their system. We suspected that pole replacements were most common during the warm summer months and this would require the ability to store poles for later sawing. This data will help to properly scale the mill and the area where poles would be stored.

Ten utilities returned usable surveys, representing approximately 1.9 million poles. Douglas-fir and western redcedar represented approximately 51.4 and 47.7 % of the total pole populations, respectively. Some utilities used small amounts of lodgepole pine, ponderosa pine or western pine. The bulk of the poles were less than 50 feet in length (72.7 % of poles), reflecting the higher numbers of poles used to distribute electricity to users. These results suggest that many of the poles removed from service will be smaller in diameter with a higher proportion of treated wood. As a result, the recovery of clear, untreated wood from these poles will be much lower.

The survey also asked about treatments used for the various poles in each system. Pentachlorophenol was used to treat the majority of the poles (63.6 %), followed by creosote (33.0 %). There were lesser amounts of ACZA, copper naphthenate and CCA, but these treatments represented only 1.52 % of the poles in systems of the survey respondents. Clearly, penta remains the dominant preservative. We also suspect that the high level of creosote treated poles represents older poles in the systems rather than continuing use of this preservative. Thus, the majority of poles removed from service will contain either pentachlorophenol or creosote.

Respondents were also asked to identify the average number of poles removed from service yearly. Respondents estimated removing 15,500 poles/year or 0.8 % of their total pole population. These figures suggest that average pole service life in the responding utilities is 62.5 years. These figures are slightly lower, but within the range of those found in previous disposal surveys in this region. Many utilities routinely use 30 or 40 years as the estimated pole service life. The results of these surveys indicate that service lives are far in excess of those figures. While this bodes well for wood use in utilities, it limits the volumes of materials available for a remanufacturing facility and would force the facility to go further from its base of operation to seek out new material sources. Utilities were also asked to estimate the rates at which they removed poles by season of the year. Although summer is the generally accepted major construction season for most utilities, the survey indicated that pole removals occurred at a steady rate over the entire year, with a peak in summer (Table III-1). The steady availability of poles would reduce the need to stockpile large numbers of poles at the manufacturing facility, reducing the need for large land areas as well as the risk that long term storage might lead to migration of preservatives from the poles into the surrounding soil.

Table III-1. Relative rate of pole removals by season of the year.

Season	Removals (%)
Winter	18 %
Spring	24 %
Summer	32 %
Fall	27 %

Survey utilities concerning current disposal methods and concerns. The ten respondents to the utility survey were also asked how they dispose of poles removed from service and whether they had experience difficulty with landfill availability in their service territory. Most utilities (90 %) continued to give away poles to either adjacent landowners or community groups (Table III-2). A majority of utilities also continued to dispose of poles in sanitary landfills, a practice that appeared to be limited to those poles that are so badly damaged that they can no longer be used for other purposes. Two respondents sent poles to a hazardous waste landfill, while three had other methods of disposal. The U.S. Environmental Protection Agency currently states that reuse of treated wood products is the preferred disposal option, although there remains some concern about the ultimate fate of these materials.

Table III-2. Summary of responses to poles disposal practices surveys administered in 1988, 1997, 1999 and 2000.

# of poles	-	8.2 x 10^6	9.2 x 10^6	1.94 x 10^6
# poles disposed	-	44,480	44,180	15,500
Treatment Chemicals				
Penta	92 %	95 %	92 %	64 %
Creosote	13 %	23 %	33 %	33 %
Arsenicals	6 %	5 %	22 %	<1 %
Cu-Naphthenate	12%	32 %	18 %	1 %
Disposal Method				
Give away	85 %	77 %	88 %	90 %
MSW Facility	40 %	45 %	55 %	60 %
Hazardous	5 %	13 %	14 %	20 %
Incinerate	-	5 %	4 %	-
Sell	-	19 %	10 %	-
Resaw	-	3 %	2 %	-
Disposal Costs Per year				
< $50,000	-	83 %	96 %	-
$50,000-100,000	-	2 %	4 %	-
$100,000 to 250,000	-	11 %	-	-
>$250,000	-	4 %	-	-
Sample size	65	62	51	10

Most utilities continue to use give-aways as the primary disposal option. This may make it difficult to develop streams for recycling poles since adjacent landowners often expect to receive poles removed from right-aways adjacent to their land. Eliminating these give-aways may change community perceptions concerning the utility.

Over the past four years, Oregon State University has surveyed utility pole disposal practices. These surveys have indicated that most utilities are concerned about disposal of poles (Table III-2) (Morrell, 1999, Morrell and James, 1997). However, most of the respondents do not currently experience difficulty in disposing of used poles, nor does this disposal represent a significant cost. Nearly all utilities spent less than $50,000 per year in disposal costs and some even made money by selling used poles. The response to our survey suggests that the presence of existing disposal pathways might make it difficult to lead utilities to consider alternative disposal options, particularly in the absence of regulatory changes that affect the ability to give poles to the general public.

In addition to utility perceptions concerning disposal, we surveyed landfill operations in Washington, Oregon and California. Landfill operators were asked if they accepted treated wood waste and what tests they required before accepting these materials. Twenty seven landfill facilities responded. Six of eight Oregon landfills surveyed accepted treated wood waste, six of ten in California accepted these materials and all nine Washington facilities surveyed accepted treated wood. Clearly, landfilling of treated wood is not limited in this region, although disposal may sometimes be locally difficult. Given the relative costs of trucking, moving poles to landfills that accept treated wood remains a viable option.

All of the respondents that accepted treated wood required that the wood passed the Toxicity Characteristic Leaching Profile (TCLP) test, although the frequency at which landfills asked for information specific to a load varied. Previous studies have shown that most treated wood easily passes the current TCLP limits for both penta and creosote (EPRI, 1990; Goodrich-Mahoney, 1992; Murarka et al., 1996). As a result, testing to confirm that a given waste stream does not exceed current TCLP limits adds some expense and logistics to pole disposal, but it does not preclude continued use of landfills as an option for these materials.

Costs for disposal in a municipal solid waste facility in the Washington, California and Oregon region varied from $18 to $60 per ton. These costs translate into total pole disposal costs ranging from as little as $4.70 for a Class 4 forty-foot long western redcedar pole to $65.38 for disposal of a Class 1 seventy-foot

Table III-3. Relative costs to dispose of distribution and transmission poles in a municipal solid waste facilities charging two tipping fees.

Wood Species	Class/Height	Disposal Costs/Pole ($)	
		Lowest Cost	Highest Cost
Douglas-fir	4/40 feet	$5.41	$20.00
	1/70 feet	$19.60	$65.38
Western redcedar	4/40 feet	$4.70	$15.68
	1/70 feet	$17.73	$59.09

long Douglas-fir pole (Table III-3). Clearly, landfill costs for distribution poles are relatively small, while costs are sharply higher for landfilling transmission poles

Determine the net recoverable yield possible and identify logistical hurdles to sawing of Douglas-fir and western redcedar poles. While the ANSI specifications ensure that utility poles contain large quantities of clear, defect free wood, much of this material is treated with preservative (ANSI, 1992). Thus, the large volumes of wood in a pole must be viewed with some caution since recoveries may actually be much lower due the treated shell. To determine the potential recovery from poles, we used two approaches. The first was direct comparison of a recovery trial run with western redcedar transmission poles in the Bonneville Power system. The preliminary trial produced recovery in the range of 53 % of the total volume entering the mill (Parry and Cahill, 2001). These figures are in general agreement with recent recovery studies of Alaska yellow cedar which produced a 50 % recovery rate for recently harvested trees (Hennon et al., 2000).

In the second approach, we surveyed the literature and examined recovery studies from the same species as well as recovery studies from logs that had been exposed to insect and fungal attack for varying periods of time prior to sawing (Table III-4). We used the latter studies because we felt that the loss of integrity of the outer zones of these logs would approximate loss in recovery from utility poles due the presence of the treated shell.

The data developed through the BPA trial provides valuable information on the rate of recovery from western redcedar poles. Cedar, however, represents only a fraction of the poles being removed from service each year. There are also large amounts of Douglas-fir, and further east, lodgepole pine removed due to internal

Table III-4. Relative lumber recovery rates from various tree species.					
Wood Species	Condition	Defects	Cubic Recovery	Literature Source	Comments
Incense cedar	Green	4-17 %	50-60 % for 6 to 34 in dia. logs	Pong and Cahill, 1980	-
Douglas-fir	Green	N/A	76 % for 20 in dia. logs	Willets and Fahey, 1988	Mostly utility and economy grades
Douglas-fir	Green	37 to 48 %	62 % for 61 in. dbh.	Snellgrove et al., 1975	-
Sitka spruce W. hemlock	Green/dead	-	spruce 61% hemlock 53% to 62%	Ernst et al., 1986	dimension mill recovery
Lodgepole pine	Green/dead	-	43/39 % for live/dead	Fahey et al., 1986	-
Various species	Dead 1,2, 3 years	1, 10, 27 % (1-3 yrs)	-	Lowell and Cahill, 1996	-

decay near the groundline. The ability to process these species may be essential for ensuring a steady raw material supply for a remanufacturing operation. While there are no recovery studies on Douglas-fir utility poles, we believe that prior recovery studies on Douglas-fir and lodgepole pine from fire or beetle killed stands may be applicable to utility poles. Deteriorating logs will tend to lose the outer sapwood shell due to decay and insect attack, while considerable recoverable wood remains at the core. The preservative treated shell of a Douglas-fir pole should also be considered unrecoverable (at least with current technologies), but there is a considerable volume of sound wood inside this treated shell.

The previous cull studies as well as the initial BPA trial suggest that recoveries between 50 and 60 % of the total volume processes would be reasonable for western redcedar poles. The recoveries from Douglas-fir poles may be a bit more difficult to assess. Most Douglas-fir poles removed from service contain substantial amounts of internal decay at or near the groundline. As a result, recovery from this zone will be sharply reduced. Since the base log tends to contain higher levels of clear wood, the presence of heartrot sharply decreases the potential recovery value. This may make it necessary to process larger amounts of Douglas-fir through the operation to produce an equivalent return.

Determine the potential for using treated wood components for production of reconstituted engineered wood products. In most cases, the poles removed from service will contain a preservative treated shell that must be removed before the untreated core lumber can be sawn (Table III-5). The depth of this shell will vary with species; western redcedar has a thin treated shell that rarely exceeds 0.5 to 1.0 inches, while Douglas-fir has a treated shell that can easily reach 3 inches. While this material can be disposed of in a municipal solid waste (MSW) facility, this process adds cost. In addition, future regulatory changes could alter the ability to dispose of this material through MSW facilities, creating an especially vexing problem.

Materials from the outer shell of the recycled pole contains elevated levels of either pentachlorophenol or creosote. A new western redcedar pole should contain 1.0 pounds of penta per cubic foot of wood or 20 pounds of creosote in outer 0.5 inch (AWPA, 1999). The penta treated wood will also contain between 6 and 8 pounds of oil per cubic foot. Processing the poles using a conventional bandsaw, will produce both sawdust and jacket boards that are contaminated with preservative. Preliminary tests on jacket boards cut from creosoted western redcedar poles in the BPA trial indicated that residual creosote levels were extremely low. In general, visible evidence of creosote or oil was a good indicator of preservative presence.

The disposition of the contaminated material is not currently a problem, but it does impose an expense. Current disposal rates in the region range from $18.00 to $60.00 per ton, provided the material has passed TCLP (Table III-6). One alternative to landfilling is to use the material for co-generation (as hog fuel) (Conlon, 1992; Karakash and Lipinski, 1998; Smith, 1992; Webb and Davis, 1992). This option would be most likely with creosoted material since the organics in creosote are easily combusted. Co-generation using discarded railroad ties has been commercially used in other parts of the U.S. for over a decade and appears to be a simple method for disposal . There are currently no facilities in the state of Oregon that are permitted to burn wood containing pentachlorophenol. As a result, it would be necessary to segregate poles on the basis of treatment. This would be difficult

Table III-5. Relative volumes of treated wood in poles containing various amounts of preservative treated shell.					
Wood Species	Pole Class/Length	Estimated Total Volume (ft^3)	Total Treated Wood Volume (ft^3)		
			0.5 in.	1.0 in.	2.0 in.
Douglas-fir	4/40 feet	16.69	-	6.70	11.64
	1/70 feet	60.54	-	17.28	31.65
W. redcedar	4/40 feet	18.67	3.78	7.11	-
	1/70 feet	70.34	9.77	18.78	-

Table III-6. Estimated disposal costs for the treated component of Douglas-fir and western redcedar distribution and transmission poles.				
Wood Species	Pole Class/Length	Treated Zone (inches)	Treated Wood Weight (lbs.)[a]	Disposal Costs ($/Pole)[b]
Douglas-fir	4-40 feet	1.0	241 lbs	$ 2.17
		2.0	419 lbs	$ 3.77
	1-70 feet	1.0	622 lbs	$ 5.60
		2.0	1,139 lbs	$10.25
Western redcedar	4-40 feet	0.5	106 lbs	$ 0.95
		1.0	199 lbs	$ 1.79
	1-70 feet	0.5	274 lbs	$ 2.47
		1.0	526 lbs	$ 4.73

[a] Assumes that treated densities for Douglas-fir and western redcedar are 36 and 28 pounds per cubic foot, respectively.
[b] Assumes a disposal cost of $18.00 per ton in a municipal solid waste facility

with heavily weathered poles that lacked their butts or an initial treatment tag. The need for segregation of preservatives and permitting at the co-generation facility may also make this approach economically unattractive, given the relatively small volumes of material.

Another alternative pathway for the sawdust, chips and slabs created during sawing is to manufacture composite materials (Geimer, 1982; Labat, 1998; Roliadi et al., 2000 a, b). There are a number of particleboard facilities within a short distance of the mid-Willamette Valley that could serve as an outlet for chips. The treated chips could provide material for producing more durable composites. A number of researchers have reported on the use of treated wood waste for the production of a variety of panel products. In general, these efforts have concentrated on wood treated with inorganic salt preservatives. While salts, such as chromated copper arsenate, can affect bonding kinetics, resins can be formulated to slow curing and produce acceptable panel properties with these materials. Oil treated materials pose a greater challenge, since the oil can interfere with adhesion, resulting in poor panel properties. In addition, flakes or chips from jacket boards (the most likely source of such materials) will not be uniformly treated, which will result in panels with much more variable durability than those produced by conventional processes (i.e. by addition of biocides to the furnish prior to pressing). Finally, the small volumes of material are likely to discourage users from taking the risk of bringing preservative treated material into their facility.

Alternatively, by-products of the sawing process could be actively biodegraded (Lamar, 1995; Lamar and Dietrich, 1992; Messner and Bohmer, 1998). This approach would only be required if regulatory changes restricted or prohibited landfilling of treated wood. There are a number of reports describing bioremediation of soil contaminated with pentachlorophenol or creosote. Both preservatives are relatively easily degraded under the proper conditions; however, reprocessing treated wood wastes through bioremediation remains a poorly understood science that is probably beyond the immediate scope of a small manufacturing facility.

Table III-7. Number of poles per truckload and costs to transport Douglas-fir and western redcedar poles 70 or 200 miles						
Pole Class/Length	Number of poles/truckload		Transport Cost/Pole			
			Douglas-fir		W. redcedar	
	Douglas-fir	W. redcedar	70 mi	200 mi	70 mi	200 mi
4- 40 feet	40	59	$6.50	$13.33	$4.41	$9.03
1-70 feet	10	14	$26.00	$53.30	$18.57	38.07

Identify transportation and storage costs for recycled poles. Wood is a bulky material, making transportation from the utility to the remanufacturing facility an important aspect in developing a steady fiber supply. We contacted five trucking firms in the region to determine costs for shipping poles 70 to 200 miles. Four of five companies provided information. We assumed that trucks would be loaded to 45,000 pounds using as many poles as possible. Using this maximum load as a guide, a single truck could transport 40 Class 4 forty-foot long Douglas-fir poles or 59 similarly classed cedar poles (Table III-7). On the transmission side, this load would translate into 10 Douglas-fir or 14 western redcedar Class 1 seventy-foot poles. These calculations use the initial treated shipping weight, which might over-estimate weight of poles from drier parts of the region. We initially assumed that the poles would be transported full length. Cutting transmission poles into smaller sections would probably reduce costs and increase the number of shippers who could bid on a contract.

Rates for shipping a full load of poles 70 miles ranged from $260 to $325 while the rates for 200 miles ranged from $533 to $575. These figures did not include loading by the shipper, which would add $60 per hour to each figure. We assumed that most utility stores yards would have access to loading equipment. The weight of the poles would depend on condition. Shipping weights for freshly treated poles can be used as a guide, but wood moisture content can markedly affect weight. Moisture contents in freshly treated poles are typically higher in the interior, ranging from 30 to 50 % at the time of treatment. These moisture levels should decline to 15 to 25 % in service, above the ground, but may be considerably higher below the ground. Any added moisture would decrease the number of poles per truckload, thereby increasing shipping costs.

