PROGRESS IN ACCELERATED PRESERVATIVE EVALUATION AT FORINTEK

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INTRODUCTION

The objective of this paper is to present an overview of Forintek's research program in the area of accelerated preservative evaluation. The emphasis will be on the reasons why the test facility was set up and the direction in which the research is proceeding. The data discussed will be limited to those necessary to illustrate the progress of the work. The Forintek facility is by no means unique in its objectives. Similar facilities are now in operation elsewhere including Australia, Germany, Great Britain, Japan, New Zealand, Sweden and the United States (1). All use large troughs of soil (soil beds) in a constant temperature room for exposure of small stakes. There the similarities end, but the objective in each case is to optimize conditions for decay in ground contact. The term "soil beds" will be used to describe all such facilities. The term "fungus cellar" should be used (2) only to denote a large scale test of building materials (developed in Germany), using an almost pure culture of the dry rot fungus (3).

The design and construction of the Forintek facility has been adequately documented by Smith and Byrne (4,5,4) and the setting up of the first experiments was reported on by Smith et al (6). Only a brief description is therefore included here.

FORINTEK'S FACILITY FOR ACCELERATED BIODETERIORATION(FAB)

The basic structure is a walk-in insulated room with four soil beds (Figure 1). One of the most sophisticated of its type, the FAB has the capability of operating over a wide range of temperatures, humidities and soil moisture contents. For the purposes of the preliminary experiments, however, it has been operated at 27^{o}C, 80 percent relative humidity, and 30 percent soil moisture content (the water-holding capacity of the soil). Soil moisture is maintained by overhead spraying at intervals, based on gravimetric determination of moisture content. The soil is a loam-based, horticultural blend with a high proportion of sand for free drainage (2). It is contained in four large stainless steel troughs.

The soil beds are intended to provide optimum growing conditions for fungi year round, protecting them from the winter cold and summer drought which would hamper growth under natural conditions. They are thus able to maintain the decay rate of wood in ground contact at a maximum only attained in nature for brief periods during the year.

The FAB is not presently set up to provide accelerated decay of products intended for out of ground contact use such as decking, siding, shakes, joinery, etc. Such tests would require a somewhat modified facility.

The limited size of the soil beds means the larger the experimental unit (stake, 2 x 4, post, pole) the smaller the replication and the lower reliability of the results. It would therefore be difficult to conceive of performing any experiments with commodities much larger than short lengths of 2 x 4 or small plywood stakes. These limitations are unlikely to affect the forseeable uses of the soil beds.

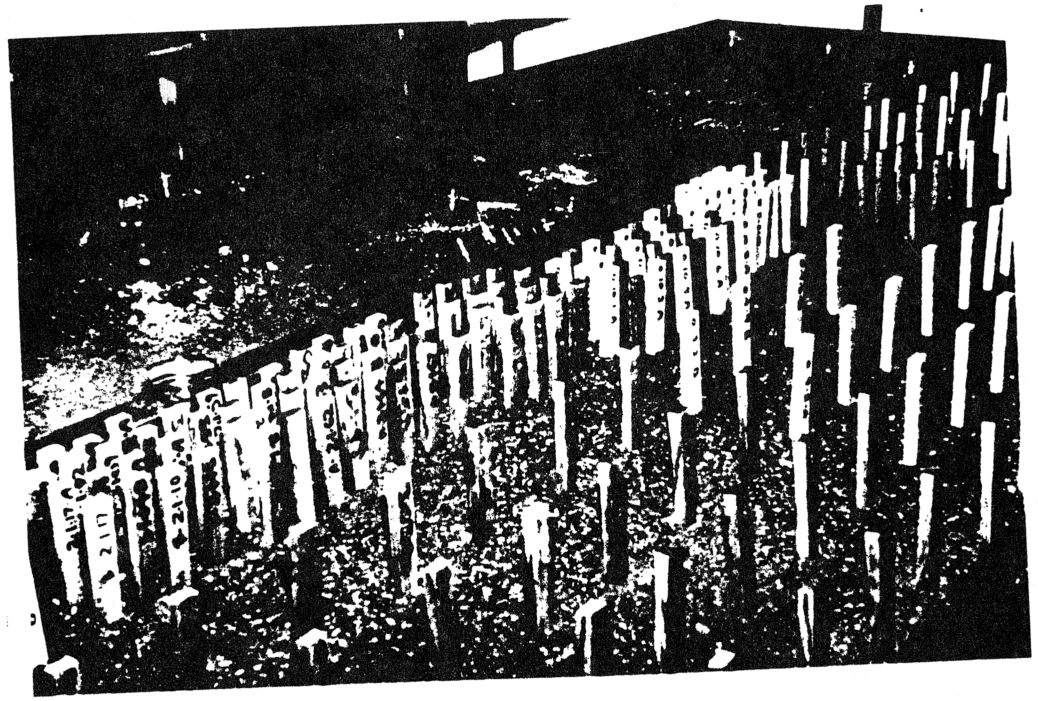
SELECTIONS FROM THE CURRENT EXPERIMENTS

The four main experiments currently underway are: the preservative performance test, the stake spacing test, the Cooperative test, and the Basidiomycete amendment test. The first of these was designed to develop long term performance data on our standard reference preservatives and to compare the results with those from field tests. The spacing test has determined the influence of stake separation and the type of treatment of adjacent stakes on the rate of decay. The Cooperative test was intended to assess the reproduceability of soil bed testing across North America; the Basidiomycete test to further accelerate decay and to ensure the involvement of wood-rotting basidiomycetes in the decay process. All of these are primarily intended to investigate the methodology of soil bed testing to ensure that we are fully confident in the data it will generate before going on to employ the system in testing of new or modified preservatives or research in support of Codes and Standards. All the current experiments employ a common methodology which is fully described by Smith and Byrne (2). Only a brief review of the methods which were used to set up the first series of experiments is therefore provided here.

