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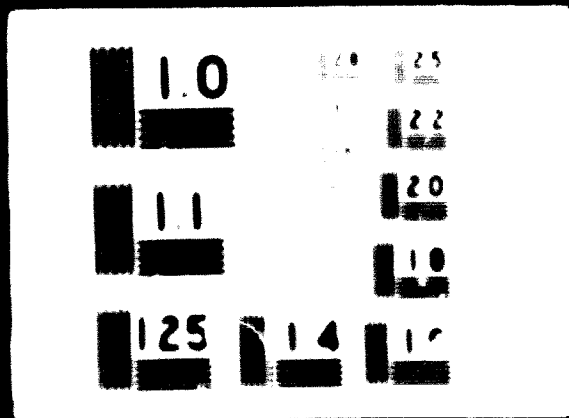
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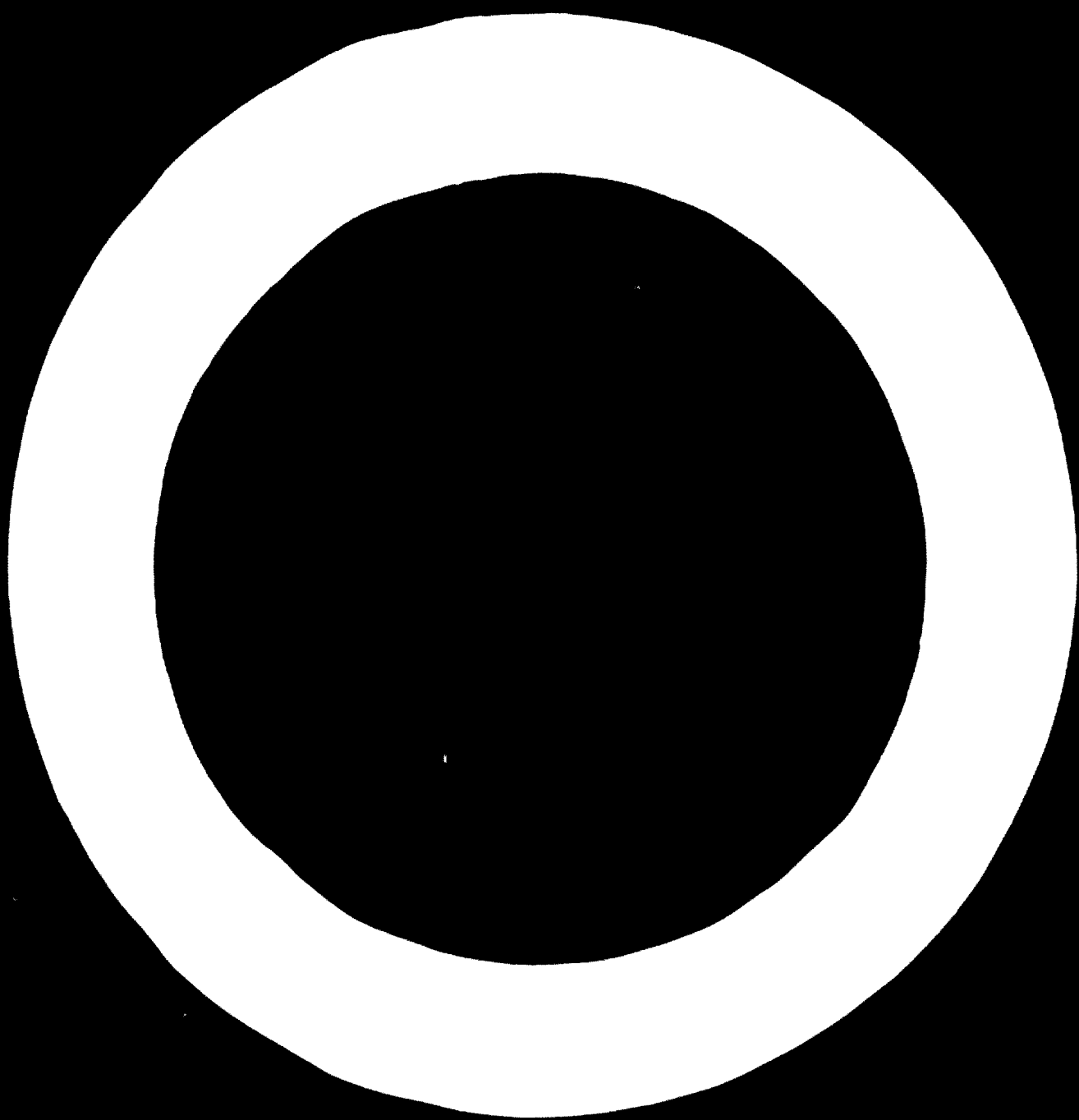
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USE OF MIXED TROPICAL WASTEWATERS
FOR PRODUCTION OF PULP AND PAPER IN INDIA 1/

