OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

D02946

United Nations Industrial Development Organization

Distr.
LIMITED

ID/WG.102/11
9 June 1971

ORIGINAL: ENGLISH

Expert Group Meeting
on Pulp and Paper

Vienna, 13 - 17 September 1971

EXPERIMENTS ON THE INDONESIAN RUBBERWOOD AS RAW MATERIAL FOR PULP AND PAPER [1]

by
Alaudin - Soeprapti K - Moehji Rn - Sri Margono
Hendayani TA - Soetrisno - Kahar

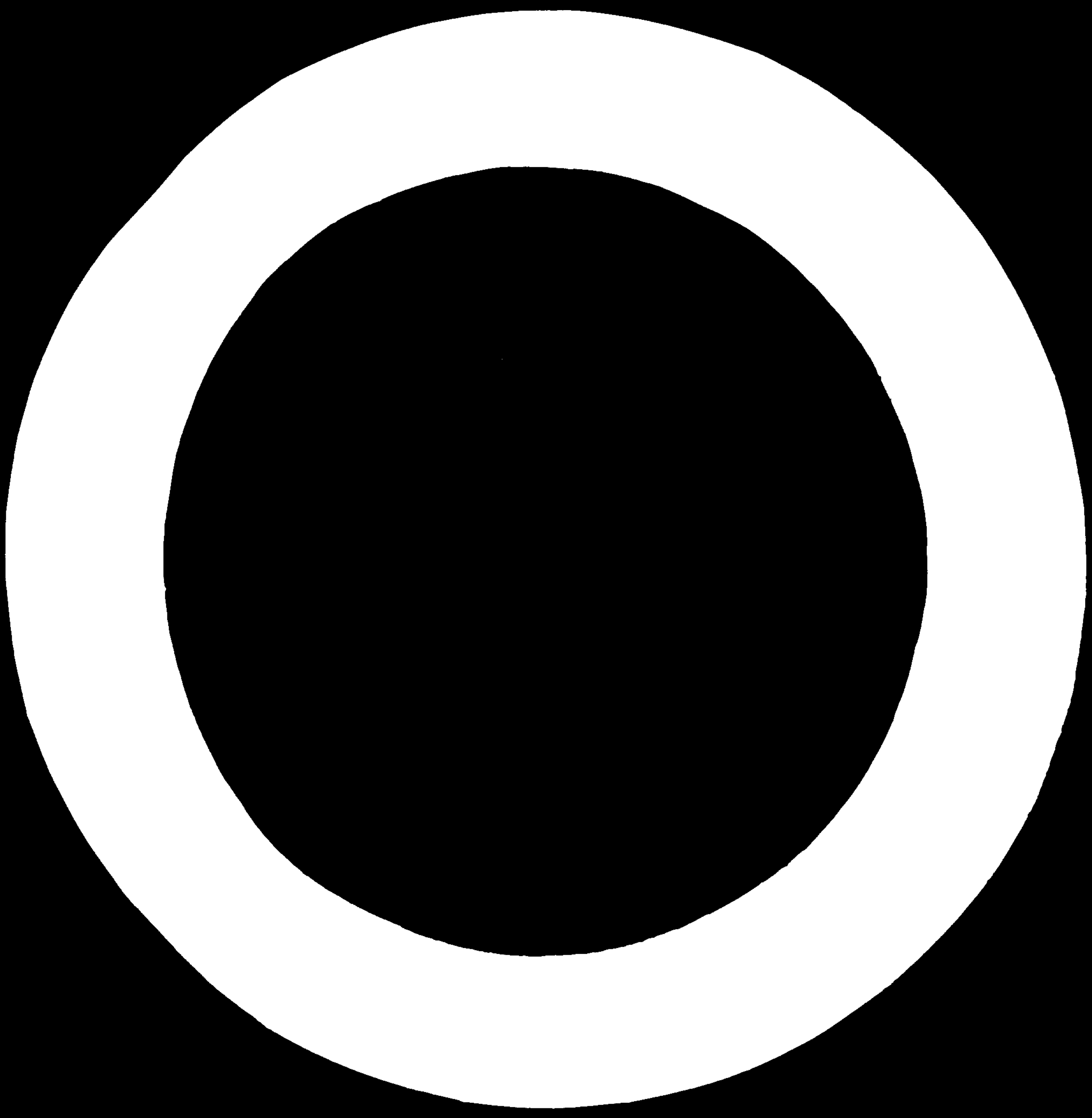
CELLULOSE RESEARCH INSTITUTE
Bandung, Indonesia

---

[1] The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

LIST OF CONTENTS. Page.

LIST OF TABLES



EXPERIMENTS ON THE INDONESIAN RUBBERWOOD AS RAW MATERIAL FOR PULP AND PAPER

by

Alaudin - Soeprapti K - Moehji Rn - Sri Margono
Hendayani TA - Soetriano - Kahar

Cellulose Research Institute
Bandung, Indonesia

SUMMARY.

In this paper an account is given on the physical, morphological and chemical properties of rubberwood along with some storage characteristics and cooking experiments.

The basic density of rubberwood (ovendry basis) is between 0.47 - 0.56 gr/cm^3 while the fiber length is around 1.30 mm, with a thin cellwall of about 2.5 microns and a lumen diameter of about 12.0 microns.

The pentosan content of rubberwood is high (about 21 %) and the lignin content relatively low (about 22 %).

Rubberwood is easily infected by bluestaining fungus, especially when stored in the open air without bark. But when stored underwater, the infection is much less and it shows for debarked logs a decreasing trend of ash and pentosan content with storage time. With the same cooking conditions, water storage caused a decrease in yield, permanganate number and pentosan content of the unbleached pulp.

Pulping experiments were performed using soda, sulphate and neutral sulfite semi chemical (NSSC) processes. With soda process, latex accumulation was found in the form of soft and sticky material which is difficult to remove, but using sulphate or NSSC processes the latex became harder and could easily be removed by proper screening.

Prehydrolysis with water and posthydrolysis with dilute acid rendered the pentosan removal, during the bleaching, easier and the resulting pulp was further used for viscose and fiber making.

Sulphate rubberwood pulp mixed with long fiber pulp, or rice-straw pulp and bamboo pulp for papermaking was experimented with satisfactory result.

INTRODUCTION

Approximately 2/3 of the total land area of Indonesia consists of forests, most of them are natural forests with hundreds of different species. Thus these forests are heterogeneous. Using heterogeneous forests as a source of cellulose for pulp industries would create many problems in the forests exploitation, if certain species are to be selected, or in the pulping process, if mixed wood pulping is to be used. On the other hand rubberwood forests are usually more homogeneous, mostly contain Hevea brasiliensis. These forests are found as plantations owned by the Government or by smallholders.

The total area of rubberwood plantations in Indonesia is about 1.808.604 ha, 27 % of which are government estates. These plantations are found mostly in Java, Sumatra and Kalimantan.

In general, the latex tapping of rubberwood started at the age of 7 years and after about 25 - 30years the value for latex production is greatly diminished. These old trees must be regenerated and usually regeneration has a rotation of about 3 - 4 % of the total plantation area per year.

Up to now, old rubber trees are used only a small part as firewood, while the major part are left to rot in the forests especially in Sumatra and Kalimantan.

Since regeneration must be carried out in any case, it woukd be beneficial if better use of the wood could be found such as for the pulping industries. Many works which concern the use of rubberwood for paper pulp have been carried out in many countries and since Indonesia has an abundant source of this wood, a thorough study of the many possibilities will be of great importance.

Since 1962 the Cellulose Research Institute has carried out a number of experimental works on rubberwood charachteristics and its use for pulp and paper.

GENERAL VIEW ON RUBBERWOOD

In the beginning of the 19 th century, many species of plants had been found to have latex and were used for similar purposes as *Hevea* rubber. The *Hevea* rubber itself has several species such as *Hevea brasiliensis*, *Hevea spruceana*, *Hevea guianensis*, and *Hevea collina*.

After the invention of vulcanization process by Goodyear in 1839 the rubber industries grow and the consumption of rubber gradually increases.

From Brazilia, Hevea brasiliensis was distributed throughout the world especially to Asia. At the end of the 19 th century Hooker and Markham introduced *Hevea* to India, and in the year 1900 an Englishman, Wickham, brought *Hevea brasiliensis* to Indonesia.

Although there are also other species in relatively small proportion, most rubberwood plantations in Indonesia ocnsist of Hevea brasiliensis. The first Indonesian latex was produced in the year 1910, and 20 years later Indonesia became one of the biggest rubber producing countries.

Rubberwood is a hardwood, thus like other hardwood species, the tree has many branches, and the first branching is generally found at a height of about 4 meters. At the age of 30 years, the tree has approximately a basal diameter of 30 cm and a height of 8 meters. The bark is greyish white and has a thickness of about 1 cm. The wood is creamy white when fresh.

Hevea has compound latex vessels originated from the fusion of neighbouring cells whose cellwalls disintegrate or disappear as the cells mature. These latex vessels are found in the leaves, flowers, fruits and barks of branches and trunk.

