Performance of an Encapsulated Chloropicrin System for Remedial Treatment of Utility Poles

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Abstract

Chloropicrin remains one of the most effective fumigants for arresting internal decay in large timber structures, but it can be difficult to handle. The potential for encapsulating chloropicrin to improve application safety and control the release rate was investigated in Douglas-fir poles. A quick-release ampule resulted in chloropicrin levels that were similar to those found with a similar amount of liquid chloropicrin, whereas moderate- and slow-release ampules resulted in proportionally less chloropicrin in the wood over a 4-year period, but levels were still well above the protective threshold. The results suggest that encapsulated chloropicrin improved handling safety without reducing performance. Further monitoring is planned.

The development of internal decay in utility poles can markedly shorten the expected service life of a pole (Graham 1973a, 1973b, 1983). Several treatments have been developed for arresting fungal attack in poles, including fused boron rods, dazomet (3,5-dimethyl-1,3,5-thiadiazinane-2-thione), metham sodium (sodium *n*-methyldithiocarbamate), and methyl isothiocyanate (Hand et al. 1970). All of these products can eliminate existing fungi from the pole and limit renewed attack for periods ranging from 7 to 14 years, depending on the chemical (Graham and Corden 1980, Scheffer et al. 1982, Zabel et al. 1982, Morrell and Scheffer 1985, Morrell and Corden 1986, Wang et al. 1989, Schneider et al. 1995, Morrell 2013).

Although all of these treatments are effective, one of the most effective treatments is chloropicrin (trichloronitromethane). Chloropicrin appears to interact more strongly with the wood and has been detected up to 20 years after application (Cooper 1973, 1974; Cooper et al. 1974; Goodell et al. 1980; Morrell and Corden 1986). This exceptional longevity provides added assurance of protection against renewed fungal attack. The primary problems associated with the use of this fumigant are that humans are very sensitive to this compound and the transportation requirements can create difficulties. There have been several attempts to create more controllable delivery systems for this compound, including gelling, gelatin encapsulation, and encapsulating in a tube for short-term handling (Cooper 1974, Goodell 1989). Only the short-term tube was used commercially (Fahlstrom 1982). A large project sponsored by the Electric Power Research Institute developed a controlled-release ampule that was registered for wood use with the US Environmental Protection Agency, but the product was never marketed (Morrell et al. 1994, 1998; Schlameus et al. 1996; Bernstein et al. 2000; Morrell and Love 2002; Love et al. 2004). Increasing restrictions on transportation of chloropicrin have virtually eliminated the use of this compound on utility poles, despite its obvious efficacy. There remains, however, continued interest in the use of chloropicrin among utilities in a controlled-release formulation.

In this report, we describe field-trial results with an ampule-based chloropicrin formulation compared with application of liquid chloropicrin over a 4-year period in western Oregon.

Materials and Methods

Ampule construction

Douglas-fir pole sections (1,200 to 250 mm in diameter by 1.8 m long) were treated with pentachlorophenol in a

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heavy oil to a target retention of 9.6 kg/m^3 and set to a depth of 600 mm at a field site located north of Corvallis, Oregon. Conditions at the site are Mediterranean with warm, dry summers and cool, wet winters. Annual rainfall averages 1.2 m. The site would be classified as having a moderate risk of aboveground decay according to the Scheffer climate index (Scheffer 1971).

Three steeply sloping treatment holes were drilled into each pole beginning at ground line and moving around the pole 120° and upward 300 mm. The holes received either an ampule containing chloropicrin or liquid chloropicrin. Each hole was then plugged with a tight-fitting plastic plug to retard chemical loss.

The treatments evaluated were ampules containing 60 g of chloropicrin designed to provide quick, moderate, or slow release, along with ampules containing 15, 30, or 45 g of chloropicrin. These treatments were compared with application of 60 g of liquid chloropicrin per hole (Table 1).

Table 1.—Chloropicrin treatments evaluated in the field trial.