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SUMMARY

The introductory paragraphs give a general description of pulp and paper industry and its cellulosic raw material consumption pattern. Annual production of writing and printing paper in India is 0.7 million tonnes for which the main cellulosic raw material is bamboo constituting 70 percent of total consumption. History and growth of the industry in India has been traced. The first paper mill was started in 1912. The forests of India, their growing stock and increment, and the man-made forests have been described to give an indication of composition and resources potential. India's forest area extends over 75 million hectares of which coniferous forest is only about 4 million hectares. The growing stock in the exploitable forest is about 2298 million cum. and the net increment is 26.65 million cum. About 0.26 million hectares of plantations of pulpwood species have been created. Economics of bamboo and hardwoods have been discussed. Mill delivery cost of bamboo is about Rs. 120/- per tonne while for hardwoods it is about Rs. 75/- per tonne. An account has been given of the researches done to ascertain technical suitability of hardwoods for making pulp and paper. Valuable information on fibre morphology, chemical and physical characteristics etc. and pulping behaviour of a large number of tropical species have been known from these work. Encouraging results from the pulping and

paper making tests carried out with these species both in laboratory scale and in pilot plant scale led to introduction of these species for paper making by enterprising mills.

Information have been furnished on the pulping of mixed tropical hardwoods by seven paper mill in India. These mills use mixed hardwood pulp in varying proportion in the paper furnish in admixture with long fibre pulp. The practical experience have brought out various problems which have been discussed. Difficulties encountered by many mills in using tropical hardwoods for making pulp have been indicated.

INTRODUCTION

1.1. The main source of cellulosic raw material for pulp and paper industry has been wood of coniferous species of gymnosperms (commonly known as softwood) in the temperate countries whereas in India bamboos constitute the principal raw material. Conifers and bamboos are favoured by the industry because of their fibre characteristics. However, dependence on this limited source of raw material resulted in limiting the location of industry to certain selected areas. Rapid expansion of pulp and paper industry during the last few decades has put increasing pressure on these traditional sources of cellulosic raw material all over the world resulting in the search for new raw material. Research is carried on to develop the pulping processes and one of the most important recent developments has been the steadily increasing use of wood of broad leaved species of angiosperms (commonly called hardwoods) for pulp and paper making thus widening the raw material base of the industry. This has helped not only to overcome the problem of shortage of raw material but also introduced flexibility in the choice of location which is of great significance in the development of industry. The percentage of broad leaved species in the manufacture of pulp has gone up in almost all countries of the world.