Shipping costs per pole are relatively small for Class 4, forty-foot long distribution poles, but the amount of recoverable lumber in these poles is also small. Costs for transporting Class 1, seventy-foot long transmission poles are much higher, increasing by 4 and 4.2 fold for Douglas-fir and western redcedar, respectively. Interestingly, however, the ratio of wood volume to transport costs suggests that smaller poles may actually be more economical to transport. For example, the ratio between recoverable wood from transmission and distribution poles was 3.60 and 3.76 for Douglas-fir and western redcedar, respectively, indicating that it costs slightly more to transport an equivalent amount of wood in a transmission pole. This relationship would tend to change as the percentage of treated wood in the cross section increased (since more non-usable treated wood would be transported).

The other aspect of transportation which we did not examine was assembly at single sites for transport. Sending trucks to pick up small units of poles would markedly increase costs, while assembling poles at centralized sites would allow for more rapid loading, thereby reducing transportation costs. The potential impacts of the assembly and storage option will be addressed in a later section.

Identify other products that might provide a steady supply of raw material for this operation such as piling and crossarms While utility poles form the dominant material source for the proposed remanufacturing facility, there may be other, equally attractive materials that could supplement the fiber supply including crossarms and marine or foundation piling.

There is little or no information on the volumes of crossarms that are removed each year, nor are there data on the manner in which these materials are disposed. Limited discussions with utility cooperators and examination of several treated wood reject piles suggests that the poor condition of most crossarms removed from service largely precludes remanufacuring. Many cross arms removed from service are cracked along knots or other defects, and have decayed on the upper surface, or are otherwise damaged. One potential option for these materials, however, may be to saw out the failed zone and sell the remaining material for landscape timbers much in the same way that railroad ties are recycled for home and garden use.

Like utility poles, piling (either marine or land and freshwater piling) are manufactured from high quality logs. As a result, they can contain high volumes of valuable lumber. While there is currently only a limited market for recycling of piling (primarily where marine piling are removed and then used as foundation piling), the availability of an outlet for these materials might lead contractors to consider recycling. In addition, there may be a limited market for the cut-offs on foundation piling. Typically, foundation piling are driven into the ground to a specific load, then all the piling on a project are cut off to a set height. Since piling are driven from the butt end downward, the most valuable part of the piling in terms of clear wood is cut off.

Unfortunately, the market for wood foundation piling in this region is fairly limited. In addition, most cut-offs are relatively short (4 to 6 feet long). Where these materials are used, such as in large construction projects, it may be possible to work with contractors to collect cut-offs , most likely through initial contacts through a general contractor organization. The infrequent nature of substantial projects using foundation piling probably relegates these materials to a relatively minor role in over all fiber supply.

One other option for a substitute fiber supply might be to perform custom sawing for local small woodland owners. This would, however, probably require some cleaning of the sawmill equipment to ensure that boards from these operations are not contaminated with preservative residues.

Evaluate the potential for using Smart Wood or other Certification program to create a specialty niche for this recycled product. Public concerns about resource utilization have encouraged the development of a variety of schemes to certify that practices surrounding the harvesting and manufacturing of a given material occur under certain environmentally acceptable practices. These materials are then certified by an accredited third party agency. While the number of companies seeking certification continues to grow, there is some debate concerning whether there is any return on the costs associated with certification (Carter and Merry, 1998; Gronroos and Bowyer, 1999, Hansen, 1997; Hayward and Vertinsky, 1999; Ozanne and Vlosky, 1997). Certification may, however, represent a method for exploiting a specific niche of consumers who are willing to pay slightly more for the knowledge that a product was manufactured in a way that minimized environmental consequences.

There are a number of Certification programs for wood products, but the Forest Stewardship Council (FSC-SmartWood) or Scientific Certification Systems are the two dominant certification programs (Hansen, 1997; Scrase, 1995). FSC has 10 principles for certification. The primary emphasis in either program is maintaining a chain of custody of the material from certified forest to finished product. Identifying a chain of custody beyond the original utility would be extremely difficult given the ages and various sources of poles removed from service. Assuming that chain of custody can begin with the utility, the next question concerning certification is the potential return on the costs of maintaining a program. Forsyth et al (1999) surveyed consumers outside home improvement retailers and found that most people would pay up to 5 % more for a certified product, but the willingness to pay more fell off sharply when the price difference was 10 %. While this suggests some willingness to pay premiums for recycled products, there has been little information on actual purchasing behavior of consumers when faced with seemingly identical certified and non-certified wood with a cost differential. Limited studies suggest that actual consumer behavior will differ substantially from surveys with most consumers purchasing the lower cost material. There does, however, appear to be a core group of consumers willing to pay a premium for certified forest products. It is, as yet unclear whether this segment of the population is large enough to support a local industry. As a result, pursuit of certification is probably not an economically viable option at the start of a pole remanufacturing operation, although it may be worth pursuing once pole supplies and markets are better established.

The FSC also has a SmartWood - Rediscovered Wood program to certify reused, reclaimed, recycled or salvaged wood products. The emphasis in this program is on demolition projects that reclaim large timbers for reuse, wood by-products from secondary manufacturers, fallen trees removed from lakes or rivers, and trees removed from abandoned orchards or other private properties. None of the current Rediscovered Wood products include chemical treatment and it is unclear whether these treated materials would be deemed appropriate for this program.

Identify the environmental concerns that might be applicable to a pole recovery operation Many of the concerns with locating a pole remanufacturing facility differ little from those with any other primary processing operation; however, the presence of preservatives brings with it special considerations. These concerns include pole storage prior to use, separation of waste streams for disposal and recycling, and the potential for off-site movement of materials from this process. In addition, there exists the potential that sawn lumber from the interior of a pole may be contaminated with the original treatment.

It is clear from the utility surveys, that nearly all of the poles entering the facility will contain restricted use preservatives. While the wood treated with these chemicals is not restricted, the risk of contamination from these poles must be carefully considered in the plant design.

The need to stockpile poles for sawing creates the risk that preservative will migrate to the wood surface, where it can drip on the ground or be dispersed by rainfall. While this risk is likely to be much lower for most weathered poles since the majority of the leaching should have occurred in service, the butt portion of the poles should contain high levels of preservative. There are two approaches for minimizing the potential for surface contamination, The first is to locate covered storage facilities that have an impermeable ground cover. The cover reduces the risk that sun exposure will heat the pole surface to the point where bleeding will occur and also eliminates the risk of precipitation solubilizing any preservative on the surface. The impermeable ground cover reduces the risk that any drippage will enter and contaminate the soil. However, large covered facilities can add significant cost to the operation.

The second approach to minimizing migration would be to use an impermeable ground cover and then use tarps to cover the stored poles. This approach is used in at least one treating plant in the Northwest, but it adds handling costs to the material and does not completely protect poles from wetting. In the absence of adequate covered storage, it probably represents a more economical approach to limiting chemical loss from poles prior to sawing.

The sawing process introduces a host of environmental issues in the process. First, all of the sawdust and many of the exterior boards will be contaminated with preservative. While previous tests indicate that this material can be disposed of safely in a MSW facility, it will be necessary to collect and store significant quantities of material. The use of a portable sawmill will likely make it a bit more difficult to capture the sawdust unless some type of dust collection system is installed. The presence of significant quantities of sawdust increases the likelihood that materials will be tracked throughout the facility, where they can contaminate soil and surface water. This may require, for example, diked areas that exclude wheeled vehicles that carry sawdust around the plant. The sawdust also poses a health risk to workers, making the use of some type of breathing protection necessary when sawing. Similarly, the presence of treated wood will require workers at the site to wear proper protective clothing when handling the treated segments of the poles. These requirements would be no different than for other workers handling treated wood.

Sawdust control will be especially important to ensure that treated materials do not leave the manufacturing site, since these materials can be carried by wind and surface waters.

Develop guidelines for selection of a pole-remanufacturing site There are an array of considerations for selecting a potential pole remanfacturing site. These considerations include:

1. Availability of impermeable surfaces for storing poles prior to sawing
2. Availability of covered storage space to minimize leaching risk
3. Proximity to pole supply- poles over 200 miles away are probably not economical to ship
4. Availability of low cost disposal for treated wood waste
5. Site should have the potential for connection to the local treatment facility should surface water runoff be restricted
6.Proximity to major interstates for ease of shipping poles to and products from the site.

One other possibility for locating a pole remanufacturing facility is to bring the facility to the pole supply. Poles could be brought to centralized processing yards around the region and the mill could be moved to each site on a rotating basis. The primary advantage of this approach would be reduced shipping costs, but it may have the more intangible benefit of creating a closer working relationship with the supplying utilities. The primary drawback to this approach is the need for multiple sites. Many years ago, it may have been possible to convince participating utilities to provide space at a sub-station or stores yard, however, previous experiences with other reprocessing operations, notably transformers, have proven extremely costly to utilities. As a result, it is doubtful that many utilities would provide this space without significant indemnification from the processor. In addition, spreading the sites increases the amount of administrative work required. Finally, the multiple sites would require establishing multiple disposal sites. Given the range of tipping fees and the unwillingness of some facilities to accept waste, it may be difficult to locate economical disposal options in all areas.

Assess the potential for market growth of this operation. While our initial survey was limited to the region around the Mid-Willamette Valley, an operation of this nature may also have application in many other areas of the country. We estimate that a single band portable sawmill can process approximately 60 eight foot long pole sections 12 inches in diameter per day or 70 sections 8 inches in diameter. We estimated that the mill would run 260 days per year. This translates into approximately 1,783 Class 1, seventy foot poles or 3,640 Class 4, forty foot long poles per year. If we assume that distribution and transmission poles would enter the facility in approximately the same ratio in which they appear in service (80:20), then the facility would process 357 transmission and 2,912 distribution poles per year. While this seems relatively small, it represents 21.1 % of the 15,500 total poles that our disposal surveys suggest are available within the Pacific Northwest. This assumes that the facility would process both Douglas-fir and western redcedar. At present, western redcedar lumber sells for approximately $200 more per thousand board feet than Douglas-fir; making this species more financially rewarding. If the facility elected to only process western redcedar, which represents only 47 % of the poles in service in this region, then the facility would need to capture 44.9 % of all available poles in a fairly large geographic area. This level of supply may be difficult to develop, given the tendency to give these materials to adjacent landowners.

While we have concentrated on a western facility, there may be potential for developing similar facilities in other parts of the country. The western surveys, as well as those completed elsewhere, suggest a pole replacement rate of approximately 0.60 to 0.75 % per year. There are an estimated 160 million poles in service in the U.S., which translates to 960,000 to 1,2000,000 pole replacements per year. These figures must be viewed with some caution since poles are removed from service for a variety of reasons including road widenings, line upgrades, car accidents, and deterioration. As a result, a percentage of these poles would likely be unusable, for example, accident poles, because of internal damage. The other major difference in other parts of the country is the diminished percentage of western redcedar. The majority of poles in most parts of the country are southern pine, which has a thick, well treated sapwood zone that would sharply diminish the recovery rates for clear, untreated wood and increase disposal costs if no market can be found for variably treated wood. Western redcedar represents less than 10 % of poles in most other parts of the country, although the majority of this material is in transmission sizes. It may, however, be difficult to develop a supply stream to that would result in nearly 2000 poles per year passing through a processing facility. The exception might be in the upper Midwest, which has historically used cedar for transmission poles.

Examples of Other Pole Remanufacturing Operations:

Remanufacturing of utility poles can take several pathways. One utility company in Alberta removes western redcedar poles from service, shaves the external, weakened wood, then retreats the poles and returns them to service (Felton and DeGroot, 1996). The advantages of this operation are that it can be contained within an individual utility and, unless the utility has an extended service area, does not require extensive storage or transport of poles. One disadvantage of this approach is the need to closely inspect each pole to ensure that it retains sufficient strength to support its intended design load. Each pole must be carefully inspected for the presence of internal defects such as shake or internal decay. More importantly, the recycling process requires the utility or its contractor to become a wood treater with all of the regulatory aspects associated with the process. In addition, the process requires the development of trained personnel who can use the treatment equipment and properly handle chemicals. This requires a substantial throughput of poles in order to make the process economical.

The more typical approach to pole recycling is remanufacturing into other products including lumber, shakes, shingles, fencing and siding (Biocycle, 1997; Cooper, 1993; Electrical World, 1992; Felton and DeGroot, 1996; Kempton, 1992; Parry and Cahill, 2001).

Cooper (1993) examined nearly 500 poles removed from service and found that 8 % could be reused, 35 % could be used as sawlogs, and 15 % for producing shingles. The remainder were suitable for lower value uses such as parking bumpers or disposal .

BC Hydro, in cooperation with BC Telephone and BC Wood Recycling Ltd, established a pole remanufacturing operation for western redcedar poles to produce lumber, siding, planking and fencing. Material is either used internally within the companies or sold to the general public. One product sold to the public is a cedar Adirondack chair manufactured by mentally disadvantaged workers and sold through BC Hydro's Power Smart Centre locations. BC Wood Recycling reports recovery rates of 70 %, which seems a bit high compared with other studies (Parry and Cahill, 2001). In general, the poles are only butt treated, thereby eliminating the potential for preservative contamination of many exterior boards.

King and Lewis (2001) recently reported on the feasibility of recycling what appears to be southern pine utility poles. They modeled manufacturing and marketing parameters for both round and sawn stock. They estimated an 80 % recovery rate, far in excess of current studies of even fresh, green material. In addition, they appear to have ignored the presence of treated wood in the pole exterior. Southern pine has a thick shell of sapwood that readily accepts treatment. Sawing this material will result in many preservative containing boards. While these might be sold as "durable" materials, the preservative levels in these boards will vary widely, making it difficult to obtain uniform performance. In addition, most of the poles removed from service will be treated with oil-based preservatives and the treated lumber cut from these poles will have a relatively limited market.

In addition to these more elaborate efforts, previous utility surveys suggest that many public utilities operate small sawmill operations to recover value from their treated poles. These operations usually use inexpensive portable sawmills or supply materials to local sawmillers who then share in the proceeds from the lumber. In either case, the volumes of poles are probably inadequate to sustain year-round operation of such facilities, but the relatively low start up costs allow for discontinuous operation.

C. POTENTIAL FOR BIOLOGICAL CONTROL OF CARPENTER ANTS USING PARASITIC FLIES

Carpenter ants are important degraders of wood poles in areas where utility right of ways pass through forested areas. Carpenter ants are difficult to control because they do not use the wood as food source, instead excavating galleries in wood where they rear their young. In addition, the ants appear to use poles as satellite colonies. While a variety of chemical treatments are applied to the ant galleries, these treatments do not always kill the queen. This means that the colony can continue either in some other part of the pole or elsewhere. Previous efforts have evaluated the potential for using juvenile hormones to disrupt the colony, but getting the chemical to the colony has proven difficult. Applying chemical barriers around each pole might limit carpenter ant attack, but the chemicals registered for this purpose are not long-lasting and would be expensive to apply on a regular basis. In addition, repeated use of chemicals in utility right of ways would raise concerns about accumulation and effects on non-target organisms.

One approach to arresting carpenter ant attack is to use biological agents. The classic approach to insect control is to identify fungi that can parasitize the insects. The most common fungi for this purpose are members of the genus *Bauveria*. These fungi invade the adults or larvae, where they grow through and eventually kill the host. Complete control of carpenter ants using this fungus would be difficult owing to the inability to deliver the fungal spores directly into colonies. One alternative to fungal control is to identify other insects that parasitize carpenter ants.

Ant decapitating flies in the genus *Apocephallus* lay their eggs on the backs of carpenter ant workers. The eggs hatch and the larvae tunnel inside. After several days, the workers head fall off, then the fly larvae pupate, complete their development and emerge to seek out new worker ants. The advantage of these parasites is their ability to move about to find potential victims. Species of these flies have been investigated for controlling fire ants in the southern U.S., but there is little work on their use for carpenter ant control. We have been investigating the use of *A. horridus* for controlling *Camponotus vicinus* as part of our broader effort to better understand the biology of carpenter ants in order to develop more effective prevention methods.

Carpenter ants in a colony of *C. vicinus* were collected during the winter. Ant workers were placed, in groups of 10, into petri dishes and fed glucose alone or amended with 3.33, 6.66, or 13.32 X10^{-4} mg/ml of the fungicide propiconazole.

These tests were initially started as feeding studies, until the flies were detected in the workers. The ants received 100 ul of glucose every two weeks. Each treatment was replicated on three petri dishes each containing 10 workers.

In addition, two other trials were established. The first used the same procedures described above but employed 20 workers per petri dish, while in the second, 40 workers were placed into large plastic containers and fed chemical treatments via a small diameter tube. Ants were monitored daily for four weeks. Ant heads usually began falling off within 2 weeks. The diameters of the decapitated ant heads were measured, then placed into petri dishes and incubated at 25°C and 70 % Relative Humidity (RH) to determine when adult flies emerged. We examined the effect of elevated temperatures on decapitation by exposing 120 worker ants from the parasitized colony at 39 C for 48 hours.

