DEVELOPMENT OF AN ENVIRONMENTALLY ACCEPTABLE WOOD POLE GROUNDLINE PRESERVATIVE FORMULATION

S.H. Hawthorne
Ontario Hydro Research Division

J.N.R. Ruddick
University of British Columbia
(formerly of Forintek Canada)

ABSTRACT

Many Canadian electrical utilities carry out groundline remedial preservative treatment on aged wood utility poles using a pentachlorophenol based grease. To ensure that in the event of restrictions on the use of pentachlorophenol electrical and telephone utilities are able to continue groundline treating a program was undertaken to identify an environmentally acceptable wood pole preservative formulation which would meet or exceed the performance criteria of present pentachlorophenol formulations. Copper naphthenate, copper-8- quinolinolate, and tributyltin oxide were evaluated and only copper naphthenate was considered to be a suitable replacement for pentachlorophenol. Groundline preservative formulations incorporating copper naphthenate at a concentration of 2% as copper metal are expected to provide protection against decay for ten years to poles originally pressure treated with oilborne or waterborne preservatives. Copper naphthenate is a low toxicity preservative, not known to harm humans, animals, or plants and is registered as a general use wood preservative with Agriculture Canada and the United States Environmental Protection Agency.

INTRODUCTION

Electrical and telephone utilities throughout the world use large numbers of wood poles for the support of overhead transmission and distribution lines. To prolong the life of these poles almost all are full length pressure treated or butt thermally treated with a suitable preservative. Creosote which had been used as a wood preservative for many years was replaced by pentachlorophenol (penta) in the mid-1950's as the preferred preservative for poles. More recently the waterborne preservatives, chromated copper arsenate (CCA) and ammoniacal copper arsenate (ACA) have been used for significant quantities of poles, particularly CCA.

It is well established with creosote and penta treated poles that after a number of years in service the preservative content in the groundline area decreases below that required to prevent decay. This leaves the pole susceptible to decay thus weakening the pole in the critical groundline area causing it to fall over or require replacement before that occurs. To prevent this from occurring, it is current industrial practice for electrical utilities to employ remedial groundline treatments to reinforce the preservative level in wood poles, thus extending their service life. Remedial groundline treatment is carried out on a regular schedule prior to the onset of decay, or on those poles in which decay is suspected. It is also undertaken when poles are relocated, or have their groundline level changed. When incorporated into a proper line maintenance program, groundline remedial treatment can extend the effective life of pentachlorophenol-treated and creosoted poles by at least ten years.

In the mid 1970's all three classes of the major wood preservatives came under scrutiny by the United States Environmental Protection Agency. Most groundline preservative formulations incorporate pentachlorophenol as the prime fungicide and it was feared that the US EPA would prohibit the use of pentachlorophenol in any application. In the United States the EPA has now classified all three chemicals for restricted use only by certified applicators and limited their use to certain applications. All three preservatives are still permitted for pressure treatment of wood poles and groundline treatment of poles with pentachlorophenol is permitted if proper clothing is worn (1).

In Canada, Agriculture Canada produced preliminary regulatory actions on chlorophenols in 1981 and has recently produced a discussion document on pentachlorophenol which is likely to form the basis for finalizing regulations on this chemical (2). It is probable that the final Canadian regulatory position will be similar to that of the United States with the general conclusion that the benefits outweigh the risks if the proper precautions are followed. However, it is possible that although the regulatory agencies may permit continued use of pentachlorophenol for groundline treatment, utilities may wish to have an alternative which is more acceptable from an environmental and health viewpoint.

To ensure that Canadian electrical utilities are able to undertake remedial groundline treatments in the future, a program was initiated to identify an environmentally acceptable wood pole preservative formulation which will meet or exceed the performance criteria for present pentachlorophenol formulations. In 1975 Ontario Hydro carried out a literature search of alternative preservative materials; three fungicides — copper naphthenate (copper nap.), bis(tributyltin) oxide (TBTO) and copper-8-quinolinolate(copper-8-Q) were selected for further study (3).

In 1979 a contract was awarded by the Canadian Electrical Association to Ontario Hydro Research Division to continue this investigation. Five formulations were prepared commercially and applied to 60 pine stubs using a hydraulic spade in the Ontario Hydro test plot at Barrie, Ontario.The preservative penetration and retention results obtained after one year were reported to the CEA and it was recommended that the project be expanded to include application to other wood species. In 1982 Forintek Canada in Vancouver, BC, was awarded a CEA Contract to extend the Ontario Hydro work specifically to determine preservative penetration, retention, and effectiveness in preventing decay in Western Canadian wood species. Preservative effectiveness in preventing decay was evaluated using a bioassay developed at Forintek. The results after one year and three years were reported in 1987 (4). In addition, in 1981 and 1982 independently of the Canadian Electrical Association, Ontario Hydro Research Division installed and groundline treated 80 additional test stubs of various species and also treated 200 pine poles in line at Bowmanville, Ontario with one of the groundline preservative formulations using copper naphthenate. In 1986 another CEA contract was awarded to Ontario Hydro and samples were obtained from: the 60 pine stubs originally installed and treated in 1979, the 80 additional stubs also in the Barrie test plot, and from 20 of the 200 poles in line. The samples were

analyzed for preservative retention and a bioassay test to determine preservative effectiveness was carried out on a limited number of samples. The results obtained five to seven years after groundline treatment were reported in 1987 (5).

ALTERNATE PRESERVATIVE SELECTION

In addition to pentachlorophenol, the American Wood Preservers Association Standard P8-77, Standard for Oil-Borne Preservatives describes three other preservatives: copper naphthenate, copper-8-quinolinolate, and bis (tri-n- butyltin) oxide. Although other oil soluble preservatives are described in the literature only these three organo-metallic compounds are recognized by the Canadian Standards Association (CSA) and the American Wood Preservers Association (AWPA).

Until recently minimum retention levels of these preservatives necessary to prevent decay in wood poles in ground contact had not been recommended by the Canadian Standards Association or the American Wood Preservers Association. In 1987 the AWPA approved the inclusion of copper naphthenate in Standard C2 for the treatment of lumber, timber and ties both for above ground and ground contact uses. It is expected that in 1988 the AWPA will approve copper naphthenate for the pressure treatment of poles at assay zone retention levels of 0.96 kg/m^3 for Southern Yellow Pine and 1.2 kg/m^3 for Douglas Fir as copper metal. The retention of copper naphthenate in poles treated by a thermal process will be specified at 1.6 kg/m^3 as copper metal in the outer 13 mm. Copper naphthenate is also recommended by CSA for the field treatment of cut edges of preserved wood foundation material, a ground contact application. The preservative solution must be prepared with a solvent conforming to CSA Standard 080-P9 and contain a minimum of 20 g/kg copper metal. Similar recommendations were made by Committee P-3 of the American Wood Preservers Association.

At this time, copper-8-quinolinolate and tributyltin oxide (TBTO) are not recommended by either association as preservatives for wood in ground contact. Solubilized copper-8-quinolinolate (AWPA P8-77) is specified in CSA Standard 080.29 for the pressure treatment of lumber for use in harvesting, storage, and transportation of food stuff for human consumption. The minimum preservative retention required is 3.2 kg/m^3 of solubilized copper-8- quinolinolate (0.6 kg/m^3 copper) in the treated wood. AWPA Standard C2-77 permits the use of TBTO for preservation of lumber, timbers, bridge ties and mine ties for above ground applications only at a preservative retention level of 1.28 kg/m^3 in the assay zone (0-15 mm).

Each of these preservatives has been the subject of laboratory and field service tests to determine their effectiveness as wood decay preventatives (6,7,8,9). Based upon the data from laboratory threshold tests and field service stake tests minimum desired retentions of these three materials have been suggested in Table 1 along with the generally accepted toximetric threshold for pentachlorophenol. It is believed that these levels, if maintained, will prevent decay when used as remedial groundline preservatives in a heavy petroleum oil grease. To maintain preservative retentions equal to or greater than these over a period of years after groundline treatment it is necessary to achieve preservative retentions which exceed these minimums within one to three years after treatment.

Table 1

Minimum Desired Retentions Necessary to Prevent Decay

a)	copper naphthenate	0.5 kg/m^3 as copper
b)	copper-8-quinolinolate	0.4 kg/m^3 as copper
c)	tributyltin oxide	0.6 kg/m^3 as tin
d)	pentachlorophenol	2.4 kg/m^3 as pentachlorophenol

It is recognized that the minimum desired retentions suggested above are subject to modification depending upon wood species, solvent carrier, fungi type, test conditions, etc. The values specified are considered to be conservative to ensure adequate protection.

PRESERVATIVE RETENTIONS

Groundline remedial treatments are intended for application to poles in which the original preservative is still providing protection against decay. It is desired by groundline treatment to increase the protection against decay for at least an additional 10 years. The present groundline remedial treatment program within Ontario Hydro is based on a ten year treatment cycle with initial remedial treatment being carried out on full-length treated poles after 25 years of service and on butt-treated poles after 15 years in service. Previous Ontario Hydro field experience had indicated that to ensure adequate protection during the ten year period between remedial treatments it is considered necessary that the preservative retention level in the outer 12 mm of the wood be at least two times the minimum level within two years of remedial treatment (11).

To evaluate the performance of the groundline preservative formulations in this work two methods were chosen. The first was the determination of the retention of the fungicide from the groundline preservative formulation in the outer 12 mm of the pole or stub to which it was applied. The second was a bioassay developed by Forintek in which cores removed from remedially treated stubs were exposed to selected wood decaying fungi to assess the ability of the total amount of preservative present to prevent decay.

The stubs or poles discussed here fall into four categories:

1. Jack Pine stubs in the Barrie test plot, groundline treated in 1979, sampled after one year in 1980, and after seven years in 1986.
2. Western Cedar and Eastern Spruce stubs in the Barrie test plot, groundline treated in 1981 and 1982, and sampled after four or five years in 1986.