1.2. Even in countries which are rich in conifers the broad leaved species have made an inroad in pulp and paper industry. However, it will be important to mention here that the utilization of hardwood has generally been confined to temperate broad leaved

species. The one tropical hardwood which has found extensive use in paper making is *Acetylus*. Associated Pulp and Paper Mills at Barmio, Tasmania, was the pioneer in making paper from *Acetylus* in 1928. Since then many other mills in Australia and to a limited extent in other countries have been using different species of *Acetylus* for making writing and printing papers, kraft paper and newsprint. In recent years rubberwood has been used for paper manufacture, primarily in Japan. Japan has also been using various other hardwood species for pulp. However the large resources of hardwood in the world in the tropical and subtropical forests, have not been given adequate attention for papermaking. Laboratory tests have been carried out to determine the pulping qualities of a large number of tropical hardwood species by various processes and many of these species have been found suitable for manufacture of pulp and paper of desirable strength and other characteristics. The above results have not been of much practical use as could normally be expected, perhaps, because of the peculiar character of the tropical and subtropical forests where usually a large number of species occur in close mixture. It is uneconomic to utilize a few selected species for utilization for a particular purpose. Mixed pulping of these species together appears to be a practical solution under the circumstances.

1.3 The paper industry in India dates back to 1832 when the first paper mill was established in West Bengal. This was followed by setting up of other mills. These early ventures used waste papers, rags, jute cuttings and grass as their cellulosic raw material. Based on the earlier findings of the Forest Research Institute at Dehra Dun (India) bamboo was first used by a paper

mill in India in 1912. At present it is the main source of cellulosic raw material for the industry in this country. The present pattern of use of cellulosic raw material by the industry is Bamboo 70 percent, hardwoods 15 percent, grasses 5 percent and agricultural waste etc 10 percent. There are 58 Pulp and Paper Mills in India with a total installed capacity of 0.8 million tonnes. The annual production is 0.7 million tonnes which includes printing and writing papers, packing and wrapping papers, paperboards and speciality papers. This, however, excludes dissolving pulp, Newsprint and straw and mill boards produced to the extent of 58,000 tonnes, 31,000 tonnes and 70,000 tonnes respectively. In India the paper mills mostly make their own pulp. The size of the mills vary from 70,000 to 500 tonnes. There are 19 mills with annual capacity over 10,000 tonnes and the rest are smaller mills.

AVAILABILITY

2.1. We are all aware that to determine the technical and economical suitability of a raw material for any industrial purpose its sustained availability in a desired quantity has to be ascertained. Therefore, a study of the forests of India would be appropriate at this stage. The forest area extends over an area of about 75 million hectares or about 23% of country's total land area. Because of the varied physical features of the country, various forest types occur and one can come across almost all types of forest from temperate to tropical. Sixteen climatic forest types recognised are: Tropical wet evergreen, Tropical semi evergreen, Tropical moist deciduous, Tropical dry deciduous, Littoral and Swamp, Tropical thorn,

Tropical dry evergreen, Tropical moist evergreen, Tropical broad leaved hill, Tropical pine, Mountain wet temperate, Himalayan moist temperate, Himalayan dry temperate, Sub-Alpine, Moist Alpine and Dry-Alpine.

2.2. The coniferous forest of the country which is confined to the higher elevation of the Himalayas cover only about 4 million hectares constituting about 6% of the total forest area. The more important species are Cedrus deodara, Pinus roxburghii, Pinus excelsa, Pinus khasya, Picea morinda and Abies Pindrow. These conifers constitute an important source of long fibre raw material for paper industry. However, as yet, due to unsuitable infrastructure and high cost of extraction it has not been possible to utilise this source of raw material by the pulp and paper industry. Various measures have been taken to improve the system of transportation and thereby reduce the extraction cost and it is expected that in near future this valuable raw material would be utilised for manufacture of quality papers.

2.3. The broad leaved species of the country occupy about 71 million hectares and most of this is of tropical and semi-tropical nature. Although there are some species like Shorea robusta which are of a gregarious nature, majority of the broad leaved forests contain a large number of species growing in close association. The most important broad leaved timber species are Lecton grandis, Shorea robusta, Dipterocarpus Spp., Dalbergia latifolia, Dalbergia sissoo, Terminalia tomentosa, Pterocarpus dalbergioides, Pterocarpus marsupium and Lagerstroemia lanceolata. All the above species yield timber which are used

for various purposes. Important from occurrence and value are Tectona grandis which occurs over an area of about 9 million hectares and Shorea robusta which covers an area of about 10 million hectares. Apart from these valuable timber yielding species there are numerous other species growing in these forests which at present do not have much timber value and presently find use mostly as fuelwood.

