An assessment of risks associated with use of CCA-treated timber in sensitive environments and options for its substitution with alternative timber materials

Michael D Hedley BSc (Hons) PhD
Resource Centre Manager
Wood Protection
Wood Processing Division
New Zealand Forest Research Institute
Private Bag 3020
Rotorua

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CONTENTS

1. IMPACTS OF USE OF CCA-TREATED WOOD ON HEALTH AND ENVIRONMENTS

List of Tables

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All the above are available through:

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Fax: (07) 347 9380

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Brief for Report

- Review data on effects of use of CCA-treated timber on the environment, identifying where there is clear evidence to support or oppose a position of using CCA-treated timber in sensitive environments. Identify where evidence is inconclusive or non-existent and give examples where in NZ or overseas there has been no research done to provide the needed evidence to form any opinion both for or against. (Reviewed in Section 1.)

- Provide a breakdown assessment of all reasonable alternative untreated timbers including specific natives which might be gifted for use. Identify for each timber their assessed performance (e.g. likely durability and strength depending on use above or below ground, ease of use and likely cost). These should be compared with similar features for CCA-treated timbers of stated types. (Reviewed in Section 2.)

- Advise on probability and likely time scale for the availability in NZ of other chemical or water-borne timber treatments which are, or may become, available as alternatives to CCA treatments. (Reviewed in Section 3.)

- Advise guidelines or suitable references to cover disposal requirements for CCA-treated timbers to mitigate or remove environmental hazards. (Reviewed in Section 4.)

- Clearly identify areas where there may be gaps in available knowledge of effects and, if necessary, make recommendations where research or monitoring maybe required to address areas where existing knowledge may be sparse, or special NZ conditions may apply. (Reviewed in Section 5.)

Executive Summary

Copper-chrome-arsenate (CCA) preservatives have been in use world-wide for some 60 years and in New Zealand since the mid 1950s. They are demonstrably the most effective of all wood preservatives.

CCA preservative manufacture is a minor industrial use of annual copper and chromium production but is an important consumer of arsenic, a by-product of non-ferrous and precious metal refining, which would otherwise accumulate as an unutilisible hazardous toxic waste.

A unique feature of CCA is that by a complex series of chemical reactions, the preservative components become fixed in the wood. Some leaching does occur, particularly from freshly treated material and especially in sea water, but most studies show that this leaching adds little to background levels of copper, chromium and arsenic in either soil, water or sediments.

An important proviso to these observations is that material must be treated, not only to conform to treatment standards and specifications, but in accordance with prevailing quality assurance requirements to ensure that the preservative is properly fixed within the wood before the timber is used in any construction and that it is free from any extraneous surface deposits ("sludge").

Inevitably, there have been recorded instances where because these conditions were not met, CCA-treated wood has posed a threat to the environment and to health. Much of the argument against use of CCA preservatives stems from this mismanagement; but this applies equally to alternative preservative systems.

In several cases, experience has shown that CCA-treated timber is inappropriate for some end-uses, or that its use requires some recognition of potential hazard, which in most instances is relatively easily managed.

Use of naturally durable timber as an alternative to CCA-treated timber is discussed. In many instances this is a technically feasible option, particularly for uses out of ground contact, but overall performance will be more variable than that of CCA-treated timber. Performance in ground contact will be even more variable, except for such species as totara and silver pine, and use could only be recommended in situations of low criticality.

Best prospects seem to be locally grown eucalypts, particularly *Eucalyptus botryoides, E. pilularis, E. saligna* and *E. obliqua,* although sourcing these in areas other than the central and northern North Island will be difficult, and even in those areas, availability is very much restricted. *Cupressus macrocarpa* and *C. lusitanica* would find some uses as alternatives to CCA-treated pine. The cost of these options may not be significantly higher than use of CCA-treated pine and there is obvious scope for the Department of Conservation to plant and manage plantations to produce timber for its own use.

Although several of the wood extractives which confer natural durability are water soluble (and hence leachable), little information is available concerning their potential for adverse environmental impact.

Alternative water-borne chemical treatments to CCA are of two types: (1) where arsenic is replaced by boron, fluoride or phosphate, (2) where both arsenic and chrome and are replaced, typically by organic biocides. Of the former, copper-chrome-boron is the favoured alternative on efficacy and environmental grounds and it can be formulated on an industrial scale in New Zealand using current plant and equipment. Its major failing is relative lack of effectiveness against brown rot fungi.

Of the second type, both ammoniacal copper quats (ACQ) and copper azoles are being extensively tested under New Zealand conditions. Realistic expectations are that both could be submitted for approval for use in above ground situations within the next 18 months and for ground contact use within the next 3 years. Performance data so far generated show both to be only slightly less effective than CCA, although costs will be significantly higher. There is little environmental impact data available for these two preservative types.

Disposal of CCA-treated wood is currently confined to re-cycling (excising decayed portions and re-using sound portions as smaller items), or disposal in landfill. Overseas examination of leachates from latter activities indicate little environmental impact. Studies are currently underway to examine impacts under New Zealand conditions.

Internationally, both disposal procedures are seen as currently best practical options, but far from ideal solutions.

Other procedures such as controlled incineration or chemical treatment to recover preservative components from treated wood are technically feasible but currently prohibitively expensive. They are not seen as realistic options in New Zealand in the immediate future.

There are no reliable data to suggest that use of alternative preservatives of the types reviewed here will have any less (or greater) environmental impact than use of CCA. Proposals are therefore made for establishment of a controlled trial in a single structure (such as a walkway), similar to one currently being established in USA, to resolve relative leachability of toxicants from variously treated timber.

Education of Department of Conservation staff on safe handling and use of CCA-treated timber and disposal of CCA-treated wood waste is seen as advantageous.

Recommendations are also made, if use of timber materials other than CCA-treated pine is accepted, for the initiation of a programme (based on that previously proposed for electric power distribution authorities), to monitor decay in wooden structures under Department of Conservation control.

While such a programme is not seen as critical to the use of CCA-treated timber, NZ FRI experience indicates far greater variability in performance of naturally durable timber or timber treated with alternative preservatives, which would require a more rigorous monitoring programme, particularly in more critical end-use situations.

1. Impacts of use of CCA-treated wood on health and environment

COPPER, CHROMIUM AND ARSENIC IN THE ENVIRONMENT

Copper, chromium and arsenic are natural constituents of the earth's crust and copper and chromium are essential micronutrients for many life forms (Brooks, 1993).

Approximately 6 million tonnes of copper are produced annually world-wide. The principal use is as a constituent of metal alloys, but other major uses are as a base for the manufacture of fungicides and for pigments.

World-wide production of chromium is 7 million tonnes annually and major uses are in metal alloys, plating, leather tanning and pigments.

Approximately 56,000 tonnes of refined arsenic trioxide (the base product in which arsenic is traded) are produced annually. Major uses are in the manufacture of alloys, herbicides, soil sterilants, wood preservatives and pesticides.

Much of the world's arsenic is produced as a by-product of essential metal refining industries, particularly copper. The point has been made (Carruthers, 1991) that if use of arsenic in wood preservatives was banned, production of arsenic would not stop and a further problem would arise; what to do with the large accumulation of arsenic waste which at that stage is concentrated and water soluble?