3. Jack Pine, Red Pine, and Western Cedar poles in line at Bowmanville, groundline treated in 1981, and not sampled previously.
4. Western Cedar, Western White Spruce, Lodgepole Pine, and Jack Pine stubs in Surrey, BC, groundline treated in 1983, sampled after one year in 1984, and after three years in 1986.

Determination of the preservative retention was straightforward when the groundline preservative was different from the preservative already present in the treated wood. However, for those stubs/poles in which the fungicide in the original treatment and the groundline treatment was the same it was necessary to obtain an estimate of the amount of fungicide contributed by the original preservative and by difference an estimate of the amount of fungicide contributed by the groundline treatment. It should be noted that the net retention data obtained for Eastern Spruce stubs pressure treated with ACA and groundline treated with a copper containing preservative are in most cases negative and are not discussed further.It was not possible to obtain estimates of the net preservative retention for the Jack Pine poles pressure treated with chromated copper arsenate (CCA) in 1949 and groundline treated with copper naphthenate in 1981 as insufficient information was available on the original preservative. The retention results from this small group of poles showed high levels of copper in the outer 12 mm but it is not possible to determine the contribution of the groundline preservative. The retention results are not discussed further but the bioassay results are presented.

In Tables 3, 4 and 5 the retentions are presented for the first 6mm and the second 6 mm of wood depth and mathematically combined to provide the preservative retentions in the outer 12 mm for the mean values of the net preservative retentions for each set of five stubs. Some of this data is presented graphically as bar graphs in Figures 1 to 10.

It should be noted that the observations and conclusions in this publication are based upon the averaged data for the outer 12 mm of wood as this was the criterion originally established for this work. Tables 2, 3 and 4 clearly indicate that much higher preservative retentions are present in the first 6 mm of wood than in the second 6 mm. This would result in greater protection for the outer 6 mm of wood than is being suggested in this publication. This effect will be examined further in a later publication.

Effect of Supplier and Concentration

It is difficult to compare the retentions obtained with various preservatives as the minimum retention desired is different for each: copper naphthenate 0.5 kg/m^3, copper-8-quinolinolate 0.2 kg/m^3, tributyltin oxide 0.6 kg/m^3, and pentachlorophenol 2.4 kg/m^3. To assist in this comparison the net preservative retention data for the outer 12 mm in Tables 2, 3 and 4 have been combined in Table 5 and divided by their respective minimum retentions to produce the net retention ratio.

$$\text{Net Retention Ratio} = \frac{\text{net preservative retention in outer 12 mm of wood}}{\text{minimum retention desired}}$$

Figure 1 illustrates the results of groundline treatment of Jack Pine stubs, originally treated with creosote, with four copper containing formulations, three of which are copper naphthenate and the other is copper-8-quinolinolate. Figure 2 illustrates the results of groundline treatment of Western Cedar .pa stubs, originally treated with creosote or penta, with two copper naphthenate preservatives and one copper-8-quinolinolate preservative (Tables 2 and 5).

Both copper naphthenate preservatives which contained 10 g/kg of copper produced similar retentions in Jack Pine stubs originally pressure treated with creosote or pentachlorophenol, particularly 1 year after groundline treatment. The 7 year data show a higher retention from the material supplied by Chapman but the difference is not sufficient to suggest a preference for one supplier over the other. The material supplied by both companies resulted in copper retentions 2-3 times the minimum desired level of 0.5 g/kg copper 1 year after treatment and 1.5-2.5 times the minimum 7 years after treatment, that is, net retention ratios of 2-3 and 1.5-2.5.The copper retentions achieved with the copper naphthenate formulation containing 5 g/kg copper in general were less than half those achieved with the two 10 g/kg formulations and except for the Jack Pine-creosoted stubs did not reach the minimum level of preservative necessary to prevent decay. Copper-8-quinolinolate and TBTO both produced retentions lower than would be expected on the basis of concentration alone and generally did not reach the minimum retention desired. These data show that while higher concentrations resulted in higher retentions there appeared to be differences in the diffusion rates of the different preservatives. With respect to copper naphthenate it is apparent that any groundline preservative formulation based on this fungicide must contain at least 10 g/kg copper.

Effect of Preservative Type, Wood Species, and Original Preservative

TBTO. From Table 5 and Figures 3 and 4 it can be seen that the retention of tin in those stubs groundline treated with TBTO rarely reached the minimum retention desired to prevent decay. Although there were some exceptions this observation was generally true for all species/original treatment combinations at 1 year, 3 years, and 7 years. The results were similar at Barrie, Ontario and Surrey, BC. The notable exceptions to the above observation were those which had not been previously treated, ie, the controls. The Lodgepole Pine controls reached a tin retention approximately twice the minimum desired within one year and maintained this level after three years. The Western Red Cedar and the Western White Spruce controls reached a retention 1.2 - 1.4 times the minimum after three years. These results suggest that the presence of the original preservative (oilborne or waterborne) inhibits the absorption of the TBTO into the wood.

Copper-8-Quinolinolate. The results obtained with copper-8-quinolinolate at Barrie are illustrated in Figures 1 and 2 and are similar to those obtained with TBTO. The retention levels observed in Jack Pine and Western Cedar creosoted and penta treated stubs in Barrie are below the minimum desired retention of 0.4 kg/m^3 after one year and after five or seven years. Similar results were observed at Surrey BC, again regardless of wood species and original treatment. Western Cedar treated with ACA did display a net retention ratio of 1.2 after 1 year, but after three years this had dropped to 0.5. It would appear that copper-8-quinolinolate could provide some additional protection where the original preservative was marginal but it could not prevent decay if it were the only means of protection.

Copper Naphthenate. The Jack Pine creosoted and penta treated stubs at Barrie reached net retention ratios of 2.9 and 2.4 respectively within one year of groundline treatment, but after seven years these had decreased to 1.9 and 1.6, still well above the minimum desired retention to prevent decay (0.5 kg/m^3) (Figure 1). The Jack Pine creosoted poles in line at Bowmanville had a copper naphthenate retention ratio of 2.5 even after five years. The Jack Pine penta treated poles had a retention ratio of 1.5 after five years and the Red Pine penta treated poles had a surprisingly low retention ratio of 1 after five years (Table 5).

The Western Cedar creosoted and penta treated stubs in the Barrie plot had net retention ratios for copper naphthenate of 1.4 and 1.2 respectively after 5 years (Figure 2). As no previous sampling had been done on these stubs it is not known if this is a decrease from a previously higher figure, but the Western Cedar creosoted poles at Bowmanville displayed a retention ratio of 2.3 after five years. It should be noted that the Western Cedar poles sampled at Bowmanville were treated and installed in 1945, over 35 years before being groundline treated in 1981. The Western Cedar stubs in the Barrie plot were treated and installed only two to three years before being groundline treated. It is likely that the original preservative in the poles at Bowmanville was well depleted before the groundline treatment making it possible for the wood to absorb a significant quantity of preservative grease and dissolved fungicide. The Barrie stubs being relatively new still contained large amounts of the original preservative and carrier making ingress of the groundline preservative by absorption of the grease more difficult with dissolution of the groundline fungicide in the original preservative or carrier assuming a greater role.

The retention ratios in the stubs at Surrey after one year were generally less than those obtained at Barrie ranging from 0.8 to 1.5. The three year data show a marked increase over the one year results except for the Western White Spruce stubs originally treated with ACA which dropped from 1.2 to 0.3. The reason for this is not known. The remaining stubs had retention ratios varying from 1.9 to 2.9 after three years (Figures 5 and 6).

The Surrey, BC data did not indicate major differences between species/original treatment combinations but the Lodgepole Pine control stubs which were prepared from aged poles had the second highest retention after three years. The stubs which had the highest retention after three years were prepared from aged Western Cedar poles originally treated with creosote. Both of these trends (aged poles and creosote as the original treatment) had been observed in the Ontario Hydro data described above. It would appear that the retentions in the first and second 6 mm zones should clearly improve the protection of the stubs.

Pentachlorophenol. Pentachlorophenol was included in this test program to provide a standard against which the other preservatives could be measured and to permit a systematic evaluation of the present pentachlorophenol based groundline formulation with various species/treatment combinations.

Relatively high levels of pentachlorophenol were achieved in the Jack Pine stubs at Barrie within one year, and maintained at significantly high levels even after seven years (Figure 7). The stubs which had originally been treated with creosote had penta retentions of 4.7 and 5 times the minimum desired retention after one year and seven years respectively. The stubs which had been originally treated with pentachlorophenol had net penta retentions due to the groundline treatment only of 3 and 2.3 times the minimum desired after five and seven years. Similar high retentions were obtained after five years in the Western Cedar stubs originally treated with creosote or penta and in the Eastern Spruce stubs originally treated with a waterborne preservative, ACA (Figure 8). As was found with the Jack Pine stubs, the Western Cedar stubs originally treated with creosote had higher retentions of the groundline preservative than the stubs originally treated with pentachlorophenol. The groundline preservative retentions found in ACA treated Spruce stubs was somewhat surprising as it was suspected that oilborne preservatives would not readily penetrate poles originally treated with waterborne preservatives.

The results obtained in Surrey, BC with few exceptions did not reach the high retention levels found in Barrie, even after three years (Figures 9 and 10). The Jack Pine/CCA stubs,the Lodgepole Pine controls, the Western Cedar/creosote stubs, and the Western White Spruce/ACA stubs exhibited the best performance with retention ratios after three years of 3.8, 2.4, 5.5 and 2.7 respectively. The remaining species treatment combinations had retention ratios ranging from 1.1 to 1.9. It can be concluded that penta would provide improved protection particularly in the first 6 mm of the pole.

Comparison of the net retention ratios in Table 5 obtained with penta to those obtained with copper naphthenate shows that penta reached higher retention ratios than copper naphthenate in the Barrie tests. This was also true in the Surrey tests after one year. After three years the net retentions obtained with copper naphthenate were sometimes higher than those obtained with penta. As had been noted with copper naphthenate the penta retention levels after three years were generally higher than those observed after one year.