Finally, we placed emerging flies in chambers containing worker ants to determine if we could encourage them to mate and lay eggs on workers. Groups of 10 workers were placed into petri dishes along with emerging flies and the worker behavior was observed.

The frequency of carpenter ants in a colony parasitized by *A. horridus* ranged from 0 to 15 % (Figure III-5). Two colonies appeared to be especially heavily parasitized, although there were no apparent reasons for the high levels of attack. While this suggests that the fly is not normally a major parasite of workers, elevated parasitism levels in some colonies implies that environmental conditions around colonies may make them more susceptible to parasitism. It also suggests that parasitism levels may be encouraged by either release of flies or manipulation of colony conditions.

The frequency of flies from workers fed glucose with or without propiconazole varied with dosage. In general, fly incidence increased with increased propiconazole dosage (Figure III-6). Results of the larger trial produced similar results. While propiconazole should not markedly affect fly physiology, it does affect fungi associated with either the ants or the parasite.

Laboratory trials using larger numbers of ants suggested that the presence of the fungicide produced less clear cut effects on the incidence of decapitated ants. Low levels of fungicide were associated with a sharp increase in head decapitation, but levels dropped then increased at higher dosages(Figure III-7). The ambiguous results suggests that the fungicide may have more subtle effects on fly/carpenter ant interactions.

Head width measurements of decapitated and normal worker heads suggested that decapitation increased

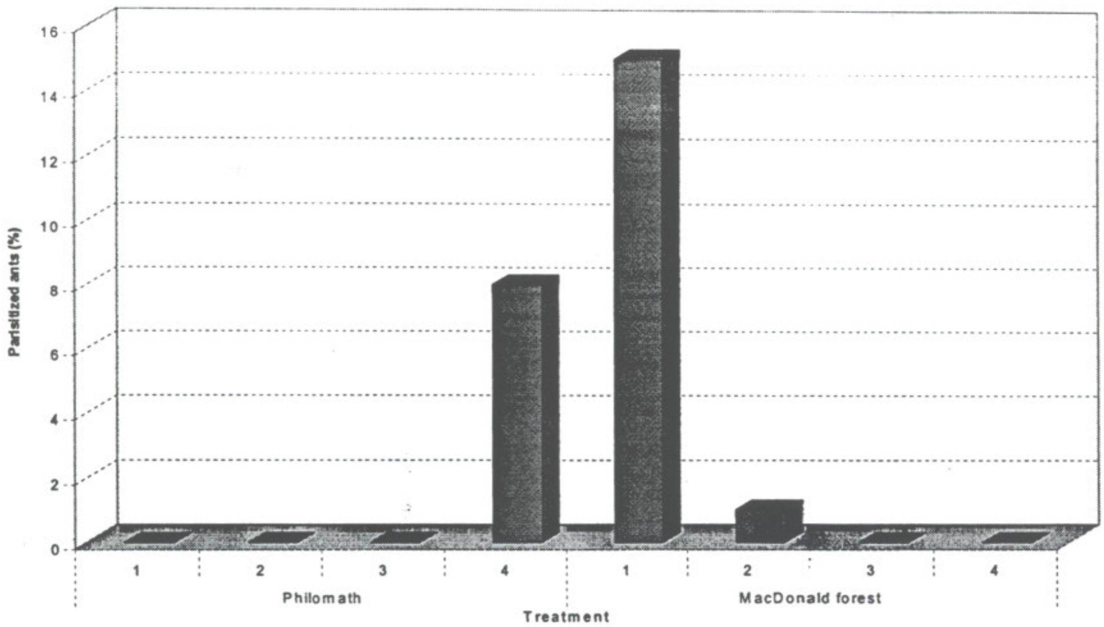


Figure III-5. Frequency of ant decapitating flies in carpenter ant colonies.

with decreasing worker head width (Figure III-8). Smaller workers may be less able to fend off flies attempting to oviposit around their heads. In other species, workers have been observed assuming defensive positions when flies appear.

Exposure to elevated temperatures (39°C) for 2 days appeared to eliminate the incidence of decapitated ants (Figure III-9). While 39°C is not extremely hot, most carpenter ant nests are located in materials that tend to insulated from substantial heating. For example, even though wood pole surfaces reach elevated temperatures that sometimes exceed 60 C, this heat is transmitted relatively slowly into the interior where carpenter ant galleries are located. The ability to alter parasite incidence by short term heat exposure implies, however, that subtle environmental changes may have dramatic effects on successful parasitism. Understanding these effects will be essential as we further explore the potential for using this insect for carpenter ant control.

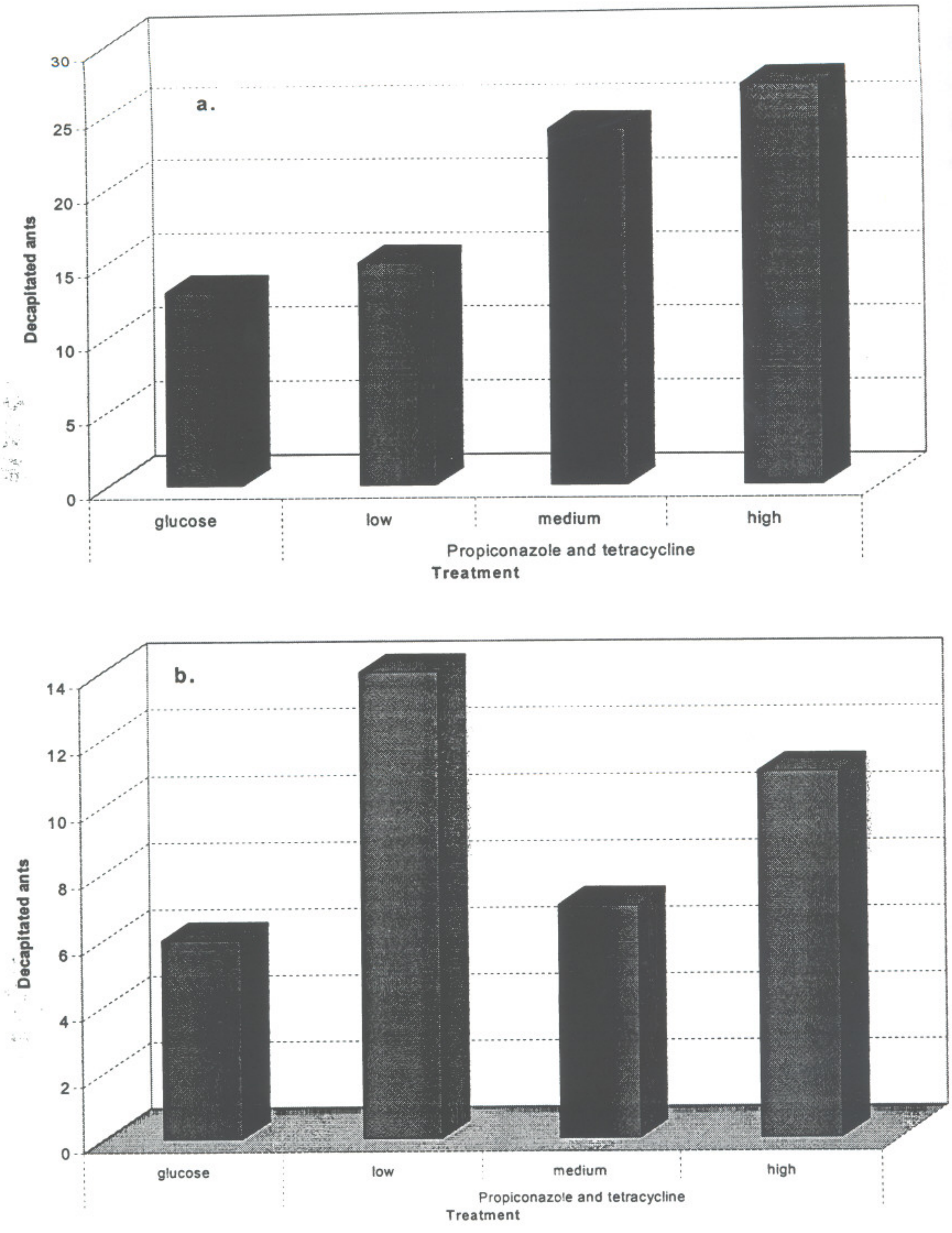


Figure III-6. Incidence of ant-decapitating flies from a) 30 carpenter ant workers or b) 120 carpenter ant workers fed diets with glucose and varying levels of propiconazole in 2 separate trials.

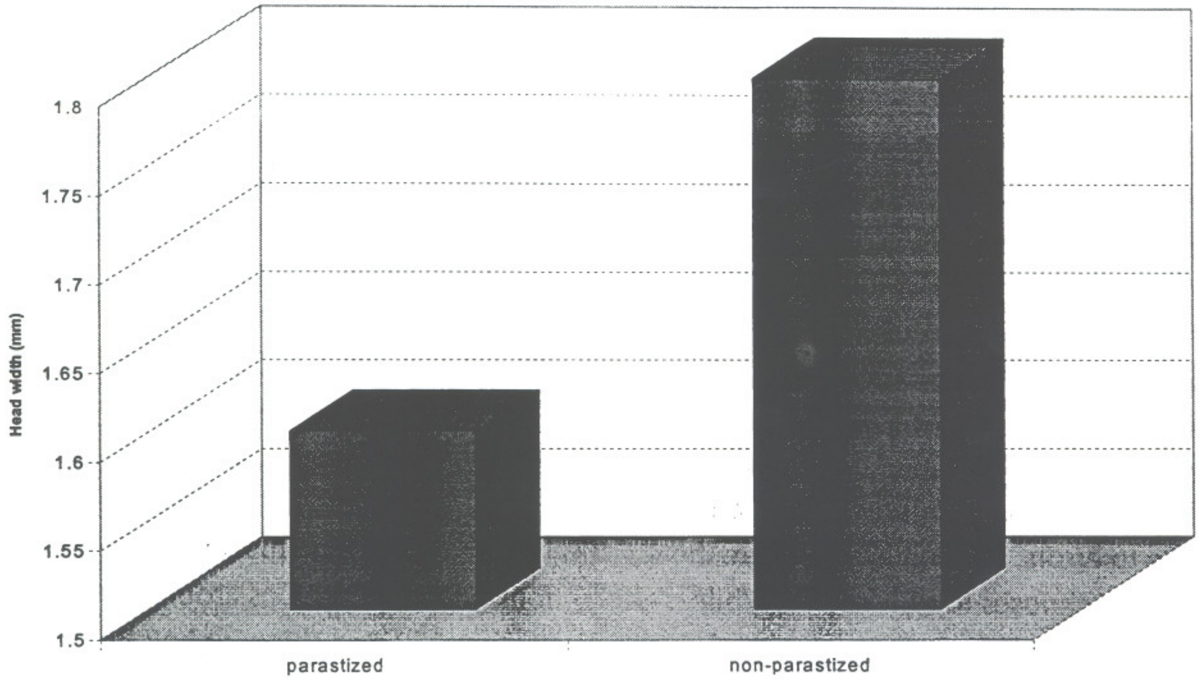


Figure III-7. Head widths of healthy and parasitized carpenter ant workers from a single colony.

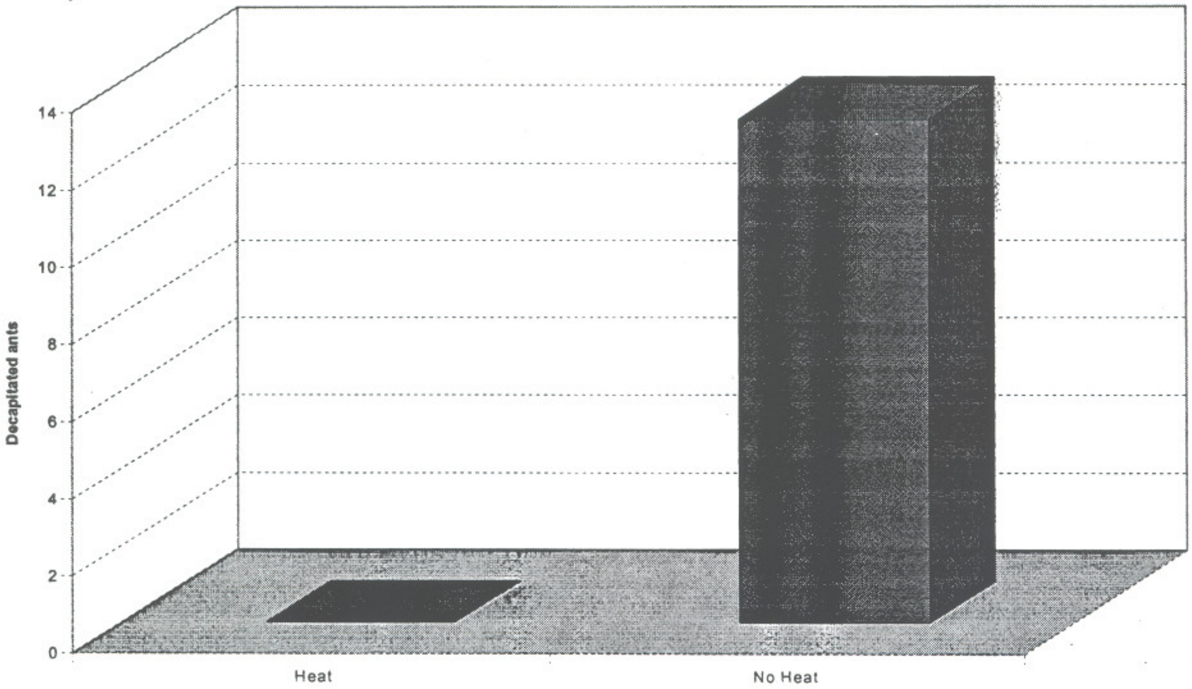


Figure III-8. Effect of heat treatment (39°C for 48 hours) on incidence of head decapitation among carpenter ant workers.

D. Ability of a Sonic Inspection Device to Detect Simulated Insect Voids in Douglas-fir Poles

Accurate detection of insect damage inside utility poles often constitutes a major challenge. While the galleries of carpenter ants and termites are fairly distinct voids, they are generally small in diameter and, at earlier stages of attack, widely spaced. Detecting these voids using conventional drilling inspections is prone to errors, depending on where the inspector chooses to drill holes. While there is probably little or no strength loss due to internal insect attack at the earlier stages of colonization, detection and treatment at this time could reduce further damage and provide a protective chemical reservoir against renewed attack.

One approach to early detection of insect attack is to use one of the acoustic devices currently marketed for assessing pole condition. While our previous results with these devices suggest that they are poor predictors of pole strength when used as stand alone inspection devices, this does not preclude their use for detecting insect galleries. There is, however, little data on the ability of these devices to detect and locate small voids in poles.

The ability of one sonic inspection device, the Purl2 to detect simulated insect galleries was investigated using untreated Douglas-fir pole sections (200-250nmm in diameter by 600 mm long), The transmitter was attached to the pole 300 mm from one end, then a series of small diameter holes from one end of each pole. The holes were either drilled at the approximate pole center or off to one side of the cross section. Hole diameters were 9, 11, 12.5, or 14 mm in diameter and extended 370 mm downward from the top. The ability of the inspection device to detect the void was determined by placing the receiver at four selected locations around the pole section 150 mm above or below the transmitter location. Readings were taken initially and after each hole was drilled, in essence testing the ability of the device to detect an increasing percentage of void. The resulting drill holes removed from 0.1 to 7 % of the cross sectional area of each pole.

