ITTO

International Tropical Timber Organization
The Research Institute of Wood Industry

CRIWI

# RUBBERWOOD PROCESSING TECHNICAL REPORT


(ITTO PD 3/96 REV.2(I))

# CONTENTS

# PREFACE

Rubber trees have been planted at large scale in southern China since early 1950's. Now the plantations reach 600 000 $hm^2$, ranking the 4th in the world, mainly in Hainan, Guangdong and Yunnan provinces. Besides providing raw material to rubber industry, rubber trees, which are no longer economical to yield latex, have become an important raw material for wood-based industry. The development of rubberwood industries is also environmentally benign as the rubber tree plantations are managed on a sustainable basis, resulting from continuing process of 25～30 years plantation cycle.

China is short of timber. Making full use of timber can solve the problem to a certain extent. Rubber trees are one of the most important tropical plantation species in south China. Its processing characters are fine, but it is not resistant to fungi and molds.

The Research Institute of Wood Industry (CRIWI) is a national comprehensive research institute, having expertise in research on wood properties and wood utilization for 40 years. During the past four years, in order to enhance the development of rubberwood industry, CRIWI organized a number of training courses and a national workshop to disseminate the technical information produced in complementing the pre-project (ITTO PPD 6/94 Rev. 1 (I)) and the project (ITTO PD 3/96 Rev. 2(I)) of "Development and Extension of Rubberwood Processing and Utilization Technology". The technology and experience gained through years of research and development has been compiled in this book. It is the primary objective that the book will serve as a useful reference material for government officials, researchers, university students, engineers, managers and traders related to rubberwood with the hope that rubberwood could be better understood and utilized to promote a better rubberwood market.

Prof. YE Kelin
Director of CRIWI

February 1999

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# CURRENT SITUATION ON RUBBERWOOD PROCESSING AND UTILIZATION TECHNOLOGY IN CHINA

## 1 Introduction

Rubber plantation area in the world is estimated at 8.98 million hectares. 91.8% of the total is located in Asia. The most important producing countries are Indonesia, Malaysia and Thailand, covering 74.1% of the world plantation area. Other main rubber producers in Asia include China, India, Sri Lanka, Vietnam and the Philippines. Africa accounts for 6% of the world total, Latin America has only 3% of the world's rubber plantation.

**Table 1 Rubber plantations worldwide[1]**

| Region | Million $hm^2$ | % |
|---|---|---|
| ASIA | 8.24 | 91.8 |
| Indonesia | 3.04 | 33.9 |
| Malaysia | 1.83 | 20.4 |
| Thailand | 1.78 | 19.8 |
| Others | 1.59 | 17.7 |
| AFRICA | 0.49 | 5.5 |
| LATIN AMERICA | 0.25 | 2.8 |
| TOTAL | 8.98 | 100 |

[1] Hong L T, Sim H C. Rubberwood Processing and Utilizition, FRIM, Malaysia, 1994

The short-term (1992～1997) physical production potential of rubberwood in the world is estimated at 39 million $m^3$ per year of which 11 million $m^3$ would be logs. The total potential will increase gradually up to 52 million $m^3$ in 2016～2021 when log output could reach 14 million $m^3$ per year. The economic availability of rubberwood in the short-term is estimated at 29 million $m^3$ and that of logs at 8 million $m^3$. This represents about 75% of the physical potential.

Rubberwood can be used for making a wide range of products: rubberwood-based panels (particleboard, plywood, MDF, etc.), furniture and joinery products; floor tiles and parquet, moldings, etc.

Among the Asian countries, India has the biggest rubberwood plywood and veneer manufacturing industry, which consumes about 525 000 $m^3$ of rubberwood annually, or 79% of the total rubberwood logs production in the country. Thailand has one of the most, developed rubberwood particleboard manufacturing industries among the rubber-producing countries of Asia.

Rubberwood logs produced in Asian countries are mostly converted into furniture and joinery products. Many processing plants in Malaysia, Thailand, Japan, Singapore as well as Taiwan Province of China use rubberwood for furniture and furniture components. The

China is short of timber. Making full use of the timber can solve the problem to a certain extent. Rubber tree is one of the most important tropical crop species in south China with annual output of around 0.9～1.2 million $m^3$ timber.

In recent years, progress on rubberwood processing and utilization technology has been achieved in China, but still legs behind these advanced countries such as Malaysia and Thailand. According to the recommendations of ITTO expert panel in 1994, survey on current situation of rubberwood processing and utilization technology in China would be described in this paper.

## 2 Rubberwood resources in China

Rubber tree is mainly distributed in Hainan Province, Xishuangbana, Yunnan Province and the western part of Guangdong Province in south China. According to the statistics of China Agricultural Department in 1996, about 591 800 $hm^2$ of rubber tree was cultivated in China (table 2), which occupied the 4th position in the world.

Planting area about 367 900 $hm^2$ in Hainan, accounting for over 60% of the total area in China. Among which, the planting area of the agricultural farm system is 242 700 $hm^2$, accounting for 66% of the total area in Hainan Province (table 2).

**Table 2 Rubberwood plantation in China (1 000 $hm^2$) [2]**

| Planting condition | Hainan | Yunnan | Guangdong | Others | Total |
|---|---|---|---|---|---|
| total area(1996) | 367.9 | 143.5 | 69.3 | 11.1 | 591.8 |
| total area(1996)* | 242.7 | 71.7 | 51.6 | 11.1 | 377.2 |
| planting time* | 1950～early1960' | 1958～early1970' | 1950～1970 | NA | / |
| species | PB 846, PR 107, GTI, RRIM600** | RRIM600,GF-1, PRL-10 and PP-86 | NA | NA | / |

[2] China agricultural yearbook, 1996
* By agricultural farm system,
* * A few Haiken No.1 and Haiken No.2

According to the replanting period of 30 years, 8 000 $hm^2$ should be cut yearly. Due to the rubber price in recent years, the cut area was only 2 560 $hm^2$ in 1997 in Hainan (table 3). In 1975, the Hainan agricultural farm system began replanting. Rubber cut area annually in Hainan agricultural farm system is listed in table 3. In Yunnan Province, rubber plantaton recycle peak should be around the year 2000 for its later plantation. In Guangdong Province, its replanting was almost finished and other tropical plants such as sisal etc were planted instead.

**Table 3 Rubber cuting area in Hainan agricultural farm system ($hm^2$) [3]**

| Year | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|---|---|
| Cut area | 156 | 727 | 672 | 428 | 550 | 1397 | 917 | 805 |
| Year | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 |
| Cut area | 1782 | 2326 | 2392 | 1830 | 2511 | 2741 | 2927 | 2885 |
| Year | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Total |
| Cut area | 3558 | 4547 | 4522 | 3824 | 3268 | 2473 | 2560 | 49935 |

[3] Data from Dept of Industry, Hainan Agricultural Farm Bureau, 1998.

Different geography and climate have strong influence on the occurrence of mold and blue stain infection. For example, in Hainan and Guangdong, where are moist and wet climate, the mold and stain infection of rubberwood is serious, while in Yunnan Province of Yungui Plateau, where is dry or arid climate, the mold and stain infection is light.

## 3 Log preservation and sawing

### 3.1 Log preservation

At present, most of the rubber-planting farms possess wood processing plants of different scale in Hainan. During the stacking period in open air, the logs usually have not been sprayed or brushed with anti-stain or anti-sapstain for mulations. Only a few plants such as the Sanya Wood Plant spray sodium pentachlorophenol solution if it is in the rainy season.

### 3.2 Sawing of log

The equipment for sawing is all Chinese-built pony band saw. The efficiency is low and its quality can not be guaranteed. Since rubberwood has small diameter, many internode scars, high content of resin, large pattern sawing equipment is not suitable, so far, some equipment imported in 1988 from UK and Italy by the World Bank's loan have been lain idle in Hainan.

The sawntimber from Hainan is mostly sold to Guangzhou and Zhujiang Delta and then the final wood products are exported to Hongkong and Japan.

### 3.3 Problems

Only a few sawmills spray sodium pentachlorophenol for temporary protection to prevent log from blue stain while most of the sawmills do nothing for that.

The equipment for sawing is poor.

## 4 Impregnating treatment

Vacuum pressure and hot/cold bath treatments are the two methods adopted for impregnating treatment. The amount of rubberwood treated by hot/cold bath process accounts for 1/3 of the total. There are about 25 sets of vacuum pressure equipment in China, of which 20 sets in Hainan, 2 sets in Guangdong, 3 sets in Yunnan. Some of the treat equipment is listed in the following table 4. About 79 farms in Hainan process sawnmill and produce sawntimber.

### 4.2 Preservatives

The preservative used for rubberwood is mixture of borax/boric acid and sodium pentachlorophenol (BBP). At present, BBP is widely used by all wood processing plants in Hainan and most of plants in Guangdong. The wood processing plants in Yunnan adopt a preservative produced by Chengdu Wood Plant (table 4).

Preservatives such as Antiblu 3738 and Antibore 3767 from Hickson Company and Engitac from Denmark had been used in several farms in Hainan and Guangdong, because their anti-stain effects were not very well. Other preservatives such as Mufang No. 2 and TWP were failed to prevent from mold, so these preservatives are not employed now. 8 kg of BBP is needed for treating 1 $m^3$ of rubberwood and most of industries consider it reasonable.

**Table 4 Preservatives and equipments used by some of the impregnating plants**

| Name of the wood plant | Impregnating equipment | Preservatives |
|---|---|---|
| Hainan | | |
| Sanya Wood Plant | Denmark (17*) | BBP |
| Xilian Wood Plant | Denmark (5.3×4) | BBP |
| Xiqing Wood Plant | Jiangxi Chemical Industry Mechanical Plant (5) | BBP |
| Xipei Wood Plant | Denmark (5.3) | BBP |
| Payi Wood Plant | Wuhan Ship-building Mechanical Plant (9.5) | BBP |
| Fuyontian Wood Plant | hot/cold bath (5) | BBP |
| Guangdong | | |
| Nanhua Farm Wood Plant | Hickson company, UK | ABTM |
| Wuyi Farm Wood Plant | Hickson company, UK | BBP |
| Xingfu Farm Wood Plant | hot/cold bath | BBP |
| Yunnan | | |
| Jinghong Farm Wood Plant | Jiangxi Yingtan | CDP** |
| Dongfeng Farm Wood Plant | Jiangxi Yingtan | CDP |
| Hekou Farm Wood Plant | Taiwan Province | CDP |
| Bashai Farm Wood Plant | hot/cold bath | CDP |

* Volume: $m^3$

** CDP: Chengdu preservative.

### 4.3 Problems

There are following problems in using BBP for preservation treatment of rubberwood:

Higher toxicity of sodium pentachlorophenol in BBP.
Severe corrosion of the drying kiln components.
Turning wood into brown.

## 5 Drying

### 5.1 Drying equipment

Most of kilns used for drying rubberwood are the conventional steam-heated kilns. Some kilns were made in Germany, Singapore and Taiwan Province of China with metallic shell and the others are made in China with brick wall. There is no much difference in quality between imported and domestic kilns. The drying scale varies with the size of kilns and supplying of raw materials. (see table 5).

**Table 5 Kilns for drying rubberwood in China**

| Name of rubberwood processing plants | Drying kilns | | |
|---|---|---|---|
| | Model of kiln | Volume of each kiln ($m^3$) | Numbers of kilns |
| Sanya Wood Plant in Hainan | Hilder-brand kiln with automatic control made in Germany | 30 | 9 |
| Xilian Wood Plant in Hainan | Hilder-brand kiln with automatic control made in Germany, | 30 | 9 |
| | Brickwall semi-automatic control kiln made in Taiwan Province of China | 100 | 2 |
| | Brickwall semi-automatic control kiln designed by Guangzhou Satellite Station. | 100 | 2 |
| Xipei Wood Processing Plant in Hainan | Hilder-brand kiln with automatic control made in Germany | 50 | 3 |
| Xiqing Wood Processing Plant in Hainan | Brickwall semi-automatic control kiln designed by Hainan Farm Bureau Wood Group Corp | 50 | 1 |
| Bayi Farm Wood Processing Plant in Hainan | Brickwall automatic control kiln designed by Singapore | 100 | 3 |
| Wood Processing Plant of Sanya light-industry and textile Imp/Exp. Corp | CWD-40B semi-automatic control kiln with metallic shell designed by the Chinese Academy of Forestry | 40 | 2 |
| | CWD-50B semi-automatic control kiln with metallic shell designed by the Chinese Academy of Forestry | 50 | 2 |
| Wuyi Wood Processing Plant in Guangdong | Kiln designed by the Nanjing Forestry University | 100 | 1 |
| Xingfu Wood Processing Plant in Guangdong | Kiln designed by the Nanjing Forestry University | 100 | 1 |

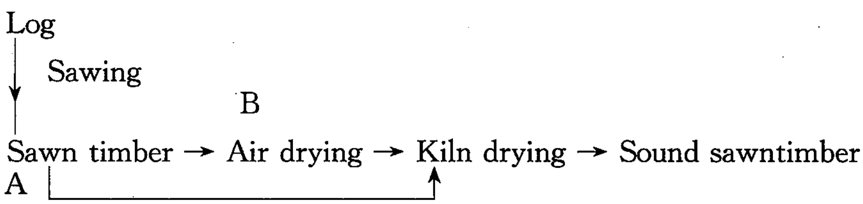
(to be continued)

| | Model of kiln | Volume of each kiln ($m^3$) | Numbers of kilns |
|---|---|---|---|
| Jinghong Wood Processing Plant in Yunnan | Kiln designed by the Nanjing Forestry University | 100 | 1 |
| Dongfeng Wood Processing Plant in Yunnan | Kiln designed by the Nanjing Forestry University | 100 | |
| Hekou Wood Processing Plant in Yunnan | CWD-50B electronic control kiln with metallic shell designed by the Chinese Academy of Forestry. | 50 | 2 |
| Bashai Wood Processing Plant in Yunnan | Kiln designed by the Nanjing Forestry University. | 100 | |
| Nanhua Wood Processing Plant in Yunnan. | Kiln designed by the Nanjing Forestry University. | 100 | 2 |
| | Brickwall automatic control kiln made in Singapore. | 100 | 4 |

The kilns imported from the Germany are automatic controlled with a fine thermal insulation. Most of domestic kilns are semi-automatic controlled.

## 5.2 Drying schedule and technology

There usually has a process of air drying before kiln drying in China. Most timber plants in China adapted route B of the following chart since sodium pentachlorophenol was used for controlling mold and stain fungi in the air drying process.




A: treated with boric acid/ borax

B: treated with boric acid/ borax/ sodium pentachlorophenol (BBP)

As most of the plants don't exclude the pith or center heart, cracking and waving often occurr during drying. Usually stickers of 40 cm × 40 cm with spacing of 40 ~ 80 cm are adopted. The time of air-seasoning for the timber stack is usually determined by the arrangement of their production but not strictly determined by the 40% M.C. During the kiln drying process, the treatment of initial, medium and final stage to spray steaming are conducted to improve drying quality.

The drying schedule for rubberwood is basically a low temperature with the maximum temperature below 90 degree centigrade. A few of the small plants in China adopt only air- seasoning process because their scale is small.

### 5.3 Problems

Currently the typical processing time between felling of the trees to charging of sawn timber into drying kiln can be as long as 10 days or more. This is one of the reasons often quoted that necessitates the use of sodium pentachlorophenol.

## 6 Secondary processing and utilization of rubberwood

General situation of secondary processing and utilization of rubberwood is listed in table 6:

**Table 6 Situation of rubberwood processing in the Chinese agricultural farm system (1997)**

| Item | Hainan | Yunnan | Guangdong |
|---|---|---|---|
| Log production * | 69.8 | 20~30 | / |
| Sawntimber production * | 69 | 7 | / |
| No. of sawntimber plants | 15 | 3 | / |
| Plywood production * | 4.5 | 5 | 3 |
| No. of plywood plants | 10 | 1 | 1 |
| Particleboard production * | 27.7 | 0 | 0 |
| No. of particle board plants | 1 | 0 | 0 |
| No. of model product plants | 1 | 0 | 1 |
| No. of MDF plants | 1 | 0 | 0 |

* 1 000 $m^3$

Sawntimber is mainly used for the manufacture of furniture, plywood for building material and particle board for furniture or sonic box.

### 6.1 Furniture

Sawntimber is mainly used for the manufacture of furniture. There are 15 rubberwood furniture factories in Hainan Agricultural Farm System with a yearly output value of RMB 160 million (US $ 19.3 million), of which the Sanya Wood Plant and Huali Furniture Plant are the bigger ones. All the furniture-making equipment of the Sanya Wood Plant was imported from Italy with a yearly output of 0.5 million sets / pieces including sofa, bed, table, chair etc. 135 sets of furniture manufacturing equipment of Huali Furniture Plant were imported from Germany. Because of poor management, Huali Furniture Plant has lent it to the merchants of US, Malaysia and Taiwan Province of China. They manufactured mainly board-type and concretion furniture. Their main products include side tables, shelves etc., which are exported to the US, and sold to Taiwan Province of China etc. Besides these there are several joint venture or private rubberwood furniture plants, whose products are mainly sold to Hainan Province and Zhujiang Delta.

### 6.2 Rubberwood based panels

The annual output of rubberwood plywood in China reached 23 100 $m^3$ in 1994, but the annual output decreased as low as 4 500 $m^3$ in 1997 due to little market. There are 10 plywood plants in Hainan. Plywood is mainly used for concrete form in Hainan.

The rubberwood plywood equipment in China is mainly Chinese-built. For example, the Xiqing Farm adopted the plywood processing line made by the Xinyang Wood Machinery Factory, Henan Province. While in Jinghong Wood Plant in Yunnan Province, the veneer lathe was imported from Italy, hot press from Japan. The plywood products are mainly sold to Guangdong, Hainan and the southwestern areas in China. Concrete form, main product of plywood, has little market share and some of the plywood plants in Hainan Province have been closed.

### 6.2.2 Particleboard

Make particleboard from the branch, slab and wood residue is an effective way to make full use of rubberwood. Sanya Wood Plant is the only plant for making rubberwood particleboard with a yearly output of 27 000 ~ 28 000 $m^3$, the processing line was introduced from Germany. The products are mainly sold to Zhujiang Delta of Guangdong Province for making high-class sonic box and then the final products are exported to Republic of Korea, and sold to Taiwan Province of China etc.

At present, there are some problems in producing particleboard. For example, the resin in the bark is seriously harmful to the knives. As there is resin in the bark, after the bark is chipped into wood flakes, its swelling rate is hard to control. But if it's stacked for a certain period of time, the resin can be reduced, on the other hand, the color of the particleboard becomes darker, which affects the quality of the products. 2 MDF lines of yearly output 30 000 $m^3$ and 80 000~100 000 $m^3$ respectively in Hainan and Yunnan Province will be set up since there is no rubberwood MDF plant in China.

## 6.3 Molded products

Molded products are made from wood chips and wood waste. Xilian Wood Plant possesses a line of 3 000 $m^3$ of molded particleboard per year, whose equipment is domestic. The products are mainly tables, chairs, etc. Besides, the Zhanjiang Molded Wood Product Plant in Guangdong Province has also used molded particle board to produce tables, chairs, etc, which are mainly for domestic market.

## 6.4 Other products

Other products made by rubberwood are finger-joint panel, blockboard, decorative board, high-class handicrafts etc. Since the diameter of rubberwood is small, it can be used to make finger -joint board to extend its usage. The Xilian Wood Plant has a yearly capacity of 3 000

$m^3$ of finger-joint panel line and 3 000 $m^3$ blockboard line.

Sanya Wood Plant is starting to produce high-class anti-electrostatic parquet with a yearly capacity of 1.5 million $m^2$. The actual production is only 10 000～20 000 $m^2$ yearly due to shortage of raw material. Jinghong Farm produces high-class parquet with a yearly capacity of 100 000 $m^2$, whose equipment was imported from Germany.

## 7 Suggestions

### 7.1 The use of environmental friendly preservative

Sodium pentachlorophenol is generally not acceptable internationally due to its high toxicity. It also contributes to the severe corrosion of the drying kiln components. Further research should therefore include elements to adapt and promote the use of environmental friendly preservatives (such as borax/boric acid) for treating rubberwood under the local conditions.

### 7.2 Improving management of processing procedure

Currently the typical processing time between felling of the trees to charging of sawn timber into drying kiln can be as long as 10 days or more. This is one of the reasons often quoted that necessitates the use of preservative of higher toxicity such as sodium pentachlorophenol. A careful study of the chain of processes and devising means to shorten the intervals between the processes will help to alleviate dependency on sodium pentachlorophenol and other associated problems.

### 7.3 Developing value-adding rubberwood products

A number of treatments of fire retardant of wood-based panel products had been developed in China. These treatments, if adopted and adapted for rubberwood veneer and thin plywood, would enable these products to be accepted as interior decorative panels, door skins, as well as material for cabinet and other joiner items, further enhance the marketability of these products. Development of fire retardant of wood-based panel will benefit other ITTO members.

### 7.4 Training courses

Many of the problems faced by the rubberwood processing industry in China at present can be traced to a general lack of understanding of the proper procedures among the workers and the supervisory staff. Guidelines on the proper techniques in sawing, preservative treatment, seasoning and machining as well as quality control measures should be drawn up. Requirements of national standards governing some of the products should also be included as codes of good practices. These guidelines can be published in the forms of booklets or pamphlets for dissemination. Regular training courses should be held for both the workers and the supervifrom countries that are much advanced in rubberwood processing, assisted by local experts, can enhance the effectiveness of these training courses.

### 7.5 Technology transfer and workshops

Rubberwood processing technology is already quite advanced in some South East Asian countries, such as Malaysia and Singapore. The further project should consider offering opportunities for scientists and industry people to visit research organizations and rubberwood processing plants in these countries. Likewise, means should be provided to encourage scientists, as well as industrialists, to attend international or regional seminars, workshops or trade fairs. All these can enhance their knowledge and expedite the digestion and adaptation of appropriate technology to upgrade the competitiveness of the industry in China.

Further work on above topic will improve processing technology in China and will also benefit other rubberwood producing countries.

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# RESEARCH REPORT ON INVESTIGATION OF FUNGAL INFECTION IN RUBBERWOOD PRODUCTION AREA IN CHINA

**Abstract** An investigation about fungal infection in rubberwood production area in China has been carried. Forty-four species of fungus samples have been identified in the research work. Among them eighteen wood decay fungi, four wood mold fungi and two wood stain fungi have been reported to be firstly found in Chinese rubber-wood and its products. The physiological-biochemical characteristics of these identified species have also been given.
**Keywords** Rubberwood; Fungal infection; Investigation

## 1 The aim and significance

Rubberwood is susceptible to fungal infection. There are three fungal infection diseases of rubberwood, i. e. decay, stain and mold. They are usually the main reason of producing inferior rubberwood products in wood processing factories. In the three types of the fungus infections, rubberwood stain fungus infection is the most serious factor for reducing economic benefits of the rubberwood processing plants and its products.

The aim of rubberwood fungus infection investigation is fully understanding the current situation of fungal infection in rubberwood production area in China, the infection happening and developing mechanism by investigating the fungal distribution in the area and identifying the fungal species and their physiological-biochemical characteristics. These data will provide important scientific bases for the research work of preservative treatment technologies of rubber wood and its products.