Previous Ontario Hydro studies showed that Red Pine poles originally treated with penta and groundline treated with penta had net preservative retentions due to the groundline treatment of 4.3 kg/m^3 and 3.9 kg/m^3 after two and four years respectively (11). These represent net retention ratios of 1.8 and 1.6 similar to the values obtained with Lodgepole Pine/ penta stubs in Surrey but less than the results obtained with Jack Pine penta stubs in Barrie.

BIOASSAY

A bioassay was employed to evaluate preservative effectiveness on all stubs at Surrey, BC and on selected aged Jack Pine stubs at Barrie and poles at Bowmanville.The bioassay tests were carried out at Forintek Canada. Four 3 mm thick disks were sequentially cut from each of the four cores taken from each pole or stub. The disks were cut to provide semi-circular pieces, enabling testing of each core against two fungi. After four weeks incubation, the fungal growth on the test pieces was rated, using the following scale:

0 = zone of inhibition

1 = fungal growth touches wood

2 = limited fungal strands over wood

3 = wood overgrown with fungus

The degree of inhibition of fungal growth was used as a measure of the effectiveness of the preservatives present in each of the four assay zones. It should be noted that fungi may grow up to the wood disc without being able to decay the wood.

All test pieces were sterilized and placed on malt agar petri plates. The plates were then inoculated with one of three standard test fungi, chosen for their resistance to the chemicals present in either the initial treatment preservative or the remedial treatment. All three test fungi, Gloeophyllum trabeum (Pers.:Fr.) Murr. (arsenic and phenol tolerant), Lentimus lepideus Fr. (creosote tolerant) and Poria placenta (Fr.) Cke. (copper tolerant), have been reported as causing decay in poles in the USA (10).

In the tests carried out at Surrey control stubs were included of untreated Western Red Cedar, Western White Spruce, and Lodgepole Pine to obtain a measure of the protection provided by the groundline treatment only. The results obtained on these stubs were compared with those observed on stubs which had been originally pressure treated with various preservatives.

It was not possible to follow the same approach at Barrie as no untreated control stubs had been included in the initial treatment program. As a considerable period of time had elapsed from the time of their original installation until 1986 it was considered that sampling the above ground portion of the pole or stub would provide a "control" against which the below ground remedially treated wood could be evaluated.

Somewhat anomalous results were observed in the bioassay of stubs at Surrey , 14 months and 3 years after groundline treatment. The preservative retentions had indicated that copper-8-quinolinolate would generally provide little additional protection to most wood pole species/treatments represented. This was confirmed in the bioassay. Preservative retention data in stubs groundline treated with TBTO had indicated that improved protection would be exhibited in the outer 6mm of most species/treatment combinations. This was not only observed in the bioassay but the TBTO provided much greater protection than could have been predicted by the chemical analysis.

On the basis of chemical analysis pentachlorophenol should have prevented growth by P. placenta and G. trabeum in almost all tests, since in many of the inner assay zones the preservative retention approached the toxic threshold determined in soil block tests. Again this prediction was confirmed by the bioassay.

The preservative retention data indicated that the outer 6mm section of cores removed from copper naphthenate-treated should all have good protection. Even the retentions for the inner zones of some stubs had adequate preservative to confer additional protection. Surprisingly in the bioassay tests copper naphthenate did not appear to provide additional protection in most cases.

The results obtained in the bioassay on Jack Pine stubs from the Barrie test plot and on poles from Bowmanville were more predictable on the basis of preservative retentions.

It was believed that those stubs in Barrie treated with TBTO or copper-8- quinolinolate did not have sufficient preservative retention in the outer 12 mm of the stub to provide improved protection against decay. This was confirmed in the bioassay as neither preservative demonstrated any improvement in protection. This is in agreement with the Surrey observations for copper- 8-quinolinolate but not for TBTO. The poor results for TBTO were entirely opposite to its excellent performance after three years

(4). This may be linked to the known susceptibility of TBTO to microbial and chemical breakdown and consequent detoxification. The retention results at Barrie and Surrey were similar but the TBTO appeared to provide much greater protection in the bioassay of the Surrey stubs than was predicted from chemical analysis. It was suggested that fungicides which have a significant vapor pressure such as TBTO or penta may appear to provide superior decay resistance in the bioassay when compared to non-volatile preservatives such as copper naphthenate.

The relatively high retentions of copper naphthenate and pentachlorophenol for most species/treatment combinations implied that both these preservatives should provide improved protection against decay. This was generally confirmed in the bioassay although the improved protection provided by either preservative was somewhat variable despite the presence of adequate amounts of preservative. These anomalies are believed due to the difficulties in obtaining true controls. The difference in rate of loss of preservative efficacy above and below ground makes assessment of the effect of the supplementary treatment particularly difficult. Ideally the below ground parts of identical poles without remedial treatment should be compared to these remedially treated pole stubs.

The original preservative treatment was still conferring sufficient protection on most of the poles to mask any additional effect of the supplementary treatment except in the outer 3 mm. All the copper naphthenate formulations and the penta showed some effect in reducing overgrowth of assay cores by the test fungi. Improved protection was provided by copper naphthenate in all analysis zones of CCA-treated Jack Pine and slightly improved protection was found in the outer 3 mm zone in most creosote-treated Jack Pine and Western Red Cedar poles. Poles remedially treated with penta were generally already well protected by the original treatment but protection against creosote- tolerant *L. lepideus* in creosote-treated Jack Pine poles was improved.

It must be emphasized that this is a severe test, optimized for the growth of fungi selected for their tolerance to the preservatives under investigation. A major consideration when examining the bioassay results is the inherent difference in the response of the fungi under the conditions of the test to the presence of oilborne or waterborne treated wood. Preservatives such as CCA or ACA are chemically bound in the wood. They are not volatile. If well fixed they are unlikely to migrate into the media. Consequently, wood may be well treated with either CCA or ACA, yet the test fungi would not be inhibited sufficiently to prevent growth up to the treated wood. This would naturally result in higher growth ratings for waterborne treated wood than for wood given equivalent protection by an oilborne preservative, which is more likely to be volatile and diffuse into the agar, resulting in a zone of fungal inhibition. Any comparison of these two preservative types based upon the bioassay method must take these facts into account when interpreting relative effectiveness of the treatments.

Similar reasoning can be applied to comparing the bioassay results obtained with TBTO and copper naphthenate in the Surrey stubs. TBTO and penta both have a significant vapour pressure while copper naphthenate does not; thus copper naphthenate may achieve a poor rating in the bioassay as the fungi grew up to, or even over a disc. Growth of a fungus up to, or even over a piece of wood, does not necessarily indicate that the fungus is able to decay the wood. Clearly, the results from the bioassay type of test, while indicating the ability of fungi to overgrow treated wood, may also indicate different toxic thresholds than those predicted from other biological tests, eg, soil or agar block tests.

ENVIRONMENTAL AND HEALTH CONSIDERATIONS

It would appear on the basis of the results presented here that only copper naphthenate will be a suitable replacement for pentachlorophenol with respect to preservative retention and effectiveness. Therefore this section will concentrate on the properties of copper naphthenate only.

Copper naphthenate is registered with Agriculture Canada and the United States Environmental Protection Agency as a general use wood preservative. It is not a restricted use wood preservative in either country and can be purchased and used by the general public.

There have been no reported cases of serious illness, poisoning, or death of animals or humans associated with the use of copper naphthenate and/or copper naphthenate treated wood (9). Copper naphthenate has been used in veterinary lotions and ointment and has been used safely in greenhouse applications (3,9). The acute oral toxicity of copper naphthenate in mineral spirits was found to be greater than 5000 mg/kg (LD50) compared to that of pentachlorophenol which was 27 mg/kg in fuel oil. Similarly the acute dermal toxicity of copper naphthenate in mineral spirits was greater than 2000 mg/kg compared to an acute dermal toxicity for pentachlorophenol of 60-170 mg/kg in fuel oil (3,9). Skin irritation is reported as moderate and temporary, inhalation toxicity is nil, and eye irritation is none.

Copper naphthenate wastes are not classified as hazardous wastes under any of the four EPA designated categories for hazardous wastes: reactive,flammable, corrosive, or appearing on the EPA list of hazardous materials. Because copper naphthenate is not classified as a hazardous waste it is not regulated for handling and disposal in the United States under the Resource Conservation and Recovery Act. Spills of copper naphthenate may normally be absorbed with sawdust and disposed of in a sanitary landfill.

Copper naphthenate is not listed as a hazardous waste chemical in Regulation 309 under the Province of Ontario Environmental Protection Act. Disposal of all chemical wastes will vary with jurisdiction within Canada and elsewhere.

CONCLUSIONS

Copper naphthenate, copper-8-quinolinolate, and tributyltin oxide have been investigated as possible replacements for pentachlorophenol in wood pole groundline preservative formulations. On the basis of preservative retentions in the outer 12 mm of the wood and fungicidal effectiveness as determined in a bioassay only copper naphthenate is considered to be a suitable replacement for pentachlorophenol in this application.

The preservative retention due to groundline treatment with both copper naphthenate and pentachlorophenol reached a maximum three years after treatment and decreased gradually thereafter. Higher preservative retentions were achieved with pentachlorophenol than with copper naphthenate, both in absolute retentions and relative to the minimum retention desired for each fungicide. Higher retentions can be obtained with higher concentrations of the fungicide in the groundline formulation. No difference was found in the results obtained with material supplied by two different suppliers. It is recommended that groundline preservative formulations based on copper naphthenate contain 2% copper metal to ensure copper retentions equal to or greater than the minimum retention desired after ten years. Present pentachlorophenol formulations incorporating 10% pentachlorophenol will provide protection against decay for at least ten years.