Methods

The protocol for setting up a standard stake test was followed as closely as possible, except that the stakes used were half the size in each dimension of the International Union of Forest Research Organization's (IUFRO) standard.

Figure 1 The facility for accelerated biodeterioration soil beds



Double length stakes were prepared from clear sapwood of ponderosa pine and white birch. These were treated with the preservatives listed below at five retention levels comparable to those used in the stake test at Westham Island: 40, 60, 100, 140 and 160 percent of the CSA specified retention.

Chromated copper arsenate type C (CCA-C) in water
Ammoniacal copper arsenate (ACA) in 5% aqueous ammonia
Pentachlorophenol (PCP) in P-9 oil
Creosote in toluene
a copper carbonate alkyldimethylbenzylammonium chloride mixture in 5% aqueous ammonia (ACQ)

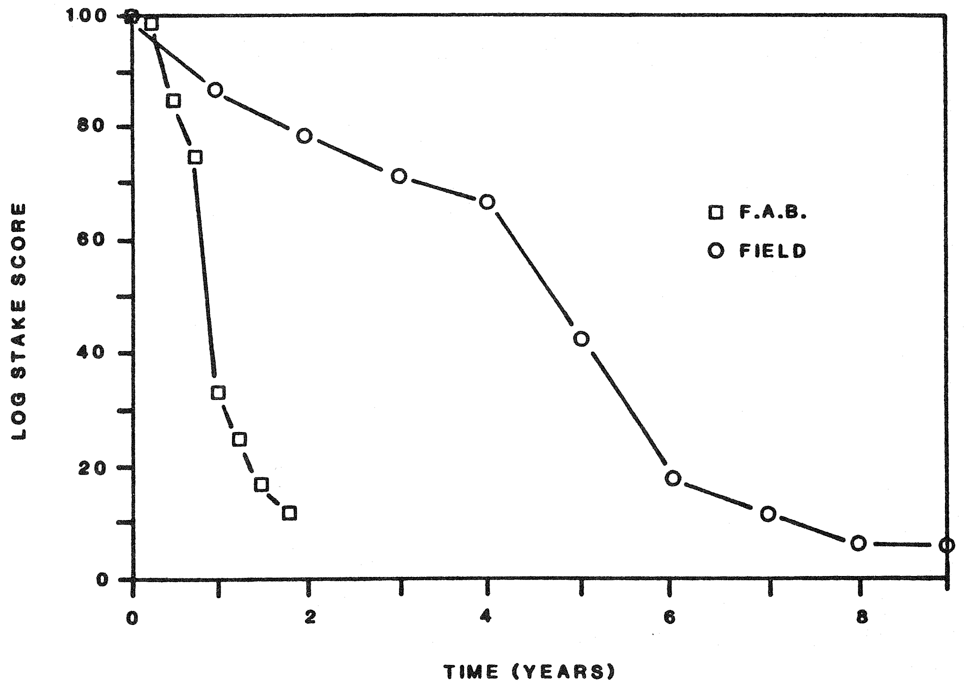
Each double length stake was cut into two daughter stakes (250 x 25 x 12.5 mm) and a center 25 mm section for analysis. Prior to installation, all treated stakes were leached for three days in running water and air dried. The stakes were installed in a randomized array at 95 mm centers. At three month intervals each stake was removed from the bed, and evaluated using the IUFRO rating scale:

0 - sound, no decay
1 - slight and superficial decay
2 - evident but moderate decay
3 - severe decay
4 - failure when flexed

Performance Test

The preservative performance test used pine treated with all five preservatives and birch treated with CCA-C, ACA and ACQ. One of the major objectives of this experiment was to compare the rates of decay in the soil beds and at Westham Island. After 1.5 years in the soil beds, decay had progressed sufficiently to estimate a factor of acceleration only for CCA, ACA and PCP in pine at the lowest retention (2.4 kg/m^3). These factors varied widely from zero for ACA through five for CCA (Figure 2) to about 16 for PCP. This degree of variation was somewhat unexpected but may be explained in part by parameters affecting the decay rate at Westham Island rather than the soil beds. It has become apparent from data presented by Dickinson and Gray (7) that Westham Island is two to three times more aggressive with respect to CCA-treated wood than the other temperate zone test sites. The possible reasons for this, including interference by iron salts, leaching, arsenic-tolerant basidiomycetes and bacterial decay, have been discussed by Ruddick and Morris (8). If Westham Island is an extreme case, the true factor of acceleration for CCA in the soil beds may be 10 to 15, comparable to that for PCP. This theory would require the parameter accelerating decay at Westham Island to be acting CCA-treated wood but not on PCP-treated wood. Several of the possible reasons mentioned above could do this.

Figure 2 A comparison of the rate of decay of ponderosa pine sapwood stakes treated to 2.8kg/m^3 with CCA exposed in the soil beds and at Westham Island



As the decay rates for ACA are almost equal in the soil bed and at Westham Island, the acceleration in the soil bed due to optimization of moisture and temperature must be nullified by the acceleration due to other parameters at Westham Island. This would suggest that ACA is more affected by these parameters than CCA, which would fit with the greater aggressiveness of Westham Island towards ACA than towards CCA (9). At other sites, the two preservatives have a very similar performance (10). The potential acceleration forces at Westham Island are currently under investigation and the differences in decay types limiting the performance of stakes at Westham and in the soil beds are being compared. These fundamental areas of research, necessary to validate the data generated by soil bed testing and field testing at Westham Island, may well provide valuable insights into the mode of action of preservatives and parameters limiting their performance. This information should then be used to optimize preservative performance and identify high hazard situations where higher preservative retentions may be required.