Southeast Asian countries have fully studied in the fungal infection of rubberwood. Some countries, such as Malaysia, India, Indonesia and Sri Lanka have offered thorough investigation reports on the fungal species and infection of rubberwood in those areas. In China, some investigations about rubberwood fungus species and rubberwood fungal infection have been carried. There are some research reports published, but the thorough investigation report including whole area of rubberwood production in China is lack. In the study and developing work on screening new rubberwood preservative agents with high efficiency and low poison, the research work of fungal infection, its happening mechanism, as well as identification of those fungal species and their physiological-biochemical characteristics have been a very important part.

## 2 Contents and fields

### 2.1 Working contents

——Literature collection and reorganization of rubberwood infection and preservative treatment technologies, offering and being to publish a review report "Current situation of study on rubberwood fungal infection and its prevention and control technology in the world";

——Collection of fungal samples and identification of the fungal specimens, finishing a research report;

——Interior poison test of agent for rubberwood temporary storage technology, finishing a testing report. The species of fungi used in the test are that from the investigation.

## 2.2 Investigation fields

Fields of the surveys include enterprises and farms of rubberwood production in Yunnan and Hainan provinces, belonged to private ownership, collective ownership and the ownership by whole people, which are subordinated to agricultural reclamation system, forestry system and locality system respectively. The fungal samples are collected from the rubberwood storage yards in rubber tree planting farms, workshops and storage of half-products or end products in rubberwood processing plants. The rubberwood materials, which the fungal specimens are picked, include fresh logs, treated logs for short time keeping and decay logs. Some samples are collected from sawed lumber and half-products and end products of rubberwood.

The fungus specimens are classified three types: wood decay fungi, wood stain fungi and wood mold fungi. Twenty-eight species of wood decay fungi, thirteen species of wood mold fungi and three species of wood stain fungi have been identified.

# 3 Results and Discusses

## 3.1 Rubber wood decay fungi

Rubber wood decay fungi destroys cell wall structure of rubberwood by decomposing the three main cell wall components cellulose, hemi-cellulose and lignin. The wood which is corroded by the fungi fully or partly loses its physico-mechanical properties.

As containing rich starches and other nutrition, rubberwood is susceptible to decay fungus infection. Especially under higher temperature and moisture content conditions the logs decay more quickly. Usually the decay happens on logs which are not treated on time or stacked unsuitably.

In the work, twenty-eight species of rubberwood decay fungi have been identified. The results have shown in Table 1.

Among them, There are seventeen specimens picked from Hainan province, eleven specimens from Yunnan province. Five species of decay fungi are firstly found in Hainan province. They are Favolus mollis Lloyd, Trametes dickinsii Berk., Trametes insularis Murr., Trametes senalis Fr.,. and Tyromyles pubescens (Schum:Fr.) Imaz. The species of Trametes confragosa Lloyd. is found first in Yunnan Province.

**Table 1 Identified rubber wood decay fungi**

| No. of samples | Name of fungus species | Location of samples picked |
|---|---|---|
| 1 | *Tremetes palisotii* (Fr.) Imaz. | Jinghong Wood Plant, Yunnan Province |
| 2 | *Inonotus sinensis* (Lloyd) Teng | Cangjing Wood Plant, Yunnan Province |
| 3 | *Tremetes insularis* Murr. | Cangjing Wood Plant , Yunnan Province |
| 5 | *Lezites acuta* Berk. | Cangjing Wood Plant , Yunnan Province |
| 6,29 | *Schizophyllum commune* Fr. | Dongfeng W. P. Yunnan Province, and Danzhou W. P. Hainan Province |
| 7 | *Trametes marilaensis* (Lloyd) Teng | Danzhou Wood Plant Hainan Province |
| 10 | *Tyromyces sambuceus* (Lloyd) Imaz. | Dongfeng Wood Plant. Yunnan Province |
| 11 | *Favolus mollis* Lloyd | Xilian wood Plant, Hainan Province |
| 12 | *Lenzites acuta* Berk. | Cangjing Wood Plant , Yunnan Province |
| 13,15 | *Trametes meyenii* (Kl.) Bose | Xilian and Zhanzhou W. P. Hainan. Province |
| 14 | *Microporus flabelliformis* | Xilian wood Plant, Hainan Province |
| 16 | *Trametes dickinsii* Berk. | Xilian Wood Plat, Hainan. Province |
| 19,20 | *Trametes Corrugata* (Pers.) Bres | Xilian and Zhanzhou W. Plants Hainan. Province |
| 17,28 | *Rigidoporus microporus* (Fr.) Overh. | Xilian, Hainan Province and Jinghong, Yunnan Province |
| 8,18 | *Trametes insularis* Murr. | Dongfeng, Yunnan Province, Zhanzhou Hainan Province |
| 21 | *Panus rudis* Fr. | Danzhou Rub. Wood Process. Plant Hainan Province |
| 22 | *Trametes senalis* Fr. | Danzhou Rub. Wood Process. Plant Hainan Province |
| 23 | *Daedalea heteromorpha* Fr. | Danzhou Rub. Wood Process. Plant Hainan Province |
| 24 | *Tyromyles pubescens* (Schum:Fr.) Imaz. | Danzhou Rub. Wood Process. Plant Hainan Province |
| 25 | *Trametes confragosa* Lloyd | Cangjing Wood Plant , Yunnan Province |
| 26 | *Auricularia polytricha* (Mont.) Sacc. | Xilian Wood Plant, Hainan. Province |
| 27 | *Inonotus sinensis* (Lloyd) Teng. | Xilian Wood Plant, Hainan. Province |
| 32 | *Trametes cinnabarina* var. *Sanguines* (L.:Fr.) Pilat. | Cangjing Wood Plant , Yunnan Province |

## 3.2 Rubberwood mold fungi

Mold fungi grow very fast on the rubberwood. The infection usually happens on surfaces of rubberwood, especially the surfaces of rubberwood products. It is one of the main reason which rubberwood products reduce their quality grade.

In the investigation, thirteen mold fungus species have been identified (see Table 2).

*hamella echinulata* Thaxter. Two species, *Trichoderma koningi* Oudem and *Trichoderma viride* Pers. Ex Fr. have not been reported in rubberwood, although they have been found in other tree species.

**Table 2 Identified Rubber Wood Mold Fungi**

| No. of samples | Name of fungus species | Location of samples picked |
|---|---|---|
| 9740 | *Penicillium decumbens* | Decayed log, Yunnan Province |
| 9741 | *Aspergillus fumigatus* | Sawed lumber, Danzhou, Hainan Province |
| 9742 | *Trichoderma koningi* Oudem. | Sawed lumber, Jinghong, Yunnan Province |
| 9743 | *Trichoderma koningi* Oudem. | Products, Jinghoong, Yunnan province |
| 9744 | *Aspergillus flavus* | Log, Jinghong, Yunnan Province |
| 9745 | *Aspergillus terreus* | Sawed lumber, Danzhou, Hainan Province |
| 9746 | *Cunninghamella echinulata* Thaxter | Log, Dongfang, Hainan Province |
| 9748 | *Aspergillus niger* v. Tiegh. | Log, Jnghong, Yunnan Province |
| 9749 | *Aspergillus niger* v. Tiegh. | Log, Danzhou, Hainan Province |
| 9750 | *Aspergillus niger* v. Tiegh. | Sawed lumber, Sanya, Hainan Province |
| 9751-2 | Mycelia sterilia | Log, Danzhou, Hainan Province |
| 9754 | *Trichoderma viride* Pers. Ex Fr. | Sawed lumber, Danzhou, Hainan Province |
| 9755 | Ramigena | Sawed lumber, Xilian, Hainan Province |

### 3.3 Rubberwood stain fungi

There are several wood stain fungi, which can cause different color changes of rubberwood such as brown stain, red stain, blue stain etc. The stain infection, as can penetrate into wood, is one the most serious disease of rubberwood products. Some rubberwood products can not be observed stain infection from the surfaces, but internal structure of the wood product has been stained by the fungi, thereby causing economic loss.

In the research, three rubber wood stain fungi have been identified (see Table3).

**Table 3 Identified rubberwood stain fungi**

| No. of samples | Name of fungus samples | Location of samples picked |
|---|---|---|
| 9751-1 | *Botrvodiplodia theobromae* Pat. | Sawed lumber, Danzhou, Hainan Provnice |
| 9752 | *Fusarium solani* (Mart) App. | Log, Jinghong, Yunnan Province |
| 9753 | *Bispora Carda* | Sawed lumber, Danzhou, Hainan Prov. |

The species of *Fusarium solani* and *Bispora carda* are reported first to be found in Chinese rubberwood.

## 4 Conclusion

**4.1** The investigation of rubberwood fungal infection is very important research work. It has supplied scientific data bases for preservative treatment technology research of rubber wood.

**4.2** In the research work, forty-four fungus sample species have been identified, including twenty-eight wood decay fungi, thirteen wood mold fungi and three wood stain fungi. Among them, six wood decay fungus species are reported first to be found in Hainan and Yunnan Provinces. Eighteen wood decay fungi species, four wood mold fungi and two wood stain fungi to be found in Chinese rubberwood. All of the identified fungus species have been offered the physiological-biochemical characteristics.

**4.3** The work aimed at the relationship of the physiological-biochemical properties of new species with the susceptibility to treatment agent should be carried for the further research work of rubberwood preservation.

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# REPORT ON THE RUBBERWOOD BIODETERIORATION CAUSED BY INSECTS IN CHINA

Rubberwood is a kind of light-coloured hardwood and is very susceptible to attack by a wide variety of insects and fungi, this is most likely because it contains relatively high starch, which is very attractive to these organisms, and low phenolic compounds which are reversely inhibitory to these organisms. It was reported that the timber of rubberwood appeared to be even less durable than bamboo (Martawidjaja 1971) or oil palm (*Elaeis guineensis*) stems (Wong & Koh 1991). Rubberwood must be therefore properly treated to prevent deterioration of wood that would result in much wastage of useful material and financial loss. According to ITTO project "Development and Extension of Rubberwood Processing and Utilisation Technology (PD3/96 Rev 2(I))", surveys of the existing state of rubberwood biodeterioration caused by insects have been made in Hainan Province and Xishuangbanna, Yunnan Province, those are the two major areas of rubber tree and rubberwood processing industry in China. Some of the classified insects that attack rubberwood in China are listed in Table 1.

**Table 1 Some biodeteriorating insects of rubberwood in China**

| Biodeteriorating insects | Attacked objects | Appearance of defects |
|---|---|---|
| *Xyleborus aquilus* Blandford<br>*Crossotarsus* sp.<br>*Platypus calamus* Blandford<br>*Platypus solidus* Schedl<br>*Platypus secretus* Sampson<br>*Platypus caliculus* Chapuis | freshly or partially seasoned logs or timbers | black bore-holes and tunnels, holes of 1mm (pin holes) or 3mm (shot holes) in diameter, shot fibriform dust |
| *Dinoderus minutus* Fabricus<br>*Sinoxylon anale* Lesne<br>*Heterobostrychus aequalis* Waterhouse<br>*Xylopsocus capucinus* Fabricius<br>*Xylothrips flavipes* Illiger<br>*Xylothrips* sp.<br>*Minthea rugicollis* Walker<br>*Lyctus brunneus* Stephens<br>*Lyctus africanus* Lesne | seasoned timbers or finished woodworks | circular holes of 1mm to 4mm in diameter, network of tunnels internally, heaps of fine powdery dust around the area of infestation, the most damage of rubberwood and its products |
| *Neotermes brachynotus* Xu et Han<br>*Coptotermes (o.) obliquus* Xia et He<br>*Coptotermes cochlearus* Xia et He<br>*Odontotermes hainanensis* Light<br>*Odontotermes conignathus* Xia et Fan<br>*Odontotermes sellathorax* Xia et Fan<br>*Macrotermes barneyi* Light<br>*Macrotermes longiceps* Li et Ping<br>*Microcerotermes remotus* Ping et Xu<br>*Cryptotermes* spp. | groundline or in-ground wood | often a distinct erosion of the wood surface about the groundline region |

(to be continned)

| | | |
|---|---|---|
| *Stromatium longicorne* Newman | wood or woody materials laid aside long, as feed or habitat of the pests | relatively bigger holes or tunnels, coarse particles of bore-dust |
| *Xystrocera globsa* Oliv. | | |
| *Merarius* sp. | | |
| *Eucorynus crassicornis* Fabricius | | |
| *Nigidius himalavae* Gravery | | |
| Colasposoma dauricum auripenne Motschulsky | | |
| *Ceropria subocellata* Cast | | |
| *Tribolium castaneum* Herbst | | |
| *Tribolium* sp. | | |
| *Gonocephalum* sp. | | |
| *Acicnemis* sp. | | |

Notes: *Acicnemis* sp. is a new record in China(see Figure 6).

As the above table show, the insects which attack rubberwood consist of types of beetle borers, termites and some other Coleopteran species, such as longicorns and snout beetles etc. Termites are very susceptible to groundline or in-ground rubberwood, the pattern of attack often shows a distinct erosion of wood surfacea bout the groundline region and to a lesser degree elsewhere along the surface. *Coptotermes formosanus* Shiraki, a widely distributed termite in the South of China is not discovered to attack rubberwood till now. The Coleopteran insect pests attacking rubberwood usually infest decayed rubberwood logs. It has been noticed that often the logs serve as their food, but sometimes just as their habitat.

The beetle borers which belong to ambrosia beetles and powder-post beetles are the most important among the types of insects which attack rubberwood in China. The ambrosia beetles are members of the families Platypodidae and Scolytidae while the powder-post beetles are mainly from the families Lyctidae and Bostrychidae.

Ambrosia beetles usually attack the fresh logs and the freshly sawn timber of rubberwood. Quite often the attack on rubberwood logs occurs at the exposed surfaces, e.g., the cut ends and the sites where the bark have been chipped off. The adult beetles bore into the wood, bringing along with them fungi that grow on the tunnel walls and serve as food for the borer's young larvae. The holes made by these borers are stained black due to the fungal development and are referred to as pin holes (about 1mm diameter) or shot holes (about 3mm diameter). As the ambrosia beetles can only live in moist wood, the moisture content of wood must be above 48% *R.H.*, rapid drying after the log cutting down is an adopted method to avoid their further infestation.

Powder-post beetles from the families Bostrychidae and Lyctidae do the most damage to rubberwood and rubberwood products(see Figure 5). The adult beetle generally lay their eggs in cracks and pores of the rubberwood, but often they tunnel into the wood to lay eggs. When the egg hatches into larva after about 1 week of oviposition, the larva thrives on starch by making tunnels in the timber, the larval tunnels, long and irregular, are generally full of bore dust which is the excreta of the larva. After a few months (dependent on the species), the larva finally changes into a pupa and then an adult. When the adult leave the timber, it will tunnel to the wood surface and make a visible exit hole. In an extensive infestation, the entire timber is completely eroded into dust and is supported only by a thin outer shell. The powder-post beetles attacking rubberwood prefer seasoned and partially seasoned timbers.

As in Malaysia, *Heterobostrychus aequalis* is the most common and destructive Bostrichid powder-post beetle of rubberwood in China. It is widely distributed in Hainan and Xishuangbanna areas. According to reports, *H. aequalis* breeds in a wide variety of commercial timbers and its attack is usually focused on the sapwood that is rich in starch and other nutrients (see Figure 3). *H. aequalis* is brownish black and about 6～10 mm in length, its antenna is a 3 segmented-clubbed, and the club is above 1/2 in the whole antenna length(see Figure 1). The pronotum is densely punctuated with coarse asperities, while the elytra are strongly punctures and without hair. The elytra are declined with a thick lateral ridge. The male has two elongated tubercles on the upper margin, the inner one is strongly hooked. Females only have traces of tubercles.

*H.aequalis* can finish 2～3 life cycles in a year in Hainan area. The overwintering larva normally goes into emergence in the period of 20th. March to the end of April, while the first and second generation of this year emerges respectively in the period of 20th. June to 10th. July and in the first 20 days of October. The newly-emerged adult is light brown and it remains feeding on the wood which is, as a supplementary nutrient, of importance to its reproduction.

The technological research on protective treatment for rubberwood may ascend to the middle of 1970's in China. As here exists a severe shortage of wood resources in China, the rubberwood processing industry has played an increasingly important part in the country's wood industry in the past 20 years. It is the current practice of most Chinese sawmillers dealing with rubberwood to preserve timbers with a mixture of boric acid, borax and sodium pentachlorophenol (BBP) and dry them through the conventional kiln dry procedure. Here the three components of the mixture are all the domestic products.

The surveys conducted during the project have revealed that there are no distinct differences in insect species that attack rubberwood between Hainan and Xishuangbanna, although the insect infestation on rubberwood is relatively serious in Hainan. Hainan, especially the South of it, is the most suitable area for rubber tree plantation in China, its annually average temperature is above 24℃ and rainfall is 1000～2140 mm, while Xishuangbanna is only 21.9℃ and 1200～1500 mm, this may be one of the reasons why the rubberwood biodegradation in Hainan is more heavy and more extensive than in Xishuangbanna.

*Platypus caliculus* Chapuis(see Figure 2), an ambrosia beetle, is discovered to be the main pest both in Hainan and Xishuangbanna areas, if any insect attack on rubberwood after the treatment with BBP(see Figure 4).

(Figure 1～6 in inside back cover)

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# STUDY ON ANTISTAIN AND ANTIMOLD FORMULATIONS FOR RUBBERWOOD LOG AND TIMBER

There are 3 relevant reports in this paper:

I. Laboratory evaluation of chrolothalonil formulations for stain and mold control on rubberwood and maple

II. Pilot test of rubberwood temporary preservation technology

III. Technical report on vacuum pressure treatment of rubberwood timber with f1/f2 and boron compounds

# I. LABORATORY EVALUATION OF CHROLOTHALONIL FORMULATIONS FOR STAIN AND MOLD CONTROL ON RUBBERWOOD AND MAPLE[1]

**Abstract** We evaluated the efficacy of several chlorothalonil fungicides (F1 and F2), Tuffbrite C, Tuffbrite 404, NeXgen etc. in the control of mold and stain fungi on rubberwood and maple. The results showed that these formulations effectively inhibited the selected fungal species such as Aspergillus niger, Penicillium sp., Trichoderma sp. (P71H), Aureobasidium pullulans, Ceratocystis minor(C-188), Ceratocystis pilifera (RWD 9472), Botryodiplodia theobromae in laboratory tests.

## 1 Introduction

Chlorothalonil is a common fungicide which has been used in many agricultural crops for preventing diseases and it also has been used for controlling certain spectra of wood stain fungi[1~14]. The most important advantage of chlorothalonil is that it is highly effectively on most fungal species and environmentally friendly if it is properly merged with other fungicides. Some potential commercial formulations containing chlorothalonil for controlling wood stain and mold fungi have been developed in recent years, such as Tuffbrite C (a. i. chlorothalonil and carbendazim), Tuffbrite 404 (a. i. chlorothalonil and copper oxine), NeXgen (a.i. 14.5% chlorothalonil and 14.7% MBT)[11]. Recently Tuffbrite C has been registered in New Zealand.

Chlorothalonil is commercially available in China and it is a potential alternative preservative to sodium pentachlorophenol, which is strictly restricted or prohibited in some countries but is currently used widely in China, for controlling wood stain and mold. The purpose of this

[1] This work was supported by the Fellowship Program of International Tropical Timber Organization and was accomplished at USDA Forest Service, Forest Products Laboratory, Madison, WI 53705-2398, USA

mold on rubberwood and maple, which are common tree species in southern China and North America, respectively.

## 2 Material and method

### 2.1 Wood sample and fungi

Wood sample size: rubberwood 50 mm×20 mm×1 mm; maple 40 mm×20 mm×3 mm.
Fungal species: *Aspergillus niger*, *Penicillium* sp., *Trichoderma* sp. (P71H), *Aureobasidium pullulans*, *Ceratocystis minor* (C-188), *Ceratocystis pilifera* (RWD 9472), Botryodiplodia theobromae.

### 2.2 Exposure to fungi

Samples were incubated with the above fungal species after dipping the samples in the solutions for 15 seconds according to ASTM D-4445-91. Four replications of wood species were used.

### 2.3 Chemicals

F1, F2: chlorothalonil fungicides.
Tuffbrite C, Tuffbrite 404 and NeXgen were provided by ISK Biosciences Co..
Tuffbrite C: One-liter liquid formulations containing 450 g chlorothalonil and 100 g carbendazim.
Tuffbrite 404: chlorothalonil and copper oxine.
NeXgen: liquid containing 14.5% chlorothalonil and 14.7% MBT.

### 2.4 Ranking standard

According to ranking standard of USDA Forest Service, Forest Products Laboratory.
1 - Clean: stain or mold covering less than 5% upper surface.
2 - Light stain: stain or mold covering 5%~20% upper surface.
3 - Moderate stain: stain or mold covering 20%~40 % upper surface.
4 - Heavy stain: stain or mold covering more than 40% upper surface.