The effect of the wood pole species and the original pressure treatment on the retention achieved with the groundline fungicide is not clear as the results are variable. Higher retentions were achieved with both copper naphthenate and pentachlorophenol in aged poles which had originally been treated with creosote, particularly Jack Pine and Lodgepole Pine. Formulations based on both preservatives are suitable for remedial treatment of poles originally treated with waterborne preservatives such as CCA and ACA as well as for treatment of poles originally treated with oilborne preservatives.

Copper naphthenate meets the requirement of being an acceptable alternative to pentachlorophenol from an environmental and health viewpoint. It has relatively low acute toxicity, will not harm humans, animals, or plants, is not listed as a hazardous chemical, and does not require specific handling or disposal. Copper naphthenate is available to the general public and is registered with Agriculture Canada and the United States Environmental Protection Agency as a general use wood preservative.

REFERENCES

1. United States Environmental Protection Agency, " Determination Concluding the Rebuttable Presumption Against Registration of the Wood Preservative Uses of Pesticide Products," United States Federal Register, July 13, 1984.
2. Agriculture Canada, Pesticides Directorate, "Discussion Document 87-02 Pentachlorophenol Wood Preservative, " June, 1987.
3. Hawthorne, S.H., " Development of an Environmentally Acceptable Wood Pole Groundline Preservative Formulation, " CEA Report 068D129. 1981.
4. Ruddick, J.N.R., " A Field Evaluation of Four Wood Pole Groundline Preservative Formulations using Western Canadian Wood Species, " CEA Report 068D129 - Part 2. 1987.
5. Hawthorne, S.H., " Development of an Environmentally Acceptable Wood Pole Groundline Preservative Formulation, " CEA Report 068D129B. 1987.
6. Parker, G.L., " Stake Test Evaluation of Wood Preservatives, " Ontario Hydro Research Report 67-157-H. 1967.
7. Davidson, H.L., " Comparison of Wood Preservatives in Stake Tests (1977 Progress Report)," USA Forest Service Research Note FPL-02. 1977.

8. Parker, G.L., " Performance of TBTO and Pentachlorophenol Treated Stakes," Ontario Hydro Unpublished Data.
9. Grove, S.L., " Copper Naphthenate: An Alternative Wood Preservative, "Forest Products Research Society 41st Annual Meeting, June 1987.
10. Ruddick, J.N.R. and co-workers. " Evaluation of Seven Wood Pole Groundline Preservative Formulations in a Field Test, " Report prepared by Forintek Canada Corp. for Ontario Hydro Research Division. February 1987.
11. Hawthorne, S.H., " Performance of Pentachlorophenol Groundline Wood Preservatives in Ontario Hydro, " Ontario Hydro Research Report 78- 450- K. 1978.
12. Gjovik, L.R., Gutzmer, D.I., " Comparison of Wood Preservatives in Stake Tests (1983 Progress Report), " USA Forest Products Laboratory, Madison WI, Research Note FPL-02. 1983.

TABLE 2

SUMMARY OF NET PRESERVATIVE RETENTIONS IN GROUNDLINE TREATED STUBS - BARRIE, ONTARIO
(Values are Means of Results From Each Set of Five Stubs)

			COPPER RETENTION kg/m³				TIN RETENTION kg/m³	PENTA RETENTION kg/m³
			COPPER NAPHTHENATE 10 g/kg Stanchem* CuN10S	COPPER NAPHTHENATE 5 g/kg Stanchem* CuN5S	COPPER NAPHTHENATE 10 g/kg Chapman CuN10C	COPPER-8-QUINOLINOLATE 3.6 g/kg Chapman Cu-8-Q	TRIBUTYLTIN OXIDE 8 g/kg Stanchem TBTO	PENTACHLOROPHENOL 100 g/kg PENTA
JACK PINE 1 YEAR DATA	CREOSOTE AGED POLES	First 6mm	2.04	0.87	2.16	0.41	0.51	16.78
		Second 6mm	0.82	0.19	0.90	0.1	0.12	5.68
		Outer 12mm	1.44	0.54	1.53	0.25	0.31	11.23
	PENTA AGED POLES	First 6mm	1.52	0.62	1.45	0.37	0.82	9.82
		Second 6mm	0.89	0.26	0.65	0.11	0.45	4.56
		Outer 12mm	1.2	0.43	1.05	0.21	0.63	7.16
JACK PINE 7 YEAR DATA	CREOSOTE AGED POLES	First 6mm	1.21	0.46	1.61	0.26	0.28	16.31
		Second 6mm	0.70	0.13	0.81	0.12	0.07	8.30
		Outer 12mm	0.95	0.30	1.21	0.19	0.18	12.30
	PENTA AGED POLES	First 6mm	1.04	0.61	1.09	0.26	0.19	7.1
		Second 6mm	0.52	0.22	0.75	0.16	0.09	3.8
		Outer 12mm	0.78	0.41	0.92	0.21	0.14	5.4
WESTERN CEDAR 5 YEAR DATA	CREOSOTE NEW POLES	First 6mm	1.04	0.55		0.22		11.11
		Second 6mm	0.36	0.20		0.07		2.95
		Outer 12mm	0.71	0.37		0.15		7.03
	PENTA NEW POLES	First 6mm	0.78	0.25		0.26		6.5
		Second 6mm	0.39	0.12		0.08		3.0
		Outer 12mm	0.58	0.19		0.17		4.8
EASTERN SPRUCE 5 YEAR DATA	ACA INCISED	First 6mm	-1.58	-0.16		-2.30		11.68
		Second 6mm	0.07	-0.65		-0.08		1.33
		Outer 12mm	-0.78	-0.35		-1.15		6.50
	ACA UNINCISED	First 6mm	-0.02	0		-0.13		14.16
		Second 6mm	-0.14	0.08		-1.08		1.48
		Outer 12mm	-0.08	0.04		-0.61		7.82

*Copper naphthenate as supplied by Stanchem at 10g/kg copper was actually 8.6 g/kg for the material applied to Jack pine stubs and 7.4 g/kg for the material applied to Western Cedar and Eastern Spruce stubs. Similarly the copper naphthenate supplied at 5 g/kg copper was actually 4.5 g/kg for all material. The retentions in this table have been normalized to the nominal concentrations to permit direct comparison with the material supplied by Chapman at 10.3 g/kg.

e.g. Net Retention = 1.71 kg/m³. Normalized Net Retention = $\frac{1.71 \times 10}{8.6}$ = 2.04 kg/m³

TABLE 3

SUMMARY OF NET PRESERVATIVE RETENTION IN GROUNDLINE TREATED POLES - BOWMANVILLE ONTARIO

			COPPER NAPHTHENATE 10 g/kg Stanchem CUN10S actual conc 7.4 g/kg Copper Retention kg/m³	COPPER NAPHTHENATE retentions normalized to the nominal concentration of 10 g/kg. Copper retention kg/m³
JACK PINE 5 YEAR DATA	CRESOTE AGED POLES	First 6mm	1.22	1.68
		Second 6mm	0.43	0.60
		Outer 12mm	0.82	1.14
	PENTA AGED POLES	First 6mm	0.76	1.06
		Second 6mm	0.34	0.47
		Outer 12mm	0.55	0.77
	CCA ** AGED POLES	First 6mm	2.10	
		Second 6mm	1.68	
		Outer 12mm	1.89	
RED PINE 5 YEAR DATA	PENTA NEW POLES	First 6mm	0.51	0.71
		Second 6mm	0.19	0.26
		Outer 12mm	0.35	0.49
WESTERN CEDAR 5 YEAR DATA	CREOSOTE AGED POLES	First 6mm	1.04	1.45
		Second 6mm	0.61	0.84
		Outer 12mm	0.83	1.16

** Gross data only reported for these poles as insufficient information is known about the original treatment to permit estimation of the net retention.

TABLE 4

SUMMARY OF NET PRESERVATIVE RETENTION IN GROUNDLINE TREATED STUBS - SURREY, BC

Data reported by FORINTEK CANADA in metal oxide form was converted to metal for this table

