Cooperators

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ISK Biotech
New York State Electric and Gas
Osmose Wood Preserving, Inc.
Pacific Corp.
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Southern Co.
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Objective I

DEVELOP SAFER CHEMICALS FOR CONTROLLING INTERNAL DECAY OF WOOD POLES

The development of decay in utility poles in service remains an important cause of reduced service life. Internal decay can occur in virtually all species, but it is most important in species with thin sapwood, such as Douglas-fir and lodgepole pine. While preservative treatment of these species produces an excellent barrier against fungal attack, checks that develop as the poles season in service provide avenues into the untreated wood inside. Left untreated, this decay can weaken the pole, rendering it prone to failure during wind, ice or other storm events.

The development of methods for arresting and preventing internal decay was the original reason for Oregon State University to become involved with Bonneville Power Administration, Pacific Power and Portland General Electric. These efforts have resulted in the widespread use of through boring and radial drilling of new poles to limit the potential for decay development as well as the development of fumigants for arresting decay once it has begun. Collectively, these advancements have saved countless millions by reducing the need to replace poles and decreasing the risk of catastrophic failure leading to litigation.

While the developments of through boring and fumigants have dramatically extended the service life of poles (one utility once estimated that its Douglas-fir poles had average service lives of 12 to 20 years- they now expect 70 to 100 years), there is a continuing need to improve upon the internal treatments to make them safer and more effective, while minimizing their potential impacts on the environment.

A. Develop Improved Fumigants for Control of Internal Decay

While there are a variety of methods for internal decay control used around the world, fumigants remain the most widely used systems for arresting internal decay in North America. Initially, two fumigants were registered for wood, metam sodium (32.1 % sodium n-methyldithiocarbamate) and chloropicrin (96 % trichloronitromethane). Of these, chloropicrin was the most effective, but both systems were prone to spills and carried the risk of worker contact. UPRC Research identified two alternatives, solid methylisothiocyanate (MITC) and basamid. Both chemicals were solid at room temperature, reducing the risk of spills and simplifying cleanup of any spills that did occur. MITC was commercialized as MITC-FUME, while basamid has been labeled as Ultra-Fume. An important part of the development process for these systems have been continued performance evaluation to determine when retreatment is necessary and to identify any characteristics that might affect performance.

1. <u>MITC movement from MITC-FUME ampules in Douglas-fir pole sections stored under varying conditions:</u>

Eighteen Douglas-fir pole sections (250 mm in diameter by 750 mm long) were end-coated with an elastomeric paint to retard drying. One half of the sections were seasoned to approximately 25 % moisture content, while the others were used while their moisture levels were above the fiber saturation point (> 24 % DF). A single 205 mm long hole (19 mm in diameter) was drilled at a 45 degree angle into the center of each pole section and single MITC-FUME ampule containing 29 g of MITC was inserted in the hole, open end downward. The holes were plugged with cork stoppers. Sets of 3 poles at each moisture content were stored at 5 C, outdoors at ambient temperatures, or at 32 C and 90 % relative humidity. At periodic internals, the ampules were removed and weighed to assess chemical loss over time.

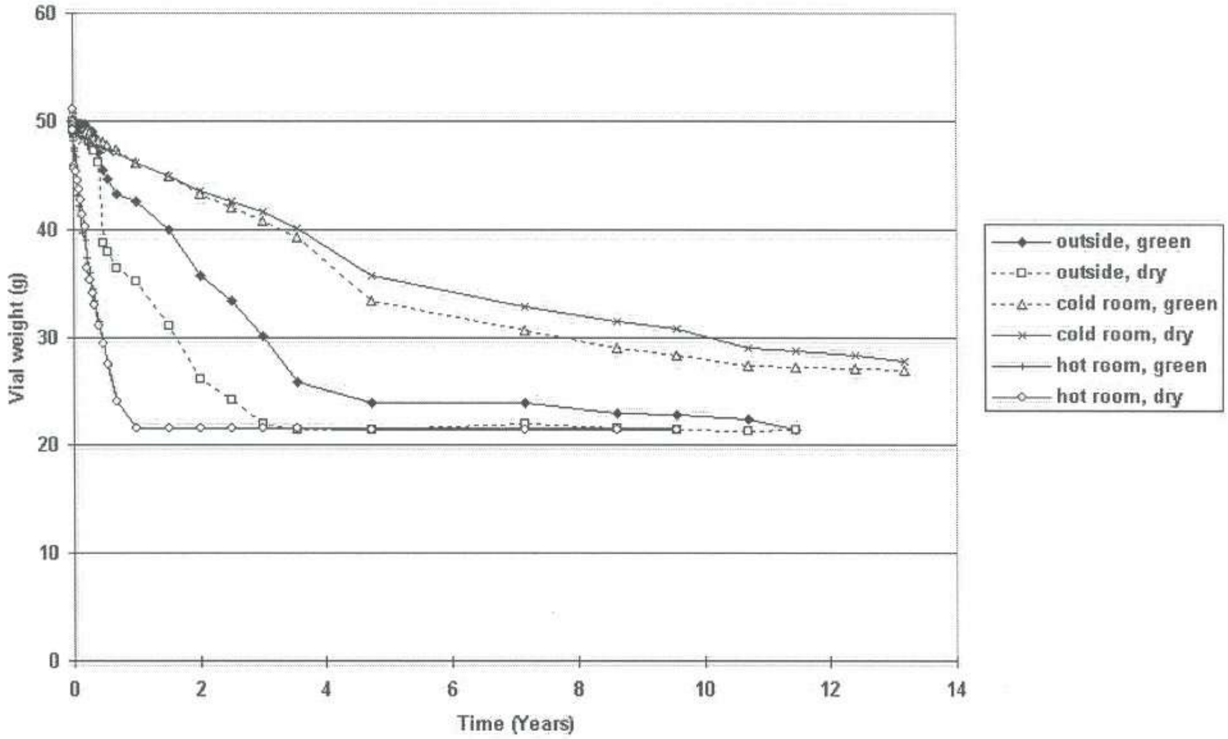
Ampules in pole sections under hot humid conditions rapidly lost chemical and were virtually empty within one year after treatment (Figure I-1). There appeared to be little or no difference in rate of chemical loss in green versus seasoned poles. Ampules stored outside required nearly 4 to 8 years to lose chemical, depending on whether the poles were treated in the green or dry condition. Ampules in dry poles tended to lose chemical more rapidly, although the reasons for these differences remain unknown. Ampules stored at 5 C lost chemical very slowly and still retained approximately 25 % of the original chemical 13 years after treatment. MITC sublimes at room temperature (goes directly from a solid to a gas), but the rate of sublimation slows markedly at lower temperatures. Clearly, poles in cooler climates will lose chemical more slowly than those exposed under warmer conditions. This characteristic has some performance advantages since more chemical will be released under warmer conditions that are also likely to favor rapid decay development. Conversely, less chemical is released during cooler periods when fungal activity is likely to be diminished. The down side to this characteristic is that chemical remains in the ampules for many years. There are, however, a number of studies showing that the amount of chemical remaining in the ampules poses a minimal risk to line crews as well as the general public.

2. Residual MITC in MITC-FUME ampules in Douglas-fir transmission poles in eastern and western Washington:

As noted in Section I-A-1, some utilities remain concerned about the length of time that MITC remains in MITC-FUME ampules following application. To provide additional information on this subject, western redcedar transmission poles in the Bonneville Power Administration system were selected for evaluation. The poles were located in lines near Pasco, Washington and Snohomish, WA. The former line is located in the drier part of the state where rainfall totals rarely exceed 325 mm per year, while the Snohomish site averages 1125 mm of rainfall per year.

The ampules were installed, 3 to a pole (except for one larger pole that received four ampules), through steeply drilled holes drilled beginning at groundline then around the pole 120 degrees and upward 150 mm. The holes were plugged with removable plastic plugs. Ampule weights were assessed 6, 12, 18, 24, 28 and 34 months after treatment. The individual ampules weighed at each time point were not the same.

Figure I-1 Residual MITC in glass ampules installed in green and dry Douglas-fir pole sections exposed at 5 C, ambient conditions or 32 C for 13 years.



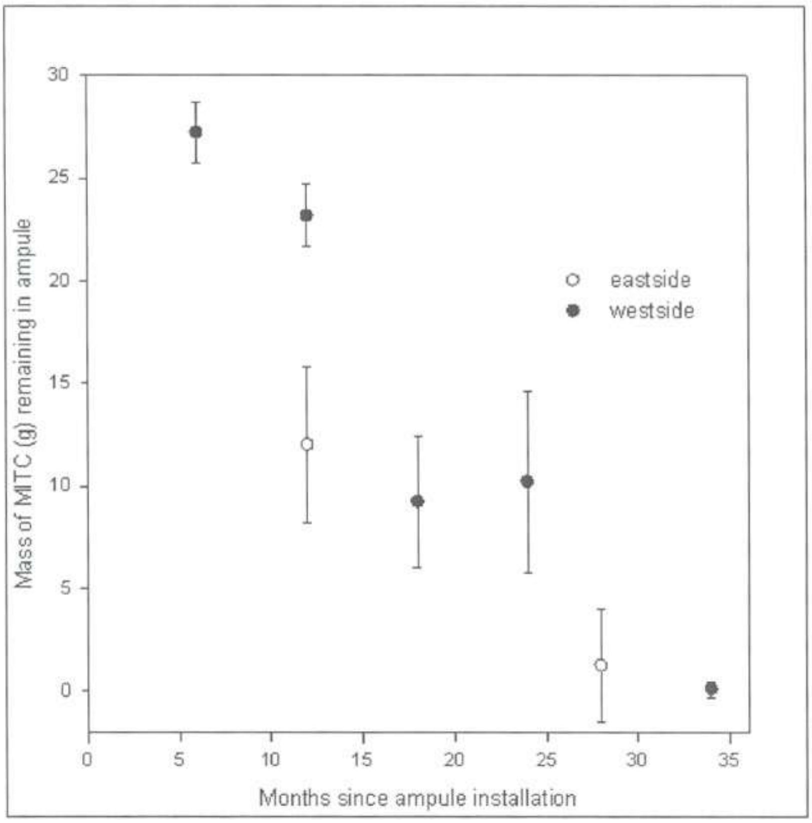
Ampule weights varied little 6 months after application, with all but one ampule retaining over 25 g of the original 29 g dosage (Figure I-2). Ampule weights became more variable 12 months after application. Two ampules contained only 5 g or less of chemical at the 12 month point. Ampule weight losses were generally much lower in poles exposed in Snohomish, reflecting the cooler, wetter conditions at this site. Ampule weights continued to decline at both sites 18 to 24 months after treatment, with the Pasco ampules losing chemical more rapidly. All of the ampules at this site contained less than 15 g of MITC 28 months after application and more than half contained less than 5 g.

These results appear to follow those found in the ambient pole sections exposed at Corvallis, with slightly higher release rates occurring at warmer temperatures. It is clear that MITC will remain in some ampules for at least 2 to 3 years after treatment. As a result, alerting line personnel to the potential for the presence of this chemical in poles being removed from service is advisable as is planning for ampule removal in the event the poles are given away to the general public.

3. Effect of copper sulfate on performance of Basamid in Douglas-fir transmission poles:

The poles treated with metam sodium or basamid and copper sulfate in 1993 were not sampled this past year. They are scheduled to be sampled in 2003.

Figure I-2 Residual MITC in MITC-FUME ampules 6 to 34 months after application to Western Redacedar poles in Pasco (eastside) or Snohomish, WA. (westside).



4. Use of copper naphthenate to enhance performance of basamid in Douglas-fir poles:

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

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

Chemical distribution was assessed 1, 2, 3 and 4 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 the groundline. The outer and inner 25 mm of each core were placed into 5 ml of ethyl acetate, extracted for 24 hour at room temperature, then the resulting extract was analyzed for residual MITC by gas chromatography. MITC levels were quantified by comparison with standards of known concentration. The increment core segment was then oven-dried and weighed so that the MITC content could be expressed on an MITC per oven dried weight of wood basis.

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

Evaluations of previously collected data suggest that the MITC threshold for fungal protection in Douglas-fir poles is approximately 20 ug/oven dried g of wood. MITC levels in poles receiving no supplemental treatment barely reached the threshold level 0.3 m above ground 1 year after treatment (Table I-1). MITC levels increased slightly over the next 4 years in these poles, but appear to have stabilized at levels well above the threshold. Chemical levels above this zone were extremely low, suggesting that the treatment effect was confined to a very narrow zone around the application point.

MITC levels 0.3 m above the groundline one year after treatment were 2 to 5 times higher when copper sulfate was added to the basamid and these levels continued to remain elevated over the four year test period (Figure I-3). MITC was also detectable 1.3 and 2.3 m above groundline 4 years after treatment at levels above the threshold. These results clearly supported the application of copper sulfate at the time of basamid treatment to increase the initial release rate.

MITC levels in pole sections receiving copper naphthenate appeared to experience less of an initial boost in release rate than poles receiving copper sulfate following treatment; however, chemical levels rose sharply 2 years after treatment and have remained elevated and similar to those for the copper sulfate treatment. MITC is also detectable 1.3 and 2.3 m above groundline but it is only just approaching the threshold 1.3 above groundline in the inner assay zone. These results indicate that copper naphthenate enhances basamid decomposition to MITC, but the levels are slightly lower than those found for copper sulfate. Despite the lower levels, copper naphthenate does appear to be useful for encouraging MITC production to more rapidly eliminate any decay fungi established in the wood.