Spacing Test

An essential component of any test method is repeatability, and in this respect standardization of methods is essential. It appeared that little attention has been paid to stake spacing and the effects of adjacent treatments in other facilities of this type. Preservatives are known to move into soil from treated wood in minute amounts and can modify the soil microflora by favouring preservative-tolerant organisms (11). These effects could result in acceleration or retardation of decay in adjacent stakes. An experiment was therefore set up to assess the effect of spacing on the decay rate of treated and untreated stakes.

Two preservatives, ACA and PCP, and two retention levels, level 1 (3 kg/m\ ^{3} for both preservatives) and level 4 (9 kg/m^3 for ACA and 11.4 kgm^3 for PCP) were selected: the lower level to permit decay in a short time period and the higher level to maximize preservative movement into the soil. Untreated control stakes were also used. Three spacings were tested: 95 mm, the standard spacing used for the first experiments in the soil best; 47 mm, half the standard spacing; and 142 mm, one and a half times the standard spacing. Untreated, ACA- and PCP-treated (3 kg/m^3) stakes were each planted at the three spacings in grids of only one type of stake. Mixed grids of ACA (9 kg/m^3) plus untreated, or PCP (11.4 kg/m^3) plus untreated, or ACA (3 kg/m^3) plus PCP (3 kg/m^3) were also planted at each of two spacings, 47 and 95 mm.

The rates of decay for untreated, ACA-treated and PCP-treated stakes are presented in Figures 3, 4 and 5, respectively. The rates of decay for untreated stakes were very rapid in all grids, but there did appear to be a faster decay rate in stakes planted at 47 mm spacing.

The proportions of untreated stakes which failed at six months or at nine or more months (Table 1) were therefore compared statistically (χ^2; α= 0.01). Decay rates of untreated stakes planted in grids of 47 mm spacing did not vary significantly whether they were planted next to other untreated, ACA-treated or PCP-treated stakes. This was also the case for untreated stakes in grids of 95 mm spacing. There was no significant difference in decay rate which could be correlated to the treatment type of neighbouring stakes.

There was, however, a significant difference in decay rates of stakes planted at different spacing distances. Seventy-five percent (36/48) of all untreated stakes planted 47 mm from treated or untreated neighbouring stakes had failed by the six month evaluation, while only 38 percent (12/32) of all untreated stakes in grids of stakes planted at 95 mm distances had failed by six months (Table 1). Stakes planted 47 mm from neighbouring stakes failed more rapidly than those planted 95 mm from neighbouring stakes. Ten of sixteen untreated stakes in the grid planted at 142 mm distances failed by the six month evaluation. Although this percentage (63 percent) was lower than that for stakes at 47 mm and higher than that for stakes at 95 mm, the failure rate was not significantly different from either.

Similar statistical analysis of the data for ACA- and PCP-treated stakes revealed no statistically significant differences in decay rates between ACA- or PCP-treated stakes planted at any of the three spacings or interplanted with other treatments. The only suggestion of an accelerated decay rate was for PCP stakes when interplanted with ACA stakes at 47 mm spacing, but this was not borne out statistically.

It would appear that interface between stakes in this experiment was limited and only occurred at the narrowest spacing. This would not therefore cause a problem with repeatability if different mixes of preservatives were used in subsequent experiments at 95 mm spacing, provided these preservatives were no more mobile than ACA or PCP.

Figure 3 Rates of decay of untreated stakes planted at 67 mm, 95 mm and 142 mm spacing

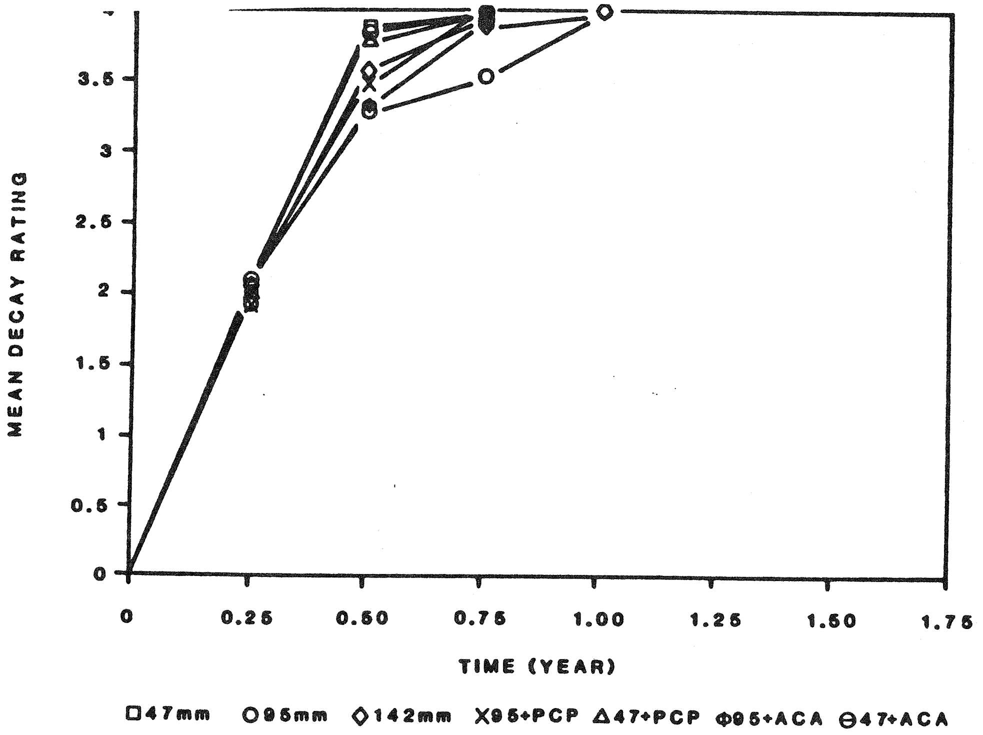


Figure 4 Rates of decay of ACA-treated stakes planted at 67 mm, 95 mm and 142 mm spacing