## 3 Results and discussion

### 3.1 Laboratory evaluation of chrolothalonil formulation for stain and mold control on rubberwood

**Table 1 Comparison of the effectiveness of anti-mold treatments against *Aspergillus niger* on rubberwood**

| Treatment | Average |
|---|---|
| untreated control | 4.0±0.0 |
| 0.5% NaPCP | 1.0±0.0 |
| 1.0% NaPCP | 1.0±0.0 |
| 0.05%F1 + 0.1% F2 | 1.50±0.50 |
| 0.05%F1 + 0.2% F2 | 1.0±0.0 |
| 0.1%F1 + 0.05% F2 | 1.0±0.0 |
| 0.1%F1 + 0.1% F2 | 1.0±0.0 |
| 0.1%F1 + 0.2% F2 | 1.0±0.0 |
| 0.2%F1 + 0.1% F2 | 1.0±0.0 |
| 0.5% Tuffbrite C | 1.0±0.0 |
| 1% Tuffbrite C | 1.0±0.0 |
| 2% Tuffbrite C | 1.0±0.0 |
| 1% Tuffbrite 404 | 1.0±0.0 |
| 2% Tuffbrite 404 | 1.0±0.0 |
| 1% NeXgen | 1.0±0.0 |
| 2% NeXgen | 1.0±0.0 |

**Table 2 Comparison of the Effectiveness of anti-mold treatments against *Penicillium* Sp. on rubberwood**

| Treatment | Average |
|---|---|
| untreated control | 4.0±0.0 |
| 0.5% NaPCP | 1.75±0.43 |
| 1.0% NaPCP | 1.0±0.0 |
| 0.05%F1 + 0.1% F2 | 1.0±0.0 |
| 0.05%F1 + 0.2% F2 | 1.0±0.0 |
| 0.1%F1 + 0.05% F2 | 1.0±0.0 |
| 0.1%F1 + 0.1% F2 | 1.0±0.0 |
| 0.1%F1 + 0.2% F2 | 1.0±0.0 |
| 0.2%F1 + 0.1% F2 | 1.0±0.0 |
| 0.5% Tuffbrite C | 1.0±0.0 |
| 1% Tuffbrite C | 1.0±0.0 |
| 2% Tuffbrite C | 1.0±0.0 |
| 1% Tuffbrite 404 | 1.0±0.0 |
| 2% Tuffbrite 404 | 1.0±0.0 |
| 1% NeXgen | 1.25±0.43 |
| 2% NeXgen | 1.0±0.0 |

**Table 3 Comparison of the effectiveness of anti-mold treatments against *Trichoderma* sp.(P71H) on rubberwood**

| Treatment | Average |
|---|---|
| Untreated Control | 4.0±0.0 |
| 0.5% NaPCP | 1.0±0.0 |
| 1.0% NaPCP | 1.0±0.0 |
| 0.05%F1 + 0.1% F2 | 1.0±0.0 |
| 0.05%F1 + 0.2% F2 | 1.0±0.0 |
| 0.1%F1 + 0.05% F2 | 1.0±0.0 |
| 0.1%F1 + 0.1% F2 | 1.0±0.0 |
| 0.1%F1 + 0.2% F2 | 1.0±0.0 |
| 0.2%F1 + 0.1% F2 | 1.0±0.0 |
| 0.5% Tuffbrite C | 1.0±0.0 |
| 1% Tuffbrite C | 1.0±0.0 |
| 2% Tuffbrite C | 1.0±0.0 |
| 1% Tuffbrite 404 | 1.0±0.0 |
| 2% Tuffbrite 404 | 1.0±0.0 |
| 1% NeXgen | 1.0±0.0 |
| 2% NeXgen | 1.0±0.0 |

| Treatment | Average |
|---|---|
| untreated control 4.0±0.0 | |
| 0.5% NaPCP | 1.0±0.0 |
| 1.0% NaPCP | 1.0±0.0 |
| 0.05%F1 + 0.1% F2 | 1.0±0.0 |
| 0.05%F1 + 0.2% F2 | 1.0±0.0 |
| 0.1%F1 + 0.05% F2 | 1.0±0.0 |
| 0.1%F1 + 0.1% F2 | 1.25± 0.43 |
| 0.1%F1 + 0.2% F2 | 1.0±0.0 |
| 0.2%F1 + 0.1% F2 | 1.0±0.0 |
| 0.5% Tuffbrite C | 1.0±0.0 |
| 1% Tuffbrite C | 1.0±0.0 |
| 2% Tuffbrite C | 1.0±0.0 |
| 1% Tuffbrite 404 | 1.0±0.0 |
| 2% Tuffbrite 404 | 1.0±0.0 |
| 1% NeXgen | 1.0±0.0 |
| 2% NeXgen | 1.0±0.0 |

**Table 5 Comparison of the effectiveness of anti-sapstain treatments against *Ceratocystis minor* (C-188) on rubberwood**

| Treatment | Average |
|---|---|
| untreated control | 2.50± 0.50 |
| 0.5% NaPCP | 1.0±0.0 |
| 1.0% NaPCP | 1.0±0.0 |
| 0.05%F1 + 0.1% F2 | 1.50±0.50 |
| 0.05%F1 + 0.2% F2 | 1.75±0.43 |
| 0.1%F1 + 0.05% F2 | 1.0±0.0 |
| 0.1%F1 + 0.1% F2 | 1.75±0.43 |
| 0.1%F1 + 0.2% F2 | 1.0±0.0 |
| 0.2%F1 + 0.1% F2 | 1.0±0.0 |
| 0.5% Tuffbrite C | 1.0±0.0 |
| 1% Tuffbrite C | 1.0±0.0 |
| 2% Tuffbrite C | 1.0±0.0 |
| 1% Tuffbrite 404 | 1.0±0.0 |
| 2% Tuffbrite 404 | 1.0±0.0 |
| 1% NeXgen | 1.0±0.0 |
| 2% NeXgen | 1.0±0.0 |

**Table 6 Comparison of the effectiveness of anti-sapstain treatments against *Botryodiplodia theobromae* on rubberwood**

| Treatment | Average |
|---|---|
| untreated control | 4.0± 0.0 |
| 0.25% NaPCP | 4.0±0.0 |
| 0.5% NaPCP | 3.0±0.0 |
| 1% NaPCP | 3.0±0.0 |
| 0.25% F1(E) | 4.0±0.0 |
| 0.5% F1(E) | 4.0±0.0 |
| 1.0% F1(E) | 4.0±0.0 |
| 0.5% F1(F) | 4.0±0.0 |
| 1.0% F1(F) | 3.0±0.0 |
| 0.20% F2 | 2.0±0.0 |
| 0.40% F2 | 1.0±0.0 |
| 0.5% F1(E) + 0.10% F2 | 1.0±0.0 |
| 0.5% F1(E) + 0.20% F2 | 1.0±0.0 |
| 0.5% F1(F) + 0.05% F2 | 1.0±0.0 |
| 0.5% F1(F) + 0.10% F2 | 1.0±0.0 |
| 0.5% F1(F) + 0.20% F2 | 1.0±0.0 |

### 3.2 Laboratory evaluation of Tuffbrite c, Tuffbrite 404 and NeXgen for stain and mold control on maple

**Table 7 Comparison of the effectiveness of anti-mold treatments against *Aspergillus niger* on maple**

| Treatment | Average |
|---|---|
| untreated control | 4.0±0.0 |
| 0.5% Tuffbrite C | 3.0±0.0 |
| 1% Tuffbrite C | 1.0±0.0 |
| 1% Tuffbrite 404 | 1.0±0.0 |
| 2% Tuffbrite 404 | 1.0±0.0 |
| 1% NeXgen | 1.0±0.0 |
| 2% NeXgen | 1.0±0.0 |

**Table 8 Comparison of the effectiveness of anti-mold treatments against *Penicillium* sp. on maple**

| Treatment | Average |
|---|---|
| untreated control | 4.0±0.0 |
| 0.5% Tuffbrite C | 1.0±0.0 |
| 1% Tuffbrite C | 1.0±0.0 |
| 1% Tuffbrite 404 | 1.0±0.0 |
| 2% Tuffbrite 404 | 1.0±0.0 |
| 1% NeXgen | 1.0±0.0 |
| 2% NeXgen | 1.0±0.0 |

**Table 9 Comparison of the effectiveness of anti-mold treatments against *Trichoderma* sp. (P71H) on maple**

| Treatment | Average |
|---|---|
| untreated control | 4.0±0.0 |
| 0.5% Tuffbrite C | 1.0±0.0 |
| 1% Tuffbrite C | 1.0±0.0 |
| 1% Tuffbrite 404 | 1.0±0.0 |
| 2% Tuffbrite 404 | 1.0±0.0 |
| 1% NeXgen | 1.0±0.0 |
| 2% NeXgen | 1.0±0.0 |

**Table 10 Comparison of the effectiveness of anti-sapstain treatments against *Aureobasidium pullulans* (MDX-18) on maple**

| Treatment | Average |
|---|---|
| untreated control | 4.0±0.0 |
| 0.5% Tuffbrite C | 1.0±0.0 |
| 1% Tuffbrite C | 1.0±0.0 |
| 1% Tuffbrite 404 | 1.0±0.0 |
| 2% Tuffbrite 404 | 1.0±0.0 |
| 1% NeXgen | 1.0±0.0 |
| 2% NeXgen | 1.0±0.0 |

| Treatment | Average |
|---|---|
| untreated control | 4.0±0.0 |
| 0.5% Tuffbrite C | 1.0±0.0 |
| 1% Tuffbrite C | 1.0±0.0 |
| 1% Tuffbrite 404 | 3.25±0.43 |
| 2% Tuffbrite 404 | 3.0±0.0 |
| 1% NeXgen | 1.0±0.0 |
| 2% NeXgen | 1.0±0.0 |

Laboratory test indicated that F1 and F2 mixture, Tuffbrite C, Tuffbrite 404, NeXgen inhibited mold and stain fungi very effectively on rubberwood (tables 1~6) although some low concentrations such as "0.05%F1 + 0.1% F2" and "0.05%F1 + 0.2% F2" against Ceratocystis minor(C-188) was not efficacy(Table 5). Botryodiplodia theobromae, a main blue stain fungi separated from rubberwood, was inhibited effectively by the mixture of 0.5%F1 and "0.05~0.20% F2", but was not by 0.25%~1.0%F1, 0.20% F2 and 0.5%, 1.0% NaPCP alone (Tables 6).

Tuffbrite C and Tuffbrite 404 as well as NeXgen inhibited mold and stain fungi very effectively on maple (tables 7~11), although some concentrations of Tuffbrite 404 inhibited mold inefficiently such as 1.0% and 2.0% on Ceratocystis pilifera (table 11) and 0.5% on *Aspergillus niger* (table 7), The higher concentrations might work very well.

The F1 and F2 mixture might be suggested for the following pilot test and the mixture might be alternative to sodium pentachlorophenol for stain and mold control in China wood industry.

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# II. PILOT TEST OF RUBBERWOOD TEMPORARY PRESERVATION TECHNOLOGY

Pilot test of rubberwood temporary preservation technology of chlorothalonil formulations has been studied briefly in this article based on the laboratory evaluation results.

## 1 Materials and method

Three kinds of rubberwood materials have be employed in this test.

### 1.1 Materials

#### 1.1.1 Disks

Fresh disks, diameter 5～20 cm, length 5 cm.

#### 1.1.2 Sawntimber

Fresh sawntimber 35 mm × 65 mm × 500 mm.

#### 1.1.3 Veneers

Dried sap veneer, 15 mm × 10 mm × 2 mm.

### 1.2 Fungicide formulations

| No. of fungicide | F1 | F2 | NaPCP |
|---|---|---|---|
| 1 | 0.50 | 0.10 | 0 |
| 2 | 0.50 | 0.15 | 0 |
| 3 | 0.25 | 0.10 | 0 |
| 4 | 0.25 | 0.15 | 0 |
| 5 | 0 | 0.20 | 0 |
| 6 | 0 | 0 | 0.50 |
| 7 | 0 | 0 | 0 |

### 1.3 Impregnating treatment

The treated disks for 1, 5 and 20 minutes marked the footnote 1, 2 and 3 respectively; The treatment of sawntimber for 5 and 15 minutes marked the footnote 1 and 2 respectively; The treated time of veneer is 1 minute.

### 1.4 Fungi species

Natural fungi species, test time: July 22 to August 10, 1997, temperature: 22℃ ~33℃, relative humidity: 70% ~92%.

## 2 Results

### 2.1 Disks

**Table 1 The areas of rubberwood disk treated with chlorothalonil formulations and NaPCP infected by natural fungi (%)**

| Treatment No | Treat time(day) | | | | | |
|---|---|---|---|---|---|---|
| | 3 | 6 | 9 | 12 | 15 | 18 |
| $1_1$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $1_2$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $1_3$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $2_1$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $2_2$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $2_3$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $3_1$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $3_2$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $3_3$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $4_1$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $4_2$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $4_3$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $5_1$ | 0 | 0 | 0 | 5 | 5 | 5 |
| $5_2$ | 0 | 0 | 0 | 3 | 3 | 3 |
| $5_3$ | 0 | 0 | 0 | 3 | 3 | 3 |

(to be continued)

continued from page 30

| Treatment No | Treat time(day) | | | | | |
|---|---|---|---|---|---|---|
| | 3 | 6 | 9 | 12 | 15 | 18 |
| $6_1$ | 0 | 0 | 0 | 3 | 3 | 3 |
| $6_2$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $6_3$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $7_1$ | 0 | 0 | 0 | 1 | 1 | 1 |
| $7_2$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $7_3$ | 0 | 0 | 0 | 0 | 0 | 0 |
| 8(CK) | 3 | 6 | 11 | 12 | 12 | 27 |

The mixture formulation F1/F2 is more effective than 0.2% F2 alone or 0.5% NaPCP in controlling mold and fungi. There is no difference among dipping time 1, 5 and 20 minutes. 1 minute is enough for this dipping treatment.

## 2.2 Sawntimber

**Table 2 The areas of rubberwood sawntimber treated with chlorothalonil formulations and NaPCP infected by natural fungi (%)**

| Treatment No | Treat time(day) | | | | | |
|---|---|---|---|---|---|---|
| | 3 | 6 | 9 | 12 | 15 | 18 |
| $1_1$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $1_2$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $2_1$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $2_2$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $3_1$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $3_2$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $4_1$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $4_2$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $5_1$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $5_2$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $6_1$ | 0 | 0 | 0 | 0 | 0 | 0.5 |
| $6_2$ | 0 | 0 | 0 | 0 | 0 | 0.5 |
| $7_1$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $7_2$ | 0 | 0 | 0 | 0 | 0 | 0 |
| 8(CK) | 15 | 80 | 100 | 100 | 100 | 100 |

Table 2 showed that the lower concentrations of formulations F1/ F2 were same or even more effective than NaPCP for controlling mold and fungi under 18 days.

## 2.3 Veneer

| Treatment No | Treat time(day) | | | | | |
|---|---|---|---|---|---|---|
| | 3 | 6 | 9 | 12 | 15 | 18 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 10 | 10 | 20 | 20 |
| 6 | 2 | 2 | 2 | 2 | 20 | 20 |
| 7 | 0 | 0 | 0 | 0 | 2 | 5 |
| 8(CK) | 2 | 50 | 100 | 100 | 100 | 100 |

Table 3 showed that the formulation F1/F2 were more effective than 0.5% NaPCP or 0.2% F2 alone for controlling mold and fungi.

### 3 Conclusions

The mixture formulation F1/F2 is more effective than 0.5% NaPCP or 0.2% F2 alone in controlling mold and fungi in this pilot test, This result is much similar to that of laboratory evaluation. The mixture formulation F1/F2 for temporary protection of log and sawntimber instead of sodium pentachlorophenol might be suggested for further test.

# III. TECHNICAL REPORT ON VACUUM PRESSURE TREATMENT OF RUBBERWOOD TIMBER WITH F1/F2 AND BORON COMPOUNDS

Vacuum pressure treatment of rubberwood sawntimber with F1/F2 and boron compounds had been conducted in Hainan based on the laboratory and pilot test of stain and mold control.

### 1 Materials and method

#### 1.1 Materials

Rubberwood sawntimber 3.5 cm×6.5 cm×50 cm

#### 1.2 Fungicide formulations

8 tone solutions of every formulation were prepared.

The active ingredients of formulations are described as follows (%):

**Table 1 The active ingredients of each vacuum pressure treatment formulations (%)**

| Formulations | Boric acid | Borax | F1 | F2 | NaPCP |
|---|---|---|---|---|---|
| 1 | 1.00 | 2.25 | 0 | 0 | 0 |
| 2 | 1.00 | 2.25 | 0 | 0.02 | 0 |
| 3 | 1.00 | 2.25 | 0.0094 | 0.018 | 0 |
| 4 | 1.00 | 2.25 | 0.0088 | 0.017 | 0.075 |

## 1.2 Treatment and survey method

Test site: Hainan Nanmiao Plywood Plant.
Test duration: Sep. 22 to Oct. 20, 1998.
Temperature: 20℃ ~33℃.

Vacuum pressure treatment: initiate vacuum −0.09 MPa for 30 min, 0.8 MPa pressure for 1 hour, final vacuum for 20 min. The treated timber was stacked and would be in drying kiln in 3 days. 10 sawntimbers of every treatment would be air drying for surveying fungal infections. Untreated timber was fresh timber. Three cubic meter of sawntimber would be treated in every treatment, the retention of every cubic meter timber was 160 kg solution.

# 2 Results

**Table 2 The infected surface area by fungi of timber treated with different formulations (%)**

| Formulations | Exposure days(days) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3 | 6 | 9 | 12 | 15 | 18 | 21 |
| 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2 | 0 | 0 | 0 | 0.05 | 0.05 | 0.10 | 0.10 |
| 3 | 0 | 0 | 0 | 0 | 0.02 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CK | 2 | 50 | 100 | 100 | 100 | 100 | 100 |

Two of 10 strip timber treated with formulation 1 (borax/boric acid) infected white mold and *Trichoderma* sp. after 12 days exposure. One of 10 strip timber treated with formulation 2 (borax/boric acid/F2) infected by a spot of white mold and *Trichoderma* sp. after 12day exposure, and another mold spot appeared after 15 days exposure. One of 10-strip timber treated with formulation 3 (borax/boric acid/F1/F2) infected by a spot of *Trichoderma* sp. after 15 days exposure, and this spot disappeared after 18 days. None of 10 strip treated timber with formulation 4 (borax/boric acid/F1/F2/NaPCP) after 21 days exposure. Some white mold appeared on the surface of the untreated timber after 3 day-exposure, heavy mold and stain appeared after 6 days exposure, and the timber almost completely infected with mold and stain after 9 days exposure (table 2).

This test indicated that F2 could prevent the treated timber for 12 days from stai[illegible] air drying procedure under the above concentrations. The higher concentration might keep the treated timber for longer time from stain and mold. The formulation of F1/F2 for temporary protection of log and timber instead of sodium pentachlorophenol might be suggested for industry use.

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# STUDY ON SHORT TERM PROTECTION OF RUBBERWOOD AGAINST SAPSTAIN AND MOULD INFECTION

## 1 Introduction

Rubberwood is very susceptible to sapstain and mould fungal attack. Hence, it must be properly treated to prevent deterioration of wood, which would result in much wastage of useful material and financial loss.

Air-drying has been using in China rubberwood industry, which can reduce both kiln drying time and drying cost of timber. However, boron preservatives do not prevent rubberwood from mould and/or sapstain fungal growth. Therefore, if the boron compounds treated rubberwood can not be dried in few days after treatment, short term protection (also called temporary treatment), such as dipping with anti-sapstain chemicals should be used. Temporary protection involves the momentary dipping of the timber into a preservative solution containing fungicide (sometime also containing insecticide). The preservatives are deposited only on the surfaces, and therefore it will be removed during further processing of the boards.

In the selection of temporary preservatives, not only the effectiveness of the chemical but also the safety of the chemical, both to the human being and to the environment, have to be considered. However, the chemical has been using in China rubberwood industry for more than 10 years was sodium pentachlorophenol (NaPCP). NaPCP contains dioxin which can cause a number of hazard: carcinogenic, ecotoxic, central nervous system damage, blood disorder, liver and kidney damage, stomach pain, vomiting, nausea, fever, eyes/skin/respiratory irritation. This is why NaPCP was banned a lot of countries, such as Sweden, Germany, Spain, Chile, Denmark, Switzerland, Italy, Greece, Indonesia, Malaysia, Japan, New Zealand, Australia and USA (restricted used). Therefore, to reach the quality level of rubberwood products internationally, it is necessary to replace NaPCP with environmental-friendly chemicals.

In order for developing appropriate technology to replace NaPCP, Antiblu 20EC was used in this study to evaluate the short term protection performance for rubberwood.

## 2 Materials and treatment

650 pieces of fresh sawn rubberwood sample with no stain, insect damage and bark were selected. The timber size was 50~100 cm long, 8 cm wide and 3 cm thick. The 650 timber samples were divided into 13 groups, 50 pieces of sample for each group.

One group (Group o) was no any treatment (no pressure treatment and no dipping treat-sure treatment. The 4 groups (Group e, f, g and h) were pressure treated with boric acid and borax at the ratio of 1:1 and at the concentration of 2.0% w/v for 60 minutes without vacuum period. The other 4 groups (Group i, j, k, l) were pressure treated with Parachem at the concentration of 1.5% w/v for 60 minutes without vacuum period. The details of pre-treatment of each group were listed in Table 1.

**Table 1 Treatment list for each group of rubberwood samples**

| Group | Pre-treatment(pressure treatment) | Dipping reatment |
|---|---|---|
| o | — | — |
| a | — | 1.0% v/v Antiblu 20EC |
| b | — | 1.5% v/v Antiblu 20EC |
| c | — | 2.0% v/v Antiblu 20EC |
| d | — | 1.5% v/v Antiblu 20EC<br>+ 0.125% v/v Antiborer 10EC |
| e | 2.0% w/v borax / boric acid | 1.0% v/v Antiblu 20EC |
| f | 2.0% w/v borax / boric acid | 1.5% v/v Antiblu 20EC |
| g | 2.0% w/v borax / boric acid | 2.0% v/v Antiblu 20EC |
| h | 2.0% w/v borax / boric acid | 1.5% v/v Antiblu 20EC<br>+0.125% v/v Antiborer 10EC |
| i | 1.5% w/v Parachem | 1.0% v/v Antiblu 20EC |
| j | 1.5% w/v Parachem | 1.5% v/v Antiblu 20EC |
| k | 1.5% w/v Parachem | 2.0% v/v Antiblu 20EC |
| l | 1.5% w/v Parachem | 1.5% v/v Antiblu 20EC<br>+ 0.125% v/v Antiborer 10EC |

Antiblu 20EC and Antiborer 10EC were in concentrated liquid form. Antiblu 20EC treatment solution was prepared by putting water (49 litres for 1%, 48.5 litres for 1.5%, and 48 litres for 2%) into the dip tank, then adding Antiblu 20EC (1 litre for 1%, 1.5 litres for 1.5%, and 2 litres for 2%) while stirring.

The dip treatment was carried out one day after the pressure treatment of boron chemicals. Each pieces of timber sample of the 14 groups (except of Group o) were individually immersed in 1.0%, 1.5% and 2.0% Antiblu solution, and 1.5% Antiblu + 0.125% Antiborer solution, respectively for at least 30 seconds. After dipping treatment, the treated samples were stacked with sticker and with space between each piece.

## 3 Inspection

The inspection was carried out at the 1st week, the 2nd week, the 4th week and the 12th week for sapstain and mould fungal growth for all of the trial timber boards. The infection area was measured for mould and blue stain at every surface except the 2 ends. The total area of the sample was measured by Length × Width × 2 + Length × Thickness × 2 + Width × Thickness × 2. And the infection ratio (in percentage) was calculated by:

$$\text{Infection ratio (\%)} = \frac{\text{infection area}}{\text{total surface area}} \times 100$$

The quantity of clean board was calculated by:

$$\text{Quantity of clean board(\%)} = \frac{\text{total number of boards} - \text{number of infected boards}}{\text{total number of boards}} \times 100$$

## 4 Results and discussion

### 4.1 Control

**Table 2 Infection ratio and number of clean board of control group**

| | 1st week | 2nd week | 4th week | 12th week |
|---|---|---|---|---|
| average infection ratio (%) | 47 | 54 | 65 | — |
| quantity ratio of clean board (%) | 0 | 0 | 0 | — |

The control group of rubberwood was no any pressure treatment and no any anti sapstain (dipping) treatment. Table 2 showed that the average infection ratio of the control was 45%, 55%, and 65% respectively at 1st, 2nd, and 4th week. The quantity ratio of clean board was 0%. This indicated that rubberwood without any treatment was very susceptible to mould and sapstain fungal attack. The trial samples of the control group were lost after 4 weeks storage.

### 4.2 Temporary protection of fresh sawn rubberwood

The fresh rubberwood samples used in the trial were no any pressure treatment with boron preservative, only dipping treated with Antiblu.

**Table 3 Infection ratio of fresh rubberwood sawn timber**

| Group | Dip chemical and concentration | Average infection ratio (%) | | | |
|---|---|---|---|---|---|
| | | 1st week | 2nd week | 4th week | 12th week |
| o | — | 47 | 54 | 65 | — |
| a | 1% Antiblu 20EC | 0 | 0 | 1.6 | — |
| b | 1.5% Antiblu 20EC | 0 | 0 | 0 | 0.16 |
| c | 2% Antiblu 20EC | 0 | 0.01 | 0.01 | — |
| d | 1.5% Antiblu 20EC + 0.125% Antiborer 10EC | 0 | 0 | 0 | 0.54 |

Table 3 and 4 showed the infection result of Antiblu 20EC treated rubberwood sawn timber. It can be seen that after storage of 1 week, all concentrations of Antiblu 20EC treated rubberwood were no any mould and sapstain. The quantity ratio of clean board was 100%.

