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SCIENCE EDUCATION SERIES

No. 3

DETERIORATION OF WOOD AND ITS
PRESERVATION

by

D. de Silva,

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NATIONAL SCIENCE COUNCIL OF SRI LANKA

47/5 Maitland Place

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FOREWORD TO THE SERIES

The dissemination of scientific information is one of the main functions of the National Science Council. The National Science Council Journal provides a medium for the publication of scientific research papers, while "Vidurava," the quarterly science bulletin of the National Science Council, contains scientific articles of a general nature which are of interest to the public.

There is still a wide gap in the availability of reading material on scientific subjects of local interest. One result of this is that science students confine their reading only to their school notes and to the few available text books which are mostly published abroad. In an attempt to improve this situation, the Science Education Research Committee (SERC) of the National Science Council decided to publish a series of booklets on scientific topics of local interest as supplementary reading material for students and the general public. The authors who have been selected by the Committee to prepare these booklets are experts in their respective fields. The manuscripts that were submitted by the authors were examined by referees before being accepted for publication. The views expressed in these publications are those of authors and not necessarily those of the National Science Council.

In conclusion I must thank the Science Education Research Committee of the National Science Council, and in particular its Honorary Director, Prof. K. Jayasena, for the work they have put in to make this project a success.

R. P. Jayewardene

Secretary-General

National Science Council of Sri Lanka

14 November, 1980.

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Chapter 1

INTRODUCCION

Wood and our environment

Wood was never intended to last very long after it had served its function in the tree. Soon after a tree dies of natural causes or is uprooted by adverse weather conditions, deterioration sets in finally reducing the wood to humus. New plants and trees grow on soil built up by the decomposing wood material. This cycle is vital to maintain the dynamic equilibrium that exists in our environment, and an array of organisms operating in the environment assist in maintaining this equilibrium. Against this background when man utilizes wood for construction and decorative purposes and expects it to last well beyond its natural life, he comes against some formidable opposition. Opposition is in the form of wood-destroying fungi and insects dependent on wood for food at some stage of, or throughout, their lifetime. These organisms are considered to be pests but the role played by them has to be viewed as being of fundamental importance for the ecological balance in our environment. However, in order to satisfy man's needs, numerous methods of extending the natural life of wood have been devised. These methods of preventing deterioration of wood are known as wood preservation treatments.

Susceptibility of wood to deterioration varies from species to species. While certain species will be attacked within a few days by fungi and insects, some species will resist deterioration for a number of years. Timber of the latter category, classed as "naturally durable" are very valuable. Sri Lanka has a number of species of high natural durability such as **Vitex pinnata** (milla), **Artocarpus heterophyllus** (jak), **Chloroxylon swietenia** (satin) and **Berrya cordifolia** (halmilla). Unfortunately due to over exploitation and indiscriminate use, these valuable timber resources have been depleted resulting in greatly diminished availability and a corresponding increase in price. The overall impact on the timber supply situation has been that the

readily available timber species within a reasonable price range are only those of low durability. Utilization of these timber species for structural purposes is a poor investment as they need replacement within a few years. There are two alternatives to overcome the problem. The first is to use naturally durable timber at whatever the cost; but this is not practical as they are very scarce and difficult to obtain. In any case if such timbers continue to be used for construction purposes even the remaining forests in Sri Lanka will gradually disappear. The second alternative is to up-grade the inferior quality timber by treating the wood with preservatives. Unfortunately utilization of treated timber is not widespread in Sri Lanka. This is partly a reflection of the poor knowledge and thereby the lack of confidence people have about treated timber.

The primary objective of this article is to enlighten the reader on the causes of wood deterioration and how best in it can be overcome. With a wider knowledge of the subject and a better understanding of the action of wood preservatives, the use of preservative treated timber will increase. This in turn will decrease the demand on the traditionally popular timber species, helping to conserve forests which have taken centuries to get established and which are vital for the preservation of our environment.

Wood as a construction material

In Sri Lanka, as in other countries which were once rich in timber resources, wood has always been an important construction material. Its low cost and availability in various forms and sizes, together with such properties as relatively high strength-to-weight ratios, ease of shaping and fastening and low heat conductivity have made it the outstanding building material from the time of the ancient civilizations up to the present.