Table I-1 Residual MITC in Douglas-fir pole sections 1 to 4 years after treatment with 200 g of Basamid supplemented with copper naphthenate or copper sulfate.

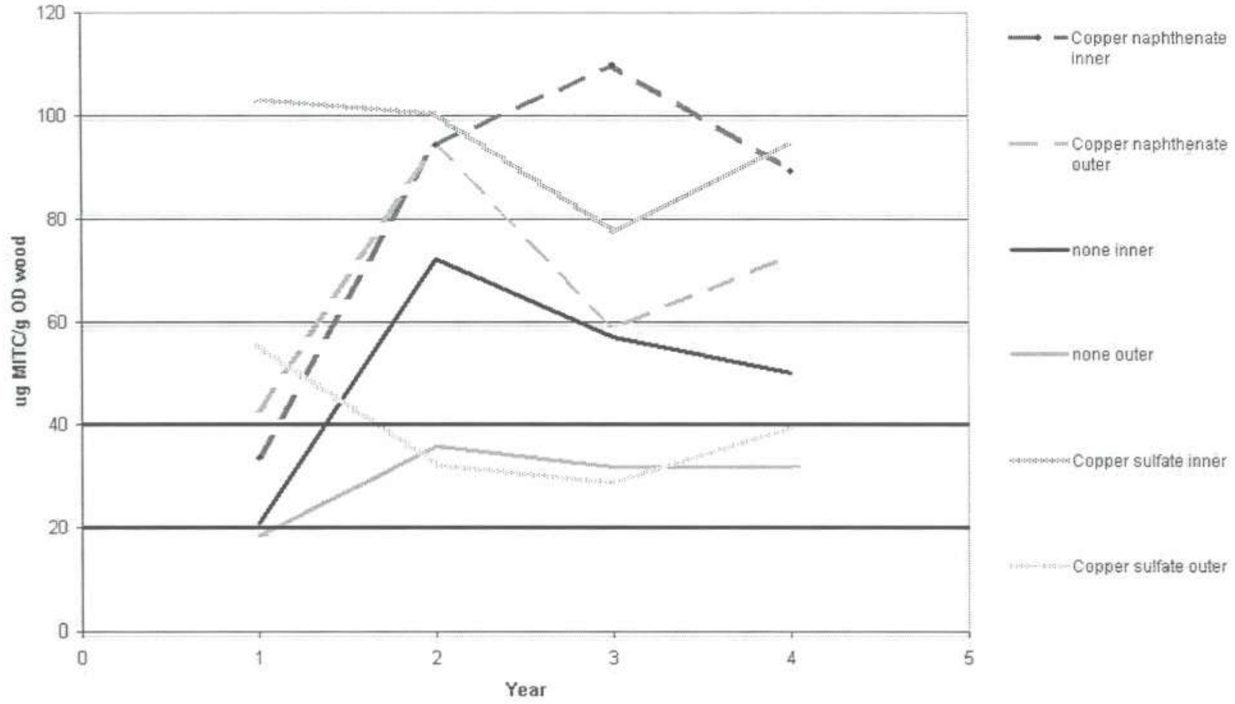
Copper Treatment	Height Meters	Core Section	Residual MITC (ug/g of wood)[a]							
			Year 1		Year 2		Year 3		Year 4	
none	0.3	Inner	21	(14)	72	(47)	57	(27)	50	(41)
		Outer	18	(37)	36	(33)	32	(42)	32	(32)
	1.3	Inner	0	(0)	0	(0)	0	(0)	6	(5)
		Outer	0	(0)	0	(0)	0	(0)	6	(6)
	2.3	Inner	0	(0)	0	(0)	0	(0)	0	(0)
		Outer	0	(0)	0	(0)	0	(0)	0	(0)
Cooper Sulfate	0.3	Inner	103	(78)	101	(36)	78	(25)	95	(61)
		Outer	55	(86)	32	(17)	29	(17)	40	(20)
	1.3	Inner	4	(6)	7	(7)	7	(7)	20	(21)
		Outer	0	(1)	3	(7)	5	(8)	21	(27)
	2.3	Inner	0	(0)	0	(0)	0	(0)	25	(36)
		Outer	0	(0)	0	(0)	0	(0)	23	(33)
Copper naphthenate	0.3	Inner	34	(19)	94	(45)	110	(29)	89	(33)
		Outer	43	(54)	94	(64)	59	(46)	73	(24)
	1.3	Inner	0	(0)	6	(7)	7	(7)	18	(9)
		Outer	0	(0)	5	(11)	4	(8)	9	(7)
	2.3	Inner	2	(5)	0	(0)	0	(0)	1	(2)
		Outer	6	(19)	0	(0)	0	(0)	0	(0)

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

Isolation of decay fungi from the inner zones of the poles one year after treatment were limited except from poles treated with basamid amended with copper compounds. Fungi continue to be isolated from the above ground zones of poles treated with basamid amended with copper sulfate, but are now absent from the copper naphthenate amended poles (Table I-2). We suspect the fungi present after one year were probably present at the time of treatment. The relatively low levels of chemical 1.3 and 2.3 m above groundline likely limited the potential for control. These results suggest that treatment patterns and the zone of protection are more limited with these controlled release formulations than they are with liquid formulations that are applied at much higher dosages.

Figure I-3. Residual MITC in the inner and outer 25 mm segments of increment cores removed from a) 0.3 m or b)1.3 m above the groundline of Douglas-fir pole sections treated with basamid alone or amended with copper naphthenate or copper sulfate.

a) 0.3m



b) 1.3 m

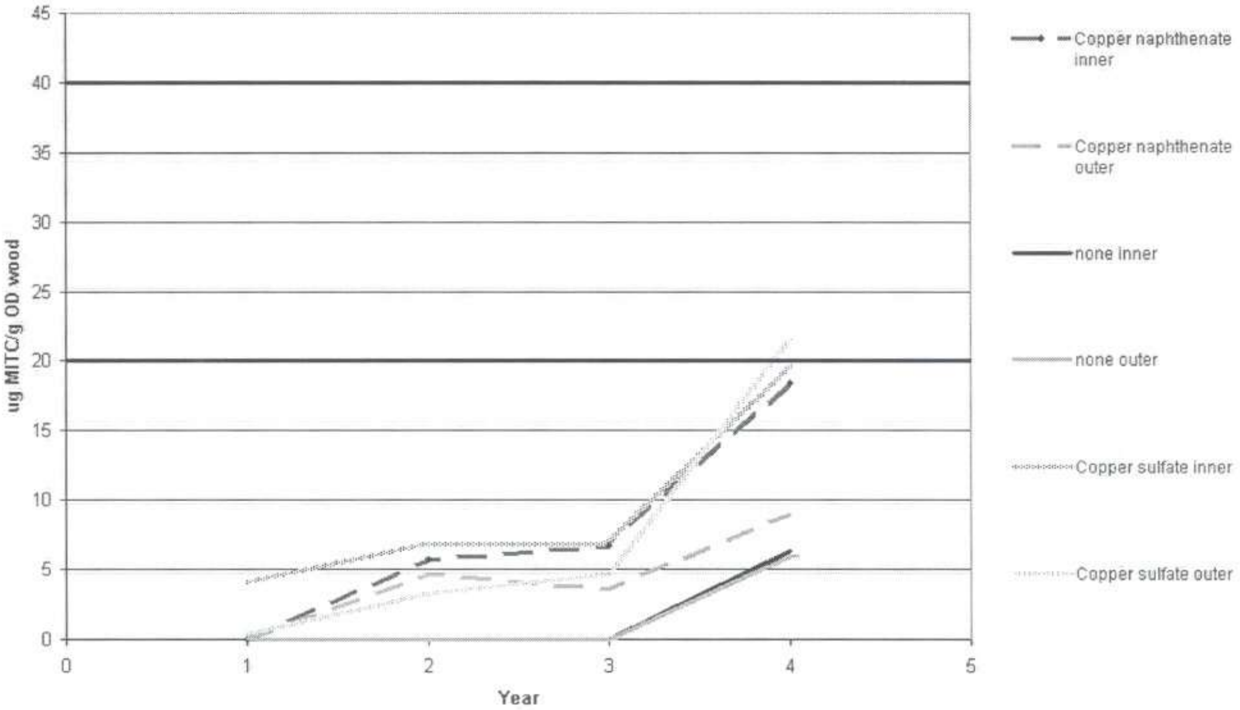


Table I-2 Isolation frequency of decay and non-decay fungi from Douglas-fir pole sections after treatment with 200 g of Basamid alone or amended with copper naphthenate of copper sulfate.

Copper Treatment	Distance above GL meters	Percent of cores with fungi			
		One Year	Two Years	Three Years	Four Years
none	0.3	0 [11]	0 [0]	0 [0]	0 [11]
	1.3	0 [11]	0 [33]	0 [33]	0 [33]
	2.3	0 [11]	0 [33]	0 [0]	0 [56]
copper sulfate	0.3	0 [11]	0 [0]	0 [0]	0 [11]
	1.3	22 [33]	44 [56]	11 [11]	22 [33]
	2.3	0 [44]	0 [33]	0 [33]	11 [33]
copper naphthenate	0.3	33 [33]	0 [0]	0 [0]	0 [0]
	1.3	0 [22]	0 [0]	0 [0]	0 [0]
	23	0 [44]	0 [67]	0 [22]	0 [67]

5. Performance of basamid in rod or powdered formulations:

Basamid was originally supplied in a powdered formulation. This formulation was originally intended for application to fields where it could be tilled into the soil. Once in contact with the soil, the basamid would rapidly react to release MITC, killing potential pathogens prior to planting. The drawbacks to the use of powdered formulations include the risk of spillage during application, as well as the potential for the presence of chemical dusts that can be inhaled. In our early trials, we have produced basamid pellets by wetting the powder and compressing the mixture into pellets, but these were not commercially available. The desire for improved handling characteristics , however, encouraged the development of a rod form. These rods simplified application, but we wondered whether the decreased wood/chemical contact associated with the rods, might reduce basamid decomposition, thereby slowing fungal control.

Pentachlorophenol treated Douglas-fir pole sections (250-300 mm in diameter by 3 m long) were set to a depth of 0.6 m at the Corvallis test site. Three steeply angled holes were drilled into each pole beginning at groundline and moving upward 150 mm and around 120 degrees. The holes received either 160 g of powdered basamid, 107 g of basamid rod plus 100 g of copper naphthenate, 160 g of basamid rod alone, 160 g of basamid rod amended with 100 g of copper naphthenate, 160 g of basamid rod amended with 100 g of water, or 490 g of metam sodium. Each treatment was replicated on five poles.

The poles were sampled one and two years after treatment by removing increment cores from equidistant points around each pole 0.3, 0.8, and 1.3 m above the groundline. The inner and outer 25 mm of each core was extracted in ethyl acetate and the extract was analyzed for MITC by gas chromatography as previously described.

MITC levels 0.3 m above groundline were all well over the 20 ug threshold one year after treatment regardless of chemical treatment (Table I-3; Figure I-4 to 9). The addition of copper compounds have little effect on MITC levels one year after treatment in the inner zones, but MITC levels appeared to be slightly elevated in the outer zones of poles receiving supplemental copper. MITC levels declined markedly in the outer zones 2 years after treatment, regardless of treatment. The addition of copper produced more variable results in the outer zone, but did appear to enhance MITC levels in the inner zones.

MITC levels 0.8 m above groundline were generally below the 20 ug threshold one year after treatment except for the outer zone in the metam sodium treatment. Chemicals levels in the inner zone all rose above the threshold two years after treatment, but there appears to be no real difference between metham sodium and any of the basamid treatments. Chemicals levels 1.3 m above groundline were all uniformly low one year after treatment, then rose dramatically in the inner zones in the second year. The presence of copper had a marked effect on MITC levels in these locations, finding that appears to contradict the results closer to the groundline.

There appeared to be little or no difference in MITC levels between poles receiving basamid in rod or powdered form. This suggests that moisture in the wood was adequate for release of chemicals despite the potential for reduced wood/basamid contact in the rods. The absence of a copper naphthenate effect with the rods may reflect a tendency for more of the liquid chemical to be sorbed by the wood rather than the rod. Conversely, the powdered formulation is more likely to sorb more chemical making it more available to participate in decomposition reactions. Further sampling will be required to determine if there is a real copper stimulatory effect.

Table I-3 Residual MITC in Douglas-fir pole sections at selected distances above the groundline one and two years after treatment with metham sodium, basamid powder, or basamid rods with or without supplemental copper.