It is also of interest to note that Woolsen (1983) estimates that each year, volcanoes contribute 7,000 tonnes of arsenic to the global environment, approximately half the amount used annually in CCA preservatives.

Some 120,000 tonnes of CCA salts are used annually worldwide (Connell, 1991). Although this manufacture requires a substantial proportion of annual arsenic production, it represents only a very small outlet for copper and chromium production.

Given the high rates of production and refinement of these metals and their incorporation into a large array of products and applications, it is not surprising that they have gradually been spread into (and been absorbed by) the global environment.

Much of this has been unintentional, e.g. poor control of industrial wastes or natural emissions, but a high proportion has been from deliberate application, particularly the use of copper and arsenic compounds in horticulture, agriculture and forestry.

For example:

- 87,500 hectares of NZ forests sprayed with 0.8 kg copper/ha annually to control *Dothistroma* pine needle blight (Ray, pers. comm.).

- Some 3800 tonnes of arsenic acid sold annually in the USA as cotton desiccation sprays (USDA, 1980).

- Some 1000 tonnes of lead arsenate used as a growth regulator in Florida grapefruit orchards annually (USDA, 1980).

- 25 % of total chromate salt production (quantity unknown) used in the leather tanning industry (Encyclopedia Britannica, 1976)

Background levels of the three elements world-wide in soil, water and sediments are thus likely to vary enormously between sampling locations, and average figures are probably meaningless.

However, to give some examples of natural levels recorded in the three environments:

Soil

In a study of some Australian soils (ANZEC, 1990), the range of levels found are shown in Table 1 (Appendix 2).

Fresh and salt-water

Background levels in water are much less and from reviewed data, Brooks (1993) gives general estimates shown in Table 2 (Appendix 3).

Sediments

Brooks (1993) also gives estimates, based on a number of studies, in sediments in unpolluted areas (Table 3, Appendix 4).

Except for the unique Waiotapu Valley records, these levels do not necessarily imply any biological significance or potential for adverse environmental impact. Once in contact with soil, complex geological and biological reactions take place between the soil, its micro-organisms and metal leachates which effectively immobilise the latter (Cooper, 1991).

For example, arsenate - the form of arsenic present in aerobic soils - reacts with iron, aluminium and calcium components of the soil to produce highly leach resistant complexes. Soils high in amorphous metal oxides such as weathered soils of volcanic origin (e.g. much of New Zealand) have high affinities for arsenic. (Cooper, 1991). Arsenic in water is sorbed by sediments and becomes unavailable to aquatic plants and animals (USDA, 1980).

New Zealand guidelines, developed by Ministry for the Environment and Ministry of Health, for maximum permitted levels in soil and water, vary with site use (soil) and beneficial use (water).The most stringent are for agricultural/ horticultural soils and potable water and these are summarised in Table 4 (Appendix 5).

THE CONTRIBUTION MADE BY USE OF CCA-TREATED WOOD TO COPPER, CHROMIUM AND ARSENIC IN THE ENVIRONMENT AND ITS POTENTIAL FOR ADVERSE ENVIRONMENTAL IMPACT OR HEALTH HAZARD

It is in the context of these background levels in the environment that any analysis must be made of the contribution that use of CCA-treated timber adds to them and whether or not this adversely effects the resident biota or poses a health hazard.

There is a very large body of data on the environmental impact of use of CCA-treated wood (inter alia Arsenault, 1975; Webb and Gjovick, 1988; Comfort, 1993; Brooks, 1993) which suggests that use of CCA-treated timber either in soil or in fresh or salt water will have little significant effect on raising these background levels and consequently will not effect eco-systems supported within these environments.

For example, Comfort (1993) notes that in soil samples taken from adjacent to a CCA-treated walkway and samples taken at remote stations away from the walkway, copper levels in all were within the background range; 2 samples, one adjacent to the walkway and one remote from it, had arsenic concentrations marginally above the maximum for the range, but 20 samples had chromium contents above those established by the ANZEC (1990) study; 14 were adjacent to the walkway and 6 were remote from it. Comfort also notes that vegetation in the vicinity of the track did not seem to be negatively affected by it.

This observation is not unexpected because, copper, chromium and arsenic tend to be immobile in soils particularly those which have a high clay or organic matter content (EPA, 1986). Thus, any leaching from CCA-treated timber into such soils will have little adverse impact since toxic components will bind with the soil, preventing serious ground-water contamination and restricting the availability of the preservative components to plants (Walsh et al., 1977).

In a Swedish study, Henningsson and Carlsson (1984) measured Cu, Cr and As contents of sand adjacent to CCA-treated timber used in children's play sandpits, a medium with low organic matter content and hence little potential for binding leached toxicants. The timber had been exposed for 2 to 4 years at the time of analysis and a summary of results is given in Table 5 (Appendix 6).

The authors note that natural levels of arsenic recorded in the type of sand in question are 1 - 40 ppm, so recorded levels were within the normal range. Results indicated that for acute poisoning to take place, at least 10-30 kg of sand derived from the immediate vicinity of the treated timber would have to be consumed on a single occasion. The authors concluded that there is little risk of arsenic poisoning for children playing in playgrounds where CCA-treated timber is in use.

There have been a number of studies on possible effects on plants when grown in the proximity of CCA-treated timber. For example, Levi *et al.* (1974) found no phytotoxic effects on grape plants and no uptake or tanslocation of wood preservative components into leaf, stem tissue and fruit of grape vines planted adjacent to treated posts.

In pot trials where soil had been amended by addition of CCA-treated saw-dust, Speir *et al.* (1992a;b) found root metal concentrations of the CCA elements were higher than those in the soil, but were not high enough to be phytotoxic.

Grant and Dobbs (1977) showed growth and cropping of carrots, dwarf beans and tomatoes to be unaffected when these vegetables are grown in soil containing up to 75 ppm Cu+Cr+As.

Studies such as these have led reviewers of the effects of CCA-treated timber on the environment to conclude that it has negligible impacts.

For example, Comfort's (1993) conclusion begins:

> "CCA treated timber has been employed in construction for more than fifty years throughout the world. There are few reported environmental problems associated with its use. In Tasmania, it has been used in walking track construction for more than 15 years with no obvious adverse effects on the environment"

And ends:

> "In summary, it is concluded that the use of CCA treated timber for walking track construction poses a very low risk to the environment and to those who work with the timber".

Webb and Gjovik (1988), considering the effects of treated wood products on the environment conclude:

> "Treated wood products can be safely used without any adverse effects on man, animals and the environment. The treated wood industry has been a part of a very thorough evaluation and appraisal of the products in conjunction with the [US] Environmental Protection Agency. As with many other chemical materials, users of treated wood products need to use good common sense and handling practices".

In referring to aquatic environments, Brooks (1993), having used very conservative (pessimistic) assumptions in his analysis concludes:

> "Even with this very conservative approach to assessing the risks involved, this analysis indicates that the levels of contaminants associated with the use of properly treated CCA and AZCA [ammoniacal zinc copper arsenate] wood products are well below regulatory standards and will produce concentrations far below those causing acute or chronic stress in even the most sensitive taxa".