The Purl functions by taking a series of readings around the pole. An indicator light notes whether the signal was received in a specific time frame. Voids or other defects delay the signal, leading to more negative readings. The locations of positive (signal transmitted) and negative (no signal detected) are recorded. The patterns of positive and negative readings are then used to infer the presence of internal defects. In principle, increasing numbers of termite tunnels should eventually reach the point where they interfere with sound wave

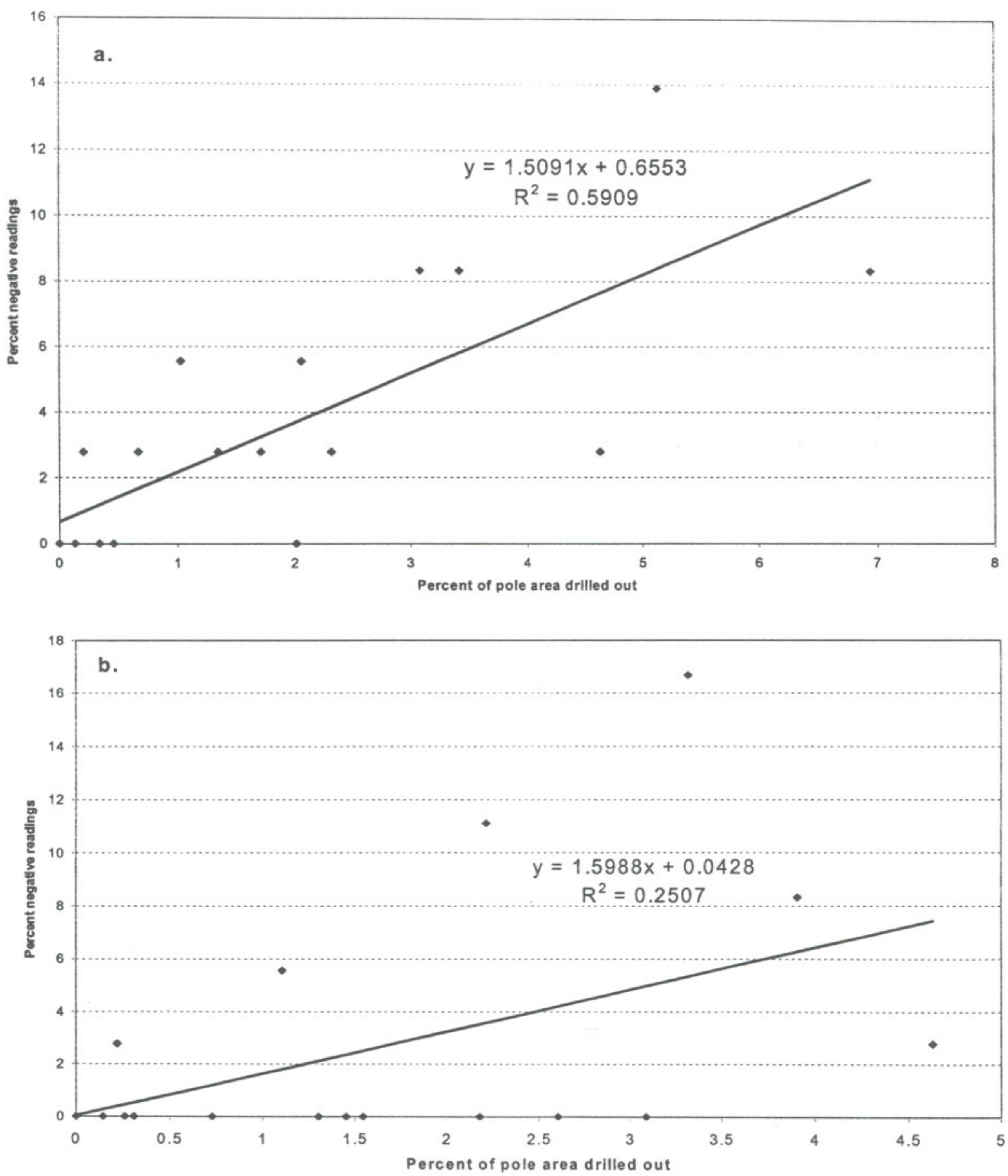


Figure III-19. Frequency of negative readings from the Purl inspection device on Douglas-fir pole sections with increasing amounts of wood removal a) to one side of the pole or b) from the center of the pole.

transmission across a given transect. The sequential drilling and measurement was designed to identify that threshold.

The percentage of negative readings tended to increase with increasing percentage of pole area removed when the holes were off to one side of the pole, although it was sometimes difficult to detect holes when less than 0.5 % of the cross section was removed (Figure III-10). The number of negative readings was reasonably correlated with percentage pole area removed ($r^2 = 0.59$), but there was wide scatter. The ability of the device to detect voids was sharply reduced when holes were centered in the pole, with the correlation between negative readings and percent pole area removed declining to 0.25%. From the perspective of total cross section removed, the PURL proved fairly sensitive when the holes were not centered, detecting all but one set of damage when as little as 1 % of the cross section was removed. The inability of the device to detect voids when the holes were centered is perplexing. The PURL was capable of detecting 6 of 11 conditions where voids exceeded 1 % of the cross section, although it did improve at higher percentages of wood removal. It is important to consider that removing 1 to 3 % of the cross section has little effect on pole properties and that this device was fairly reliable for detecting damage above this level.

E. Incidence of decay in western redcedar poles

Over the past decade, we have done a number of studies evaluating the durability of western redcedar heartwood. These studies have shown that the heartwood of western redcedar continues to be decay resistant. Despite these findings, we continue to receive questions concerning the incidence of early decay in this species as well as more recent concerns that current treating practices fail to adequately sterilize the heartwood. In this report, we describe field evaluation of in-service western redcedar poles and bioassays of pole before and after thermal treatment.

<u>1. Condition of western redcedar poles in northern California:</u> Western redcedar poles generally have a reputation for extreme durability, with average service lives ranging from 60 to 80 years in many locations. As with any natural material, cedar heartwood durability can vary widely, leading to concerns when individual poles develop decay.

This past year, we initiated a limited survey of the condition of western redcedar poles in Central and Northern California. Poles located in the Bakersfield, Lodi, Merced, Chico, and Fort Bragg were selected for evaluation. Poles ranged in age from 2 to 71 years old and were treated with either pentachlorophenol or creosote. The poles were inspected by removing increment cores from three locations at groundline and 150 mm below groundline. The cores were placed into plastic drinking straws, which were stapled shut and shipped to OSU. Once there, small discs were cut from each core just inside the treated zone, in the middle of the heartwood and near the pith. These discs were briefly flamed to kill any contaminating surface microflora, then placed on petri dishes containing malt extract agar. The plates were incubated at room temperature and observed for growth of fungi from the wood. Any fungi growing from the wood were observed under a microscope for evidence of clamp connections that are typical of basidiomycetes, a class of fungi containing many important wood decayers. Fungi with clamp connections were classified as decay fungi, while those lacking these structures were classified as non-decayers.

The remainder of each core was then visually examined for evidence of decay which was mapped along the core length. In addition, the extent of exterior decay on the below ground portion was noted as was the presence of any insect damage. A total of 100 poles were inspected using these procedures Forty seven of these poles were creosote treated, 43 were treated with pentachlorophenol and 10 were believed to have been treated with fluor-chrome arsenic phenol (FCAP). No decay fungi were isolated from any of the poles treated with either penta or creosote (Table III-8). This finding is consistent with previous efforts to isolate decay fungi from western redcedar heartwood, even when visible decay is present. Non-decay fungi were present in most poles, but there were no consistent trends with either pole age or initial treatment. For example, older poles in the Lodi/Chico area had fewer non-decay fungi than newer poles in the same general area, while this trend was reversed in the Bakersfield area. Clearly, fungal isolations, while useful for assessing the risk of fungal attack in most wood species, was less useful when field surveying western redcedar poles.

Visible decay was evident in 2 to 37 percent of poles examined. Visible decay increased with pole age in the Bakersfield sample, but the trends were less consistent at the other sites.

Table III-8. Fungal Isolations and condition of cores from butt treated western redcedar and redwood distribution poles in service								
					Percentage of			
Pole Species	Area	Brand Years	N	Preservative	Cores with Decay Fungi	Cores with Non-decay Fungi	Core Length Decayed	Core Decay Exterior
WRC	Bakersfield, CA	1930-69	11	creosote	0	30	27	63
WRC	Bakersfield, CA	1975-81	10	creosote	0	25	24	61
WRC	Bakersfield, CA	1991-98	11	creosote/ penta	0	18	10	73
WRC	Chico/Lodi/ Merced, CA	1943-66	14	creosote/ penta	0	24	15	57
WRC	Chico /Merced, CA	1975-89	6	penta	0	47	20	82
WRC	Chico/Lodi/ Merced, CA	1991-99	17	creosote/ penta	0	7	4	91
RW	Ft. Bragg, CA	~1940	10	CZA	3	97	7	91
WRC	Ft. Bragg, CA	1989-90	10	penta	0	93	2	100
WRC	Ft. Bragg, CA	1991-95	12	creosote/ penta	0	71	3	67

2. <u>Ability of thermal treatments to eliminate fungi from western redcedar poles:</u> Living trees are remarkably resistant to colonization by most fungi. Once cut, however, trees lose this resistance and can be colonized by a variety of fungi and insects. The rate of colonization depends on the wood species, as well as moisture content (MC) and temperature. For example, the heartwood of species with natural durability, such as redwood (*Sequoia sempervirens*) or western redcedar (*Thuja plicata*), will be colonized more slowly than species with thicker, less durable sapwood, such as southern pine (*Pinus* spp.). Colonization is less of a problem with lumber, since these materials are generally either kiln-dried shortly after sawing or dipped in fungicides to provide surface protection until the wood can be dried below the fiber saturation point. In poles and other large timbers, however, portions of the wood may remain at or above the fiber saturation point for many months after felling, providing an opportunity for colonization by any array of decay fungi (Smith et al., 1987).

The potential for fungal damage during seasoning and before either drying or treatment has encouraged the development of both storage limitations and sterilization requirements (Taylor, 1980). The most common sterilization requirement is 66°C for 60 minutes at the pith center (AWPA, 1999). The amount of time required to achieve sterilization can vary widely depending on MC, pole size, and temperature conditions (MacLean, 1952). Although sterilization is an excellent approach for eliminating decay fungi, questions have arisen concerning whether it is necessary for species with naturally durable heartwood, such as western redcedar.

The specifications and methods of treatment for western redcedar differ markedly from those used for other species because the thin sapwood shell of western redcedar generally does not require substantial pressure treatment to achieve complete penetration (AWPA, 1999). As a result, western redcedar is often treated by using either relatively short thermal processes or very low pressures that may not result in internal sterilization. In addition, the specification for western redcedar typically allows for the presence of some internal decay in the butt (ANSI, 1992). This defect is allowed because most heartrot fungi present in the standing tree do not continue to grow once the tree is cut and processed (Zabel and Morrell, 1992). One other important feature of western redcedar is that the naturally durable heartwood should be less susceptible to colonization by decay fungi during air-seasoning (Scheffer et al., 1984). As a result, there may be less need to eliminate fungi that might become established during the seasoning process. In fact, the risk of fungal invasion in the heartwood should be sharply lower than for species with little or no heartwood durability. For example, Douglas-fir, which contains a high proportion of moderately durable heartwood, is far less susceptible to degradation during air-seasoning than is southern pine, which consists primarily of more decay susceptible sapwood (Sexton et al., 1992; Smith et al., 1987). Western redcedar heartwood should be even less prone to colonization during the seasoning period.

Over the past decade, the processes used to treat western redcedar utility poles have evolved so that the treatment cycle is shorter and enclosed cylinders are used instead of the open tanks more typical of the older thermal process. Concerns were raised by utilities that the shorter treatment times might allow fungi to survive the treatment process, and become a problem for in-service poles. There is little information on the effects of these shorter cycles on survival of fungi in cedar poles. The following study was undertaken in order to better understand the potential for fungal survival.

Two hundred western redcedar poles ranging in size from 15.0 to 22.5 m long (Class 2 to Class 3, according to the American National Standard Institute Standard ANSI 05.1) were selected for study. Fifty poles were evaluated at each of four sites: Olympia, WA; Sandpoint, ID, Galloway, BC, and New Brighton, MN. The poles were inspected prior to treatment by measuring the amount of visible sapwood on the butt, and measuring MC at the butt and tip with an electrical resistance type moisture meter 25 mm from the surface. The presence of decay at the butt, as well as in knots along the length of each pole, was noted. Increment cores were taken to the pith at the intended groundline (10% of the length plus 0.6 m) as well as at the mid-point and near the tip. The increment borer holes were plugged with tight fitting wood dowels. The poles were numbered so that they could be identified after treatment. The cores were placed into plastic drinking straws, which were labeled and stapled shut prior to being shipped to Oregon State University, Corvallis. The cores were removed from the straws and small chips (approximately 1 mm square) were cut from five locations along each core. These chips were briefly flamed to eliminate possible contaminating surface fungi, then placed on the surface of 1.5 percent malt extract agar in plastic petri dishes. The plates were observed for 4 weeks, and any fungi growing from the wood were examined for characteristics typical of basidiomycetes, a class of fungi containing many important wood decay fungi. Fungi were classified as decay (basidiomycetes) or non-decay (all other fungi) for reporting purposes.

The poles were then commercially treated using various cycles (Table III- 9). Then additional increment cores were taken within 300 mm of the original sampling sites and these cores were cultured as described above. The incidence of both non-decay and decay fungi in cores from poles at the four sites before and after treatment was used as a measure of treatment effectiveness.

After treatment, the relationship between treatment cycle and fungal colonization was examined. The maximum temperature at the pith was extrapolated by using heating curves generated by MacLean (1952) from the diameter of the largest pole in a given charge. For simplicity, the total heating times were combined to produce an average temperature over the treatment cycle and the initial wood temperature was considered to be 15.6°C. This was probably higher than the actual pole temperature since several of the treatments occurred during the winter, but it provided a basis for comparison among charges.

Internal pole temperatures: The four treatment facilities used very different treatment cycles (Table III-9). One plant used a more traditional thermal process with a total treatment time of 27.0 to 27.5 hours at temperatures between 90° and 107.8°C. The

TABLE III-9. — Characteristics of western redcedar poles and the conditions used to heat them during preservative treatment at four treatment plants.

Charge #	Site	Initial MC (%)	Largest pole		Poles with visible decay	Time (hr) and temperature (°C)				Maximum temperature at pith [a] (C)
			Class	Diameter (cm)		Conditioning	Pressure/Soak	Expansion	Vacuum	
93-187D	WA	21	2-75	43.5	6/50	2.5 @ 82.2	2.0 @ 82.2	2.0@ 87.8	—	21.1
93-188D			2-75	43.5		2.5 @ 82.2	2.0@ 82.2	2.0@ 87.8	—	21.2
B14	BC	16	2-65	41.0	9/50	6.0@ 107.8	20@ 93.9	1.0@ 103.3	—	80.0
B16			2-65	41.0		6.5@ 107.8	20@ 90.0	1.0@ 103.9	—	80.0
18F13	ID	19	2-70	42.3	12/50	9.25@ 110	4.0@ 87.8	1.75@ 101.7	—	65.0
18F14			2-75	43.5		9.0 @ 110	3.5@ 87.8	2.0@ 101.7	—	59.4
62	MN	13	2-75	43.5	14/50	2.5@ 80.0	0.3@ 78.3	0.5@ 77.2	2@ 73.9	18.3
64			2-75	43.5		1.75@ 80.6	0.25@ 76.1	0.3@ 75.0	2@ 71.7	16.7
67			2-65	43.5		1.83 hr @ 78.3	0.25 hr @ 74.4	0.3 hr @ 74.4	2@ 74.4	16.7

[a] Values estimated from a starting temperature of 15.6 C at the pith center using the data of MacLean (1946).

remaining plants used lower treatment temperatures and shorter treatment times.

Estimated pole temperatures (based upon the reported treatment cycles) varied widely. The target time and temperature required by the American Wood Preservers' Association (AWPA) for sterilization of Douglas-fir utility poles is 66°C at the pith center (AWPA, 1999). The average internal temperature for the test poles ranged from as low as 16.7°C for the two charges that used relatively short treatment times (4.3 to 4.4 hours) and lower treatment temperatures (71.7° to 80.0°C) to 80°C for the two charges that used more traditional thermal treatment processes. The target temperature (65.6°C) for fungal elimination was only achieved in four of the nine charges (Chidester, 1939).

Pre-treatment pole condition: Poles from the four sites varied slightly in MC at the butt (Table III- 9). The Washington poles were the wettest at 21 percent , while those from Minnesota were the driest at 13 percent . The presence of visible decay in the poles also varied by site. Six of fifty poles from Washington contained visible decay at either the butt or in knots along the length, while 14 of 50 poles from the Minnesota site contained decay. At the British Columbia site, 9 of the 50 poles contained visible decay, whereas at the Idaho site, 12 poles had visible decay. A total of 20.5 percent of the poles in the test contained visible decay. It is unknown whether this level of decay is typical of current pole production, but it suggests that decay fungi were already present in many poles.

Pre-treatment fungal colonization: Relatively few decay fungi were isolated from poles prior to treatment (Table III-10). The low levels of isolation are typical of western redcedar. Previous studies have shown that decay fungi are not broadly distributed in the wood of this species and even isolations adjacent to visible decay pockets often fail to isolate the causal organism (Duncan and Lombard, 1965; Eslyn, 1970; Scheffer et al., 1984; Southam and Erich, 1950). No decay fungi were isolated from poles prior to treatment in Minnesota or British Columbia, while 2.7 percent of cores from the Washington poles and 2.0 percent of cores from Idaho contained decay fungi. Only one decay fungus was isolated from a pole where decay was evident. No decay fungi were isolated from the other 40 poles showing visible evidence of decay. Inconsistent isolation of decay fungi is typical of this species. These low levels of isolation make it difficult to accurately assess the potential impacts of the treatment cycle on survival of decay fungi.

Colonization by so-called non-decay fungi tended to be higher at all sites, although there was considerable variation among the four sites (Table III-10). Fungal colonization was highest at both Washington and Idaho sites. It is interesting to note that the pre-treatment MC at those two sites was slightly higher than the MC found at either the British Columbia or Minnesota sites (Table III-9). Fungal colonization was somewhat lower at British Columbia and was only 12 percent of that found in Washington. Once again, MC of the British Columbia poles was only 13 percent, compared with 21 percent at the Washington site. Wetter poles should be more receptive to fungal colonization. Although the moisture levels in the poles were at or below the levels typically considered acceptable for microbial colonization (Zabel and Morrell, 1992), the differences imply that moisture conditions might have been suitable for fungal growth for a longer time in the Washington poles.

