THE EFFECTIVENESS OF BFCA AND CCA WOOD PRESERVATIVES ON THE DURABILITY OF TEN LESSER-USED TIMBER SPECIES OF MYANMAR

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ABSTRACT

This paper dealt with the promotion of durability of ten Myanma Lesser-Used Timber Species (LUS) through wood preservation. The species tested were Didu, Gyo, Nabe, Pyinma, Taukkyan , Taw-thayet, Thabye, Thadi, Thande and Thitsein. In this study, the decay resistance of ten LUS treated with two wood preservatives, BFCA and CCA was evaluated by laboratory decay test, Agar-Block test. Standardized heartwood blocks of test species were impregnated with three concentrations of CCA (1%, 3% and 5%) using Vacuum - Pressure treatment and three concentrations of BFCA (5%, 15% and 25%) using Dip-Diffusion treatment. The untreated and treated specimens were exposed to white rot fungus (*Schizophyllum commune*) for 16 weeks. Oven-dry weight loss percentage was used as a measure of severity of decay. Three observations were undertaken namely; (a) the natural durability of test species; (b) the effects of BFCA and CCA on the durability of test species; (c) the calculated retention for test species. The percentage loss in weight at the end of the 16 weeks varied according to the type of preservatives and timber species used .Of the test species, Gyo was durable species, Didu, Nabe and Taw-thayet were non-durable species and the rest were moderately-durable species. Among the CCA concentration levels, although 5% CCA was the most effective, 3% CCA can effectively control the decay caused by *S commune*. For the effect of BFCA on the test species, only at higher concentration level was successful in controlling decay caused by *S. commune*.

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1. INTRODUCTION

Myanmar is a tropical country with a wide range of climates and soils. So, Myanmar possesses greater diversity of vegetation than its neighbouring counterparts. Varying topographic, climatic and geographic multitudes support existence of different types of forest and its associates. About one half of the country is covered with forest which consists of hundreds of timber producing tree species.

Registered number of tree species in Myanmar accounted for about 1200 (Hundley et. al.). According to the latest forest inventory report this number varies from around 400 to 472 depending on localities (UNDP/FAO: MYA/85/003, 1991). Furthermore, when only large trees (ie.6'gbh&above) are considered the number of species would be around 375.

Among these species, Teak (*Tectona grandis*) is famous world- wide and constitutes one of the most valuable resources of the nation. There are few more commercially acceptable species both domestic and abroad. The number of tree species involved in the trade are barely a dozen-compared to hundreds of timber species in the forest. These include durable species such as Pyinkado (*Xylia dolabriformis*), Padauk (*Pterocarpus macrocarpus*), Thitya-Ingyin (*Shorea* spp:) and decorative species such as Tamalan (*Dalbergia oliveri*), Thinwin (*Millettia pendula*), Hnaw (*Adina cordifolia*) and Taung-thayet (*Swintonia floribunda*)(Win Kyi -1 et al, 1993). Many of the rest are being lesser- used timber species (LUS). As only a few species of the wide variety available are used in both domestic consumption as well as export, so that scarcity of those species is expected eventually. The situation of diminishing supply and an increasing demand of such quality - timbers will be met at an increased cost. Growing demand for timber paralleled with shrinking supply of commercial species lead to find means of utilization of species previously unconsidered.

Effective utilization of wood depends on strength, durability, beauty and availability of species. Many LUS have good utilization potential (Win Kyi -1 et al, 1993). But a basic problem has been indicated that the LUS have a bad reputation because of poor durability. Most of the LUS are not durable and susceptible to the attack of fungi and insects. If this non-durability could be reduced, the chance of commercial acceptance would be much improved (Win Kyi – 2, 1995).

Preservation is one of the resource management strategies. Preservation may enhance the service life of wood by 5 to 15 times, depending on the type of commodity and end use environment. Increased life span is the major advantage of preservative treated wood. Hence, replacement of timbers (and its components) in use is minimized with prior treatment. This will lessen the pressure on the demand of the renewable resources.

In this laboratory study, ten LUS of Myanmar were tested by Dip-Diffusion method with BFCA and by Vacuum-Pressure method with CCA wood preservatives.

The objectives of this study are:

(1) To study the durability of ten LUS of Myanmar, with or without treatment using CCA and BFCA wood preservatives.

(2) To compare the performance of CCA treated timbers and BFCA treated timbers.

(3) To determine the optimum concentration of CCA and BFCA toxic level that could effectively control the growth of decay fungus (*Sehizophyllum commune*).

2. LITERATURE REVIEW

2.1. Decay and Natural Durability of Timber

Wood is made up of biodegradable molecular structures. Wood can be destroyed by wood-boring insects, wood-rotting fungi or marine borers, but some timbers resist attack better than others. The word "durability", however, normally refers to deterioration caused by wood-rotting fungi (Wilkinson, 1979). The reason for the variations in durability of wood mainly lies in the chemical composition inherently deposited in each wood. The more the component of toxic chemical deposited on wood, the more the durability of wood.Generally, hardwoods are relatively more susceptible to white rot decay than softwood (Savory, 1954; Panshin & DeZeeuw, 1980). This is the reason why a white rot fungus was chosen as an agent for wood deterioration in this research.

2.2. Testing Decay Resistance in the Laboratory

The natural durability of timbers is determined from data obtained through field trials by long - term exposure of timbers to biodegrading organisms in the field (Jackson, 1957). Many researchers had used this procedure for classifying natural durability of timbers (Anon 1975; Anon 1979; Chudnoff 1984; Matsuoka et.al. 1984; Mohd. Dahlan & Tam 1985; L.T. Hong, 1989). Such tests give good estimates of the natural durability because timbers are exposed to various types of biodeteriorating agents. This kind of study usually takes a long time to predict the life time of species tested in service.

Laboratory tests, however, are simple and obtain the results in a matter of months. Laboratory test was requires small specimens of wood exposed to the conditions favourable for the rapid growth of wood-rotting fungi. Percentage weight losses of the specimens at the end of period tested is used as the parameter of decay development since wood-rotting fungi decompose structural material of wood into gases and water (Win Kyi -2, 1995).

In order to provide rapid evaluation of the relative durabilities of species, a series of laboratory tests of the relative decay and resistance of different species was carried out (Da Costa and Aplim, 1959; Da Costa et al. 1957).

Many scientists had demonstrated the standard laboratory methods for estimating fungal decay and insect resistance.

The method described by Findlay (1938) is as follows: Basically, the test fungus is grown on sterile malt – agar in a Kolle flask until the medium is well covered with mycelium. Then, a sterile glass support rod is placed between the fungus mat and block of wood. Degree of attack is measured by the difference in oven dry weight before exposure to the fungus and oven dry weight after exposure on the culture. This is called Agar-Block test and widely used in Europe and specified in British Standard and German Standard DIN 52176.

In North America and Australia, the Soil-Block test as outline in AWPA Standard M-10-63 or ASTM Standard D1413-61 is most widely used by researchers. It is much like the previous described agar-block test, except soil is used as the substrate for growing the fungus.