Table 4 Clean board quantity ratio of fresh rubberwood sawn timber

| Group | Dip chemical and concentration | Quantity ratio of clean board (%) | | | |
|---|---|---|---|---|---|
| | | 1st week | 2nd week | 4th week | 12th week |
| o | — | 0 | 0 | 0 | — |
| a | 1% Antiblu 20EC | 100 | 100 | 96 | — |
| b | 1.5% Antiblu 20EC | 100 | 100 | 100 | 88 |
| c | 2% Antiblu 20EC | 100 | 98 | 98 | — |
| d | 1.5% Antiblu 20EC + 0.125% Antiborer 10EC | 100 | 100 | 100 | 94 |

After storage of 2 weeks, 1 sample of 2% Antiblu 20EC treated rubberwood was stained, but the infection ratio was very small, only 0.53%. The average infection ratio was 0.01%. The quantity ratio of clean board was 98%. However the other 3 groups (a, b and d) were no any stain, the quantity of clean board was 100%.

After storage of 4 weeks, 2 samples of 1% Antiblu 20EC treated rubberwood were mould, the infection ratio were 35% and 45%. The average infection ratio was 1.6%. The quantity ratio of clean board was 96%. And 1 sample of 2% Antiblu 20EC treated rubberwood was stained, but the infection ratio was still only 0.53% and average infection ratio was 0.01%. The quantity ratio of clean board was 98%. However the other 2 groups (b and d) were no any stain, the quantity of clean board was 100%.

After storage of 12 weeks, group a and group c were lost. For 1.5% Antiblu 20EC treated rubberwood (group b), 6 samples were stained and the infection ratio were 1.29%, 1.27%, 1.96%, 0.26%, 1.19% and 2.16% respectively, all less than 3%. The average infection ratio was 0.16%. The quantity ratio of clean board was 88%. For 1.5% Antiblu 20EC + 0.125% Antiborer 10EC treated rubberwood (group d), 3 samples were stained, and the infection ratio were 0.02%, 4.12%, and 16.99%. The average infection ratio was 0.54%. The quantity ratio of clean board was 94%.

The result showed that only 3 boards of totally 200 trial samples were stained after one month storage. After 3 months storage, 9 boards of totally 100 trial samples were stained, in which the infection ratio of 8 boards was less than 5%. It indicated that the anti-mould and anti-sapstain efficacy of Antiblu was rather good for fresh rubberwood sawn timber.

If less than 5% of the infection ratio on timber was considered as acceptable, the acceptable rubberwood were 100% for 1.5% Antiblu treatment and 98% for 1.5% Antiblu + 0.125% Antiborer treatment after 3 months storage.

## 4.3 Temporary protection of rubberwood pressure treated with borax and boric acid

**Table 5　Infection ratio of borax and boric acid treated rubberwood**

| Group | Dip chemical and concentration | Average infection ratio (%) | | | |
|---|---|---|---|---|---|
| | | 1st week | 2nd week | 4th week | 12th week |
| o | — | 47 | 54 | 65 | — |
| e | 1% Antiblu 20EC | 0 | 0 | 0 | 0.38 |
| f | 1.5% Antiblu 20EC | 0 | 0 | 0 | 0.032 |
| g | 2% Antiblu 20EC | 0 | 0 | 0 | 0.11 |
| h | 1.5% Antiblu 20EC + 0.125% Antiborer 10EC | 0.0076 | 0.0076 | 0.0076 | 0.62 |

**Table 6　Clean board quantity ratio of borax and boric acid treated rubberwood**

| Group | Dip chemical and concentration | Quantity ratio of clean board (%) | | | |
|---|---|---|---|---|---|
| | | 1st week | 2nd week | 4th week | 12th week |
| o | — | 0 | 0 | 0 | — |
| e | 1% Antiblu 20EC | 100 | 100 | 100 | 80 |
| f | 1.5% Antiblu 20EC | 100 | 100 | 100 | 94 |
| g | 2% Antiblu 20EC | 100 | 100 | 100 | 94 |
| h | 1.5% Antiblu 20EC+ 0.125% Antiborer 10EC | 98 | 98 | 98 | 84 |

Table 5 and 6 showed the infection result of Antiblu 20EC dipping treated rubberwood which was pre-treated with borax and boric acid by pressure. It can be seen that all 3 concentrations of Antiblu 20EC-treated rubberwood were no any mould and sapstain after 1, 2 and 4 weeks' storage. All of the quantity ratios of clean board were 100%.

After storage of 1, 2 and 4 weeks, 1 sample of 1.5% Antiblu 20EC + 0.125% Antiborer 10EC-treated rubberwood (Group h) was fungal attacked. The infection ratio were 0.5% and the average infection ratio was 0.0076%. The quantity ratio of clean board was 98%.

After storage of 12 weeks, 10 samples of 1% Antiblu 20EC treated rubberwood (Group e) were stained, in which the infection ratio of 1 sample were 6% and that of others were less than 5%. The average infection ratio was 0.38% and the quantity ratio of clean board was 80%.

For 1.5% and 2% Antiblu 20EC treated rubberwood (Group f and Group g), 4 timber samples each group were fungal attacked. Of which, the infection ratio were all less than 3% and the average infection ratio were 0.03% and 0.11%. The quantity ratio of clean board were all 94%.

For 1.5% Antiblu 20EC + 0.125% Antiborer 10EC treated rubberwood (Group h), 8 timber samples were fungal attacked. Of which, the infection ratios of 2 samples were 5.5% and 15.47% respectively, and the other 6 samples were less than 3%. The average infection ratio was 0.62% and the quantity ratio of clean board was 84%.

The result showed that only 1 boards of totally 200 trial samples were fungal attacked after 1 month storage. After 3 months storage, 26 boards of totally 200 trial samples were stained, in which the infection ratios of 23 boards were less than 5%. It indicated that the anti-mould wood sawn timber.

If less than 5% of the infection ratio on timber was considered as acceptable, the acceptable rubberwood were 98% for 1% Antiblu treatment, 100% for 1.5% and 2% Antiblu treatment, and 96% for 1.5% Antiblu + 0.125% Antiborer treatment respectively, after 3 months storage.

## 4.4 Temporary protection of rubberwood pressure treated with parachem

**Table 7 Infection ratio of Parachem treated rubberwood**

| Group | Dip chemical and concentration | Average infection ratio (%) | | | |
|---|---|---|---|---|---|
| | | 1st week | 2nd week | 4th week | 12th week |
| o | — | 47 | 54 | 65 | — |
| i | 1% Antiblu 20EC | 0 | 0 | 0 | 0 |
| j | 1.5% Antiblu 20EC | 0 | 0 | 0 | 0 |
| k | 2% Antiblu 20EC | 0 | 0 | 0 | 0 |
| l | 1.5% Antiblu 20EC+ 0.125% Antiborer 10EC | 0 | 0 | 0 | 0 |

**Table 8 Clean board quantity ratio of Parachem treated rubberwood**

| Group | Dip chemical and concentration | Quantity ratio of clean board (%) | | | |
|---|---|---|---|---|---|
| | | 1st week | 2nd week | 4th week | 12th week |
| o | — | 0 | 0 | 0 | — |
| i | 1% Antiblu 20EC | 100 | 100 | 100 | 100 |
| j | 1.5% Antiblu 20EC | 100 | 100 | 100 | 100 |
| k | 2% Antiblu 20EC | 100 | 100 | 100 | 100 |
| l | 1.5% Antiblu 20E + 0.125% Antiborer 10EC | 100 | 100 | 100 | 100 |

Table 7 and 8 showed the infection result of Antiblu 20EC dipping treated rubberwood which was pre-treated with Parachem by pressure. It can be seen that all 3 concentrations of Antiblu 20EC and Antiblu + Antiborer treated rubberwood were no any mould and sapstain after 1, 2, 4 and 12 weeks' storage. All of the quantity ratios of clean board were 100%. This indicated that Antiblu treatment was mostly effective for controlling mould and sapstain fungal attack on Parachem pressure treated rubberwood.

# 5 Conclusion

It can be drawn from the result that the protection of fresh sawn rubberwood from deterioration (mould and sapstain) can be achieved for 4 weeks by dipping treatment with Antiblu 20EC. For the boron preservative (borax and boric acid, or Parachem) treated rubberwood, dipping treatment with Antiblu 20EC can provide 12 weeks' protection against mould and sapstain fungal infection.

In order to replace sodium pentachlorophenol (NaPCP) which is toxic to both human being and environment, the preservation of rubberwood may be divided into 2 treatments. One is pressure treatment with boron chemicals; the other is dipping treatment with anti-sapstain and anti-mould chemical, such as Antiblu 20EC.

If pressure treated rubberwood with boron preservative can not be kiln dried in few days, or air drying is taken to reduce the drying cost, short term protection of rubberwood against mould and sapstain fungal infection during air-dry period can be achieved by dipping treatment with Antiblu 20EC.

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# STUDY ON LONG TERM PROTECTION OF RUBBERWOOD AGAINST DECAY AND INSECT ATTACK

## 1 Introduction

Rubberwood is very susceptible to decay and insect attack. Hence it must be properly treated to prevent the deterioration of wood which would result in wastage of useful material and financial loss.

The preservative used in China rubberwood industry for more than 10 years was the mixture of borax decahydrate, boric acid and sodium pentachlorophenol (NaPCP), often called BBP formulation. However, NaPCP contains dioxin which can cause a number of hazard: carcinogenic, ecotoxic, central nervous system damage, blood disorder, liver and kidney damage, stomach pain, vomiting, nausea, fever, eyes/skin/respiratory irritation. This is why NaPCP was banned a lot of countries, such as Sweden, Germany, Spain, Chile, Denmark, Switzerland, Italy, Greece, Indonesia, Malaysia, Japan, New Zealand, Australia and USA (restricted used). Therefore, to reach the quality level of rubberwood products internationally, it is necessary to replace NaPCP with environmental-friendly chemicals.

Two treatment methods for long term protection (also called permanent treatment) were normally used: dip-diffusion process or hot-cold immersion and vacuum-pressure impregnation process.

In order for developing appropriate technology to replace NaPCP, pressure treatment were carried out with borax, boric acid, Parachem and Sodium Borate Special in this study to evaluate the long term protection performance of boron preservative for rubberwood.

## 2 Materials and methods

### 2.1 Timber

7 200 pieces of fresh sawn rubberwood sample with no stain, insect damage and bark were selected. The timber size was 50 ~ 100 cm long, 8 cm wide and 3 cm thick. The timber samples were divided into 36 groups, 200 pieces of sample for each group.

### 2.2 Chemicals

a. Borax decahydrate: manufactured by Shanghai Jiading Borax Company;
b. Boric acid: manufactured by BOR;
c. Borax pentahydrate, ETiBOR-48: manufactured by ETiBANK;
d. Boric acid: manufactured by ETiBANK;

e. Parachem: manufactured by Koppers-Hickson Chemical (M) Sdn. Bhd.;
f. Sodium borate special: manufactured by Borax Morarji Ltd.

## 2.3 Preparation of treatment solution

For making 1% concentration of treatment solution, 5 ton of water was firstly put into the mixing tank, then 50kg solid chemical were gradually put into the tank while stirring by the agitator. After the chemical was totally dissolved, the working solution was poured into the storage tank. The preparation of other treatment solution with different concentrations was similar. 3 concentrations of treatment solutions for 4 chemicals or mixtures of chemicals were prepared in this trial, namely:

1%, 1.5% and 2% of 1:1 borax decahydrate and boric acid (a/b);
1%, 1.5% and 2% of 1:1 borax pentahydrate and boric acid (c/d);
1%, 1.5% and 2% of Parachem;
1%, 1.5% and 2% of Sodium Borate Special.

## 2.4 Pressure treatment cycle

3 treatment cycles were used in the study for each concentration and each chemical or mixture of chemicals as follows:

| | Pressure time(min) |
|---|---|
| 1 | 40 |
| 2 | 70 |
| 3 | 100 |

## 2.5 Treatment

For the treatment with the mixture of 1:1 of borax decahydrate and boric acid (chemical a and b), 3 groups were treated at 1% solution concentration, 3 groups were treated at 1.5% solution concentration, and 3 groups were treated at 2% solution concentration respectively.

For the treatment with the mixture of 1:1 of borax pentahydrate and boric acid (chemical c and d), 3 groups were treated at 1% solution (concentration), 3 groups were treated at 1.5% solution concentration, and 3 groups were treated at 2% solution concentration respectively.

For the treatment with Parachem (chemical e), 3 groups were treated at 1% solution concentration, 3 groups were treated at 1.5% solution concentration, and 3 groups were treated at 2% solution concentration respectively.

For the treatment with Sodium Borate Special (Chemical f), 3 groups were treated at 1% solution concentration, 3 groups were treated at 1.5% solution concentration, and 3 groups

**Table 1 Treatment details**

| Chemical | Concentration(%) | Pressing time (min) |
|---|---|---|
| borax decahydrate / boric acid | 1.0 | 40 |
| | | 70 |
| | | 100 |
| | 1.5 | 40 |
| | | 70 |
| | | 100 |
| | 2.0 | 40 |
| | | 70 |
| | | 100 |
| borax pentahydrate / boric acid | 1.0 | 40 |
| | | 70 |
| | | 100 |
| | 1.5 | 40 |
| | | 70 |
| | | 100 |
| | 2.0 | 40 |
| | | 70 |
| | | 100 |
| Parachem | 1.0 | 40 |
| | | 70 |
| | | 100 |
| | 1.5 | 40 |
| | | 70 |
| | | 100 |
| | 2.0 | 40 |
| | | 70 |
| | | 100 |
| Sodium Borate Special | 1.0 | 40 |
| | | 70 |
| | | 100 |
| | 1.5 | 40 |
| | | 70 |
| | | 100 |
| | 2.0 | 40 |
| | | 70 |
| | | 100 |

## 2.6 Post treatment

Following the preservative treatment, the rubberwood samples were sticker stacked in the air-dry room. Then after 5 days storage, the timber samples were put into the conventional kiln using the steam heating and forced air-drying system. The moisture content of below 12% was reached after drying.

## 3 Testing of boron in timber

The testing of the penetration of boron preservative was carried out by spot test using curcumin method (qualitative analysis). The testing of the retention of boron preservative was carried out by chemical titration method (quantitative analysis).

### 3.1 Qualitative analysis

The curcumin agent was prepared by mixing of concentrated hydrochloric acid, ethanol, salicylic acid, and curcumin. 5 pieces of rubberwood sample of every group were randomly selected. Each piece of timber sample was cross cut at least 25cm from one end. The testing for preservative penetration was applied by spraying the solution of curcumin agent on the newly exposed cross-section of the sample piece.

### 3.2 Quantitative analysis

10 pieces of rubberwood sample of each group were randomly selected. For each piece of timber sample, 2cm thick biscuit was cut by cross cutting in the middle of timber. Then half of the biscuits were grounded into 40 mesh wood powder for chemical analysis and half were used for the testing of moisture content

This method for analysis of boric acid in rubberwood samples employs the extraction of boric acid in timber samples followed by titration with NaOH in the presence of mannitol. The procedures were including the standardization of NaOH solution, the extraction of boric acid from rubberwood sample, and the titration of boric acid in solution. The amount of boron preservative in rubberwood was calculated in boric acid equivalent (BAE) in percentage.

## 4 Result and discussion

**Table 2 BAE in Borax decahydrate/Boric acid treated rubberwood**

| Concentration (%) | Pressing time(min) | BAE(w/w, %) |
|---|---|---|
| 1.0 | 40 | 0.40 |
| 1.0 | 70 | 0.36 |
| 1.0 | 100 | 0.41 |
| 1.5 | 40 | 0.58 |
| 1.5 | 70 | 0.60 |
| 1.5 | 100 | 0.61 |
| 2.0 | 40 | 0.71 |
| 2.0 | 70 | 0.67 |
| 2.0 | 100 | 0.79 |

| Concentration (%) | Pressing time(min) | BAE(w/w, %) |
|---|---|---|
| 1.0 | 40 | 0.41 |
| 1.0 | 70 | 0.48 |
| 1.0 | 100 | 0.47 |
| 1.5 | 40 | 0.51 |
| 1.5 | 70 | 0.52 |
| 1.5 | 100 | 0.54 |
| 2.0 | 40 | 0.80 |
| 2.0 | 70 | 0.77 |
| 2.0 | 100 | 0.61 |

**Table 4 BAE in Sodium Borate Special treated rubberwood**

| Concentration (%) | Pressing time(min) | BAE(w/w, %) |
|---|---|---|
| 1.0 | 40 | 0.37 |
| 1.0 | 70 | 0.43 |
| 1.0 | 100 | 0.45 |
| 1.5 | 40 | 0.84 |
| 1.5 | 70 | 0.56 |
| 1.5 | 100 | 0.55 |
| 2.0 | 40 | 0.76 |
| 2.0 | 70 | 0.84 |
| 2.0 | 100 | 0.89 |

**Table 5 BAE in Parachem treated rubberwood**

| Concentration (%) | Pressing time(min) | BAE(w/w, %) |
|---|---|---|
| 1.0 | 40 | 0.36 |
| 1.0 | 70 | 0.45 |
| 1.0 | 100 | 0.47 |
| 1.5 | 40 | 0.59 |
| 1.5 | 70 | 0.65 |
| 1.5 | 100 | 0.77 |
| 2.0 | 40 | 0.84 |
| 2.0 | 70 | 0.79 |
| 2.0 | 100 | 0.71 |

The spot test result showed that boron preservative can not penetrated into the surrounding area of rubberwood pitch. The penetration of boron chemical increased with increasing the pressing time, but the pitch and the area closely around the pitch can not be penetrated.

It indicated that rubberwood pitch should be cut off during the processing of rubberwood log because it may cause biological problems during following processing and the use of rubberwood. It may also cause other problems, such as drying checks.

The chemical analysis result showed that the boric acid equivalents of most concentrations of borax/boric acid, Sodium Borate Special and Parachem used in this study were over 0.4%, which was required by most down stream processing of rubberwood, such as Malaysian and Thailand rubberwood industry.

The result also showed that the boric acid equivalent increased with increasing boron preservative solution strength. But the change of boric acid equivalent was small by increasing pressure time.

## 5 Conclusion

By using borax/boric acid, Sodium Borate Special or Parachem, the boric acid equivalent (BAE) over 0.4% can be achieved with pressure treatment. Therefore, rubberwood can be processed with good anti-insect (especially borers) attack performance.

The spot test using curcumin agent was a practical way to check the quality of the preservation treatment for rubberwood. It was simple, easy to apply, and fast to show the checking result.

However, kiln drying of rubberwood should be carried out in very few days after preservation treatment because boron preservative does not prevent mould or sapstain fungus. If pressure treated rubberwood with boron preservative can not be kiln dried in few days, or air drying is taken to reduce the drying cost, short term protection of rubberwood against mould and sapstain fungal infection during air-dry period should be used, for instance, by dipping treatment with Antiblu 20EC.

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STUDIES ON THE DRYING TECHNIQUE OF PRESERVATIVES

# TREATED RUBBERWOOD

## 1 Introduction

Being one of tropical species, rubberwood(*Hevea brasiliensis*)has been planted in large scale in Hainan, Yunnan, Guangdong and Guangxi Province since 1950's in order to crop the latex to make rubber. The economical life-span of rubberwood trees is 25 to 30 years, in order to improve the output of the latex, the rubberwood trees must be regenerated in a period of time. From the 1980's, rubberwood trees have been cut in fixed quantity and refreshed every year, it is estimated that the output of rubberwood log is about 500～800 thousand $m^3$ every year, this is a very large amount of tropical wood resource in China.

In old days, rubberwood was mainly consumed as the fuel wood with little commercial value because it is likely to be eroded and is easy to be attacked by the insects. Studies on the utilization and the development of rubberwood has been taken into account in China since the middle of 1970's, and the rubberwood preservation problem has been solved in the end of 1970's. In addition, the related studies such as rubberwood properties, drying techniques and utilization have also been done.

At present, the main preservatives for rubberwood are those containing the sodium pentachlorophenol (NaPCP), which are very effective in the preservation. However, the toxicity of NaPCP is very severe and preservatives treatment by NaPCP can cause pollution, therefore, the uses of NaPCP are strictly limited or forbidden in many countries. Considering the environment protection and the development of international market, developing the new preservatives without containing NaPCP is the common study topic of both China and all other rubberwood production countries.

The key problem to be solved of this project is to determine the best rubberwood drying technique after they are treated by new preservatives with containing none NaPCP.

## 2 Test method

### 2.1 Test material

Species: rubberwood(*Hevea brasiliensis*)

Tree age:25～33 years

Producing area: (1) Xilian Farm, Hainan Province; (2) Nanmao Farm, Hainan Province

Log diameter:220～450 mm

Log length:2 000～2 200 mm

### 2.2 Drying characteristics test

In order to determine the drying schedule of rubberwood, drying characteristics were tested in the electricity heated oven. Test sample (with the size of 200 mm × 100 mm × 20 mm) were put into the oven with the constant temperature at 100 ℃. Before the test, the initial status, including the weight, and the visible surface defects were measured. The initial checks were checked according to a fixed time. When the moisture content is below 1 percent, the test was over. At this time, calculate the number of all invisible drying defects, and then cut the samples to calculate the final moisture content, in the meantime, observe the inner checks and calculate the cross-section deformation value.

**Table 1 Status of initial checks**

| No | Surface checks | | | End-surface checks | | | End checks | | Defects grade |
|---|---|---|---|---|---|---|---|---|---|
| | Long-narrow | Short-narrow | Wide | Long-narrow | Short-narrow | Wide | Long | small | |
| 1 | 0 | 4 | 0 | 0 | 9 | 0 | 0 | many | 2 |
| 2 | 0 | 2 | 0 | 0 | 7 | 0 | 0 | many | 2 |
| 3 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | many | 1 |
| 4 | 0 | 1 | 0 | 0 | 3 | 0 | 0 | many | 2 |
| 5 | 0 | 3 | 0 | 0 | 7 | 0 | 0 | many | 2 |
| 6 | 0 | 2 | 0 | 0 | 5 | 0 | 0 | many | 2 |
| 7 | 0 | 4 | 0 | 0 | 4 | 0 | 0 | many | 2 |
| 8 | 0 | 9 | 0 | 0 | 7 | 0 | 0 | many | 2 |
| 9 | 0 | 3 | 0 | 0 | 11 | 0 | 0 | many | 2 |
| 10 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | many | 1 |
| 11 | 0 | 3 | 0 | 0 | 8 | 0 | 0 | many | 2 |
| 12 | 0 | 2 | 0 | 0 | 5 | 0 | 0 | many | 2 |

**Table 2 Status of internal checks and cross-section deformation after drying**

| No | Internal checks | Defects grade | Cross-section deformation(mm) | Defects grade |
|---|---|---|---|---|
| 1 | no check | 1 | 0.10 | 1 |
| 2 | no check | 1 | 0.03 | 1 |
| 3 | no check | 1 | 0.12 | 1 |
| 4 | no check | 1 | 0.18 | 1 |
| 5 | no check | 1 | 0.32 | 1 |
| 6 | no check | 1 | 0.06 | 1 |
| 7 | no check | 1 | 0.00 | 1 |
| 8 | no check | 1 | 0.17 | 1 |
| 9 | no check | 1 | 0.09 | 1 |
| 10 | no check | 1 | 0.03 | 1 |
| 11 | no check | 1 | 0.33 | 1 |
| 12 | no check | 1 | 0.25 | 1 |

| No. | 0 | 1 | 3 | 5 | 7 | 13 | 19 |
|---|---|---|---|---|---|---|---|
| 1 | 73.6 | 50.3 | 34.7 | 25.0 | 17.5 | 4.2 | 1.1 |
| 2 | 71.5 | 47.6 | 34.1 | 24.8 | 17.9 | 6.2 | 1.2 |
| 3 | 70.3 | 48.1 | 34.5 | 25.6 | 18.9 | 6.5 | 1.2 |
| 4 | 68.2 | 48.2 | 35.4 | 26.2 | 19.8 | 7.2 | 1.3 |
| 5 | 69.1 | 48.9 | 34.8 | 25.0 | 20.2 | 6.3 | 1.2 |
| 6 | 70.4 | 48.6 | 34.2 | 24.5 | 19.5 | 5.1 | 1.2 |
| 7 | 71.6 | 48.1 | 34.8 | 24.2 | 18.7 | 4.5 | 1.2 |
| 8 | 72.9 | 50.9 | 36.1 | 26.3 | 19.2 | 4.1 | 1.1 |
| 9 | 68.9 | 48.2 | 34.0 | 25.1 | 18.5 | 5.4 | 1.2 |
| 10 | 75.8 | 53.1 | 38.6 | 29.1 | 19.2 | 4.9 | 1.1 |
| 11 | 67.8 | 49.0 | 39.3 | 28.0 | 20.5 | 4.8 | 1.0 |
| 12 | 72.0 | 49.2 | 37.5 | 27.9 | 18.7 | 6.7 | 1.2 |

100℃ drying test showed that the check of rubberwood was not serious. The main types of checks were end check, surface check and end-surface check. Because the initial moisture content of rubberwood was high, the moisture content of the surface part decreased rapidly under the FSP and begin to shrink, while that of the inner part was still higher. Therefore, the drying stress occurred and the surface check appeared. After the drying test lasted for one hour, the slight end checks appeared on all the test samples, and with the test continuing, the checks became more and more seriously, even some of these end checks were stretched to the outer surface to form that called end-surface checks. When the sample's mean moisture content reached about 30%, all the initial checks stopped. 100 ℃ drying characteristics test showed there were some surface checks, end checks and end-surface checks in the initial drying stage but not seriously (see table 1), and the defect grade of initial checks of 100 ℃ drying test was grade 2.