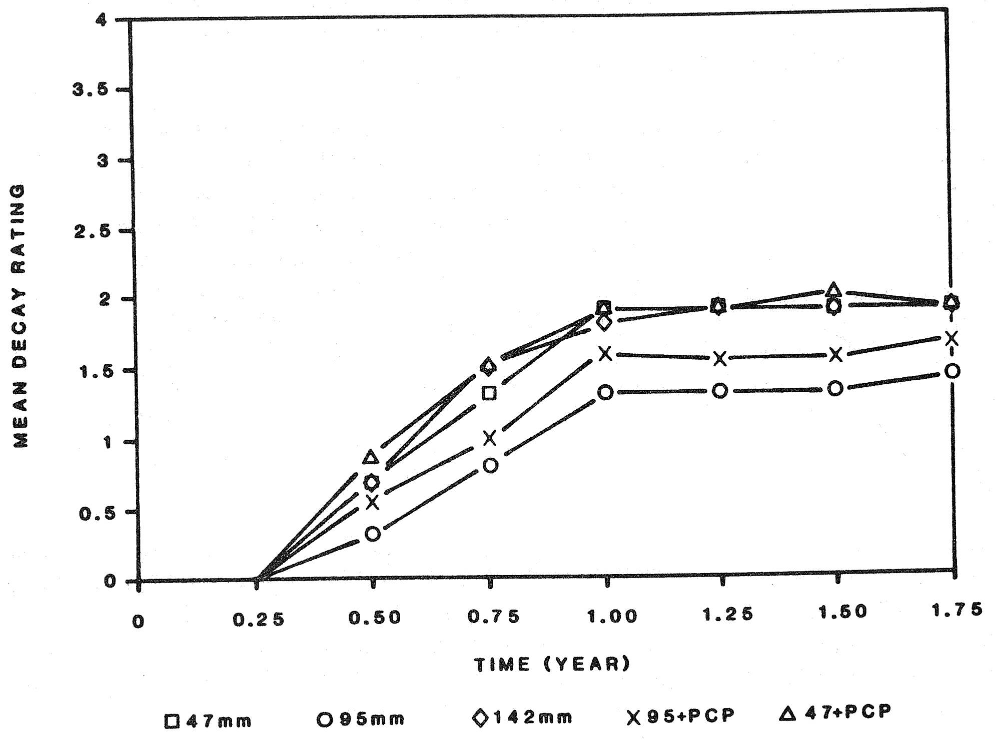


Figure 5 Rates of decay of PCP-treated stakes planted at 67mm, 95 mm and 142 mm spacing

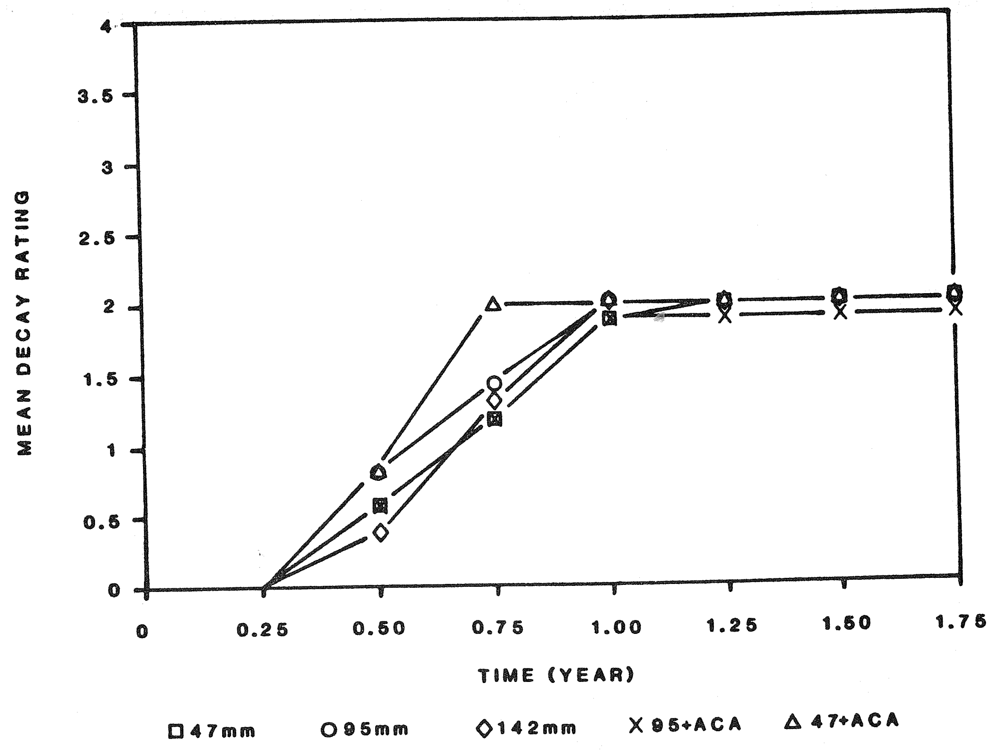


Table 1

The Proportions of Untreated Stakes Planted at Three Different Spacings Failing in Six and Nine or More Months