Nearly all studies relating to use of CCA-treated timber and its impact on the environment have been conducted overseas. It can be argued that there is no evidence to suggest that these studies have any direct relevance to New Zealand conditions (different timber species treated, different geological and climatic conditions). While this argument may seem pedantic, it is an issue which should not be avoided and recommedations are made to address it (see p. 19).

A crucial element in Brooks' conclusion (and implicit in those of the other authors cited) is use of the phrase "properly treated", for if this condition is not met, the conclusion may well be invalidated.

"Properly treated" is the essential proviso when assessing the risk of using CCA-treated wood in sensitive environments.

"Properly treated" means that the wood has been treated in accordance with prescribed specifications and standards, and that the necessary quality assurance and regulatory procedures required for its production have been implemented to ensure that at the time of delivery for installation in a structure on site, the CCA-treated wood is a fit product for the required purpose.

Without any doubt, the key issue is that the preservative has had time to completely "fix" in the wood before it leaves the treating facility, and that it is free of noticeable surface deposits of preservative sludge (green-white deposits of precipitated preservative indicative of poor plant control). Current research at NZ FRI and elsewhere is in development of treatment processes which guarantee that these conditions are consistently met.

Inevitably, there have been recorded instances where because they were not met, CCA-treated wood had the potential to pose a threat to the environment and to health. In other cases, experience has shown that CCA-treated timber is inappropriate for some end-uses, or that use requires some recognition of potential hazard. It is the ". . . good common sense and handling practices" of Webb and Gjovik.

Examples of these cases, mostly related to New Zealand experience, are summarised below.

FRESHLY-TREATED TIMBER

The unique feature of multi-component preservatives containing hexavalent chromium, such as CCA, is that when solutions are impregnated into wood, the components react both between themselves and with cellulose and lignin in the wood, a process known as "fixation".

CCA treating solutions are highly acidic (pH 1.9 - 2.2) and because wood is much less acidic than the treating solutions, it triggers the complex reactions which take place between the wood and preservative components resulting, eventually, in fixation of the preservative in the wood, making it highly resistant to leaching.

Like most chemical reactions, the rate of reaction is time and temperature dependent. If freshly-treated wood is stored outdoors during winter, the reaction may take many weeks, even months, to complete. Even at ambient temperature in summer, the reaction is unlikely to be completed in less than two weeks. For this reason, CCA-treated wood should never leave the treatment site for at least two weeks following treatment.

During the late 1970s and early 1980s there was an almost insatiable demand for treated roundwood, particularly for establishment of kiwifruit orchards and deer farms. An inevitable result was that treated timber often left treatment sites well before the fixation period had ended. In one known instance, in South Waikato, this led directly to the deaths of 27 deer fawns, which had licked freshly treated and installed posts (Milligan, 1980). One would expect there were more unreported cases of similar stock poisoning.

When properly fixed in wood, CCA is harmless to stock (Harrison, 1959).

SHINGLE ROOFS

Rainwater, when collected from experimental CCA-treated shingle roofs exposed at NZ FRI test site, was shown to contain levels of arsenic higher than those recommended by the World Health Organization (WHO) for potable water (0.05 ppm). These levels may be present for some years after original installation. For this reason, CCA-treated shingles should never be used where water is collected from roofs for domestic purposes, even though the human body can absorb (and excrete in 24 hours) 4.84 mg arsenic per day without any clinical effect (Arsenault, 1973).

WATER TANKS

In 1984, the tabloid newspaper "NZ Truth" reported that 0.26 ppm arsenic (5 times higher than WHO recommended upper limit) had been found in a CCA-treated timber water tank in South Auckland. Checks on other tanks revealed this to be an isolated case. It was noted, however, that the tank in question had been filled with water to only one fifth of its capacity which had effectively led to concentration of contaminants. If the tank had been filled, as recommended by the manufacturer, to its full capacity, detectable arsenic levels would have been within WHO guidelines.

PLAYGROUND EQUIPMENT

An Australian study (Johanson and Dale, 1973) concluded that the health hazard to children posed by CCA-treated playground equipment was very small. They recommended, however, that because of possible variation in the extent of fixation and uncertainty as to the toxicity of fixed arsenic to humans, such equipment should be thoroughly washed and scrubbed before it became accessible to children. Cooper (1991) notes that the US Environmental Protection Agency and the US Consumer Products Safety Commission Health Services Directorate consider health risks associated with dermal absorbance of arsenic through contact with CCA-treated wood to be negligible.

MARINE PILES

Recent studies (Weis and Weis, 1994) indicate that in marine environments, CCA leaches appreciably, components accumulate in biota that live in wood, and the plant and animal community diversity may become reduced. The accumulated preservative components may be transferred to their consumers with deleterious effects. The extent and severity of effects in any particular area depend on the amount of wood, its age, water quality parameters and degree of dilution by water movement.

This conclusion is at odds with that of Brooks (1993), which would indicate that there is doubt about possible effects of use of CCA-treated wood in some marine environments.

From a New Zealand perspective, only 0.172 % of CCA-treated wood produced annually is used in marine environments. Thus, while the above observations may occur with respect to CCA-treated wood in New Zealand waters, their biological significance is likely to be limited to localised areas.

However, it is pertinent to note in this context, that the Tasmanian Pacific Oyster farming industry (sales of ~ $A 20 million/year) relies solely on use of CCA-treated pine timber; it would not be a viable industry if treated pine was unavailable and the use of CCA-treated pine by this industry has never been seen as a health or environmental issue (Anon, 1991).

BURNING CCA-TREATED WOOD

When burnt, a large percentage of the arsenic in CCA-treated wood becomes volatilised. A U.K. study (Dobbs and Grant, 1976), concluded that burning of treated wood is unlikely to add significantly to the quantity of arsenic present in the atmosphere, generated mainly by the burning of coal. However, the preservative components accumulate in ash and this can cause adverse environmental effects unless disposal is carefully controlled.

A New Zealand investigation (Watson, 1958a) showed that bacon cured with smoke generated from burning CCA-treated wood was contaminated by up to 2.3 ppm arsenic. Fish, similarly smoked, contained up to 25 ppm arsenic (Watson, 1958b).

The above examples show that there are potential dangers in the use of CCA-treated wood, but these can be largely circumvented by good treatment plant management, particularly adoption of proper fixation processes and common sense by the consumer.

2. Naturally durable untreated species as alternatives to CCA-treated pine

NATURAL DURABILITY

Natural durability is a property conferred on the heartwood (or truewood) of timber by the presence of fungitoxic components deposited due to chemical changes which take place during the transition from living sapwood to dead heartwood.

These fungitoxic components come from a wide range of chemical families of which the more important are tropolones, flavanoids, isoflavanoids, anthocyanins and phenolic mono- di- and sesquiterpenes (Rudman, 1963). Many of these compounds are water soluble (for example, the tropolones which confer durability to western red cedar). Little is published on the toxicology of these compounds and the presumption by advocates for use of naturally durable timber as an alternative to preservative treated wood appears to be that it is negligible. However, Peters *et al.* (1976) showed that hot water extracts of western red cedar (*Thuja plicata*) were highly toxic to aquatic life.