In addition to the isolation of fungi, a number of poles contained various bacteria prior to treatment. The role of bacteria in wood is poorly understood, but as with the non-decay fungi, they can serve as indicators of treatment efficacy. Bacteria were most abundant in the British Columbia poles, but were present at nearly similar levels in poles from Idaho and Minnesota. No bacteria were isolated from poles from Washington.

Post-treatment colonization: A single decay fungus was isolated from one core from a pole treated in British Columbia. The significance of this isolation is difficult to determine, particularly since the pole did not contain visible decay nor were decay fungi isolated from any poles at this site prior to treatment. Treatment conditions at the British Columbia site also entailed the longest heating periods of any site. As a result, the single isolation should be viewed cautiously.

Given the higher isolation frequencies of non-decay fungi in the poles prior to treatment, we elected to use these fungi as potential indicators of heating effectiveness. Although isolation levels of non-decay fungi were high before treatment, isolations declined precipitously after treatment. Isolations declined 99, 99, 93, and 100 percent in poles from Washington, Idaho, British Columbia, and Minnesota, respectively. The higher isolation level from British Columbia is again puzzling, particularly given the long heating cycles.

The low levels of fungi in most poles suggest that the combination of the naturally durable heartwood, which initially limits fungal colonization, and the heating cycles are adequate for eliminating most fungi initially colonizing the wood. A similar trend was found with bacteria. No bacteria were isolated from poles treated in British Columbia, Idaho, or Minnesota. Bacteria had not been isolated from poles in Washington prior

TABLE III-10. — Microbial colonization of western redcedar poles seasoned at four sites as measured before and after preservative treatment with pentachlorophenol in P9 Type A oil.

Test site	Isolation Frequency (%)[a]					
	Pre-treatment			Post-treatment		
	Decay fungi	Non-decay fungi	Bacteria	Decay fungi	Non-decay fungi	Bacteria
WA	2.7	76.7	0	0	0.8	2.0
ID	2.0	68.7	6.0	0	0.7	0
BC	0	45.3	10.7	0.7	4.0	0
MN	0	9.3	8.7	0	0	0

[a]Values represent cultures of 150 cores removed from 50 poles per test site before and after preservative treatment.

to treatment, but were present at low levels after treatment. Bacteria are often overgrown by fungi and may have been missed in the pre-treatment samples. Although the isolates were not identified to species, they may be heat-tolerant *Bacillus*. The role of these organisms in redcedar performance is difficult to assess, but it is clear that, like their fungal counterparts, they were mostly eliminated by treatment.

The relatively low isolation levels following treatment temperatures that would not normally be classified as lethal to fungi may be because the fungi were established near the wood surface. Although maximum temperatures at the pith might remain relatively unchanged over the shorter treatment cycles, the temperature near the surface will be higher. In many cases, more fungi will be isolated from the sapwood of the poles than from the heartwood, reflecting the availability of nutrients in this zone (data not shown). Temperatures in the relatively thin sapwood of western redcedar are likely to approach and exceed the lethal temperature, even with the shortest treatment cycle employed (MacLean, 1952). In addition, preservative penetration in the zone should kill any established fungi. Thus, a major component of the reduced incidence of fungi and bacteria might be attributed to the combined action of the near-surface heat and penetrating preservative.

Although many poles contained

visible evidence of decay, it was difficult to culture active decay fungi from the wood. Exposure to various treatment processes produced marked declines in the incidence of non-decay fungi, suggesting that the relatively low temperatures achieved during these processes were adequate for eliminating these fungi. Further studies to characterize the distribution of fungi in western redcedar logs prior to treatment might help to better understand the relationship between heating at various depths and fungal survival.

F. Evaluation of ammoniacal copper arsenate treated Douglas-fir poles

Ammoniacal copper arsenate (ACA) was developed in the 1930's through research at the University of California at Berkeley. The primary niche for this treatment was the to improve preservative penetration in refractory wood species such as Douglas-fir. ACA has been used to treat Douglas-fir utility poles since the 1940's, but there is little long term performance data on wood treated with this system. Last year, as part of an investigation of the potential for above ground decay in utility poles, we found a significant population of ACA treated Douglas-fir poles in the Portland General Electric system located near Salem, Oregon. This past year, we returned ot this area to further investigate the condition of these poles.

Forty ACA treated Douglas-fir poles were selected for inspection. The poles had been installed between 1946 and 1950 and had been subjected to 3 internal inspection cycles that included application of a fumigant (either chloropicrin or metham sodium).

Each pole was inspected by digging out one side of the pole to a depth of 450 mm, then taking an increment core from 300 mm below the groundline. An additional 3 increment cores were removed from 3 equidistant locations around each pole at groundline and from 0.9 m above this level. The presence of external decay was noted, then the outer zones of each increment core were digested in hypochlorite and macerated to break up the fibers. The fibers were then examined for evidence of soft rot attack. The percentage of fibers in each section that contained soft rot attack was estimated. Finally, the outer portion of the below ground zone was assayed for residual ACA by x-ray fluorescence spectroscopy (XRF). An addition sample was then digested and analyzed by atomic absorption spectroscopy to confirm the XRF analyses

Retentions in the assays zones for the poles ranged from 0.64 to 1.76 kg/m^3 (Table III-11). These values are well below the 9.6 kg/m^3 specified for new poles treated with this chemical. Atomic absorption spectroscopy of an additional sample revealed a retention of 0.38kg/m^3.

Table III-11. Preservative penetration, retention and degree of fungal colonization in ACA treated Douglas-fir poles						
Pole Class/ Length	Retention (kg/m^3)	Penetration (mm)	Age (Yrs)	Frequency of Decay$^{non-decay}$(%)		
				50-100 mm	100-150 mm	>150 mm
4-25	1.44	32.4	54	0^{100}	0^{63}	0^{63}
4-40	0.64	31.1	55	0^{100}	0^{70}	0^{60}
4-40	1.76	35.5	55	0^{90}	0^{90}	0^{100}
3-40	1.60	25.1	55	0^{90}	0^{80}	0^{67}

The overall low levels of chemical remaining in the poles 50 years after installation suggest that the exterior should be heavily colonized by fungi. Culturing, however, revealed that no decay fungi were present in the poles sampled. The continuing fumigant treatment cycle undoubtably accounted for the absence of decay fungi. Culturing also revealed that 44 % of the cores contained non-decay fungi. These numbers are consistent with cultural data from Douglas-fir poles treated with other preservatives.

Microscopic examination of macerated wood from the outer zones of cores removed from below groundline as well as 0.3 and 1.2 m above groundline revealed the presence of some soft rot cavities in each pole (Table III-12). As expected, soft rot attack tended to be more prevalent in the below ground portion of the poles, reflecting the tendency of these fungi to grow best under moist, high nutrient conditions. Nearly 21 % of the cells in macerated wood from below the groundline exhibited soft rot cavities; however, soft rot attack was also detected in some sections taken from cores 0.3 m and even 1.2 m above the ground. The presence of limited soft rot attack above ground is not surprising. While soft rot fungi are typically considered to be a soil contact issue, these fungi are also found on the outer cell layers of wood exposed out of soil contact. As expected, soft rot damage in the sections was quite variable. For example, 38.8% of the sections examined had no evidence of soft rot, while 17.4 % of the sections exhibited attack in over 70 % of the wood cells. The results indicate that, while the ACA poles continue to perform remarkably well, the chemical levels remaining have declined to the point where fungal attack is occurring. As a result, these poles should be supplementally protected with an external preservative to prolong their useful life.

Table III-12. Incidence of soft rot attack in macerated cells removed from below groundline (GL) or 0.3 or 1.2 m above that zone.		
Frequency of soft rot cavities (%)[a]		
Below GL	0.3 m above GL	1.2 m above GL
21 (31)	7 (15)	10 (14)

[a] Values represent mean of 98 values for the groundline, 33 for the 0.3 m sample and 35 for the 1.2 meter sample. Figures in parentheses represent one standard deviation.

G. Effect of through boring on preservative penetration and strength of lodgepole pine

Lodgepole pine is an important timber species with a range that extends across much of western North America. This species has long been locally used for utility poles in this region, either butt treated or full length treated, but lodgepole pine has seen little use elsewhere. Although lodgepole pine is not typically available in transmission pole sizes, there are abundant supplies of smaller trees that could be used for distribution poles. The primary advantage of these poles would be lower cost in comparison with Douglas-fir.

The treatment characteristics of lodegpole pine should be similar to those for Douglas-fir, with a thin (25 to 50 mm) band of treatable sapwood surrounding a largely untreatable, but moderately durable heartwood core. As with Douglas-fir, checking after treatment will allow entry by fungi and insects, leading to the development of internal decay. While remedial treatment with fumigants or diffusible chemicals can arrest this attack, it is far better to enhance treatment to the point where attack does not occur. Internal decay at groundline in Douglas-fir is typically prevented by either through-boring or radially drilling. There is, however, no data on the effectiveness of this process for lodgepole pine. In this report, we describe tests on the ability of through boring to enhance treatment and affect strength of lodgepole pine posts.

Sixty five lodgepole pine posts (77.5 mm in diameter by 3 m long) were kiln dried. The poles were then coated with an elastomeric sealant from 0.3 to 1.35 m above groundline. A series of 9 mm diameter holes were then drilled at a slight angle into one face of the poles beginning approximately 12.5 mm from one edge and then moving across 50 mm and downward 25 so that holes in the longitudinal direction were at least 75 mm apart mm. The elastomeric selant was designed to concentrate preservative through the drill holes and limit the potential for sapwood penetration in the radial direction. An additional set of posts was drilled using a 50 mm lateral spacing but a 150 mm longitudinal spacing between holes in the same plane. Finally, one set of posts was left undrilled to serve as the control. Each treatment was replicated on 22 post sections.

Following drilling, the poles were subjected to pressure treatment with creosote in which the poles were flooded with creosote which was heated to 90 C and held for 3 hours. The oil was then removed and the posts were subjected to a 30 minute pressure period at 50 psi, then the treatment solution was added and the pressure was raised to to 150 psi and held for 6 hours. The pressure was released and the solution was withdrawn. The posts were then subjected to a series of vacuums and steam to clean the wood surface and hasten pressure release inside the wood.

Following treatment, the posts were subjected to third point loading to failure. Load and deflection were recorded or each sample, then these data, along with specific gravity measurements were used to calculated modulus of elasticity and modulus of rupture. Posts were tested with the holes oriented perpendicular or parallel to the direction of the load application.

These tests were only completed recently and the preliminary results will be reported with the expectation that complete results will be available later in the year. Nearly all posts failed in tension, although two failed near knots. While bending strength varied between the treatments, the differences were not consistent. Bending strength tended to be lower when load was applied perpendicular to the hole direction (Table III-13). This trend probably reflects the likelihood that more wood will be removed from zones near the surface on either the compression or tension face when tested in this direction. Further analyses are underway to better characterize the failures and to compare the treatment groups.

Preservative penetration measurements above and below individual treatment holes indicated that longitudinal movement of creosote averaged 106 mm (Table III-14). Lateral creosote penetration was minimal, often extending no more than3 or 4 mm on either side of the hole. The average degree of preservative penetration in cross sections cut from the posts ranged from 43.7 to 56.2 %. There appeared to be relatively little difference in total percentage of penetration between control and through-bored samples; however, this data must be viewed with some caution since the posts were relatively small and contained a higher proportion of treatable sapwood. As a result, the potential benefits of through boring on treatment may have been masked by the low proportion of the sapwood present. Further tests on larger materials will be necessary to determine if through boring enhances treatment of this species to the same extent that it does in Douglas-fir.

Table III-13. Bending strength of lodgepole pine posts with or without through boring[a]

Treatment	Test Direction	Replicates	Maximum Force (N)	Bending Strength (nm/mm^2)	E Apparent (N/mm^2)
Control	NA	22	37,121 (4.646)	94.1 (11.4)	32,118 (12,909)
Narrow	Parallel	11	33,985 (2,937)	85.1 (8.3)	29,771 (2,606)
	Perpendicular	10	26,911 (5,857)	65.9 (15.0)	26,681 (4,316)
Wide	Parallel	9	33,638 (9,080)	90.2 (15.3)	28,628 (4,335)
	Perpendicular	12	30,541 (3,474)	77.2 (8.4)	28,696 (2,079)

a Values represent means, while those in parentheses represent one standard deviation

Table III-14. Preservative penetration in lodgepole pine posts with or without through boring[a]

Treatment	Replicates	Cross Section Penetrated (%)	
		Surface Open	Surface Sealed
Control	22	54.7 (20.2)	51.4 (17.3)
Narrow	21	48.7 (14.1)	56.2 (14.2)
Wide	21	43.7 (17.7)	48.6 (17.2)

a Values represent means, while those in parentheses represent one standard deviation

Literature Cited

American National Standards Institute. 1992. American National Standard for wood poles: specifications and dimensions. ANSI 05.1-1992. ANSI, New York, NY. 26 p.

American Wood Preservers' Association (AWPA). 1999. Annual Book of Standards. AWPA, Granbury, TX. 466 pages.

American National Standards Institute (ANSI). 1992. Specification and dimensions for wood poles. ANSI 05.1-1992. ANSI, New York, NY. 26 pages.

BioCycle. 1997. Woody materials recycling: Recovering treated lumber. BioCycle 38(7):34-37.

Cahill, J.M. 1980. Prelimin(n)ary lumber recovery for dead and live Englemann spruce. Res. Note PNW-365. Portland, OR: USDA Forest Service, Pacific Northwest Forest and Range Experiment Station. 11p.

Carter, D.R. and F.D. Merry. 1998. The nature and status of certification in the United States. Forest Prod. J. 48(2):23-28.

Chidester, M.S. 1939. Further studies on the temperatures necessary to kill fungi in wood. *In*: Proceedings American Wood Preservers' Association 35:319–324.

Conlon, P. 1992. Crosstie disposal problem or opportunity? Proceedings of the Treated Wood Life-Cycle Management Workshop, Am. Wood Preservers Institute, Vienna, Va. p. 18-26.

Cooper, P.A. 1993. The potential for reuse of treated wood poles removed from service. *In:* Proc. 2nd Inter. Symp. on Wood Preservation. Doc. No. IRG/WP 93-50001. Inter. Res. Group on Wood Preservation IRG Secretariat, Stockholm Sweden. p. 251-264.

Duncan, C.G. and F.F. Lombard. 1965. Fungi associated with principal decays in wood products in the United States. USDA Forest Service Res. Pap. WO-4. Washington, D.C.

Electric Power Research Institute (EPRI). 1990. Pentachlorophenol (PCP)-treated wood poles and crossarms: Toxicity characteristic leaching procedures (TCLP) results. Prepared by the Environmental Management Services, Interim Report EPRI EN 7062, EPRI, Palo Alto, CA.

Electrical World. 1992. Salvaging utility poles: Turning poles into wood and paper products. Electrical World October:70-71.

Ernst, S., M.E. Plank, and D.J. Fahey. 1986. Sitka spruce and western hemlock beach logs in southeast Alaska: suitability for lumber, pulp and energy. Res. Pap. PNW-352. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 25p.

Eslyn, W.E. 1970. Utility pole decay. II. Basidomycetes associated with decay in poles. Wood Science and Technology 4:97-103.

Fahey, T.D., T.A. Snellgrove, and M. E. Plank. 1986. Changes in product recovery between live and dead lodgepole pine: a compendium. Res. Pap. PNW-353. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 25p.

Felton, C.G. and R.C. DeGroot. 1996. The recycling potential of preservative-treated wood. Forest Prod. J. 46(7/8):37-46.

Forsyth, K., D. Haley and R. Kozak. 1999. Will consumers pay more for certified wood products? Journal of Forestry 97(2):18-22.

Geimer, R.L. 1982. Feasibility of producing reconstituted railroad ties on a commercial scale. Res. Pap. FPL-411. Madison, WI: USDA Forest Service, Forest Products Laboratory. 8 p.

Goodrich-Mahoney, J. 1992. TCLP test data on utility pole and crossarms treated with penta and creosote. In: Treated Wood Life-Cycle Management Workshop Proceedings, American Wood Preservers' Institute, Vienna, Virginia Pages 195-213.

Gronroos, J.C.M. and J.L. Bowyer. 1999. Assessment of the market potential for environmentally certified wood products in new homes in Minneapolis/St. Paul and Chicago. Forest Prod. J. 49(6):28-34.

Hansen, E. 1997. Forest certification and its role in marketing strategy. Forest Prod. J. 47(3):16-22.

Hayward, J. and I. Vertinsky. 1999. High expectations, unexpected benefits: What managers and owners think of certification. J. of Forestry 97(2):13-17.