Treatment	Dosage	Supplement	Year Sampled	Residual MITC (ug/g wood)[a]											
				0.3 m				0.8 m				1.3 m			
				inner		outer		inner		outer		inner		outer	
Basamid powder	160 g	none	Year 1	50	(35)	24	(24)	6	(17)	4	(8)	0	(0)	0	(1)
			Year 2	52	(70)	16	(55)	42	(54)	1	(3)	25	(32)	27	(41)
Ultrafume	107 g	100g Cu naphthenate	Year 1	45	(57)	46	(44)	2	(4)	6	(8)	0	(0)	0	(0)
			Year 2	51	(70)	1	(2)	36	(51)	1	(3)	73	(101)	14	(28)
Ultrafume	160 g	none	Year 1	54	(95)	30	(30)	2	(4)	4	(7)	0	(2)	1	(3)
			Year 2	29	(37)	3	(6)	35	(53)	1	(3)	33	(46)	6	(12)
Ultrafume	160 g	100g Cu naphthenate	Year 1	49	(63)	85	(88)	9	(16)	9	(16)	1	(2)	1	(2)
			Year 2	80	(104)	17	(45)	49	(64)	4	(9)	62	(75)	5	(11)
Ultrafume	160 g	100 g water	Year 1	22	(22)	29	(35)	4	(6)	6	(10)	0	(0)	1	(2)
			Year 2	33	(47)	1	(2)	32	(34)	1	(5)	41	(41)	6	(11)
Metham sodium	490 ml	none	Year 1	64	(44)	75	(74)	17	(18)	22	(27)	1	(3)	2	(4)
			Year 2	37	(49)	7	(11)	30	(27)	4	(7)	50	(78)	5	(10)

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

Figure I-4 Residual MITC in Douglas-fir poles 1 or 2 years after treatment with 160 g of powdered basamid.

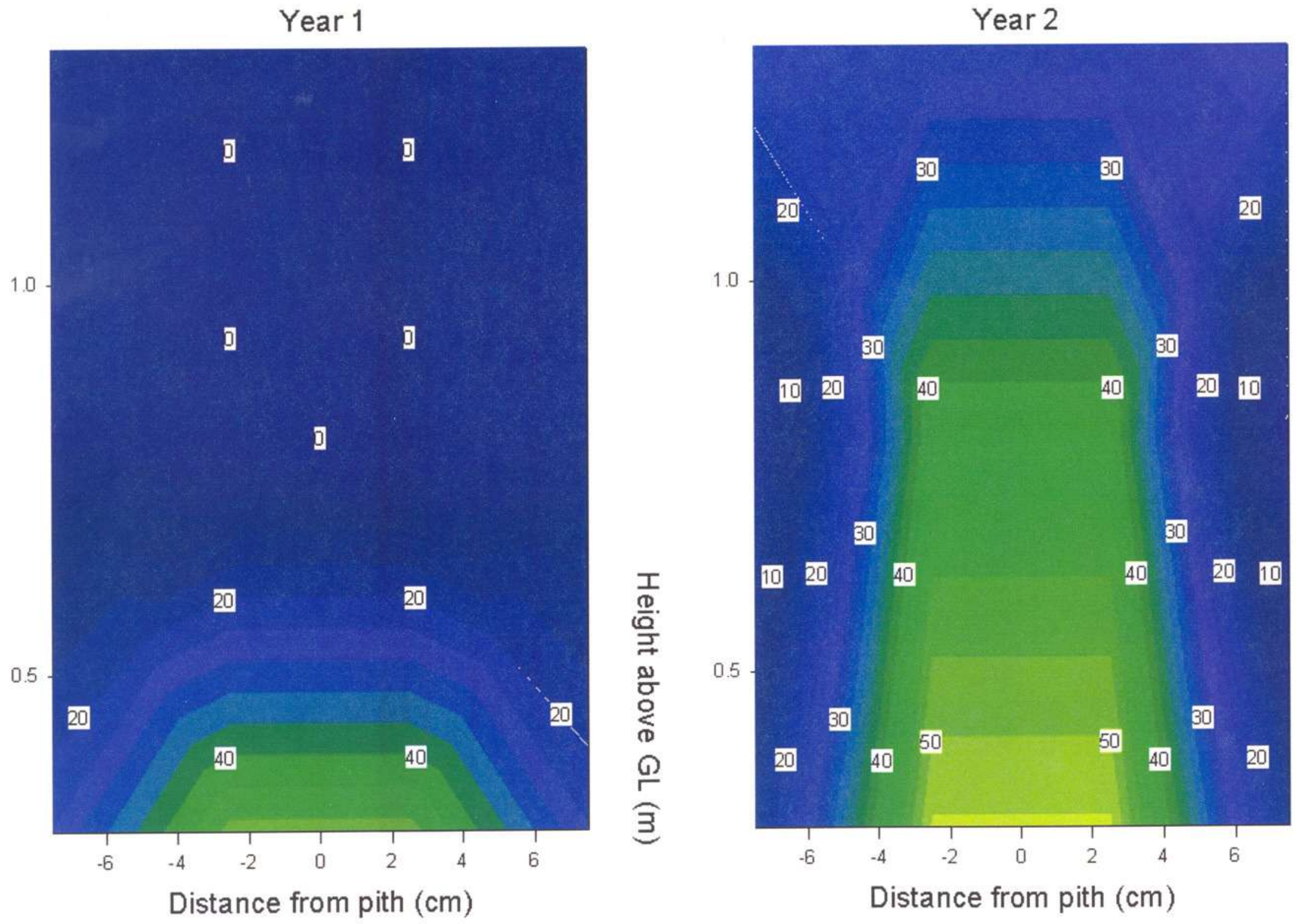


Figure I-5 Residual MITC in Douglas-fir poles 1 or 2 years after treatment with 160 g of Ultrafume rods.

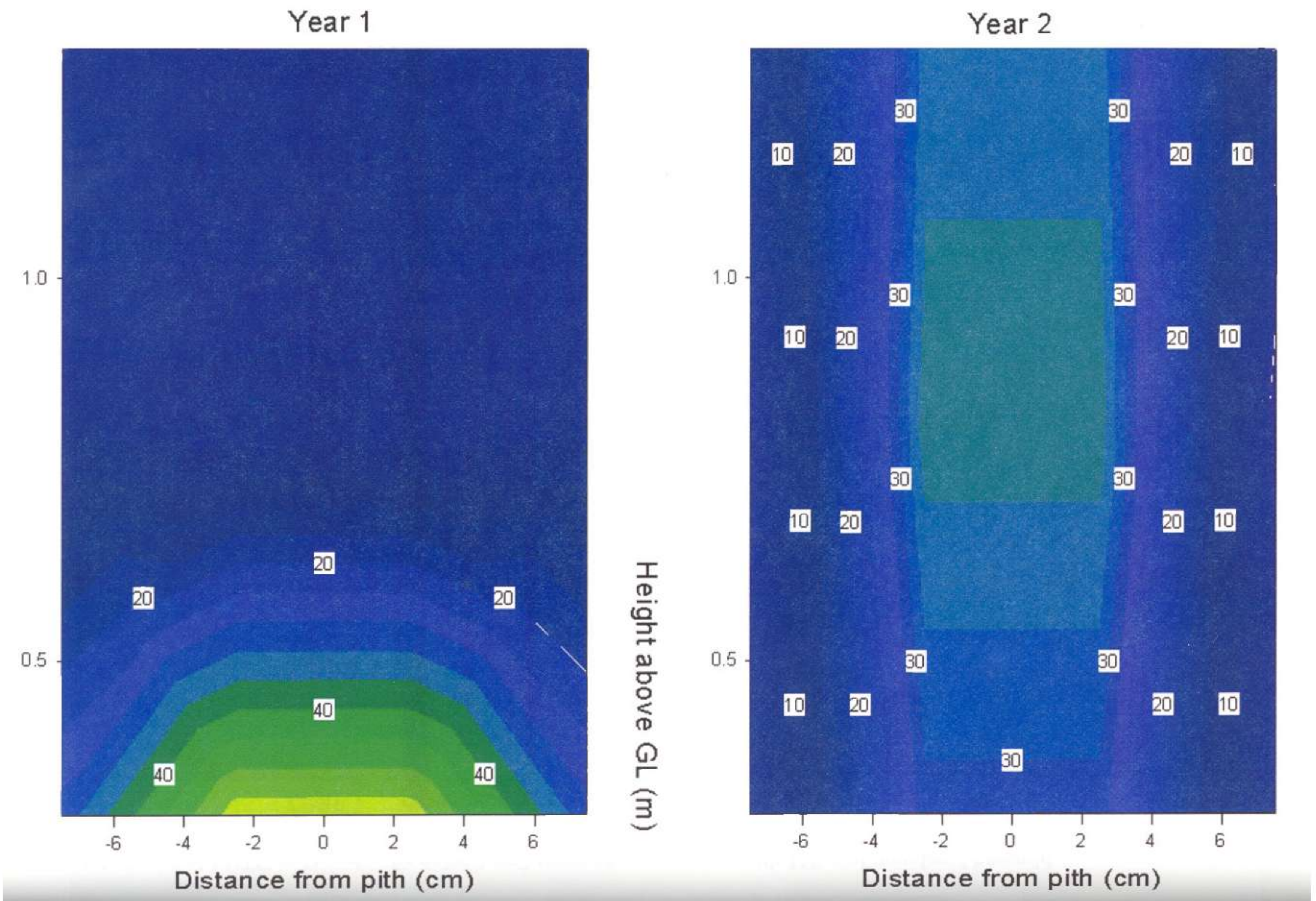


Figure I-6 Residual MITC in Douglas-fir poles 1 or 2 years after treatment with 160 g of Ultrafume rods plus 100 g of water.

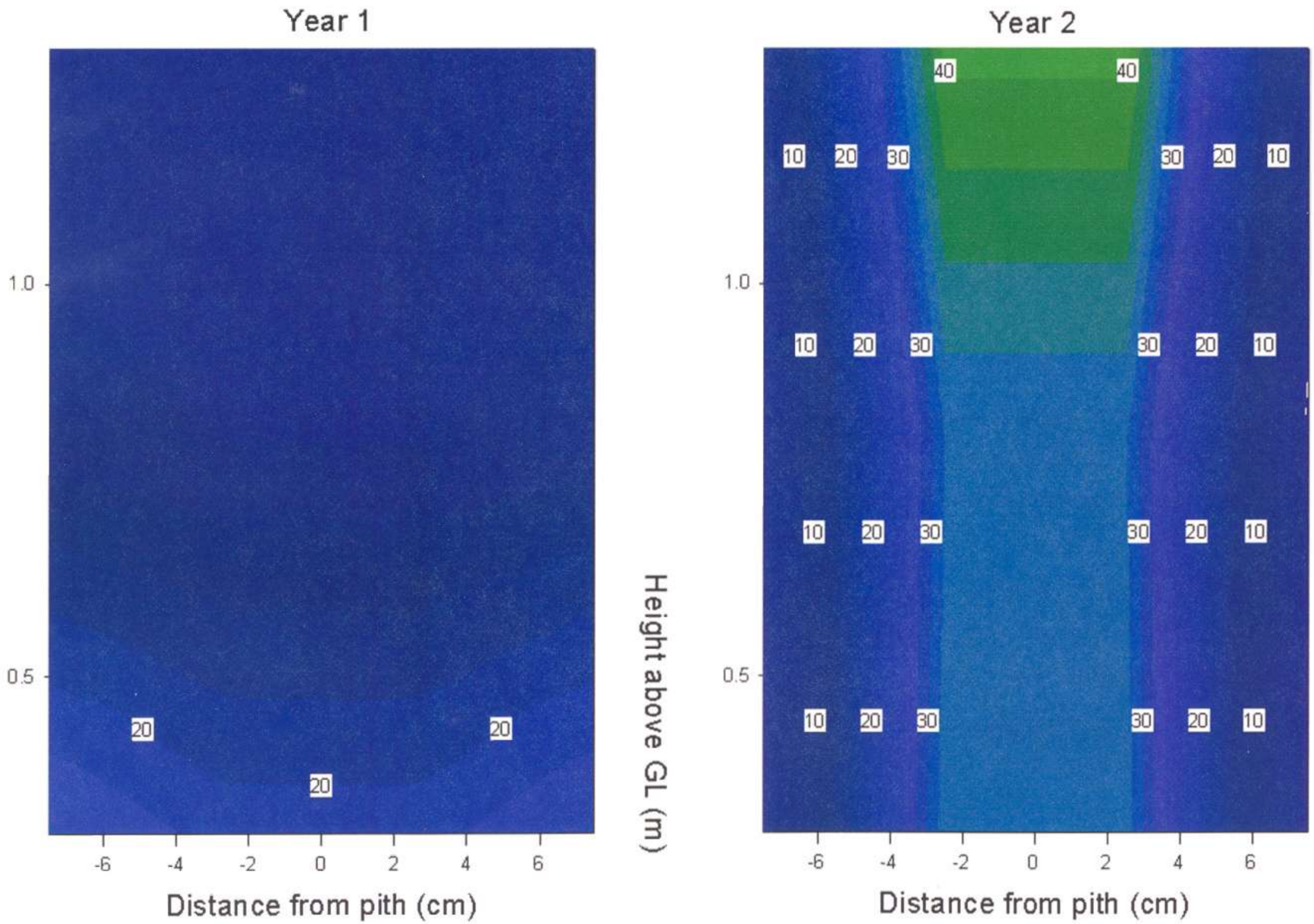


Figure I-7 Residual MITC in Douglas-fir poles 1 or 2 years after treatment with 160 g of Ultrafume rods and 100 g of copper naphthenate.