			COPPER NAPHTHENATE 10 g/kg Stanchem CuN10S Copper Retention kg/m³	COPPER-8-QUINOLINOLATE 3.6 g/kg Stanchem Cu-8-Q Copper Retention kg/m³	TRIBUTYLTIN OXIDE 8 g/kg Stanchem TBTO Tin retention kg/m³	PENTACHLOROPHENOL 100 g/kg PENTA Penta Retention kg/m³
JACK PINE 1 YEAR DATA	CCA NEW POLES	First 6mm	0.96	0	0.48	6.0
		Second 6mm	0.56	0.08	0.16	2.6
		Outer 12mm	0.76	0.04	0.32	4.3
JACK PINE 3 YEAR DATA	CCA NEW POLES	First 6mm	1.36	0	0.24	12.4
		Second 6mm	0.88	0.08	0.08	5.8
		Outer 12mm	1.12	0.04	0.16	9.1
LODGEPOLE PINE 1 YEAR DATA	CONTROL AGED POLES	First 6mm	1.04	0.24	2.08	7.8
		Second 6mm	0.32	0.08	0.40	4.9
		Outer 12mm	0.68	0.16	1.24	6.4
	PENTA NEW POLES	First 6mm	0.96	0.24	0.72	6.8
		Second 6mm	0.24	0.08	0.16	2.2
		Outer 12mm	0.6	0.16	0.44	4.5
LODGEPOLE PINE 3 YEAR DATA	CONTROL AGED POLES	First 6mm	1.6	0.32	1.68	6.6
		Second 6mm	1.12	0.16	0.80	4.9
		Outer 12mm	1.36	0.24	1.24	5.8
	PENTA NEW POLES	First 6mm	1.36	0.24	0.64	4.1
		Second 6mm	0.96	0.08	0.16	2.4
		Outer 12mm	1.16	0.16	0.4	3.3
WESTERN CEDAR 1 YEAR DATA	CONTROL AGED POLES	First 6mm	0.88	0.24	0.56	1.7
		Second 6mm	0	0	0.08	1.0
		Outer 12mm	0.44	0.12	0.32	1.4
	ACA AGED POLES	First 6mm	0.88	0.56	0.16	3.6
		Second 6mm	0.32	0.4	0.08	1.0
		Outer 12mm	0.66	0.48	0.12	2.3
	PENTA AGED POLES	First 6mm	0.72	0.24	0.64	3.4
		Second 6mm	0.08	0.08	0.16	0.8
		Outer 12mm	0.4	0.16	0.40	2.1
	CREOSOTE AGED POLES	First 6mm	0.64	0	0.96	17.1
		Second 6mm	0.16	0	0.16	3.1
		Outer 12mm	0.4	0	0.56	10.1
WESTERN CEDAR 3 YEAR DATA	CONTROL AGED POLES	First 6mm	1.36	0.24	1.28	4.7
		Second 6mm	0.64	0.08	0.4	0.6
		Outer 12mm	1.00	0.16	0.84	2.7
	ACA AGED POLES	First 6mm	1.44	0.24	0.16	7.5
		Second 6mm	0.64	0.16	0	0.8
		Outer 12mm	1.04	0.2	0.08	4.2
	PENTA AGED POLES	First 6mm	1.2	0.24	0.64	4.7
		Second 6mm	0.72	0.16	0.32	0.6
		Outer 12mm	0.96	0.20	0.48	2.7
	CREOSOTE AGED POLES	First 6mm	1.76	0.16	0.8	22.0
		Second 6mm	1.12	0.08	0.16	4.5
		Outer 12mm	1.44	0.12	0.48	13.3
WESTERN WHITE SPRUCE 1 YEAR DATA	CONTROL NEW POLES	First 6mm	1.04	0.16	0.8	5.7
		Second 6mm	0.24	0.08	0.16	1.6
		Outer 12mm	0.64	0.12	0.48	3.7
	ACA NEW POLES	First 6mm	0.88	0.32	0.4	4.3
		Second 6mm	0.32	0.16	0.24	1.0
		Outer 12mm	0.6	0.24	0.32	2.7
	PENTA AGED POLES	First 6mm	0.96	0.24	0.48	3.9
		Second 6mm	0.24	0	0.08	3.0
		Outer 12mm	0.6	0.12	0.28	3.5
WESTERN WHITE SPRUCE 3 YEAR DATA	CONTROL NEW POLES	First 6mm	1.44	0.24	0.96	4.6
		Second 6mm	1.04	0.16	0.48	1.3
		Outer 12mm	1.22	0.2	0.72	3.0
	ACA NEW POLES	First 6mm	0.08	0	0.24	7.9
		Second 6mm	0.24	0.24	0.16	5.0
		Outer 12mm	0.16	0.12	0.2	6.5
	PENTA AGED POLES	First 6mm	1.44	0.24	0.72	6.3
		Second 6mm	0.96	0.16	0.48	2.9
		Outer 12mm	1.2	0.2	0.6	4.6

TABLE 5

SUMMARY OF NET PRESERVATIVE RETENTION RATIOS IN GROUNDLINE TREATED STUBS AND POLES

NET RETENTION RATIO = (NET PRESERVATIVE RETENTION IN OUTER 12mm OF WOOD)/(MINIMUM RETENTION DESIRED)

		COPPER NAPHTHENATE 10 g/kg Stanchem CuN10S	COPPER NAPHTHENATE 5 g/kg Stanchem CuN5S	COPPER NAPHTHENATE 10 g/kg Chapman CuN10C	COPPER-8-QUINOLINOLATE 3.6 g/kg Cu-8-Q	TRIBUTYLTIN OXIDE 8 g/kg Stanchem TBTO	PENTACHLOROPHENOL 100 g/kg PENTA
BARRIE, ONTARIO							
JACK PINE 1 YEAR DATA	CREOSOTE AGED POLES	2.9	1.1	3.1	0.6	0.5	4.7
	PENTA AGED POLES	2.4	0.9	2.1	0.5	1.0	3.0
JACK PINE 7 YEAR DATA	CREOSOTE AGED POLES	1.9	0.6	2.4	0.5	0.3	5.0
	PENTA AGED POLES	1.6	0.8	1.8	0.5	0.2	2.3
WESTERN CEDAR 5 YEAR DATA	CREOSOTE NEW POLES	1.4	0.7		0.4		2.9
	PENTA NEW POLES	1.2	0.4		0.4		2
EASTERN SPRUCE 5 YEAR DATA	ACA/INCISED NEW POLES						2.7
	ACA/UNINCISED NEW POLES						3.3
BOWMANVILLE, ONTARIO							
JACK PINE 5 YEAR DATA	CREOSOTE AGED POLES	2.3					
	PENTA AGED POLES	1.5					
RED PINE 5 YEAR DATA	PENTA AGED POLES	1					
WESTERN CEDAR 5 YEAR DATA	CREOSOTE AGED POLES	2.3					
SURREY, BC							
JACK PINE 1 YEAR DATA	CCA NEW POLES	1.5			0.1	0.5	1.8
JACK PINE 3 YEAR DATA	CCA NEW POLES	2.3			0.1	0.3	3.8
LODGEPOLE PINE 1 YEAR DATA	CONTROL AGED POLES	1.4			0.4	2.1	2.6
	PENTA NEW POLES	1.2			0.4	0.7	1.8
LODGEPOLE PINE 3 YEAR DATA	CONTROL AGED POLES	2.7			0.6	2.1	2.4
	PENTA NEW POLES	2.3			0.4	0.7	1.4
WESTERN CEDAR 1 YEAR DATA	CONTROL AGED POLES	0.9			0.3	0.5	0.6
	ACA AGED POLES	1.3			1.2	0.2	1.0
	PENTA AGED POLES	0.8			0.4	0.7	0.9
	CREOSOTE AGED POLES	0.8			0	0.9	4.2
WESTERN CEDAR 3 YEAR DATA	CONTROL AGED POLES	2.0			0.4	1.4	1.1
	ACA AGED POLES	2.1			0.5	0.1	1.8
	PENTA AGED POLES	1.9			0.5	0.7	1.1
	CREOSOTE AGED POLES	2.9			0.6	0.8	5.5
WESTERN WHITE SPRUCE 1 YEAR DATA	CONTROL NEW POLES	1.3			0.6	0.8	1.5
	ACA NEW POLES	1.2			0.6	0.8	1.1
	PENTA AGED POLES	1.2			0.3	0.5	1.5
WESTERN WHITE SPRUCE 3 YEAR DATA	CONTROL NEW POLES	2.4			0.5	1.2	1.3
	ACA NEW POLES	0.3			0.3	0.3	2.7
	PENTA AGED POLES	2.4			0.5	1.0	1.9