2.4 It is estimated that the exploitable forest of this country extends over about 30 million hectares and the growing stock thereof is about 2255 million cu.m. The net increment from this forest has been calculated to be about 26.65 million cu.m. after deducting natural losses.

The total production of wood in the country is about 23.5 million cu.m. which is less than the net increment of the exploitable forests. Out of this, fuelwood constitutes 14.9 million cu.m. Most of the wood production is from broad leaved species. It would be seen from the above that a large proportion of wood production is utilised as fuel which is recognised as one of the lowest form of wood use. Apart from the above quantity of fuelwood which comes from recorded source an appreciable quantity of fuelwood is also extracted from unrecorded sources.

2.5 With a view to find out available surplus wood in the country for expansion of forest based industries a project called Pre-investment Survey of forest resources has been started in 1965. This project has completed survey over certain forest areas in the country. It has been ascertained that in a tropical mixed deciduous forest in Central India the growing

stock over 2.91 million hectares is 123 million cu.m. giving an average mean volume of 41 cu.m. per hectare. In addition to the wood resources as above a sizeable quantity of bamboo occur in this area. The extent of bamboo is over 0.53 million hectares and the estimated annual growth is 0.466 million tonnes. Similarly in the evergreen and moist tropical mixed forest in Southern India the growing stock over an area of 0.706 million hectares has been found to be 110 million cu.m. The average mean growing stock calculates to 220 cu.m. per hectare. These forests also contain an estimated 1.2 million tonnes of bamboo and 5 million tonnes of reeds.

Many of the species occurring in these forests are valued for their use in industries like plywood, veneer, furniture, sleepers, packing boxes, matches etc. The survey has ascertained the availability of saw logs and also the need of wood and timber for other purposes. They have indicated that after meeting these demands and excluding the logs and tops of non-commercial species, the pulp wood available from these areas would be about 40% which is indicative of the potential source of available hardwood for pulping from the country's forests. These studies are continued in other areas and information about these forests are expected to be available in due course.

It is necessary to mention here that the species occurring in these forests are many and they grow mostly in an intimate mixture. In the survey of Central Indian Forests mentioned above the growing stock is composed of about 100 species of which 13 species make up two-third of total volume. The highest occurrence

by a single species is only 1%. Only nineteen species have occurred over 100 years. There are a many 1-4 species each of which contribute from 0.1% to 1% each of total volume. Still only 10 species are found in the crop. It has been found that the crop is composed of 10-15 species in ratio to mixture, of which 10 species are of present or potential importance.

2.6. Apart from the existing forests to be used as source of pulpwood, large extent of land is being created in the country with which growing pulpwood species, both indigenous and exotic. Till now about 0.56 million hectares have been planted or with various wild growing species and it is planned to add about 6,000 hectares each year. In creating such man-made forests usually monoculture is resorted to. The average yield of pulpwood from such plantations of wild growing species is estimated to be about 6 tonnes per hectare per year as against 1.5 tonnes per hectare per year from plantations of bamboo. Concentrated plantations of the high yield would reduce the production and delivery cost of pulpwood as well as on the new mills to be set up in locations with desirable infrastructure.

CONCLUSIONS

3.1. Selection of raw material for an industry is highly influenced by its economic availability. Apart from the needs of the source of supply from the mill, the infrastructure which may include nature of terrain, mode and type of transport facilities, labour position etc., also determine the delivery cost. Comparison from other industries for the same raw material is also an important factor in determining economical suitability. Deteriorative nature of raw material and their behaviour in storage also affect the cost.