Despite its versatility, the use of wood in the construction industry has decreased over the past few hundred years. One of the significant features of the present day building industry is the rather widespread replacement of wooden frame structures with forms of construction involving the use of brick, stone, concrete, steel and aluminium. This shift in architectural practices can be attributed to a number of causes,

one of which is that wooden structures are liable to be destroyed by insects and fungi. Another factor is that wood is readily combustible and this can increase susceptibility to fire damage. To counter the deterioration of wood, various techniques of improving its serviceability and durability have been evolved. These techniques along with improvements in manufacturing methods, seasoning prior to use, etc. have not only raised the quality and added to the usefulness of the wood already regarded with favour but also brought about the acceptance of some of the species previously considered as inferior.

Benefits of wood preservation

The primary objective of the preservative treatment of wood is to increase the life of the material in service, thus decreasing the cost in the long term and avoiding the need for frequent replacement in permanent or semi-permanent constructions. No timber is entirely immune to fungal decay or insect damage, but several are immune for most practical purposes. Different species of timber vary greatly in their resistance to decay, but sapwood (ie. the outer zone of wood from a tree, which is usually lighter in colour) is almost always perishable. This is believed to be the result of the absence of secondary organic constituents in this tissue and also the presence of nutrients in the conducting elements. Among the methods that have been developed to improve the serviceability of wood, chemical treatment of timber is outstanding.

Agencies of wood deterioration

Timber in its various forms is subject to several types of deterioration. Wood inhabiting fungi especially those whose activities result in decay, destroy or depreciate enormous quantities of timber and other forest products annually. Wood boring insects, particularly termites, are responsible for extensive damage to wood in storage and in service. Fire causes extensive damage to buildings, and marine borers are a constant and serious menace to piling and other forms of wood exposed to marine environments.

Deterioration of timber used for construction and other purposes represents a loss of millions of rupees annually. A large percentage of the destruction and depreciation of these products is unavoidable, but much of it can be prevented or at least reduced by the intelligent selection, preparation and the use of wood for specific purposes. To this end a basic knowledge of the organisms responsible for deterioration of wood, the causes of deterioration and the methods of prevention are essential.

Chapter 2

WOOD DETERIORATION

Wood inhabiting fungi

Wood is commonly invaded by certain low forms of plants known as fungi. Unlike green plants they are unable to synthesize their own food but must have organic material already prepared for their use. Three groups of fungi may be distinguished, depending on the nature of their development in and on wood and the type of deterioration they cause. These are the wood-destroying fungi, the wood-staining fungi and the moulds. The first group is by far the most important, embracing those fungi that are capable of disintegrating the cell walls and thereby changing the physical and chemical characteristics of the wood. This disorganization of the material gives rise to the condition known as decay. The staining fungi and moulds, on the other hand, usually feed on the easily digestible organic compounds stored in the wood and frequently have little or no appreciable effect on the properties of the wood.

Cause of decay

Decay of wood is the result of the activities of wood destroying fungi. Following infection, the fungus develops within the wood, forming microscopic thread-like structures called hyphae. The conditions necessary for the development of fungi are fourfold: (a) a supply of suitable food, (b) sufficient quantity of moisture, (c) at least a small amount of air and (d) a favourable temperature. A deficiency of any one of these requirements will inhibit the growth of a fungus even though it may be already well established in the wood.

Food: The required nourishment of a wood destroying fungus is supplied chiefly by the actual wood substance (cell walls), although the starches, sugars and other material stored in the cavities may also be utilized. The fungus secretes certain chemical substances known as enzymes which assist in the breakdown of complex cell wall substances

(cellulose and lignin) to simpler components which are soluble and readily assimilated. The degradation of cellulose is the chief cause for the loss of mechanical strength in wood. The action of the fungus varies from species to species. While some degrade only the cellulose (brown rots) others attack cellulose and lignin (white rots). There are also types intermediate between the two. Examples of wood destroying fungi are *Polyporus versicolor*, *Lenzites trabea*, *Fusarium* sp. etc. Few, if any, of the decay producing fungi are able to attack all kinds of wood indiscriminately, presumably because of dissimilarities in the chemical composition of different woods (especially the secondary organic constituents) and the types of enzymes secreted by the fungi. Some of them confine their activities to a group of timbers, whereas others are apparently restricted to a single host species. Some timbers containing secondary constituents are exceptional in being able to withstand attack even under conditions that are most favourable to the growth of fungi. Such timbers are also resistant to attack by insects. These, known as naturally durable timbers, have been widely utilized in Sri Lanka.