Eusebio and Banatin (1965) stated that although *Schizophyllum commune* shows low decaying capacity, its presence on wood should not be ignored. This is particularly important when the material will be exposed to conditions favoring the growth of the fungus or exposed for an extent period of time as in the seasoning yard. *S commune*'s abundance under field conditions may later lead to degradation of the physical and mechanical properties of the wood being attacked.

Anon (1996) reported that *Schizophyllum commune* had tolerance to both types of CCA (oxide type and salt type). On the other hand, *Schizophyllum commune* growth was inhibited at all levels of both CCA types. The results also showed that a minimum concentration level of 3% for both CCA types effectively controlled the fungal mycelia. Therefore, *S. commune* (white rot) fungus was chosen as an agent for wood deterioration in this research.

2.3. Classification of Timbers Based on Durability

It is usual to classify timber into five classes with respect to their durability. In the following table, the corresponding "life" of 2inch x 2 inch stake in average soil was compared with the average loss in dry weight percent of wood specimens caused by one of the selected decay fungi in laboratory tests. Findlay (1938) classified the timbers which he tested into five groups.

Table (2.1) Classification of Timbers based on Durability

Durability Class	Life of Test Stake in the field		Average loss in dry weight %
	England	Tropics	
Very Durable	Over 25 yr.	Over 10 yr.	Nil or negligible
Durable	15 - 20 yr.	5 -10 yr.	Up to 5%
Moderately Durable	10 - 15yr	(not given)	5 - 10%
Non-Durable	5- 10 yr.	2 - 5 yr.	10 - 30%
Perishable	Less than 5 yr.	Less than 2yr	Over 30%

Source: W.P.K.Findlay (1985)

2.4. Improving Durability

Preservation is one of the resource management strategies. Preservation may enhance the service life of wood by 5 to 15 times, depending on the type of commodity and end use environment. Increased life span is the major advantage of preservative treated wood. Hence, replacement of timbers (and its components) in use is minimized with prior treatment. This will lessen the pressure on the demand of the renewable resources.

Wood preservation means treating wood with solutions which make it poisonous to fungi, insects and marine borers. Primary objective of wood preservation is to increase the life of materials in service thus decreasing the need of frequent replacement in permanent and semi-permanent construction (Hunt & Garret, 1938).

There are distinct advantages for treating wood such as:

(1) Problems of generally severe wood decay in the tropics can be avoided by proper preservative treatment. Treatment can extend the service life of decay susceptible timber appreciably;

(2) Preservation reduces replacement of timber products and associated costs since there will be less chances of damage to treated wood by microbial activity;

(3) Preservation can encourage the use of many timbers, including the sapwood, which in the past have been rejected because of their susceptibility to biodegradation.

(4) Ideally, a state of conservation is achieved by utilizing treated wood in the long term, since less replacement timbers are harvested (Wong. et al, 1990).

3. MATERIALS AND METHODS

3.1. Materials

3.1.1. Wood samples

Ten LUS tested in this study were collected from Phyukun and Kabaung Reserved Forests of Taungoo Forest District, Bago Division. Wood samples were obtained from the Wood Preservation Section, Forest Research Institute (FRI). These wood samples have been authenticated at Wood Anatomy and Herbarium Sections, FRI.

Ten LUS tested were arranged alphabetically as follows:-

(1)	Didu	*Salmalia insignis* Schott. & Endl.
(2)	Gyo	*Schleichera oleosa* (Lour.) Merr.
(3)	Nabe	*Lannea coromandelica* (Houtt.) Merr.
(4)	Pyinma	*Lagerstroemia speciosa* (L.) Pers.
(5)	Taukkyan	*Terminalia tomentosa* W.&A.
(6)	Taw-thayet	*Mangifera* spp.
(7)	Thabye	*Eugenia* Spp;
(8)	Thadi	*Protium serratum* Engler.
(9)	Thande	*Stereospermum personatum* Chatt.
(10)	Thitsein	*Terminalia bellerica* Roxb.

Criteria for selection of species in this experiment were (1) it must be non-commercial species and (2) it must be available in large quantity in Myanma forest in order to ensure constant supply.

Sample sticks of size (2 in x 2 in x 20 in) were cut from the lower portion of the trunk and outer portion of the heartwood. These sticks were free from knots, drying defects and without visible evidence of fungus infection.

Then, each sample stick was planed and cut into small blocks of size (0.5 in x 0.5 in x 1 in). 150 blocks for each species were taken and among them, 100 clear blocks were selected to study.

Both ends of each block were coated with lacquer thoroughly to restrict the penetration of preservatives from the ends. Among the 100 blocks of each species, 10 samples were used for control and marked as C_1, C_2, C_3, - - - - -, C_{10}.
10 samples were used for the treatment of 5% BFCA and marked
as T_{1-1}, T_{1-2}, ------, T_{1-10}.
10 samples were used for the treatment of 15% BFCA and marked
as T_{2-1}, T_{2-2}, -------, T_{2-10}.
10 samples were used for the treatment of 25% BFCA and marked
as T_{3-1}, T_{3-2}, -------, T_{3-10}.
10 samples were used for the 1% CCA and denoted as T_{4-1}, T_{4-2}, T_{4-3}, - - ---, T_{4-10}.
10 samples were used for the 3% CCA and denoted as T_{5-1}, T_{5-2}, T_{5-3}, - - - - ,T_{5-10}.
10 samples were used for the 5% CCA and denoted as T_{6-1}, T_{6-2}, T_{6-3},- - - - , T_{6-10}.
The rest 30 samples denoted as moisture content samples (MC-samples) were used for estimating the initial M.C of 70 samples to be tested.

3.1.2. Preservatives

For the treatment of selected species, two preservatives namely BFCA (Borofluoride-Chrome-Arsenic) and CCA (Copper-Chrome-Arsenate) were used.

3.1.2.1. BFCA for dip - diffusion treatment

BFCA used is the product of Koppers (PNG) PTY. Ltd. The active constituents in it are as follows:

132.8 g/kg Boron present as boric acid and sodium tetraborate

84.2 g/kg Fluorine present as sodium fluoride

77.2 g/kg Arsenic present as arsenic pentoxide

44.1 g/kg Chromium present as sodium dichromate

Three concentrations of 5%, 15 % and 25% BFCA solutions were prepared as follows:-

5% BFCA solution	:	was prepared by dissolving 5 g of BFCA dry salt in 100 ml of water.
15% BFCA solution	:	was prepared by dissolving 15 g of BFCA dry salt in 100 ml of water
25% BFCA solution	:	was prepared by dissolving 25 g of BFCA dry salt in 100 ml of water.