Spacing Distance (mm)	Neighbour Stake	Number Failed at		Total
		6 Months	≥ 9 Months	
47	untreated	10	6	16
	ACA-treated	14	2	16
	PCP-treated	12	4	16
	TOTAL	36	12	48
95	untreated	6	10	16
	ACA-treated	2	6	8
	PCP-treated	4	4	8
	TOTAL	12	20	32
142	untreated	10	6	16

Cooperative Test

If soil bed testing is to be accepted by codes and standards authorities, the reproducability of the method must be demonstrated. Different laboratories must be able to carry out the same experiment with broadly similar results in terms of comparative preservative performance. A collaborative project was therefore set up with the research institute operating the two other soil bed facilities in North America: Domtar Chemicals Group in Senneville, Quebec, and the Institute of Wood Research (IWR), Houghton, Michigan. Each laboratory prepared enough preservative-treated stakes for installation at all three facilities. Unfortunately, IWR removed the set of stakes from their facility after three months' exposure due to pressure of other work. Evaluation of the one year exposure data from the Forintek and Domtar facilities is currently underway. These results will be reported to the CSA and the AWPA Subcommittee on Standardized Methodology in Soil Bed Testing.

Basidiomycete Amended Soil Bed

The objective of this experiment was to further accelerate the rate of decay in the soil beds and ensure the involvement of wood-rotting basidiomycetes by adding standard test fungi to the soil. The preservatives used were CCA, ACA and ACQ at the full range of retention levels. Ten replicates of each retention of each preservative were planted in each half of a soil bed, separated by a stainless steel plate. The two half-beds were innoculated, five days before planting the stakes, one half with *Coniophora puteana* Schum Karst, and one half with *Poria placenta* (Fr) Cke Sensu. J. Erikss, grown on a rye grain medium.

After 1.25 years' exposure, sufficient decay for a comparison of decay rates had occurred only in solvent-treated stakes and at levels 1 (2.4 kg/m^3) and 2 (4.4 kg/m^3) for CCA (Figures 6 and 7) and level 1 (2.8 kg/m$_3$) for ACA (Figure 8). Stakes in the two amended half-beds were compared to the unamended performance test. Although the rate of decay was initially faster in the two amended half-beds for CCA levels 1 and 2 and ACA level 1, the performance test material later caught up or overtook. For solvent-treated stakes, the decay was much more rapid and the differences between the soil beds were only noticeable towards the end of the life of the stakes. The pattern of decreasing decay rate - *C. puteana* amended soil > *P. placenta* amended > unamended soil - held for both water (CCA solvent) and ammonium hydroxide solution (ACA/ACQ solvent) treated stakes. Only in the case of ammonium hydroxide solution treatment in *C. puteana* amended compared to unamended soil, however, were the differences statistically significant (X^2,   = 0.05).

Figure 6 **Decay rate of ponderosa pine sapwood stakes treated to 2.8 kg/m^3 with CCA exposed to unamended and basidiomycete amended soil**

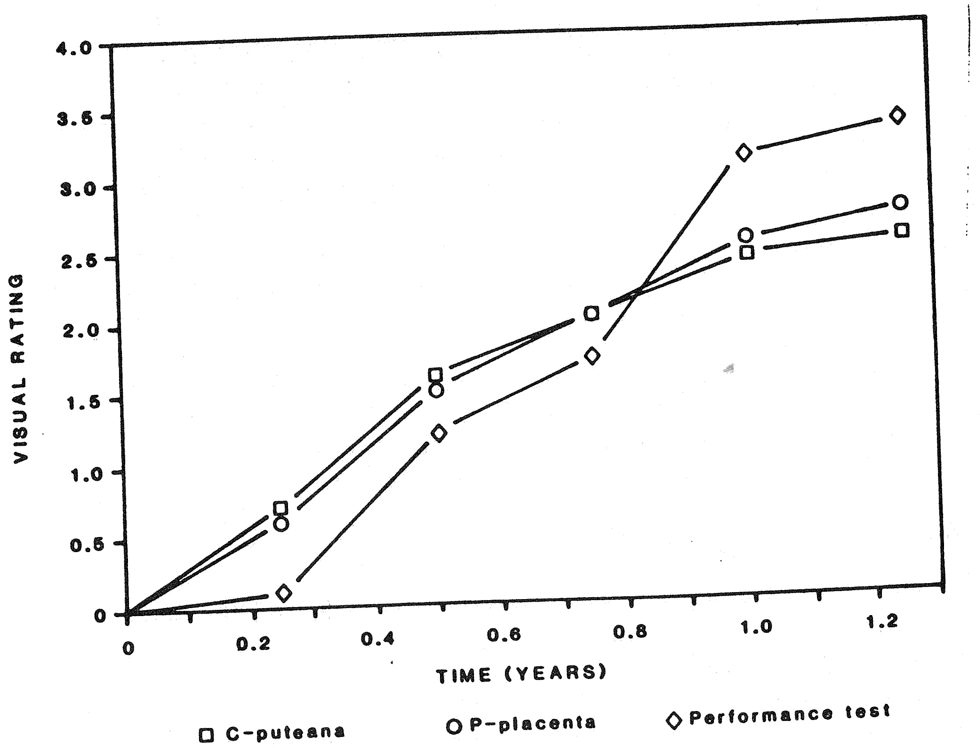


Figure 7 **Decay rate of ponderosa pine sapwood stakes treated to 4.4 kg/m^3 with CCA exposed to unamended and basidiomycete amended soil**