The use of naturally durable timbers worldwide is decreasing rapidly because the majority of supply is from non-renewable virgin forest resources. However, some naturally durable species of commerce, such as teak and many of the Australian eucalypts, are amenable to sustainable plantation forest management. Evidence suggests that because growth as a plantation tree is more rapid than in "natural" forest, there is a concommitant lowering of durability, but this effect on durability properties is likely to be less than that associated with the genotypic makeup of the tree.

Although there are very few uses whereby naturally durable timber cannot be replaced by preservative treated timber, Findlay (1985) lists five uses where naturally durable timber is recommended:

- Structural timbers of very large size which cannot be easily treated.
- Boat building in which large timbers have to be fashioned to particular shapes on site.
- Vats that are to contain liquids which must not be contaminated by traces of any poisonous chemicals.

- External decorative woodwork in which the natural colour and beauty of the untreated wood must not be lost.

- Plywood for external and marine use.

NATURAL DURABILITY TESTING IN NEW ZEALAND

It is customary to categorise natural durability of timber species in terms of years that a standardised specimen will last in the ground before extent of decay causes failure.

In New Zealand tests, specimens have been of two cross-sectional dimensions: 50 x 50 mm and 20 x 20 mm and durability classifications in terms of years to failure are shown in Table 6 (Appendix 7).

Using the above criteria, native and locally-grown exotic species which have been tested in sites controlled by NZ FRI have been assigned to the durability classes in Table 7 (Appendix 8).

In general, species rated moderately durable or better would have sufficient durability for most above ground uses; species rated durable or better would have sufficient durability for all above ground uses and most ground contact uses and those rated very durable would be suitable for any above ground or ground contact use.

Note that this classification concerns itself only with durability and not with any mechanical or machining properties of the wood. For example, *E. cladocalyx*, although rated very durable, is very dense and often has interlocked grain, which makes nailing extremely difficult.

One practical problem associated with using naturally durable species as an alternative to treated timber is that many species will exhibit a considerable range in durability, both within a single tree and between different trees of the same species.

This is illustrated in results of an NZ FRI test in which 10 samples were cut from each of 5 different trees of *Eucalyptus pilularis, E. muellerana* and *E. globoidea*.

Number of specimens remaining after 14 years' exposure is shown in Table 8 (Appendix 9).

On the basis of this test to date, it would be difficult to decide which of these species is the better option for utilisation;

E. pilularis has 10 specimens left from 3 different trees and the average life so far determined (from 2 trees) is 6.3 years.

E. muellerana has only 6 specimens left spread evenly over 4 trees with an average life established from 1 tree of 8 years.

E. globoidea has 13 specimens left, 10 of which are from 2 trees, but average life from 1 tree was only 4 years.

Thus, there will always be a risk of early failure when using naturally durable timber in high decay hazard situations. However, this risk can be managed (as it has been for many years by, for example, electric power authorities which have many thousands of naturally durable poles in distribution lines) by a regular monitoring and maintenance programme (see p. 20).

In addition to stake tests to determine basic durability properties, NZ FRI has a number of service tests to determine the suitability of various species for some end-uses.

Results of relevant tests of commercially available alternative species are shown in Table 9 (Appendix l0). For comparative purposes, this table also contains results for CCA-treated radiata pine.

In many ways, results confirm those of the basic in-ground natural durability tests. There is little to choose between the eucalypt species *E. botryoides*, *E. pilularis*, *E. saligna*, *E. muellerana* and *E. obliqua*. All perform reasonably well in above ground situations, but all have limited durability in ground contact.

CCA-treated radiata pine is, however, clearly superior in all tests.

COST AND AVAILABILITY OF NATURALLY DURABLE TIMBERS

Table 10 (Appendix 11) gives \$/m³ costs GST exclusive at the wholesale level for rough sawn kiln-dried sawn timber purchased ex-yard Auckland. Timber prices are subject to substantial fluctuations and regional variation. The prices in Table 10 must be regarded as indicative and representative of the second quarter 1995/96.

AVAILABILITY

Kwila and balau are imported mainly as dressed boards, principally for decking. Larger sizes would be imported against a specific order.

There are approximately 15,000 hectares of eucalypt forest in New Zealand, but nearly 50 % of this is given over to ash-type eucalypts grown for short fibre pulp (Haslett, 1988).

Areas and ages of durable species being grown for sawn timber production are shown in Table 11 (Appendix 12).

Plantations are located in the North Island from Bay of Plenty northwards and are characterised by generally low aged stands. Only 100 hectares is currently mature enough for sawing and processing and this is nearly all *E. saligna* (Haslett, 1990).

The cypresses (*C. macrocarpa* and *C. lusitanica*) have rarely been planted in anything other than small woodlots and volumes available cannot be assessed. They are likely to be small and of variable quality.

Thus, although use of locally-grown naturally durable timbers is an attractive and technically feasible option, lack of availability of suitable timber will severely limit its adoption.

3. Chemical timber treatments as alternatives to CCA

Research and development of multi-salt water-borne formulation alternatives to CCA have been in two phases: replacement of arsenic and replacement of arsenic and chromium.

REPLACEMENT OF ARSENIC

In the 1970s formulations were produced in which arsenic was replaced with perceivably less toxic components such as phosphate to give copper-chrome-phosphate (CCP), boron (CCB) or fluoride (CCF).

Although detailed relative costs of the different formulations are not known, it is likely that they will be more expensive than CCA since arsenic is the least expensive component in CCA formulations. This cost differential is unlikely to be large since the replacement chemicals are widely used and are industrial commodities of trade. Manufacturing plant required to formulate the preservatives is essentially the same as that used to formulate CCA.

Of primary interest is the preservative efficacy of these alternatives relative to that of CCA.

All formulations noted above have been in tests under control of NZ FRI for 16 years. Results of the tests are reproduced below (Table 12).

The five test sites have differences in climate and soil type. These features have a marked effect on decay types present. In general terms, Sites 1, 2 and 5 have exposure conditions which encourage soft rot decay, which is best described as a erosion of the wood from the outer faces in contact with soil gradually spreading through the wood. Soft rot decay can be prolific in situations where wood moisture content is permanently high.

Sites 3 and 4 have conditions which favour brown rot. Brown rot decay tends to be "all-or-nothing", some treated samples may remain perfectly sound for a few years, and then suddenly fail, whereas those similarly treated will show no obvious deterioration for many more years.

These site differences have had a profound influence on the relative performance of CCA and the other non-arsenical formulations which is well illustrated in the Table. At some sites, particularly Hari Hari which has a very high rainfall and is an active soft rot site, the alternatives perform as well as CCA, at others (particularly Hanmer which is an active brown rot site) they perform much less well.

It is not possible to state which site represents an "average" exposure hazard, i.e. a site which typifies the majority of exposure conditions which treated timber is subjected to in service. However, Sites 3 (coastal sand-based soil), 4 (a dry, stony montane site) and 5 (a very high rainfall site) probably represent extremes of conditions met in New Zealand, whereas Sites 1 and 2 are probably typical of inland Northland and central North Island respectively.