Moisture: The moisture content of wood has a considerable influence on the activity of fungi. Generally a moisture content considerably above the fiber saturation point of wood is required for optimum development. At that point, when the moisture content is generally between 20 and 30 per cent, growth is generally retarded, and below 20 per cent it is completely inhibited. Sound wood that is adequately seasoned by kiln drying or air drying is immune to decay unless subjected to wetting or to dampness sufficient to raise its moisture content above the required minimum. Moreover when wood with established fungi is dried to a moisture content below 20 per cent, the development of the fungus is arrested.

Effect of decay on wood properties

As decay-producing fungi develop, they tend to alter certain of the physical and chemical characteristics of the infected wood, the intensity of such changes depending primarily on the extent of decay and the organism producing it. In the advanced stage, all decay producing fungi cause a serious reduction in the strength and density of wood.

The normal colour of wood is more or less permanently modified, and in certain types of decay, distinctive odours are imparted to the rotting wood.

The decomposition of the wood substance may also have a significant effect on the yields of certain products obtained in industries, viz. pulp and paper.

Wood inhabiting insects

The loss and damage to wood and timber by insect borers is considerable. Damage to standing timber is unavoidable though it can be reduced by proper forest management. In the case of saw logs and converted forms of wood, marked savings can be effected by the proper handling of material and by the application of preservatives where practicable. In most instances the damage by wood boring insects is done in the larval stage. The larvae or grubs burrow through the wood to obtain food and shelter and often make characteristic galleries or holes. In some cases, however, the adult forms take an active part in the attack. This is the case with subterranean termites whose adult 'workers' are the destructive individuals.

Although wood boring insects may be grouped into two classes, viz. those that confine their activities to wood before it is put into use and those that attack wood in service, the two categories overlap. The group of insects causing damage to wood in service is of more direct importance. Their effects can be significantly reduced by the use of preservative treatments. Termites are the most widespread wood destroying insects, and they cause great financial losses in both temperate and tropical countries. Considerable damage is also caused by powder post beetles and other species of beetles.

Termites: Subterranean termites are very common in tropical countries such as Sri Lanka and cause considerable damage. These insects are by nature soil inhabiting. They enter the wood only from the ground and require a constant supply of moisture for their existence. They readily invade both sound and decaying timbers set in or on damp soil and also have the ability to build covered

runways over impenetrable obstructions as well as to erect towers directly upward from the earth and thus reach wood removed from contact with the ground. Dry wood termites are another variety and are distinct from subterranean termites in that they are entirely wood inhabiting, never entering the ground, and require little moisture for their existence. The presence of subterranean termites may not be discovered until the more seriously attacked pieces of wood begin to show definite evidence of failure. On the other hand the presence of the earthen semicircular tunnels over brick or concrete foundations and along walls and the seasonal swarming of the winged reproductive adults are definite signs of termite activity.

Dry wood termites enter a crevice or crack in wood at the time of swarming directly from the air. In excavating their galleries, they form tiny faecal pellets which are occasionally discharged through holes temporarily opened for the purpose in the protective outer shell of the wood. The accumulation of these characteristic pale coloured pellets at the base of or under the structures in which the insects are working affords a definite indication of the presence of the termites. Dry wood termites are able to work in wood having a moisture content as low as 10-12 per cent and, consequently, may invade thoroughly air seasoned timber.

Since termites avoid the open air, they give little outward evidence of their presence in wood. Even though a timber may be more or less completely riddled in the interior, the protective outer shell will remain intact, unless it is broken down by some other agency, such as decay or mechanical damage. It is interesting to note that the protective instinct of these insects is such that they seldom excavate the infested wood to the point that it will fail due to its own weight.

Powder post beetles: There are a number of insects that produce so-called powder post defects in wood. The larvae of these insects bore through the wood for food and shelter leaving the undigested parts of the material in the form of a fine powder. When an infested piece is moved or jarred, this powdery residue falls out of holes made on the surface by the winged adults as they emerge to spread the infestation. The larvae honeycomb the wood with their irregular, large burrows and when the attack is severe, usually leave little sound wood other than a thin outer shell which may be easily broken down.