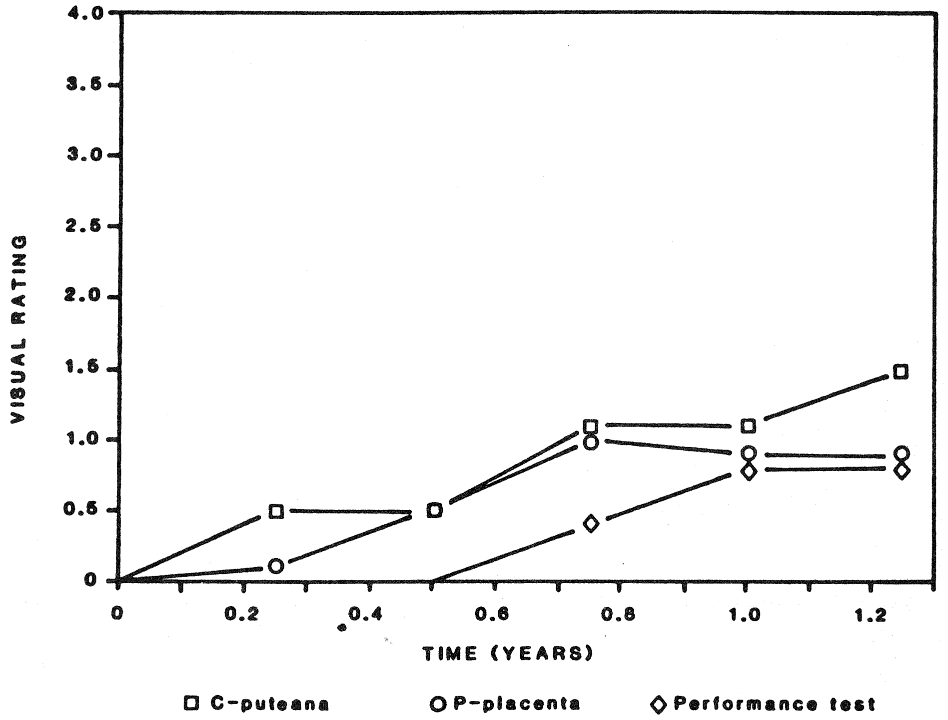
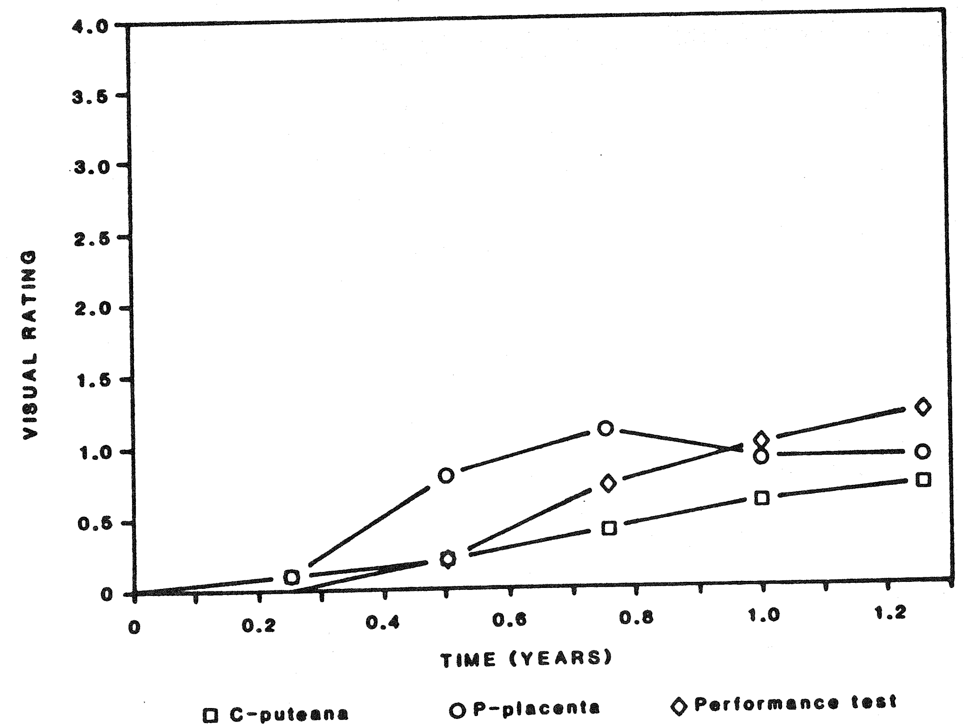


Figure 8 Decay rate of ponderosa pine sapwood stakes treated to 2.8 kg/m^3 with ACA exposed to unamended and basidiomycete amended soil



Isolations from failed untreated stakes and from soil onto media selective for wood-rotting basidiomycetes failed to yield either C. puteana or P. placenta. Observations of the macroscopic features of the decay in solvent-treated failed stakes from all beds suggested soft-rot attack, rather than brown or white rot caused by basidiomycetes. It is, however, possible that these fungi, in particular C. puteana, did become established in solvent-treated stakes and caused some acceleration of decay before being replaced by soft-rot fungi. There are no indications of basidiomycete attack on treated stakes.

Current Efforts to Promote Basidiomycete Activity

The fungi used in the study described above, although economically important in untreated wood and reliable in pure culture decay tests, have not been isolated from soil and are assumed to infect wood via airborne spores (12). It is normally very difficult to introduce exotic organisms to a balanced community, but a massive innoculation, accompanied by nutritional amendment might have been expected to succeed in establishing certain desired fungi long enough for them to colonize test stakes. It would, however, be more useful to establish wood-rotting basidiomycetes as a continuing component of the soil microflora as seems to be the case at the Westham Island test site (13). For this purpose, wood-rotting basidiomycetes naturally present in FAB soil or other soils might be more effective. Three approaches to this problem are currently being pursued:

1. Testing the decay capabilities of a basidiomycete which grows naturally and had fruited in the soil bed: a Coprinus sp. (Figure 9).
2. Testing the ability to grow in FAB soil of two wood-rotting basidiomycetes commonly isolated from failed stakes at Westham Island.
3. Adjustment of the soil moisture content to favour growth of wood-rotting basidiomycetes.