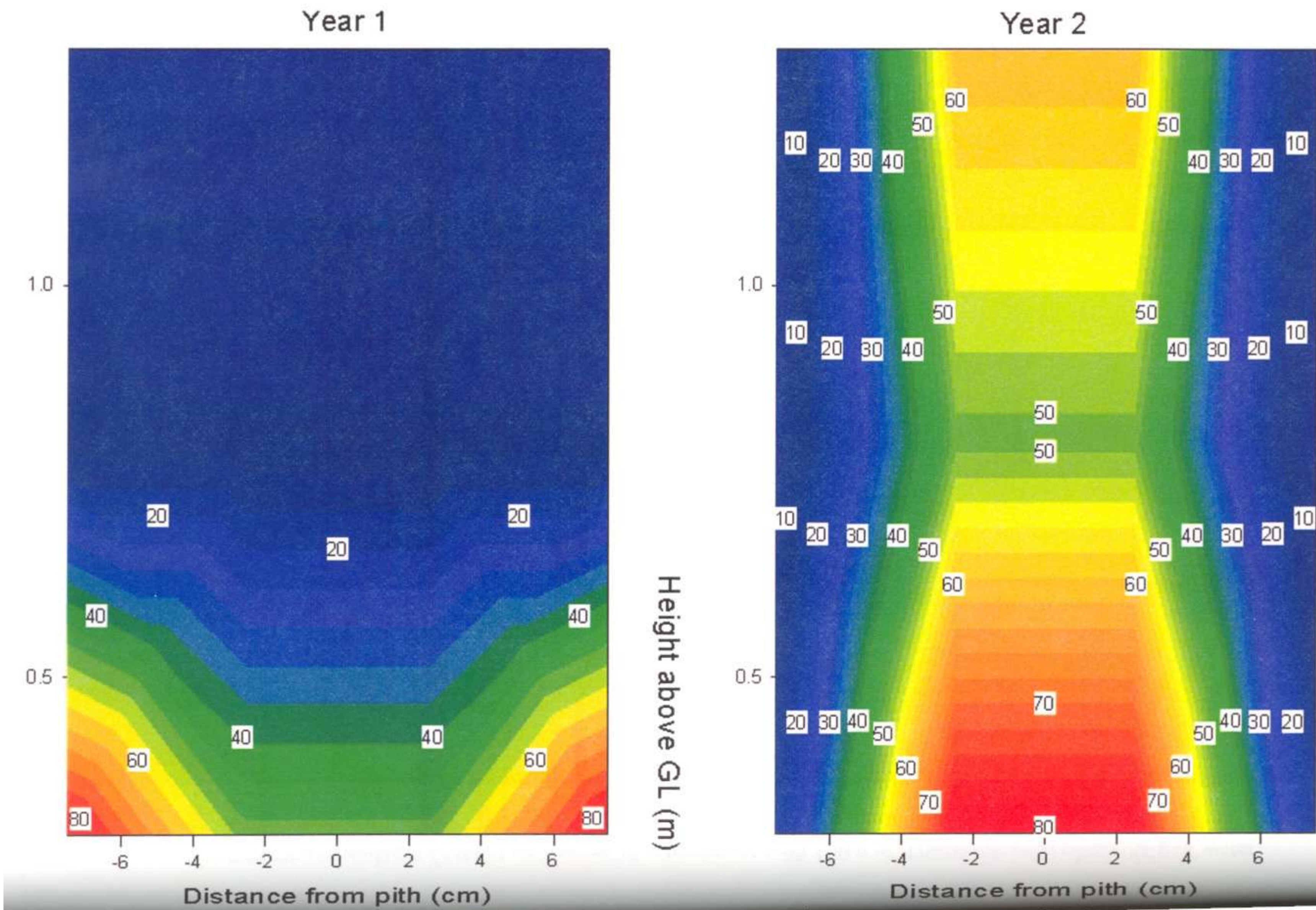


Figure I-8 Residual MITC in Douglas-fir poles 1 or 2 years after treatment with 107 g Ultrafume rods plus 100 g of copper naphthenate.

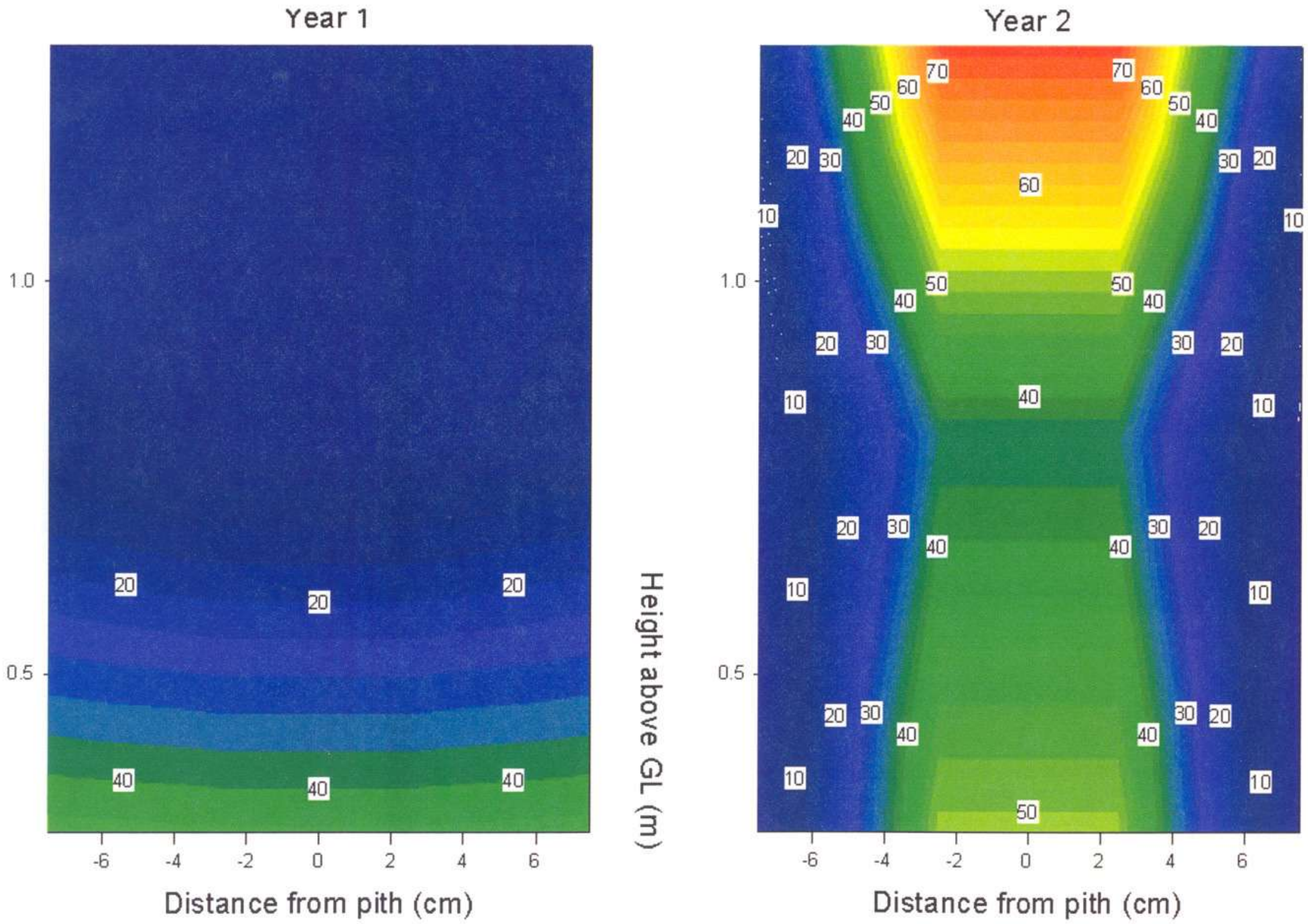
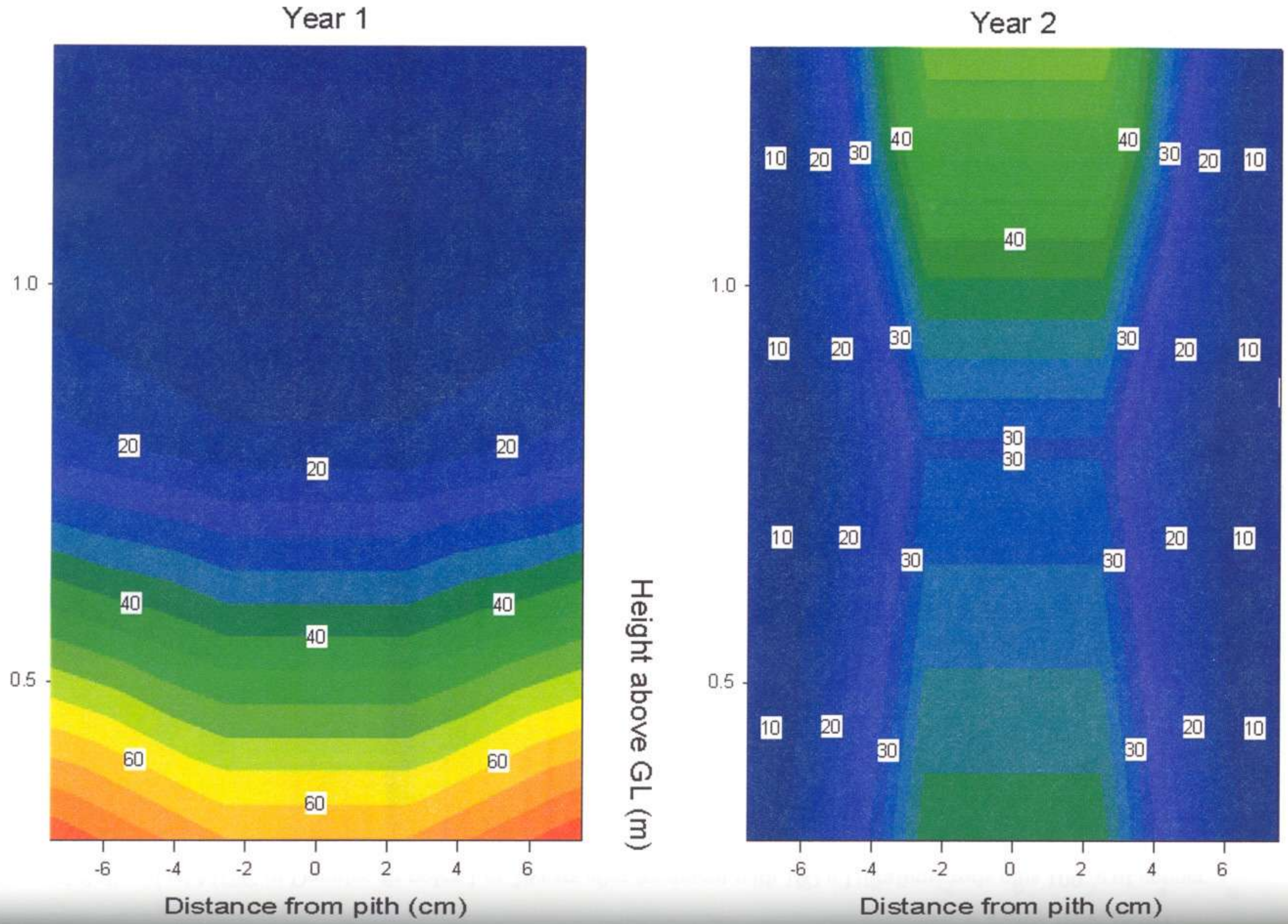


Figure I-9 Residual MITC in Douglas-fir poles 1 or 2 years after treatment with 490 ml of metham sodium.



6. Residual MITC in Douglas-fir posts treated with MITC-FUME:

The Fort Vancouver National Historic site is a reconstructed Hudson's Bay Trading Post. The Fort was reconstructed in the 1960's using Douglas-fir and Lodgepole poles that had been treated with pentachlorophenol in light oil. Shortly after the Fort was completed, it became apparent that deterioration was progressing far more rapidly than had been planned. Investigations showed that posts had been treated with the bark on and many had been frozen at the time of treatment. As a result, the poles were poorly treated and were experiencing substantial internal decay. At that time, the posts were treated with chloropicrin, then in 1992, the posts were retreated with MITC-FUME. This past Spring we had an opportunity to evaluate residual MITC levels on the main support posts in this Fort (called Kingposts) 10 years after treatment.

Increment cores (approximately 150 mm long) were removed from 104 kingposts and gateposts around the Fort. The outer and inner 25 mm of each increment core were placed into individual test tubes containing 5 ml of ethyl acetate, a solvent with a high specificity for methylisothiocyanate (MITC). Each post was sampled at 2 locations approximately 120 degrees apart at groundline and at one location 0.3 m above the groundline. The increment core holes were then plugged with tight fitting wooden dowels to limit the potential for fungal attack in the sampling holes.

The cores were extracted in ethyl acetate for 48 hours at room temperature, then each core was removed, oven dried (104 C) and weighed. The ethyl acetate extracts were then analyzed for MITC content by gas chromatography. Briefly, 3 ul of the extract was injected into a Shimadzu gas chromatograph equipped with a flame photometric detector with filters specific for sulfur. The level of MITC in the extract was determined by similar analysis of prepared standards. The amount of MITC was then calculated on a ug of MITC/ oven dry gram of wood basis. Previous field and laboratory tests have shown that a minimum level of 20 ug of MITC/oven dry gram of wood is required for wood protection.