3.1.2.2. CCA for vacuum - pressure treatment

CCA used in this study is Celcure A (P) Type, the product of Celcure Ltd. The components of the treating solution were as follow:

Copper Sulphate penta-hydrate 31.5 % (w/w)

Sodium dichromate dihydrate 39.0 % (w/w)

Arsenic pentoxide dihydrate 24.5 % (w/w)

Three concentrations (1%, 3% and 5%) solutions were used in this study and the solutions were prepared as follows:

1% CCA solution	:	was prepared by dissolving 4.7194 g of CCA paste together with 1 liter (1L) of distilled water
3% CCA solution	:	was prepared by dissolving 14.1598 g of CCA paste together with 1L of distilled water
5% CCA solution	:	was prepared by dissolving 23.5972 g of CCA paste in 1L of distilled water.

3.1.3. Test fungi

Schizophyllum commune, the white rot was used in this study because *S.commune* is a common decay fungi species attacking logs in service and in storage. This fungus was widely distributed but very few studies had ascertained their tolerance to wood preservatives (Anon, 1996). This fungus - specimen was cultured in 2% malt extract agar medium, kept in the room temperature and it was carried by Dr. Rashid, consultant of ITTO PD/96 from the Forest Research Institute of Malaysia (FRIM) during the ITTO project.

Potato - Dextrose -Agar (PDA) media was used for the stock test tube culture and for petridish culture of the test fungus .The procedure taken for the fungus culturing was as follows : -

(a) 200 g of peeled, diced potatoes, 20 g of dextrose and 15 g of Agar were weighed.

(b) Those were dissolved with 1000 ml of distilled water in a flask.

(c) The media was distributed into test tubes, approximately 20 ml in each tube.

(d) The test tubes were plugged with cotton and sterilized in autoclave for 20 minutes at 105 °C (250° F) and 15 lbs (15psi) pressure.

It was necessary to sterilize the media before using in order to kill bacteria or fungal spores which were possibly present in the media or in the glassware.

(e) The test tubes were taken out from the autoclave and cooled to room temperature.

(f) Then, the fungus inoculums were cut and placed on the media.

(g) After 3 to 5 days, the fungus grew well, with mycelium.

(h) These were ready for decay test.

This fungus culturing was carried out at Forest Pathology laboratory FRI, Yezin.

3.2. Methods of Treatment

Out of several methods of preservative treatment, only two methods, Dip – Diffusion treatment and Vacuum – Pressure treatment, were used in this study.

3.2.1. Dip - diffusion treatment

(a) This treatment was known to be suitable for freshly sawn timber. Therefore, the blocks to be treated by using Dip- Diffusion treatment were soaked in water for 24 hours to obtain the approximate green condition. The water - soaked blocks were weighed and noted as W_1.

(b) 10 blocks of each of the test species were dipped separately in the prepared 5%, 15% and 25% BFCA solutions respectively for 5 minutes.

(c) After that, the treated blocks were taken out and wrapped in plastic bags for further diffusion of salt into the wood.

(d) Diffusion period was two weeks.

(e) After two weeks, the treated - blocks were weighed and noted as W_2 to determine the retention of BFCA preservative.

3.2.2. Vacuum - pressure treatment

This method was applied using 1% CCA, 3% CCA and 5%CCA preservative solutions. The procedure taken for each of the three concentrations were shown as follow:-

(a) Before the treatment, each sample block was weighed and it was designated as W_1.

(b) The treatment plant was loaded with wood blocks and was sealed tightly.

(c) Vacuum was drawn slowly until 20-25 inch - Hg and maintained for one hour.

(d) While under vacuum, prepared CCA solution was introduced into the plant.

(e) Pressure was applied into the plant until 200 psi. and maintained for 1 hour.

(f) The pressure was gradually released and the remaining preservative solution was drained.

(g) Treated blocks were allowed to sit for 15 minutes, the blocks were taken out and left at room temperature for one week to allow the preservative to fix.

(h) After that treated - samples were weighed and noted as W_2.

3.2.3. Laboratory decay test

The laboratory decay test was designed to determine the fungicidal efficacy of six concentrations of two preservatives (plus control), using white rot (*S. commune*) fungus.

Among the several laboratory decay tests, **Agar - Block Test** was used. The following procedures were carried out for this test.

(a) BFCA and CCA treated samples and control samples were exposed to fungal attack by placing them over the culture in the test tubes containing test fungus.

(b) A tiny chips of glass-rod were placed between wood samples and the fungus in order to prevent the direct contact between wood samples and the fungus.

(c) The test tubes were placed at ordinary room temperature and incubated for 16 weeks.

(d) After completion of the incubation period, the blocks were taken out and the attached mycelium was carefully cleaned.

(e) Then, these blocks were oven-dried at 103 ± 2° C until the constant weights were obtained and then, the oven dry -weights were recorded to calculate the weight loss percentages of the blocks.

3.3. Method of Analysis

3.3.1. Determination of calculated oven dry weight of the test samples

To estimate the calculated oven dry weight of each of the test blocks, the average initial M.C of the MC – samples were used. Average initial M.C of each of the MC –samples was determined by using **Oven-Dry Method.**

(a) The initial weight of each moisture content sample at air -dry condition was weighed and recorded as initial weight for air-dried.

(b) Then, the samples were soaked in water to obtain the approximate green condition and green weights were taken.

(c) After that, the samples were oven-dried at 103 ± 2° C to obtain the constant weight and the oven dried samples were weighed and recorded.

(d) The M.C of each samples at air dry and green conditions were calculated by using the following equation.

$$M.C.(\%) = \frac{I.Wt - O.D.Wt.}{O.D.Wt} \text{ x } 100 \text{ ----------- } 3.1$$

where,

M.C	=	Moisture content of the sample
I.Wt	=	Initial weight of the sample
O.D.Wt	=	Oven Dry weight of the sample

Then, average initial MCs of MC-blocks were calculated based on the average initial air-dry M.C. The calculated oven dry weight of each test sample for Vacuum-Pressure treatment was calculated by using the following formula.

$$C.O.D.Wt = \frac{I.Wtx100}{(100 + M.C\%)} \quad \text{-------------------- 3.2}$$

where,

C.O.D.Wt = Calculated oven dry weight of the sample

Similarly, calculated oven dry weight of each of the test samples for Dip-Diffusion treatment was calculated based on the average initial green M.C.

3.3.2. Determination of weight loss percent

The following formula was used in order to determine the weight loss percent of each of the test samples.

$$\text{Wt. Loss (\%)} = \frac{(C.O.D.Wt - F.O.DWt)}{C.O.D.Wt} \times 100 \quad \text{-------------- 3.3}$$

Where, C.O.D Wt = Calculated oven dry weight

F.O.D Wt = Final oven dry weight

3.3.3. Determination of retention

The purpose of the test is to determine the minimum amount of preservative that is effective in preventing decay, under the conditions of the test, by a particular fungus. This amount of preservative, in terms of pounds per cubic foot (or kilograms per cubic meter) of wood, is referred to as the threshold retention. The threshold is determined by estimating the point at which percentage weight loss caused by decay do not occur.

To calculate the retention of preservatives the volume of test blocks were measured by using water displacement method. Retention of treating chemicals were calculated by using the following equation.

$$R = \frac{0.01C(W_2 - W_1)}{V} \text{ x } 100 \quad \text{-----------------------} \; 3.4$$

Where,
R = Retention in g cm^{-3}
C = Concentration of chemical in percent
W_1 = Weight of block before treatment in gram
W_2 = Weight of blocks after treatment in gram.
V = Volume of block after treatment in cm^3.