The cells which later become latex vessels are formed by the cambium in a certain sequence alternating with the parenchyma cells. Due to the fact that the cambium forms the latex vessel mothercells, the latex vessels run in concentric circles or cylinders. These latex vessels are laterally or transverselyand radially interconnected, however the number of these connections usually varies from seedling to seedling.

The rubber particles measure from 0.03 micron to 3 microns in diameter.

The shape of the smallest particles is spherical, that of the largest is oval to pear-shaped. The composition of the latex varies, depending upon the different organs from which it has been extracted (1).

RUBBERWOOD PLANTATION IN INDONESIA.

The area of rubberwood plantations in Indonesia is 1.808.604 ha, 27 % of which (504.624 ha) are government estates while the rest are owned by small-holders. This total area is approximately 35 % of the total world rubber plantation area.

In Indonesia rubberwoods are planted with a planting distance of 5 meters, so that in one hectare 400 trees can be planted. The tapping of these trees started at the age of 7 years, by wounding the bark outside the cambium. The tapping started from the height of 1.30 meter with a width of 1/3 or 1/2 of the diameter of the trunk, gradually move downward until 10 centimeter from the soil, and afterward the tapping is continued to the other side of the trunk. The wound of

Table I

Planted area in various natural rubber producing countries (2)

Territory	Planted area (ha)
A. Indonesia +	1.808.604
Malaysia ++	1.947.475
Thailand	339.543
Ceylon	229.319
India	164.719
Vietnam	101.175
Burma	55.328
Cambodia	47.727
Other Asian countries	37.329
B. Nigeria	116.554
Liberia	99.040
Congo	93.039
Other African countries	36.080
C. brasilia	16.795
Other Latin American countries	5.463
D. Fiji and Samoa	505
Total world : - - - - - - - - - - - -	5.098.695

+) West Irian not included .

++) Malaya, Serawak, Sabah and Brunei.

the tapping zone will be healed by the cambium and after 8 years this zone can be tapped again. The production of latex at first increases with increasing age and then decreases, and after 25 - 30 years old the production is very small and the rubberwood must be regenerated or renewed. The regeneration area per year is about 3 - 4 % of the total plantation area.

The government estates are mainly found in Java, Sumatra and Kalimantan.

Table II

Number and area of government rubberwood estates in Indonesia (3)

Region	Number of Estates	Planted area (ha)
Java	396	193.930
Sumatra	159	301.216
Kalimantan	11	8.439
Sulawesi	4	837
Bali	1	204
Total :- - - - - -	671	504.624

When we calculate the government plantations area only, the regeneration area/year is 3% x 504.624 hectares. If every hectare consists of 400 trees and every tree has at least ½ m^3 solid volume, the regeneration area will give about 3027744 m^3 or 1.513.872 tons of ovendry wood per year.

The utilisation of extracted wood from the regeneration area is not great, and until now it is only used partly as firewood by neighbouring small industries such as in lime kilns, firebrick factories and also by the estates for drying rubber sheets. The main part has no utilisation and is often left to rot in the plantations.

Rubberwood plantations in Indonesia, especially the government estates have already enough and well maintained roads and latex collecting places, these facilities can also be used for wood exploitation. Labour for exploitation can also be collected from the rubber estates or nearby villages. Thus rubberwood has great possibilities as a source of cellulose for pulp industries.

SAMPLES FOR EXPERIMENTS.

For experimental works rubberwood from different regions and of differentages were used.

a. Location : Smallholder estate Kaumpandak, Bogor, (W. Java).
A g e : 29 years, seedling.
Part of trunk : 2.00 to 3.00 meters from the soil, upper part of tapped zone.
Date of felling : 18 April 1962
Diameter of trunk : appr. 20 cm.

b. Location : Smallholder estate Prabumulih, Palembang, (South Sumatra).
A g e : 21 years.
Part of trunk : 3.00 to 4.75 meters from the soil, upper part of tapped zone .
Date of felling : 29 April 1962
Diameter of trunk : appr. 18 cm.

c. Location : Government estate Tjurug, Purwakarta (W. Java).
A g e : 21 years.
Part of trunk : 0.50 to 3.50 meters from the soil 1.50 m from the tapped zone and 1.50 m from the untapped zone.
Date of felling : 30 July 1963.
Diameter of trunk : appr. 18 cm.

d. Location : Government estate Radjamandala, Bandung (W.Java).
A g e : 45 - 50 years.
Part of trunk : 0.50 to 2.00 meters from the soil,tapped zone and untapped zone.
Date of felling : 1965.
Diameter of trunk : appr. 65 cm.

e. Location : Government estate Tjikumpaj, Purwakarta, (W. Java).
Age : 38 years.
Part of felling : 1968 - 1969 - 1970.
Diameter of trunk : appr. 30 cm.

f. Location : Government estate Daneusalak, Martapura, (South Kalimantan)
Age : -
Part of trunk : 2.00 to 3.00 meters from the soil, upper part of the tapped zone.
Date of felling : 1969
Diameter of trunk : appr. 20 cm

RUBBERWOOD PROPERTIES.

Physical and morphological properties.

Rubberwood is a hardwood with a basic density between 0.47 to 0.56 gr/cm^3 (ovendry basis). On green basis, after felling the basic density was greater than 1, so that transportation of logs after felling can not be done by water transportation system.

The wood fiber length was in the range of 1.27 - 1.33 mm with thin cell wall appr. 2.5 microns and relatively large lumen appr. 12.0 microns The fiber dimensions of rubberwood are listed on table III.

Chemical analysis of rubberwood.

The chemical analysis of rubberwood showed that the pentosan content is high, while the lignin content is relatively low as compared with most of the tropical wood species. Table IV shows the analysis of rubberwood from different regions in Indonesia and of different ages.

These values are compared with those obtained by other workers.

Table III.

Fiber Dimension of rubberwood

	A	B	C	D	
Fiber length (L) in mm	1.33	1.27	1.29	1.50	
Fiber diameter (D) in micron	17.0	17.3	15.5	22.0	
Lumen diameter (l) in micron	12.0	11.5	10.7	16.4	
Cellwall thickness (W) in micron	2.5	2.9	2.4	2.8	
Runkel number($\frac{2W}{l}$)	0.42	0.50	0.45	0.48	
Felting Power($\frac{L}{D}$)	78	74	83	68	(calc).
Fiber flexibility ratio ($\frac{l}{W}$)	0.71	0.66	0.69	0.51-0.63	

A. : Indonesian wood, Radjamandala estate, examined at The cellulose Research Institute Bandung - Indonesia (1965).

B : Indonesian wood, Danaumalak, estate, ditto (1969)

C : Indonesian wood, Tjikumpaj estate, ditto (1968)

D : Malaysian wood(4), examined by The Forest Research Institute, Selangor - Malaysia (1960)

Table IV.

Chemical Composition of Rubberwood

		A	B	C	D	E	F	G	H
Total Cellulose	(%)	-	60.6	64.3	67.9	66.4	-	-	-
Cellulose (Cross-Bevan)	(%)	57.4	59.8	64.7	61.0	64.9	-	-	42.6 - 47.1 *)
Holocellulose	(%)	-	-	-	-	-	80.3	-	-
Alpha cellulose	(%)	46.6	39.2	44.4	43.7	44.7	45.3	35.7	39.6 - 42.1
Lignin (Klason)	(%)	27.0	19.8	24.4	22.0	21.8	21.5	19.4	21.8 - 29.2
Pentosan	(%)	20.5	19.5	23.5	20.5	21.8	-	14.5	18.2 - 19.9
A s h	(%)	2.15	1.29	0.86	1.02	0.85	0.88	1.2	0.74 - 2.35
Alc. benz extractives	(%)	-	1.22	4.01	5.01	3.31	2.36	2.2	1.6 - 4.9
Hot water solubility	(%)	-	7.17	2.72	5.14	2.56	7.68	-	2.9 - 9.0
Cold water solubility	(%)	-	4.85	1.53	2.78	1.87	-	-	-
1 % NaOH solubility	(%)	-	-	18.3	19.0	14.7	22.0	-	15.7 - 21.2

Notes :
A : Indonesian wood, Radjamandala estate, tapped zone, examined at the Cellulose Research Institute (CRI), Bandung - Indonesia (1965)
B : Indonesian wood, Radjamandala estate, untapped zone, ditto (1965)
C :: Indonesian wood, Tjikumpaj estate, untapped zone, ditto (1968)
D : Indonesian wood, Banausalak estate, untapped zone, ditto (1969)
E : Indonesian wood, Tjikumpaj estate, untapped zone, ditto (1969)
F : Indonesian wood, examined at The Foochow Paper mill, China - (1965)
G : Indonesian wood, examined at The Laboratory of Waldhof Zellstof fabriek, Mannheim - Germany (1968)
H : Malaysian wood (4), examined at The Forest Research Institute, Kepong, Selangor - Malaysia (1980)
*) : Cellulose acc. Kurschner.

STORAGE EXPERIMENT (5)

Rubberwood is readily attacked by blue staining fungus which results in greyish blue coloration on the originally creamy white wood. This coloration occurs within a few days after felling.