A total of 104 kingposts and gateposts were sampled and 624 samples were analyzed for MITC content. The results were summarized to show the average MITC content of lodgepole pine and Douglas-fir kingposts or Douglas-fir gateposts in the inner and outer zones. In addition, histograms were created to show the range of MITC retentions in the various locations. The goal was to identify not only the average chemical content, but also the relative numbers of posts with acceptable levels of residual chemical.

MITC levels were generally lower in the outer zones of the posts, regardless of species or type (Table I-4). This probably reflects the tendency for MITC to volatilize near the wood surface. In general, chemical levels deeper in the posts are more important since this is the zone where internal decay is most likely to occur. MITC levels in the inner zones at groundline averaged 25.0 and 15.6 ug/g of wood for Douglas-fir and lodgepole pine kingposts, respectively. MITC levels above the groundline tended to be slightly higher, averaging 29.2 and 49.2 ug/g respectively for Douglas-fir and lodgepole pine. MITC levels in Gateposts were also low in the outer zones, and averaged 26.9 and 18.9 ug/g of wood in the inner zones 0 and 0.3 m above groundline, respectively. Nearly all of these average values are at or above the threshold for fungal attack found in previous tests of Douglas-fir, suggesting that the posts do not need retreatment.

Examination of the distribution of MITC content among the various posts, however, provides a different measure of residual chemical content. Over 80 % of the outer groundline Gatepost samples contained less than 1 ug/g of MITC and all of the samples at 0.3 m contained less than this level of chemical (Figure I-10). MITC levels in the inner zones were slightly better, but nearly 50 % of the inner cores at groundline and over 30 % of those from the 0.3 m location contained less than 1 ug/g of MITC. Clearly, a high percentage of samples contained very low levels of chemical in the gateposts.

A similar examination of the outer zones of the lodgepole pine kingposts showed that virtually all samples contained less than 1 ug/g of wood, while nearly 70 % of inner zone samples at groundline in the posts contained 20 ug or less of MITC (Figure I-11). While the levels were slightly better 0.3 m above groundline, the real risk of internal decay is highest at groundline and declines with distance away from direct soil contact.

A similar examination of the Douglas-fir kingposts showed that outer zone levels were slight better than those found with the lodgepole pine, but a majority of samples contained 1 ug/g or less of chemical (Figure I-12). Examination of MITC distribution in inner zone samples showed that over 40 % of cores from groundline contained less than1 ug/g of MITC and over 60 % contained 20 ug or less. Results were similar 0.3 m above groundline.

Implications: Fumigant performance is a function of the ability of the chemical to eliminate fungi already established and then remain in the wood at levels capable of preventing renewed fungal attack. The protective period provided by most fumigants in the Pacific Northwest is 7 to 10 years. The exception to this rule is chloropicrin, which provides a much longer residual protective period. Determining the exact period of fumigant performance is complicated by the fact that once the chemical levels have depleted, the decay fungi must find pathways for reinvading wood. Thus, the rate of reinvasion and renewed fungal attack is a function of soil conditions and the fungi present. There is also some evidence that fumigant treatment alters the types of fungi present in the wood, sometimes encouraging the growth of fungi that do not cause wood decay. Some of these fungi are capable of inhibiting decay fungi and limit the ability of decay fungi to reinvade the posts.

All of this means that it is sometimes difficult to accurately predict fumigant service life, however, it has been our experience that wood with less than 20 ug of MITC is at a much higher risk of fungal attack. Our results indicate that a majority of the samples examined contain less than this minimum threshold retention and should be retreated. The presence of some residual MITC in most samples, albeit at low levels, does provide some latitude for retreatment. As a result retreatment within the next 2 years would probably provide a reasonable degree of protection to the posts.

Table I-4 Residual MITC in Douglas-fir or lodgepole pine kingposts at the Fort Vancouver National Historic Site.

Post Type	Distance Above Groundline (m)	Residual MITC (ug/oven dry g of wood)[a]							
		Douglas-fir				Lodgepole pine			
		Outer Zone		Inner Zone		Outer Zone		Inner Zone	
		Mean	Max	Mean	Max	Mean	Max	Mean	Max
King	0	3.5 (7.0)	32.2	25.0 (36.7)	150	0.7 (3.7)	34	15.6 (38.7)	358
	0.3	9.4 (15.6)	82.4	29.2 (52.1)	210	1.4 (6.3)	45	49.2 (144.2)	1100
Gate	0	3.6 (9.1)	29.3	26.9 (43.7)	144	-	-	-	-
	0.3	0	0	18.9 (24.3)	64.4	-	-	-	-

[a] Values in parentheses represent one standard deviation.

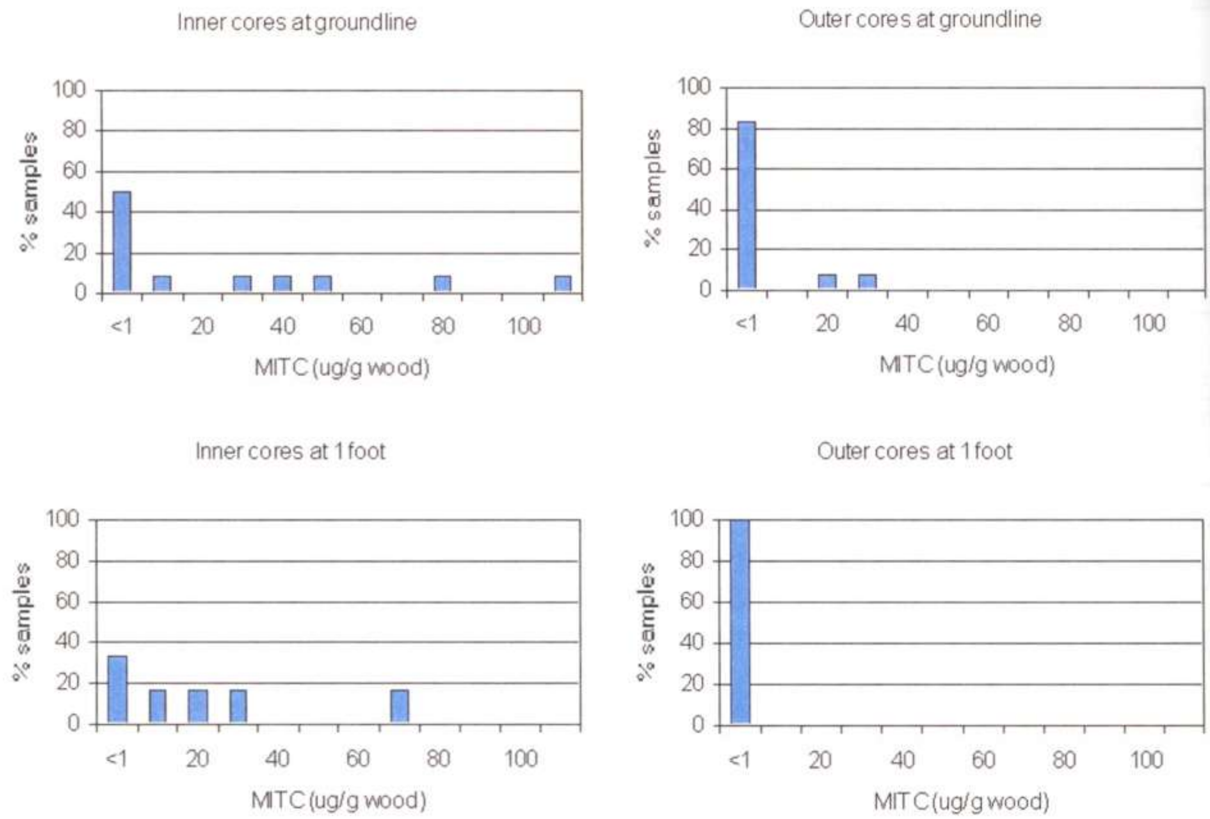
7. Performance of metam sodium in Douglas-fir timbers:

While the majority of our research has focused on remedial treatment of poles, treatment of timbers is also an important component of the remedial treatment markets and these applications help to support the costs for label registration. Given the relatively small markets for wood fumigants, we have taken an approach to develop data for supporting applications wherever the cost for developing this data is small and there are potential benefits in terms of long term continued availability of the chemicals.

Fumigant performance on large timbers might be expected to differ slightly from that found on round stock because of the thinner treated shell and presence of numerous cut fibers on the timber surfaces that can act as conduits for fumigant diffusion from the wood. Under these circumstances, fumigants might be expected to provide shorter protective periods than would be found on round stock, but there is little data available on this subject.

Metham sodium was applied to 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 wood dowels. Residual chemical levels were assessed 1, 3, 6, 7, 10, and 12 years after treatment by removing increment cores from near the top and bottom edges 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 each increment core was placed into 5 ml of ethyl acetate and extracted for 48 hours at room temperature. The resulting extract was analyzed for MITC content by gas chromatography. The remainder of each core was placed on malt extract agar and observed for the growth of decay fungi, which served as a measure of failure of the remedial treatment.

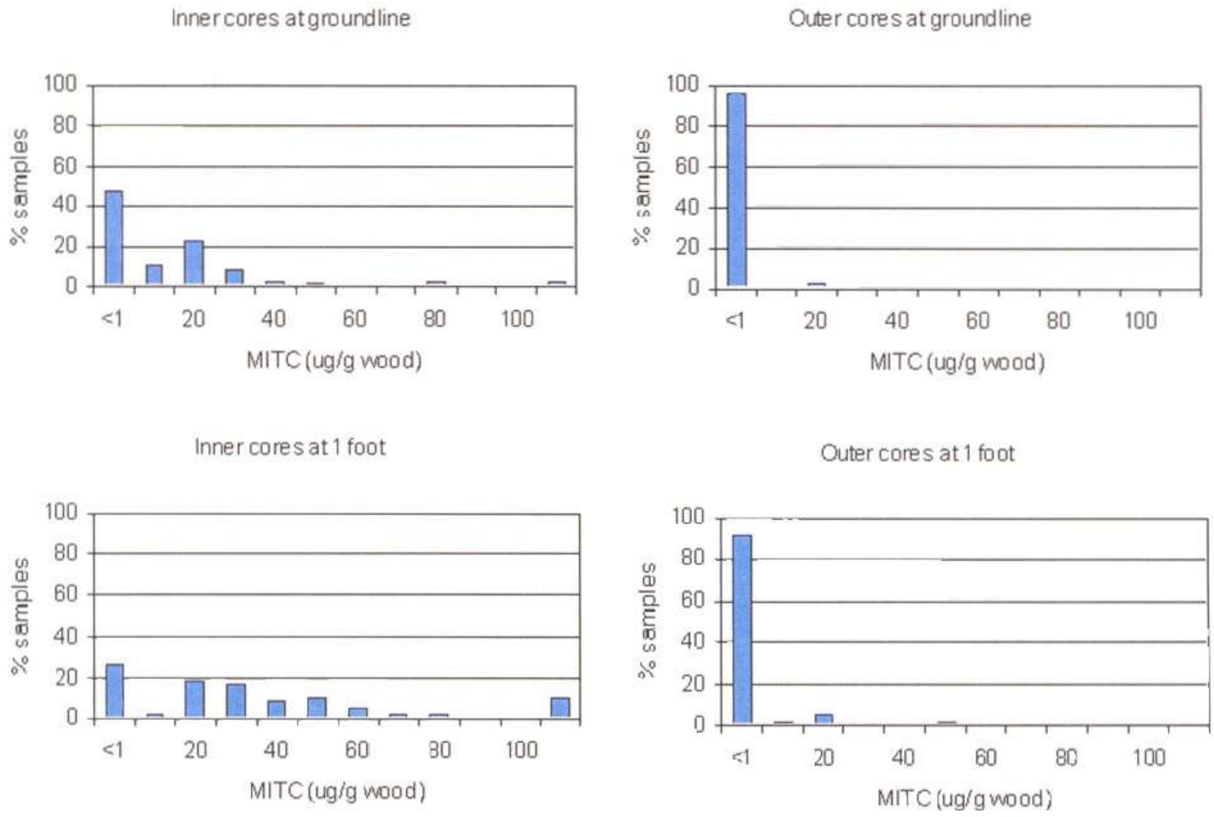
Figure I-10 Residual MITC in the inner and outer 25 mm of increment cores removed from Douglas-fir gateposts10 years after treatment with MITC-FUME.



MITC levels in the timbers continue to remain detectable, although the levels have largely declined below the protective threshold for MITC against fungi (Table I-5). Fungal isolations continue to indicate that few decay fungi have reinvaded the timbers, but non-decay fungi have invaded the timbers in substantial numbers (Table I-6). The absence of decay fungi reflects the residual chemical levels as well as the lack of soil contact. Soil contains high levels of spores and hyphal fragments of a variety of fungal species, including decay fungi. The absence of soil contact sharply slows the rate of fungal attack, further enhancing the effectiveness of the remedial treatment.

The results indicate the retreatment of the timbers would be advisable to provide continued protection.