These larvae attack timber under a wide range of conditions. They may attack heartwood or sapwood and softwood or hardwood. The important powder-post beetles are the Lyctid and Bostrychid beetles. Lyctids attack only those hardwoods in which vessels are of sufficient diameter to receive their eggs. Only sawn timber is attacked by Lyctids. Rubberwood and a few other low grade timbers are particularly susceptible to *Lyctus* attack. Bostrychids are similar, except that the female lays her eggs on the rough surfaces of the timber. The adult may even bore into the sapwood to lay the eggs causing extensive damage. The larvae of both Lyctids and Bostrychids bore into the wood making extensive galleries. The powdery undigested wood is packed in the galleries from which they fall out through the exit holes made by adults. These insects are capable of attacking comparatively dry timber and attack is usually confined to sapwood because starch appears to be essential for their diet.

Marine borers: The animals responsible for deterioration of wood in marine environments are known as marine borers. These organisms are quite different from the animals responsible for destruction on land. The degradation of wood in marine conditions has no relationship to the terrestrial situation, and therefore this aspect of wood preservation will not be discussed here.

Chapter 3

WOOD PRESERVATIVES

Properties of wood preservatives

Wood preservatives are chemical substances that, when suitably applied to wood, make it resistant to attack by fungi, insects and marine borers and therefore increases the usable life of timber. The protective effect is achieved by making the wood poisonous or repellent to the organism that would attack it.

An efficient wood preservative should be toxic or repellent to the wood destroying organisms, permanent, penetrable, harmless to the wood, and should be retained in the wood over a long period. Apart from these basic requirements, depending on the specific use, the preservatives should have other properties. For example for outdoor use the preservative should not be leached by water, and for furniture and decorative uses the treatment should not discolour the wood or prevent it being painted or varnished. Where the wood comes into direct contact with people the chemicals should not be a health hazard.

There are three main types of wood preservatives in general use to-day, tar oils such as coal tar and creosote, water-based preservatives and organic solvent based preservatives.

Coal tar—Creosote preservatives

This is the most widely used preservative for utility timbers such as railway sleepers, transmission poles and piles. Creosote is obtained by the destructive distillation of coal. It is a dark brown oily liquid and is usually diluted with furnace oil before application. The treated wood is dark brown in colour with an oily surface and it "bleeds" for a few years. Therefore this preservative cannot be applied to wood used for decorative purposes and for furniture. Creosote is a mixture of phenolic compounds, cresols, xylenols, naphthols and hydrocarbons. The latter which make up most of the volume of

creosote includes benzene, toluene, xylene, naphthalene, phenanthrene, acenaphthene, anthracene and fluorene. Creosote is a broad spectrum preservative effective in controlling fungal infection and insect attack.

Water borne preservatives

Copper-chrome-arsenic (CCA) is the most widely used water-based preservative. This multisalt mixture is sold under different proprietary brands a few of which are 'Celcure A', 'Tanalith C' and 'Treatim CCA'. CCA is pressure impregnated and is the most effective of the various multi-salt formulations. In the past other salts have been used singly but without much success as they soon leach out of the wood. It was in order to overcome this disadvantage that multi-salt mixtures were developed. CCA, for instance, becomes permanently fixed in the wood and is not leached out in service. For this reason CCA treated timber is suitable for external use and can even be painted. The timber acquires a pale green colour and is reported to be safe even for use in situations where children may come into contact with it, eg. in play-grounds. The only limitation of CCA is that unless the wood is pressure impregnated the effectiveness is greatly reduced.

A more versatile water borne wood preservative is a mixture of boric acid and borax. This is applied by a simple diffusion process to sawn green timber. Boron treated timber is suitable for most purposes in building construction where leaching is not a normal hazard. Roof battens, trusses, ceiling joists, internal structural members and door frames as well as painted external joinery are all examples where boron treated timber could be used satisfactorily. Success of the treatment depends largely on the speed with which it is carried out. The timber should be felled, sawn, cut to size and treated within 5-7 days, before fungal and insect attack sets in and while the timber is green.