Due to this fact, an investigation on methods of rubberwood storage is of great importance, especially since in Indonesia, at the present time, rapid wood transportation from the forest to the mill is not always possible. And this may cause delay before the logs could be processed.

Itis easier to prevent blue stain attack than to treat wood already infected by this fungus.

In this investigation rubberwoods from Prabumulih and Kaumpandak estates (20 - 30 years old) with an average diameter of 18 - 20 cm were used. Logs of 1.50 - 1.75 m were stored under various storage conditions. For comparison, some logs were left with the bark while others without bark.

At certain period of storage, the extent of fungus attack was noted along with density measurement, microscopical investigation, chemical analyses and several cooking trials The fungus attack was investigated only up to a length of 50 cm from both ends along the trunk axis and also from the trunk surface.

The fungus attack was very rapid on logs stored under the roof or in the open air, especially when debarked. Within 4 - 5 weeks logs with bark were attacked up to a length of 10 - 20 cm along the trunk axis and 2 cm from the trunk surface, while that of logs without bark the attack was more severe (up to 40 - 50 cm along the axis and 6 - 10 cm from the surface)-Within 13 - 15 weeks, the attack on logs with bark was 35 - 45 cm along the axis and 4 - 8 cm from the trunk surface, while on logs without bark more than 50 cm along the axis and from the trunk surface the whole logs was infected.

Logs stored underwater were infected by blue stain only at the ends. Within 32 weeks only about 5 cm along the axis and 2 cm from the trunk surface. Within one week the water had a bad smell due to evoluted gases. The pH of water was 7.0 for the first three days, then decreased to 5 - 6.0 and after the tenth day remained at pH 4.5 - 5.0.

In other experiment, logs of rubberwood from Tjurug estate (21 years) old, each 3 m long (diameter 18 cm), 1.50 m of which from the tapped zone and 1.50 m from the untapped zone, were at first stored in the open air for 4 weeks and was then put under water shower. 4 weeks storage in the open air caused blue stain infection on the ends of the logs. After water showering, the infection still continued at a slower rate. After 8 - 10 weeks under water shower, blue stain could be seen up to about 25 cm along the axis and - within this length and 8 - 9 cm from the trunk surface.

Tapped zone as well as untapped zone were both infected by blue staining fungus in nearly the same manner.

It was obvious that the rate of fungus attack along the trunk axis was faster than from the trunk surface. This could be seen on the chips as blue streaks parallel to the wood fibre rather than perpendicular to it.

Blue stain is caused by fungus having dark colored hyphae.

It is a Pyrenomycete of the Ceratostomella pilifera species (6). This fungus lives on wood cell content (starch and other soluble matters) and hardly causes deterioration of the cell wall but may cause a decrease in toughness.

This fungus grows fast in a warm and humid surrounding. The optimum temperature of growth is 22 - 25°C and the maximum temperature 35°C. Water content of the surrounding should be arround 24 - 28 %. Further this fungus is aerobic, thus always needs oxygen for the growth. For this reason this fungus rarely grows on standing trees, because although the water content is favourable, the oxygen content of the cells is not sufficient.

From the following microscopical photographs it could be seen the dark hyphae penetrating the cell wall.

Cross section (2000 x)

Radial section (250 x)

In underwater storage, oxygen reserve is limited and is quickly used up, moreover sterckes and other soluble matters of the wood dissolves. Thus the condition is not favourable for the growth of blue staining fungus. Water showering, athough less effective in preventing the fungus attack, yet is more practical to carry out.

The ovendry wood density was between 0.51 - 0.56 g/cm^3 and after 4 - month storage the density was not much changed.

Some chemical analysis were carried out including the determination of ash, alcohol-benzene extractives, total cellulose, pentosan, lignin and 1 % NaOH solubility.

Table V.

Effect of storage on chemical composition

Sample No.	Time of storage (Weeks)	Alc-Benz Extract. %	Total Cell. %	Pentosan %	Lignin %	1 % NaOH Sol. %	Ash %
I K_2	13	2.5	63.3	18.4	24.4	18	1.50
I K_3	24	2.2	65.7	22.1	25.6	22	0.86
I T_1	4	1.8	66.8	20.7	23.6	-	0.85
I T_2	14	1.5	64.3	21.9	23.6	16	0.59
I T_3	24	2.4	66.2	21.7	22.8	17	0.59
II K_1	5	2.7	64.0	19.6	25.4	11	[illegible]
II K_2	15	.23	62.5	20.9	24.1	16	0.94
II K_3	25	2.7	61.2	20.0	24.0	20	0.58
II T_1	5	1.6	62.7	22.9	23.1	16	0.68
II T_2	15	2.2	62.8	20.1	23.7	24	0.86
II T_3	30	2.5	66.6	24.6	22.4	22	1.87
III K_1	6	1.8	64.6	20.0	22.6	16	1.08
III K_2	19	2.7	62.8	21.6	25.3	13	0.61
III K_3	31	1.8	61.8	21.6	23.7	16	0.89
III T_1	6	1.2	61.3	24.0	25.[illegible]	8	0.97
III T_2	19	2.1	64.1	20.2	23.0	13	0.93
III T_3	32	1.3	69.1	19.5	21.7	15	0.48

I : Stored under the roof
II : " in the open air
III : " underwater.

K : With bark
T : Without bark

From the results obtained no clear trend of composition change was observed, except for logs stored underwater without bark (III T_1, III T_2, III T_3)where a trend of decreasing ash, pentosan and lignin content was seen along with an increase of total cellulose content. Underwater storage seemed to dissolve starches and other soluble carbohydrates. Also the evolution of acids in water might cause ash content to decrease (due to soluble minerals).

During the 6 - 8 months storage the increase of 1% NaOH solubility was not so consistent in some cases.The same wood after many years of storage had a 1% NaOH solubility of about 32%.

In connection with the problem of latex on storage, an experiment on standing trees (25 years old) were attempted.

Groups of 5 trees were wounded 5 cm deep from the cambium, all around the trunk, 50 cm wide. It was expected that with this treatment the trees would eventually die and the latex would stop to flow and became dry on the standing trees. After wounding the trees, they were then tapped daily as usual and the latex collected.

Compared with untreated trees, the latex yield increased within the first two days, then gradually decreased. Within about 3 weeks the latex yield was only 1/3 of the untreated trees.

This decrease in latex yield was observed along with the falling of leaves. But new leaves were then seen to grow anew.

The experiment was not continued and it was concluded that wounding 5 cm from the cambium around the trunk was not enough to kill the trees.

In other experiment logs taken from the lower (0-1m),middle (4-5 m) and upper (8-9 m) parts of the tree were left in the open air. It was observed that logs from the upper part showed almost no latex flow even within one week after felling. But from the middle and lower parts, latex still flowed after 3 weeks. The lower part of the tree seemed to contain more latex than the middle part. After 4 - 5 weeks the ends of the logs showed no sign of latex flow (due to drying) but the middle part of the logs still showed latex flow. Only after 6 - 7 weeks no latex flow could be seen on any of the logs.

Cross section of the tapped zone often showed broken rings of hardened latex amidst the growth of wood. These rings were probably caused by incorrect tapping where the wounding was too deep, passing the usual cambium zone. The wood of the tapped zone was generally hard and knots were often present.

The effect of storage was further studied on cooking experiments, but will be discussed later in pulping section.

Debarking was easier when the logs were yet fresh, while for logs stored under the roof or in the open air, after about 3 months storage, debarking and chipping became more difficult. This difficulty was not encountered when the logs were stored underwater or under water shower.

PULPING EXPERIMENT.

Pulping experiments were carried out using sulphate, soda and neutral sulphite semi chemical processes both in laboratory and pilot scale. The yield and the permanganate number of the unbleached pulp were calculated and the characteristics of the paper were studied. The analyses were carried out using the TAPPI standards.

A. Laboratory scale experiments

I. Paper Pulp :

a. Sulphate process.

Cooking conditions for paper pulp should be selected as such that hemicellulose should not be removed too much but that lignin and colouring matter be removed as much as possible in order that the resulting pulp would be easy to bleach.

For this purpose a series of experiments was performed using 45 - 50 year old rubber trees from Radjamandala estate, cooked in a directly heated tumbling digester (30 l). The cooking conditions were selected as follows : active alkali concentration 13.65, 14.45, 15.78 %, maximum temperature 150°C, time at maximum temperature 2.5 hrs; total cooking time 4 hrs; wood to liquor ratio 1 : 4 and sulphidity 25 %. The unbleached pulp was then devided into two portions. One portion was used for paper, the other portion was post-hydrolised and bleached to obtain dissolving pulp.

The resulting permanganate number (see table VI) were somewhat higher than usual. Possibly it was due to the old age of the tree and thus needed stronger cooking condition, But with an active alkali of 15.78 % the permanganate number was 17.3, and this was considered good enough for preparing bleached paper pulp. The yield which was around 49 - 50 % seemed unaffected by the change in active alkali concentration up to 15.78 %.

The physical testing of the sheets revealed that they had good strength and increasing the active alkali concentration slightly decreased the strength.