After drying test ended, the samples were sawn to make the final moisture content test sample and to check the status of internal check and to measure cross-section deformation value (see table 2). The results showed there was no internal check in the rubberwood, and the defect grade of internal checks of 100 ℃ drying test was grade 1. The cross-section deformation value was very small, its defect grade of 100 ℃ drying test was grade 1 too (see table 2).

## 2.3 Rubberwood drying schedule test

Rubberwood drying schedules for test were made out according to the results of 100 ℃ drying characteristics testing. and all the drying schedules tests were carried out in one of the rubberwood processing mill located in Hainan Province. The test sample size of rubberwood was 800~1 200 mm long , 80 mm wide and 30 mm thick. After preservatives treatment, the test samples were deposited in the air-drying shelter for a short term. And then the kiln drying tests were executed in this mill. After a series of testing, 3 drying schedules were finally selected (see table 4~6).

**Table 4  Drying schedule A(thickness: 25～30 mm)**

| Moisture content (%) | Dry bulb temperature (℃) | Temperature difference between dry bulb and wet bulb (℃) | Relative humidity (%) | Lasting time (h) |
|---|---|---|---|---|
| pre-treatment | 55 | 1 | 95 | 5～6 |
| >50 | 48 | 3 | 85 | |
| 50～40 | 50 | 4 | 80 | |
| 40～30 | 52 | 6 | 70 | |
| 30～25 | 55 | 8 | 65 | |
| 25～20 | 60 | 12 | 52 | |
| 20～15 | 65 | 15 | 45 | |
| <15 | 75 | 20 | 37 | |
| end-treatment | 65 | 6 | 78 | 3～4 |

**Table 5  Drying schedule B(thickness: 25～30 mm)**

| Moisture content (%) | Dry bulb temperature (℃) | Temperature difference between dry bulb and wet bulb (℃) | Relative humidity (%) | Lasting time (h) |
|---|---|---|---|---|
| pre-treatment | 65 | 1 | 95 | 5～6 |
| >50 | 60 | 3 | 85 | |
| 50～40 | 62 | 5 | 78 | |
| 40～30 | 64 | 8 | 67 | |
| 30～25 | 66 | 10 | 60 | |
| 25～20 | 70 | 12 | 55 | |
| 20～15 | 75 | 15 | 48 | |
| <15 | 80 | 20 | 39 | |
| end-treatment | 85 | 6 | 60 | 3～4 |

**Table 6  Drying schedule C(thickness: 25～30 mm)**

| Moisture content (%) | Dry bulb temperature (℃) | Temperature difference between dry bulb and wet bulb (℃) | Relative humidity (%) | Lasting time (h) |
|---|---|---|---|---|
| Pre-treatment | 70 | 1 | 95 | 5～6 |
| >50 | 66 | 6 | 75 | |
| 50～40 | 70 | 9 | 65 | |
| 40～30 | 75 | 11 | 60 | |
| 30～25 | 80 | 12 | 58 | |
| 25～20 | 80 | 15 | 50 | |
| 20～15 | 85 | 20 | 40 | |
| <15 | 90 | 25 | 33 | |
| End-treatment | 85 | 6 | 60 | 3～4 |

## 3 Drying schedule testing results analysis

The main indices taken into account in these drying schedule tests were the drying quality and drying speed. The objective of the tests was made out the optimum drying schedule of rubberwood with the shortest drying time at the precondition of good drying quality.

### 3.1 Drying quality

All visible drying defects, including end check, end-surface check, surface check, warp and deformation were counted after the test (see table 7). The results showed that, during the drying, the checks were not serious. The main types of checks were slight end checks, in which, some of them were developed into end-surface checks. And some small checks sometimes occurred in the surface of rubberwood boards along with the vessels, which were so imperceptible that they can be removed after planing and will not affects its use.

When drying rubberwood timber containing the pith with drying schedule B, few checks were found and only some deformation occurred; while drying with schedule C, severe checks even splits and deformation were found in about one fourth of those timber which containing pith. Considering these facts, timbers with pith and without pith should be dried respectively. Those containing pith should be dried according to schedule B and proper middle term treatment were needed, while Those pith free rubberwood timber could be dried fast according to schedule C and the drying time would be shorten.

**Table 7 Inspected drying indices (%)**

| Drying Schedule | Index | Max | Min | δ | V | Average | Visible drying defects |
|---|---|---|---|---|---|---|---|
| A | $W_i$ | 78.6 | 42.4 | 27.1 | 37.6 | 60.5 | Surface checks and deformation were found on 5 samples containing pith; No split, warp and inner checks were found |
| | $W_f$ | 10.9 | 9.4 | 0.51 | 18.4 | 10.3 | |
| | $W_g$ | 2.1 | 1.05 | 0.11 | 8.6 | 1.9 | |
| | $Y$ | 2.0 | 0.69 | 0.33 | 11.2 | 1.20 | |
| B | $W_i$ | 80.1 | 43.3 | 20.6 | 35.2 | 58.6 | End-surface checks were found on few samples, no surface checks and inner checks were found. The dried rubberwood kept the original color. |
| | $W_f$ | 10.1 | 7.6 | 0.98 | 10.6 | 9.2 | |
| | $W_g$ | 2.0 | 1.30 | 0.53 | 35.1 | 1.5 | |
| | $Y$ | 1.90 | 0.35 | 0.22 | 19.8 | 1.09 | |
| C | $W_i$ | 84.2 | 45.8 | 19.3 | 29.8 | 64.9 | End-surface checks were found on a few samples, surface checks were found on the samples containing pith. Other samples were dried with good quality, and the color of the samples became darker. |
| | $W_f$ | 10.9 | 9.2 | 0.50 | 5.2 | 9.6 | |
| | $W_g$ | 1.2 | 0.90 | 0.31 | 31.4 | 1.0 | |
| | $Y$ | 1.90 | 0.35 | 0.22 | 19.8 | 1.09 | |

Note: $W_i$—initial moisture content; $W_f$—final moisture content; $W_g$—moisture content gradient along the thickness direction; $Y$—drying stress; δ—mean deviation, $V$—coefficient of variation

### 3.1.2 Final Moisture contents ($W_f$)

The desired final moisture content of this test was 10%. Due to the limited test samples, 100 to 300 test samples were dried together with other rubberwood timber of the factory and were put into the different kilns with capacity from 35 to 75 cubic meters. After drying, moisture contents were calculated by means of making the pieces of moisture content samples. The results showed the final moisture contents of rubberwood were around 10%, and the difference of moisture content between different samples was very small. The drying quality meets the need of grade one or grade two of national drying standard sawn timber.

### 3.1.3 Moisture content gradient along the thickness direction ($W_g$)

When drying, the water in surface layer was firstly removed from the rubberwood, so the moisture contents in different layers were different, thus the moisture content gradient existed. This gradient still existed when the drying process ended. Therefore, final treatment must have been done before the rubberwood was removed out of the kiln. The results of moisture content gradient along the thickness direction showed that the moisture content variation between different layers was small, and the drying quality was in order of grade one of national drying standard of sawn timber.

#### 3.1.4 Drying stress index ( *Y* )

Drying stress existed all the time during the drying because of different evaporating speed along the thickness direction, and when the stress was big enough, surface checks or internal checks appeared. Therefore, middle term treatment must have been carried out when the moisture content was at about 30% in order to reduce the drying stress. When the drying was finished, the residual drying stress still existed and would cause deformation during final using. Moisture balance treatment has been done in these tests in order to reduce the variation of moisture content between different layers or different samples, and the residual drying stress reduced a lot. The results showed that, the drying stress index was in order of grade one of national drying standard of sawn timber.

### 3.2 Deformation

Rubberwood is a fast growing specie with big structure variation. When drying, they are easily formed severe deformation, including bowing, cupping, warping and twisting. It was found that the rubberwood deformation on the upside of the stack was bigger than the lower side because the timber in the lower side endured large compression, thus the deformation was restricted. So in the later testing, all the spacing stickers were kept in straight lines and some heavy load were put on the top of stack, meanwhile the proper middle term treatment also was executed. Results showed that all kinds of deformation greatly reduced.

### 3.3 Drying speed

Drying speed is also an important index. Improving the drying speed, shortening the drying time and reducing the drying costing should put into practice at the precondition of good drying quality. This will greatly improve the annual drying production amount, and thus improve the economic benefits.

**Table 8 Drying time and speed of different drying period thickness: 25~30 mm**

| Drying Schedule | Initial *MC* (%) | Final *MC* (%) | Total drying time(h) | Drying time of different period (h) | | | Drying speed of different period(%/h) | | | Average (%/h) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | >30% | 30~20% | <20% | >30% | 30~20% | <20% | |
| A | 60.5 | 10.1 | 260 | 122 | 60 | 78 | 0.25 | 0.17 | 0.13 | 0.19 |
| B | 58.6 | 9.2 | 190 | 83 | 49 | 58 | 0.34 | 0.20 | 0.18 | 0.26 |
| C | 64.9 | 9.6 | 110 | 41 | 29 | 40 | 0.85 | 0.34 | 0.26 | 0.50 |

Three reasonable drying schedules were made out and showed that, the drying time was about 11 days when drying these preservatives treated rubberwood according to schedule A, about 8 days according to schedule B and about 4.5 days according to schedule C. The tests showed the rubberwood could be fast dried at some high temperature.

### 3.3 Rubberwood color after drying

Rubberwood is diffuse porous wood with straight grain, its heartwood and sapwood is hard to distinguish. The fresh rubberwood is light yellow in color, beautiful in grain, and well in processing. The preservative was mainly consisted with boron and boric acid and with none NaPCP, so after vacuum treating, the rubberwood almost maintained the original color. In order to keep the original natural color of rubberwood, the color of dried rubberwood was analyzed. The results showed the color of dried rubberwood had a close relationship with the drying temperature and humidity. The higher the drying temperature was, the bigger the humidity was and the longer the drying time was, the darker the color was. The rubberwood color became darker and brown when they were dried according to schedule C, while the color almost kept the original natural color when they were dried according to schedule A.

### 3.5 Drying costing

Drying is an important procedure in rubberwood processing, and is the most energy consumed one. In order to get more benefit, not only the loss caused by degrade should be reduced but also the drying cost should be strictly restricted.

The factors affect the rubberwood drying cost include drying time, electricity consumption, vapor consumption, labor cost and equipment depreciation. In order to be convenient for comparing, the costing was calculated based upon a 50 $m^3$ kiln. The drying costs indices include 9kw power consumption, 5 to 8 tone vapor consumption per $m^3$ rubberwood, and 3 labors a day. The other indices includes electricity expense (0.80 Yuan/kW·h), vapor expense (50 Yuan/tone) and labor expense (30 Yuan/person day). Drying costing of three schedules are list as following:

**Table 10 Drying costing**

| Drying schedule | Electricity consumption | | Heat consumption | | Labor | | Total cost (Yuan) | Cost per unit (Yuan/$m^3$) |
|---|---|---|---|---|---|---|---|---|
| | Amount (kW·h) | Cost (Yuan) | Vapour consumption (t) | Cost (Yuan) | Labor (person day) | Cost (Yuan) | | |
| A | 2367.0 | 1900.8 | 55.0 | 2750.0 | 33 | 990.0 | 5640.8 | 112.8 |
| B | 1728.0 | 1382.4 | 48.0 | 2400.0 | 24 | 720.0 | 4502.4 | 90.0 |
| C | 992.0 | 777.6 | 36.0 | 1800.0 | 14 | 420.0 | 2997.6 | 60.0 |

From table 10, it is showed that the difference of drying costs according to different drying schedules was very huge. The drying costing was 112.8 Yuan/$m^3$ when the rubberwood was dried according to schedule A, while it would be greatly reduced to 60 yuan/$m^3$ when the rubberwood was dried according to schedule C.

## 4 Conclusion

(1) The drying characteristic grade of rubberwood with new preservatives treated was grade 2 of initial check, grade 2 of internal check and grade 1 of deformation.
(2) According to the results of drying characteristic test and a series of the drying schedules tests, 3 optimum drying schedules were made.
(3) Rubberwood with or without pith should be dried separately. Pith free rubberwood could be dried according to the high temperature drying schedule C with good drying quality which the drying checks, deformation and moisture contents of dried rubberwood were all fit the national drying standard of grade 1.
(4) Uniform spacing stickers and heavy load on top of stack was recommended to reduce deformation. When drying rubberwood with pith, the drying temperature should be lower and middle term treatment time should be increase.
(5) The color of dried rubberwood has a close relationship with the drying temperature and humidity. In order to keep the original color of rubberwood, the rubberwood should be dried according to drying schedule A with a lower drying temperature.
(6) Drying time had a close relationship with the drying schedule. When drying rubberwood according to the 3 different schedules, their drying time were 11, 8 and 4.5 days respectively.
(7) Drying time greatly affected the drying costing. Improving the drying speed or shortening drying time will reduce the drying costing.
(8) Above all, in order to improve the drying efficiency and reduce the drying costing, the rubberwood should be dried according to schedule C; In the other hand, in order to keep the original color of rubberwood, they should be dried according to schedule A; Schedule B can also be adopted according to the requirement of final products of the rubberwood by the manufactory.

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# RUBBERWOOD PLYWOOD

## 1 Introduction

There exists a big potential market in China for rubberwood or rubberwood plywood as interior decorative building materials. On the one hand, in pace with the improvement of Peaple' s life, wooden interior decorative building materials have been more and more received in China. However, China is confronted with the exhaustion of natural forest resource. Therefore, the importance of comprehensive utilization of rubberwood, which is the product of renewable plantation, has been manifested. In addition, rubberwood has beautiful colour and grain, good physical and mechanical properties. The solid rubberwood can be used as floor, door.... etc., and plywood can be used as dado, ceiling, partition, door skin.... etc. On the other hand, these interior decorative building materials must reach required specification of fire retardance, according to the nation's compulsory code GB 50222-95. It is necessary for rubberwood products to be fire-retardant treated if rubberwood products are going to take a certain share in the market of construction materials. Therefore, fire retardant treatment (FR treatment) of rubberwood and its products is one of the important techniques for processing and utilization of rubber wood .

In recent years, the development of fire-retarding formulas tends towards low toxicity, environment friendliness, low hygroscopicity, leaching resistance and long duration of service. Low cost and little inverse effect on wood strength (or glue bonding strength as for plywood) have also to be considered to ensure profit of the factory and security in service. Previous research in the Research Institute of Wood Industry, Chinese Academy of Forestry (CRIWI, CAF) revealed that Formula $WFR_1$ (donated by $WFR_{1\text{-}1\text{-}a}$ in this paper), which was used for FR treatment of wood and plywood, was good in fire retardance, low in toxicity and environmental pollution. It had a certain extent of decay resistance and mould resistance. Hygroscopicity of $WFR_1$ was lower than that of common phosphor-nitrogen category.

The objective of this subject "Flame-retardant Rubberwood Plywood" was to develop a technique which can impart rubberwood or rubberwood plywood the required fire-retardance. The subject was executed in two steps: laboratory step and pilot production step:

(1) The following work was included during the first step:

a. Investigation on the feasibility for applying $WFR_1$ to treat rubber wood plywood;
b. Evaluation of anti-stain and anti-mould activity for FR rubberwood plywood (fire-retardet rubberwood plywood);
c. Study on hygroscopicity of FR rubberwood plywood;
d. Investigation on the burning behavior and thermal properties of FR rubberwood plywood.

(2)A pilot test for producing 5 $m^3$ FR rubberwood plywood was conducted during the second step. The glue bonding strength and the burning behavior of pilot test products were tested. The authorized test centers were entrusted with the tests. The test results suggested that $WFR_{1-2-a}$, modified on the basis of $WFR_1$, showed the same good fire-retardant efficacy as $WFR_1$. The pilot test products reached grade $B_1$, GB/T 8624-97 (classification method for burning behavior of building materials). Glue bonding strength of $WFR_{1-2-a}$ treated rubberwood plywood was at the same level as or a little bit higher than that of the untreated ones. in addition, $WFR_{1-2-a}$ treated rubberwood plywood was good in resistance to blue stain fungus and had a certain degree of resistance to other mould fungi. Hygroscopicity of $WFR_{1-2-a}$ treated samples was lower than $WFR_1$ treated ones.

## 2 Materials and methods

### 2.1 Experiment materials

#### 2.1.1 Plywood

Rubberwood plywood, provided by Nanmao Plywood Factory, Hainan Province, China, was 3-layer plywood with 1 mm thickness per layer and was glued with UF resin.

#### 2.1.2 Fire-retardingt formulas

$WFR_{1-1-a}(=WFR_1)$, $WFR_{1-2-a}$, $WFR_{1-3}$ were the different formulas based on $WFR_1$. The main components of these formulas were resinous phosphor-nitrogen category. $6^{\#}$ was a common formula of phosphor-nitrogen category.

#### 2.1.3 Fungi for test

mould fungi
(A) *Aspergillus niger*
(B) *Trichoderma lignorum*
(C) *Penicillium citrinum*

mixed fungus
(D) *Botriodiplodia theobromae*
(E) mixed cultures infecting rubber wood plywood in open air

#### 2.1.4 Culture medium

Potato dextrose agar (PDA) culture medium was prepared according to GB/T 13942.1-92.

### 2.2 Experiment methods

#### 2.2.1 Treatment of rubber wood plywood

##### 2.2.1.1 FR treatment in laboratory—vacuum-pressure impregnation

the samples, of which glue bonding strength would be tested, were cut from the middle of (1) into two pieces. The size of each piece was about 450 mm × 200 mm . One would be treated and be tested for bonding strength. The other would be as the control for the test of bonding strength.

Above samples were oven dried at 60℃ ~80℃ to a constant weight ( $W_0$), and then, vacuum-pressure impregnated with $WFR_{1\text{-}1\text{-}a}$, $WFR_{1\text{-}2\text{-}a}$, $WFR_{1\text{-}3}$ and 6#. The technical parameters for treatment were showed in table 1.

**Table 1 Technical parameters for the treatment in lab.**

| Parameter | 1 | 2 | 3 |
|---|---|---|---|
| vacuum (MPa) | 0.08 | 0 | 0.08 |
| pressure (MPa) | 0.65 | 0.65 | 0.65 |
| pressure time(minutes) | 30 | 30 | 30 |

After the treatment, the impregnated samples were taken out of the tank and oven dried at 60℃ to a constant weight ( $W_1$). WPG ( weight percent gain) was calculated according to the following formulation:

$$WPG(\%) = (W_1 - W_0) \div W_0 \times 100$$

wherein, $W_0$ – sample's weight before treatment;
$W_1$ – sample's weight after treatment;

#### 2.2.1.2 Pilot test—pressure-only impregnation

Pilot test was conducted in Zhong Mei Linmu Chemistry Limit., Yong Da Group, PanYu county, Guang Dong Province, China. 5 $m^3$ rubberwood, plywood provided also by Nanmao Plywood Factory, was 900 mm × 1800 mm in size, consisted of 3 layers with 1 mm per layer and glued with UF resin. Owing to the limitation of equipment of the factory, pressure-only impregnation method was adopted. Rubber wood plywood was impregnated with $WFR_{1\text{-}2\text{-}a}$ at pressure of 0.3 MPa for 5 hours. Rubberwood plywood for comparison was impregnated at atmosphere pressure for 22 hours.

### 2.2.2 Test of burning behavior and thermal properties

#### 2.2.2.1 Determination of limiting oxygen index (LOI)

Test was conducted on ON-1D combustibility test meter, following the method of GB/T 2406-93. Sample size was 150 mm × 10 mm × the thickness of plywood.

#### 2.2.2.2 Determination of ignition temperature

Plywood was grounded to 20 mesh. particles. The test was conducted using DW-1 ignition temperature test meter, according to the method introduced in reference 3.

#### 2.2.2.3 Determination of FSR

Tunnel test was adopted to determine FSR. Three samples with the size of 160 mm × 90 mm were cut from every untreated plywood . Three with similar WPG were selected from plywood treated with every formula. Two samples with the size of 160 mm × 90 mm were cut from every selected treated plywood. Test was conducted according to GB/T 15442.3-1995. The results of the test was expressed by fire-spread ratio FSR. FSR was calculated as following formulation:

(1) calibrating constant of tunnel furnace ($K$):

$K = 100 \div (L_r - L_a)$;

$L_r$—fire spread length of standard oak board;

$L_a$—fire spread length of standard asbestos board;

(2) FSR of samples:

$FSR = K \times (L_s - L_a)$;

$L_s$—fire spread length of a sample;

The larger FSR value is, the more quickly fire spreads.

#### 2.2.2.4 Determination of release heat

Treated and untreated plywood were grounded into 20 mesh. particles. The test was conducted on JR-7A calorimeter according to the method in reference 3.

#### 2.2.2.5 Determination of smoke density

Sample size was 150 mm × (8～10) mm × the thickness of plywood. following the method of JIS D 1201-77, the test was conducted on ON-1D combustibility test meter and smoke generation property of a material is graded into four grades shown in table 2.

**Table 2 Grades of smoke generation of material**

| Grade | Light consuming coefficient($C_s$) |
|---|---|
| 1 | $C_s < 0.2$ |
| 2 | $0.2 \leqslant C_s < 1.0$ |
| 3 | $1.0 \leqslant C_s < 2.4$ |
| 4 | $C_s \geqslant 2.4$ |

#### 2.2.2.6 Thermo-gravimetric analysis

Plywood was grounded into 20 mesh. DELTA SERIES TGA 7 thermo-gravimetric meter was adopted. Test was conducted in a flow system. High purity nitrogen was used

#### 2.2.2.7 Test for difficult-flammability of building materials

The Chinese National Center for Quality Supervision and Testing of Fixed-extinguishing Systems and Fire-resisting Building Components was entrusted with the test for difficult-flammability of Pilot test products. The standard method was GB/T 8625~8267-88 and the sample was graded according to GB/T 8624-97. The size of the sample was 190 mm × 1000 mm × the thickness of plywood.