Hennon, P.E., D.T. Wittwer, J. Stevens, and K. Kilborn. 2000. Pattern of deterioration and recovery of wood from dead yellow-cedar in southeast Alaska. West. J. Appl. For. 15(2):49-58.

Hess, R. 1988. Handling and disposal practices of Northwest utilities. In: Proceedings, Wood Pole Conference, October 20-21, Portland, Oregon. Pages 26-27.

Jordan, G.H. 1996. Forest certification and timber tracing: The issues and the needs. J. of the Institute of Wood Science 14(1):15-20.

Karakash, J. and G. Lipinski. 1998. Disposal of pentachlorophenol-treated wood by combustion, report of recent compliance testing and project status. Proceedings Northeast Utility Pole Conference. Binghamton, New York. p. 60-62.

Kempton, C.C. 1992. Life cycle management of treated wood products: issues & answers. Proceedings of the Treated Wood Life-Cycle Management Workshop, Am. Wood Preservers Institute, Vienna, Va. pp. 54-105.

King, S.A. and D.K. Lewis. 2000. Solid wood products from used utility poles: an economic feasibility study. Forest Products Journal 50(11/12):69-78.

Labat, G. 1998. Alternative technologies for wood wastes recycling. Document No. IRG/WP 98-50101, International Res. Group on Wood Preservation, Stockholm Sweden. p. 205-220.

Lamar, R.T. 1995. Use of wood-decay fungi for disposal of PCP-treated wood. *In:* Proc. 3rd Inter. Symp. on Wood Preservation. Doc. No. IRG/WP 95-50040. Inter. Res. Group on Wood Preservation IRG Secretariat, Stockholm Sweden. p. 441-449.

Lamar, R.T. and D.M. Dietrich. 1992. Use of lignin-degrading fungi in the disposal of pentachlorophenol-treated wood. J. of Industrial Microbiology 9:181-191.

Lowell, E.C., and J.M. Cahill. 1996. Deterioration of fire-killed timber in southern Oregon and northern California. West. J. Appl. For. 11(4):125-131.

Malecki, R.L. 1992. The utility perspective on treated wood life-cycle management. Proceedings of the Treated Wood Life-Cycle Management Workshop, Am. Wood Preservers Institute, Vienna, Va. p. 27-50.

MacLean, J.D. 1952. Preservative treatment of wood by pressure methods. USDA Forest Service Agricultural Handbook 40. Washington, D.C. 160 p.

Messner, K. and S. Bohmer. 1998. Evaluation of fungal remediation of creosote treated wood. Paper IRG/WP 98-50101, International Res. Group on Wood Preservation. IRG Secretariat, Stockholm Sweden. p. 321-331.

Morrell, J.J. 1999. Pole disposal in the Pacific Northwest . In: Proceedings Utility Pole Structures Conference and Trade Show, Silver Legacy Hotel, Reno, NV, October 21-22. Pages 53-59

Morrell, J.J. and R. James.1997. Pole disposal in the Pacific Northwest . In: Proceedings Utility Pole Structures Conference and Trade Show, Silver Legacy Hotel, Reno, NV, November 6-7. Pages 27-36

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

Ozanne, L.K. and R.P. Vlosky. 1997. Willingness to pay for environmentally certified wood products: A consumer perspective. Forest Prod. J. 47(6):39-48.

Parry, D. and J. Cahill. 2001. Retired transmission poles make good fencing products. Unpublished Report. Bonneville Power Administration. Portland Oregon.

Pong, W.Y., and J.M. Cahill. 1988. Lumber recovery from incense-cedar in central California. Res. Pap. PNW-RP-393. Portland, OR: USDA Forest Service, Pacific

Northwest Research Station. 22p.

Portier, R.J. and J.N. Kressbach. 1992. Recovery of wood fiber from treated wood products by combined physical, chemical, and biological approaches. Proceedings of the Treated Wood Life-Cycle Management Workshop, Am. Wood Preservers Institute, Vienna, VA. p. 148-160.

Roliadi, H., C.Y. Hse, E.T. Choong, and T.F. Shupe. 2000a. Gluability of out-of-service utility poles. Forest Prod. J. 50(10):76-81.

Roliadi, H., C.Y. Hse, E.T. Choong, and T.F. Shupe. 2000b. Decay resistance of out-of-service utility poles as related to the distribution of residual creosote content. Forest Prod. J. 50(11/12):64-68.

Scrase, H. 1995. The Forest Stewardship Council: Its contribution to independent forest certification. Commonwealth For. Rev. 74:192-194.

Scheffer, T.C., B.S. Goodell, and F.F. Lombard. 1984. Fungi and decay in western redcedar utility poles. Wood and Fiber Science 16:543-548.

Sexton, C.M., S.M. Smith, J.J. Morrell, B.R. Kropp, M.E. Corden, and R.D. Graham. 1992. Identity and distribution of Basidiomycotina colonizing Douglas-fir poles during three years of air-seasoning. Mycological Research 96:321-330.

Smith, G. 1992. Reduction, handling and burning of treated wood. Proceedings of the Treated Wood Life-Cycle Management Workshop, Am. Wood Preservers Institute, Vienna, Va. p. 139-143.

Smith, S.M., R.D. Graham, and J.J. Morrell. 1987. Influence of air-seasoning on fungal colonization and strength of Douglas-fir pole sections. Forest Products Journal 37(9):45-48.

Snellgrove, T.A., J.W. Henley, and M.E. Plank. 1975. Lumber recovery from large, highly defective, low grade Coast Douglas-fir. Res. Pap. PNW-197. Portland, OR: USDA Forest Service, Pacific Northwest Forest and Range Experiment Station. 23p.

Southam, C.M. and J. Ehrlich. 1950. Etiology of some sap rots of western redcedar poles.

Phytopathology 40:439-444.

Taylor, J.A. 1980. Pretreatment decay in poles. *In:* Proceedings American Wood-Preservers' Association 76:226–245, AWPA, Granbury, Tex.

Vassou, Z, A. Satanakis, C. Koutsikopoulus, and J. Petinarakis. 1998. The rate of losses of creosote from power transmission poles during storage. International Research Group on Wood Preservation, 4th International Symposium on Wood Preservation. Document No IRG/WP/98-50101. Stockholm, Sweden. Pages 311-320.

Webb, D.A. and D.E. Davis. 1992. Spent creosote-treated railroad crossties – alternatives and their reuse. Proceedings of the Treated Wood Life-Cycle Management Workshop, Am. Wood Preservers Institute, Vienna, Va. pp. 109-138.

Willits, S., and T.D. Fahey. 1988. Lumber recovery of Douglas-fir from the Coast and Cascade Ranges of Oregon and Washington. Res. Pap. PNW-RP-400. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 32p.

Zabel, R.A. and J.J. Morrell. 1992. Wood Microbiology: Decay and Its Prevention. Academic Press, San Diego, Calif. 474 p.

OBJECTIVE IV
PERFORMANCE OF EXTERNAL GROUNDLINE PRESERVATIVE SYSTEMS

A. Effect of paste thickness on movement of copper, boron, or fluoride into Douglas-fir sapwood: While previous tests have clearly demonstrated the ability of the copper/boron external preservative paste to move into a variety of wood species, some utilities have questioned the exact dosage required to produce a given level of protection. External paste labels generally allow a range of coating thicknesses, presumably to allow for higher dosages where the risk of decay is greater, but there is little guidance concerning dosages. This past year, we evaluated the effect of paste thickness on diffusion of copper and boron from one formulation and compared this to a self-contained wrap system containing copper, boron and fluoride.

Douglas-fir sapwood blocks (nominally 2 by 4 inches by 6 inches long) were machined on one surface to produce a well 10 mm deep in an area 25 mm indiameter. The blocks were oven-dried and weighed before being pressure soaked with water. The blocks were conditioned to 60 % moisture content then the well area was covered with duct tape and the entire block was dipped in molten paraffin to retard further moisture changes. The blocks were then stored at 5 C for one month prior to use.

The blocks were treated by removing the duct tape, and applying either a 25 mm square of the copper/boron/fluoride bandage or a layer of the copper/boron paste 1.5, 3.0, 6.0, or 9.0 mm thick to the well area. The paste or bandage were held in place using duct tape and the blocks were incubated for 1, 3, or 6 months at room temperature. At each time point, 5 blocks from each treatment group were removed and, the bandage was removed or the excess paste was scraped away from the well. The 25 mm square well region was then cut from the block using a band saw, taking care to remove any paste that might catch on the sawblade to contaminate wood away from the surface. The section was then segmented to zones corresponding to 0-5, 5-10, 10-15, 15-20, and 20-25 mm from the surface. The wood from a given zone was ground to pass a 20 mesh screen. The samples were first analyzed for copper using an ASOMA 8620 x-ray fluorescence analyzer. The samples from the bandage system were then thoroughly mixed and divided into 2 parts. The copper/boron paste samples, and one half of the copper/boron/fluoride samples were then extracted in hot water and the resulting extract was analyzed for boron using the Azomethine H method as described in AWPA Standard A2 Method 16 (AWPA, 2000) .

The remainder of the copper/fluoride/boron samples were then analyzed for fluoride using an alternative method in which 0.015 g of wood was added to a 25 ml screw cap glass tube along with 15 ml of 0.1 M $HClO_4$ and sonicated for 3 hours at 28 C. The tubes were the allowed to stand for 2 to 8 hours. Ten ml of the supernatant was withdrawn and added to a tared 125 ml glass bottle containing 27 ml of distilled water. A pH electrode was placed in the bottle, then 2 % NaOH was added drop-wise to adjust the pH to between 5.0 and 6.0. A solution of 0.1 M $HClO_4$ was then added to bring the solution weight to 50 g. Five ml of Orion TISAB III was added to this mixture and a pH electrode along with a fluoride specific ion electrode were placed directly in the solution. The solution was shaken and allowed to stand for one minute. Readings were taken until the display stabilized. Solutions containing low levels of fluoride sometimes required up to 20 minutes prior to readings. This method produces results that are similar to those found with the AWPA Method for fluoride analysis but requires far less time per sample.

Copper was largely confined to the outer 5 mm of most of the samples tested, although some copper was detected 5 to 10 mm from the surface in the 6 and 9 mm thick copper/boron pastes (Figure IV-1). The amine copper naphthenate in this system retains some water solubility for as long as the amine remains associated and this appears to have enhanced penetration at the higher dosages. For the most part, however, the copper compound remained near the surface and should act as an excellent barrier against reinvasion. Copper levels in the outer zone rose steadily with paste thickness, although the increases were not directly proportion to thickness increases. For example, doubling paste thickness from 1.5 to 3.0 mm produced a doubling of copper levels after one month, but a further doubling produced only an 18 % increase in copper levels and an additional doubling in thickness produced only a 12 % increase. Clearly, there is a diminishing return on paste thickness, at least in the short term. The presence of excess copper may prove useful over time, although its presence on the surface may make it more likely to be lost to the surrounding soil.

Boron levels in the self-contained wrap tended to follow a declining gradient from the surface inward, one month after treatment (Figure IV-2). This gradient tended to flatten over the 3 and 6 month sample, following trends seen in previous tests with boron based systems. Boron levels in blocks treated with the copper/boron paste also followed gradients inward, but the levels of boron were consistently higher than those found

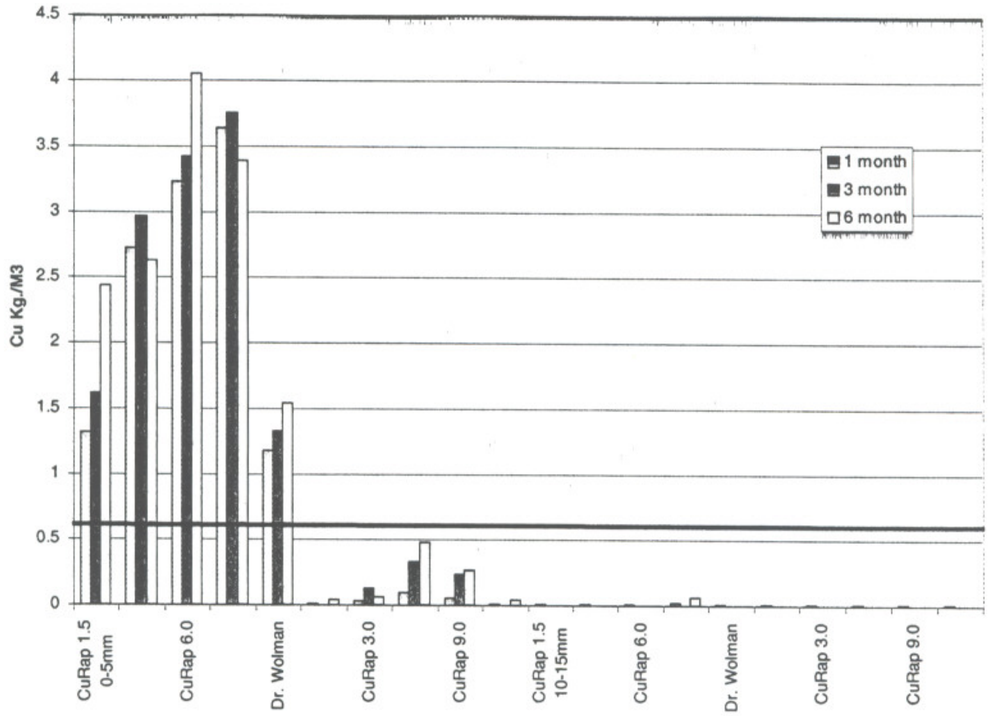


Figure IV-1. Copper levels at selected depths in Douglas-fir sapwood blocks 1, 3, and 6 months after application of either a copper/boron/fluoride bandage or varying thicknesses of a copper/boron paste.

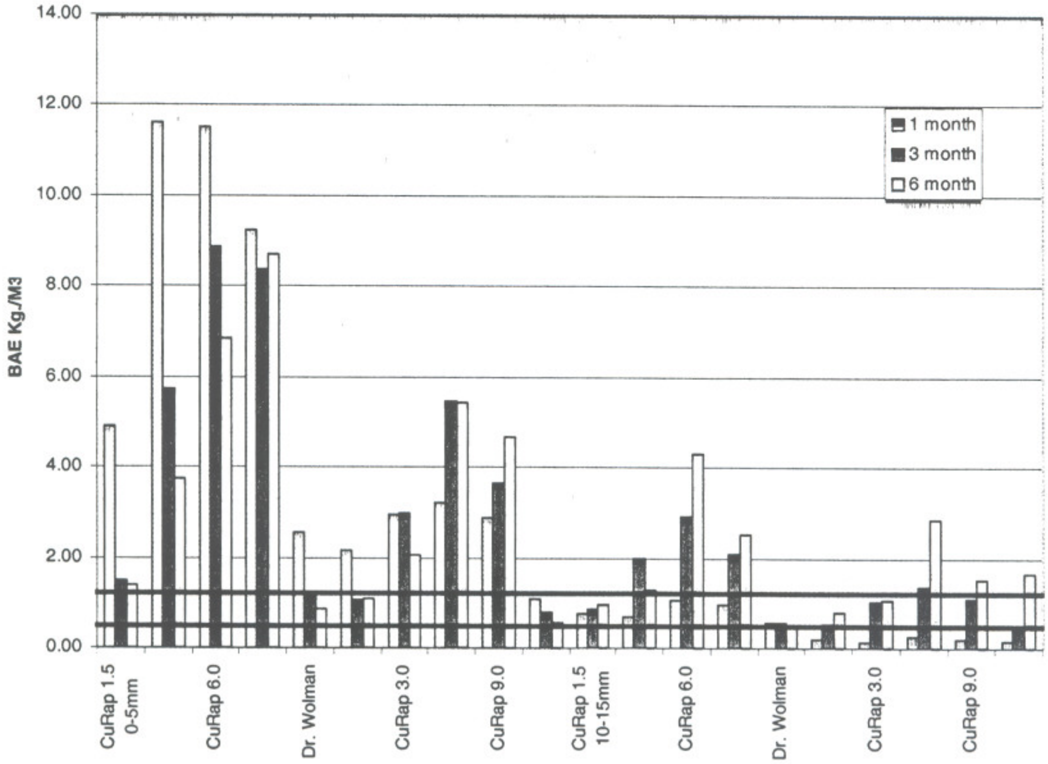


Figure IV-2. Boron levels at selected depths in Douglas-fir sapwood blocks 1, 3, and 6 months after application of either a copper/boron/fluoride bandage or varying thicknesses of a copper/boron paste.

with the self-contained system. As with copper, increasing paste thickness produced greater effects at lower thicknesses. For example, increasing from 1.5 to 3.0 mm produced a 136 % increase in boron level, while a further doublings produced no change in boron level one month after treatment. Prolonged incubation did result in detectable differences in boron levels through all 5 assay zones with increasing paste thickness. Clearly, the thicker paste near the surface provided a reservoir for continued boron diffusion that should translate into deeper protection over time.