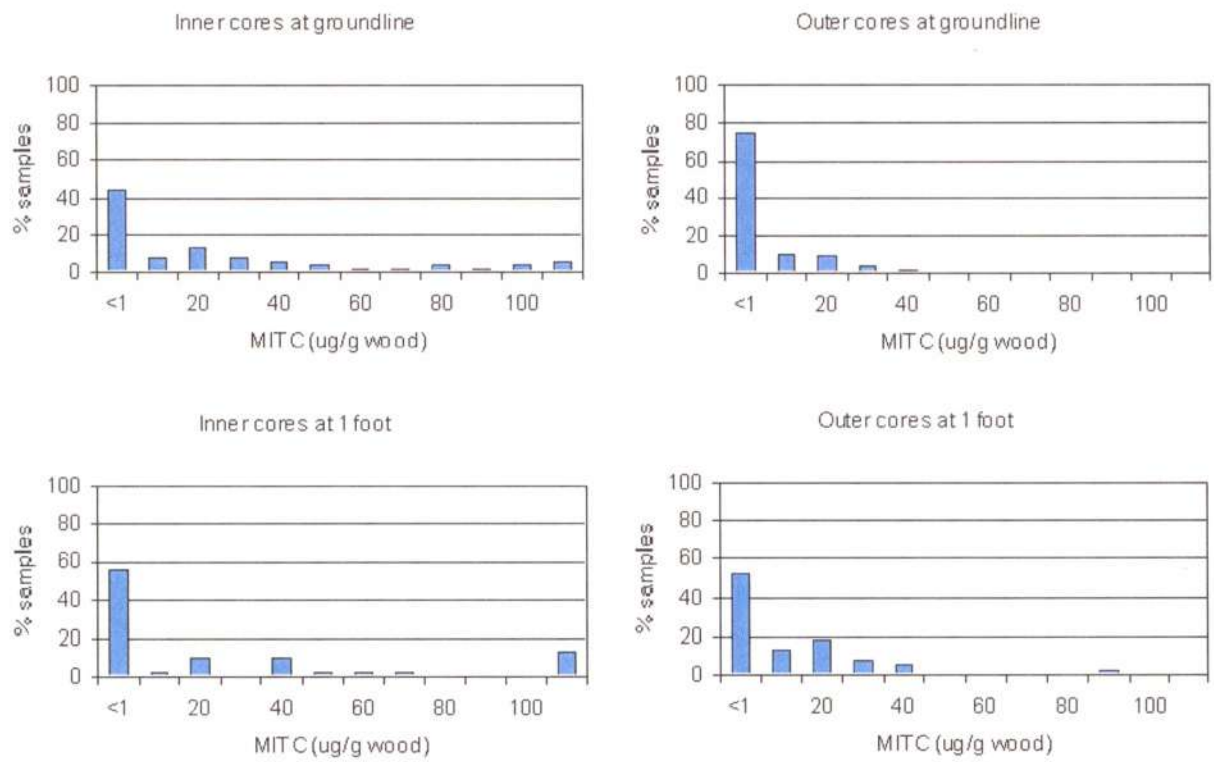
Figure I-11 Residual MITC in the inner and outer 25 mm of increment cores removed from lodgepole pine kingposts 10 years after treatment with MITC-FUME.



8. <u>Release rates of chloropicrin from controlled release ampules exposed in utility poles:</u>

While pressure treatment of wood with preservatives produces a product that will perform extremely well under a variety of environmental conditions, species and treatment characteristics will generally result in a limited percentage of poles that experience biodeterioration at some point in their useful lives (AWPA, 1999; Graham, 1983). These "problem" poles can be detected through a regular inspection program and the problem arrested by application of remedial treatments. Decay in service generally takes two forms, surface decay that is caused by soft rot fungi and internal deterioration that is caused by either decay fungi or insects (primarily carpenter ants or termites). Surface decay has long been controlled by application of topical preservative pastes that kill fungi in the wood near the surface and create a supplemental barrier against renewed attack.

Figure I-12 Residual MITC in the inner and outer 25 mm of increment cores removed from Douglas-fir kingposts 10 years after treatment with MITC-FUME.



Internal decay control has generally posed a greater problem. In most cases, internal decay occurs in the heartwood that originally could not be impregnated using pressures between 100 and 200 psi. The inherent resistance to fluid penetration renders nearly all conventional liquid treatments ineffective for internal decay control. Liquid preservatives can be applied to the voids through inspection or treatment holes, but are unable to move for substantial distances through the heartwood to effectively arrest fungal attack away from the void. For many years, internal decay control treatments were limited to oil and water-based systems that lacked the ability to move rapidly for substantial distances from the point of application (Hand et al., 1970).

Table I-5 MITC levels in increment core segments removed from Douglas-fir timber 1 to 12 years after treatment with metham sodium.

MITC Content (ug/g o.d. wood)																
Structure #	Top/bottom	in/out	Year 1		Year 2		Year 3		Year 6		Year 7		Year 10		Year 12	
5	Bottom	inner	**60**	(85.8)	**35**	(39.4)	**31**	(56.1)	**40**	(27.3)	**28**	(34.9)	**30**	(18.8)	**29**	(16.8)
		outer	**24**	(27.1)	**112**	(120.5)	**84**	(145.7)	**108**	(89.1)	**127**	(60.9)	**38**	(25.9)	**26**	(15.7)
	Top	inner	4	(6.1)	**52**	(106.2)	10	(13.4)	**40**	(64.3)	1	(3.1)	4	(4.2)	6	(15.3)
		outer	0	0.0	**28**	(39.7)	3	(5.3)	**50**	(105.3)	4	(5.2)	0	0.0	5	(10.5)
10	Bottom	inner	**76**	(83.2)	**115**	(110.6)	**43**	(62.7)	**60**	(35.4)	**42**	(20.3)	15	(11.0)	13	(7.5)
		outer	**40**	(27.8)	**59**	(47.0)	**116**	(200.9)	**58**	(42.8)	15	(9.2)	14	(8.3)	19	(9.8)
	Top	inner	**40**	(45.2)	**136**	(110.9)	**71**	(59.4)	**47**	(28.8)	**21**	(15.3)	14	(12.1)	4	(6.5)
		outer	**53**	(49.1)	**60**	(51.6)	77	(92.8)	**43**	(17.5)	**42**	(31.4)	6	(6.8)	10	(12.8)
15	Bottom	inner	16	(27.6)	**100**	(95.1)	18	(26.6)	**38**	(33.9)	**32**	(19.9)	19	(29.1)	2	(5.4)
		outer	**24**	(26.8)	**113**	(111.3)	**43**	(56.3)	**55**	(36.0)	**30**	(27.4)	11	(21.6)	12	(8.8)
	Top	inner	**27**	(30.2)	**66**	(78.2)	**46**	(28.1)	**64**	(40.8)	**54**	(25.3)	**31**	(23.2)	15	(9.8)
		outer	**37**	(67.0)	**59**	(61.7)	**145**	(121.1)	**66**	(46.5)	**43**	(22.3)	**28**	(15.6)	**27**	(9.8)
20	Bottom	inner	**74**	(84.8)	**43**	(52.8)	**68**	(73.4)	**57**	(25.6)	**75**	(49.5)	**28**	(15.0)	17	(7.7)
		outer	**24**	(33.5)	20	(23.9)	**163**	(164.1)	**52**	(22.1)	**72**	58.3)	**33**	(26.1)	**21**	(11.0)
	Top	inner	**26**	(35.9)	**117**	(126.4)	**58**	(31.8)	**32**	(24.7)	**21**	(12.6)	**56**	(77.1)	4	(5.8)
		outer	**65**	(63.9)	**131**	(185.4)	**45**	(46.8)	**66**	(38.6)	**35**	(10.6)	8	(6.4)	10	(6.4)
25	Bottom	inner	**33**	(33.3)	**83**	(146.2)	**86**	(75.1)	**59**	(35.6)	**54**	(21.60	**41**	(20.1)	13	(8.5)
		outer	**66**	(71.8)	**95**	(85.3)	**32**	(21.4)	**52**	(35.2)	**52**	(29.7)	18	(17.5)	**29**	(8.7)
	Top	inner	**26**	(32.5)	**63**	(48.30	**41**	(25.2)	16	(9.5)	20	(19.6)	16	(5.0)	13	(1.6)
		outer	13	(20.1)	**44**	(51.9)	**52**	(37.2)	**29**	(11.3)	**27**	(11.3)	13	(4.4)	12	(2.7)

MITC Content (ug/g o.d. wood)																
Structure #	Top/bottom	in/out	Year 1		Year 2		Year 3		Year 6		Year 7		Year 10		Year 12	
30	Bottom	inner	**84**	(66.4)	**41**	(61.8)	**83**	(87.6)	**28**	(12.0)	**35**	(21.0)	19	(8.5)		
		outer	**76**	(100.8)	**64**	(99.5)	**49**	(34.4)	**40**	(23.6)	**24**	(2.4)	11	(5.2)		
	Top	inner	**73**	(52.9)	**127**	(99.1)	**78**	(42.1)	**40**	(25.5)	**50**	(25.6)	**28**	(13.1)		
		outer	**100**	(74.2)	**96**	(57.6)	**70**	(50.1)	**37**	(26.3)	**36**	(29.1)	**30**	(16.5)		
35	Bottom	inner	14	(19.8)	75	(100.3)	19	(17.9)	**36**	(24.9)	**28**	(7.4)	10	(6.5)		
		outer	9	(17.5)	**42**	(40.7)	9	(10.2)	**37**	(25.3)	15	(12.0)	6	(3.3)		
	Top	inner	**44**	(50.1)	**74**	(88.1)	**109**	(113.0)	**31**	(17.0)	**64**	(30.5)	**31**	(29.5)		
		outer	**61**	(88.6)	**121**	(235.8)	**57**	(56.9)	**59**	(54.5)	**78**	(45.6)	5	(7.8)		
40	Bottom	inner			**92**	(145.1)					18	(12.1)	18	(12.2)		
		outer			**57**	(53.5)					8	(9.8)	9	(5.6)		
	Top	inner			**50**	(70.5)					17	(16.8)	**33**	(15.1)		
		outer			**140**	(112.9)					**50**	(50.3)	**35**	(22.5)		

Values represent means of 6 replicates. Values in parenthesis represent one S.D.
Figures in boldface type are above the fungitoxic threshold of 20ug/g wood.

Table I-6 Isolation frequency of decay and non-decay fungi from Douglas-fir bridge timbers prior to and 1 to 12 years after treatment with metham sodium.

	Percent of Cores with Fungi[a]							
Structure	0 Year	1 Year	2 Years	3 Years	6 Years	7 Years	10 Years	12 Years
5	--$^{--}$	0^{42}	0^{90}	0^{22}	0^{0}	0^{0}	0^{0}	0^{92}
10	0^{17}	0^{42}	0^{50}	0^{50}	0^{0}	0^{0}	0^{0}	8^{92}
15	0^{17}	0^{0}	0^{100}	8^{67}	0^{0}	0^{0}	0^{0}	0^{92}
20	--$^{--}$	0^{0}	0^{100}	0^{80}	0^{0}	0^{0}	0^{0}	0^{100}
25	0^{29}	0^{0}	0^{100}	8^{50}	0^{0}	0^{17}	0^{0}	0^{50}
30	29^{40}	0^{0}	0^{100}	0^{0}	0^{0}	0^{0}	0^{0}	--$^{--}$
35	13^{87}	0^{0}	0^{17}	8^{90}	0^{27}	0^{0}	0^{0}	--$^{--}$
40	0^{17}	--$^{--}$	8^{42}	--$^{--}$	--$^{--}$	0^{0}	0^{0}	--$^{--}$
Average	8^{35}	0^{10}	1^{70}	4^{60}	0^{7}	0^{4}	0^{3}	2^{87}

[a] Values represent mean percent of 12 cores containing decay fungi. Superscripts represent percent of non-decay fungi present in same cores.

The prospects for internal decay control received a substantial boost in the early 1960's with the development of fumigants (Ricard et al., 1967; Hand et al., 1970; Graham, 1973, Graham and Corden, 1980). These volatile chemicals were widely used in agriculture for sterilizing soil prior to planting. Field trials in poles indicated that some fumigants including chloropicrin and metham sodium, were capable of moving rapidly through Douglas-fir heartwood to eliminate established decay fungi. More importantly, these chemicals remained in the wood for 3 to 20 years after application where they limited recolonization by decay fungi (Graham, 1973; Helsing et al., 1984; Morrell and Scheffer, 1985; Schneider et al., 1995). Although they appear to provide a shorter protective period in more permeable species such as southern pine (Zabel et al., 1982), these treatments are also applied these species, albeit at more frequent intervals. The effectiveness of fumigants was widely recognized and by 1983, nearly 90 % of utilities surveyed used fumigants as a part of their inspection and maintenance programs (Goodell and Graham, 1983).

While fumigants are widely used, many applicators remained concerned about the risk of spills (Morrell and Corden, 1986). In addition, chloropicrin, the most effective of the registered chemicals, requires the use of full face respirators during application. This was clearly a negative public-image issue with many utilities, who responded by either using only metham sodium or restricting chloropicrin use to overland transmission poles away from inhabited areas.

The development of methylisothiocyanate (MITC) in the early 1980's provided the first alternative to metham sodium and chloropicrin (Zahora and Corden, 1985). This formulation is a solid at room temperature, but must be encapsulated to limit the risk of skin burns. It is also the active ingredient of metham sodium (Turner and Corden, 1963; Lebow and Morrell, 1993; Morrell, 1994). The MITC formulation was first encapsulated in glass tubes, then finally aluminum. Field tests showed that the MITC released from the capsules over periods ranging from several months to years, depending on the temperature and provided performance that was slightly better than metham sodium, but did not approach that of chloropicrin (Morrell et al., 1992).