Treatment[a]	Dosage per hole (g)
Liquid	60
Quick-release (immediate-release) ampule	60
Moderate-release (~ 6-mo) ampule	60
Slow-release (~12-mo) ampule	60
Low-dosage ampule	15
Moderate-dosage ampule	30
Elevated-dosage ampule	45

[a] Each treatment was replicated on five poles, each receiving three ampules.

Ampule loss rates

The rate of chloropicrin movement from ampules designed to provide quick, moderate, or slow release was assessed by weighing each ampule at the start of the test and then periodically removing and weighing ampules for the first 22 months of exposure.

Chloropicrin levels in wood

The poles were sampled 6, 12, and 48 months after treatment by removing increment cores from three equidistant points around each pole 150 mm below the ground line, at ground line, and 600 mm above ground line. The 150 mm belowground sampling point was omitted in the 12-month sampling, and the 48-month sampling involved only removing samples 300 and 900 mm above the ground line. The sampling pattern at 48 months was modified to concentrate on assessing chloropicrin levels in and above the treatment zone.

The outer preservative-treated shell was removed from each increment core; then the inner and outer 25 mm of the remaining core were individually placed into tubes containing 5 mL of hexane. The tubes were incubated for 48 hours at room temperature to allow for chloropicrin extraction. An aliquot of hexane was retained for analysis and the remaining hexane was poured off. The increment cores were aerated for 4 to 5 days before being oven dried at 104°C and weighed.

The extract was analyzed for chloropicrin on a Shimadzu GC-14A gas chromatograph equipped with an electron capture detector (specifically used to detect halogens). The injector and detector temperatures were 100°C and 220°C respectively; the column oven was programmed to an initial temperature of 60°C for 8 minutes. Temperature was then increased at 20°C/min for 2 minutes and held at 100°C for an additional 2 minutes. Separation was achieved using a 2.1 m long by 2.6 mm inner diameter glass column packed with GP 20 percent SP-2100/0.1 percent Carbowax 1500 on 100/120 Supelcoport (Supelco product). Ultrahigh-purity nitrogen was used as the carrier gas at a flow rate of 60 mL/min. Chloropicrin levels were quantified by comparisons with prepared standards and concentrations were expressed on a microgram of chloropicrin per oven-dried gram of wood basis (Morrell and Scheffer 1985).

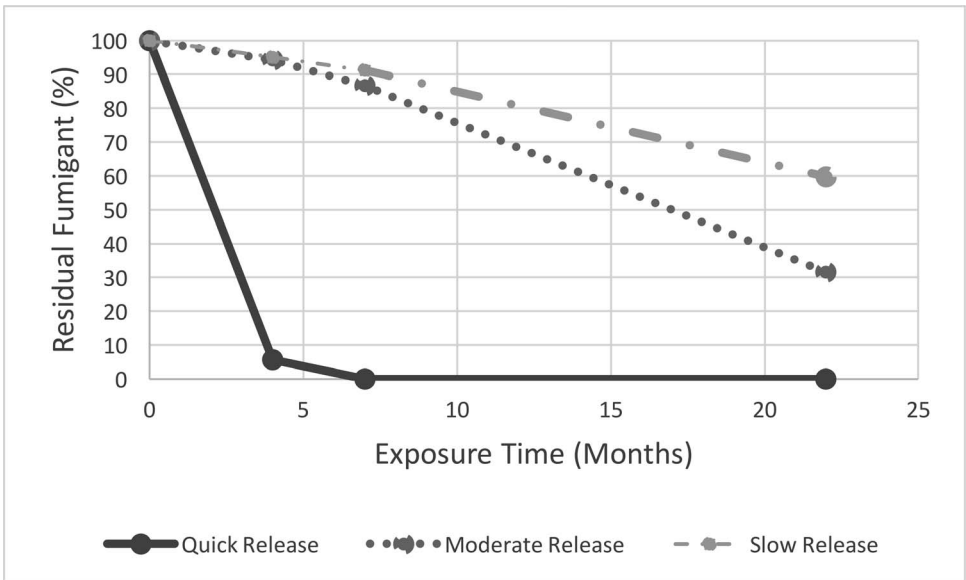

Figure 1.—Rates of chloropicrin release from controlled-release ampules designed to produce quick release, moderate release or slow release as measured in Douglas-fir poles at a 22-month period.