3.4. Statistical Analysis

The data recorded were mean weight loss percentage of individual species and Average Retention (kg/m^3). The data obtained were statistically analyzed using ANOVA (Analysis of Variance), following a Complete Randomized Design (CRD). Mean comparison was done by using Duncan Multiple Range Test (DMRT).

4. RESULTS AND DISCUSSIONS

Results of the experiments were evaluated as mean weight loss percent of individual species and as average preservative retention (kg/m^3) of individual species.

Mean weight losses for each of the tested species treated with different solution strengths of two preservatives and untreated samples which were exposed to decay test are shown in Table (4.2). In order to clearly reveal the difference between the weight losses of untreated and treated blocks, statistical analysis was also carried out by using DMRT (Duncan Multiple Range Test). In this table, mean weight loses were arranged from highest to lowest. The highest weight loss was denoted as ‘a’.

Mean weight losses against the preservative solutions are shown graphically in Figures (1) to (10).

To know the effects of treatment variables, the analysis of variance (ANOVA) was made by using an ‘F’ test. The variables in the experiment were: (1) Species of wood (2) Wood preservatives (3) Concentrations of preservatives.

The ‘F’ test indicates highly significant difference between species and concentration of preservative at 99% confidence interval. The ANOVA table was shown in Table (4.5).

4.1. Natural Durability of the Tested Species

The weight losses of untreated wood blocks were varied depending on the species. According to the Natural Durability Classification (Findlay, 1938), the natural durability of the tested species are given in Table (4.1). This table indicates that, Didu was found to be the most susceptible to decay caused by *S.commune* and Gyo was the most resistance to *S. commune*. It can be seen that Gyo was durable species, Taw thayet, Nabe and Didu were Non-durable species and the rest were moderately durable.

Table (4.1) Natural Durability of the Tested Species

Species	Weight loss percent of untreated blocks	Natural Durability Class
Gyo	3.7095	Durable
Thande	5.2688	Moderately Durable
Taukkyan	5.6571	Moderately Durable
Thabye	5.6725	Moderately Durable
Thadi	5.8840	Moderately Durable
Thitsein	8.2951	Moderately Durable
Pyinma	9.2305	Moderately Durable
Taw thayet	11.2000	Non Durable
Nabe	12.9696	Non Durable
Didu	17.0326	Non Durable

Win Kyi-2 (1992) observed that the weight loss of untreated Didu was 41.31% with soil-burial test. In this study, that of Didu was 17.03%. Similarly, the weight losses of Thadi, Nabe, Thitsein and Thabye in the wet soil were 3.6%, 4.11%, 16.88% and 20.76% respectively. In this study, that of which with agar-block test were 5.88%, 12.79% 8.29% and 5.67% respectively. The results suggested that the untreated wood varies in their durability depending on decay types.

4.2. The Effect of CCA on the Durability of the Test Species

The effect of CCA on the *S.commune* decay fungus was expressed as percentage of weight loss. According to Table (4.2), all tested species treated with CCA was found to be effective than the untreated ones.

The weight losses of 1% CCA – treated blocks of the tested species ranged from 1.5% to 5.3% except Gyo and Thande. For Gyo and Thande, it was found that even 1% CCA solution give good results (weight loss 0.6% and 0.1%) and the durability class of those two species were improved from durable to very durable.

For moderately durable species (Taukkyan, Thabye, Thadi, Thitsein and Pyinma), the weight losses were significantly decreased by treating even with 1%CCA and their durability classes were improved from moderately durable to durable.

For non-durable species (Taw thayet, Nabe and Didu), it can be seen that the weight loss percent of 1%CCA-treated blocks were decreased about 4 fold than that of untreated (control) blocks except Didu and their durability classes were improved from non-durable to durable. As for Didu, the weight loss percent of 1%CCA-treated blocks decreased about 3 fold than that of untreated blocks.

It was also found that, **the weight losses of 3%CCA - treated blocks** ranged from 0.2% to 3.1% .By treating with 3%CCA, it can be seen that the durability class was improved from moderately durable to very durable and non-durable to durable.

Thus 3%CCA solution can effectively control the decay caused by *S.commune*. In fact, *S. commune* growth was inhibited at the minimum concentration level of 3% CCA.

The weight losses of 5%CCA –treated blocks ranged from 0.2 to 1% and the durability classes of all the tested species were promoted to very durable. The blocks were almost free from rots by *S.commune* except Didu. This indicated that there was no decay in 5%CCA –treated blocks. However, this assumption needs to be substantiated by microscopic observation.

Generally, the weight losses of CCA-treated blocks were lower than the control for all the species. All the CCA-concentration levels were found to provide almost complete control against decay of *S.commune* except 1%CCA. Although 5%CCA was found to be the most effective, 3%CCA solution gave the satisfactory results within the test range (1% to5%) of CCA solutions.

4.3. The Effect of BFCA on the Durability of Test Species

The weight losses of untreated and three concentrations of BFCA –treated blocks of test species against *S.commune* are given in Table (4.2). This table showed that the weight losses of BFCA-treated blocks were lower than the control for almost all of the tested species. According to the table, it was found that for all species, the higher the BFCA concentration, the lesser the weight loss percent and the more the effectiveness except for Didu.

The weight losses of 5%BFCA-treated blocks ranged from 3% to 7.68%. For Gyo, Thabye and Thadi, it can be seen that there was not significantly difference between untreated and 5% BFCA-treated blocks. This indicates that 5% BFCA solution is not effected on those species.

According to the results, the weight loss percent of 5%BFCA –treated blocks of Thande, Taukkyan, Thitsein and Pyinma were decreased to one half than that of untreated blocks of those species. Their durability classes were improved from moderately durable to durable.

It can be found that the weight loss percent of 5%BFCA–treated blocks of non-durable species (Taw thayet, Nabe and Didu) , were decreased about 2 to 3 fold and their durability increased from non-durable to moderately durable.

The weight losses of 15% BFCA-treated blocks ranged from 1.59% to 4.15%. It can be found that the weight losses were about 2 fold to 4 fold depending on the species and the durability was increased to durable.

The weight losses of 25% BFCA-treated blocks ranged from 0.7% to 4.1% depending on the species. Gyo and Thande are found to provide almost complete control against decay of S. commune. The weight losses of the rest species lies between 1.2% and 2.2%. Therefore, it can be concluded that a much higher concentration than 25% BFCA is required to prevent decay caused by *S. commune*.

4.4. The Calculated Retention for Test Species

Average retention (kg/m3) of selected test species impregnated with three different solution strengths of CCA by using Vacuum – Pressure treatment are shown in Table 4.3.

Average retention of test species treated with three different solution strength of BFCA by using Dip – Diffusion treatment are shown in Table 4. 4.

Analysis of variance was made by using an ‘F’ test. The ‘ F ’ test indicated significant difference between species and concentration of preservatives at 99 percent confidence interval. The ANOVA table was shown in table (4.6).