To obtain pulp for further bleaching, an active alkali of 15.78 % was choosen.

Table VI.

Sulphate cooking yield of rubberwood and the pulp evaluation.

Sample No.	Active Alkali (%)	Yield (%)	P.N.	Beating time (min)	Freeness (°SR)	Tear Fact.	Burst Fact.	Breaking length (m)	Folding end.	Bulk
ABS I	13.65	50.1	19.0	0	10.0	98	1.6	1300	2	2.28
				30	20.7	140	32.0	5530	59	1.81
				60	40.7	131	47.9	7752	524	1.56
				90	69.5	115	56.5	8835	1409	1.35
ABS II	14.45	49.9	19.3	0	12.2	94	3.0	2325	2	2.35
				30	29.0	131	45.7	7170	225	1.58
				60	75.5	110	55.8	8251	1822	1.27
				90	88.8	99	53.2	8625	2618	1.15
ABS III	15.78	49.3	17.3	0	12.0	97	1.6	1685	1	2.00
				30	34.5	130	41.6	6860	184	1.30
				60	72.0	102	49.2	7550	933	1.32
				90	86.6	94	48.7	6910	1278	1.03

b. Soda process(7)

25 - 30 year old rubber trees from Tjikumpej estate (W.Java) were cooked in small digesters of 4 liters heated in an oil bath. Shaking was done only from time to time.

Per every cook 400 gr chip was used. Variations were taken in maximum temperature, concentration of alkali and time at maximum temperature (see Table VII).

Table VII.

Cooking experiment of rubberwood by using soda process
(Wood to liquor ratio 1 : 4)

Sample No.	Temp. °C	Time at max. temp (hr)	Total time (hr)	NaOH (%)	Yield (%)	Permanganate number
I a	155	3	6	18	68.5	27.0
b	155	3	6	20	63.5	24.9
c	155	3	6	22	62.0	22.0
II						
a	160	3	5½	20	58.6	19.2
b	160	3	5½	22	51.7	17.4
c	160	3	6	24	36.0	15.0
III						
a	165	3	7	18	51.1	26.0
b	165	3	7	20	42.5	14.8
c	165	3	5	22	44.5	15.0
d	165	3	5	24	43.9	13.4
IV						
a	155	4	6	22	52.5	16.5
b	160	4	6	22	43.7	17.1
c	165	4	5½	22	46.8	12.7

Beating was done in a Niagara beater having a capacity of 10 l, with a load of 10 kg/cm^2.

The freeness of around 50°SR was reached in 20 - 30 minutes. For the pulp cooked at 155 - 165°C for 3 hrs, the tear factor was between 100 - 115, burst factor 30 - 50, and breaking length 6.000 - 7.500 m. Prolonging the cooking time to 4 hrs markedly reduced the tear factor, but other properties were not much influenced.

Table VIII.

Evaluation of soda rubberwood pulp.

Sample No.		Beating time (minute)	Freeness (°SR)	Tear factor	Burst Factor	Breaking length (m)	Folding endurance
I.	a	0	13.0	-	-	-	-
		30	55.0	114	37.2	6900	111
	b	0	16.0	-	-	-	-
		30	52.5	114	35.9	6000	122
	c	0	17.0	60	6.0	1027	2
		30	43.0	105	36.8	6300	160
II	a	0	17.0	10	-	-	-
		20	48.0	101	33.3	5300	50
	b	0	16.0	-	-	-	-
		20	42.0	117	46.0	6800	144
	c	0	19.0	69	5.5	2600	3
		20	48.0	102	42.2	6700	146
III	a	0	16.0	51	3.2	1475	-
		30	56.5	117	50.5	7600	389
	b	0	17.0	64	5.5	2170	2
		30	56.5	100	47.4	7200	215
	c	0	17.5	64	4.5	2240	2
		20	54.0	111	41.2	6400	170
IV	a	0	16.0	16	2.5	750	3
		30	65.0	57	39.8	7000	428
	b	0	16.0	13	5.2	810	3
		30	60.0	35	38.0	6900	366
	c	0	19.0	60	1.4	1680	2
		20	61.0	104	34.1	6600	122

Since sulphate cooking of old rubber trees produced pulps with good strength, an investigation on old rubber trees using soda process was also carried out. For the experiments 50 and 25 year old rubber trees from Radjamandala (West Java) and 25 years old from Martapura (Kalimantan) were used.

Cooking were carried out with 20 % caustic soda, maximum temperature 160°C for 2½ hours. It was noted that older trees had lower yield, but the strength of the pulp were all higher compared with the younger trees (Table IX). This result was in accordance with that from previous work(8) which indicated that for rubber wood of more than 30 years old, the older the tree the greater the strength and at the same permanganate numbber the lower the yield.

Table IX

Evaluation of soda pulp made from old rubber trees.

Age (Year)	Origin	Yield %	Perm. No.	Freeness °S.R.	Tear factor	Burst factor	Breaking length m	Folding endurance
50	Radjamandala.	40.0	18.3	13.0	-	1.4	1285	2
				54.0	-	45.3	8450	458
				80.0	-	46.3	8150	1063
25	ditto	43.5	18.6	18.0	35	3.3	1385	2
				44.0	87	37.5	5775	97
				72.0	76	45.0	7425	5845
25	Martapura	43.5	15.9	14.0	47.	3.2	810	2
				48.0	91	32.0	6200	131
				70.0	55	34.6	6750	245

c. Neutral Sulphite Semi Chemical Process (NSSC).

Besides sulphate and soda processes, further use of rubberwood to obtain high yield pulp was studied by using neutral sulphite semi chemical process.

Variables were taken in the concentration of the chemicals and in cooking temperature as can be seen in table X.

The experiments were carried out in 4 l digester and defibrated in a laboratory Sprout Waldron disk refiner, using teeth no. 12527 - A for breaker and no.17804 for brushing. Screening was done in laboratory Sprout Waldron plate screener with 0.25 mm slot.

After cooking, the chips were then defibrated by using breaker disk with 1.3 mm clearence, and followed by rubbing disk with 1.2 mm, 0.3 mm and 0.15 mm clearence respectively. The consistency was 3 - 4 %.

Beating and sheet making were done as mentioned previously.

The experiments showed that the yield was highest at 10 % Na_2SO_3 and 2 % $NaHCO_3$.

At 170°C, Na_2SO_3 concentration higher than 10 % caused the yield to decrease, reaching an almost constant value between 12 - 16 % Na_2SO_3. From this serie the effect of increasing $NaHCO_3$ concentration on yield was not much (Table XI).

Increasing the cooking temperature generally decreased the yield but for 10 % concentration of Na_2SO_3 up to 160°C the decrease was very small.

After the cooking process, the chips mostly retained the original form , only they were softer. Blue stain could be seen on these cooked chips but was not visible after the chips were defibrated. Hardened latex was seen as strands parallel to the wood fiber. It seems that latex is not only found in the bark, but also within the wood. Most of these latex could be seperated after passing the screener (0.25 mm flat screen). With finer screen (0.15 mm) more latex could be removed.During the previous laboratory experiments using soda and sulphate processes this latex problem was not observed .

For pulp evaluation 45°SR freenes was chosen. Increasing the cooking chemicals decreased the lignin content (figure 1). The pulp strength started to increase at a lignin content of 14 % but lower than 12 %, the strength did not changed much.

Burst factor and breaking length increased with increasing Na_2SO_3 concentration up to 12 %, above which the value was almost constant.

Tear factor of rubberwood pulps was good. The effect of Na_2SO_3 concentration higher than 10 % on tear factor was not obvious.

Folding and brightness increased with increasing Na_2SO_3 concentration but increasing $NaHCO_3$ concentration slightly reduced the pulp brightness.

At 8 and 10 % Na_2SO_3, increasing the temperature up to 170°C didn't change the strength much, but at 10 % Na_2SO_3 tear factor increased with increasing temperature.

Also above 10 % Na_2SO_3 the folding endurance was almost constant. But lower than 10 % Na_2SO_3, at temperature higher than 150°C folding endurance decreased, and this decrease was more pronounced with increasing $NaHCO_3$ concentration.

Higher temperatures also decreased the pulp brightness.