Results and Discussion

Ampule release rates

Chloropicrin release rates were assessed for the first 22 months after treatment. Chloropicrin release from the quick-release ampules was nearly complete 4 months after treatment, indicating that the ampule controlled the chemical until it was safely inside the treatment hole, then allowed for rapid movement into the wood (Fig. 1). Release rates were also similar for the moderate- or slow-release ampules 4 months after treatment, but then began to differentiate with time. Although ampules for these treatments were not empty 22 months after treatment, the slow-release ampules still retained 59.8 percent of the original chloropicrin, whereas the moderate-release ampules contained 31.6 percent of the original chemical. The results illustrate the ability to tailor chloropicrin releases into the wood through ampule design.

Chloropicrin levels in poles

Chloropicrin is highly effective against fungi in wood. Previous testing has indicated that the presence of 20 μg of chloropicrin per oven-dried gram of wood is sufficient to protect against renewed fungal attack, and this level has been used as a target threshold for protection (Morrell and Love 2002).

In general, there were large variations in chloropicrin levels in poles regardless of treatment (Tables 1 and 2). This wide variation is consistent with previous tests and reflects the effects of various wood features such as knots and moisture content on fumigant diffusion. As a result, it is best to look at overall trends to assess the effects of the ampules on chemical levels in the wood.

Chloropicrin levels in poles treated with liquid chemical were orders of magnitude above the protective level in the inner zone of poles 6 and 12 months after treatment, but much lower in wood samples near the outer surfaces (Table 1). The trend toward high levels deeper in the wood reflects the tendency for the steep-sloping treatment holes to direct chemical toward the pole center and is consistent with previous tests. Chemical levels in poles receiving the quick-release ampules were similar to those found with the liquid chloropicrin, reflecting the designed rapid release of the chemical. This system was primarily designed to improve applicator safety and reduce the risk of spills or leaks.

Chloropicrin levels in poles 6 or 12 months after receiving ampules designed for moderate or slow release were lower than those receiving quick-release ampules, which would be consistent with the slower release rates observed through ampule weighing. The results also showed that chloropicrin was present 600 mm above the ground line except at a few locations in the outer zone.

Varying dosages in ampules also produced differing levels of chloropicrin in the wood. Chloropicrin levels were lowest in poles receiving ampules containing only 15 g of chemical and nearly doubled near the ground line in poles receiving ampules with 30 g. Chloropicrin levels in poles receiving ampules with 45 g did not differ markedly from those receiving the 30-g ampules 6 or 12 months after treatment. The lack of a noticeable difference between the two ampule systems is consistent with the small differences in ampule release rates observed through weighing. The results indicate that chloropicrin levels were generally above protective levels within 1 year of application.

Table 2.—Residual chloropicrin in Douglas-fir poles 6 or 12 months after treatment with liquid chloropicrin or chloropicrin in controlled-release ampules.

Treatment	Chloropicrin content (μg/g of wood)[a]									
	−150 mm		Ground line				600 mm above ground line			
	Inner	Outer	Inner		Outer		Inner		Outer	
	6 mo	6 mo	6 mo	12 mo	6 mo	12 mo	6 mo	12 mo	6 mo	12 mo
Liquid	18,398 (19,597)	3,156 (10,177)	13,230 (16,435)	2,311 (3,076)	41 (77)	59 (45)	2,725 (8,112)	5,067 (5,089)	149 (516)	254 (520)
Quick release	22,208 (38,303)	3,166 (10,176)	13,230 (16,435)	895 (578)	41 (77)	83 (52)	2,725 (8,112)	6,124 (5,494)	149 (516)	143 (254)
Moderate release	11,040 (27,396)	67 (191)	4,880 (6,309)	809 (651)	136 (467)	209 (378)	481 (1,288)	4,757 (5,353)	124 (308)	222 (429)
Slow release	2,255 (2,706)	5 (2)	30,147 (3,173)	772 (542)	14 (23)	49 (42)	83 (87)	4,003 (5,227)	47 (123)	67 (47)
Low dose (15 g)	7,901 (13,054)	8 (15)	7,577 (13,601)	638 (568)	57 (198)	44 (25)	412 (276)	3,606 (6,166)	175 (210)	59 (33)
Moderate dose (30 g)	18172 (28166)	122 (187)	17,158 (27,112)	1,031 (558)	191 (465)	116 (204)	302 (229)	20,546 (260)	25 (51)	260 (504)
High dose (45 g)	17,182 (29,866)	128 (225)	61,241 (15,3853)	1,206 (380)	73 (179)	158 (314)	265 (214)	15,836 (29,589)	274 (756)	206 (357)