Fluoride was only present in the self-contained wrap. Fluoride was present in the outer 2 assay zones 1 month after treatment and levels steadily increased inward over the next 5 months (Figure IV-3). There is some debate over the levels of fluoride for protection against fungal attack; however, this component has clearly moved into the wood and appeared to have become uniformly distributed in the 6 month test period

B. Ability of a copper/boron/fluoride bandage to migrate through Douglas-fir heartwood

Douglas-fir heartwood blocks (100 mm cubes) containing a 25 mm square by 5 mm deep well on either the radial or transverse face were oven dried and weighed before being pressure soaked with water. The wet blocks were then conditioned to 30 or 60 % then the well was covered with duct tape before the blocks were dipped in molten paraffin to retard further moisture changes. 25 mm squares of a foam-backed preservative bandages containing a mixture of copper, boron and fluoride was then placed into the treatment well. The blocks were incubated at room temperature for 1 to 12 months. Five blocks from each treatment were removed 1, 4, 6, 9, and 12 months after treatment and sampled as described above except that the assay zones were altered to 0 to 6 mm, 6 to 13 mm, 13 to 25 mm, and 25 to 38 mm form the wood surface. The samples were ground to pass a 20 mesh screen and analyzed for copper, boron and fluoride as described in Section IV A.

Copper was largely confined to the outer 6 mm in blocks oriented to produce radial diffusion regardless of moisture content (Figure IV-4). These results suggest that the copper component in the system would largely remain near the surface of a pole where it would primarily serve as a barrier against renewed fungal attack. Copper levels appeared to decline slightly over time in blocks at 30 % MC and remained similar with time in the 60 % MC blocks. Copper levels in blocks oriented to produce largely longitudinal diffusion produced much deeper copper distribution over time. Copper levels

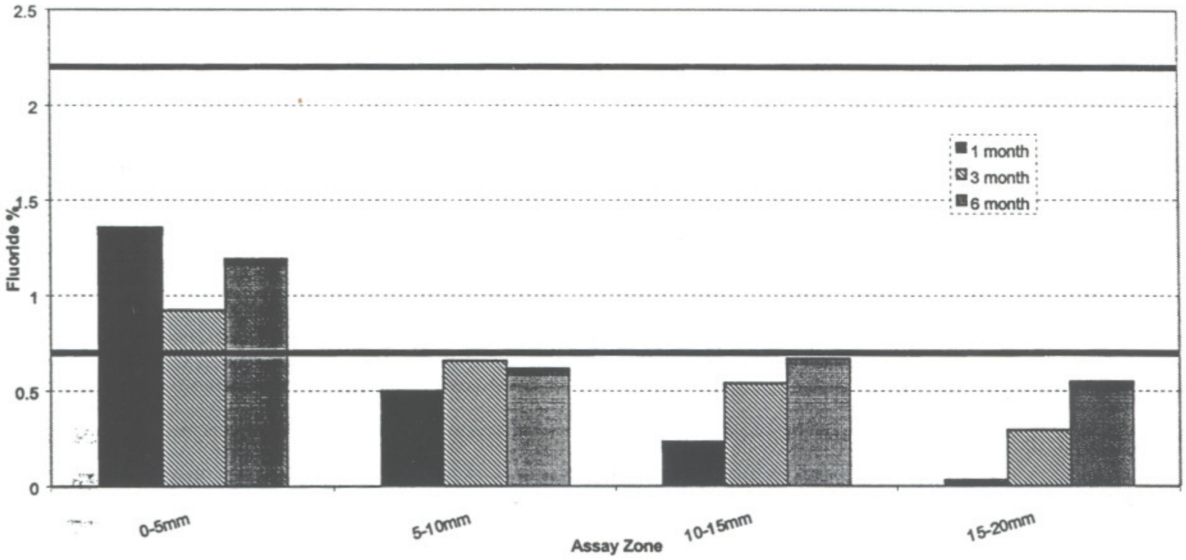


Figure IV-3. Fluoride levels at selected depths in Douglas-fir sapwood blocks 1, 3, and 6 months after application of a copper/boron/fluoride bandage.

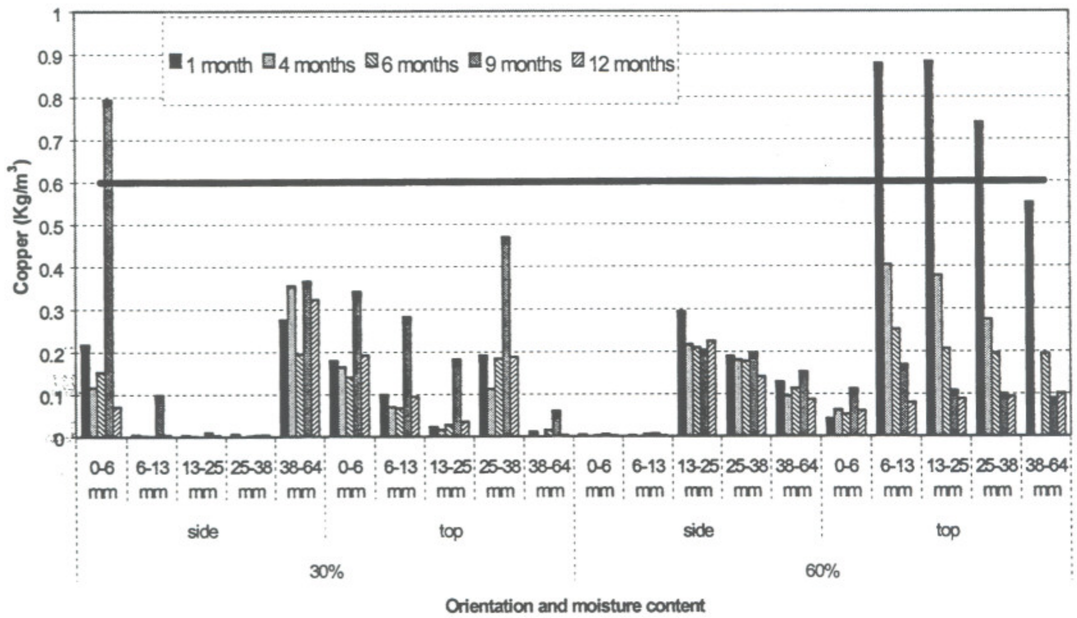


Figure IV-4. Copper levels at selected distances from the surface of Douglas-fir heartwood blocks at 30 or 60 % MC 1 to 12 months after application of a copper/boron/fluoride bandage.

varied more widely in blocks at 30 % MC, but followed a declining gradient inward form the surface. These gradients tended to be more uniform in the 60 % MC blocks. The results indicate that the copper component in this system can move well longitudinally over time and that this system may be useful for protecting exposed end-cuts or other areas where large amounts of transverse face are exposed.

Boron levels in the blocks tended to vary more widely than the copper levels, although the depth of penetration was, as expected, much deeper (Figure IV-5). Boron levels tended to be above the threshold shortly after treatment, but declined over time as the surface boron became more evenly distributed within the wood. The role of boron in this system should be to provide supplemental protection inward from the surface. Clearly, the boron is moving inward, but the levels remain somewhat below those considered effective. Boron movement longitudinally tended be better and more uniform, against reflecting the longer, more accessible flow paths in this direction.

Fluoride levels in the blocks were initially high in the outer zone, then declined over time (Figure IV-6). At the same time, fluoride levels inward from the surface increased slightly over time, suggesting that the initial high loading was diffusing further inward. While this inward movement is promising, the lack of continued fluoride movement from the bandage to the outer zone of the wood was surprising. It was unclear whether the inability to maintain a high fluoride level near the surface reflected a cessation of fluoride movement or a depletion of fluoride from the bandage. Further evaluation of exposed bandages will be necessary to assess these possibilities.

At present, the three components appear to be moving reasonably well into the blocks, with diffusion occurring move easily longitudinally. None of the components is present deeper in the wood at levels that, by itself, would confer protection to the wood, but the combination of chemicals along with the heartwood extractives of Douglas-fir, should provide some potential synergy.

C. EVALUATION OF SELECTED GROUNDLINE PRESERVATIVE SYSTEMS ON DOUGLAS-FIR, WESTERN REDCEDAR, AND PONDEROSA PINE IN MERCED,CA

The field test evaluating copper naphthenate, sodium fluoride and copper naphthenate/sodium fluoride external preservative systems near Merced, CA was sampled this past Spring 10 years after treatment. The chemical analyses are underway and results from this inspection will be included in the 2002 Annual Report.

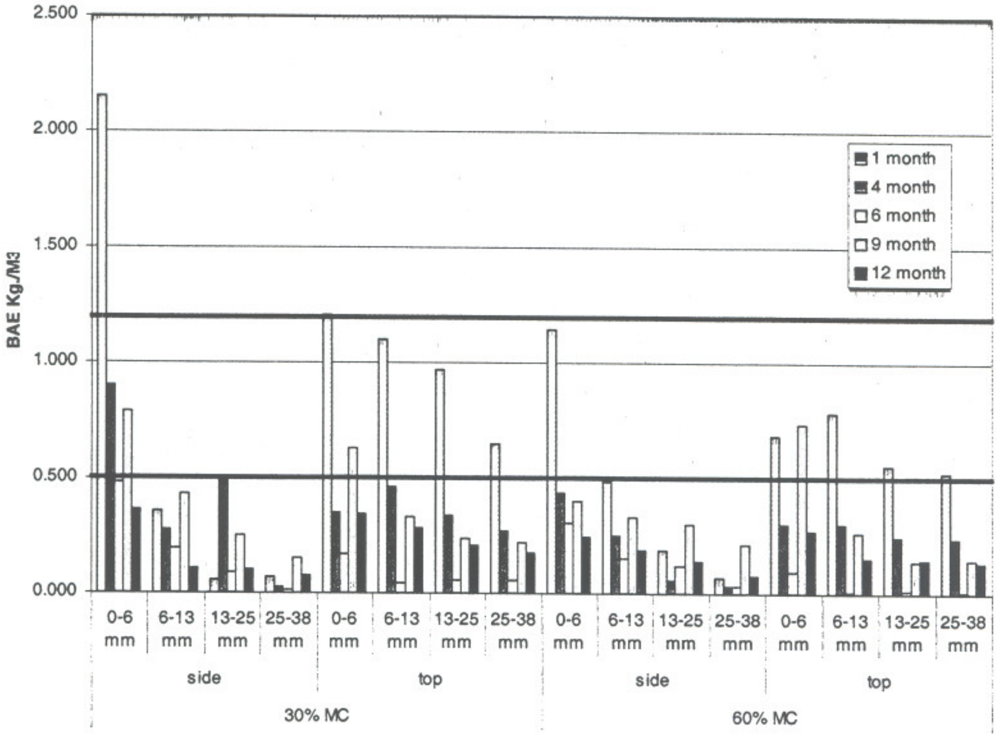


Figure IV-5. Boron levels at selected distances from the surface of Douglas-fir heartwood blocks at 30 or 60 % MC 1 to 12 months after application of a copper/boron/fluoride bandage.

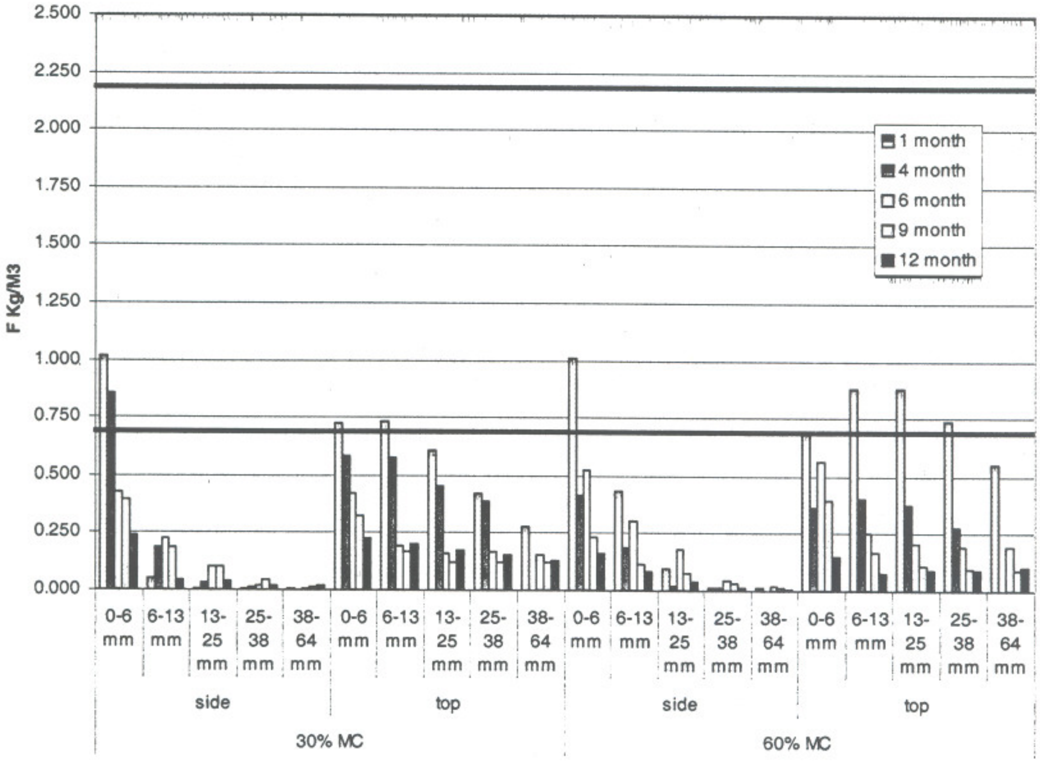


Figure IV-6. Fluoride levels at selected distances from the surface of Douglas-fir heartwood blocks at 30 or 60 % MC 1 to 12 months after application of a copper/boron/fluoride bandage.

D. EVALUATION OF EXTERNAL PRESERVATIVES IN SOUTHERN PINE AND WESTERN REDCEDAR POLES IN BINGHAMTON, NY

The field test in New York of copper naphthenate, copper naphthenate/boron, and sodium fluoride external preservative systems was evaluated in 1999, four years after treatment. It is next scheduled to be sampled in 2002.

E. PERFORMANCE OF COPPER/BORON/FLUORIDE, COPPER/BORON, AND PROPICONAZOLE EXTERNAL PRESERVATIVE SYSTEMS IN DOUGLAS-FIR POLE SECTIONS AT PEAVY ARBORETUM

Seasoned Douglas-fir pole sections (250-300 mm in diameter by 2 m long) were treated with one of three formulations, beginning at the butt and extending upward 0.8 m. The pole sections were then set to a depth of 0.6 to 0.7 m in the ground at our Peavy Arboretum test site, located approximately 20 km north of Corvallis. Two of the formulations were pastes that were applied according to the manufacturers recommendations. One formulation contained an amine based copper naphthenate and sodium tetraborate decahydrate, while the other contained propiconazole as the active ingredient. Both of these materials were covered with a polyethylene backed paper wrap to confine the chemical to the pole surface. The third system was a self-contained wrap containing copper carbonate, sodium fluoride, and sodium octaborate tetrahydrate.

Chemical movement into the pole section was assessed 1 and 2 years after treatment by removing increment cores from three equidistant sites around each pole 150 mm below groundline. The cores were divided into zones corresponding to 0-4, 4-9. 9-16, and 16-25 mm segments and segments from the same pole were combined prior to being ground to pass a 20 mesh screen.

Samples containing copper compounds were first assayed for copper by x-ray fluorescence spectroscopy. The samples were then analyzed for boron or fluoride (where appropriate) using methods described in Section IV A of this report. Wood dust containing propiconazole was analyzed for this compound following procedures described in AWPA Standard A23-94, wherein the wood is extracted in methanol and the resulting extract is analyzed for the active ingredient by High Performance Liquid Chromatography. The resulting chromatograms are compared with those from standard prepared from known concentrations of propiconazole.

Chemicals levels in all three treatments were relatively low one year after treatment. Copper levels in the

...n treatment averaged 0.12 in the outer 6 mm zone, then declined sharply further inward after one year (Table IV-1). Copper levels rose sharply in the second year, averaging 3.69 kg/m^3 in the outer zone and almost one third of that level in the next 5 mm inward. Boron levels in pole sections treated with this system also increased between years one and two, although the differences near the surface were relatively slight. The boron distribution gradient further from the surface was relatively flat 2 years after treatment, indicating that the boron component in ...is system had become evenly ...ributed in the outer 25 mm.

Copper levels in the .../boron/fluoride system were ...y low one year after treatment, ...harply in the second year. ...dings in the outer zone were ...hose found with the ...ystem, but were still above ... preventing fungal attack. ...e negligible further ...'s over the two years ...w. Boron loadings ... ranged from 0.16 ...e basis) ...n the wood ... from 0.06 to ...h. The low ...lly out

re...

relat... althou... range th... against w... outer zone ... the second ye... chemical conti... wood. Chemical remained low, sug... chemical was largel... wood surface. These r... previous lab tests sugge... compound was capable o... moisture into Douglas-fir h...