According to table (4.3), it can be seen that Didu has the highest retention (10.61 kg/m^3), followed by Taw thayet (10.2 kg/m^3). Thabye and Thadi have the lowest retention (2.9 and 2.5 kg/m^3).

For all species, 5%CCA is the best in retention. Generally, wood of low specific gravity should accommodate more preservative in it except Pyinma. Low chemical loading in the Pyinma samples might have been due to the presence of tyloses in the vessels (Than Than Aye, 1991), which can block the chemical movement.

Table (4.4) showed Thitsein has the highest retention (10.15 kg/m3), followed by Taw thayet (8.33 kg/ m^3) and Didu (7.22 kg/m^3). It can also be seen that, Taukkyan has the lowest retention (1.67 kg/m^3), followed by Gyo (2.41 kg/ m^3) and Pyinma (2.65 kg/m^3). The retention of the blocks treated with 25%BFCA gave the satisfactory retention.

Didu and Taw thayet are the species which are easy to treat (A Handbook of Myanma LUS), therefore, they could be treated with both Vacuum – Pressure treatment and Dip- Diffusion treatment.

Gyo, Taukkyan and Thande should be treated with Vacuum – Pressure method because of giving more preservative retention by that method than Dip-Diffusion method. For Vacuum – Pressure treatment, it is quite reasonable to calculate the amount of chemical deposited in the treated wood. However, there might be differences in concentrations of chemical deposited depending on the depth of penetration.

Since diffusion treatment relies on the mobility of molecules due to concentration gradients rather than absorption of fluid, there might be differences between calculated retention and actual deposition of the chemicals.

Effective utilization of wood depends on strength, durability, beauty and availability of a species. Most of the properties of timber depend on the density of wood. Generally, high- density timbers are more durable than lighter ones. Medium density timbers get wider range of most indoor utility purposes such as furniture, paneling, flooring, doors and windows. Light density timbers get limited uses such as toys, packing box and match box etc.

Many of the LUS have good utilization potential but the major deterrent to their fuller utilization has been problems associated with their deterioration in service.

The construction industry, followed by the furniture industry is the largest consumer of solid wood. Wood is also used for railway sleepers, transmission poles, fencing posts, piling and wharf structures. Strength and durability are the most important factors for consideration in the choice of species for construction.

Win Kyi-1 (2002) stated that Gyo (sp.gr.-0.938) and Taukkyan (sp.gr.-0.815) are very heavy species. Their basic specific gravity are higher than that of Pyinkado (*Xylia dolabriformis*) (sp.gr.-0.779), which is accepted as the best structural timber in Myanmar. According to specific gravity, they could be assumed as suitable for structural timber. However, for structural timber, durability is the important factor. The durability of those timber species after treatment with preservatives are found to be promoted to very durable. Therefore, after treatment with preservatives, Gyo and Taukkyan could be used as structural timbers and sleepers as substitutes for Pyinkado.

Win Kyi-1 (2002) also expressed that the specific gravity of Taw-thayet is almost equal to that of Kyun (*Tectona grandis).* The mean oven dry weight loss of Kyun infested by (*Trametes cingulator*) after 16 weeks was 4.17% (Win Kyi-2, 1989). According to this study, that of Taw-thayet was 11.2%. But after treating with two types of preservative, the weight loss of taw-thayet becomes to that of Kyun. Therefore, it was suggested that treated Taw-thayet can be used as Kyun.

Strength properties of Thabye, Thadi, Thande and Pyinma are almost similar to those of In and Kanyin which are already accepted as construction timbers. Therefore, treated timber of those species could be used as construction timbers.

Win-Kyi-1(2000) stated that Nabe, Taukkyan and Taw-thayet are found to be suitable for making high quality wood products, since their dimensional stability and tangential shrinkage are closed to 2.0 and 7.0 %. They have market potential for both domestic as well as world market. According to the results of this study, after treatment with wood preservatives they become very durable. Therefore, it was suggested that treated timber of these species could be used as high quality wood products.

Win Kyi-2 (1992) stated that the weight loss of untreated Didu was 41.31% with soil-burial test. In this study, that of Didu was 17.03%. Similarly, the weight losses of Thadi, Nabe, Thitsein and Thabye in the wet soil were 3.6%, 4.11%, 16.88% and 20.76% respectively. In this study, that of which with agar-block test were 5.88%, 12.79% 8.29% and 5.67% respectively. The results suggested that the untreated wood varies in their durability depending on decay types.

Table (4.2) Mean Weight Losses for Test Species Treated with Different Solution Strengths of Two Preservatives

Treatment	Mean Weight Loss (%) by Species										
	Didu	Gyo	Nabe	Pyinma	Taukkyan	Tawthayet	Thabye	Thadi	Thande	Thitsein	Mean
Control	17.03 a	3.71 a	12.97 a	9.23 a	5.66 a	11.20 a	5.67 a	5.88 a	5.27 a	8.30 a	8.49
BFCA 5%	7.48 b	3.67 a	6.37 b	3.56 b	2.99 b	4.00 b	5.03 a	5.29 ab	3.18 b	4.22 b	4.58
BFCA 1%	3.61 c	1.59 b	4.16 c	2.15 c	1.87 bc	3.67 b	3.97 ab	3.50 bc	1.80 c	3.54 bc	3.00
BFCA 2%	4.31 c	0.89 bc	2.68cd	1.27 cd	2.20 bc	2.73 bc	2.72 bc	1.02 e	0.81 d	1.43 de	2.01
CCA 1%	5.33 b	0.62 bc	3.45 c	3.07 b	1.51 c	2.75 b	2.04 c	2.38 cd	0.11 d	2.03 cd	2.33
CCA 3%	3.16 c	0.27 c	1.84 d	1.26 cd	0.59 d	1.12 c	0.32 d	1.09 e	0.23 d	0.92 e	1.08
CCA 5%	1.27 d	0.34 c	0.15 e	0.61 d	0.31 d	0.17 b	1.84 c	1.56 de	0.22 d	0.45 e	0.69
Mean	6.03	1.59	4.52	3.02	2.16	3.66	3.09	2.96	1.66	2.98	3.17

Where, a = The highest weight loss

e = The lowest weight loss

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table (4.3) Average Retention of CCA using Vacuum-Pressure Treatment in Heartwood of Tested Species

Species	Sp.Gr.	Average Retention (Kg/m^3)			Mean
		1%CCA	3%CCA	5%CCA	
Didu	0.385	4.78 a	11.71 a	15.34 a	10.61
Gyo	0.938	2.59 ab	4.29 b	8.06 bc	4.98
Nabe	0.704	1.83 ab	2.86 b	9.02 b	4.57
Pyinma	0.563	1.53 ab	2.28 b	5.56 c	3.12
Taukkyan	0.885	1.51 ab	3.45 b	5.07 c	3.34
Taw thayet	0.611	2.81 ab	14.14 a	13.66 a	10.20
Thabye	0.732	1.32 ab	3.47 b	3.90 d	2.90
Thadi	0.764	1.09 b	2.86 b	3.54 d	2.50
Thande	0.725	2.79 ab	3.31 b	9.01 b	5.04
Thitsein	0.788	2.94 ab	4.29 b	9.46 b	5.56