It was concluded that using Na_2SO_3 10 - 12 % at 160 - 170°C could produce good pulp and to obtain good brightness, the so-

Table X

Effect of temperature and chemical concentration on NSSC pulp properties

Wood to liquor ratio = 1 : 5; time to max. temp. 2 hrs; time at max. temp. 2½ hrs; pulp evaluation at 45° SR

Cooking conditions (1)			(2)	(3)	Burst	Breaking	Tear	Folding		Brightness
Na_2SO_3 %	$NaHCO_3$ %	Temp. °C	Yield %	Lignin %	factor	length (m)	factor	endurance	Bulk	(GE)
8	2	140	65.0	14.8	18.7	5057	76	24.8	1.82	40.0
8	2	150	65.1	13.8	29.0	-	68	32.4	1.53	31.8
8	2	160	62.8	14.6	26.5	3751	59	27.0	1.60	23.4
8	2	170	62.1	14.5	27.3	4144	98	28.0	1.56	23.8
8	3	140	70.1	15.0	21.6	4797	74	23.4	1.60	41.9
8	3	150	64.4	14.1	35.3	5750	60	79.3	1.52	33.7
8	3	160	63.8	14.6	28.7	4863	67	45.0	1.61	32.7
8	3	170	57.1	14.4	17.4	3515	66	17.4	1.60	17.9
8	4	140	65.9	13.5	29.0	5381	84	53.0	1.59	39.9
8	4	150	65.4	14.0	32.3	5406	76	-	1.59	33.3
8	4	160	61.6	14.9	34.2	5400	64	46.1	1.48	23.0
8	4	170	55.1	15.9	9.7	2600	44	3.2	1.80	16.9
10	2	140	71.5	17.1	18.7	4338	66	9.8	1.85	43.7
10	2	150	70.4	15.9	22.3	5297	72	45.7	1.52	38.7
10	2	160	68.6	18.9	31.0	5282	76	34.0	1.70	39.2
10	2	170	64.6	13.1	34.6	5990	84	82.3	1.61	31.9
10	3	140	72.6	18.4	19.7	4127	73	14.4	1.93	44.2
10	3	150	65.8	12.8	25.2	4440	85	43.0	1.67	31.4
10	3	160	64.7	18.4	20.0	4432	86	48.3	1.59	37.3
10	3	170	63.1	13.3	28.1	4680	91	84.1	1.54	29.2
10	4	140	69.9	17.1	35.5	6000	77	-	1.42	37.6
10	4	150	66.7	17.7	32.2	5507	83	45.4	1.71	37.4
10	4	160	60.8	14.9	33.0	5113	82	69.4	1.46	22.2
10	4	170	60.2	14.1	30.8	4822	92	57.2	1.62	26.3

(1) and (2) ovendry-wood basis

(3) ovendry pulp basis.

Table XI

Effect of Chemical Concentration on NSSC Pulp Properties

Wood liquor = 1:5; max. temp. 170°C; time to max. temp. 2 hrs; time at max. temp. 2½ hrs.

Cooking liquor (1)		(2) Yield %	(3) Lignin %	Freeness °SR	Bulk	Tear factor	Burst factor	Breaking length (m)	Folding endurance	Brightness (GE)
$NaHCO_3$ %	$NaHCO_3$ %									
6	2	57.9	14.9	8	-	-	-	-	-	-
				45	1.77	60	16.2	4655	14.4	17.3
6	3	60.2	17.8	8	2.38	43	3.2	1060	1.5	-
				45	1.61	71	22.4	3400	28.8	18.5
8	2	62.1	14.5	7	2.35	46	2.9	525	-	-
				45	1.56	90	27.0	4144	28.0	23.9
8	3	57.1	14.4	10	2.52	48	2.9	873	-	-
				45	1.60	66	17.2	3515	17.4	17.9
8	4	55.1	15.9	8	2.69	27	2.2	582	-	-
				45	1.80	45	9.2	2600	3.2	16.9
10	2	64.6	13.1	8	2.60	45	3.6	805	1.0	-
				45	1.61	84	34.6	5900	82.3	31.9
10	3	63.1	13.1	8	-	-	-	-	-	-
				45	1.54	91	28.0	4660	64.1	29.2
10	4	60.2	14.1	9	2.26	40	3.0	720	1.5	-
				45	1.62	92	30.7	4922	57.2	26.3
12	3	60.1	13.6	7	2.55	42	3.7	1382	2.8	-
				45	1.55	77	40.6	8114	131.5	29.2
12	4	54.3	14.0	13	2.40	50	6.5	1467	2.0	-
				45	1.60	77	30.0	5934	66.0	23.3
12	6	54.4	11.9	8	2.61	57	4.5	1288	2.0	-
				45	1.63	77	39.1	7262	80.0	26.3
14	3	54.5	9.7	8	2.54	57	4.2	1659	2.0	-
				45	1.56	89	39.2	7236	108.7	31.9
14	4	55.8	10.6	7	2.55	37	3.3	1152	2.0	-
				45	1.56	79	34.0	7343	60.0	31.8
14	6	54.3	11.0	7	-	-	-	-	-	-
				45	1.55	95	40.0	7128	104.2	26.0
16	3	55.4	-	7	2.29	38	3.3	615	2.0	-
				45	1.62	78	34.0	7568	114.6	33.4
16	4	54.2	10.8	7	2.62	48	3.7	918	2.0	-
				45	1.56	76	30.0	6128	226.0	35.6
16	6	53.6	10.0	7	2.61	44	3.4	1034	2.0	-
				45	1.41	86	39.8	7271	307.0	28.9

(1) and (2) ovendry-wood basis

(3) ovendry-pulp basis

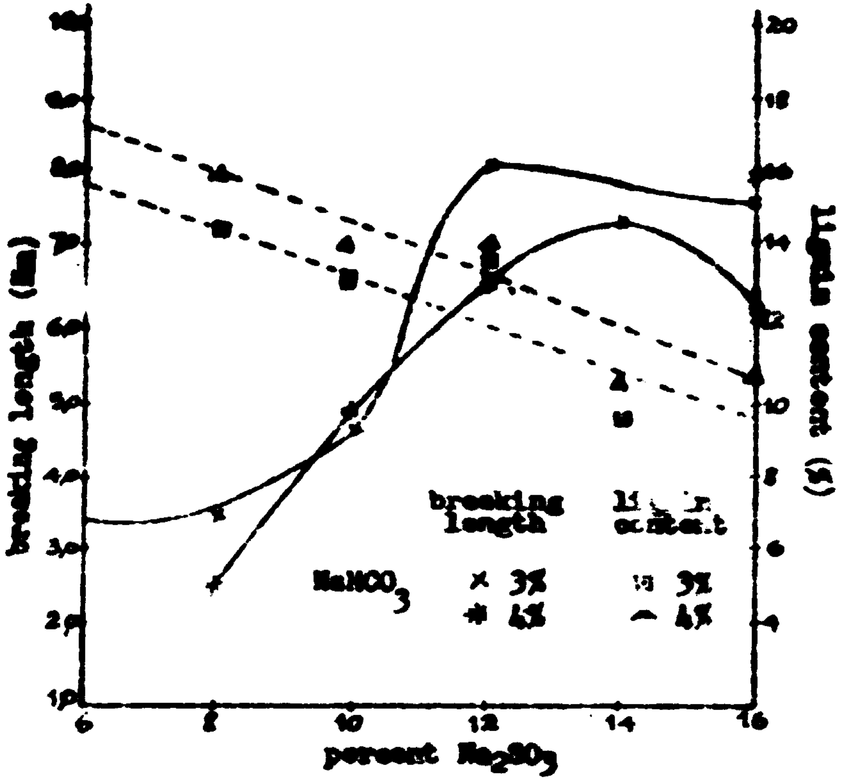


Fig 1. EFFECT OF CHEMICAL CONCENTRATION ON BREAKING LENGTH AND LIGNIN CONTENT.

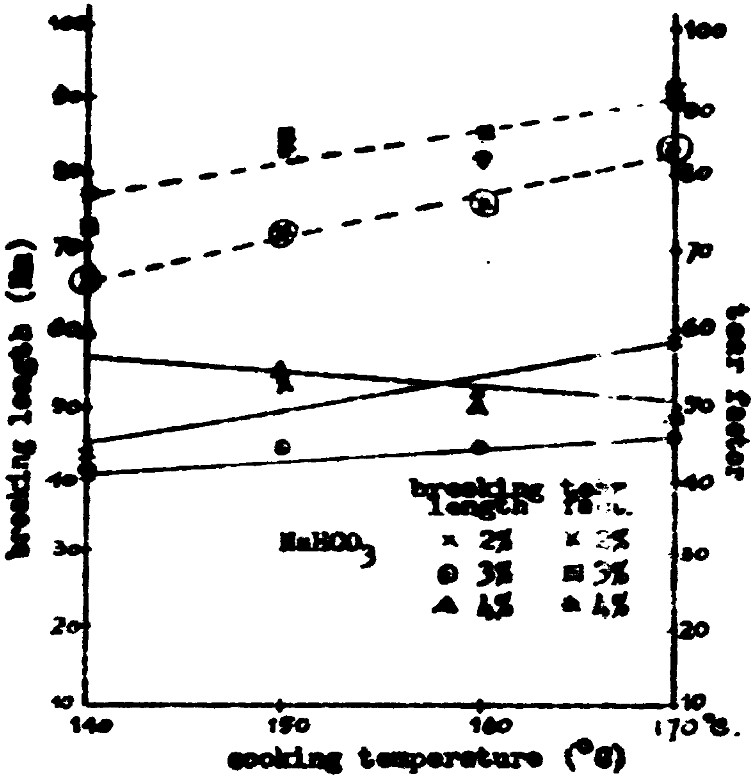


Fig 2. EFFECT OF COOKING TEMPERATURE ON BREAKING LENGTH AND TEAR FACTOR. AT 10 % Na_2SO_3

dium bicarbonate should be kept to a minimum.