Chloropicrin is an especially attractive remedial treatment. It is effective against a range of fungi at low dosages, and tends to be strongly sorbed to wood (Goodell, 1989; Peralta and Morrell, 1992). These properties have continued to encourage studies to identify safer application methods that overcome chloropicrin's strong lachrymatory properties. Goodell (1989) developed a gelled chloropicrin formulation which reduced the risk of spills but had little effect on volatility. Fahlstrom (1982) developed an encapsulating tube for containing chloropicrin prior to delivery in to the wood. While this system limited the risk of spills, the tubes had to be filled on the job site and could not be stored for long periods. As a result, it has only been used for treating timbers in bridges or other structures where large amounts of wood are being treated in one area.

The desire to produce a safer chloropicrin formulation led the Electric Power Research Institute (EPRI) to sponsor a research program through the Southwest Research Institute (SwRI) (San Antonio, TX) to develop a controlled release formulation that was safe to store, handle and apply and that provided an estimated protective period of 20 years (Bernstein et al., 1998; Schlameus et al., 1996; Love et al., 1996; Morrell et al., 1994). A series of polymer encapsulated formulations of chloropicrin were developed and evaluated in pole sections exposed near Corvallis, Oregon. The results from these tests indicated that one polymer appeared to provide the desired release rate and this material was subsequently registered with the U.S. Environmental Protection Agency. As with any material destined for utility use, field performance data in actual utility systems provides the best basis for assessing the value of the treatment. A series of field trials were established to assess the formulation under a variety of climatic conditions. This report describes the continuing field tests of this controlled release formulation.

At the conclusion of the initial EPRI support, a single polymer was selected for further field testing. The ampule selected was installed in a series of utilities across the U.S. The goal was to identify sites with varying climatic conditions as well as pole species. In most instances, the cooperating utilities were also selected on the basis of their willingness to participate through EPRI's Tailored Collaboration Program.

A total of 10 sites were selected (Table I-7) which ranged from Gulf Coast to the dry Rocky Mountain region. Each utility was asked to identify up to 45 poles that included the most prevalent wood pole species in their service area. The ampules were applied to each pole through three steeply angled holes drilled at groundline then upward at 150 mm intervals and around the pole 120 degrees. The holes were plugged with tight fitting, but removable plastic plugs.

Chloropicrin movement from the ampules was measured 1, 2 and 3 years after treatment by first removing the ampules from each pole for weighing. The ampules were returned and the holes were replugged. Ampule weights were monitored at all test sites for the first three years of the test, then at three of these sites over the next 3 years.

Chloropicrin content in the poles was also assessed for the first 3 years after treatment by removing increment cores from 3 sites around the poles, 0.3, 0.6, and 1.2 m above the groundline. An additional core was taken 150 mm below the groundline on one side of the pole directly below the highest treatment hole. The results from these assays have already been presented (Bernstein et al., 1998) and showed that the chemical moved at fungitoxic levels into the wood, despite the slower release rate. We have continued to monitor ampule weights at several sites when other activities bring us near the lines.

Chloropicrin release rates

Chloropicrin release rates varied from as little as 0.60 to 2.35 g per month, depending on location (Table I-8). Release rates were fastest at the Galveston, Texas site, reflecting the warm, humid conditions that are prevalent at this site for much of the year. Chemical release was slow in poles at the Oregon, Indiana, and Missouri sites as well as in one species of poles at the New York site. The Oregon site is a drier location with widely fluctuating temperatures. Climatically, it is very similar to the Colorado site and we were surprised by the differences in release rates between these two sites. Release rates were generally similar between the New York, New Jersey and Pennsylvania sites (with the exception of the cedar and pine poles in New York). These similarities reflect the close proximity of the test sites which are within 100 miles of each other.

Chloropicrin release rates appeared to vary between species at a given site, but the differences were not consistent. The lack of consistency implies that other factors such as initial treatment, pole age or microclimate may be affecting release rates. As a result release rate data should be used cautiously for predicting retreatment cycles

Continued monitoring of ampules in poles at the Oregon, Colorado and Texas sites shows that the chemical continued to diffuse at a steady rate (Figure I-13). Ampules at the Galveston site were nearly empty after 4 years, while those in Oregon and Colorado still contain considerable quantities of chemical.

Table I-7 Locations and characteristics of poles used to evaluated a controlled release chloropicrin formulation at 10 sites across the U.S.

Location	Pole Species	Age of pole (Years)	Pole type
Lapine, Oregon	26 western redcedar 19 Douglas-fir	47	Transmission
Liberty, New York	15 Douglas-fir 15 Western redcedar 15 Southern pine	20	Transmission Distribution
Sterling, Colorado	45 Douglas-fir	20	Transmission
Galveston, Texas	19 Douglas-fir 23 Southern pine	15 to 36	Transmission Transmission
Charlotte, NC	45 Southern pine	17 to 50	Distribution
Chattanooga, Tennessee	45 Southern pine	9 to 46	Transmission
Edison, New Jersey	30 Southern pine	N/A	Distribution
Philadelphia, Pennsylvania	45 Southern pine	14 to 39	Distribution
St. Louis, Missouri	45 Southern pine	17 to 52	Distribution
Merrillville, Indiana	35 western redcedar 10 Southern pine	14 to 38	Transmission Transmission

The release rate data clearly show that chloropicrin will move rapidly from ampules in more tropical climates and implies that the retreatment cycle will be correspondingly shorter. This trend differs little from that found with liquid fumigants and reflects both the higher biological hazard and more rapid diffusion of chemical under warmer temperatures.

Future Trends

The results indicate that chloropicrin readily moved from the ampules and into the surrounding wood over a three year period. Except at the Texas site, all of the ampules still contained chloropicrin 3 to 6 years later and should release chemical for an 4 to 5 additional years. Once the chemical release is completed, it will be essential to sample these poles as the chloropicrin continues to diffuse from wood and eventually declines below a toxic threshold. Based upon current data, our results suggest that a 5 to 10 year release rate coupled with 3 to 5 years for the chemical to diffuse from the wood should produce a minimum protective period of 8 to 15 years. Previous studies have also shown that reinvasion by decay fungi is relatively slow; taking 3 to 5 years in some instances. The exception to these assumptions is the Texas site, where the release occurred much more rapidly. Determining appropriate retreatment rates for this site will require additional sampling to more accurately characterize loss and reinvasion rates.

Table I-8 Release rates of chloropicrin from ampules placed in Douglas-fir, western redcedar or southern pine poles at 10 field test sites located across the United States.

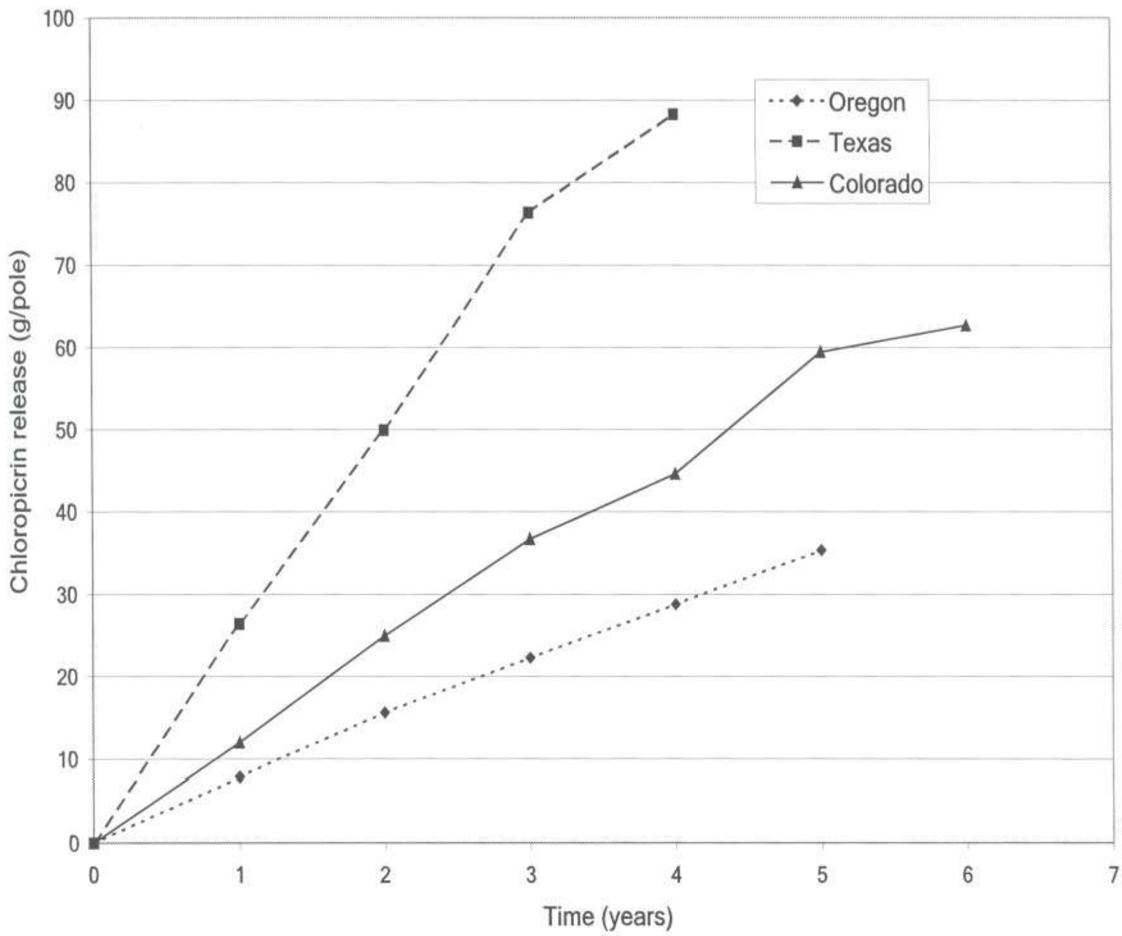
Site	Species	# Poles	Average Fumigant Release/pole/month (g)					
			0-12	12-24	24-36	36-48	48-60	60-72
Oregon	WRC DF	26 19	0.66 0.65	0.66 0.66	0.56 0.51			
New York	WRC DF SYP	15 15 15	0.60 0.83 0.59	0.65 0.97 0.66	0.81 1.12 0.81	- - -	- - -	- - -
Colorado	DF	45	1	1.09	1.06	0.91	1.07	1.14
Texas	DF SYP	19 23	1.82 2.51	1.96 2.08	1.67 2.12	0.56 0.67	- -	- -
N. Carolina	SYP	45	1.16	1.27	-	-	-	-
Tennessee	SYP	45	1.11	1.21	1.16	-	-	-
New Jersey	SYP	30	0.96	1.02	0.9	-	-	-
Pennsylvania	SYP	45	0.9	0.92	0.9	-	-	-
Missouri	SYP	45	0.64	0.73	0.72	-	-	-
Indiana	WRC SYP	35 10	0.60 0.63	0.61 0.64	0.72	- -	- -	- -

One aspect of the ampules that has raised considerable concern among potential users is the long time period in which the liquid chemical remains in the ampules. While slow release was the original goal of this project, the longer the liquid remains in the pole the greater the risk that the pole may be struck by a vehicle or otherwise fail. While the ampules have been shown to be capable of resisting impacts and crushing, no design could make the ampules completely tamper proof. One alternative may be to select alternative polymers that allow for more rapid release of chemical following application. Thus, utilities could take advantage of the exceptional application safety of the system while avoiding the long term risk.

B. Performance of Water Diffusible Preservatives as Internal Treatments

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

Figure I-13 Chloropicrin release rates from ampules installed in poles in Texas, Oregon and Colorado.



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

Fluoride has also been used in a variety of preservative formulations going back to the 1930's when fluor-chrome-arsenic-phenol was employed as an initial treatment. Fluoride, in rod form, has long been used to treat the area under tie plates in railroad tracks and has been used as a dip-diffusion treatment in Europe. Fluoride has a slightly higher toxicity profile than boron and it can be corrosive to metals. Sodium fluoride is also formed into rods for application, although the rods contain less chemical per unit area than the boron rods.

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

1. Performance of fused boron rods in Douglas-fir pole sections:

The field tests evaluating fused borate rods in Douglas-fir pole sections were evaluated two years ago 10 years after treatment and the 12 year data will be presented next year. Boron levels in the various treatments were at or slightly above the threshold at or below the treatment holes, but there was little evidence of upward movement after 10 years. Levels after 10 years had declined to the point where retreatment would be advisable. These poles will be inspected in 2002.

2. Performance of fluoride rods in Douglas-fir poles:

The test to evaluate sodium fluoride rods in Douglas-fir poles was last sampled in 2000 (5 years after treatment) and is not scheduled to be sampled until the summer of 2002. The results to date indicate that fluoride levels generally remained below the accepted threshold for fungal protection (based upon previous soil block tests) but near our laboratory determined threshold levels .

3. Effect of voids on movement of remedial treatments in above ground locations of Douglas-fir poles:

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

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

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

Twenty one Douglas-fir, 2 western redcedar, and 1 ponderosa pine pole in the Portland General Electric system were inspected. Six were found to have substantial above ground decay pockets. Each pole was cut to a length of approximately 8 m and removed from the ground for transport to a site near Salem, Oregon.

While on the ground, each pole was thoroughly inspected to characterize the location and size of the void. The poles were divided into four groups of six poles each. Each group contained at least one pole with a void.