3.2 Initially when the sizes of the mills were small they were located usually near the consumption centres. With the increase in the size, preference has to be to the mills near the source of raw material. However, the bamboo yield per unit area is low which has to be collected from a large extent of area. The average distance of transport of raw material to feed a 100 tons a day mill will be 100 miles and in some cases even more. This necessarily increases the extraction cost. Another important factor which has contributed significantly to a rise in extraction cost of bamboo is the nature of cutting. Stipitately bamboo has to be removed on selection system. Each single bamboo has to be selected and cut from a congested clump, and carried to the nearest road usually. The mill delivery cost of bamboo varies to a great extent primarily due to a widely varying distance of forest from mill. However, a cost of Rs. 100/- per tonne at factory would not be uncommon. Competitive demand by different mills, as well as, by other users on this limited raw material is contributing to a rise in price.

In case of hardwoods, the volume output per unit area is more, the felling and extraction are simpler and concentrated, and is comparatively less. Hardwood extraction also allows mechanisation. These would result in a lesser cost of this raw material. Further the competition for this raw material is less. Although unlike softwood and bamboo, hardwood cannot be extracted by floating, which is a cheaper mode of transport, this factor is not of much significance in India where land transport in these areas is common. The cost of land transport available to a per mill is about Rs. 75 per tonne. Cost calculations made in the Pre-

Investment curves are shown in figure 1 and 2. Forest Dept. collected the cost at different locations for varying quantities of hardwood extracted. The average cost according to this survey is Rs. 70 per cum in one location and Rs. 96 per cum in another location if the total quantity of 2.4 million cu ft of valuable wood is extracted annually. This, however, includes cost for other industrial purposes which can afford to pay higher cost than bringing down the cost of pulpwood.

TECHNICAL FEASIBILITY

As far as apart from the fact that hardwoods are not adapted to water transportation and are not available in large quantities in large commercial areas other factors which have go for disfavoured their use in pulping are their hardness, dense structure, dark colour, chemical composition, high percentage of extractives and heavy - all their short and coarse fibres. In determining the technical suitability of a wood species for making pulp the variables to be ascertained would include fibre length, fibre width, cell wall thickness, lumen width and intrinsic fibre strength. To ascertain the technical suitability for making paper, scientists have been working with the various tropical hardwoods in different countries. Valuable information on the morphology, chemical characteristics etc. and pulping behaviour of different tropical hardwoods have been known from work being others of Peters with tropical hardwoods of Africa, of Harjo and Ols with thirteen tropical hardwoods of Philippine and Borneo, of Nicolas with twentyone hardwoods of Philippine, of Tomlinson with seventeen hardwoods, and of Jackson and Parkinson with eight tropical hardwoods of Central America. In India, investi-

gations on the suitability of hardwood species for pulping started in 1930, in the Forest Research Institute. This work was initially carried on individual species on a laboratory scale. Preliminary chemical analysis of the woods were made and their fibre dimensions were determined. The woods were tested to ascertain the quality and yield of pulp. Several digestions by the Sulfito process were carried out to find out optimum digestion conditions. After digestion, the pulp was washed and bleached in two stages. Standard sheets were made from the bleached pulp and tested for strength properties. The tests revealed that standard sheets from a few of the hardwoods tested have strength properties which compare favourably with those of bamboo pulp sheets and the pulp yield of hardwoods are mostly higher than bamboo. In view of the positive results obtained in the laboratory tests, further work in these lines were carried out on a pilot-plant scale. These pilot-plant trials generally corroborated the pulp yields obtained in laboratory tests but the strength properties of paper made on a machine were comparatively less although of standard standard. These properties of papers could be suitably improved by adding certain proportion of long-fibred pulp. It may be pertinent to mention here that results obtained from these tests carried out with treated hardwoods suitably were more of a indicative nature. Utilization of species by selection for paper making proved uneconomical because of the composition of treated hardwood forest which contain a large number of species in an intimate mixture. Even then, these tests results have indicated a highly potential source of raw material for the paper industry. The industry

could not afford to ignore this. The results thus were incorporated in paper making in India as advised by selective use of the species in the manufacturing mills. This is the work which brought out a number of problems and further work continues to get over these.