FIGURE 1 — BARRIE ONTARIO

JACK PINE — CREOSOTE — AGED POLES

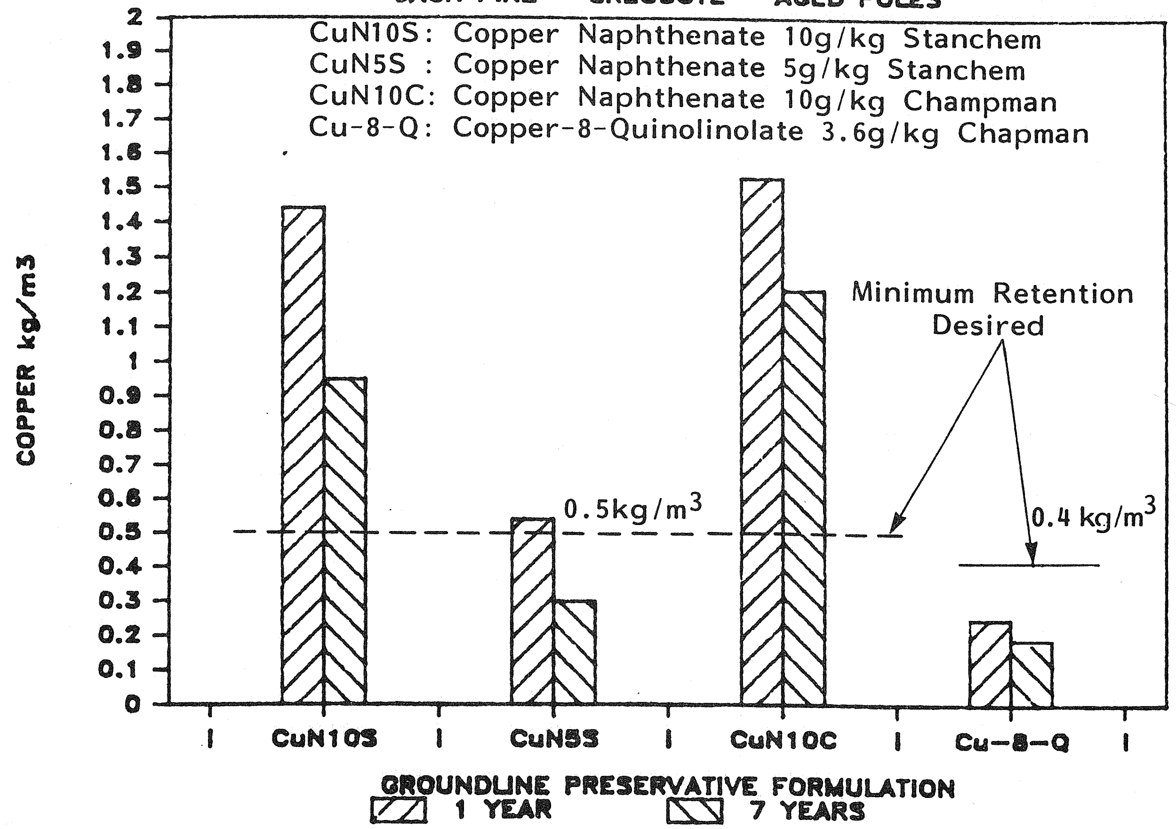

FIGURE 2 — BARRIE ONTARIO

WEST. CEDAR—CREOSOTE & PENTA—NEW POLES

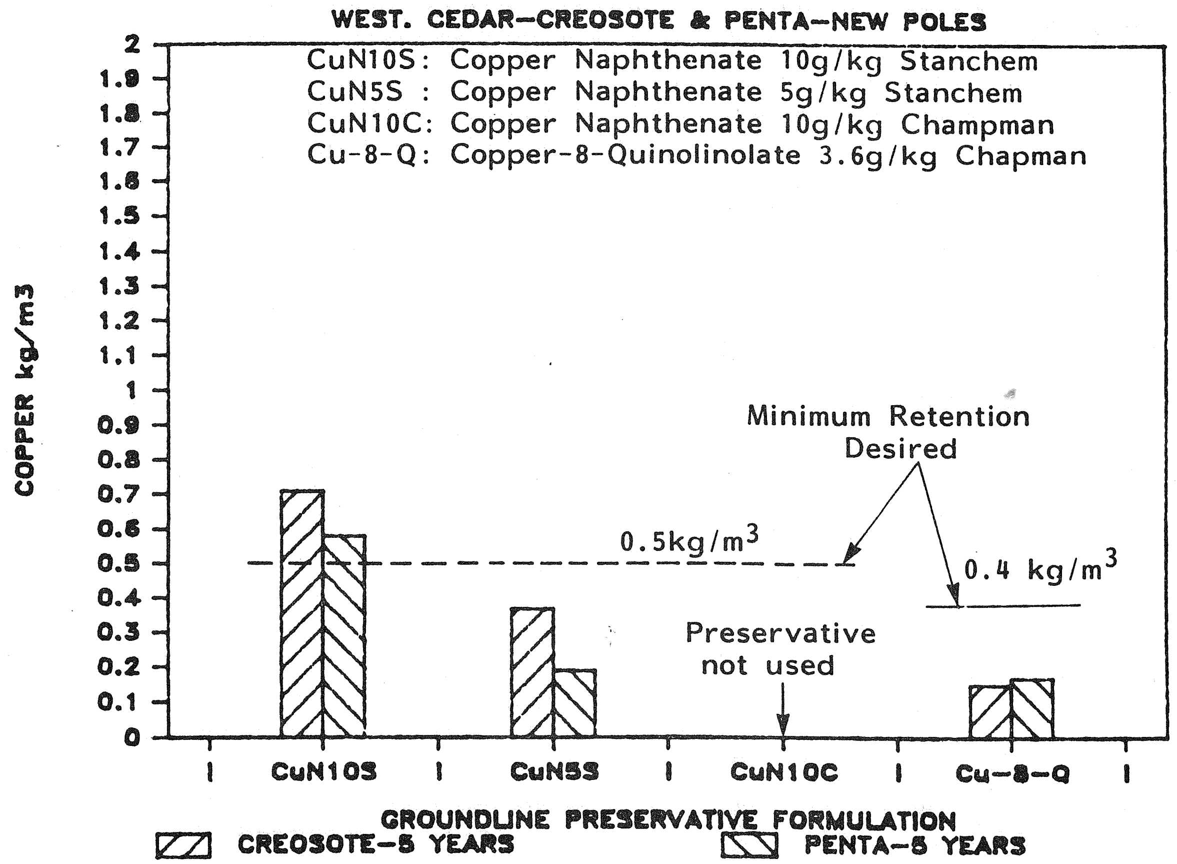

FIGURE 3 — BARRIE ONTARIO

TBTO GROUNDLINE TREATED STUBS

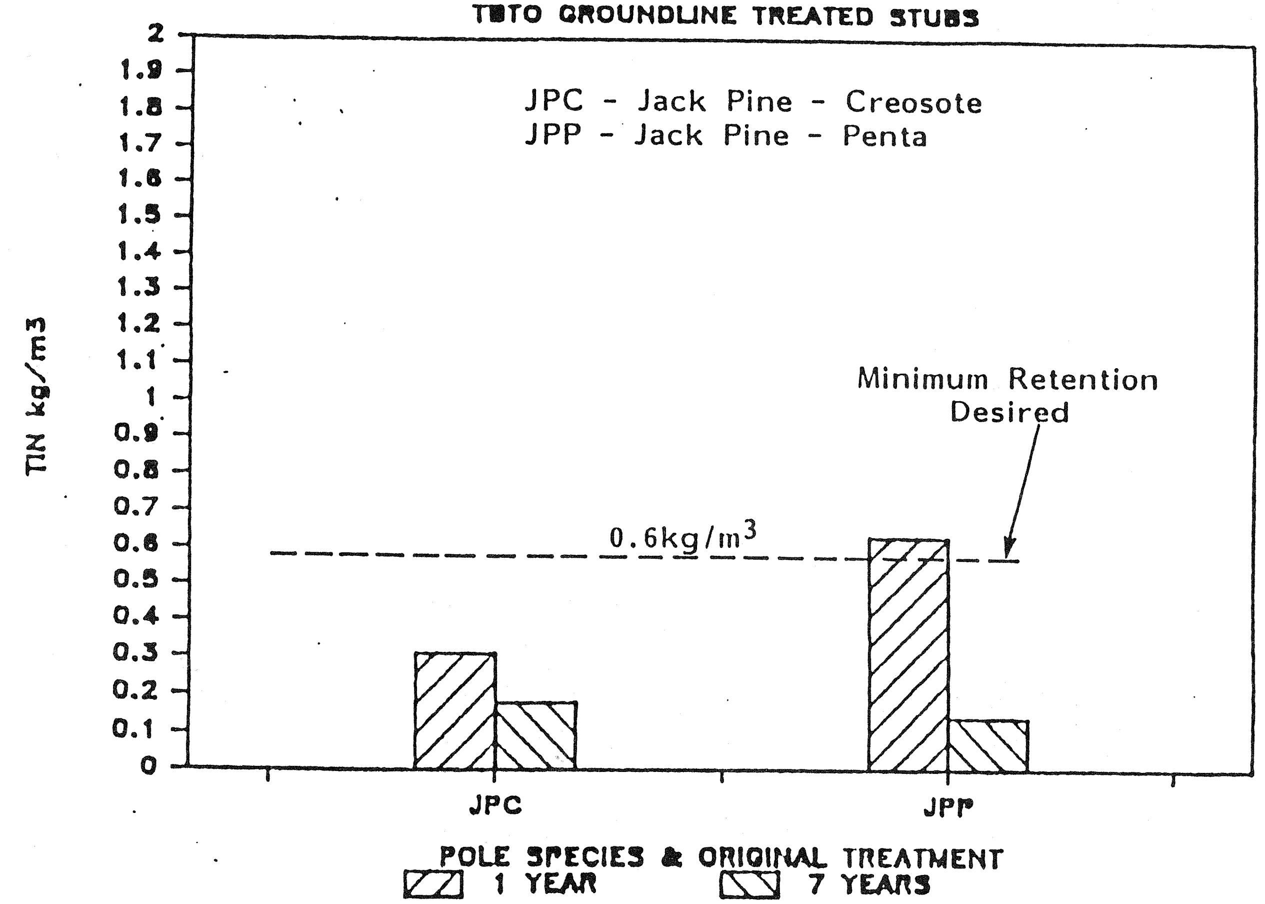