The poles in each group were treated with three rods applied to three 20 mm diameter holes drilled above and below the void.

Each pole received 3 rods applied to 3 horizontal holes drilled around the pole at the top and bottom of the void, or if no void was detected, the 3 holes were drilled 1 m apart. The rods evaluated were fused borate rods (Impel Rods), copper/boron rods (Cobra Rods), fluoride rods (Flurod), and basamid (Ultrafume).

The treated poles were set in a spacing that permitted easy access around each pole. Two poles from each treatment group were removed 12 months after treatment. The treated section was cut from the pole and split with wedges. Each exposed surface was sprayed with the appropriate indicator. Poles treated with the copper/boron rods had one exposed face sprayed with chrome azurol S, a copper indicator and the other with the boron indicator. The sprayed surfaces were photographed. Then the percentage of area between the 2 sets of treatment holes stained by the indicator was measured by counting squares in a 2.5 cm grid.

Poles treated with basamid rods were sampled by removing increment cores from three equidistant locations around each pole 300 mm above and below the treatment sites. 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. The resulting extract was analyzed for MITC by gas chromatography since there is no indicator for MITC. The extracted cores were oven-dried and weighed. MITC content in the poles was expressed on a ug MITC oven-dried g of wood basis.

The first 6 months of the exposure were during the drier summer months when very little movement of chemical would be likely to occur. The remainder of the first year of exposure was an average rainfall period at the test site. Boron and fluoride both diffused between the two points of application in the poles within one year after treatment (Figure I-14 to16), although the degree of movement was variable. For example, fluoride movement from the Flurods differed by ten fold between the two poles sampled, while boron levels in the Cobra rod treated poles differed by a factor of 7 (Table I- 9). Interestingly, copper movement appears to be slightly better than boron movement in this poles, a finding that contradicts prior work. The results indicate that diffusion of the boron or fluoride into the wood remains variable in above ground locations. Examination of the rods removed from the treatment holes showed that all had experienced some degree of degradation, but a majority of the originally applied material remained in the treatment hole (Figure I-17). The condition of the rods suggests that additional diffusion is likely as moisture conditions once again become favorable.

MITC concentrations in poles receiving basamid rods also varied widely (Table I-10). One pole contained chemical levels that would meet or exceed the threshold for fungal protection, while the other has levels that were only 20 to 50 % of the threshold. Basamid tends to decompose more slowly than other fumigants and this rate of decomposition is tied to the levels of moisture present in the wood. The long drying periods typically found above the groundline clearly affected MITC levels in these poles much in the same was as it affected the diffusion of the boron and fluoride.

These results must be viewed cautiously since they represent a limited sample taken early in the treatment cycle. Additional poles will be sampled in the coming year to further delineate the rate of chemical movement in the above ground portion of the poles.

Figure I-14 Degree of fluoride movement in Douglas-fir pole sections treated with fluoride rods in three holes drilled around the pole at two locations one meter apart as determined using an indicator which turns yellow in the presence of fluoride.

Figure I-15 Degree of boron movement in Douglas-fir pole sections treated with fused borate rods in three holes drilled around the pole at two locations one meter apart as determined using an indicator which turns red in the presence of boron.

Figure I-16. Degree of boron and copper movement in Douglas-fir pole sections treated with fused borate/copper rods in three holes drilled around the pole at two locations one meter apart as determined using indicators that turn red in the presence of boron or green in the presence of copper.

Figure I-17 Condition of fluoride, fused borate, and copper/borate rods removed from poles one year after application.

Table I-9 Degree of fluoride, boron or copper movement from remedial treatment rods applied to Douglas-fir pole sections and exposed for one year near Salem, Oregon.

Original Treatment	Rod Treatment	Degree of Treatment (% of area)			
		Area (cm^2)	Fluoride	Boron	Copper
DF-Penta	Impel	2530	-	31	-
DF-Creosote	Impel	1860	-	64	-
WRC- Penta	Cobra	1390	-	4	18
DF-Penta	Cobra	1860	-	30	25
DF-Penta	Flurod	1860	47	-	-
WRC Creosote	Flurod	1860	4	-	-

Table I-10 Residual MITC content in Douglas-fir poles one year after application of basamid above and below the sampling zone.

Original Treatment	Residual MITC Content (ug/g of wood)			
	0.3 m		0.7 m	
	inner	outer	inner	outer
Creosote	9.4 (8.5)	0	8.4 (7.3)	4.5 (7.7)
Penta	52.9 (9.2)	20.8 (20.3)	54.5 (19.2)	13.3 (12.1)

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Objective II

IDENTIFY CHEMICALS FOR PROTECTING EXPOSED WOOD SURFACES IN POLES

Preservative treatment prior to installation provides an excellent barrier against fungal, insect, and marine borer attack, but this barrier only remains effective as long as it is intact. Deep checks that form after treatment, 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 zone can all expose untreated wood to possible biological attack. The Standards of the American Wood Preservers' Association currently recommend that all field damaged to treated wood be supplementally protected with solutions of copper naphthenate. While this treatment will never be as good as the initial pressure treatment, it provides a 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 the treatment and know that it is highly unlikely that anyone will later check to confirm that 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 hole, 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 above ground zones of poles in this region and to develop more accelerated test methods for assessing chemical efficacy. Despite the length of time that this Objective has been underway, above ground decay and its prevention continues to be a problem facing many utilities as they find increasing restrictions on chemical usage. The problem of above ground decay facilitated by field drilling promises to grow in importance as utilities find a diverse array of entities operating under the energized phases of their poles with cable, telecommunications and other services that require field drilling for attachments. Developing effective, easily applied treatments for the damage done as these systems are attached can lead to substantial long term cost savings and is the primary focus of this objective.

A. Evaluate Treatments for Protecting Field Drilled Bolt Holes

The test to evaluate field drilled bolt holes was inspected last year after 20 years of exposure. This test is largely completed, although some follow-up inspection to assess residual chemical levels around bolts in specific poles is planned.

B. Develop Methods for Ensuring Compliance With Requirements for Protecting Field-Damage to Treated Wood.

While most utility specifications call for supplemental treatment whenever a hole or cut penetrates beyond the depth of the original preservative treatment, it is virtually impossible to verify that a treatment has been applied without physically removing the bolt and inspecting the exposed surface. Most line personnel realize that this is highly unlikely to happen, providing little or no motivation for following the specification.

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

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

Penetration of copper from bolts coated with only copper naphthenate was 2 mm one week after treatment and not detectable after 2 weeks of exposure (Table II-1). These results suggest that the copper was largely unable to move from the rod into the wood. While limited movement might not pose a problem if the preservative created a sufficient barrier around the surface of the bolt hole, small checks or cracks could easily compromise this barrier. The inability of the copper to move into these cracks would largely negate the benefits of treatment. The inability to move with moisture into freshly opened checks also appeared to be one of the primary causes of failure for topically applied bolt hole treatments such as the pentachlorophenol in diesel oil treatment used in the original bolt hole test in Objective IIA of this report.

Bolts treated with the the copper/boron paste also had minimal copper penetration 1 week after treatment, but the depth of penetration increased markedly with a second week of exposure. Boron distribution proved more variable. Initially, boron movement appeared to be substantial, but samples exposed for 2 weeks tended to have much shallower boron penetration. These results suggest that measurement errors influenced the initial results. The boron indicator is very sensitive and even small amount of boron inadvertently smeared across the wood surface could lead to a positive result.

The preliminary tests suggested that the presence of a water diffusible component in the paste would be useful for providing deeper protection to the field damaged wood. For this reason, we established the subsequent field trial.

Table II-1 Degree of longitudinal penetration of copper or boron from rods coated with preservative paste and installed in Douglas-fir poles for one or two weeks.

Treatment	Exposure Period (weeks)	Chemical Penetration (mm)			
		Copper		Boron	
		Upward	Downward	Upward	Downward
Cop-R-Nap	1	2	2	-	-
	2	0	0	-	-
CuRap 20	1	2	2	36	42
	2	7	10	6	5

Galvanized rods (300 mm long by 12.7 mm in diameter) were coated along the center 200 mm with a layer of either 5 g of Cop-R-Plastic (copper/fluoride) or 3 g of CuRap 20 (copper/boron)(oven dry basis). The rods were oven dried (54 C), then painted with 2 coats of Plastidip (Figure II-1). One rod from each treatment was applied to each of 26 pentachlorophenol treated Douglas-fir pole sections that were exposed at the Peavy Arboretum test site. Selected poles were split lengthwise around the bolt hole one year after treatment and the average and maximum degree of diffusion of the each paste components was measured after the wood had been sprayed with the appropriate chemical indicator.

The average degree of copper penetration away from the rods tended to be small, ranging from less than 1 mm to 3 mm, while the maximum penetration of copper approached 30 mm in some samples (Table II-2). The copper naphthenate in the CuRap 20 formulation has some water solubility that should help it to move away from the rod, although it clearly did not have an enormous effect on movement.

Average boron and fluoride diffusion were also somewhat limited 1 year after treatment, although substantial diffusion was noted at some locations along the rods (Table II-2, Figures II-2,3). The relatively slow rate of diffusion might reflect, in part, the presence of the spray-on plastic coating. This coating was applied to protect the chemical prior to application since the dry chemical was prone to flaking during handling. We presumed that the plastic coating would be disrupted as the rod was driven into the hole and would also decompose in the presence of the oil. It is unclear if this, in fact, occurred, but the application of only one coat or the use of other less robust coatings might be prudent.

Figure II-1 Examples of galvanized rods coated with copper/boron and copper/fluoride pastes.

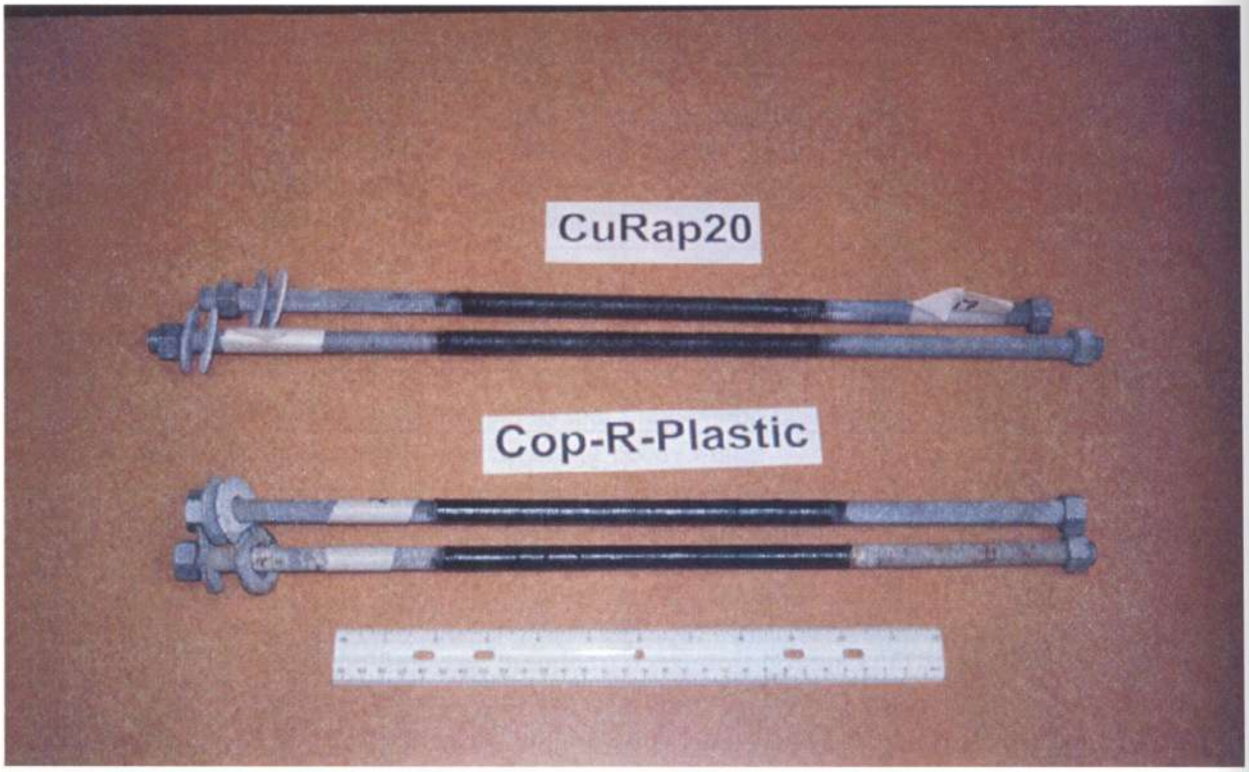

Figure II-2 Degree of copper and fluoride movement away from the sites in Douglas-fir poles where Cop-R-Plastic coated galvanized rods were installed one year earlier.

Figure II-3 Degree of copper and boron movement away from the sites in Douglas-fir poles where CuRap 20 coated galvanized rods were installed one year earlier.

Table II-2. Degree of copper, boron , or fluoride diffusion from galvanized rods one year after installation in creosote treated Douglas-fir pole sections.

	Degree of Chemical Movement (mm)[a]	
Treatment	**Copper Average**	**Boron or Fluoride Average**
Cop-R-Plastic	<1	<1
CuRap 20	3 (1)	3 (1)

[a]. Value represent means, while figures in parentheses represent 1 standard deviation