4.2 The practical difficulty faced by paper makers in obtaining selective species of wood from a mixed tropical forest led the research to be conducted with mixed hardwoods. Tests were carried out with different species of wood mixture to ascertain their pulp yield and quality of paper produced both on laboratory scale as well as on pilot plant scale. While determining the proportion of different woods to be used in the mixture for purpose of tests, their relative standing in the forest was taken as a basis. For each wood mixture, such tests have been carried out under different digestion conditions and the optimum condition ascertained. Apart from the Forest Research Institute at Dehra Dun, tests on mixed tropical Indian hardwoods relating have been carried out at the Central Laboratory of Andhra Cellulose Industries, National Chemical Laboratory of Bombay, Institute of Paper Technology at Schenck, Montreal for a Circle of Canada, as well as at the laboratories of a few progressive paper mills in India. The most significant conclusion made from these various tests has been that a mixture of tropical hardwoods can yield paper with acceptable qualities which can be improved through refined production techniques.

PRACTICAL APPLICATIONS

5.1 In view of the acute shortage of long fibre pulpwood and as it will take several years to increase the availability and as the time scale is long, it is desirable to partially modify the

process, acceptable paper or newsprint can be made by increasing the proportion of short fibre pulp in the furnish, it is recommended that the minimum quantity of long fibre pulp should be used. It was one of the many recommendations made in 1965 by the working group of the committee on Forest Resources of the Planning Commission of this country set up to undertake a study of cellulosic raw material for pulp, paper and newsprint industries. The paper makers were aware of the widening gap between the supply and demand of long fibred pulp and were making efforts to find alternate raw material. Some of the mills were experimenting on pulping of mixed hardwoods occurring in available forests and introducing the short fibred pulp in varying proportion in the furnish. Experience gained by these efforts were made available in a "symposium on utilisation of hardwood for pulp and paper" held in August 1968 in the Forest Research Institute at Dehr-Dun, India. This symposium discussed the new situation with a view to find suitable solution. The industry stressed on the importance of sustained supply at economic price of hardwood species of proven pulping qualities of stipulated specifications. Necessity of further research on pulping of mixed tropical hardwoods was recognised. Study on morphological and anatomical characteristics of hardwoods growing in the country in relation to their paper making qualities was considered necessary.

5.2. The Bengal Paper mill in West Bengal with an annual production of 36,500 tonnes, a veteran pioneers is using mixed hardwoods for paper making, on commercial scale. This mill has been using a mixture of 60 p.c. bamboo and 40 p.c. mixed hardwood chips

for pulping by sulphate process. The hardwoods used include Boswellia serrata, Butea monosperma, Antilecephalis glandulosa, Anogeissus latifolia, Spondias foetida, Dioscorea glauca and Lagerstroemia spp. The mixture of wood and bamboo chips are cooked in a continuous digester under optimum conditions, washed, screened, washed again, bleached and beaten. The pulp is run on a 1500 ft/minute paper machine to obtain six different varieties of paper of acceptable good quality. The mill mostly produces writing and printing paper.

5.3. The State Paper Mills in Uttar Pradesh manufacture about 28,000 tonnes of Kraft paper annually by using mixed hardwoods and pinewood in equal proportions. Although initially this Mill had been digesting hardwoods and softwood together they did not find this satisfactory and have started separate cooking of hardwood (mixture) and softwood. The hardwood used include Schinus molle, Melastoma malabaricum, Blumeodendron integrifolium, Mimosa cordifolia, Trewia nudiflora, Hymenoclelea excelsissima, Albizia excelsa, Kydia calycina, Boswellia serrata, Garuga pinnata, Mitragyna parviflora, Lannea coromandelica, Bumelia papyrifera, Millettia philippinensis, Cedrela toona.