FIGURE 4 — — SURREY, BC

TBTO GROUNDLINE TREATED STUBS

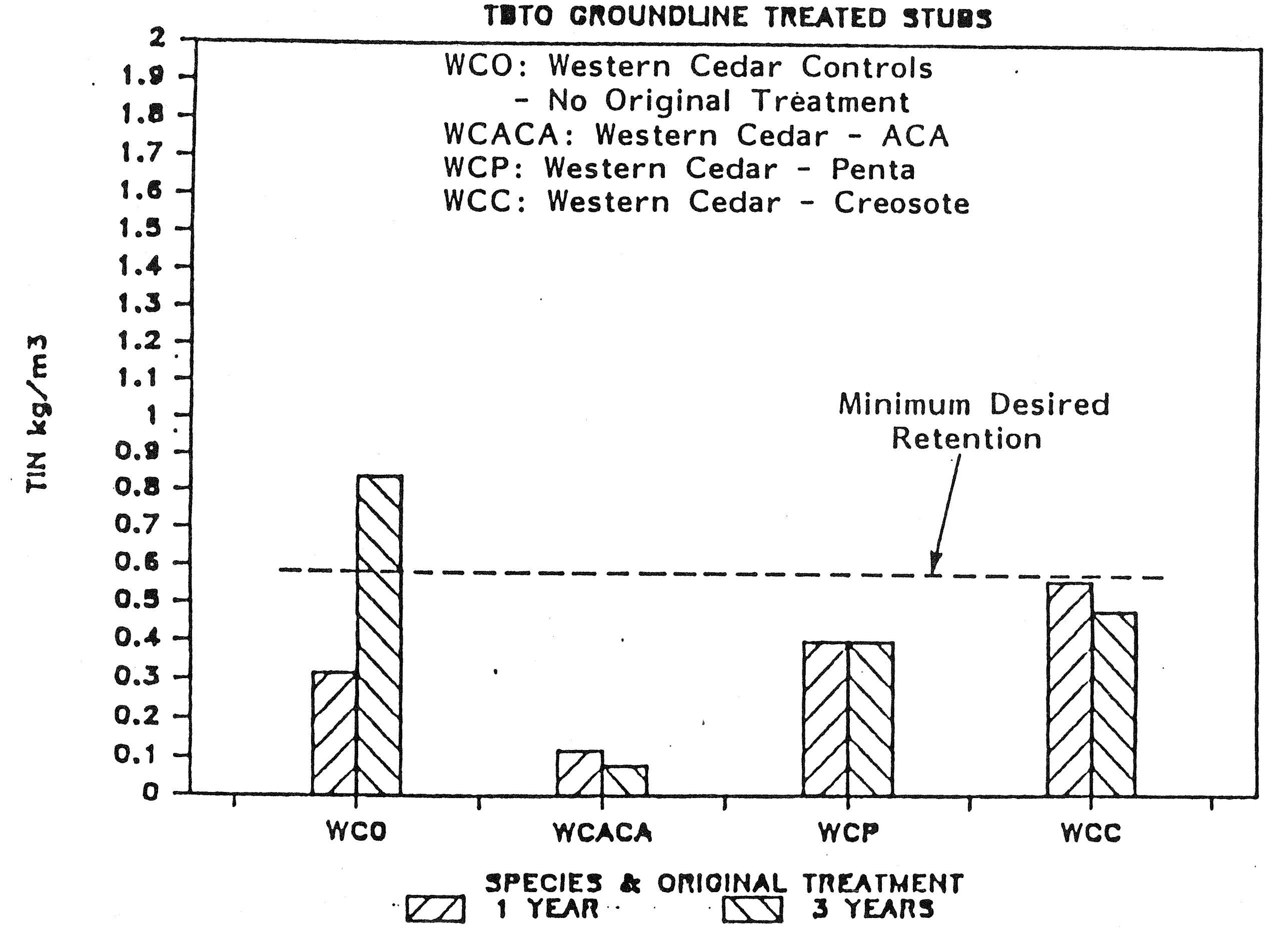

FIGURE 5 — SURREY, BC

COPPER NAP. GROUNDLINE TREATED STUBS

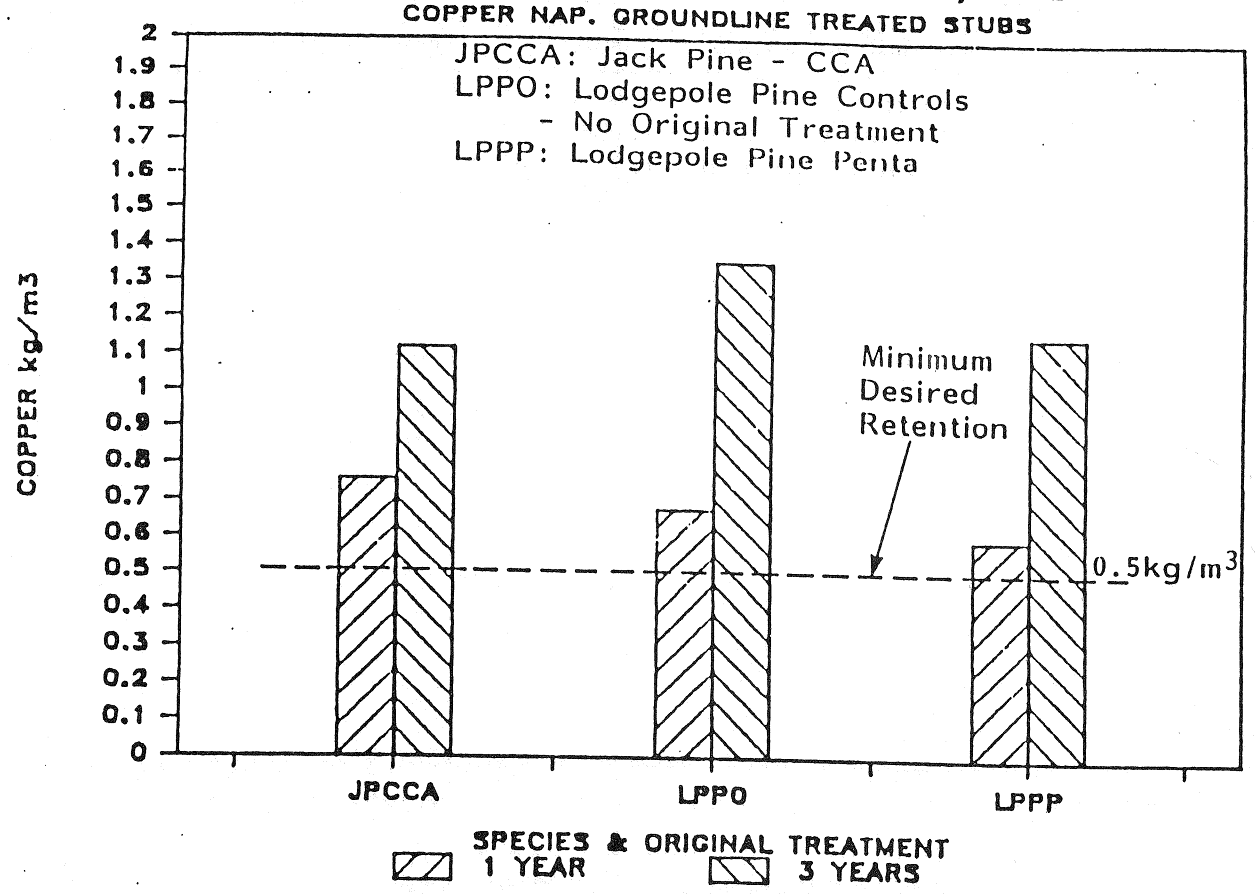

FIGURE 6 — SURREY, BC

COPPER NAP. GROUNDLINE TREATED STUBS

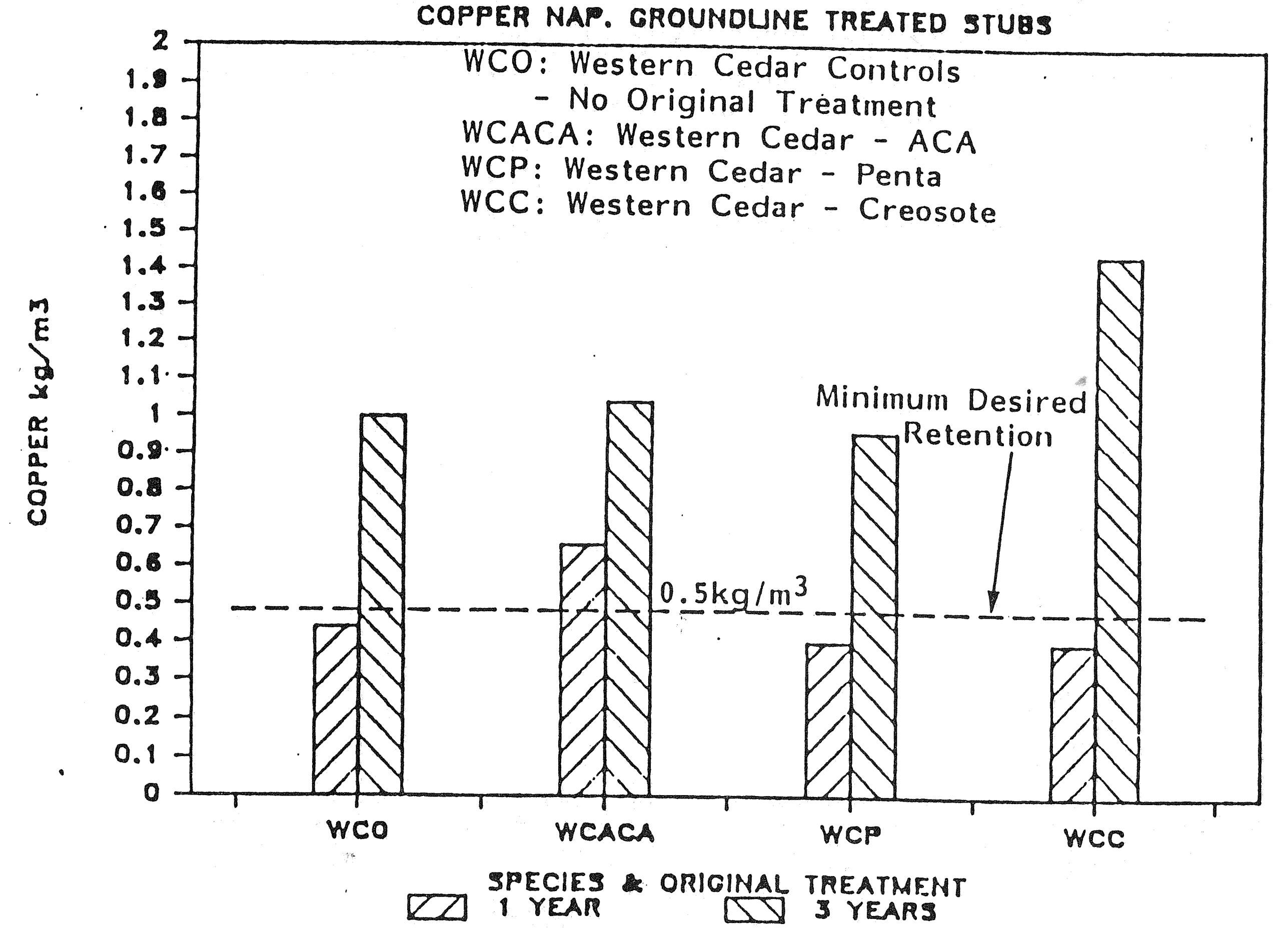