Using the above procedure no latex was found in the test-sheets, it could already be removed during the screening.

Compared with other NSSC pulps prepared in our laboratory, using Eucalyptus alba and Albizia falcata, rubberwood pulp had lower yield and strength, only the tear factor was comparable.

Experiments on rubberwood using polysulfide process is now being carried out.

Other experiments using Indonesian rubberwood had been attempted at Fuchow paper mill, China(9), to obtain mechanical pulp for newsprint, but the result was not satisfactory. The pulp obtained was powdery and had a low breaking length.

II. Dissolving Pulp. :

In order to obtain high purity pulp, sulphate process alone is not sufficient because it could not effectively remove pentosan. Therefore, prehydrolysis as well as posthydrolysis were attempted. Hydrolysis is meant to weaken bonds of non-alpha constituents, primarily pentosans, rendering them soluble in the subsequent treatments.

a. Prehydrolysis.

As a continuation of the storage experiments(5), rubberwood after being stored with various conditions, was cooked using sulphate process and preceded by hydrolysis. The prehydrolysis with water (wood to water ratio 1 : 5) was done at 150°C for 1 hour, and this proved useful for obtaining pulp with low pentosan content (8.4 % as compared to 17.6 % for pulp without prehydrolysis).

The prehydrolysis yield varied considerably (78 - 97 %) but no clear trend of storage effect on the yield was observed. The prehydrolized wood was further cooked.

Cooking was done using sulphate process with wood to liquor ratio 1 : 5, maximum temperature of 150°C for 3 hours, active alkali 18 %; effective alkali 15.4 % and sulphidity 28.4 %.

The unbleached pulp obtained showed a decrease in pentosan content with storage. The pentosan seemed to be more easily removed after a certain period of storage. Also the yield and permanganate number showed a decreasing trend with storage time (table XII).

Low permanganate number indicates that the extent of delignification was far enough and that the pulp will be relatively easy to bleach. But the fact was that dark spots observed on the pulp could not easily be removed by bleaching. Bleaching was done in six stages (C-E-H-E-H-Acid). The resulting bleached pulps had fairly good quality with high α- cellulose content and low Cu number. Unfortunately brightness of the pulps was not determined, because at that time the equipment was not available yet.

Another cooking condition but with the same prehydrolysis condition, was attempted using wood to liquor ratio of 1 : 4, maximum temperature of 150°C for 2½ hours, active alkali 16.3 %, effective alkali 13.8 %, sulphidity 30.1%.

The pulp yields were higher than the first pulping serie (40 - 47 %) but the permanganate number were also higher (14 - 19). This pulping condition was not strong enough. The resulting bleached pulps, after sixstage bleaching, showed a pentosan content of around 5 %, higher than the first serie of cooking where the pentosan content of the bleached pulp was around 2 %.

Table XII

Effect of storage on yield and chemical composition of prehydrolised unbleached pulp.

Sample No.		Yield %	Permanganate No.	Ash %	Alc-Benz Extr. %	% Lignin %	Pentosan %
I	K_1	43	16.3	1.15	1.49	2.68	7.74
I	K_2	37	10.0	2.55	0.97	2.20	8.89
I	K_3	42	12.4	0.67	0.77	0.87	1.72
I	T_1	44	11.3	0.83	1.20	1.27	9.77
I	T_2	37	9.7	0.75	0.92	3.12	6.88
I	T_3	39	8.3	0.55	0.77	1.09	4.53
II	K_1	44	14.2	1.67	1.04	1.69	11.6
II	K_2	34	11.9	0.12	0.90	2.59	9.73
II	K_3	32	8.4	0.51	0.73	1.16	2.98
II	T_1	44	12.5	0.94	0.82	1.67	10.6
II	T_2	35	12.4	1.33	0.99	0.74	7.54
II	T_3	.32	13.4	1.80	0.81	2.87	4.19
III	K_3	42	7.7	1.16	0.78	1.36	9.35
III	K_2	29	5.0	0.47	0.77	0.67	4.48
III	K_3	36	7.0	1.14	0.68	1.52	4.96
III	T_1	41	8.7	0.94	0.70	1.30	8.08
III	T_2	31	7.2	0 88	0.76	1.10	6.32
III	T_3	25	6.3	0.51	0.80	0.93	6.60

* See table V.

In other experiments (10) prehydrolyses were carried out in water at different maximum temperature ranging from 120 to - 180°C, for one hour and with wood to water ratio 1 : 5. This was then followed by a sulphate cook with 16.8 % active alkali, 25 % sulphidity, maximum temperature 150°C for 2½ hrs; wood to liquor ratio 1 : 4.

The preheating time was 2 hours. The pulp was then bleached using multi-stage process.

Increasing the hydrolysis temperature caused a decrease in yield of prehydrolized wood especially above 170°C and a fall of pH resulting in a decrease of ash content. The lignin content was high and seemed to increase with the increase of temperature up to 160°C. This was believed to be due to the formation of humic material which was isolated together with lignin. The pentosan content was slightly reduced with the increase of hydrolysis temperature, but at 170°C a sharp decrease to-gether with a decrease in yield and an increase in alcohol benzene soluble matters were observed.

Chemical analyses of the pulps showed that on increasing the prehydrolysis temperature, ash and lignin contents were decreased while alcohol benzene solubles increased.

The pentosan contents were lowered to approximately 8 % up to prehydrolysis temperature of 160°C but could reach approximately 4 % at 180°C, as can be seen in table XIII.

The pulps were relatively easy to bleach. At low hydrolysis temperature (120 - 150°C) the pentosan content of the bleached pulp was still rather high(6-8 %), but increasing the prehydrolysis temperature succeeded in lowering the pentosan content to approximately 2 % (Table XIV).

b. Posthydrolysis (10).

The pulp obtained from the sulphate cooks with 3 different active alkali concentrations mentioned previously (table VI) were further post-hydrolized using 0.15 %, 0,25 %, sulphuric acid for 60 minutes at 125°C and pulp to liquor ratio 1 : 6. The chemical analysis of the unbleached pulp showed a decrease in permanganate and lignin content, but the pentosan contents were still high (15 - 17 %), see table XV.

But after six stage bleaching, a remarkable decrease of pentosan content, ash content together with a sharp increase in α-cellulose were observed (Table XVI).

Thus post-hydrolysis with dilute mineral acid followed by multistage bleaching can produce dissolving pulp out of ordinary paper pulp.

Table XIII.

Analysis of water prehydrolized unbleached pulps.

Sample No.	Hydr. Temp. °C	Yield %	P.N.	Ash %	Alc.benz. extr. %	Lignin %	Alpha-cell. %	Pentosan %
1	120	46.3	11.1	0.32	0.18	1.22	88.1	11.3
2	135	43.1	10.7	0.29	0.13	1.08	90.1	10.9
3	150	42.3	9.8	0.28	0.25	0.96	89.1	9.94
4	160	39.9	9.3	0.27	0.45	0.85	90.3	8.48
5	170	33.8	6.7	0.26	0.56	0.75	92.7	6.15
6	180	31.4	6.8	0.22	0.66	0.74	94.3	3.56

Table XIV.

Analysis of bleached pulp from prehydrolysis experiments.

Sample No.	Hydr. Temp. °C	Yield* %	Ash** %	Alc.Benz. extr. %	Alpha-cell. %	Pentosan %	Cu No.
1	120	37.8	0.34	0.13	93.4	7.58	0.43
2	135	35.8	0.25	0.09	94.2	7.62	0.40
3	150	35.2	0.29	0.04	93.9	6.12	0.30
4	160	35.2	0.30	0.02	97.3	3.10	0.32
5	170	31.4	0.25	0.02	97.8	2.26	0.31
6	180	29.5	0.21	0.11	98.0	1.98	0.37

* Wood basis. ** High ash content probably due to the use of tap water for the whole process.

Table XV.

Chemical analysis of posthydrolised unbleached pulp.

Sample	H_2SO_4 %	Yield %	Perm. No.	Alc.Benz. extr. %	Lignin %	Alpha-cell. %	Pentosan %
ABS I	-	100	19.8	1.30	4.66	79.9	17.2
	0.15	95.8	16.3	0.44	1.70	85.2	15.6
	0.25	94.5	16.0	0.56	1.25	85.1	15.9
ABS II	-	100	19.3	-	2.51	80.1	17.8
	0.15	98.3	15.7	1.08	1.54	85.1	15.9
	0.25	96.3	15.6	1.47	2.60	84.4	16.9
ABS III	-	100	17.3	-	3.30	84.3	16.7
	0.15	98.3	15.6	1.03	2.78	83.9	15.8
	0.25	97.3	15.4	0.82	2.00	83.8	15.9

Table XVI.

Chemical analysis of posthydrolised bleached pulp.

Sample	H_2SO_4 %	Ash* %	Alc.Benz. extr. %	Alpha-cell. %	Beta+gamma cell. %	Pentosan %
ABS I	0.15	0.24	0.27	97.8	3.45	3.19
	0.25	0.20	0.19	97.4	3.25	3.19
ABS II	0.15	0.16	0.25	97.3	3.03	5.74
	0.25	0.21	0.63	96.9	2.66	6.88
ABS III	0.25	0.22	0.71	96.8	2.57	6.40

* High ash content probably due to the use of tap water

c. Viscose making (11).