5.4. The State Paper and Boards Mill in Tamil Nadu have been using hardwoods mixed with bamboo since 1965. At present about 10,000 tonnes of mixed hardwoods and 50,000 tonnes of bamboo are used annually for making paper. The species of hardwood used in admixture with bamboo include Albizia globulus, Albizia tereticornis, Hovea brasilienis, Syzygium siberose, Acacia decurrens, Albizia lebbek and Greville robusta. The wood is

cooked in stationary digesters or in fluid continuous digester
clean with bamboo.

3.5. Most of the paper mills in India have recently started
using Sesbania egyptica for making pulp and paper with a chief story
result. This species is reported to be very fast growing giving
an extremely high yield. The economics of plantation and exploit-
ation on a commercial scale are however yet to be worked out.
Some problems to be considered.

3.6. The 11 paper mills in West Bengal are at
present using 1,10,000 tonnes of bamboo and 50,000 tonnes of mixed
hardwood annually. The price of mill site works out to be Rs. 100
per tonne for bamboo and Rs. 150 per tonne for hardwood. The cost
of the process is used in batch digesters.

3.7. The 11 paper mills in West Bengal are at
present using bamboo, mixed hardwoods and jute sticks in the ratio
8:1:1. The sulphite process is used and the three types of raw
materials are cooked separately for making pulp suitable for
writing and printing papers.

3.8. The 11 paper mills in West Bengal are using annually
about 20,000 tonnes of mixed hardwoods and 100,000 tonnes of bamboo
for making pulp of different types of paper.

3.9. Pulping of mixed tropical hardwoods posed various problems
to the different mills. One of the main reasons of wood to reject
is the presence of bark which has been found to be useful. This very dense, dry
and knotty woods which are to chipping and other difficulties
are eliminated. Some of the mixed hardwood woods as well as bark
rejects are being used for the production of wood by wet chipping
is fast in tropical countries particularly in the area. Cost of

tion of woods and spreading of various chemicals have been suggested but their economic and other associated problems have not been studied. Shortening of wood fibres after pulping is conventional and also prevent forest block to a certain extent.

Physical condition and chemical composition of hardwoods being different the pulping conditions to obtain best result varies. Taking guidance from the research results the mills determine the optimum pulping condition for the wood mixture used by them. The same applies to be-tling of pulp for making paper. Difficulties have been encountered in bleaching recovery operation.

CONCLUSION

1.1 "Necessity is the mother of invention". Widening gap between supply and demand of traditional cellulose raw material has made it possible to find a new source in the tropical hardwood. The demand for pulp and paper is closely linked with population, literacy, education, industrialization and per capita income. Even if an accurate forecast of the growth of demand of various types of papers may not be possible, a realistic estimate of the same can be made. Although the projected demand indicated by different authorities vary considerably the studies herein have already in focusing attention to the availability of long fibre resources and its capability to sustain growth of the industry at the desired level.