### 2.2.3 Determination of glue bonding strength

Glue bonding strength of treated and control samples were tested according to the method of GB 9846.12-88. Pilot test samples were tested by the National Center for Supervision and Testing of Quality of Wood-based Panels.

### 2.2.4 Evaluation of anti-stain and anti-mould activities

#### 2.2.4.1 Preparation of samples

50 mm × 20 mm × 3 mm test blocks were cut from treated and untreated samples, respectively. Wherein No.0 was control one. No. 2 and No. 7 were $WFR_{1\text{-}2\text{-}a}$ treated blocks.

#### 2.2.4.2 Culture plate

The PDA plates inoculated with 5 cultures for test were cultivated at 28 ℃ in an electrothermal incubator. About four days latter, when the colony in each dish was well established, spore suspension was ready to be prepared.

#### 2.2.4.3 Preparation of spore suspension

The spore and mycelia with some culture medium were picked up from dishes and then, moved into a sterile cone-shaped flask which had contained some sterile water and glass beads in. Shake the flask for a few minutes. The suspension in the flask was then, ready for the next inoculation.

#### 2.2.4.4 Inoculation of the spore suspension

The prepared spore suspension was drawn into a sterile needle tube and then moved onto the dishes which had contained PDA culture medium. 0.2~0.5 mL suspension was added on each dish. After culture at 28 ℃ for about 3~4 days, plywood blocks were ready to be inoculated in the dishes on which the mycelia had thrived

#### 2.2.4.5 Inoculation of plywood blocks

Two methods were adopted for the inoculation of plywood blocks:

(1)Sample blocks were wrapped with layers of gauze and then, steam-sterilized at 100 ℃ for 30 minutes. After cooled down, the sterilized blocks were inoculated into the dishes (see also 2.2.4.4). Two blocks for each dish were put horizontally on two glass bars with a certain distance between. The block did not contact with culture medium. The dishes were immediately removed to an electro-thermal incubator at 28 ℃, 85% *R.H.* or higher for 28 days. Six duplication were for each treated plywood sample. The assessment could be made after the blocks had been exposed to the test fungi at 28 ℃, 85% *R.H.* or higher for 28 days.

(2)Sample blocks were put together with seriously infected rubberwood veneers on a plastic shelf that stood in an iron trough with clean water in. The trough was then, covered with a piece of cloth or plastic film. Each duplication contained 10 blocks. The assessment could be made after the blocks exposed at 23℃ ~26℃ and 90% *R.H* or higher for about 20 days.

#### 2.2.4.6 Test assessment

Observation of the trail was made at least once every 7 days to check the infectiosity of the blocks. When the final observation was finished, the blocks were taken out and checked for their discoloration both on the surface and inside the blocks. Anti-mould or anti-stain efficacy was calculated according to the infectiosity grade that was determined by the infected area on the surface of blocks and discolored degree inside the blocks. The method for grading infectiosity was shown in table 3.

**Table 3 Grades for infectiosity of tested blocks**

| Infectiosity grade ($D$) | Infected area and discolored degree |
|---|---|
| 0 | without infection on the surface, without change in color on the surface and inside the blocks |
| 1 | Infected area on the surface <1/4 of the whole surface area, without change in color inside the blocks |
| 2 | Infected area on the surface = 1/4 ~ 1/2 of the whole surface area, without change in color inside the blocks |
| 3 | Infected area on the surface = 1/2 ~ 3/4 of the whole surface area, or blue stained area inside the blocks = 1/10; |
| 4 | Infected area on the surface >3/4 of the whole surface area, or blue stained area inside the blocks >1/10 |

Calculation: $E = (1 - D_1/D_0) \times 100$

wherein: $E$—anti-mould efficacy

$D_1$—average infectiosity ($D$) of treated blocks

$D_0$—average infectiosity ($D$) of controls

### 2.2.5 Determination of hygroscopicity

Each duplication contained two pieces of samples with the size of 8 cm × 15 cm. Samples were put in an oven at 80℃ to a constant weight before and after the treatment. Weighted the samples to the accuracy of 0.01 gram and WPG was calculated.

#### 2.2.5.2 Test of hygroscopicity

Au samples were vertically put on the wire netting, that was as a partition in a large size desicator from distilled water in the bottom. The environment in the desicator kept at 25 ℃ ~30 ℃, 100% $R.H.$ Weight the samples once a day ($W_2$).

#### 2.2.5.3 Calculation of hygroscopicity

(1) Hygrospic rate of samples($B$):

$$B = (W_2 - W_1) \div W_0 \times 100$$

Wherein, $W_2$ = weight of the treated sample after exposure in the test environment;
$W_1$ = weight of the treated sample before exposure in the test environment;
$W_0$ = weight of untreated samples.

(2) Hygroscopic rate of the treated sample, of which WPG was assumed to be 1% :

$$C = (B_s - B_0) \div A$$

Wherein, $B_s$ = hygroscopic rate of treated sample;
$B_0$ = hygroscopic rate of untreated sample;
$A$ = WPG.

## 3 Results and discussions

### 3.1 Laboratory experiment

#### 3.1.1 Treating parameters

##### 3.1.1.1 Effect of vacuum on fire-retardance

Table 4 showed the data.

**Table 4 Effect of vacuum on fire-retardance**

| No. of samples | Formula | Vacuum (bar) | WPG (%) | LOI (%) |
|---|---|---|---|---|
| 21 | $WFR_{1\text{-}1\text{-}a}$ | 0 | 11.6 | 48 |
| 22 | $WFR_{1\text{-}1\text{-}a}$ | 0.8 | 16.9 | 54 |

Obviously, vacuum did effect on the treatment efficacy. WPG and LOI were lowered if vacuum was not applied.

#### 3.1.1.2 Effect of pressure on fire-retardance

Efficacy of treating with the same formula at the same concentration was in table 5.

**Table 5 Effect of pressure on fire-retardance**

| No. of samples | Pressure (MPa) | Pressure time (min) | WPG (%) | LOI (%) |
|---|---|---|---|---|
| 12 | 0.65 | 30 | 17.5 | 58 |
| 20 | 0.50 | 30 | 15.6 | 53 |

It was indicated that pressure did effect treatment efficacy. WPG was lower when pressure was low. Although protracting the treatment could reach the required WPG and LOI, the output of production would be decreased.

### 3.1.2 Burning behavior and thermal properties

#### 3.1.2.1 Ignition property

(1) Ignition temperature: The ignition temperature of $WFR_{1\text{-}2\text{-}a}$ treated rubberwood plywood and control one was listed in table 6.

**Table 6 Ignition temperature of FR rubberwood plywood**

| Plywood | WPG (%) | Moisture content (%) | Ignition temperature (℃) |
|---|---|---|---|
| Control | 0 | 6.72 | 283 |
| $WFR_{1\text{-}2\text{-}a}$ treated | 15.82~16.59 | 7.10 | 280 |

FR rubber wood plywood showed lower ignition temperature than the control one. Because FR treatment changed the mode of thermal degradation of the material, thermal degradation started at lower temperature.

(2) Limiting oxygen index: The result was in table 7.

**Table 7 Limiting oxygen index of FR rubberwood plywood**

| Number | Formula | WPG (%) | Limiting oxygen index (%) |
|---|---|---|---|
| 1-1 | $WFR_{1\text{-}1\text{-}a}$ | 20.43 | 59 |
| 1-2 | $WFR_{1\text{-}1\text{-}a}$ | 17.50 | 58 |
| 1-3 | $WFR_{1\text{-}1\text{-}a}$ | 16.90 | 54 |
| 1-4 | $WFR_{1\text{-}1\text{-}a}$ | 15.27 | 57 |
| 1-5 | $WFR_{1\text{-}1\text{-}a}$ | 15.30 | 59 |
| 1-6 | $WFR_{1\text{-}1\text{-}a}$ | 13.88 | 57 |
| 2-1 | $WFR_{1\text{-}2\text{-}a}$ | 23.22 | 62 |
| 2-2 | $WFR_{1\text{-}2\text{-}a}$ | 16.80 | 56 |

(to be continned)

| Number | Formula | WPG (%) | Limiting oxygen index (%) |
|---|---|---|---|
| 2-3 | $WFR_{1-2-a}$ | 15.70 | 54 |
| 2-4 | $WFR_{1-2-a}$ | 15.58 | 60 |
| 2-5 | $WFR_{1-2-a}$ | 13.82 | 59 |
| 2-6 | $WFR_{1-2-a}$ | 13.40 | 54 |
| 3-1 | $WFR_{1-3}$ | 14.50 | 54 |
| 0 | Untreated | 0 | 28 |

By comparison, the above three formulas were almost at the same level of LOI. However, the cost of $WFR_{1-3}$ was higher than $WFR_{1-1-a}$ and $WFR_{1-2-a}$. $WFR_{1-2-a}$ was the cheapest one of the three.

Limiting oxygen index of untreated rubberwood plywood was greatly lower than the treated one.

### 3.1.2.2 Fire spread property

FSR of untreated and treated rubberwood plywood were showed in table 8.

FSR of rubberwood plywood treated with both $WFR_{1-1-a}$ and $WFR_{1-2-a}$ were greatly lower than control one's. It was suggested that fire spread more slowly for treated samples than for untreated samples. FSR of $WFR_{1-1-a}$ treated samples was almost the same as FSR of $WFR_{1-2-a}$ treated samples.

**Table 8 FSR of FR rubberwood plywood**

| Plywood | Formula | WPG (%) | Ls (cm) | FSR | Average FSR |
|---|---|---|---|---|---|
| control-1 | - | 0 | 406.7 | 117.88 | |
| control-2 | - | 0 | 403.3 | 116.61 | 110.01 |
| control-3 | - | 0 | 346.7 | 95.54 | |
| treated 1-1 | $WFR_{1-1-a}$ | 15.00 | 153.3 | 23.56 | |
| treated 1-2 | $WFR_{1-1-a}$ | 15.00 | 143.3 | 19.84 | |
| treated 3-1 | $WFR_{1-1-a}$ | 15.27 | 176.7 | 32.25 | 25.21 |
| treated 3-2 | $WFR_{1-1-a}$ | 15.27 | 180.0 | 33.48 | |
| treated 6-1 | $WFR_{1-1-a}$ | 15.01 | 163.3 | 27.27 | |
| treated 6-2 | $WFR_{1-1-a}$ | 15.01 | 130.0 | 14.88 | |
| treated 9-1 | $WFR_{1-2-a}$ | 16.68 | 180.0 | 33.48 | |
| treated 9-2 | $WFR_{1-2-a}$ | 16.68 | 166.7 | 28.53 | |
| treated 12-1 | $WFR_{1-2-a}$ | 16.26 | 190.0 | 37.20 | 31.82 |
| treated 12-2 | $WFR_{1-2-a}$ | 16.26 | 193.3 | 38.43 | |
| treated 15-1 | $WFR_{1-2-a}$ | 15.58 | 166.7 | 28.53 | |
| treated 15-2 | $WFR_{1-2-a}$ | 15.58 | 156.7 | 24.81 | |

### 3.1.2.3 Releace heat of combustion

The test data was showed in table 9.

**Table 9　Calorific value of FR rubber wood plywood**

| Plywood | Heat value | |
|---|---|---|
| | Cal/g | kJ/g |
| control | 4630 | 19.35 |
| fire-retardant | 4276 | 17.87 |

Obviously, FR treatment lowered the heat value of rubberwood plywood.

### 3.1.2.4　Smoke-generation property

Grade of smoke-generation for untreated and treated rubberwood plywood was in table 10.

**Table 10　Smoke-generation grade of FR rubber wood plywood**

| No. | Formula | WPG(%) | Penetration rate of light (%) | LCC* | grade |
|---|---|---|---|---|---|
| 2 | $WFR_{1-1-a}$ | 20.43 | 99.5 | <0.2 | 1 |
| 3 | $WFR_{1-1-a}$ | 15.27 | 99.2 | <0.2 | 1 |
| 7 | $WFR_{1-1-a}$ | 13.88 | 99.3 | <0.2 | 1 |
| 8 | $WFR_{1-2-a}$ | 13.82 | 99.0 | <0.2 | 1 |
| 13 | $WFR_{1-2-a}$ | 23.22 | 98.4 | <0.2 | 1 |
| 15 | $WFR_{1-2-a}$ | 15.58 | 98.8 | <0.2 | 1 |
| 0 | Untreated | 0 | 99.1 | <0.2 | 1 |

* light-consuming coefficient.

FR rubberwood plywood was at the same grade of smoke-generation as the control one. Both $WFR_{1-1-a}$ and $WFR_{1-2-a}$ did not increase smoke concentration .

### 3.1.2.5　Thermal gravimetric analysis

curve 1 and curve 2 (See appendix) were the thermal gravimetric curves of untreated and WFR treated rubber wood plywood. From the 2 curves, table 11 was summarized.

**Table 11　Data of thermogravimetric analysis of FR rubberwood plywood**

| | FR rubber wood plywood | Control |
|---|---|---|
| sample weight (mg) | 9.021 | 10.103 |
| outset of pyrolysis (℃) | 179.33 | 232.6 |
| weight lost (%) | 58.334 | 74.659 |
| peak pyrolysis temp. (℃) | 319.20 | 360.71 |

FR rubberwood plywood showed the following characteristics in comparison with control one:

started pyrolysis and release combustible gas at lower temperature. It resulted in decrease of the concentration of combustible gas and decrease of heat released from burning the material. The same explanation could be given to the test result of ignition temperature of FR rubberwood plywood.

(b) Lower weight loss: It suggested that FR treatment provided protection to rubberwood plywood resulted from the formation of thicker charring layer.
(c) lower peak temperature: It indicated that treating with WFR lowered the temperature at that the highest thermal decomposition rate was reached.

Comprehensive flammability of FR rubberwood plywood was lower than untreated one . Rubberwood plywood could be modified from a flammable material to a difficult- flammable material by FR treatment with $WFR_{1\text{-}1\text{-}a}$ or $WFR_{1\text{-}2\text{-}a}$.

### 3.1.3 Glue bonding strength

Glue bonding strength of treated rubber wood plywood was showed in table 12.

Bonding strength of treated samples was the same as that of untreated samples. This result agreed with the result in previous research.

**Table 12 Glue bonding strength of vacuum-pressure impregnated samples**

| Samples | WPG (%) | Glue bonding strength (MPa) / Qualification rate (%) | |
|---|---|---|---|
| | | Treated plywood | Untreated plywood |
| 10 | 13.8 | 1.32 / >80% | 1.75 / >80% |
| 12 | 17.5 | 1.49 / 100% | 1.43 /100% |
| 13 | 16.8 | 2.43 / 100% | 1.75 / 91% |
| 19 | 6.68 | 1.3 / 100% | 1.9 / 100% |
| 20 | 15.6 | 1.25 / 100% | 1.6/ 100% |
| 21 | 11.6 | 1.17 / 100% | 1.55 / 100% |
| 22 | 16.9 | 2.5/ 100% | 1.3/ 100% |
| 23 | 15.7 | 1.4/ 90% | 1.5/ 70% |
| 24 | 14.5 | 1.45 / 88.9% | 1.41 / 92% |

### 3.1.4 Hygroscopicity

The test results were showed in table 13 and figure 1. It was showed that hygroscopic rate for No.6 was significantly higher than that of No.7 and No.22. No.22 showed the lowest hygroscopic rate.

**Table 13 C of FR rubberwood plywood samples**

| Days | sample | | |
|---|---|---|---|
| | 6# | 7# | 22# |
| 1 | 0.2 | 0.11 | 0.11 |
| 2 | 0.35 | 0.19 | 0.16 |
| 3 | 0.37 | 0.23 | 0.24 |
| 4 | 0.79 | 0.38 | 0.41 |
| 5 | 0.93 | 0.51 | 0.38 |
| 6 | 1.05 | 0.52 | 0.36 |
| 7 | 1.22 | 0.59 | 0.43 |
| 8 | 1.15 | 0.62 | 0.5 |
| 9 | 1.05 | 0.68 | 0.48 |
| 10 | 0.98 | 0.59 | 0.44 |
| 11 | 0.88 | 0.59 | 0.48 |
| 13 | 1.15 | 0.7 | 0.44 |
| 14 | 1.16 | 0.77 | 0.43 |
| 15 | 1.28 | 0.87 | 0.47 |
| 18 | 1.39 | 1.03 | 0.5 |
| 17 | 1.79 | 1.12 | 0.68 |
| 19 | 1.86 | 1.35 | 0.74 |
| 20 | 2.21 | 1.52 | 0.99 |
| 21 | 1.99 | 1.27 | 0.91 |
| 22 | 2.19 | 1.49 | 1.08 |
| 23 | 2.19 | 1.42 | 1.1 |
| 25 | 2.54 | 1.64 | 1.32 |
| 26 | 2.61 | 1.65 | 1.41 |
| 28 | 2.74 | 1.69 | 1.55 |
| 29 | 2.77 | 1.68 | 1.6 |
| WPG (%) | 8.09 | 17.04 | 17.16 |

* No.6: rubberwood plywood treated with 6# formula;
* No.7: rubberwood plywood treated with $WFR_{1\text{-}1\text{-}a}$;
* No.22: rubberwood plywood treated with $WFR_{1\text{-}2\text{-}a}$.

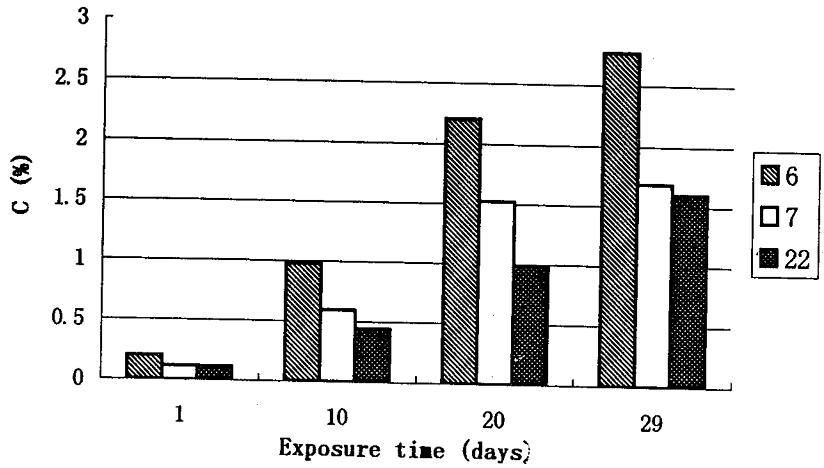


Figure 1 Comparison of hygroscopic rate among 3 formulas

### 3.1.5 Anti-stain and anti-mould efficacy

The data in table 14 showed that No. 2 and No. 7 had strong resistance to blue stain fungi. After 28 days of exposure, infection and stain was hardly fond both on the surface and inside the blocks, while No. 0 was infected 4 days latter and mycelium had covered the surface. After 28-day exposure, more or less stain was fond inside the blocks No. 0.

**Table 14 D of blocks infected by testing fungi (culture dish)**

| No. | *Aspergillus niger* | | | | *Trichoderma lignorum* | | | | *Penicillium citrinum* | | | | *Botriodiplodia theobromae* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7 | 14 | 21 | 28 | 7 | 14 | 21 | 28 | 7 | 14 | 21 | 28 | 7 | 14 | 21 | 28 |
| 0 | 0 | 4.00 | 4.00 | 4.00 | 0 | 2.83 | 3.83 | 4.00 | 0 | 2.17 | 3.50 | 3.67 | 1.33 | 2.33 | 2.33 | 3.00 |
| 2 | 0 | 0.83 | 1.33 | 3.50 | 0 | 0.50 | 0.67 | 2.00 | 0 | 0.17 | 1.33 | 2.33 | 0 | 0 | 0 | 0 |
| 7 | 0 | 0.67 | 1.83 | 3.50 | 0 | 0.33 | 0.50 | 1.33 | 0 | 0.33 | 0.67 | 1.33 | 0 | 0 | 0 | 0 |

The test result of water trough showed that within 7 days, treated blocks without sterilization were infected by 3 other fungi but less than the untreated ones. No. 0 was covered by mycelia within 7 days, while No. 2 and No. 7 were covered by mycelia within 14 days (Table 15).

### 3.1.5.2 Anti-mould efficacy

The results of anti-mould and anti-stain efficacy were showed in table 16, table 17, respectively.

**Table 15 *D* of blocks infected by mixed testing fungus in culture box (water trough)**

| No. | Mixed testing fungus | | | |
|---|---|---|---|---|
| | 7 days | 14 days | 21 days | 28 days |
| 0 | 4.00 | 4.00 | 4.00 | 4.00 |
| 2 | 1.70 | 4.00 | 4.00 | 4.00 |
| 7 | 2.50 | 4.00 | 4.00 | 4.00 |

**Table 16 *E* of FR rubberwood plywood (28 days)**

| No. | Duplication | Average of *D* | | | Total *D* | Anti-mould efficacy *E*** (%) |
|---|---|---|---|---|---|---|
| | | A* | B* | C* | | |
| 0 | 6 | 4.0 | 4.0 | 3.67 | 11.67 | 0.00 |
| 2 | 6 | 3.5 | 2.0 | 2.33 | 7.83 | 32.90 |
| 7 | 6 | 3.5 | 1.33 | 1.33 | 6.16 | 47.22 |

* A—*Aspergillus niger*;
* B—*Trichoderma lignorum*;
* C—*Penicillium citrinum*;
* * *E* for treated blocks was in reference to *E* for No. 0.

Table 17 $E$ of rubberwood plywood (28 days)

| No. | Duplication | Average $D$ *Botryodiplodia theobromae* | anti-blue stain efficacy $E^*$ (%) |
|---|---|---|---|
| 0 | 6 | 3.0 | 0.00 |
| 2 | 6 | 0 | 100 |
| 7 | 6 | 0 | 100 |

$E$ for treated blocks was in reference to $E$ for No.0.

After 28-day exposure in culture dishes, No. 0 was fully covered by mycelia and seriously covered by blue-stain fungi. The anti-mould efficacy was assumed to be 0%. In reference to No. 0, anti-mould efficacy of No. 2 and No. 7 were 32.98% and 47.22%, respectively. The anti-blue efficacy of both No. 2 and No. 7 were 100%.

#### 3.1.5.3 Resistance of rubberwood plywood to mixed cultures infecting rubber wood veneer in open air

Considered the effect of sterilization at high pressure and high temperature on the anti-mould efficacy and bonding strength of plywood, steam-sterilization (at 100℃ for 30 minutes) was adopted in this paper. However, samples were easily contaminated by some naturally growing myceto-community in the case without thorough sterilization, especially in the south of China where the weather keeps humid and hot. After 7 days of exposure, the blocks began to be contaminated by some other myceto-community (mainly by some species of Aspergillum sp.). 28 days latter, No. 0 was fully covered by some myceto-community, No. 2 and No. 7 were more or less infected.