FIGURE 7 — BARRIE ONTARIO

PENTA GROUNDLINE TREATED STUBS

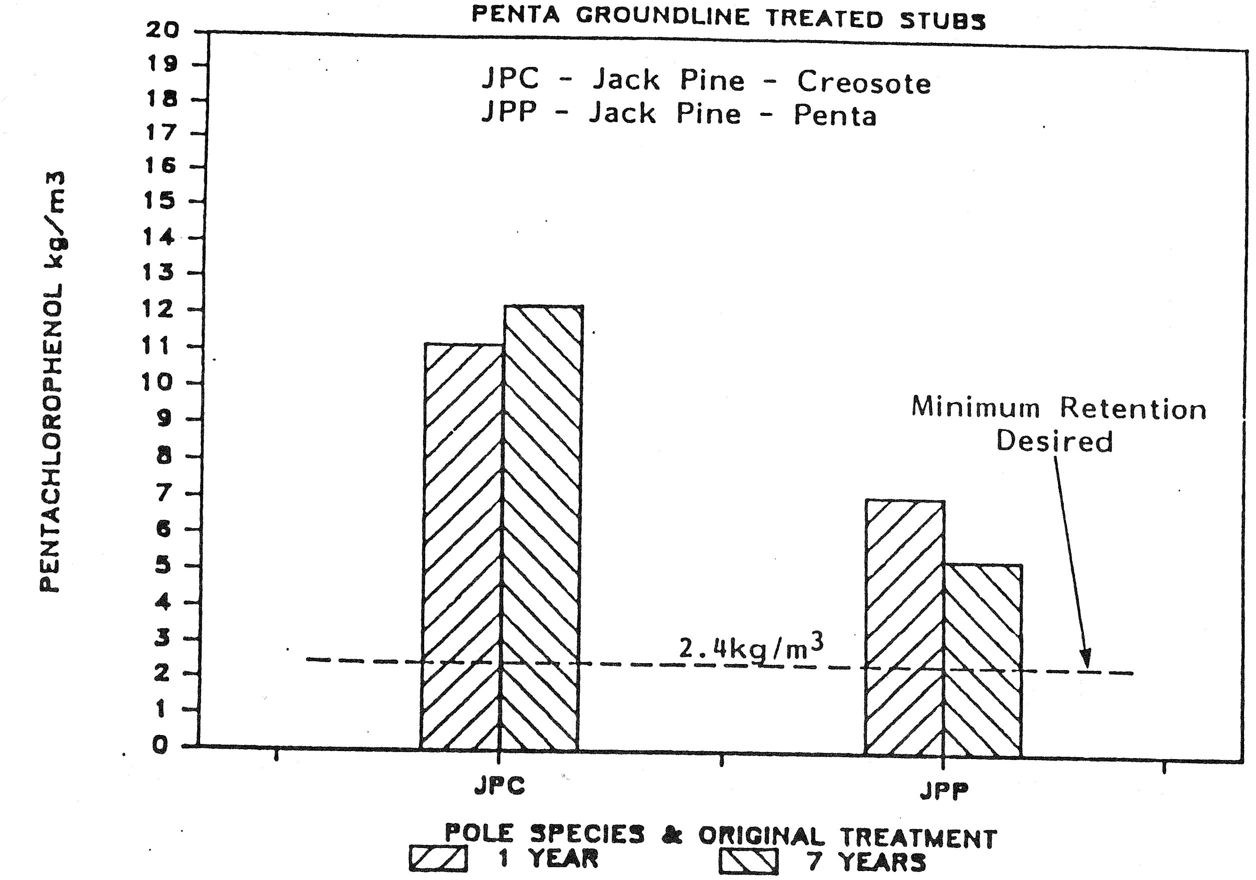

FIGURE 8 — BARRIE ONTARIO

PENTA GROUNDLINE TREATED STUBS

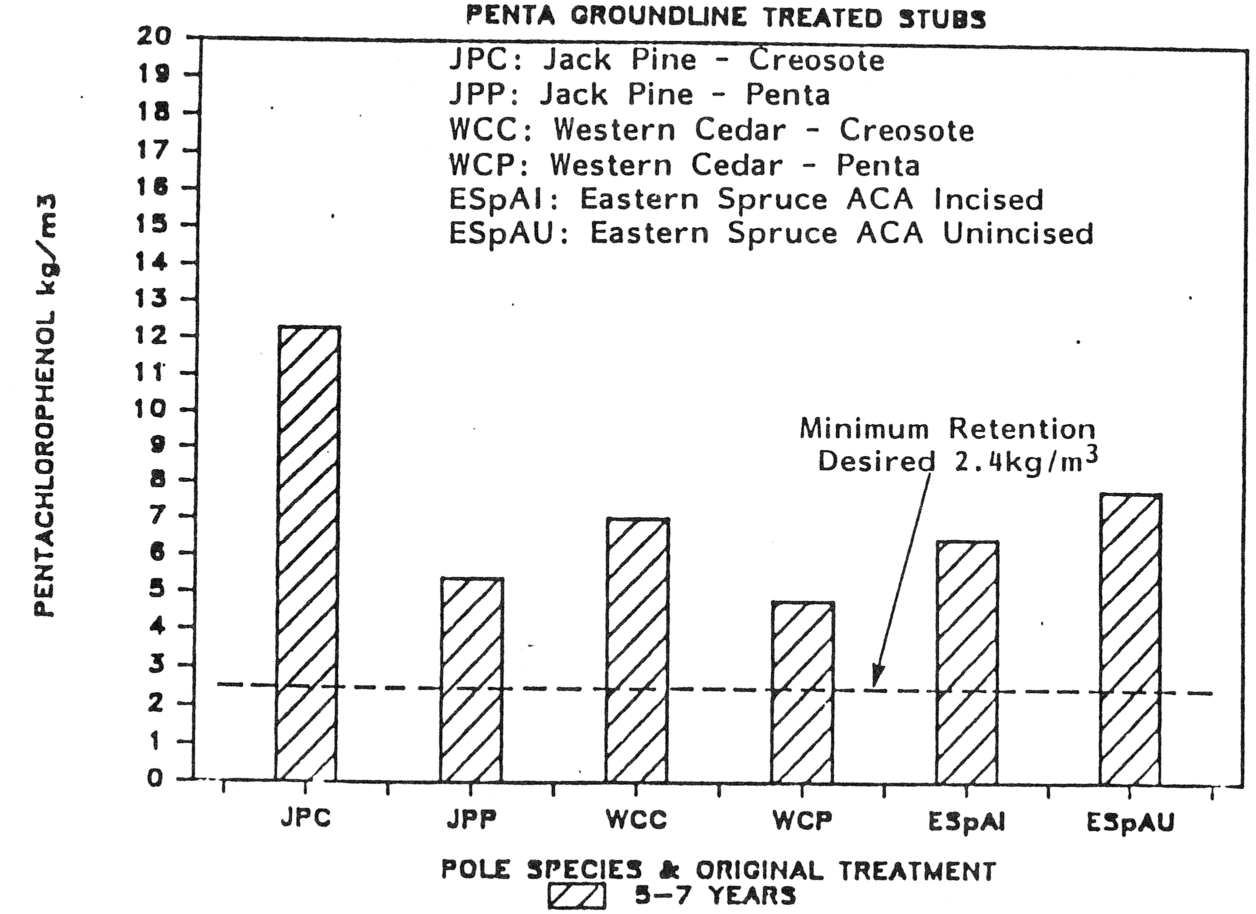

FIGURE 9 — SURREY, BC

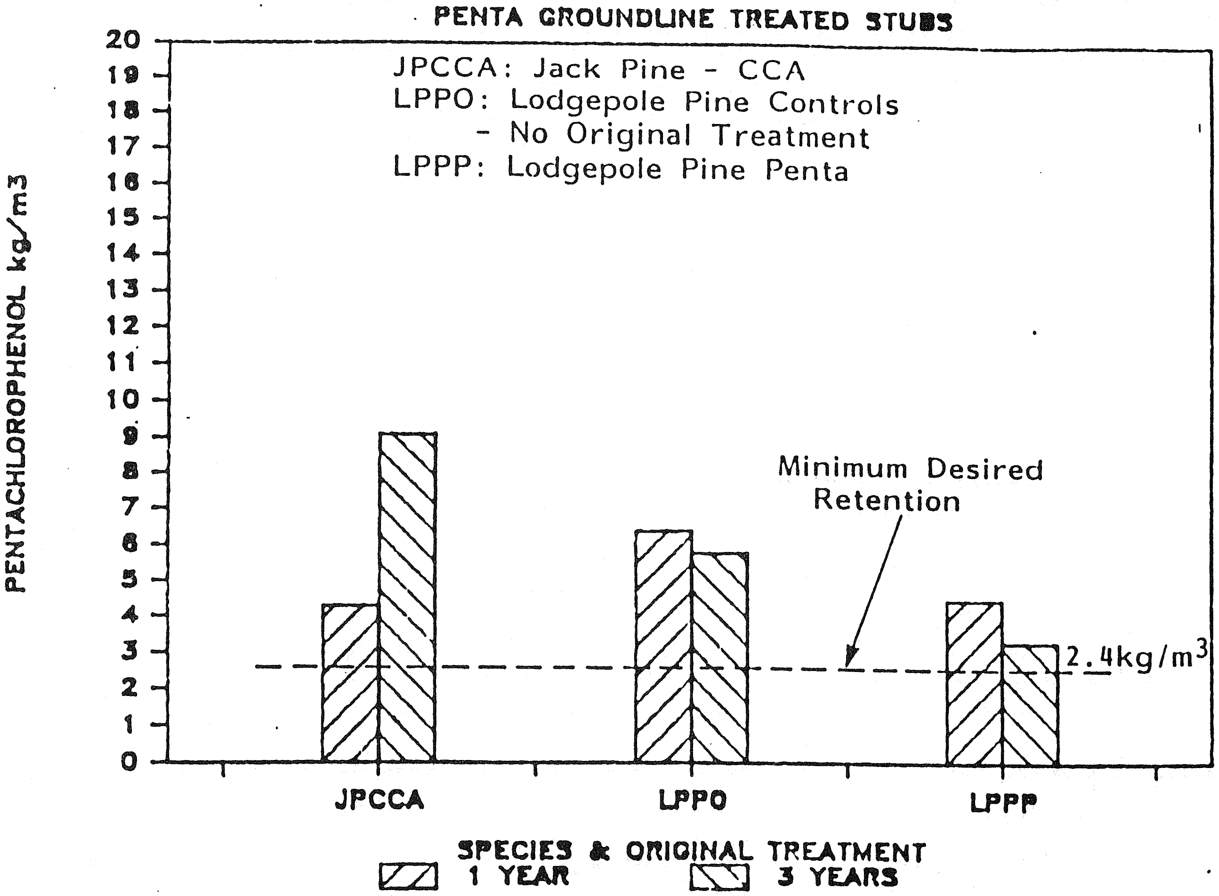

FIGURE 10 — SURREY, BC