The results indicate th... bandage or paste components to move at higher levels into the following an additional year of ex... This movement is especially promis... since rainfall level last year were belo... historical averages. While some of the loadings remain slightly below the levels believed to confer protection, it is likely that lower levels of combinations will provide protection. These pole sections will be assessed this year to contin... monitor movement.

Table IV-1. Residual chemical levels in Douglas-fir pole sections one or two years after treatment with preservative pastes containing copper/boron or propiconazole or a self-contained bandage containing copper/boron/fluoride.

Treatment	Assay Zone (mm)	Residual Chemical Loading (kg/m³)							
		Copper		Boron (BAE)		Fluoride		Propiconazole	
		Yr. 1	Yr. 2	Yr. 1	Yr. 2	Yr. 1	Yr. 2	Yr. 1	Yr. 2
Cu/B	0-4	0.028 0.028	**3.689** 1.040	0.466 0.209	**3.434** 2.516	-	-	-	-
	4-9	0.020 0.007	**1.195** 0.861	**0.868** 0.485	**3.167** 1.720	-	-	-	-
	9-16	0.033 0.027	0.247 0.344	**1.33** 0.908	**2.968** 2.035	-	-	-	-
	16-25	0.118 0.085	0.000 0.000	**2.418** 1.681	**1.559** 1.365	-	-	-	-
Cu/B/F	0-4	0.017 0.006	**1.138** 0.386	0.367 0.275	0.114 0.099	0.011 0.007	0.522 0.194	-	-
	4-9	0.015 0.005	0.152 0.240	0.296 0.326	0.158 0.184	0.015 0.015	0.352 0.114	-	-
	9-16	0.014 0.009	0.000 0.000	0.277 0.213	0.152 0.138	0.041 0.058	0.361 0.176	-	-
	16-25	0.038 0.071	0.000 0.000	0.329 0.184	0.166 0.103	0.120 0.106	0.317 0.138	-	-
Propiconazole	0-4	-	-	-	-	-	-	**0.208** 0.324	**1.063** 1.184
	4-9	-	-	-	-	-	-	**0.133** 0.317	0.045 0.037
	9-16	-	-	-	-	-	-	**0.137** 0.301	0.028 0.044
	16-25	-	-	-	-	-	-	0.048 0.085	0.023 0.034

F. CHEMICAL DISTRIBUTION 6 YEARS AFTER APPLICATION OF A FLUORIDE/BORON BASED BANDAGE

Air-seasoned, untreated Douglas fir pole sections (250 to 300 mm in diameter by 2 m long) were obtained locally. Each of 10 pole sections were treated from the butt to approximately 0.6 m above that zone with a fluoride/boron containing external groundline bandage. Unlike traditional bandages, this bandage consisted to indented plastic sheeting, with each indentation containing a pellet of the fluoride/boron rod. The poles were set to a depth of 0.6 m at our Peavy Arboretum test site. Chemical movement was assessed four and six years after treatment by removing increment cores from locations 150 mm below groundline at three equidistant locations around each pole section. The samples removed after 4 years were assayed as a single 25 mm long segment, while those from the 6 year sampling were first divided into zones corresponding to 0-5, 5-10, 10-15, 15-20, and 20-25 mm from the surface. These zones from a given pole were combined before being ground to pass a 20 mesh screen. The resulting wood flour was then assayed for boron and fluoride as described previously in this section.

Boron levels were extremely high in the outer 25 mm of the pole sections 4 years after treatment, averaging 0.96 kg/m^3 and ranging from 0.15 to 1.92 kg/m^{-3}(Table IV-2). While the lower levels would not be protective, the majority of retentions measured would be protective. This was particularly surprising, given the reputation of boron as a preservative that is extremely susceptible to leaching. Average boron levels 6 years after treatment were similar to those found after 4 years, although the levels among individual pole sections were more variable, ranging from 0.16 to 3.32 kg/m^3. Average boron levels did appear to be relatively uniform with distance from the surface, suggesting that the boron remained uniformly distributed in the outer zones of the pole sections. The Arboretum test site is characterized by extreme water-logging during the wet winter months, a condition that should lead to extensive boron loss. The presence of substantial quantities of boron suggests that the external plastic barrier coupled with the pelletized formulation must have limited boron loss.

Fluoride levels in the same 25 mm assay zone were generally far lower that those found with boron four years after treatment, averaging one tenth the boron level. While fluoride levels in 2 poles approached the low end of the threshold range for this chemical, the majority of poles did not contain protective levels of fluoride four years after treatment. Fluoride levels 6 years after treatment were slightly lower than those found after 4 years. Declines were noted in 9 of the 10 poles sampled, suggesting that fluoride had depleted from the external bandage. None of the fluoride levels approached the threshold for this chemical. Assays at selected distances from the wood surface revealed that fluoride levels were uniform with depth in the outer 25 mm. These results are consistent with those found with boron and suggest that both water diffusible compounds have moved well through the outer shell of the poles.

Implications: The implications of the results are difficult to completely assess. First, both boron and fluoride are generally considered to be relatively mobile in wood and previous external preservative paste studies with boron compounds indicated that boron levels declined sharply 3 to 4 years after treatment. The boron/fluoride wrap clearly did not experience this loss of chemical, even 6 years after treatment. In addition, the samples removed from these poles continue to remain sound, indicating that the levels of chemical present continue to be protective in the absence of more traditional initial wood treatments. One other factor in this test is the possible synergism of fluoride and boron. While boron is present at levels near the traditionally accepted threshold for ground contact exposures, the low levels of fluoride present in the wood could act to enhance the residual levels of both components decline over time.

Table IV-2. Residual levels of boron and fluoride in Douglas-fir pole sections 4 and 6 years after application of a boron/fluoride external preservative bandage.

Assay Zone (mm)	Residual Chemical Levels (kg/m^3)[a]			
	BAE KCM		Fluoride	
	Year 4	Year 6	Year 4	Year 6
0-5	-	1.895 (0.695)	-	0.376 (1.61)
5-10	-	1.912 (2.065)	-	0.161 (0.113)
10-15	0	1.999)1.868)	0	0.275 (0.109)
15-25	0	1.946 (1.864)	-	0.150 (0.041)
0-25	1.698 (1.068)	1.929	0.342 (0.176)	0.24

[a] Values represent means of 10 replicates per assay. Values in parentheses represent one standard deviation. Five mm assay segments were only performed after 6 years.

G. EVALUATION OF SELECTED BORON, FLUORIDE, AND COPPER BASED EXTERNAL BANDAGES IN SOUTHERN PINE POLES IN NEW YORK.

OSU has evaluated a variety of external preservative bandages over the past decade. The goal of these tests was to provide a third party assessment of chemical migration under controlled field conditions. Since the establishment of our last test, a number of alternative systems have been developed for which we do not have comparative data, especially on southern pine. Since external preservatives are most often used on this species, we propose the establishment of a new field test in the Cental Hudson Gas and Electric System.

Materials and Methods: Seventy pentachlorophenol treated southern pine poles in the Central Hudson system will be selected by the cooperating utility.

The poles will be dug to the specified depth. The poles will then be randomly assigned to one of 7 treatment groups as follows:

1. Osmose Cop-R-Plastic
2. Osmose PoleWrap RTU Bandage
3. Dr. Wolman chemical 1
4. Dr. Wolman chemical 2
5. Genics chemical 1
6. Genics chemical 2
7. Triangle Laboratories (a biological control system)

Each group will contain 10 poles. The external preservative systems will be applied according to the label instructions. The amount of preservative paste applied will be measured by weighing container before and after each pole is treated.

The poles will be assessed 1, 2, 3, 5, and 7 years after treatment. To minimize possible strength effects, only 5 poles/treatment will be sampled at each time, so that poles will be sampled either 1,3, and 7 years, or 2 and 5 years after treatment.

At each time point, holes will be dug at three equidistant points around the chemically treated poles and plugs will be cut 150 mm below the surface at each location. The holes will be plugged with tight fitting wood or plastic plugs, then a section of duct tape will be placed over the plug to reseal the bandage system. The plugs will be cut into zones corresponding to 0-5, 5-10, 10-15, 15-25, 25-38, 38-50, and 50-75 mm from the wood surface, then ground to pass a 20 mesh screen. The ground wood will be analyzed for the respective components using the appropriate method. Copper components will be analyzed using the XRF system. Boron will be analyzed using the Azomethine H method, while fluoride will be analyzed using our extraction/specific ion electrode method for the Wolman systems and the AWPA Standard A2-Method 7. While we realize the use of two methods for fluoride analysis may lead to deviations, previous comparative analyses using the two methods have shown them to be similar in response to low levels of fluoride, even in the presence of preservative oils.

In the case of the biological control, we will assess efficacy in a different fashion. This system poses an assessment challenge since it alters the external soil environment, but does not deposit measurable active ingredients in the wood. As a result, we will be forced to assess this system using indirect measures. First each pole treated with this system, as well as 10 other non-treated poles will be assessed 150 mm below ground prior to treatment using a Pilodyn. This device indirectly measures wood density, which should decrease as soft rot progresses in a pole. Each pole will be sampled at three equidistant locations around the pole 150 mm above and below the groundline. Poles will be sampled 1, 2, 3, 5, and 7 years after treatment using this method. At each time point, we will excavate one side of each of 5 poles- then sample using the Pilodyn. In addition, increment cores or plugs will be removed from 5 treated and 5 untreated poles at each time point. A series of smaller chips will be cut from each of these cores and plated on malt extract agar amended with streptomycin to retard bacterial growth. The plates will be observed for evidence of fungal growth, which will be subcultured onto fresh media for later identification.

If the treatment depresses microbial activity around the pole, we would expect to see a reduction in isolation levels over time. Fungi can sometimes survive in wood for long periods under unfavorable conditions. As a result, we do not expect to see a sudden reduction in fungal levels. Rather, we would expect to see a gradual decline in fungal isolation frequencies, which, in combination with the Pilodyn, can be used to assess treatment efficacy in comparison to the untreated controls.

Anticipated Results: The results should provide a relative guide to diffusion of the various external preservative components into the southern pine under field conditions. In the case of the biological control, the results may be more difficult to interpret, but changes in either pilodyn readings or fungal isolations would indicate an effect on the decay environment surrounding the pole.

OBJECTIVE V
PERFORMANCE OF COPPER NAPHTHENATE TREATED WESTERN REDCEDAR

Western redcedar continues to be a premium species for wood poles, owing to its naturally durable heartwood. Previous surveys suggest that average service lives for poles of this species easily range from 60 to 80 years or longer. While the heartwood of this species has a well deserved reputation for durability, the sapwood is easily degraded and must be supplementally protected by preservative treatment. While many utilities continue to rely on pentachlorophenol or creosote for this purpose, some utilities have sought alternative systems. One such system is copper naphthenate.

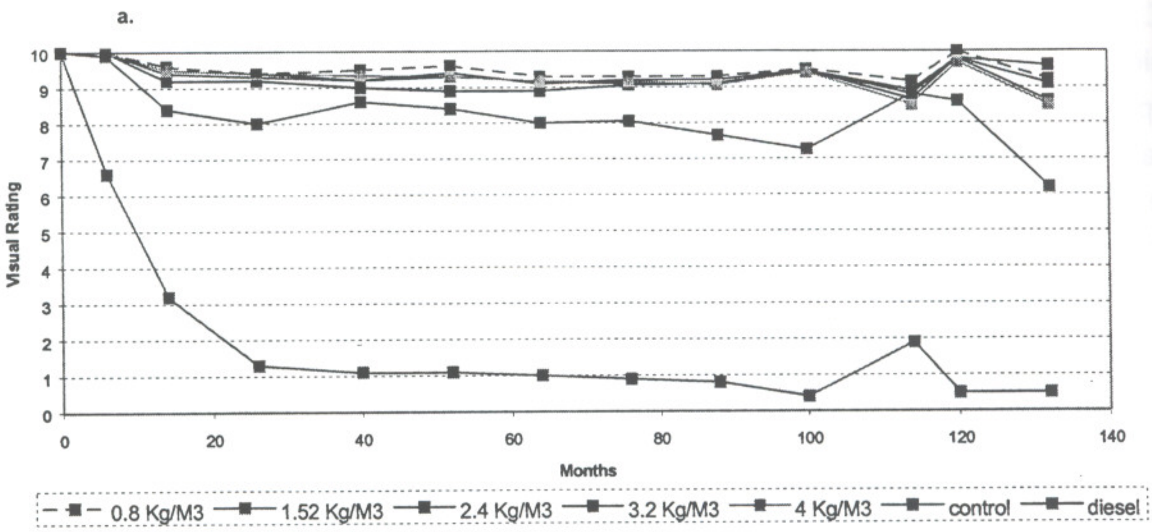
Copper naphthenate is a complex of copper and naphthenic acid. Naphthenic acids area by-products of the oil refining process. Copper naphthenate has been available as a wood preservative since the late 1930's and was used to supplement supplies of creosote during the Second World War, but its use declined sharply in the face of lower cost pentachlorophenol. Interest in copper naphthenate resurfaced in the late 1980's as the U.S. Environmental Protection Agency contemplated the continued use of pentachlorophenol and eventually listed this preservative as a restricted use pesticide. While the listing of penta did not affect the use of wood treated with this chemical by utilities, continued efforts by the EPA to regulate disposal of penta treated wood have encouraged some utilities to examine the use of alternative wood preservatives.

While copper naphthenate has been available as wood preservative since the early part of the last century, there was little performance data on western wood species. As part of an effort to develop data on this chemical, we established a test of western redcedar sapwood.

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

The stakes were conditioned to 13 % moisture content and weighed prior to pressure treatment with copper naphthenate solutions 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 applied to 10 freshly sawn and 10 weathered stakes. The stakes were then exposed in a fungus cellar maintained at 28 C and approximately 80 % relative humidity. The original soil was a compost amended garden loam with an elevated sand content. The soil was watered regularly, but was allowed to dry out between waterings to simulate a more natural exposure. The condition of the stakes was visually assessed annually on a scale from 10 (completely sound) to 0 (destroyed).

Both the untreated controls and the diesel treated weathered stakes have failed 120 months after treatment as have the freshly sawn untreated controls (Figure V-1). The diesel treated freshly sawn stakes have begun to experience more substantial decay over the past 2 years, suggesting that the substantial amount of diesel originally delivered to these samples (probably in the range of 80 to 90 kg/m^3 has begun to lose its protective effect. The remainder of the weathered stakes continue to experience a slow decline in condition, although the two higher retention levels continue to provide reasonable protection (Ratings approximately 8.0). Clearly, the prior weathering has reduced the serviceability of the treatment; however, even these stakes continue to remain serviceable 11 years after treatment to current treatment specifications for this preservative under exposures conditions that would be more extreme than those found in many parts of the country. In addition, poles of these species would normally be inspected after 15 to 20 years of service, providing an opportunity to supplement the original treatment below groundline . Freshly sawn, treated stakes continue to remain sound with most stakes rating 9.0 or better suggesting that treatment of sound, freshly peeled western redcedar poles with copper naphthenate should provide materials that will result in excellent performance.



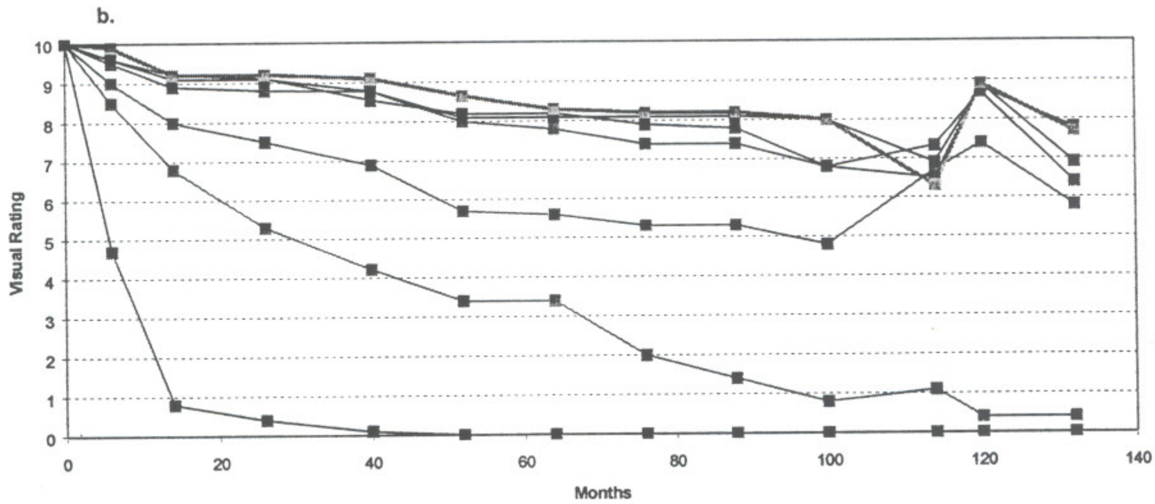


Figure IV-1. Conditions of a) freshly harvested and b) weathered western redcedar sapwppd stakes treated with selelcted retentions of copper naphthenate and exposed for 132 months in a fungus cellar.