The first of these approaches has had mixed success. The Coprinus sp. decays birch but not pine and, as softwoods are our major area of interest, we need a fungus that can decay pine. A combination of the second and third approaches appears more promising. We have successfully grown one of the Westham Island basidiomycetes in jars of unsterile FAB soil at 20 percent soil moisture content and demonstrated significantly increased decay of buried pine blocks. It now remains to reproduce this in a FAB soil bed.

Figure 9 Fruitbody (mushroom) of a Coprinus sp. in the soil bed

THE NEED FOR ACCELERATED PRESERVATIVE TESTING

Preservative Performance Testing

Among the reasons why a preservative performance test might be set up, the following five are probably the most obvious and the first two the most important.

1. To compare modified or new preservatives to preservatives of known performance.
2. To determine the effect on product performance of potential changes in specifications for preservation or retention.
3. To assess the effect of wood species on preservative performance.
4. To assess the effect of the makeup of composite wood products on preservative performance.
5. Fundamental studies of the decay process and its prevention.

The first of these makes the assumption that there is a need for modified or new preservatives. Modification of the preservative may constitute addition of substances intended to alter wood properties other than durability; e.g., dimensional stability, hardness or colour. These substances could unintentionally affect preservative performance or permanence. More radical modification, such as a formulation change, might also be considered for example to improve the performance of copper-based preservatives in hardwoods.

The need for entirely new preservatives is debatable. We have four approved ground contact preservatives currently available; all of which have good track records over many years of testing and use in service. There are, however, two clouds on the horizon which could mar this view. First, the economic swings and ultimate limitation of the oil supply are likely to have an impact on both of our oil borne preservatives, creosote and pentachlorophenol (PCP) in P-9 oil. Long before fossil fuels are exhausted, increasing proportions of the cheaper fossil fuel fractions are likely to be diverted into higher value end uses, pushing up costs to the preservation industry.

Second, the environmentalist lobby, having turned its attention to the wood preservation industry, may eventually promote legislation to limit the range of chemicals available to us. This need not result from a ban on the use of specifc chemicals, but more likely from the imposition of restrictions on production, importation, handling, discharge or disposal. It is only prudent, therefore, to ensure the availability of alternative preservatives as a fallback in anticipation of such events.

With regard to the second reason for preservative testing, good examples of the generation of data in support of codes and standards may be found in the area of penetration and performance both in plywood and in lumber. Field test data have already been supplied to the Canadian Standards Association (CSA). The relationship between penetration and performance in lumber is currently under investigation at Forintek and will eventually employ a range of laboratory, FAB and field test methods.

TYPES OF TESTS AVAILABLE

Preservative testing may be subdivided into five major groupings, listed in order of increasing complexity, duration and likely sequence of employment in a standardized testing protocol:

1. Laboratory screening - M10 soil block test, various soft rot tests (soil or vermiculite burial)
2. Accelerated field test - fungus cellar, soil bed simulation
3. Standard field testing - the stake test
4. Commodity testing - poles, posts, etc.
5. Service tests - monitoring treated products in service

The second of these is a relatively recent phenomenon and Codes and Standards authorities have historically relied heavily on types one, three and five in setting standards. Each type of test has its own advantages and disadvantages.

Laboratory screening tests normally have a fixed time limit and often use a limited range of microorganisms. The toxic thresholds obtained can be compared to those of standard preservatives or may be multiplied by a safety factor to provide recommended retentions in practice. Leaching may be employed to simulate one of the effects of long term exposure, but many of the factors affecting preservative performance are eliminated to ensure reliability and repeatability of the test method. The mainstay of laboratory screening, the M10 soil block test, only uses wood-rotting basidiomycetes, whereas in practice the performance of treated wood may be limited by soft-rot fungi and possibly bacteria. Detoxification of preservatives by other microorganisms and synergistic interaction between decay fungi do not occur in this test. It is therefore possible for preservatives such as the unmodified quaternary ammonium compounds (quats) to perform well in the soil block test and poorly in service (14). Attempts to develop a standard laboratory soft-rot test (15, 16) will go some way towards broadening the range of screening tests available.

Accelerated field test simulation should essentially be regarded as forming a bridge between laboratory and field testing, both in terms of methodology and its potential employment by the industry and Codes and Standards authorities. Data from soil bed tests could be used to give provisional approval to a preservative or a standard alteration pending the results of long term field tests.

The standard stake test is still the workhorse of any testing program and is relied on to give an accurate indication of the comparative performance of preservatives in ground contact. Today, before a new or substantially modified preservative is approved by the CSA, it must have a proven efficacy over ten years of field testing. Some prediction of performance may be made from early decay of preservative loadings below specification but ideally we would wish to compare the performance of stakes treated to CSA specified retentions. This cannot be done within a reasonable time scale because our standard preservatives, to which new or modified preservatives must be compared, do not, of course, permit decay within a short time scale.

In the stake test, the wood is completely penetrated with preservative, but this is rarely the case with treated commodities. It is therefore necessary to maintain representative commodities in test to investigate the protective effect of envelope treatments on the untreated interior and the converse effect of the presence of adjacent untreated wood on the performance of the treated zone. Commodity testing can bridge the gap between the results of stake tests and the performance of commodities in service.

By far the oldest form of test is the service trial and, despite the problems of assessment due to the variables involved, this must be the ultimate test of a preservative. The restrictions imposed on sampling are the major limitation and can eliminate its usefulness as a predictive test. Such trials are thus of the longest duration.