CCB, CCF and CCP have been used for a number of years in several European countries as alternatives to CCA. There is little doubt that they could be used almost immediately as alternatives in New Zealand since their manufacture uses similar technology to that used to manufacture CCA preservatives.

A major reason why they are acceptable alternatives to CCA in Europe is that expectation of longevity of treated timber is much less than in New Zealand. This is largely because many commercial European timber species are very difficult to treat effectively and failure in service is often due to poor distribution of the preservative rather than lack of efficacy of the preservative itself and it will make little difference to the life of the total system whether CCA or a less effective formulation is used.

NZ FRI results (from tests designed solely to determine relative preservative efficacies) indicate that performance in ground contact, at equivalent preservative retentions, will be much more variable than CCA, except on very wet sites, and life of treated timber is expected to be lower. These differences are likely to be much less (perhaps, even insignificant) where the treated timber is exposed in above ground situations which present an inherently lower decay hazard.

Of the three types, CCB is the most acceptable alternative on both environmental (Tillott and Coggins, 1981) and efficacy grounds (Hedley, 1992; 1995).

Limited data on relative leaching rates (Tillott and Coggins, 1981) indicate that boron (from CCB) and fluoride (from CCF), are readily leached, but phosphate (from CCP) is relatively well fixed.

Little information has been found on toxicities (which with leaching data give some indication of potential environmental impact) of non-arsenical copper-chrome formulations relative to that of CCA. Relative toxicities of individual components are as follows:

Acute Oral LD50 (mg/kg) Mouse

Copper sulphate:	613
Sodium dichromate:	166
Arsenic pentoxide:	31
Boric acid:	1,740
Sodium orthophosphate:	>100
Sodium fluoride:	80

Comparison of acute oral LD50 values for boric acid, sodium orthophosphate and arsenic pentoxide indicates that CCB and CCP would be expected to have lower toxicity than CCA, and presumably proportionately less potential for adverse environmental impact. CCF formulations would be expected to be equally as toxic as CCA given the relatively low LD50 for sodium fluoride and its lack of resistance to leaching. Since the proportions of B, F and P in CCB, CCF and CCP are less than A in CCA, these relative toxicity observations can only be regarded as indicative.

REPLACEMENT OF ARSENIC AND CHROMIUM

The purpose of chromates in CCA is to insolubilise ("fix") in the wood the other components so rendering them resistant to leaching. In the 1980s, it became increasingly perceived that chromates posed just as great an environmental and health threat as did arsenicals. Removal of chromates thus required an alternative method of copper fixation.

AMMONIACAL COPPER QUATERNARY (ACQ)

First developments were of ammoniacal systems, particularly ammoniacal copper quaternary (ACQ (the last component being one of a very large family of common organic biocides which have many industrial and household applications). "Quats" have relatively low human toxicity and are the active ingredients in a number of common household products including sanitisers, disinfectants and hair conditioners.

There are a number of versions of ACQ and some have been under test at NZ FRI for more than 10 years. Formulations which are now used commercially in USA and Australia have been in test in New Zealand for only 3 years. Current indications are that ACQ formulations are more consistent in performance than the copper-chrome formulations in Table 11 and therefore are likely to be a better option as alternatives to CCA for use in New Zealand. Disadvantages are the pungent ammonia odour of concentrated solutions and their high corrosivity to treatment plant fittings.

As regards relative costs, for Hazard Class H3 (above ground, exposed to the weather) treater's chemical costs in Australia per cubic metre of timber treated for CCA are $A 20-00 and forACQ, $A 60-00. Selling price of the treated wood is $A 706/m≥ for CCA and $A 800/m≥ for ACQ. Thus CCA chemical costs represent 2.8 % of the treated timber selling price and ACQ 7.5 % of the treated timber selling price.

ACQ is approved for use in New Zealand for treatment of timber which will be exported to Australia, but not for use in New Zealand. Application for approval for use in New Zealand is likely within the next 3 years when field testing is more advanced. Approval is likely, given that the preservative is currently approved for use in Australia.

One potential disadvantage of ACQ-treated wood as an alternative to CCA-treated wood is the greater susceptibility to leaching of the copper component in the former. This is illustrated in Table 13 (Appendix 14) (CSI, 1994).

The ecological/environmental significance of these laboratory generated data is unknown, but they indicate that some of the attributes of CCA preservatives (high degree of preservative fixation) are not necessarily reproduced in new systems.

OTHER COPPER-BASED SYSTEMS

Formulations which do not have the disadvantage of ammonia odour include Copper Triazoles and Copper HDO, both of which have limited use in Europe. The former class of preservatives are undergoing extensive testing at NZ FRI and although results to date are very promising, tests have been underway for too short a time for critical assessments to be made. These, like ACQ systems, are less toxic than CCA preservatives (although triazole fungicides have recently been shown to have adverse effects on steroid synthesis and some concerns have been raised about their chronic toxicity impacts), but have a higher unit cost. Chemical costs per cubic metre of treated wood will be approximately 3 times that of CCA, increasing the price of, say, treated decking by about 20 0.

Like ACQ, application for registration is likely within the next three years.

Copper HDO has not been tested in New Zealand.

ORGANIC SOLVENT-BASED SYSTEMS

Light organic solvent preservatives (LOSP) find a wide range of uses for treatment of timber which will be used only in above ground situations. Because of the high cost of the solvent (- $1.00/litre), which is not recovered during the treatment process, their use tends to be confined to those products, such as window joinery, weatherboards and fascia which, because of relatively high unit cost, can absorb extra treatment costs.

LOSP currently used in New Zealand have tri-n-butyltin compounds as active ingredients. These compounds exert extremely adverse effects on marine life, and although there is little data on other environmental impacts, it would be difficult to justify them as alternative treatments for timber used in sensitive environments.

Although some work is underway in New Zealand researching LOSP alternatives to tri-n-butyltin compounds (Hedley and Maynard, 1995), some years will elapse before this work is sufficiently advanced for any recommendations for use to be made.

4. Disposal options for CCA-treated wood

CURRENT OPTIONS

Re-cycling (which, essentially, merely delays disposal) and burial in a secure landfill are the only current economic options in New Zealand for disposal of CCA-treated wood.

Re-cycling is an option when, for example, a 15 m pole is removed from service for reasons other than complete destruction, say, excessive decay at ground line. The pole may be shortened to remove the decayed portion, possibly re-treated, and put back into service as a shorter pole. Alternatively, the pole may be cut into even smaller units and used in less demanding situations, e.g. garden landscaping. Re-cycling of redundant NZ Telecom transmission poles has been by this procedure (Drysdale, pers.comm.).

CCA-treated timber which cannot be recycled in this way may be chipped to produce furnish for treated particleboards or other reconstituted wood products. However, there is a very limited market for this option in New Zealand.