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table (4.4) Average Retention of BFCA using Dip – Diffusion Treatment in Heartwood of Tested Species

Species	Sp.Gr.	Average Retention (kg/m^3)			Mean
		5%BFCA	15%BFCA	25%BFCA	
Didu	0.385	2.35 a	7.54 b	11.76 b	7.22
Gyo	0.938	0.83 a	1.52 c	4.87 c	2.41
Nabe	0.704	4.14 a	8.50 ab	10.63 b	7.76
Pyinma	0.563	0.55 a	2.23 c	5.18 c	2.65
Taukkyan	0.885	0.74 a	1.47 c	2.79 d	1.67
Taw thayet	0.611	2.24 a	8.92 ab	13.83 a	8.33
Thabye	0.732	1.08 a	2.68 c	5.48 c	3.08
Thadi	0.764	1.62 a	6.04 b	9.86 b	6.58
Thande	0.725	1.51 a	4.04 c	5.71 c	3.75
Thitsein	0.788	3.49 a	11.23 a	15.75 a	10.15

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

Table (4.5) Analysis of Variance for Mean Weight Loss

BASED ON VALUES TRANSFORMED TO Arcsine (Sqr (X/100))

SV	DF	SS	MS	F
TREATMENT	69	14717.01377	213.29005	25.17**
CON(C)	6	10119.06910	1686.51152	199.03**
SPP(S)	9	2712.60156	301.40017	35.57**
CxS	54	1885.34311	34.91376	4.12**
ERROR	630	5338.29547	8.47348	
TOTAL	699	20055.30923		

** = significant at 1% level

Table (4.6) Analysis of Variance for Retention

BASED ON VALUES TRANSFORMED TO Arcsine (Sqr (X/100))

SV	DF	SS	MS	F
TREATMENT	59	9563.42128	162.09189	13.25 **
CON (C)	5	3258.70403	651.74081	53.27 **
SPP (S)	9	3530.64192	392.29355	32.07 **
C X S	45	2774.07530	61.64612	5.04 **
ERROR	540	6606.42301	12.23412	
TOTAL	**699**	**16169.84429**		