[a] Values represent averages of 15 samples per position per treatment. Values in parentheses represent 1 standard deviation.

Table 3.—Residual chloropicrin content of increment cores removed from Douglas-fir poles 48 months after application of chloropicrin in liquid form or encapsulated in ampules designed to deliver a specific dosage or release chemical at a specific rate.

	Residual chloropicrin content (μg/ g of wood [oven-dried])[a]			
	300 mm above ground line		900 mm above ground line	
Treatment	Inner	Outer	Inner	Outer
Liquid	52,571 (59,296)	31,025 (34,742)	38,209 (50,271)	1,154 (1,118)
Quick release	41,121 (55,073)	31,785 (45,836)	13,987 (26,045)	685 (804)
Moderate release	94,366 (92,791)	38,262 (57,632)	9,240 (15,454)	1,155 (1,584)
Slow release	120,633 (95,470)	114,940 (107,933)	2,735 (3,111)	1,101 (1,518)
15 g	49,389 (73,706)	17,655 (38,791)	249 (141)	94 (99)
30 g	104,897 (41,798)	68,176 (81,725)	428 (131)	120 (106)
45 g	277,438 (207,156)	52,244 (58,510)	21,859 (47,933)	7,577 (16,735)

[a] Values are means of six samples from each of five poles per treatment.Values in parentheses represent 1 standard deviation.

Chloropicrin levels in poles 48 months after treatment were considerably higher than those found after 12 months, particularly 300 mm above the ground line (Table 2). Chloropicrin levels in the inner zones of poles receiving either liquid chloropicrin or the quick-release ampule were similar, but the levels 900 mm above the ground line were lower in poles receiving the quick-release ampule. It is unclear why these differences emerged away from the application point, although levels in poles receiving either system are well above the threshold.

Chloropicrin levels in the poles receiving the moderate- or slow-release ampules tended to be much higher 300 mm above the ground line than those found in poles receiving either the liquid or quick-release ampule. Once again, chemical levels were orders of magnitude above the protective threshold. The higher levels of chloropicrin in poles treated with the slower-release-rate ampules was perplexing, but may reflect how the chemical diffuses through the wood. Large releases of chloropicrin associated with either the liquid or quick-release treatments may overwhelm the capacity of the wood to sorb chemical, whereas slower release rates may allow for more complete interactions. This difference was not noted 900 mm above the ground line and farther away from the ampules, where chloropicrin levels were more consistent with the 6- and 12-month observations.

Chloropicrin levels in the inner zones of poles receiving ampules with 15, 30, or 45 g of chemical tended to follow a trend of increasing concentrations with increasing ampule dosage (Table 3). This effect was nearly linear 300 mm above the ground line, but more variable at the 900-mm location. Chloropicrin levels in the outer zones of these poles were more variable, although there was a trend of increasing concentration with increasing dosage 300 mm above the ground line.

Although the test is relatively young, given the typical 7- to 10-year treatment cycle for these chemicals, the results show that encapsulating chloropicrin had no negative effects on the resulting fumigant distribution. The ampules also sharply reduce the risk of accidental releases during application. Further assessments of these poles are planned.

Conclusions

Controlled-release ampules resulted in chloropicrin levels in the wood that were well above those required for fungal protection and did not differ markedly from levels found with application of liquid chloropicrin. The results indicate that the ampules can reduce the risk of inadvertent chloropicrin release without affecting efficacy.

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