It was thus clear that $WFR_{1-3}$, $WFR_{1-1-a}$ and $WFR_{1-2-a}$ were almost at the same level of fire retardance . The cost of the three formulas was: $WFR_{1-3} > WFR_{1-1-a} > WFR_{1-2-a}$. $WFR_{1-2-a}$ was determined to be the fire-retardant formula for the pilot test because it showed good fire retardance , low cost and little inverse effect on the bonding strength of treated rubberwood plywood. In addition, hygroscopicity of $WFR_{1-2-a}$ treated sample was lower than that of $WFR_{1-1-a}$-treated one . It could also impart rubber wood plywood good resistance to blue stain fungi and a certain extent of resistance to the other moulds.

## 3.2 Pilot production test

### 3.2.1 WPG of treated products

WPG for pilot treated rubberwood plywood were listed in table 18.

| No. | Weight before impregnation (g) | Weight after impregnation (g) | WPG (%) |
|---|---|---|---|
| 1-50 | 1.88 | 2.20 | 17 |
| 1-95 | 1.81 | 2.15 | 19 |
| 1-70 | 1.70 | 1.95 | 15 |
| 2-39 | 1.79 | 2.20 | 22.9 |
| 2-101 | 1.72 | 2.05 | 19.2 |
| 3-50 | 1.65 | 1.92 | 16.7 |
| 4-90 | 1.69 | 2.00 | 18.3 |

Limited by the equipment, the technical parameters for treatment were changed for the pilot production. In this case, WPG of treated samples could reach at least 15%. However, production efficiency was very low. Besides, it might be in danger of delamination of the plywood after impregnated for a long time. Therefore, vacuum-pressure impregnation was still recommended in production.

### 3.2.2 Glue bonding strength of the pilot products

The test data were showed in table 19.

**Table 19 Glue bonding strength of the pilot product**

| Sample | Standard specification | Test data | |
|---|---|---|---|
| | | Treated sample | Control sample |
| maximum (MPa) | – | 3.12 | 2.89 |
| minimum (MPa) | 0.70 | 1.17 | 0.99 |
| wood fracture (%) | – | 61 | 41 |
| Judgment | | qualified | qualified |

Bonding strength of rubberwood plywood was not decreased, but slightly increased after the plywood was impregnated with $WFR_{1-2-a}$.

### 3.2.3 Limiting oxygen index of pilot products

Limiting oxygen index of pilot products was showed in table 20.

**Table 20 Limiting oxygen index of pilot products**

| Technical parameter | LOI (%) | |
|---|---|---|
| | Edge | Middle |
| pressure: 0.3 MPa, 5 hours | 64 | 61 |
| atmosphere pressure, 22 hours | 57 | 47 |

It was remarkable that impregnation at atmosphere was not as efficacious as impregnation at pressure of 0.3 MPa, although the former one was conducted for as long as 22 hours.

Comparing with the edge of the sample, LOI in the middle of the sample was lower. For the samples treated at the atmosphere, the difference was more remarkable.

### 3.2.4 Difficult-flammability of building materials

The test result was listed in table 21.

**Table 21 Test result for difficult-flammability of building materials**

| Test items | Standard and specifications | Test result | Conclusion |
|---|---|---|---|
| Test for flammability | burning behavior meet the specification of GB/T8626-88, without filter paper being ignited by burning droplet | The pointed end of the flame does not reach graduated line within 20 seconds after ignition, without droplet | qualified |
| average residual length after burning (mm) | GB/T 8625-88, >150 mm, | 305 mm | qualified |
| average temperature of smoke (℃) | GB/T 8625-88, ≤200℃ | 147℃ | qualified |
| smoke density (SDR) | GB/T 8627-88, SDR≤75, | SDR = 38 | qualified |
| judgment | GB/T 8624-97 | grade $B_1$ | qualified |

Pilot products passed the test for difficult-flammability of building materials and meet all specifications of grade $B_1$, GB/T 8624-97.

## 4 Conclusion

Conclusions could be drawn out from the results of both laboratory experiment and pilot test:

(1) Formula $WFR_{1\text{-}2\text{-}a}$ could impart desirable fire retardance to rubberwood plywood. Sampling tests showed the mode for pyrolysis of Rubberwood plywood was changed after treating with $WFR_{1\text{-}2\text{-}a}$. Pyrolysis started at lower temperature and combustible gas was released at lower temperature. It resulted in lowered concentration of combustible gas, lower heat value released during burning the rubberwood plywood and accelerated the formation of charcoal layer. Therefore, treatment with $WFR_{1\text{-}2\text{-}a}$ could greatly restrain rubber wood plywood from gaseous-burning that was the key stage for the formation and spread of fire disaster.

(2) The treatment with $WFR_{1\text{-}2\text{-}a}$ did not damage the adhesive layer of rubberwood plywood.

(3) Rubberwood plywood treated with $WFR_{1-2-a}$ showed relatively higher resistance to stain fungus and a certain extent of resistance to other moulds that usually infect rubber wood.

(4) $WFR_{1-2-a}$ resulted in lower hygroscopic rate to treated rubber wood plywood than common phosphor-nitrogen category and $WFR_{1-1-a}$.

(5) Cost of $WFR_{1-2-a}$ was cheaper than $WFR_{1-1-a}$ and much cheaper than the imported ones.

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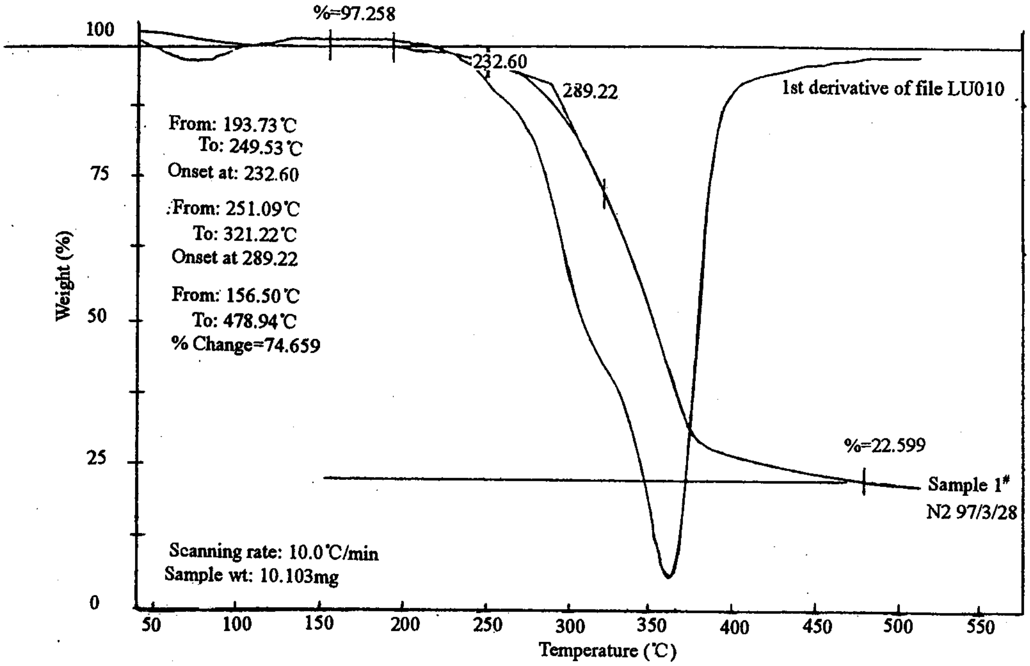
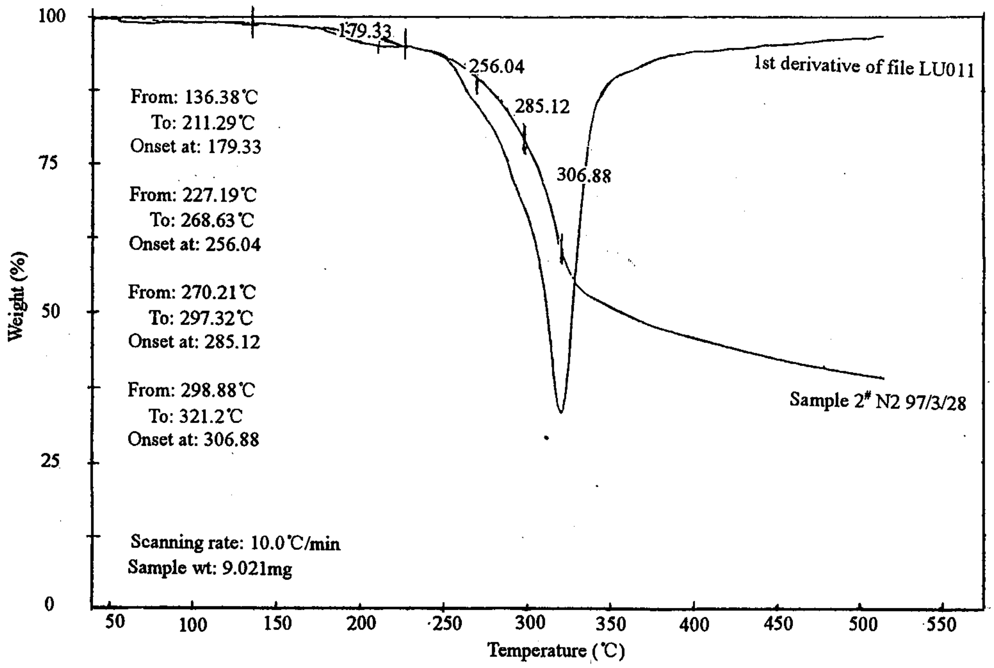



Curve 1 Thermogravimetric analysis—untreated rubberwood plywood




Curve 2 Thermogravimetric analysis—$WFR_{1\text{-}2\text{-}a}$ treated rubberwood plywood

# STUDY TOUR REPORT ON RUBBERWOOD PROCESSING IN MALAYSIA AND THAILAND

## 1 Acknowledgment

We would like to take this opportunity to express our sincere gratitude to the following organizations and persons for the assistance, which is necessary for the success of our study tour to Malaysia and Thailand on the processing and utilization of rubberwood:

The Chinese government, particularly the Ministry of Forestry, Chinese Academy of Forestry, and the Chinese Research Institute of Wood Industry, for nominating Mrs. Yang Hong, Mr. Li Yudong, Mrs. Xing Jiaqi and Mr. Lin Zechuan as the candidate of the participants of the study tour.

The International Tropical Timber Organization and Forest Industry Department of ITTO for concurring in our proposal concerning the participants of the study tour and supporting the visit.

Dr. Hwan-Ok Ma, Project Manager from ITTO for his guidance and strong support of the study tour programme.

Mr. Colin Braithwaite, Managing Director, Mr. Eric Loh Kok Seng, General Sales Manager, Koppers-Hickson Timber Protection (M) Sdn. Bhd. in Kuala Lumpur, for the excellent organizing our study tour programme.

Mr. Hong L.T., Director of Corporate Affairs Division, Dr. Daniel Baskaran Krishnapillay, Director of Plantation Forestry Division, Dr. Laurence G. Kirton Entomologist from Environmental Division, Dr. Sim Heok Choh, Head of Constancy & Technical Services unit from Corporate Affairs Division, Mr. Ho Kam Seng, Research Officer of Wood Processing, Mr. AB. Rasip AB. Ghani, Research Officer of Tree Improvement, at Forest Research Institute of Malaysia; Mr. Singaram, Assistant Director, Technical Division of The Malaysia Timber Industry Board; Mrs. Chithra Raj, Mrs. Young Kam Han, Technical and Quality Manager, Mr. Cheam Tat Kong, Sales Manager, Mrs. Cathy Lau yen Kwan, Technical Service Executive, Mr. Minh Nguyentien, Technical Manager, from Koppers-Hickson both in Kuala Lumpur and Bangkok; Mr. Narong Pengpreecha from Wood Industry Research and Development, Forestry Research Office, Royal Forest Dept. in Thailand for their effective assistance and personal guidance to our study tour.

## 2 Outline of the arrangement

According to the agreement of the ITTO project "Development and Extension of Rubberwood Processing and Utilization Technology" PD 3/96 Rev.2(I), the proposal concerning the itinerary and the participants of the study tour for Malaysia and Thailand were completed and forwarded to ITTO by Madam Yang Hong, Project Leader on 22 April and 13 May 1997, and the arrangement for the study tour was approved and finalized by ITTO as informed by Dr. Hwan-Ok Ma's Fax dated on 13 May 1997.

The countries to be visit was changed to Malaysia instead of Indonesia as planned in the original project document, because Malaysia has become the centre and model for the processing and utilization of rubberwood in the world. The date of the visit was delayed three months due to the visa application.

## 3 Introduction

We were pleased to have had a three-week study tour to Malaysia and Thailand to study the rubberwood processing and utilization technology, which was cued to the project activity 2.2 under the assistance of acknowledged institutions, organizations and persons mentioned above. As Malaysia and Thailand have very rich rubber-tree resources and rubberwood is one of the more popular timbers used for the manufacture of quality furniture and furniture components, this two countries have become the model for the processing and utilization of rubberwood in the world. The objective of the study tour was to learn and share their successful processing and utilization of rubberwood in the field of plantation management, treatment, sawn timber, furniture and panel products processing, government support programmes and uses etc.

This study tour was successfully carried out in two countries and was made great progress. We are sure that what we learnt during the visit would benefit not only the R&D conducted by the project group but also the rubberwood industries in China. We will do our best to make full use of the newly learnt knowledge in our R&D work and will share it with the people from rubberwood industries in China. This report is written both in English and in Chinese, the Chinese version is being sent to related aspects in China.

## 4 Main activities

| | | |
|---|---|---|
| 1 June (Sun) | | travel from Beijing to Kuala Lumpur |
| 2 June (Mon) | | visit the Forest Research Institute of Malaysia (FRIM) |
| | Am | meet Mr. Hong L. T. , Director of Corporate Affairs Division, and visit the Forest Products Division, including: Joinery Workshop, Plywood Production Line, Fire Retardant Test Chamber, Solar Drying Kiln, Test Spot of Preservatives Evaluation and Bamboo Processing Workshop, etc. |
| | | visit Plantation Forestry Division and discuss with Dr. Daniel Baskaran Krishnapillay, Director, on rubber plantation, such as clone, site and management |
| | Pm | discuss with Mr. Ho Kam Seng, Research Officer of wood processing |

| | | |
|---|---|---|
| 3 June (Tue) | | visit FRIM |
| | Am | visit the Tropical Plantation on Canopy Walkway in FRIM |
| | Pm | discuss with Mr. Hong L. T. on the cooperation between FRIM and CRIWI on this ITTO project;<br>visit Insect Specimen Showroom and discuss with Dr. Laurence G. Kirton, Entomologist, about wood damaging insects |
| 4 June (Wed) | | visit Koppers-Hickson (KH) Office in Kuala Lumpur |
| | Am | presentation on "The Rubberwood in General" by Ms. Young Kam Han, Technical and Quality Manager, KH |
| | Pm | open discussion: 1) rubberwood processing in Hainan; 2) the treatment of rubberwood |
| 5 June (Thu) | Am | visit The Malaysian Timber Industry Board (MTIB) to meet Mr. Singaram, Assistant Director, Technical Division; open discussion, collect information at Publications at MTIB |
| | Pm | visit IKEA's Furniture Show in Kuala Lumpur |
| 6 June (Fri) | | inter-group discussion |
| 7~8 June (Sat, Sun) | | free |
| 9 June (Mon) | Am | travel from Kuala Lumpur to Kluang |
| | Pm | visit Belandar (Sawn Timber)Sdn. Bhd.<br>visit Sindora Berhad (A Member of the Johor Corporation Group of Companies), including Plantation, Swan Timber, Sindora Door, Sindora Furniture Sdn. Bhd.<br>visit Teckching Timber (M) Sdn. Bhd. |
| 10 June (Tue) | Am | visit Techwood Lumber Products<br>visit Haleywood Industries Sdn. Bhd. for rubberwood furniture manufacturing<br>visit GCT Wood Industries Sdn. Bhd.<br>visit Syarikat Kayu Wangi Bhd. for rubberwood door making |
| | Pm | visit Abolute Progress Sdn. Bhd. for rubberwood sawntimber<br>visit Buan Lee Industries Sdn. Bhd. (a new treatment plant) |
| 11 June (Wed) | Am | Group Discussion |
| | Pm | visit the Tropical Plantation near KL |
| 12 June (Thu) | | Seminar |
| | Am | Utilization of Rubberwood for Panelboard in Malaysia |

| | | |
|---|---|---|
| | Pm | Frame Saw Technology and Solid Wood Flooring Manufacture |
| 13 June (Fri) | | de-briefing and discussion |
| 14 June (Sat) | | travel from Kuala Lumpur to Bangkok |
| 15 June (Sun) | | free |
| 16 June (Mon) | Am | visit Wood Industry Research & Development, Forestry Research Office, Thai Royal Forest Dept. in Bangkok |
| | Pm | fly to Hatyai |
| 17 June (Tue) | Am | visit A + S Sawmill Co. Ltd<br>visit Furniture Co. Ltd. for sawntimber and finger jointed lumber manufacturing |
| | Pm | visit AP Wood Treatment Plant |
| 18 June (Wed) | Am | visit TN Parawood Co. Ltd. for sawntimber and furniture manufacturing<br>visit NARA Para Co. Ltd. Treatment Plant |
| 19 June (Thu) | | travel from Hatyai to Kuala Lumpur |
| 20 June (Fri) | | Seminar on Rubberwood Downstream Activities and International Marketing |
| 21 June (Sat) | | travel from Kuala Lumpur to Beijing |

## 5 Major findings

### 5.1 Rubberwood

Rubberwood is a light hardwood with an air-dry density ranging from 560 ~ 640 $kg/m^3$. Sawlogs are typically less than 2.5 metres long and are between 15 and 40 centimetres in diameter. Offen logs are knotty and contain defects caused by careless latex tapping. Rubberwood sands and turns well, and has a distinctive grain. The wood stains readily and can be made to look like higher priced hardwoods including cherry, oak, walnut and mahogany. Rubberwood is pale yellow when cut but seasons to pale red or cream. Colour varies according to locality and colour mis-matching can hinder the use of rubberwood in high value products. The wood has a suitable strength and good machining properties, but its high starch content attracts a range of insects and fungal diseases, especially blue stain. Hence, it must be properly treated to prevent deterioration of wood which would result in much wastage of useful material and financial loss.

reason could be its fast biodegradation and susceptibility to insect infestations after felling. The shortage of logs, together with a weakening demand by the export markets because of the economic downturn worldwide have resulted in the closure of a number of sawmills in Malaysia in the mid 1980's. It was timely that during the same period, rubberwood utilization was initiated. At present, rubberwood as a waste product of the rubber industry and as an environmentally acceptable substitute for rain forest timber, it is a direct competitor with other hardwoods in the furniture, panelboard and joinery markets. Malaysia and Thailand have now become the centre and model for the processing and utilization of rubberwood worldwide.

## 5.2 Rubberwood resources

The total area of rubber plantations world wide is more than nine million hectares. Almost all of this is in South-east Asia, with three-quarters of the world's rubber resource found in Indonesia, Thailand and Malaysia. The availability of rubberwood is assured through the systematic replanting programmes of rubber plantations. The total available rubberwood in the ASEAN region is estimated to be about 17 million$m^3$.

Malaysia has 2.0 million $hm^2$ of rubber plantations of which 1.7 million $hm^2$ is in Peninsular Malaysia. Replanting is carried out at an estimated rate of 3% per annum and about 8 to 10 million $m^3$ of rubberwood, including branch wood greater than 15 cm diameter is available annually. Rubberwood supplies are at a peak of 700 000 $m^3$ per annum. But production is expected to drop sharply to 450 000 $m^3$ by 2000, then rise slowly after this. In Peninsular Malaysia, it is estimated that about 2 million $m^3$ rubberwood are utilized by the timber and wood-based annually, even though about 3.2 million $m^3$ are suitable for conversion into sawn timber.

In a plantation, the trees are usually felled 25 ~ 35 years after planting, and rarely grow higher than 25 metres. The available wood volume per hectare is dependent upon numerous factors, such as clone, site and management. In general, between 160 ~ 185 $m^3$ per $hm^2$ for diameter above 15 cm could be obtained. Sawlogs are typically less than 2.5 metres long and are between 15 ~ 40 cm in diameter. Often logs are knotty and contain defects caused by careless latex tapping.

## 5.3 Clonal development and management system for rubberwood production

At present, the rubber-growing in the country has focused not only on the production of latex but also on the production of good timber. The clone or species to be used has been different before. These changes are needed to achieve the quality and quantity of rubberwood required for the downstream activities. The Rubber Research Institute of Malaysia (RRIM) have re-oriented their emphasis to look for rubber clones which can provide a high wood volume at harvest. It is also placing emphasis in breeding fast-growing clones with good latex and timber production and finding a management system suitable for rubber tree forest plantations. As we learnt from a recent paper by RRIM during our stay in FRIM, the clones identified suitable for rubberwood-latex plantations are 25 clones from the RRIM 900 series, RRIM 2000 series and PB 200 and PB 300 series . These materials have good secondary characteristics and can be considered suitable for wood production.

The establishment and management system of rubber plantation for the production of latex as the main crop and timber as secondary product is well known. To ensure an adequate of rubberwood, one of the approaches is to increase timber yield at the end of the economic cycle of the latex production. This requires and adjustment to the present management system. One of the approaches is to replant with planting materials of high timber and latex production. To ensure that the wood quality and quantity is not effected, tapping systems such as short-cut and puncture tapping for latex extraction can minimize wood injury, thus resulting in good wood recovery.

Another option possible to ensure an adequate supply of rubberwood is to reduce the planting cycle of rubber plantation from the original 25～30 years cycle to 15～20 years cycle, and latex extraction only commences at the 8th year after planting and will continue over 7 years before the initial felling. The proposed initial density is 700 trees/$hm^2$ and expected to have a stand of 570 trees/$hm^2$ at the end of the planting cycle.

The establishment and maintenance of rubber plantation for timber production is a new concept, and the private sector and the Forest Department are looking into forest plantations of rubber trees for such purpose. The combine silvicultural techniques of forest plantation and some agronomic inputs from hevea plantation are used. RRIM has proposed that a 15 year rotation cycle with an initial planting density of 1 000 trees/$hm^2$ instead of the normal 25～30 years for the production of rubberwood.

Prior to the utilization of rubberwood by the wood-based industry, the rubber plantation owners had to pay contractors to fell and remove the trees during replanting. Presently the reverse situation is taking place in which rubberwood users have to pay the rubber plantation owners from between M $ 300 to M $ 2 000 per $hm^2$ to fell and remove the rubberwood logs during replanting. This has greatly benefited the rubber plantation owners especially during periods when the latex price is low.

81% of rubberwood in Malaysia and almost all in Thailand are grown on small holdings. Small holdings are privately-owned between 0.5 and 5 hectares. It is usually not economical to recover rubberwood from small holdings. Most estates are owned by national or regional governments, larger than 40 $hm^2$ and often date from colonial times. They are usually located on productive sites with good access to markets.

## 5.4 Rubberwood processing

Since the success in the utilization of rubberwood, the rubberwood processing capacity in ing solely rubberwood. These consisted of 175 swamills, 12 panel products manufacturing mills, 45 moulding and joinery mills and 87 furniture plants. In Thailand, there are 211 rubberwood processing mills with consumption of 1.2 million $m^3$ rubberwood each year.

### 5.4.1 Sawn timber

The convertion of rubberwood log into sawn timber is normally conducted in the sawmill which involves sawing, treatment and kiln drying. There are about 790 sawmills with capacity of 10 million $m^3$ in Malaysia, in which rubberwood is processed as a raw materials in more than 100 sawmills.