Decay of treated wood is of course extremely slow. No indication of comparative performance can be made if wood treated with both preservatives remains completely sound until the question becomes immaterial after thirty or forty years in test.

In summary, the standard tests which give the best indications of preservative performance are necessarily long term unless the unknown preservative has an extremely poor performance, because our standard reference preservatives do impart a long life to treated wood. The need for a more rapid response to requests for data to support Canadian Codes and Standards and to compare preservative performance led to the design and construction of a Facility for Accelerated Biodeterioration (4).

CONCLUSIONS

1. The factor of acceleration of Forintek's soil bed for CCA-treated wood is between five and fifteen times, depending on the field test site with which the comparison is made.
2. There is no significant interference between adjacent stakes at the standard spacing used in these experiments.
3. Standard test wood-rotting basidiomycetes are not the most appropriate for ensuring the presence of this decay type in the soil beds.
4. The soil bed can, in its present form, be used for high priority Codes and Standards research with a high degree of confidence in the data generated.

THE DIRECTION OF CURRENT AND FUTURE RESEARCH

Having established an operating facility, our next major goal is to gain acceptance (by Codes and Standards authorities) of the data it will generate before taking on any contract testing work. To this end we are concentrating on three types of experiment:

1. Experiments that will demonstrate a relationship to field testing such as the performance test and the field/FAB comparison test.
2. Experiments that will define the reproduceability and repeatability of the method such as the Cooperative test and the spacing test.
3. Experiments that are directed towards modifying the balance of decay types present to more closely simulate field conditions.

In the course of these experiments we are doing such fundamental studies on the decay process and preservative action, as may be required to bring the knowledge of accelerated soil bed testing level to that available in conventional stake testing.

At this stage we anticipate taking on contract testing in this facility in the Fall of 1989, although full approval of the methodology by Codes and Standards authorities may take a little longer. We already have sufficient confidence in the test method to devote one bed to critical Codes and Standards work in the area of penetration of preservative versus performance of treated commodities. Material protected by various depths of treatment will be installed before the end of the 1987/88 fiscal year. We would anticipate obtaining useful results from this test within four years; results which it would have taken perhaps forty years to generate using a normal field test site.

REFERENCES

1. Butcher, J.A. 1983. Report on Questionnaire Facility for Accelerated Stake Tests in Unsterile Soil. International Research Group on Wood Preservation, Document No. IRG/WP/2169. 5pp.

2. Smith, R.S. and A. Byrne. 1987. Construction and Use of a Facility for Accelerated Decay. For. Prod. J. (In press).

3. Gersonde, M. and G. Becker. 1958. Prufung von Holzschutzmitteln fur den hochbau auf wirksamkeit gegen pilze an praxisgemassen holzproben (Schwammkeller-Versuch) Holz Roh. Werkst. 16:346-357.

4. Smith, R.S. and A. Byrne. 1984. Feasibility of a Facility for Accelerated Biodeterioration. Contract Report No. 02-65-66-018 to the Canadian Forestry Service. Forintek Canada Corp., Vancouver, B.C.

5. Smith, R.S. and A. Byrne. 1985. Establishment of a Facility for Accelerated Biodeterioration. Contract Report No. 02-65-10-397 to the Canadian Forestry Service. Forintek Canada Corp., Vancouver, B.C.

6. Smith, R.S., A. Byrne, J.E. Clark and L. Parker. 1986. Operation of a Facility for Accelerated Biodeterioration. Contract Report No. 02-17-10-397 to the Canadian Forestry Service. Forintek Canada Corp., Vancouver, B.C.

7. Dickinson, D.J. and S.M. Gray. 1986. Hardwood Field Experiment: Progress Report 1977-1986. International Research Group on Wood Preservation, Document No. IRG/WP/3391. 9pp.

8. Ruddick, J.N.R. and P.I. Morris. 1987. The Movement of Iron into Field Test Stakes. International Research Group on Wood Preservation, Document No. IRG/WP/2286. 14pp.

9. Ruddick, J.N.R. and C.D. Ralph. 1984. Field Testing of Treated and Untreated Wood Products. Contract Report No. 02-65-57-051 to the Canadian Forestry Service. Forintek Canada Corp., Vancouver, B.C.

10. Gjovik, L.R. and D.I. Gutzmer. 1985. Comparison of Wood Preservatives in Stake Tests (1985 Progress Report). U.S. Dept. Agriculture, Forest Products Laboratory, Research Note. FPL02.

11. Murphy, R.J. and D.S. Dickinson. 1981. The Effect of Copper-Chrome-Arsenate (CCA) Treated Timber on Soil Fungi. International Research Group on Wood Preservation, Document No. IRG/WP/1131. 12pp.

12. Cartwright, K. St. G. and W.P.K. Findlay. 1958. Decay of Timber and its Prevention. 2nd Edition. Her Majesty's Stationery Office, London. 294pp.

13. Morris, P.I. and L. Parker. 1987. Mycological Assessment of Field Test Material. Contract Report No. 02-17-10-051 to the Canadian Forestry Service. Forintek Canada Corp., Vancouver, B.C.

14. Ruddick, J.N.R. 1986. The influence of staining fungi on the decay resistance of wood treated with alkyldimethylbenzylammonium chloride. Mat. Org. 21(3):139-149.

15. Dickinson, D.J. and S.M. Gray. 1986. Proposals for Collaborative Work on Laboratory Soft Rot Testing. International Research Group on Wood Preservation, Document No. IRG/WP/2265.

16. Dickinson, D.J. and S.M. Gray. 1987. Final Proposals for Collaborative Work on Laboratory Soft-Rot Testing. International Research Group on Wood Preservation. 5pp.