Some of the prehydrolised pulps obtained with sulphate process were further investigated in viscose and fiber making, among which there were pulps with high pentosan content.

Viscose was made by using slurry steeping with NaOH 18 % at 20°C for 1 hrs and pulp to liquor ratio 1 : 4 Pressing to press factor 2,7 - 3,5 and shredded by disk refiner.

Aging was performed at 25°C for various time, then xanthation with 37 - 50 % CS_2 at 30°C for 2 hrs. Dissolving was done using a stirrer at 10°C for 3 hrs and the composition of the viscose was made into 7 % cellulose and 7 % NaOH.

Ripening was performed at 20°C for 10 - 25 hrs. After filtration and deaeration, the viscose was spun through a coagulating bath consisted of sulphuric acid, sodium sulphate and zinc sulphate. The further treatments were washing the fiber with water, then with sodium sulfide solution several times and finally drying the fiber in the air.

During the viscose making, rubberwood pulps appeared to give normal and satisfactory performance. The purer the pulp the better the spinning performance and the addition of small amount of surface active agent could improve the spinning performance. But some viscose had rather high clogging constant (Kw about 400).

On investigating the pulp small yellow rubber particles were seen and in the filter residue small undissolved fibre bundles, resinous matter and other impurities were found.

It is presumed that large particle did not disturb much, but whether the filtration characteristic might have any relation with those impurities, further investigation is still necessary. This difficulty was also experienced by Von Kohorn International Corporation in their feasibility study on using rubberwood for dissolving pulp for South Sumatra Rayon Project(12).

The physical properties of the fiber were comparable with ordinary rayon. Dry strength 3.6 g/d, wet strength 2.05 g/d, breaking length 32.4 m and elasticity 28 %. The fiber was further made into cloth.

B. Pilot Scale Experiments.

The Cellulose Research Institute has a pilot plant with a capacity of 750 kgs/day dissolving pulp or 1000 kgs/day paper pulp. The equipments are, among others, one chipper with 10 m^3/hour capacity, one 8 m^3 digester equipped with direct and indirect heating system. Screening is done in two stages using Johnson vibrating screen and Biffar centrifugal screen. Unbleached pulp is passed through a sand trap (type DR 800) to remove heavy particles, sand etc; and bleaching can be done with chlorine or sodium hypochlorite both with high or low consistency and for high brightness, multistage bleaching can also be carried out. There are also two-stage centricleaner (type RB 80 X) for final cleaning. The bleached pulp can be dried or be made into the form of wet lab with 70 % water content.

For the experiments, rubber trees were first debarked by hand using hammer.

After debarking the logs were chipped 20 mm long and 3 - 6 mm thick. Cookings were done using white and black liquor in a ratio of 3 to 1. Process conditions were chosen from the result of laboratory experiments. For soda process the conditions were 20 - 24 % NaOH, maximum temperature 165°C and total cooking time 5 hours.
The permanganate number, yield and pulp strength were comparable with the result obtained from laboratory experiments.

During screening, soft latex accumulations which easily sticked to the metals or the chests were found and the bleached pulp still contained small rubber particles. This was not encountered during laboratory experiments.

In an attempt to solve this latex problem, special debarking was attempted where not only the bark, but also the wood a few millimeters under the cambium and both ends of the logs, were removed.

Table XVII.

Pilot scale soda cooking of rubberwood.

Cooking No.	NaOH %	P.N.	Screened yield %	Tear factor	Burst factor	Breaking length (m)	Folding endurence
85	24.0	8.0	31.0	98	36.4	5750	83
88	22.6	10.8	41.6	56	32.7	4820	65
89	21.5	10.6	41.6	75	31.9	7000	58
90	20.2	11.9	43.3	63	34.1	6700	91

Care was taken to use only untapped parts of the logs to eliminate the presence of hardened latex in the wood which is due to incorrect tapping as was mentioned before. Also because wood of the tapped zone is usually very hard. This treatment was done in order that latex which is thought to occur in the bark could be removed. But the cooking results showed that latex strands could still be found in under - cooked chips although in lesser amount, and also that the bleached pulp still contained latex particles. From the above experiment we believe that latex is found not only in the bark but also in the wood.

Sulphate cookings were experimented in the hope that latex could be coagulated by the sulphur compounds. The cooking conditions were 17 % active alkali, 25 % sulphidity and the temperature (165°C) was somewhat higher than was used in the laboratory experiments.

The results as shown in table XVIII indicated that compared with laboratory results, the permanganate number and yield were lower, but this was expected because of higher cooking temperature. The pulp strength was not much different.

In the unbleached pulp, latex accumulation were much found, but it could easily be separated during screening. Therefore it was concluded that the latex problem could be solved by using sulphate process with some improvements in screening .

Table XVIII.

Pilot scale sulphate cooking of rubberwood

Cooking No.	P.N.	Screened yield %	Tear factor	Burst factor	Breaking length (m)	Folding endurance
24	9.4	39.5	101	36.3	7070	201
28	8.0	40.1	80	37.3	6990	279
31	11.2	42.2	98	43.2	7480	216

Cooking with low sulphidity, just enough to coagulate the latex were also attempted, because the price of sodium sulphide was higher than that of sodium hydroxide. The results (table XIX) showed that permanganate number, yield and pulp strength were comparable to that of normal sulphate cooking (table XVIII), while the latex alredy accumulated at the time the pulp was blown from the digester.

Table XIX.

Pilot scale sulphate cooking of rubberwood with low sulphidity

Cooking No.	Active alkali %	Sulphidity %	P.N.	Screened yield %	Burst factor	Breaking length (m)	Folding endurance
92	16.2	7.43	11.8	42.5	34.9	6425	90
93	15.0	7.10	12.8	40.0	32.0	5410	104
94	14.0	4.72	12.3	43.0	40.0	8290	240
95	14.4	6.90	13.9	41.2	36.2	6910	271

Bleaching was done with NaClO in 3 stages : H-E-H. The brightness obtained for soda as well as sulphate pulps was on the average 78 GE.

For low sulphidity pulps three bleaching variations were attempted using calcium hypochlorite, sodium hypochlorite and 3 stage bleaching (H-E-H). By using Ca-hypochlorite the brightness obtained was rather low.

Table XX.

Bleached rubberwood pulp from sulphate cooking with low sulphidity

P.N.*	Bleaching	Cl_2 Used %	Brightness GE	Tear factor	Burst factor	Breaking length m	Folding endurance
13.7	Ca-hypo	6.6	71.4	88	37.5	5820	238
13.4	Na-hypo	6.6	78.5	94	27.0	6070	141
14.1	H-E-H	6.6	79.0	76	28.8	6160	298

* of unbleached pulp.

PAPER MAKING.

The sulphate pulp obtained from pilot scale experiments at the Cellulose Research Institute was further used for papermaking at the Padalarang (West Java) and Blabak (Central Java) papermills.

The Padalarang mill was built in 1921 with a capacity of 10 tons/day. This factory used rice straw (the upper part) as raw material, mixed with imported bleached long fiber pulp. Beating and the addition of sizing, filler etc are done in a Hollander. The maximum speed of the paper machine is 100 m/min.

Rubberwood pulp was mixed with long fiber bleached kraft pulp (Pinus merkusii), also produced at the institute, with a ratio of 88 % rubberwood (hevea kraft) pulp and 12 % pine kraft pulp. The mixing was first done in a Kollergang for - about 2½ hours and beating was continued in a Hollander.

In further experiments hevea pulp was mixed with rice straw pulp and in an other experiment hevea pulp was mixed with rice straw pulp and bamboo pulp.

During the preparation of writing paper, some latex sticked to the calender rolls. This may be due to the large addition of alum as compared with that used for duplicating paper, with the result that the pH was low. This acid condition probably caused the dispersed latex to accumulate and to stick to the calender. The paper machine speed was 30 - 55 m/min.

Other experiments were done at the Blabak mill. This mill started operation in 1960 with a design capacity of 24 ton/day and using rice straw as raw material. Beating is done in a Jordan refiner and the maximum design speed of the paper machine is 200 m/min.

Hevea pulp was mixed with bleached spruce pulp. Both writing paper and liplicating paper were made. The paper machine speed was 80 - 100 m/min.

The above experiments were carried out as long as 10 hours continuously without any due difficulty and the resulting paper was satisfactory. Occasionally small spots were seen on the writing paper but this was not observed on the duplicating paper. The bulkiness of rubberwood pulp seemed to be suitable for duplicating paper.

Some of the results can be seen in table XXI. For comparison, paper made from a mixture of rice straw pulp and spruce kraft pulp is also included.