The rubberwood sawing is often done within 24 hours after the log cutting down. The log pith rubberwood is separated from the sap wood in Malaysia and in Thailand for good quality of sawntimber and easy control of the later drying process. The yield of timber for the rubberwood normally is around 35% when using band saw. The commercial size of the sawn timber are 4″×4″(in the best price), 1″× 2″, 1″×3″, 1″×4″ etc. Sometimes, it should be decided according to the demand of the customers from furniture industry. In general, the moisture content (*MC*) of a single piece of sawn timber to be used in the manufacture of products for export to temperate regions as the U.S.A., Europe and Japan is approximately 10 %. The usual trade practice is to allow a tolerance of + 2% *MC* from the specified *MC* The rubberwood sawn timber must be protected immediately after sawing to avoid biodegradation.

### 5.4.2 Preservation treatment

Rubberwood is very susceptible to fungal and insect attack. Hence, it must be properly treated to prevent deterioration of wood which would result in much wastage of useful material and financial loss.

Both temporary protection and permanent protection have been used in the rubberwood sawn timber industry. Temporary protection involves the momentary dipping of the timber into a preservative solution containing an insecticide and a fungicide, the preservatives are deposited only on the surfaces, and therefore it will be removed during further processing of the boards. In Malaysia and Thailand, the log usually has not been sprayed or brushed with any chemicals to prevent stain or sap-stain during the storage period in the plantation, because it's not necessary as the felled log to be tansported to and treated in the sawmill very soon.

For permanent protection, the two suitable methods of treatment are: the dip-diffusion process and vacuum-pressure impregnation process. The dip-diffusion process works on the principle that water-soluble preservatives applied in concentrated form to the surface of very wet timber automatically tend to dilute themselves in the water contained in the wood cells and so will penetrate deep into the wood which have a lower concentration. Thus, it is best to carry out this treatment on freshly-sawn timber. The preservative used is a mixture of borax and boric acid in the proportion of 60% borax: 40% boric acid at 30% weight/volum solution concentration.

Boron preservatives do not prevent mould or sap-stain fungus. Therefore sap-stain and mould inhibiting chemicals has to be added to the solution, Suitable anti sap-stain additives available in the market are MBT, TCMTB, quartenary ammonium compounds and captafol.

The timber is impregnated under pressure with a preservative solution followed immediately by kiln drying. After sawing, the rubberwood timber is immediately (within half day) treated by vacuum-pressure impregnation treatment, usually Bethell or full-cell method. In the vacuum-pressure process, the preservative is forced into the timber using hydraulic pressure and this provides permanent protection for the timber. Preservatives commonly used are borax/ boric acid formulations or other approved preservatives to achieve a minimum net retention of 0.2 % boric acid equivalent (BAE) at 12 mm from the surface of timber in addition to treatment with an appropriate anti sapstain preservative. This is recommended by the Malaysian Timber Industry Board (MTIB).

The average capacity of the vacuum-pressure plant is 6~8 t/J (about 10 $m^3$). The most commonly used treatment (vauum-pressure) process for 1 inch thickness timber is:

| | |
|---|---|
| Initial vacuum: | 25 inches Hg for 15~20 minutes |
| Pressure : | 60 minutes |
| Final vacuum: | 25 inches Hg for 15~20 minutes |

For 2 inches thickness timber, the treatment time is double. For 3 inches thickness timber, the treatment time is trible. That is, 1 hour (pressure time) for 1 inch (thick timber).

In Malaysia and Thailand, since there is normally no delay for the delivery (within 1 day) to sawmills after log felling, no delay for the sawing (within 1 day), no delay for the treatment (within half day), no much delay for the kiln drying (within 3 days), it is not usually to carry out the short term (temporary) protection treatment for anti sapstain and insect attack. For the long term /permanent protection, all of the preservatives used in Malaysia and Thailand are boron compounds (formulation), namely borax/boric acid, Parachem, Timbor, Celbor, P-Born, etc. But, NaPCP has not been found in use.

The time elapsed between sawing to drying is very critical as this is the time when most fungal and insect attack will take place, no matter what sort of chemical and treatment process is used. Sawing is normally within 24 hours; preservation treatment is almost in one day; and kiln drying of the preservative treated timber is from less 3 days to 8 days, depend different air drying condition and kiln drying capacities in different plant. The shorter the time is inbetween, the less risk will take place in term of fungal and insect attack.

### 5.4.3 Kiln drying

two types of kilns, one is the dehumidifying system and ... air drying system (i.e., the conventional kiln), to achieve a final moisture content of 10%. The latter is preferred in drying rubberwood as the high temperatures and high humidity used are particularly more effective in eliminating fungi and insects. Also because of the fast drying period, the establishment of sap-stain mould is easily checked.

After treatment, the timber is immediately and properly stacked with evenly spaced stickers of uniform thickness to enable air drying of the timber to commence immediately.

In most sawmills, there are at least 7 ~ 10 kiln drieres with average capacity of 30~50 tons per chamber for the rubberwood. The initial *MC* of the timber before drying is up to 85%, so that in actural, 3 ~ 8 days air drying is needed for saving the energy of the kiln drying.

Rubberwood is usually kiln-dried in order to achieve quicker drying with minimum degrade. The steam-heated, forced air-drying system is commonly used tô kiln-dry rubberwood. The high temperatures and humidities used in this method effectively prevent fungal and insect infestation as well as reduce warping and moisture gradients during seasoning. The timber generally dries fairly slowly with rather serious seasoning defects. The drying time is normally 6~7 days for rubberwood with the thickness of 1 inch (25 mm). The drying schedule used in most sawmills is according to the Schedules recommended by the MTIB, i.e. Schedule D for rubberwood timber with thickness of 50 mm and above and Schedule E for rubberwood timber with thickness below 50 mm. The two schedules are showed as follows:

**Kiln Schedule D for drying rubberwood**

| Moisture content (%) | Dry bulb temperature (℃) | Wet bulb temperature (℃) | Approximate relative humidity (%) |
|---|---|---|---|
| Green | 40.5 | 38 | 85 |
| 60 | 40.5 | 37 | 80 |
| 40 | 40.5 | 35.5 | 70 |
| 35 | 43.5 | 36 | 60 |
| 30 | 46 | 36 | 50 |
| 25 | 51.5 | 38 | 40 |
| 20 | 60 | 40.5 | 30 |
| 15 | 65.5 | 44.5 | 30 |

**Kiln Schedule E for drying rubberwood**

| Moisture content (%) | Dry bulb temperature (℃) | Wet bulb temperature (℃) | Approximate relative humidity (%) |
|---|---|---|---|
| Green | 48.5 | 46 | 85 |
| 60 | 48.5 | 45 | 80 |
| 40 | 51.5 | 46.5 | 75 |
| 30 | 54.5 | 47 | 65 |
| 25 | 60 | 49 | 55 |
| 20 | 68 | 53 | 45 |
| 15 | 76.5 | 58 | 40 |

The rubberwood boards are generally prone to warping. Weighting down the stack with pressures of about 250 $kg/m^2$ and using closer sticker spacing, similar to that for air-drying is necessary and recommended to reduce warping. long-period of pre-steaming (at 70℃ ~ 100℃ for a few hours) and equalizing treatment are also recommended for better kiln-dry recovery.

Typical kiln design from reinforced concrete and brick construction with heavy duty reinforced floor; kiln doors from prefabricated aluminium framework and panels, as well as front end forklift loading entry. The chamber construction is from brick and reinforced concrete or prefabricated of rigid polyurethane insulation core, interior skin of aluminium and exterior aluminium colour bond. Kiln superstructure designed from steel and aluminium. Another important point is that during kiln drying, the wood produces some acidic vapour which is corrosive to the iron components in the kiln. Several charges in a row may cause extensive damage to the kiln. Kilns with aluminium parts have been successfully used to dry rubberwood.

The waste wood and dust are to be burned as the fuel for the boilers of kiln dryers in sawmills in Malaysia and Thailand.

### 5.4.4 Panel products

#### 5.4.4.1 Wood species used for panelboard production in Malaysia and Thailand

| Countries | Plywood | Particleboard | MDF |
|---|---|---|---|
| East Malysia | mixed tropical hardwoods | mixed tropical hardwoods | mixed tropical hardwoods |
| West Malysia | mixed tropical hardwoods | mainly rubberwood (80%~90%) | rubberwood |
| Thailand | hardwoods and rubberwood | rubberwood bagasse | rubberwood |

The success in the utilization of rubberwood has now resulted in the presence of some panels products manufacturing mills in Malaysia and Thailand using solely rubberwood as the raw material. According to rubberwood properties, the advantages and disadvantages for making pnaelboards showed as follows:

Advantages
- Low cost
- Good woodworking & machining properties
- Light & uniform colour
- Good bond strength

Disadvantages
- Non-durable wood
- High carbohydrate (sugar & starch) content
- Rubberwood is susceptible to mould & fungus and to insect attack
- Need to dry quickly
- Sapstain (discolouration)
- Veneer warping on drying
- Lay up problems
- Small diameter logs for peeling
- Latex spots in MDF

### 5.4.4.3 Plywood production

The rubberwood is not as good as other tropical hardwood for making plywood mainly because of its small diamter logs for peeling. There are 4 plywood mills solely used rubberwood as raw materials in Malaysia, 2 of them are quite small.

| Countries | 1995 | 1996 | 1997(est) |
|---|---|---|---|
| Malysia | 3 800 000 $m^3$ | 3 700 000 $m^3$ | 3 550 000 $m^3$ |
| Thailand | 480 000 $m^3$ | 400 000 $m^3$ | 390 000 $m^3$ |

### 5.4.4.4 Particleboard production

The first particleboard mill was set up in Malaysia in 1974, using mixed hardwood as the raw material. Additional mills were established after the utilization of rubberwood was started in the early 1980's. Almost all new mills use rubberwood as the raw materials; the old mills still use plywood residues of mixed hardwood because they were just built beside the plywood mills. At present, five particleboard mills, one moulded particleboard mill and one wood fibre cementboard mill using rubberwood as the raw material are in operation in Malaysia.

| Countries | 1995 | 1996 | 1997(est) |
|---|---|---|---|
| Malysia | 207 000 $m^3$ | 450 000 $m^3$ | 580 000 $m^3$ |
| Thailand | 600 000 $m^3$ | 760 000 $m^3$ | 900 000 $m^3$ |

#### 5.4.4.5 MDF Production

The first MDF mill was set up in 1987 using rubberwood as the raw material. All subsequent MDF mills set up were influenced by the availability of rubberwood. Rubberwood is most suited for the production of MDF because it has the required properties, is homogenous, available in large volumes and is a renewable resource, that is, coming from sustainable plantations. Presently 9 MDF mills in Malaysia are capable of producing about 1.5 million cubic meters annually. Rubberwood is the main raw material for making MDF in Malaysia and Thailand.

| Countries | 1995 | 1996 | 1997(est) |
|---|---|---|---|
| Malysia | 360 000 $m^3$ | 580 000 $m^3$ | 800 000 $m^3$ |
| Thailand | 350 000 $m^3$ | 420 000 $m^3$ | 470 000 $m^3$ |

## 5.5 The Uses of rubberwood

Rubberwood, with its inherent properties such as light density, attractive appearance and easy workabiligy, makes it a versatile timber suitable for a munber of uses. As mentioned above, the rubberwood logs are manufactured into sawn timber, plywood, MDF, particleboard, blockboard and wood cement board etc.

It is remanufactured into value-added products, such as a wide range of furniture and furniture components, including dining sets, garden furniture, lounge sets, bedroom sets and other occasional furniture like rocking chairs, bar stools, table tops, chair seats, chair legs and other turnery items. The furniture may be made from the solid wood or laminated components for thicker sections. The manufacturing of rubberwood furniture for export is one of the fastest developing industries in Malaysia and Thailand during the last ten years. It is projected that Malaysia will achieve an export of M $ 2.5 billion (US $ 1.0 billion) worth of furniture by the end of 2000.

Rubberwood is also suitable for moulding such as thresholds and makes attractive panelling, beading, skirting and edging. It is also sufficiently hard for parquet and strip flooring, this product can be easily produced from sawmill waste and off-cuts from furniture manufacturing plants. Rubberwood has also been glue-laminated to form various components such as steps, railings and balusters for stairs, and door and window components, household utility items such as salad bowls, cheese boards, knife blocks, trays, etc.

## 5.6 Government support programme in Malaysia

The Malaysia government through the Malaysian Timber Industry Board (MTIB) ensure that Malaysian rubberwood are of high-quality, the MTIB has introduced a quality control system whereby only rubberwood which has been properly kiln-dried and permanently treated with approved preservatives and treatment methods shall be allowed to be exported. Suppliers of kiln-drying plants and exporters dealing with rubberwood sawntimber are required to comply with the requirements of the Quality Control System. On the other hand, through the Timber Information Exchange System (TIES), the MTIB also assists local processors and exporters of rubberwood with information on the potential supply sources of rubberwood in the country.

In addition, the Government, through the concerted efforts of several specialized agencies such as the Forestry Department, the FRIM and the MTIB is emphasising greater utilization of rubberwood as a source of high quality timber products.

## 6 Recommendations

### 6.1 Plantation of rubber tree for both latex and timber

All rubberwood now being utilized come from rubber plantations originally for latex production in China. Therefore rubberwood is a secondary or by-product of rubber plantations. Therefore the quality of rubberwood timber/log is not very good for making wood products. Now the establishment of rubber plantations solely for timber production is a new concept. The replanting of existing rubber areas with vigorous clones which can provide high wood volume at harvest and the establishment of rubber forest plantation are ways to enhane rubberwood production. The planting rubber tree for both latex and timber would be benefit to both latex industry and rubberwood processing industry in China. 25 clones, including RRIM908, 910, 912, 913, 918, 921, 922, 928, 929, 931, 932, 936, 2001, 2002, 2008, 2009, 2014, 2015, 2016, 2020, PB 235, 260, 350, 355 and 359, may be suitable as planting materials for both timber and latex production. In view of the attractive returns that can be obtained from both latex and rubberwood, Estate Farm Bureau should be encouraged to adopt a more options towards rubber planting.

### 6.2 Management of rubberwood processing

The time elapsed between sawing and kiln drying is very critical as this is the time when most fungal and insect attack will take place, no matter what sort of chemical and treatment process is used. The shorter the time is, the less risk will take place in term of fungal and insect attack. The rubberwood processing industry in China does not take the "time awareness" very seriously. This may be one of the main reasons they have to use sodium pentachlorophenol (NaPCP) to protect rubberwood from stain, mold and insect attack. In the matter of fact, if the sawing, treatment and drying can be done quickly without delay, it is not necessary to use NaPCP, for instance in Malaysia. So the key factor for the management of rubberwood processing is "quickly": rubberwood should quickly go to sawing, quickly go to treatment, and quickly go to kiln-dry. This needs the match of capacity of sawing, treatment and kiln drying. And the matched capacity would allow lees delay. In every stages of processing, the shorter the rubberwood stays, the better the quality of the timber is.

## 6.3 Treatment of rubberwood with low toxic chemicals

Rubberwood is susceptible to fungal and insect attack. Hence it must be properly treated to prevent the deterioration of wood which would result in wastage of useful material and financial loss. But we have to consider not only the effectiveness of the chemical but also the safety of the chemical, both to the human being and to the environment. The chemical has been using in China rubberwood industry——sodium pentachlorophenol (NaPCP) contains dioxin, which can cause cancer. Actually NaPCP can cause a number of hazard: carcinogenic, ecotoxic, central nervous system damage, blood disorder, liver and kidney damage, stomach pain, vomiting, nausea, fever, eyes/skin/respiratory irritation. This is why NaPCP was banned a lot of countries, such as Sweden, Germany, Spain, Chile, Denmark, Switzerland, Italy, Greece, Indonesia, Japan, New Zealand, Australia and USA (restricted used). Therefore, to reach the quality level of rubberwood products internationally, it is necessary to take away NaPCP and use much more safe chemicals, such as borax and boric acid. In fact, these are what have been done in Malaysia and Thailand.

If the boron compounds treated rubberwood can not be dried soon for some reasons, temporary treatment (dipping) with anti bluestain chemicals and anti wood borer chemicals (such as TCMTB, MBT) is recommended.

## 6.4 More applications of the rubberwood

The rubberwood as a source of raw material for the wood-based industry in Malaysia and Thailand has indeed determined and accelerated the development of the downstream timber industry with respect to furniture manufacturing and panel production, especially MDF. And rubberwood is also being used for the production of other products such as laminated veneer lumber (LVL) and laminated board for the end uses. The growth in this kind of panel products not only imporves the application of rubberwood for furniture manufacturing, parquet flooring and craft production etc., but also opens a new market for rubberwood waste. The new kind of rubberwood board products and more added-value products with high quality would increase the competition in the market for the rubberwood industry in China.

## 7 Reference

1 Malaysian Rubberwood —— A Beautiful & Versatile Timber. the Malaysian Timber Industry Board
2 Clonal Development and Management System for Heveawood Production. Rubber Research Institute of Malaysia
3 Technical Guide No. 1 MEI 1995, Guidelines on the use of Rubberwood Sawn Timber. The Malaysian Timber Industry Board.
4 Rubberwood: Why it is So Good. Asian Timber, 1996(10): 40～46

Following are the main areas for

1. To establish a research and development centre for advanced processing and product development— The advance processing in rubberwood comprises of finger joint edge glued laminated panels, beams and columns. The main components to be studied are the process of finger joining and the physical characteristics of the input timber as follows:

a. Moisture content
b. Warpage
c. Size tolerance
d. Surface pH

Further, it may be necessary to identify the proper resin with reference to the enduse specifications. In the case of finger joining, the finger configuration like fibre slope, contact area, the relationship with the butt area and the behaviour of joints with different types of finger profile etc. has to be studied. Incase of lacquering, the lacquering parameters and the lacquer surface specification also has to be formulated.

2. A scheme for development of advanced floor level skills in operating equipment for secondary processing — In secondary processing especially in the case of edge lamination, the important components are:

a. Glue surface preparation
b. Assembling time
c. Resin spread quantity
d. The pressing pressure

For finger joining also such parameters has to be worked out and standardised. The operators have to under go on the job training on the major machines like finger joining, core composers etc. Skill in lacquering with various specifications also has to be acquired.

3. Preparation of specifications for input raw material

4. Preparation of specifications for end-product and possible end-uses

5. Formulation of specifications for each stage of production and overall

4&5 Preparation of specifications for end-product and possible end-uses, Formulation of specifications for each stage of production and overall — The specifications of the product has to be established. The major components for specifications will be attributes, size tolerances and warpage. The specification for each stage of production comprising of the above mentioned, has to be prepared. While preparing the specification, wastage has to be computed at each stage of production and the input volume to each process has to be mentioned.

6. Development of process control mechanism — Process control has to be either on a linear measurement basis or on volume, especially in the case of recovery. The production volume should co-relate with the operational speed (feed speed, tool performance etc.). The established quality standards has to be applied to the important processes to achieve the best results.

The general impression on other areas like preservation, drying etc. is that limited additional inputs is required to upgrade the following:

Replacing of sodium pentachlorophenate (NaPCP), is found necessary as it exceeds the safe toxicity limit. Experiments have to be carried out with TCMBT and other equivalent chemicals, which are of lower mammalian toxicity.

In view of the acute shortage of timber in China, development of builders -ware from rubberwood also has to be studied. The end use performance of the existing secondary processed rubberwood items has to be assessed and an end-use performance related technological adjustment has to be made in the existing process. A laboratory for random testing of components in process and product has to be organized with CRIWI or similar institutions acting as the certification agency.

A tool room for tool development and tool maintenance has to be organized for servicing the secondary processing in rubberwood industry. A product profile, with clear technical specifications for various rubberwood products has to be prepared for reference of the domestic as well as the overseas market. Catalogue for furniture already manufactured and proposed to be manufactured is to be prepared as a reference document for the buyers.

The training component is fairly well covered in the earlier project, but it has to be treated as a continuing activity during the subsequent follow-up projects.

The verifiable indicators of the future projects should include primary information from the end-users also.

K. P. JAYABHANU
Technical Director

# Xing Jiaqi: REPORT ON THE RUBBERWOOD BIODETERIORATION CAUSED BY INSECTS IN CHINA

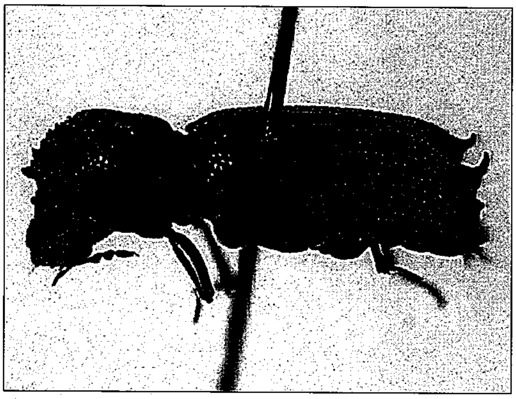


Figure 1 Adult beetle of *Heterobostrychus aequalis*, the most common and destructive powder-post beetle of rubberwood in China

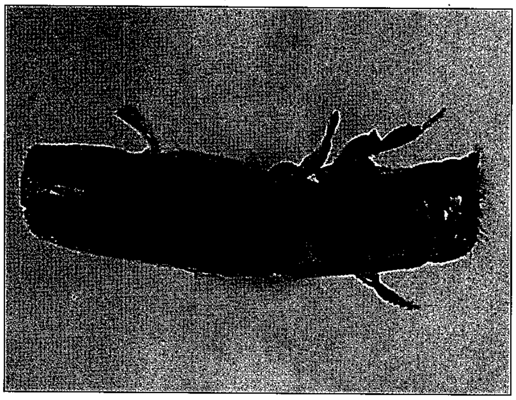


Figure 2 Adult beetle of *Platypus caliculus*, the main pest attacking rubberwood timber after the treatment with BBP

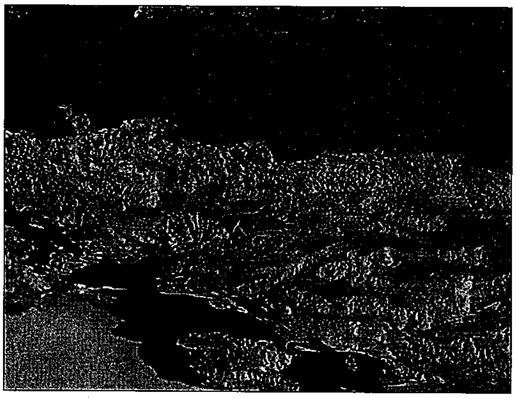


Figure 3 A serious infestation of rubberwood timber by *H.aequalis*, powder-like wood dusts

Figure 4 A typical infestation of BBP treated rubberwood timber by *P.Caliculus*, shot fibriform wood dusts

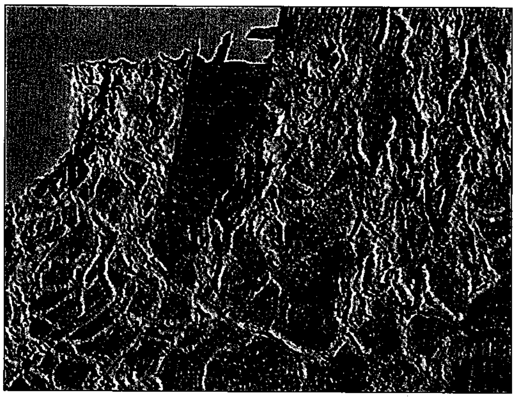


Figure 5 Rubberwood veneer attacked by powder-post beetles

Figure 6 *Acicnemis* sp., a new record in China

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