Based on environmental considerations, the least attractive option for disposal of chemically contaminated waste is burial in landfill, but it is the most common and certainly the most economical current option. An important consideration is the potential for leaching of the contaminant into the surrounding ground, where it may also contaminate the groundwater. In one study (Mortimer, 1991), it was shown that losses in one year were within the range of normal background levels. Current research at NZ FRI (Gifford et al., 1995) is examining leaching under New Zealand conditions from a variety of treated wood wastes in simulated landfills.

Under water-logged conditions, the presence of anaerobic bacteria can influence the loss of preservative and depletion of copper from CCA can be very high (Ruddick and Morris, 1991).

One approach to overcoming the potential for preservative leaching from wood waste in landfills is to encapsulate the waste, e.g. in concrete. Leach tests on such material have shown that losses can be below detection limits for available analytical methods (Mitchell, 1990).

FUTURE OPTIONS

Incineration of CCA-treated wood as a disposal option has received much consideration (Ruddick, 1994). The impact that the combustion of chemicals may have on the environment is a primary concern and such factors as the volatile chemicals produced during burning as well as the form of chemicals present in the ash after combustion also require consideration.

Pasek and McIntyre (1992) have demonstrated the feasibility of burning CCA-treated wood without any losses of the components in gases when temperatures are in excess of 1100°C and Cornfield et al. (1993) concluded that at lower temperatures of 800°C, the copper retained in the ash could be recovered using acid extraction.

Based on current knowledge, Ruddick (1994) concludes that burning CCA-treated wood in a controlled incinerator is a practical option, but whether it will be an economically feasible option is another matter.

Chemical (acidic or ammoniacal) treatments of CCA-treated wood waste are capable of recovering the preservative components (Pasek, 1993). With the current state of knowledge, this is unlikely to be an immediately practical or economically feasible disposal option.

5. Recommendations

CCA-TREATED PINE, NATURALLY DURABLE TIMBER, OR ALTERNATIVELY TREATED PINE

With the possible exception of the marine environment, there is little evidence to suggest that use of CCA-treated timber, if properly treated, has anything other than a negligible effect on sensitive environments. The main structural advantage of using CCA-treated timber is that performance in service will generally be predictable, will be consistent and maintenance costs will be low. For these reasons there would seem little practical or technical advantage to be gained by discontinuation of its use, particularly where long term structural integrity is essential.

Use of naturally durable timbers is a technically valid alternative option, particularly in above ground situations, but performance is likely to be variable. This deficiency can readily be managed (but at a cost) by implementation of a programme for regular monitoring of structures (see below and Appendix 1). Lack of availability of suitable species will severely limit general use of this option, which, in any case, is recommended only in situations of relatively low structural criticality, or where aesthetic considerations are important.

There is little information available on long term environmental impacts of alternative chemical treatments as replacements for CCA. This issue is currently being addressed both nationally and internationally. The bad press that CCA has acquired stems largely from poor practices at the treatment plant or mis-use in service and any resultant adverse environmental impacts apply equally to replacement formulations if such mis-management is repeated.

Performance testing in New Zealand of alternatives is well advanced for some products, but is only 2-3 years down the track for "second generation" alternatives. Application for registration of the latter is expected in 2-3 years time and test results to date would support acceptance of such an application. Because of lack of data on specific environmental impacts - although this can be remedied (see below) - and because there is no evidence of effectiveness superior to that of CCA (in some situations there is marked inferiority), there are currently no good technical grounds for their widespread use as replacements for CCA.

EDUCATION PROGRAMME - SAFE HANDLING AND DISPOSAL OF CCA-TREATED TIMBER AND WASTE

Comfort (1993) noted that Tasmanian Parks and Wildlife Service (PWS) staff who handled and worked with CCA-treated timber, generally had inadequate knowledge of the material and held a number of common misconceptions about its properties. Major concerns were in precautions to be taken when handling freshly treated timber (which, in any case, should never be allowed to occur), precautions to prevent inhalation of sawdust when using power tools to work CCA-treated wood, personal hygiene procedures following handling of CCA-treated wood and lack of understanding of reasons why CCA-treated wood should not be burnt.

Much of the required information is available (e.g. Thorpe, 1987; Anon, 1993), although not in a format specifically targeted at the CCA-treated timber user. However, preparation of specifically targeted user guidelines would be a relatively simple exercise.

PRESERVATIVE IMPACT MONITORING PROGRAMME

Concerns over the risks associated with the use of preservative treated wood in sensitive environments has prompted the US Forest Service and Bureau of Land Management, in association with wood preservative suppliers, to set up a trial to determine its environmental impact (Anon, 1995).

The trial consists of a 550 m boardwalk containing timber treated with CCA and with current alternatives approved for use in USA: ACQ, ACZA (ammoniacal copper zinc arsenate, and CDDC (copper dimethyldithiocarbamate). The design and location of the structure will expose the preservatives to potentially severe leaching into soil, water and sediments conditions and so present a "worst case" scenario.

Water, soil and sediments in the vicinity of the boardwalk will be sampled in a very carefully controlled programme to ensure total lack of bias in sampling and analysis.

The programme seems an eminently sensible approach to the issue. There is ample NZ expertise to develop a similar programme and initiate a trial, which would be expected to attract significant support from the NZ wood preservation industry.

TIMBER STRUCTURE DECAY MONITORING PROGRAMME

Major owners of older wooden structures, such as railways (sleepers, bridges), power distribution authorities and telecommunications industry (poles, cross arms), roading authorities (bridges), implement monitoring programmes to regularly check their serviceability. The intensity of any programme is tailored to the relative susceptibilities of structures to decay, their age and the consequences of sudden failure. Costs associated with such programmes are, of course, significant.

Requirements of any programme are an ability to detect decay, determine its extent within a structure, its likely effect on the strength of a structure and its likely rate of progress. An inspectorate thus requires knowledge of types of decay associated with different timber species/preservative treatments and methods available for detecting decay.

Because alternatives to use of CCA-treated timber will almost certainly result in less predictable performance, an important precautionary adjunct to their use is implementation of a well-constructed monitoring programme.

Appendix 1 is a presentation given to the annual conference of the Electricity Supply Authorities Engineers' Association (Hedley, 1990) which discusses some of the issues to be addressed when developing a monitoring programme for line transmission poles.

It is appended as an example of the concepts which must be considered, most of which can readily be adapted for monitoring decay in any structure.

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Appendix 1

DECAY IN WOODEN POLES AND ITS DETECTION - STEPS TOWARDS ESTABLISHING A POLE MONITORING PROGRAMME (See References - Hedley 1990)

by
M.E. Hedley, B.Sc. Ph.D
Scientist,
Wood Technology Division
Forest Research Institute Rotorua

SUMMARY

Types of decay which may be encountered in wooden poles are described in relation to the types of poles they most frequently attack. It is shown that poles vary in their susceptibilities to decay and that different methods for detection are necessary to confirm the presence of decay on or within the different types of poles.

No method of decay detection is considered to be capable of giving a totally accurate indication of pole condition and hence its residual strength. However, a device is described which can simulate wind loads on poles and can give a true indication of residual strength.

Strategies for development of a pole monitoring programme are proposed based on the information in this review.