Table XXI

Results of some papermaking experiments

Pulp properties	Paper Grade	Addition of size, filler etc.	Paper properties					
			Freeness °SR	Breaking length (m)	Tear fact.	Folding endurance	Bulk	Brightness (GE)
1. 20% hevea kraft	Duplicating	20% kaolin	48	DM 5150	DM 54	DM 10	1.37	73
80% straw soda	69 gr/m^2	0.9 % rosin						
		1.5 % alum		CM 2830	CM 59	CM 8		
2. 20% hevea kraft	Duplicating	ditto	-	DM 4381	-	DM 110	-	-
13.5% bamboo kraft	69 gr/m^2			CM 3137	-	CM 70		
66.5% straw soda								
3. 88% hevea kraft	Duplicating	ditto	29	DM 3520	DM 77	DM 7	1.63	74
12% pine kraft	67 g/m^2			CM 1800	CM 80	CM 4		
4. 88% straw soda	Duplicating	ditto	46	DM 5900	DM 53	DM 137	1,40	74
12% spruce kraft	76 gr/m^2			CM 3670	CM 56	CM 56		
5. 90% hevea kraft	Writing	10% kaolin	30	DM 3480	DM 59	DM 25	1.48	77
10% spruce kraft	56 gr/m^2	5.5 % starch						
		1.7 % rosin						
		3.4 % alum		CM 1800	CM 63	CM 10		
6. 90% straw soda	Writing	ditto	44	DM 4480	DM 82	DM 240	1.51	77
10% spruce kraft	62 gr/m^2			CM 2690	CM 87	CM 212		

CONCLUSIONS.

1. Unless using raft, water transportation of fresh rubberwood is not possible.

2. Underwater storage (preferably in unbarked condition) is best to minimize bluestain attack and to avoid difficulty in debarking. Also underwater storage decrease ash and pentosan content of the wood.

3. Using the same cooking condition, the yield, permanganate number and pentosan content of the unbleached pulp showed a decreasing trend with storage time.

4. Tapped zone of rubberwood trunk should not be used for pulping due to the presence of hardened latex within the wood, and because the wood itself becomes hard.

5. Latex is present not only in the bark but also in the wood.

6. Using soda process, soft and swollen latex was found in the pulp which is sticky and difficult to remove. But by using sulphate and NSSC processes (or any process containing sulfur compound) latex accumulation was not sticky and the removal by proper screening became easier.

7. NSSC process for rubberwood requires relatively low chemical concentration (10 - 12 % Na_2SO_3) as compared with other hardwoods such as Eucalyptus alba and Albizia falcata.

   For high brightness a minimum amount of $NaHCO_3$ (2 %) should be used. Cooking temperature should be 160 - 170°C.

8. Prehydrolysis with water of the wood renders the pentosan more soluble during the subsequent treatments. Increasing the prehydrolysis temperature from 120 - 180°C decreased the ash, lignin and pentosan content of the unbleached pulp.

   Bleaching decreased the pentosan content even more.

9. Posthydrolysis of sulphate pulp by dilute acid (0.15 %, 0.25 % H_2SO_4) for 60 minutes at 125°C slightly decreased the lignin content of the unbleached pulp but the pentosan content is still high, only after bleaching pentosan content decreased remarkably.

10. Papermaking experiment using sulphate rubberwood pulp mixed with long fiber pulp, rice straw pulp and bamboo pulp, and using a speed of only up to 100 m/min gave satisfactory result especially for duplicating paper.

11. Experiments using rubberwood dissolving pulp for viscose and fiber making could produce satisfactory result although the clogging constant was still rather high (Kw = 400). The physical properties of the fiber were comparable with those of ordinary rayon. Further experiments are still necessary.

ACKNOWLEDGEMENTS.

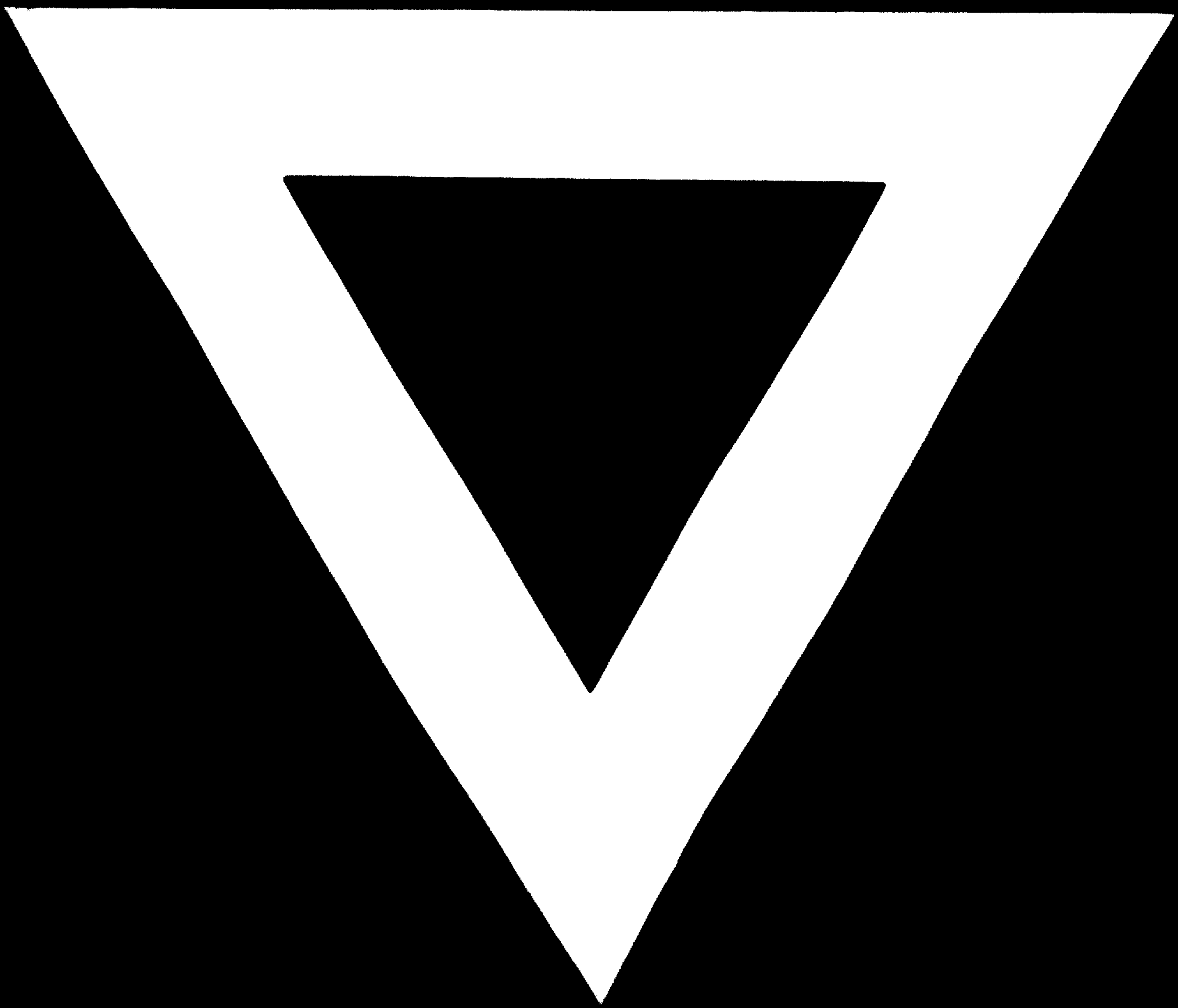
The help of Plantation Government Enterprises and private estates in supplying the necessary samples and data is hereby gratefully acknowledged.

Also thanks are due to the Padalarang and Blabak papermills and the Martapura Paper Project, whose cooperation made this work, especially the papermaking, possible.

Last but not least the writers wish to express their gratitude to the other colleagues, especially Dr. Rochjati J, for their guidance and advice during the experiments and to many members of the laboratory and pilot plant of the Cellulose Research Institute especially Mr. Negi I.M. who contributed in the experimental works.

REFERENCES:

1. Dijkman, M.J.,
   Hevea, Thirty Years of Research in the Far, East, University Miami Press, Coral Gables, Florida, 1951.
2. Rubber Statistical Book,
   Badan Pimpinan Umum PPN Karet, Djakarta, 1965.
3. Indonesian Central Bureau of Statistics (refised), 1965.
4. Peel, J.D., and Peh, T.B.,
   Pulp and Paper Prospects in Asia and the Far East,II,1962, F.A.O. of the United Nations.
5. Berita Selulosa, I, No.2, Djan. 1965.
6. Cartwright, K.St.G., and Findlay, W.P.K.,
   Decay of Timber and Its Prevention, His Majesty Stationary Office, London, 1948.
7. Unpublished report of the Cellulose Research Institute Bandung for Martapura Paper Project, 1969.
8. Reid, A.H., APPITA vol. 15, 102, 1962.
9. Unpublished report of the Fuchow Paper Mill, China, 1965.
10. Joedodibroto, R., and Alaudin,
    Berita Selulosa, II, No. 2, Sept. 1966.
11. Nogi,I.M.,
    Berita Selulosa, II, No. 2, Mei 1966.
12. Unpublished report of the Von Kohorn International Corporation for South Sumatra Rayon Project, 1962.



74.10.14