** = significant at 1% level

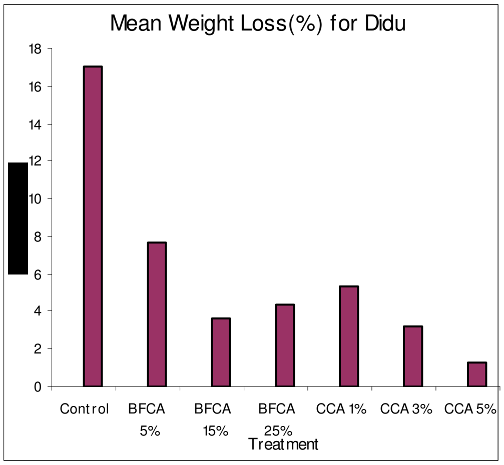

Fig. (1) Analysis of Decay for Didu exposed to *S. Commune*

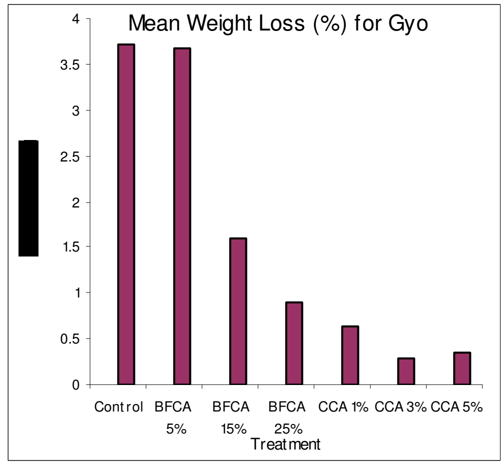

Fig. (2) Analysis of Decay for Gyo exposed to *S. Commune*

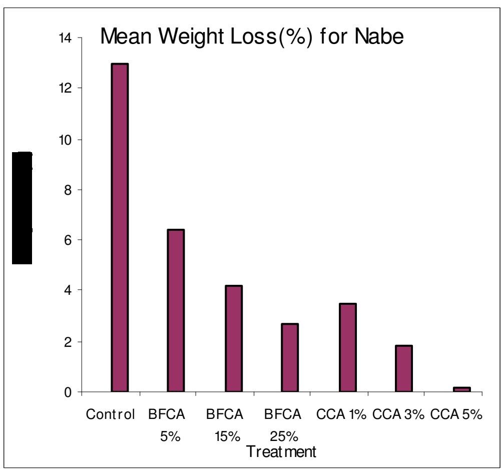

Fig. (3) Analysis of Decay for Nabe exposed to *S. Commune*

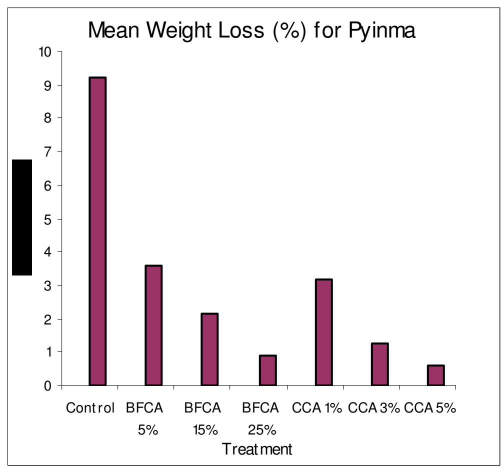

Fig. (4) Analysis of Decay for Pyinma exposed to *S. Commune*

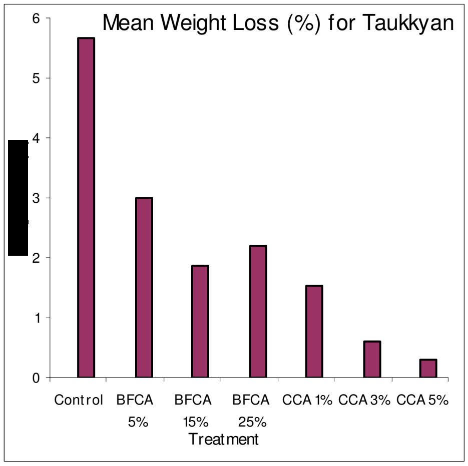

Fig. (5) Analysis of Decay for Taukkyan exposed to *S. Commune*

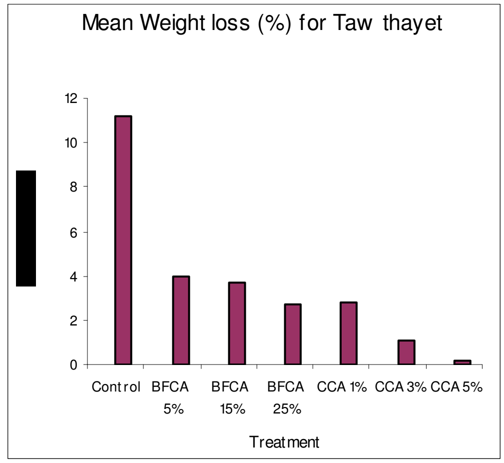

Fig. (6) Analysis of Decay for Taw-thayet exposed to *S. Commune*

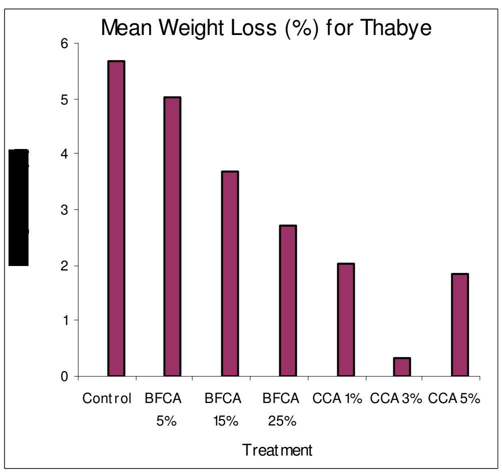

Fig. (7) Analysis of Decay for Thabye exposed to *S. Commune*

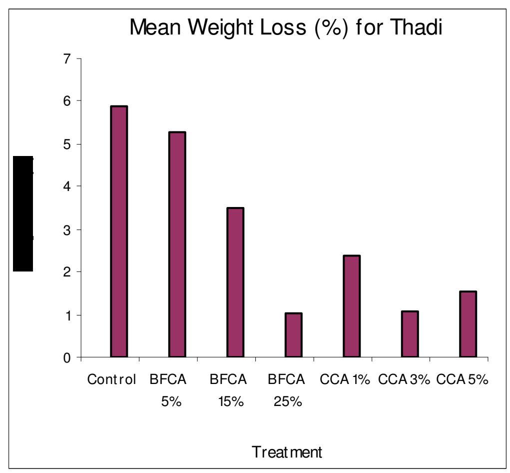

Fig. (8) Analysis of Decay for Thadi exposed to *S. Commune*

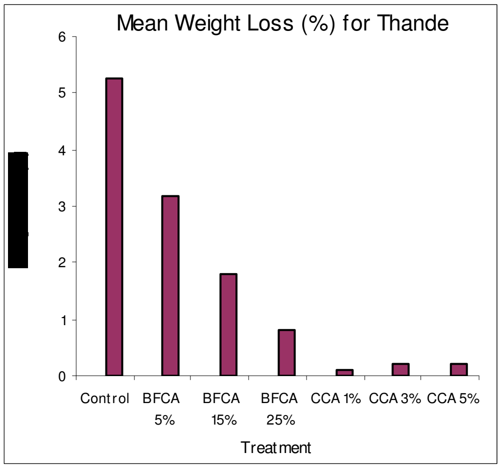

Fig. (9) Analysis of Decay for Thande exposed to *S. Commune*

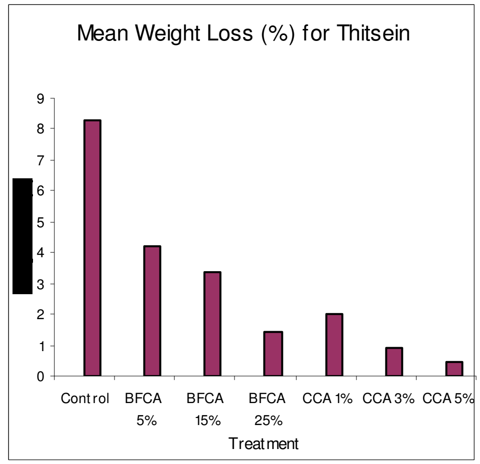

Fig. (10) Analysis of Decay for Thitsein exposed to *S. Commune*

5. RECOMMENDATIONS AND CONCLUSIONS

5.1. Recommendations

Based on results obtained from the present study, the following recommendations are made and should be considered for future research works**.**

(1) Findings from this study recommend the use of low durable woods such as moderately-durable and non-durable species after rendering proper preservative treatment.

(2) Some LUS possesses equal properties or even superior in workability to known commercial species. One of the major deterrents to the fuller utilization of the LUS has often been the lack of adequate knowledge on their durabilities and treatabilities.

There is a growing demand for tropical timber for various end-uses. Therefore, establishing information on durability-treatability-uses and other relevant facts become necessary in order to expand the timber trade to include LUS for the mutual benefit of both the timber producers and consumers.

(3) The potential for wider application of preservatives and development of other process of treatment are tremendous. It is suggested that appropriate treatments be applied to timber and timber components that are not receiving treatment yet in order that their life span in service could be prolonged. Preservatives could also extend and widen the application of wood, thereby maximizing the usefulness of the timber resources.

(4) The fuller utilization of preservative treated wood would reduce the pressure for the demand to cut down forests so that an efficient conservation program for the proper management of this vital natural resource (timber) could be successfully implemented.

(5) A fair idea of natural durability of some common hardwood species was gained from this initial decay study. The results give only a relative measure of natural durability and are most reliable from the stand - point of immunity. However, if field tests are carried out in conjunction with the laboratory test, some qualitative supports can be obtained to ascertain to the results. Therefore, further decay tests both in the laboratory and in the field stake tests are necessary to complete the knowledge of durability of LUS.

(6) Numerous references have related the effect of water-borne preservatives on mechanical properties of wood. Generally, some losses in mechanical properties of wood treated with water-borne preservatives could be expected than that treated with oil-borne

preservatives. Toughness is the one most severely affected by CCA preservative treatment. Effects of preservative treatments on physical and mechanical properties of Myanmar LUS should be studied.

5.2. Conclusions

The results of the experiment indicated that the durability of test species could be promoted through wood preservation. It can be successfully decreased the weight loss percent of test species when using the appropriate preservatives and treatment methods. According to the results of this study, it can be concluded that:

(1) The results of the experiment indicated that among the test species, Didu was found to be the most susceptible to decay and Gyo was the most resistance.

(2) It can also be seen that Gyo was durable species, Didu, Nabe and Taw-thayet were non-durable species and the rest were moderately - durable species.

(3) The weight losses of CCA-treated blocks were lower than the control for all species.

(4) Among the CCA concentration levels, although 5% CCA was the most effective, 3% CCA solution can effectively control the decay caused by *S.commune* fungus.

(5) BFCA preservative was successful, only at high concentration level in controlling decay caused by *S.commune* fungus in these species.

(6) For the effect of BFCA on the test species, a much higher than 25% is required to prevent decay caused by *S. commune*.

(7) In the case of retention, generally, wood of low specific gravity accommodate more preservative in it except Pyinma.

(8) Didu and Taw-thayet could be treated both Vacuum-Pressure and Dip-Diffusion methods.

(9) Nabe, Thabye,Thadi and Thitsein could be treated with Dip-diffusion method.

(10) Gyo, Taukkyan and Thande should be treated with Vacuum-Pressure method.

