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# **Potential for migration of boron from fused boron rods used as internal remedial treatments of utility poles**

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## **ABSTRACT**

The distribution of boron in Douglas-fir utility poles and in the surrounding soil was assessed over a 54 month period following application of fused boron rods. Boron levels in the wood never reached the levels that might be predicted if diffusion were to produce a uniform chemical distribution, nor did levels in the soil suggest that boron was becoming more concentrated. The results suggest the need for further studies to better delineate boron distribution in wood and to better understand the rate at which boron moves from wood and into the surrounding soil

**Keywords:** boron rods, Douglas-fir poles, migration, soil contamination

## **INTRODUCTION**

Fused boron rods have a long history of successful usage, first in Europe and later in AustralAsia and North America for arresting internal decay in windows, timbers, utility poles and other large timbers (Dickinson et al., 1988; Dietz and Schmidt, 1988; Dirol, 1988; Ruddick and Kundzewicz, 1992). Boron has exceptional activity against insects and is also effective against most conventional wood decay fungi. Boron rods are attractive for these applications because they introduce a highly concentrated dosage of boron directly inside the wood where the decay is presumably occurring. A variety of field trials have shown that subsequent boron diffusion from the rods and into the surrounding wood is a primarily function of wood moisture content, although wood permeability can also affect the rate of movement (Morrell et al., 1990; 1992). Field trials have shown that protective levels of boron remain in Douglas-fir poles up to 15 years after rod application.

While boron rods have excellent potential for remedial treatment of utility poles and large timbers where wood moisture levels are suitable for adequate diffusion, the ability of boron to diffuse with moisture means that it can, in theory, also diffuse out of the wood and into the surrounding environment (Smith and Williams, 1967). While the overall levels of boron applied to poles are relatively small and boron is a naturally occurring element, there is general concern over uncontrolled releases of any pesticide into the environment. As a result, it is important to begin to quantify the potential for movement of boron from fused boron rods in poles into the surrounding environment.

In this report, we evaluate boron levels in Douglas-fir poles treated with fused boron rods as well as the soil surrounding these poles to determine potential migration of boron.

## MATERIALS AND METHODS

*Pole Installation:* The poles were at a site located near Corvallis, Oregon that receives approximately 1.1 m of rainfall per year. The climate is Mediterranean with warm dry summers and wet, cool winters. The site has a Scheffer climate index of approximately 45 (Scheffer, 1971). The soil is Olympic silty-clay loam. The top 200 mm is slightly acidic (pH 5.4) and has approximately 12 mm of humus. Organic matter and nitrogen content are 4.71 % and 0.14 % respectively. Brush on the site is controlled through regular mowing coupled with periodic application of glyphosate (Monsanto Chemical Co, St. Louis, MO).

Pentachlorophenol treated Douglas-fir pole stubs (280-300 mm in diameter by 2.1 m long) were set to a depth of 0.6 m. Three steeply sloping treatment holes (19 mm x 350 mm long) were drilled into the poles beginning at groundline and moving upward 150 mm and around the pole 120 degrees. The boron rods were added to the holes at a total dosage of 238 g (345 g boric acid equivalent (BAE) basis) per pole. The holes were plugged with plastic reusable plugs.

*Boron Analysis:* Chemical movement in the poles was assessed 18, 30, 42, and 54 months after treatment by removing increment cores from three equidistant sites beginning 150 mm below ground, then 0, 300, 450, and 600 mm above groundline. The outer, preservative-treated shell was removed, and then the outer and inner 25 mm of each core was retained for chemical analysis. The core segments from a given height on a pole were ground to pass a 30 mesh screen and the resulting dust was extracted in hot water. The resulting extract was analyzed using the azomethine H/carminic acid method. (AWPA, 2012) Boron content was expressed on a  $\text{kg/m}^3$  of boron on a boric acid equivalent. The data were used to develop boron distribution maps at various locations in the pole. The amount of boron present in the wood and the surrounding soil were then estimated on a wt/wt basis based upon the original dosage (345 g on a BAE basis) and assumed densities of  $448 \text{ kg/m}^3$  for the wood and either  $1620$  or  $2160 \text{ kg/m}^3$  for the soil using several hypothetical scenarios:

1. All boron remained in the pole within a zone extending 300 mm above groundline to the butt
2. Boron diffused to a steady state within the wood and into the soil for a distance of approximately 150 mm around the pole
3. Boron diffused to a steady state within the wood and into the soil for a distance of 300 mm around the pole

These approaches are predicated on the premise that boron will diffuse at a steady rate from the treatment hole, into the wood and finally the surrounding soil. It was also assumed that boron will diffuse into the soil at the same rate without interacting with soil components. We also recognize the potential for boron to interact with soil elements or for it to diffuse through soil at a much more rapid rate than it might in wood.