INTRODUCTION

All timber except that kept permanently at a moisture content below 20% is susceptible to decay. However there is considerable variability in the rate that this decay occurs which is dependent on such factors as environment, species of wood and the presence or not of preservative treatment.

It must also be appreciated that there are a number of types of decay which tend to be associated with different types of wood.

The two major problems facing the pole inspector are firstly detection of decay and its extent on or within a pole and then relating this to residual strength and hence its safety. There are several traditional, albeit "primitive", methods used for decay detection which have proved successful in capable hands. However, they usually result in some damage to the pole.

During the past few years a number of more "sophisticated" techniques have been introduced, but they tend to rely on delicate electronic instruments which require sympathetic technical skill in their use. They are generally much more sensitive to minor defects than traditional methods which can lead to unnecessary condemnation of poles which otherwise would still be serviceable.

It is the purpose of this paper to discuss decay in poles and the merits of different methods for decay detection. The relative susceptibilities of different types of poles to different types of decay is discussed in the context that this knowledge is essential for the development of any wooden pole performance monitoring programme.

TYPES OF DECAY

Three broad categories of decay are recognised: brown rots, white rots and soft rot.

Brown rots are usually associated with decay of softwoods, occasionally infecting the surface of poles, but more commonly associated with internal decay. Some types of brown rot are very tolerant to wood preservatives, particularly those based on copper, but these strains are only rarely encountered. As their name suggests, brown rots induce a brown discolouration within the wood as decay proceeds. When dry, brown-rotted wood develops a characteristic cuboidal cracking or splitting and in severe cases, the wood substance readily disintegrates into a brown powder.

White rots are more commonly associated with hardwoods. They are much less tolerant to preservatives than brown rots and are rarely found either on or in preservative-treated poles. White-rotted wood has a bleached appearance and in advanced stages of decay, its structure becomes stringy or fibrous.

Soft rot fungi attack both softwoods and hardwoods, although they have a preference for hardwoods and most are very tolerant to wood preservatives, particularly multi-salt types such as copper-chrome-arsenate (CCA). Attack invariably starts on the pole surface and gradually progresses into the pole.

It is important to appreciate that the observable depth of easily identifiable decay may not be completely indicative of its true extent. This is particularly so with soft rot and wood beyond the visibly decayed zone which looks apparently sound can be heavily infected to the point where significant strength loss has occurred.

RELATIVE SUSCEPTIBILITY OF DIFFERENT POLE TYPES TO DECAY

Untreated hardwoods

Most hardwood poles used in New Zealand were imported as "Mixed Australian Hardwoods". In 1938 a New Zealand Standard Specification (NZS 168:1938) was published for New South Wales desapped and dressed desapped hardwood poles. This limited species to six types: Ironbark, Grey gum, Grey box, Tallowwood, White mahogany and Red bloodwood.

These are the so-called "Royal" species of Class 1 durability. Durability Classes are based on the average time in years it takes for 50 x 50 mm stakes cut from the heartwood when placed in the ground to decay to the point of almost complete loss of strength. To attain Class 1 status, this average time must exceed 25 years.

For any species, natural durability is a very variable characteristic. Not only does it vary between trees of the same species, but it varies with position within the stem. Heartwood in the upper part of a stem is less durable than that in the lower part, thus heads of poles may deteriorate more rapidly than wood at the groundline, even though the latter is a more hazardous decay environment.

Radially, durability first increases with distance from the central core and then decreases at the transitional zone between heartwood and sapwood. Therefore, in a desapped pole, external decay may be initiated quite early in its service life but the rate of progress of decay into the pole may then be expected to slow down. Thus if a pole is inspected once at, say, 35 years' service and 35 mm of decay is detected, it is wrong to assume a steady rate of deterioration of 1 mm per year and that after 50 years' service there will be 50 mm of decay. It is quite probable that the majority of the observed decay occurred in the first 5-10 years of service and consequently the current rate of decay may be much slower than suggested by the single observation. True rates of deterioration can only be assessed by regular and repeated measurements at, say, 3-5 yearly intervals.

NZS 168 was revised in 1969 to take into account the different nature of New South Wales forests remaining for pole production compared with those previously available. It allowed for slightly more defects than the original specification: an indication of the poorer quality of the remaining pole resource. Generally speaking, therefore, the durability of poles produced to the revised standard may be expected to be rather more variable than that of poles conforming to the older specification.

Treated hardwoods

Treatment of hardwoods used in New Zealand has almost invariably been with CCA and major imports began in the early 1970s. The most common type imported was spotted gum, a eucalypt of Class 2 durability. Preservative retentions in early imports tended to be well below those now considered necessary to prevent soft rot decay and this group are strong candidates for careful monitoring. Extensive soft rot decay has been recorded in Australia in this type of pole which has led to the development of a substantial remedial treatment industry.

Treatment specifications for poles used in New Zealand were tightened in the early 1980s, and treated poles imported after that time are unlikely to develop significant soft rot decay for many years.

Treated softwoods

It is very important to distinguish between oil-treated Douglas fir or larch and treated pines, since the two categories vary considerably in relative susceptibility to decay.

Neither Douglas fir or larch are very amenable to preservative treatment and both have a relatively narrow sapwood band. This means that preservative penetration is usually very shallow, particularly in poles treated by the older Hot and Cold Bath Process. Any rupture of the narrow envelope of treatment, such as that caused by checking or cracking in service can allow infection by decay fungi into the untreated inner sapwood zones and into the non-durable heartwood.

Better preservative penetration was achieved by the Rueping Process, introduced in the mid-1950s and used for the treatment of poles until the mid-1980s, but decay induced by severe checking in service can still occur. Any post-treatment cutting, boring or gaining of Douglas fir or larch poles should be avoided unless very thorough precautions are taken to permanently seal the exposed wood against future infection.

Pine poles, particularly Corsican and radiata pines, have very wide sapwood which is readily treated with either oil- or water borne preservatives. Consequently there is deep preservative penetration and checking in service is unlikely to lead to internal decay. From FRI service test records, the only poles likely to be at risk of extensive soft rot decay are those treated with the preservative Boliden S25. This preservative was used from the late 1950s to mid 1960s.

METHODS FOR DETECTING DECAY IN POLES

External decay

"Primitive" methods

Standard procedures are to excavate the ground at the base of a pole and assess the depth of decay by digging out the decayed wood from the pole surface until sound wood is struck. The inspector must then use his judgement to decide whether or not the depth of decay is sufficient to make the pole unserviceable. The pitfalls in this approach are that some forms of decay can produce significant reduction in the strength of wood without visible evidence of decay. Soft rot in treated hardwood and some softwood poles is a good example of this and one has to resort to microscopic examination of core samples to get a true indication of the extent of decay. White rot decay of hardwood poles and the less common brown rot decay on the surface of treated softwood poles pose less of a problem since the depth of visible or recognisable decay is a better indication of the depth of pole deterioration.