(11) Of the two preservative treatment methods, Vacuum- Pressure treatment method can give the best result (greater retention). But, using CCA involves high initial investment for the installation of treatment plant.

(12) Diffusion treatment requires only dipping tank and chemicals. However, it takes longer time enough for the penetration of solution into wood than the pressure process depending on the sizes of wood used.

Appendix I

Types of Wood Preservatives

Type	Major Constituents	Specification
Tar Oil		
T.O.1	Coal tar creosote	B S 144
T.O.2	Creosote oil type of preservatives other than creosote (Creosote – Pentachlorophenol)	B S 3051
Organic Solvent		
O.S.1	Chloro naphalenes	
O.S.2	Metallic Naphthenate(Copper / Zinc Naphthenates)	
O.S.3	Pentachlorophenol (NaPCP)	BWPA 104
Water Borne		
W.B.1	Copper / Chrome	B S 3452
W.B.2	Copper /Chrome / Arsenate	BWPA102/ 103
W.B.3	Fluoride / Arsenate / Chromate / Dinitrophenol	B S 3453
W.B.4	Sodium pentachlorophenate, Sodium fluoride	
W.B.5	Boron compounds (sodium octaborate / boric acid)	

Appendix II

Non-Pressure Process of Preservative Treatment

Type of Treatment		**Uses**
Brushing & Spraying	The simplest treatment . It requires a minimum investment in equipment.	Oil-born and water-borne preservative are used.
Dipping	It involves the immersion of the wood in a treating solution for a period of a few minutes. Little more effectiveness than B&S. Na PCP & Boron preservative are used.	The method is used for protection against sap-stain and insect infestation.
Steeping & Cold soaking	The timber is immersed in cold preservative. The longer the period of immersion , the more increase depth of penetration and amount of retention.	If oil solution is used, it is called cold soaking. If water-borne preservative is used, it is steeping.
Hot & Cold Bath	Timber is placed in a tank of preservative which is heated, then it removed and placed in a tank of cold preservative solution. Coal tar creosote and other oil based preservatives are used.	The method is used for treatment of rail-sleeper fence post and poles for use in ground contact.
Diffusion	The timber is dipped into preservative solution for 30 minutes or more. Then removed and covered for a period of time to prevent loss of moisture for diffusion to take place. Usually used Boron & Borax compounds.	The method is used for timbers used out of ground contact and protected from the weather e.g. framing , flooring , interior finishing etc.

Source: Hong & Daljeet Singh (1985).

Appendix III

Pressure Process of Preservative Treatment

Types of Treatment	**Uses**
I. Bethell (full-cell) vacuum - pressure	Timber is placed in a metal cylinder and the preservative forced into the timber under pressure. Both vacuum and hydraulic pressure are used. Usually used for water – borne preservatives like CCA. The method is used for treatment of rail-sleepers posts and poles use in ground contact and also use in marine environments.
II. Rueping Process	Hydraulic pressure and Final vacuum are used. Usually used for oil –based preservatives like creosote.
III. Lowry or Empty-cell	Similar to II above, but air pressure is used in this treatment.
IV. Oscillating Pressure	Pretreatment steaming of the timber is required. Repeated applications of high (860 kPa) and low (vacuum) pressure are used. Usually water-borne preservatives like CCA are used.
V. Alternating Pressure	Similar to IV above, except that low pressure used here is atmospheric pressure.

Source: Hong & Daljeet Singh (1985).

Appendix IV

Some Common Preservatives Used for Wood Preservation

Name / Type	Major Constituents	Uses
Creosote	Creosote in diesel oil.	Against decay and insects. For use in external condition rail-sleepers, power line posts, fences.
Tanalith	Copper sulphate.	Against decay & insects.
Celcure	Potassium or sodium dichromate.	For use in external condition, rail-sleepers, power-line posts, foundation piles and marine conditions.
Copos LC	Arsenic pentoxide	
Chlorophenols	Sodium pentachlorophenate (Na PCP) Pentachlorophenol in fuel oil.	Against sap-stain. For use in indoor conditions or temporary protection.
Boron	Mainly sodium octaborate, also boric acid.	Against insects. For use in indoor condition usually as an additive to Na PCP.
Haipen, Difolatan Basilit SAB	Captafol.	Against sap-stain. Against sap-stain.
Alkyl ammonium compounds	Alkyldimethyl benzyl, ammonium chloride, Alkyl dimethylamine acetate.	Against decay, sap-stain, insects, marine borers.
Organotins	Tributyltin oxide. Triphenyltin oxide.	Against decay and insects. For low hazard condition window frame joinery etc.

Source: Malaysian Forester (1985).

Appendix V

Some Common End-uses of Malaysian Timber Treated with Common Wood Preservatives.

Types of Timbers and timber components	**Main timbers used locally**	**Preservative used**	
		Local	**Elsewhere**
Foundation Piles	Kemps, Keruing	CCA	CCA, pentaphenol in fuel oil (PCP). Phenol + inorganic fluoride = 6PF
Rail-sleepers	Kemps, Keruing	Creosote Diesel Oil and CCA.	CCA, PCP, Creosote
Wooden post (or poles)	Tualang, Kempas Keruing.	CCA, occasionally creosote	CCA, creosote, PF
Window frames and joinery for house construction	Medium or light hardwood	Nil, occasionally CCA	Organotins in light organic solvent (LOS) CCA, Boron compounds.
Shingles	Heavy hardwood	Nil or CCA	Copper Napthenate, LOS, CCA
Furniture Light-coloured woods	Light hardwood Jelutong, Ramin, White Merantic Merpauh, Rubberwood	Nil NaPCP + borax, Basilit SAB	LOS NaPCP, sodium tetraborate alkylammonium, copper-8-quino linate, captafol.
Fence posts	Medium and light hardwood	Nil or CCA	CCA, Creosote, PCP alkyl ammonium compounds.
Plywood	Light hardwood	gamma-BHC	Organotins in LOS, copper Napthenate, CCA

Source: Hong & Daljeet – Singh (1985).

Appendix VI

Definition of Hazard and Typical Overall Average CCA Retentions for a Variety of Timber Commodities.

Hazard Description	Timber Commodity	Retention of CCA Kg/m^3
Not in ground contact Exterior timbers not in contact with the ground but exposed to the weather and to termite attack	Exterior building timbers, cladding, barge boards, doors, window and door frames, stadium seating, decking, mining timbers refrigerator linings, railway wagons	8
In ground contact Timbers in contact with or buried in the ground exposed to the weather	Posts and ground line timber in buildings, railways sleepers, bridge timbers, fence-posts, gates, farm buildings, posts for stadium seating	12
High hazard (1) Timbers frequently or permanently immersed in *freshwater* or in condition of high humidities and condensation	Poles, telephone and power distribution. Land- drains, cooling towers, revetments. Piling and foundation timbers, cable drums	16
High hazard (2) Timbers frequently or permanently immersed in *sea water*	Groynes, jetties, boat building timbers	24

Source: David Aston, 1985

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