*Soil Analysis:* Boron levels in soils were assessed 58 months after treatment by collecting soil from immediately adjacent to the poles, as well as 150 and 300 mm away. Additional soil samples were taken from a site immediately adjacent to, but uphill from the poles to provide

insights into background levels at the site. The soils were air-dried, then sieved through a 2 mm screen to remove rocks and other materials. The soils were acid digested and the resulting extract was analyzed for boron by Ion-Coupled Plasma Spectroscopy (Anonymous, 1989; Gaviak et al., 1994). The results from soils around the poles were compared with those for soil removed uphill from the test where no boron had been used. These results were compared with those predicted using the three scenarios for boron distribution outlined above.

## RESULTS AND DISCUSSION

The threshold for boron for protection against internal decay has been calculated at 0.5 kg/m<sup>3</sup>. This value is based upon carefully controlled trials of wafers treated to specific levels with boron (Freitag and Morrell, 2005). The boron levels in poles receiving boron rods tended to be below the threshold of 300 or more mm above the groundline, regardless of sampling time or core position (inner/outer)(Table 1, Figure 1). While boron is water diffusible, it has only a limited ability to diffuse upward. Boron levels 150 mm below groundline and at groundline were above the threshold in the inner zone 18 months after treatment, but below the threshold in the outer zone. The difference reflects the tendency of the sloping treatment holes to direct chemical downward toward the center of the pole. Boron levels were above the threshold for both the inner and outer zones 30 months after treatment, but still below threshold in the outer zone 150 mm below groundline. Boron levels were all well above threshold both below and at groundline 42 and 54 months after treatment. These results are consistent with previous tests showing that uniform movement of boron requires several years (Freitag et al., 2000; Morrell et al., 1990, 1992; Morrell and Schneider, 1995). If these trends continue, we would expect to find elevated boron levels in the poles for 5 to 7 more years. The overall trends indicate that the boron based systems are producing protective levels within the groundline zone, but diffusion above this zone is very limited.

One way to approach the potential for boron movement from the wood and into the surrounding soil is to determine a mass balance. This approach is not without risk of error since it assumes that boron will move from the rods and into the wood, through the

Months after Treatment	Boron Content (kg/m <sup>3</sup> BAE)						Avg
	-150 mm		Groundline		300 mm above		
	Inner	Outer	Inner	Outer	Inner	Outer	
18	2.59 (1.44)	0.37 (0.35)	7.68 (10.11)	0.16 (0.20)	0.02 (0.03)	0.97 (2.17)	4.61
30	6.67 (8.01)	0.39 (0.40)	1.30 (0.47)	2.14 (3.60)	0.16 (0.13)	0.15 (0.14)	1.80
42	5.49 (5.77)	0.98 (0.88)	6.30 (7.76)	3.09 (3.91)	0.53 (0.74)	0.72 (1.25)	2.85
54	3.34 (2.06)	1.12 (1.42)	3.57 (2.76)	0.84 (0.46)	0.47 (0.87)	0.13 (0.18)	1.58

oil treated shell and into the surrounding soils at a uniform rate, but it also represents the simplest approach to determine how much boron might be present in a given area.

For this purpose, we considered the volume of the wood in the treated zone to be 300 mm above the groundline to the butt of the pole or approximately 950 mm. We considered the possibility that small amounts of boron might be wicked upward by adding 50 mm to the upper zone. The total volume of this area for the poles in question would be 0.0636 m<sup>3</sup>. Since the total amount of boron applied was 0.345 kg in the treated zone, the average boron distribution, assuming that no boron migrated from the wood would be 5.42 kg boron/m<sup>3</sup> of wood (on a boric acid equivalent basis). This would be approximately 1.68 % bae (wt/wt basis) which represents about 3 times the threshold of 0.5 % bae (wt/wt) (Williams and Amburgey, 1987). Average boron levels detected in the poles between 18 and 54 months ranged from 1.58 to 4.61 kg/m<sup>3</sup> with the highest level detected 18 months after treatment. Boron levels varied between 1.58 and 2.85 kg/m<sup>3</sup> over the next 36 months. The highest levels were detected 150 mm below the groundline toward the pole centers, reflecting the tendency of the application pattern to direct boron in this direction. Levels in individual samples removed from the same location but on different poles varied widely, as evidenced by the high standard deviations. This is typical of field trials of this nature and reflects the variability of the wood coupled with the relatively small wood sample analyzed. The results indicate that boron levels remain below those that would develop through uniform diffusion. The results suggest that using an averaging approach to determine distribution may not be suitable. Another problem with the current approach is our limited sampling zone. Boron should tend to move downward in the poles, but our sampling zone was limited to the zone 150 mm below the groundline and ignored the zone below that level. We plan to remove selected boron rod-treated poles to sample this deeper zone to determine if boron levels are correspondingly higher as a result of downward migration. The other short-coming of averaging boron distribution is the lack of data on boron content of the treated zone. In our tests, we routinely remove the treated zone and analyze the remaining untreated wood. This approach is taken because the boron is primarily intended as a remedial treatment for the non-treated heartwood. The boron content of the treated zone is largely ignored in our tests as well as in previous studies. We plan additional trials to determine the ability of boron to diffuse through an oil treated shell.