Organic solvent type preservatives

Organic solvent preservative solutions are in general more expensive than either creosote or the water borne preservatives and their cost normally limits their method of application to brushing or dipping. The main advantage that organic solvent preservatives have over the

water-borne type is that they do not swell or distort the timber. The chief chemicals used are copper naphenate, pentachlorophenol and its derivatives and tributyltin oxide. There are some which contain in addition specific water-repellent constituents, such as synthetic resins and waxes and, where additional protection against insects is required, contact insecticides of the chlorinated hydrocarbon type such as dieldrin and gamma - BHC are incorporated.

Chapter 4

METHODS OF TREATMENT

Introduction

Most of the wood preserving methods now in use may be classified roughly as either 'non pressure processes' which are carried out without the use of artificial pressure, or 'pressure processes' in which the wood is placed in a treating cylinder or retort and impregnated with preservative under considerable force.

Painting and varnishing of finished wooden articles can also be considered as preservative treatments. However, unless the wood is naturally durable the protection obtained by this type of treatment will be of limited duration as fungi and insects will attack the wood through cracks on the paint or varnish coat. Nevertheless for internal use and for furniture where the chances of exposure to moisture and other hazardous situations are remote, surface coatings will suffice.

The types of treatment normally associated with wood preservation are as follows:

Non-pressure processes

Brush and spray treatments: The preservative is brushed or sprayed over the surface of the timber. Some of the liquid is drawn into the wood as a result of capillary action, but penetration is usually slight, at best. The superficiality of treatment is largely attributed to the natural resistance that wood offers to penetration, but is also influenced by the small amount of preservative applied. All types of wood preservatives may be applied by this method, but the penetration obtained is so shallow that very limited protection may be expected. The quantity of preservative available per unit of surface area is also very low, decreasing the effectiveness.

It is unfortunate that this least effective preservative treatment is the most widely practiced in Sri Lanka and the term wood preservation is commonly associated only with brush application of preservative formulations. In order to obtain the optimum benefits from brush and spray methods, the preservative should be flooded over the surface of the timber and allowed to soak into the wood as much as possible.

It should not be applied thin like paint. All checks and other openings should be filled with preservative as thoroughly as possible. It is of little use to employ these methods on surfaces of timbers already in service in buildings and other structures. The concealed areas, which cannot be reached by the chemical will be still susceptible to decay and attack by insects.

Dipping: As applied to structural forms of timber, dipping consists of merely immersing the wood in a bath of creosote or other preservative (organic solvent or water borne) for few seconds or minutes. It is generally more expensive than brushing or spraying, since it requires more equipment and larger quantities of preservative. However, the protection afforded is greater if the dipping time is over three minutes. The time may be extended to several days or even weeks for a very thorough treatment. If the treatment solution is heated penetration will be greater.

Pressure processes

Non-pressure methods do not give adequate protection unless the timber is in the form of 2-5 cm thick planks and even then penetration may not be total. Complete penetration may be achieved by the pressure treatment processes.

There are two principal types of pressure treatment, the "full cell" and the "empty cell" methods. In the full cell process the wood is placed in a pressure cylinder and a vacuum is applied. The cylinder is then filled with the preservative and hydraulic pressure is applied for a period long enough to give the requisite treatment. After emptying the preservative, a final vacuum is generally given to clean the surface of the charge for convenience of handling.

It is the full cell process that is normally used with the water-borne preservatives. The preservative uptake is determined to a great extent by the structure of the wood. Soft woods are generally easier to impregnate than hardwoods and the bulk of the liquid impregnated is taken up by the sapwood.

In the empty-cell processes a preliminary vacuum is not used and, as a result of air found in the cells, the cell cavities of the wood get only partially filled with preservative. These methods are normally restricted to treatments with creosote or similar preservative oils.

Pressure treatment is the most effective for timber to be used under adverse conditions since it ensures a deeper penetration and a higher loading of preservative than methods such as dipping, brushing and spraying. However, the capital investment for a pressure treatment plant is very high and it will be economical only for the large scale preservative treatment of timber.

Choice of treatment

A timber structure with an appropriate preservative treatment will last, with little or no maintenance, for as long as it is likely to be required. Before treatment is considered, the question should be asked: what is the design life planned for the component or structure? And before preservation is considered it is as well to know what performance can be obtained from the timber if used untreated.

Any timber with low durability that is to be used for over a few years in contact with the ground or under other damp conditions, should be pressure treated with either creosote or CCA preservative. If durable timber is used a treatment may not be necessary depending on whether sapwood has been excluded. Sapwood of all timber species is susceptible to insect and fungal infestation.