"Sophisticated" methods

An impact resistance instrument, the "Pilodyn" has been used successfully in Scandinavia (softwood poles) and Australia (hardwood poles) to quantify the depths of soft rot decay. The hand-held instrument fires a spring-loaded pin with constant force into the pole surface and the depth of penetration is read from a scale incorporated in the instrument. The penetration depth can be compared with that when the instrument is used on sound wood. Depth of pin penetration is dependent on wood density and moisture content if the wood is below fibre saturation point. In practice, the Pilodyn may be able to deliver little more information than that which can be obtained from "Primitive" methods.

Internal decay

"Primitive" methods

In experienced hands the traditional methods of sounding, boring and drilling can give useful information on whether or not decay is present within a pole. However, these methods can seldom be used as reliable guides to the extent of decay. For example, if decay is detected when a core sample is taken, it may require several further core samples to ascertain whether a large or small pocket of decay is present. This is a dubious procedure for oil treated Douglas fir and larch poles as it causes breaches of the narrow treated wood zone and stringent measures must be taken to effectively seal these holes against future decay infection. If this is not undertaken, residual life of the pole can be significantly reduced.

Special core extractors are required for use on hardwood poles, but drilling is the preferred method for internal assessment of hardwood poles in New Zealand. Although drilling can be used successfully to identify presence of decay, it is very difficult to assess its extent using this procedure. Drilling or coring CCA-treated pine pole is unnecessary, as they are exceedingly unlikely to contain internal decay.

"Sophisticated" methods

There are a number of "black box" devices for accurate detection of internal decay. One group of these records the time taken for a sound or ultra sound impulse to pass across the diameter of the pole. In sound wood the impulse travels in a straight line, but a pocket of rot impeding its path causses the pulse to be deflected around it through the surrounding sound wood, so producing a longer time lapse between transmission and reception of the signal. A number of readings can be taken around and up and down a particular pole to build up a picture of the extent of the rot pocket. However, other defects in a pole such as internal shakes or checks will also cause deflection of the pulse, giving rise to misleading results.

One of the main advantages of the sonic techniques is that nothing has to be done to the pole before readings can be taken. Other procedures such as those which measure the electrical resistance of the wood between two contact points requires pre-drilling of holes in the wood to insert the necessary probes.

Not only is this time consuming, but it causes further damage to the pole.

Many of these sophisticated techniques are used routinely overseas, notably USA, Europe and Australia. The only ones known to have been tested in New Zealand are the "Pol-Tek" and "De-K-tector". The former transmits an ultrasound impulse across the pole and has been used routinely by the Forest Research Institute for the last 20 years for assessing the condition of its Service Test poles.

Success has been achieved in detecting decay in oil-treated Douglas fir and larch poles, but considerable operator skill is required in its use. It is of no value for detecting external decay. The De-K-tector reputedly can detect both internal and external decay. It is currently being trialed by the Wairoa Electric Power Board and some success has been reported when used to detect decay in hardwood poles.

EFFECT OF DECAY ON THE STRENGTH OF POLES

The following tables show the effect on residual strength of decay progressing from the outside of a pole to the centre, and from the centre outwards.

1. Decay from outside

% Reduction in Diameter	% of Original Strength
10	73
20	51
30	34
40	22

2. Decay from inside

% Rotten Core	% of Original Strength
10	100
20	100
30	99
40	97
50	94
60	87
70	76
80	59

The values in the tables are theoretical and assume cylindrical poles and even progress of decay along all radii. Nevertheless the tables illustrate the differences in importance to pole strength of the two types of decay. Thus the loss of 30% of the diameter due to external decay results in a loss of 66% of pole strength. However, if 30% of the pole diameter is lost from the pole centre, there is negligible effect on pole strength.

OBJECTIVE ASSESSMENTS OF POLE CONDITION

In the hands of experienced operators, the above decay detection techniques can give the pole inspector a reasonable indication of the presence of decay in a pole and some can give an estimate of its extent. However, the most important information the inspector requires is whether or not the pole is safe, either capable of sustaining its design load or is safe for linemen to work on. The Deuar Pole Tester has recently been developed in Australia specifically to provide this information.

The device simulates wind loads by applying a lateral force onto the pole through a hydraulic ram which is anchored to the base of the pole. The loading conditions on a pole are readily calculated on a hand held computer by imputting data such as pole height, number of circuit spans and their angles, size and number of conductors etc. The computer calculates the required pole bending strength at groundline and converts it to the value of an axial load exerted by the hydraulic ram. If the pole survives this load, and any desired safety factor can be built in, the pole is considered to be safe. A safety factor of 2 is considered sufficient to allow for any fungal degrade during the next 3-5 years.

It is claimed that by using the Deuar Pole Tester the number of prematurely condemned pole can be reduced to about 10% of that which results from the use of traditional inspection criteria.

STRATEGIES FOR A POLE MONITORING PROGRAMME

In order to develop a realistic and meaningful pole monitoring programme, it is first necessary to build up an accurate inventory of the wooden pole population under each Supply Authority's jurisdiction. Ideally, this should include dates when poles were installed, or at least a "best estimate" of when this occurred. When completed, it will then possible to identify the "at risk" groups of poles and establish priorities for preliminary inspection and monitoring frequency.

Untreated hardwood poles pose the biggest problem since, as noted above, natural durability is a very variable characteristic and poles installed 50 years ago may be in no worse condition than those installed 20 years ago. Poles which have been in the ground for more than 20 years must be considered at risk of significant decay. Thus, if a monitoring programme were to be implemented immediately, priorities for inspection would be the oldest poles down to, say, 20 years in service.

The FRI Pole Service Test Programme has identified those preservative-treated poles which are at most risk of decay and those in which significant decay is unlikely to be a problem in the near future.

At most risk of decay are:

- Creosote or PCP/oil treated Douglas fir and larch (internal decay - brown rot or white rot). Poles treated before the mid-1950s are at greater risk than those treated later.
- CCA-treated hardwoods imported before 1980 (external decay - soft rot)
- Copper-zinc-chrome-arsenate (CZCA) - Boliden S25 treated softwoods (external decay - soft rot). Treatments took place from late 1950s to mid-1960s.

In addition, all "non-standard" treatments must be viewed with suspicion. A number of experimental treatments have been undertaken over the years, such as CCA-treatment of kahikatea and creosote treatment of rimu. Most of these were undertaken in conjunction with the old Post and Telegraph Department, but some may be in power transmission lines.

At least risk of decay are:

- CCA or creosote treated pine poles.
- CCA-treated hardwoods imported after mid-1980s.

It is unlikely that either group will show evidence of decay until at least 20 years' service.

Overseas experience suggests that inspection cycles should be 3 to 5 years. A 3-year cycle has been used in the FRI monitoring programme and this has enabled a reasonably accurate picture of the rate of pole deterioration to be compiled. A 3-year cycle is considered to be the minimum for "high risk" groups, but this could be extended to five years for the low risk groups.

CONCLUSIONS

Accurate assessment of decay in poles requires considerable skill particularly when estimating the extent of decay and how this relates to pole safety. A recommended priority is therefore a thorough evaluation of modern decay detection techniques and the development of a formal training programme for pole inspectors. Individual Supply Authorities need an inventory of their pole populations in order to establish the relative proportion of "high risk" poles which can then be targeted as priorities for a pole monitoring programme.

Continue to next file: casn154a.pdf