Background levels of naturally occurring boron in soil at the test site ranged from 0.6 to 0.8 ppm (Table 2). Analysis of soil immediately adjacent to the poles as well as 150 mm away produced results that were similar to those found in control soil samples removed up-gradient from the test site. If boron had moved uniformly into the soil, concentrations would have approached 2000 ppm within 150 mm of the pole. Clearly, this did not occur. While this does not necessarily mean that boron is not migrating from the poles, it is clearly not migrating at levels that would alter the concentrations surrounding the pole. One possible explanation is that the boron is migrating so quickly into the surrounding soil that it is not detectable; however, that seems less likely, given the lack of noticeable differences in boron levels immediately adjacent to the pole. Boron may also be retained more closely by the preservative treated shell and this possibility is supported by the exceptional length of time that boron can be found in Douglas-fir heartwood after rod application. The widely spaced distribution of poles that could be treated with boron rods also reduces the risk of developing elevated boron levels in any given soil. The results; however, also suggest the need for a

more detailed examination of boron diffusion from rods into poles and the surrounding soil given the inability to account for all of the material applied.

Table 2. Boron content in soil samples removed immediately adjacent to or 150 mm away from penta-treated Douglas-fir poles 60 months after internal application of boron rods.		
Pole #	Boron Content (ppm) <sup>a</sup>	
	Adjacent to pole	150 mm from pole
Pole 408	0.6	0.5
Pole 415	0.6	0.6
Pole 428	0.6	0.5
Pole 448	0.9	0.7
Pole 454	0.7	0.6

<sup>a</sup>Boron content up-gradient ranged from 0.6 to 0.8 ppm

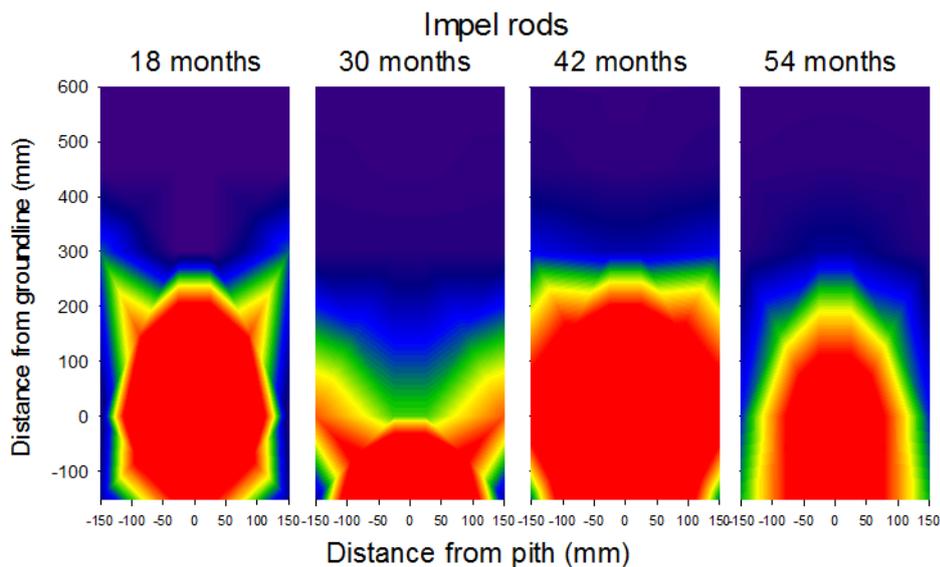


Figure 1. Boron levels in Douglas-fir poles 18 to 54 months after application of fused boron rods where dark blue indicates levels below the threshold for fungal attack and trends towards red indicate increasing boron levels.

## CONCLUSIONS

Analysis of boron levels in poles 18 to 54 months after boron rod application illustrate the difficulty of predicting distribution; however, the lack of increase in boron concentration in the soil suggests that the boron is not migrating from the wood at high levels. Further studies are underway to better understand both the complete distribution of boron in the poles as well as the potential for boron to move through soils.

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