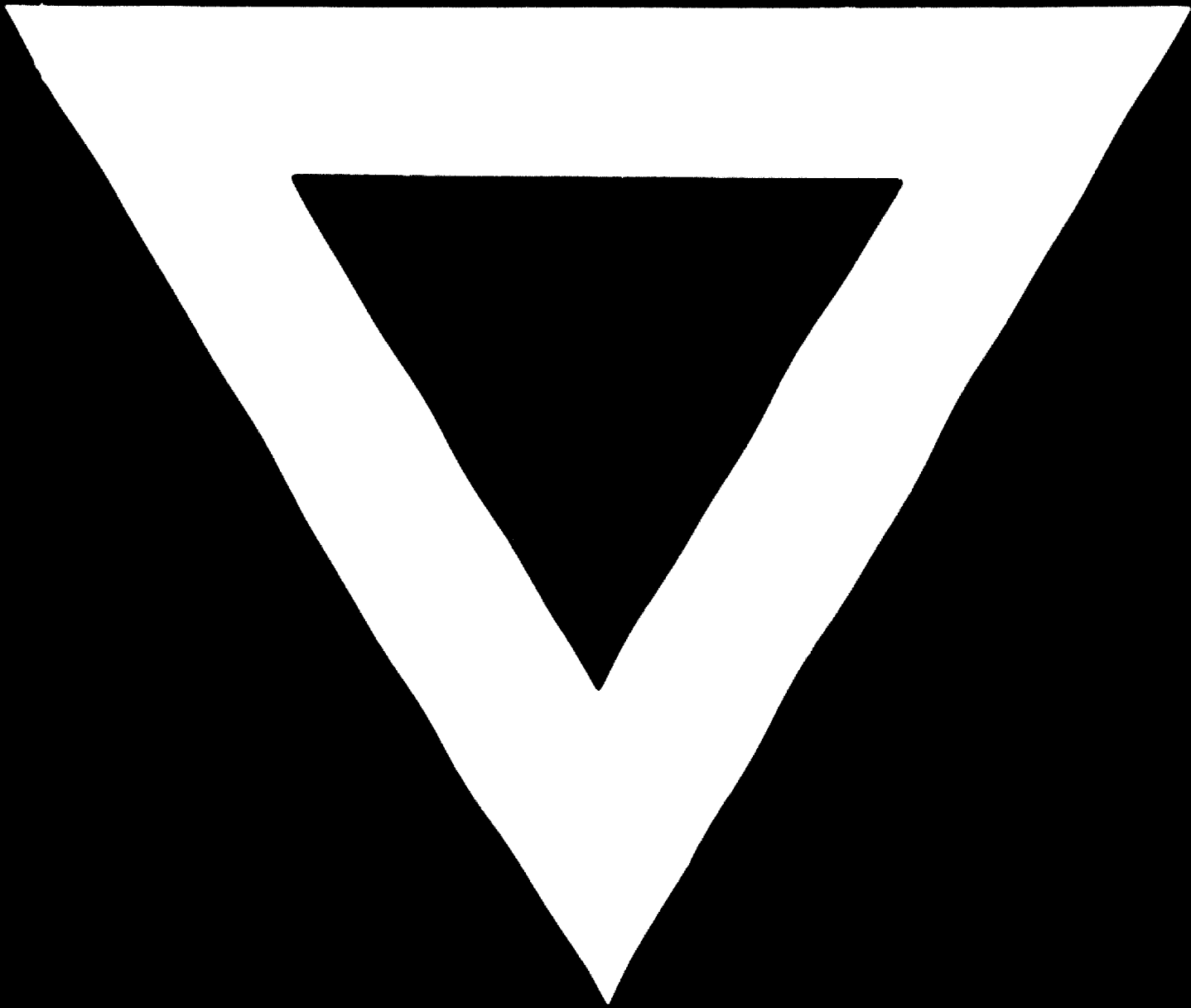
1.2 The difficulties of the long fibre hardwoods being used on an extensive scale by the industry have been discussed earlier. Inauguration of research with increasing suitable

redwood species are certain to play a dominant role in the growth of this industry. The source of raw material has also been discussed earlier. However, it will be sometime until an efficient system of such plantations is created and these wide forests are fit to be exploited. During this period the river stream woodlands from the natural forests appear to be an important source of available raw material for pulp and paper industry; other potential sources being exploitation by products like B grasses, Jute sticks etc. However, the mills in this country were planned and designed to use mainly birch and pine. Switchover to a new type of raw material by the existing mills poses many problems. Location of many units where availability of suitable hardwoods is economic. Many units find it difficult to introduce necessary changes in equipments. The venture becomes particularly risky for the very small units which are many in this country. Despite of various difficulties many mills have started exploiting hardwoods for making paper. For the long growth and survival of the industry it is essential that this rich source of raw material is not to be used. However, there are several problems to be solved. A sense of confidence has to be established for direct investment for setting up of new mills, planned and designed to use mixed tropical hardwoods. While fundamental research is essential, exchange of information and sharing of experiences gained in other parts of the world in a periodic review of the case would help.

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