The choice of a preservative for less hazardous situations is not difficult. The differences between the various preservative materials are generally slight; all are toxic (or repellent) and will do the job required of them if present in the wood in adequate quantities and to

an adequate depth in relation to the conditions of exposure. It is therefore important to select a method of treatment that will achieve this. The choice of treatment should not be based simply on cost, but the technical merits should also be considered. There is no simple relationship between cost and effectiveness, so it is wise to know what one is paying for.

The main criteria to be considered when deciding upon the treatment of any timber installation are the service life required and the probable costs of repair or replacement. Obviously it is not economic to impregnate a structure to give a possible 60 to 70 years life when perhaps it is only needed to last 20 to 25 years. On the other hand it is false economy to use a cheaper treatment which would only give perhaps 20 years life when the structure is expected to last 60 years or more. Sometimes surface treatments are adequate where a shorter life is required or where the hazard is not so great and treatments can be repeated periodically.

In general, the cost of treating interior building timbers can be regarded as an insurance against the possibility of insect attack and decay. Remedial treatments to structural timbers may cost 5 to 10 times the cost of initial preventive treatment.

Chapter 5

TREATED TIMBER FOR SRI LANKA

Sri Lanka is blessed with a number of timber species which are naturally durable and therefore the need to use preservative treated timber had not been very great. However due to over exploitation of the timber resources the situation has changed rapidly over the past few years. Timber normally accepted by consumers as suitable for building construction and furniture are in short supply and very expensive. In future the situation will worsen. The only solution will be to use low quality timber such as *Hevea braziliensis* (rubber wood), *Melia dubia* (lunumidella) *Mangifera indica* (amba) and, other fast grown timber species such as eucalypts and *Pinus*. These timbers generally have low natural durability in our humid tropical environment and are susceptible to fungal and insect infestation. Before they can be utilized as structural timber, preservative treatment is essential. For interior use boron salt treatment will give adequate protection from decay and most insect attack. This treatment is particularly suitable for furniture. For exterior use and for structural timber CCA or creosote treatment is essential. Although the initial cost may be high, the investment will be justified considering the cost of replacement of untreated low durability timber. At present treated timber is not freely available in Sri Lanka, and consumers have very little choice in selecting timber to suit their needs. This is partly a reflection of the consumer preference for the traditional timber species. Along with the introduction timber treatment the public has to be educated on the salient features of treated timber. They should be informed that such timber is nearly equal in quality and durability to jak or teak; otherwise our forest resources will continue to diminish. To save our forests fast grown timber plantations need to be established and their timber, after treatment with preservatives, introduced to the local market to take the pressure off the traditional timber species.

It must be kept in mind that the most effective way of extending the national timber supply is to use available wood resources in such a manner that the service life of the wood is increased, and this can be achieved by the proper use of wood preservatives.

ADDITIONAL READING

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II 402 pages.
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Ceylon. Ceylon Forest Department. 99 pages.

APPENDIX

BORON DIFFUSION TREATMENT FOR TIMBER

It is very important to note that timber treated by the above process can only be used for indoor work and cannot be used in ground contact or in places where timber is likely to get wet.

This treatment is suitable for several low grade Sri Lankan wood species including *Hevea brasiliensis* (rubber wood)

Diffusion Process

Green timber is treated by one of the following : (a) immersing in the preservative solution till diffusion is complete, (b) immersing in the preservative solution briefly and block stacking for an extended period until diffusion is complete, and (c) percolating the solution through a stack of timber until diffusion is complete.

With (a) and (c) the period of treatment for 2.5 cm thick planks will be 12-18 hours. With (b) the total period will be 2-4 weeks

Preservative Chemicals

A mixture of Borax and boric acid dissolved in water is used. (A fungicide such as sodium pentachlorophenate* may be incorporated to inhibit mould growth)

Borax (Sodium borate deca hydrate)	—	3.00 parts
Boric acid	—	2.00 parts
Water	—	100.00 parts

Concentration of the treatment solution could be determined by analysis of specific gravity, ie. by using a hygrometer. Increasing the temperature of the treatment solution will improve the diffusion.

Finally the treated timber should be seasoned to a 15-20% moisture content.

* extremely toxic.